

Princess Royal Theatre Flood Consequences Assessment

Version 1

July 2024

Prepared for:

**MORGAN
SINDALL**

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1 Introduction

1.1 Terms of Reference

JBA Consulting (JBA) were commissioned by Morgan Sindall Construction & Infrastructure Ltd to undertake a Flood Consequences Assessment (FCA) for the extension and redevelopment of the Princess Royal Theatre, and the enhancement of the riverside public realm in Port Talbot. This FCA has been prepared to demonstrate the suitability of the proposed development, describing the flood mitigation measures recommended to manage flooding at the site.

1.2 FCA Requirements

This FCA follows Welsh Government guidance on development and flood risk set out in Technical Advice Note 15: Development and Flood Risk (TAN-15). Where appropriate, the following aspects of flood risk should be addressed in all planning applications over their expected lifetime:

- The likely mechanisms of flooding
- The likely source of flooding
- The depths of flooding through the site
- The speed of inundation of the site
- The rate of rise of flood water through the site
- Velocities of flood water across the site
- Overland flow routes
- The effect of access and egress and infrastructure, for example, public sewer outfalls, combined sewer outflows, surface water sewers and effluent discharge pipes from wastewater treatment work
- The impacts of the development in terms of flood risk on neighbouring properties and elsewhere on the floodplain

2 Site Description

2.1 Site Summary

The proposed development areas are split into two sites. The first is the Princess Royal Theatre site and the second the Riverside Public Realm, as shown in Figure 2-1.

The first site (hereby referred to as the Princess Royal Theatre and Civic Square Redevelopment) is located at the Princess Royal Theatre, Civic Centre, Port Talbot as shown in Figure 2-1. The site is approximately 0.68ha in size and is currently comprised of the theatre building, associated car parking and landscaping. The main access is from the B4286 Heillbronn Way located along the north eastern boundary. Pedestrian access is available from Station Road to the south east, and the B4286 located along the northern site boundary. To the north of the site is the B4286 Heillbronn Way, to the east, the River Afan, to the south the Ebernezer Welsh Baptist chapel and to the west the Siopa Aberfan Shopping Centre.

Further information on the site is summarised in Table 2-1.

Table 2-1 Site Summary

Site name	Princess Royal Theatre Redevelopment
Site area	0.68ha
Existing land use	Theatre & public realm
Purpose of development	Extension to the theatre
OS NGR	SS 76558 90256
Local Planning Authorities	Neath Port Talbot Council
Lead Local Flood Authority	Neath Port Talbot Council

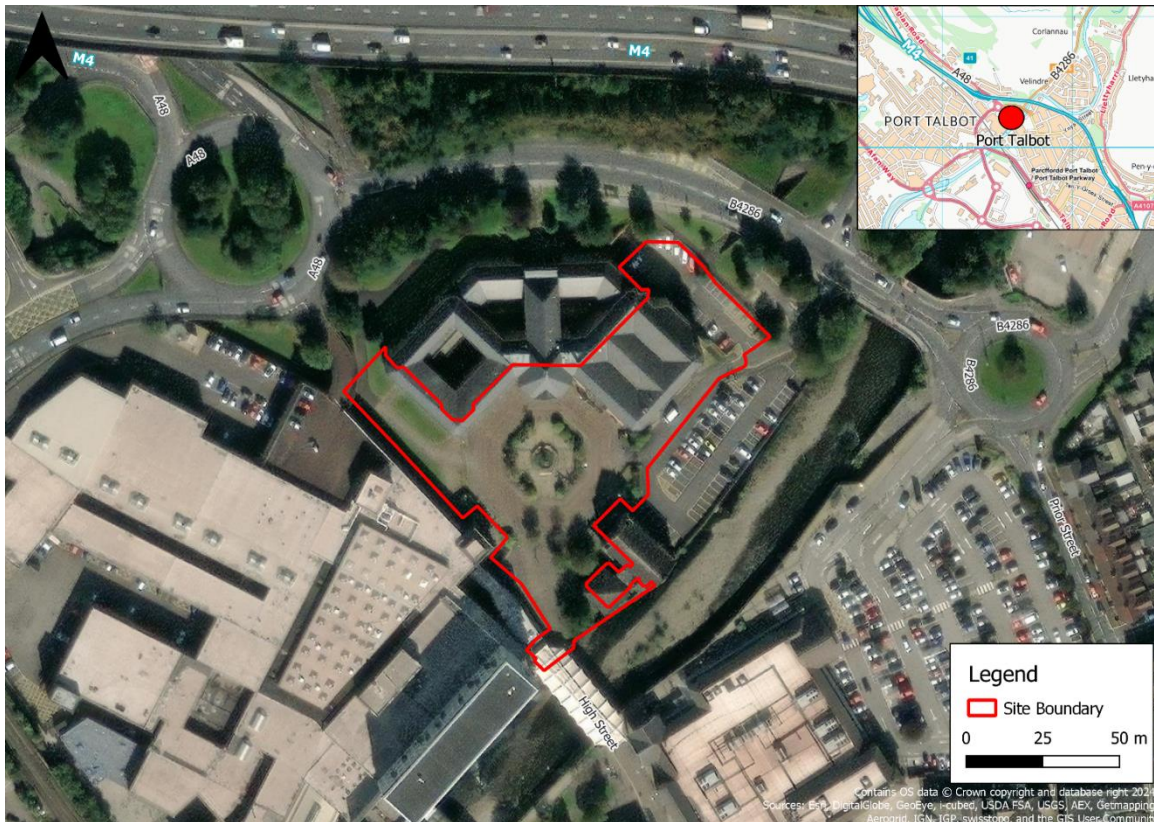


Figure 2-1 Site Location- Princess Royal Theatre and Civic Square Redevelopment

The second site (hereby referred to as the Riverside Public Realm Improvements) is located at the area of public open space between Riverside Road and High Street in Port Talbot, as shown in Figure 2-2. The site is approximately 0.40ha in size and is currently comprised of landscaped public open space, pedestrian bridge across the River Afan, and the Riverside Baptist Church to the south. Pedestrian access is available from High Street along the northern boundary, and Riverside to the south of the site. To the north of the site is High Street and associated commercial buildings, to the east are commercial buildings, to the south is Riverside Road and to the west the River Afan.

Further information on the site is summarised in Table 2-1.

Table 2-2 Site Summary

Site name	Port Talbot Town Centre Riverside Public Realm and Green Infrastructure
Site area	0.40ha
Existing land use	Baptist church and public open space
Purpose of development	Public open space redevelopment
OS NGR	SS 76502 90087
Local Planning Authorities	Neath Port Talbot Council
Lead Local Flood Authority	Neath Port Talbot Council

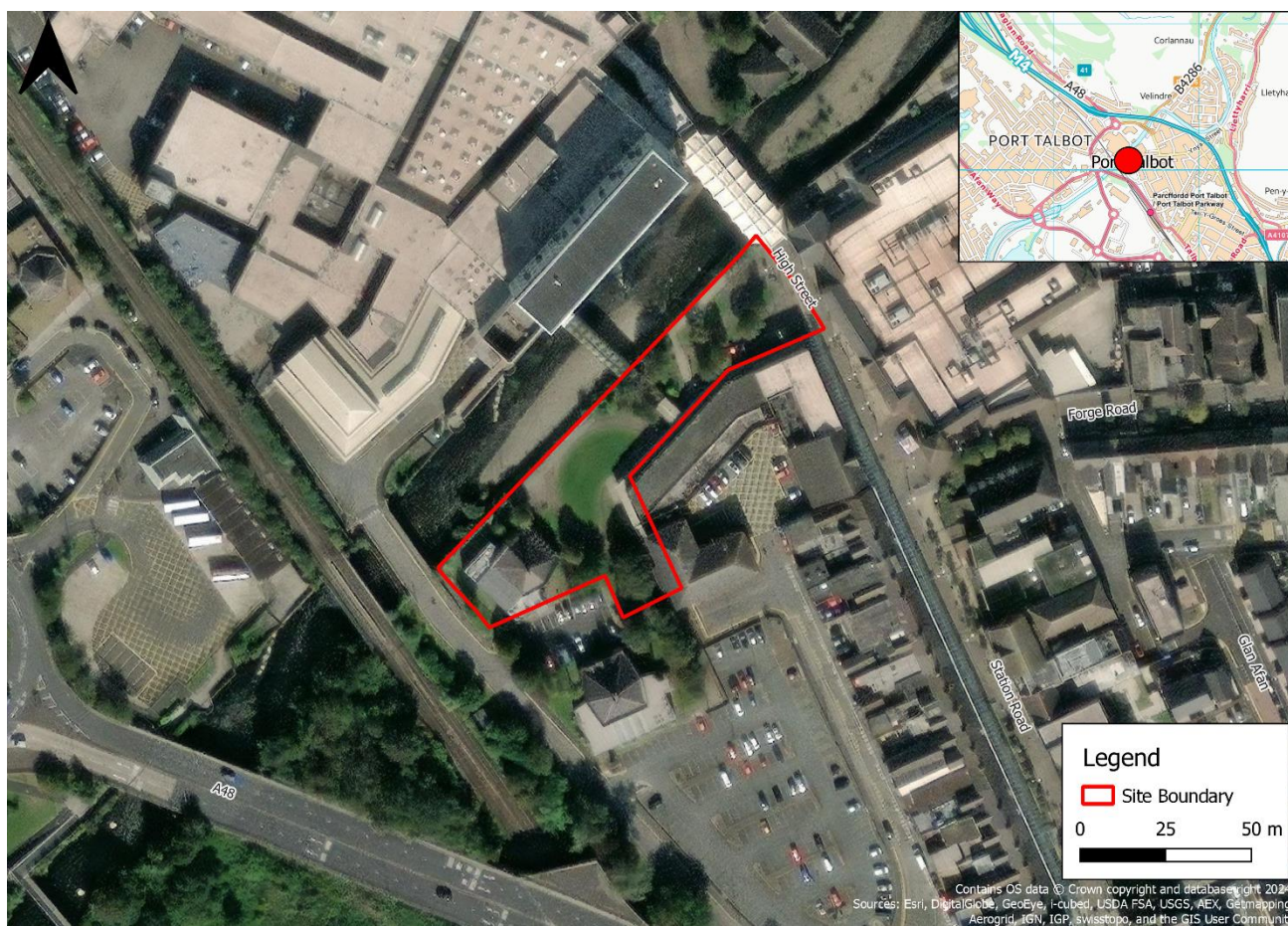


Figure 2-2 Site Location- Port Talbot Town Centre Riverside Public Realm

2.2 Site Topography

A topographic survey of the site was undertaken by Gwalia Surveyors in March 2024 and is provided in Appendix A. Figure 2-3 shows Natural Resources Wales (NRW) Light Detection and Ranging (LiDAR) data, which provides an alternative illustration of the site topography.

Ground levels across the Princess Royal Theatre and Civic Square Redevelopment site fall in a north easterly direction from the higher points in the south of the site and at the main building towards the northern topographic depression. The theatre building has a Finished Floor Level (FFL) of 10.14mAOD.

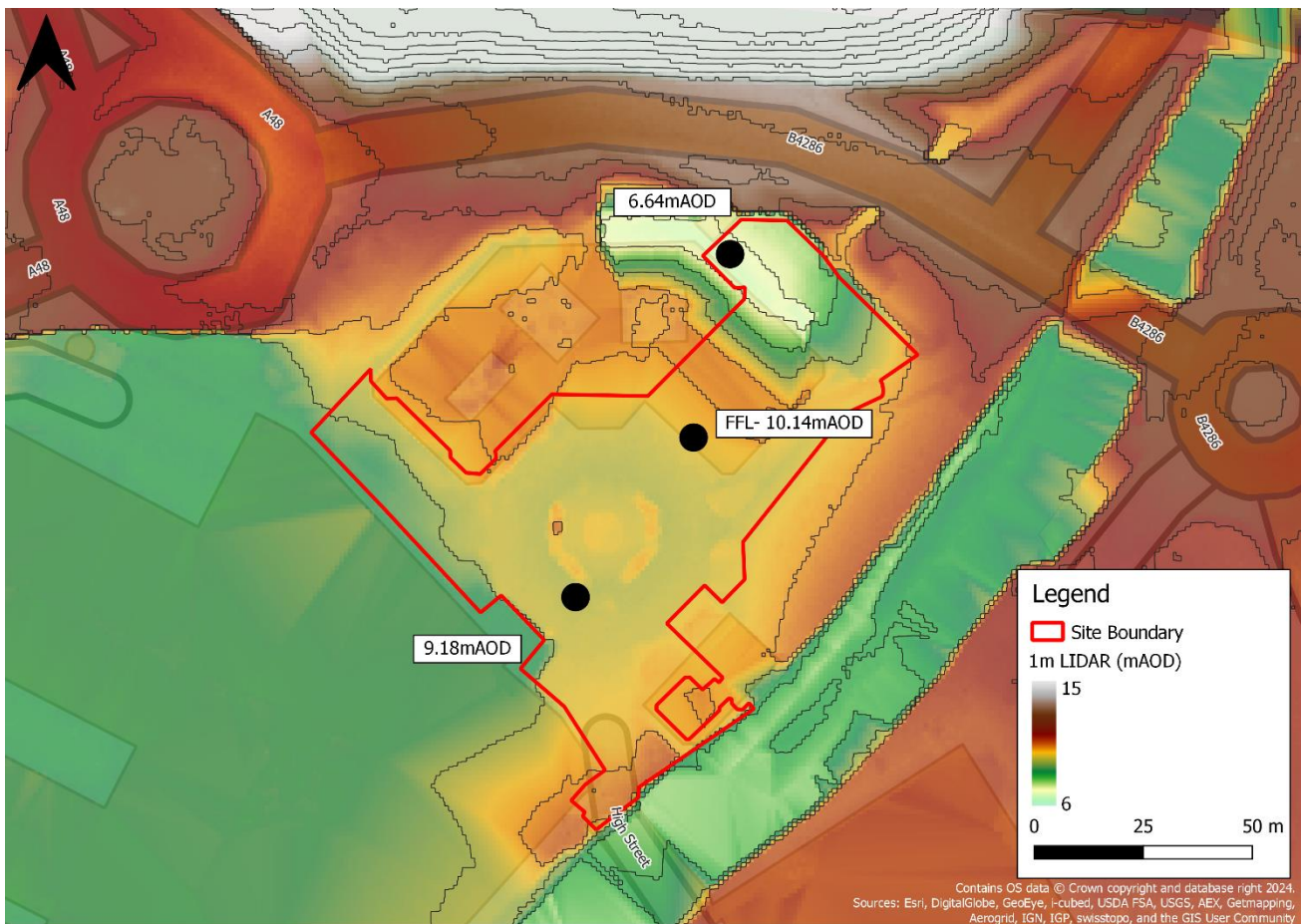


Figure 2-3 1m LiDAR Topography

Ground levels across the Riverside Public Realm Improvements site are predominantly flat with a small fall towards the western and eastern site boundaries from the higher points in the west and east of the site south of the site.



Figure 2-4 1m LiDAR Topography

2.3 Soils and geology

The geology of both sites has been assessed using the British Geological Survey (BGS) GeoIndex¹. The bedrock of both sites is shown to be South Wales Upper Coal Measures Formation made up from mudstone, siltstone and sandstone. The superficial geology is formed of tidal flat deposits comprised of clay, silt and sand.

The soils on the sites have been assessed on the Cranfield University Soilscape viewer². The soils on the Princess Royal Theatre and Civic Square Redevelopment site are shown to be two separate types of soils. The northern part of the site is shown to be freely draining acid loamy soils over rock and the southern part is shown to be loamy and clayey soils of coastal flats with naturally high groundwater. At the Port Talbot Town Centre Riverside Public Realm site, the northern part of the site is shown to be freely draining acid loamy soils over rock and the southern part is shown to be loamy and clayey soils of coastal flats with naturally high groundwater.

¹ Geology of Britain viewer - British Geological Survey (bgs.ac.uk)

² Soilscales soil types viewer - Cranfield Environment Centre. Cranfield University (landis.org.uk)

2.4 Watercourses and flood defences

Figure 2-5 shows the locations of nearby waterbodies and watercourses. The Princess Royal Theatre and Civic Square Redevelopment site is bordered on its eastern boundary by the River Afan. The River Afan is an NRW designated Main River and flows in a southerly direction through Port Talbot before flowing into the Severn Estuary.

The Port Talbot Town Centre Riverside Public Realm is bordered on its western boundary by the River Afan.

Both sites are protected by flood defences which are present along the banks of the River Afan and comprise of a flood wall which protects the sites from a 1% AEP event.

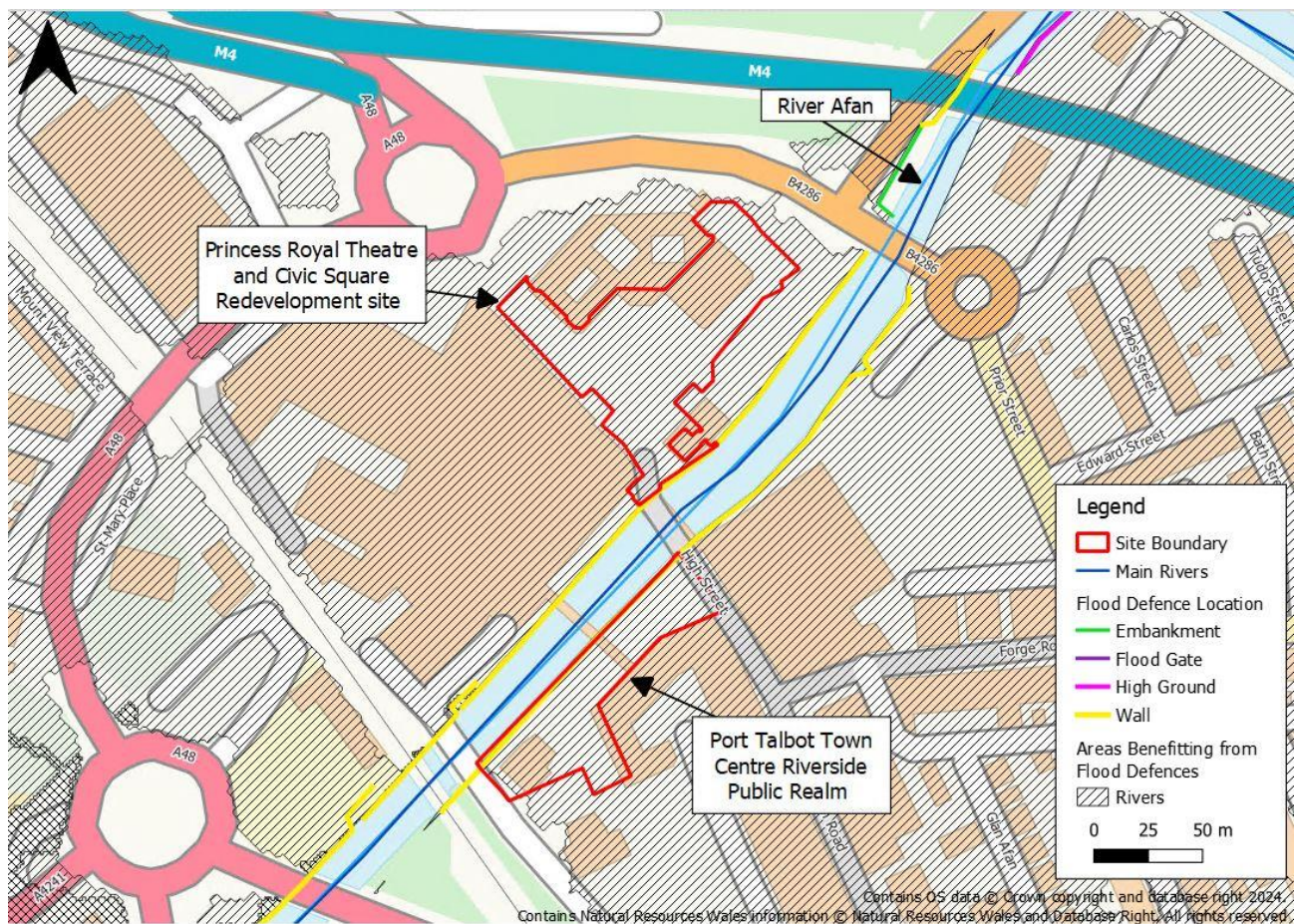


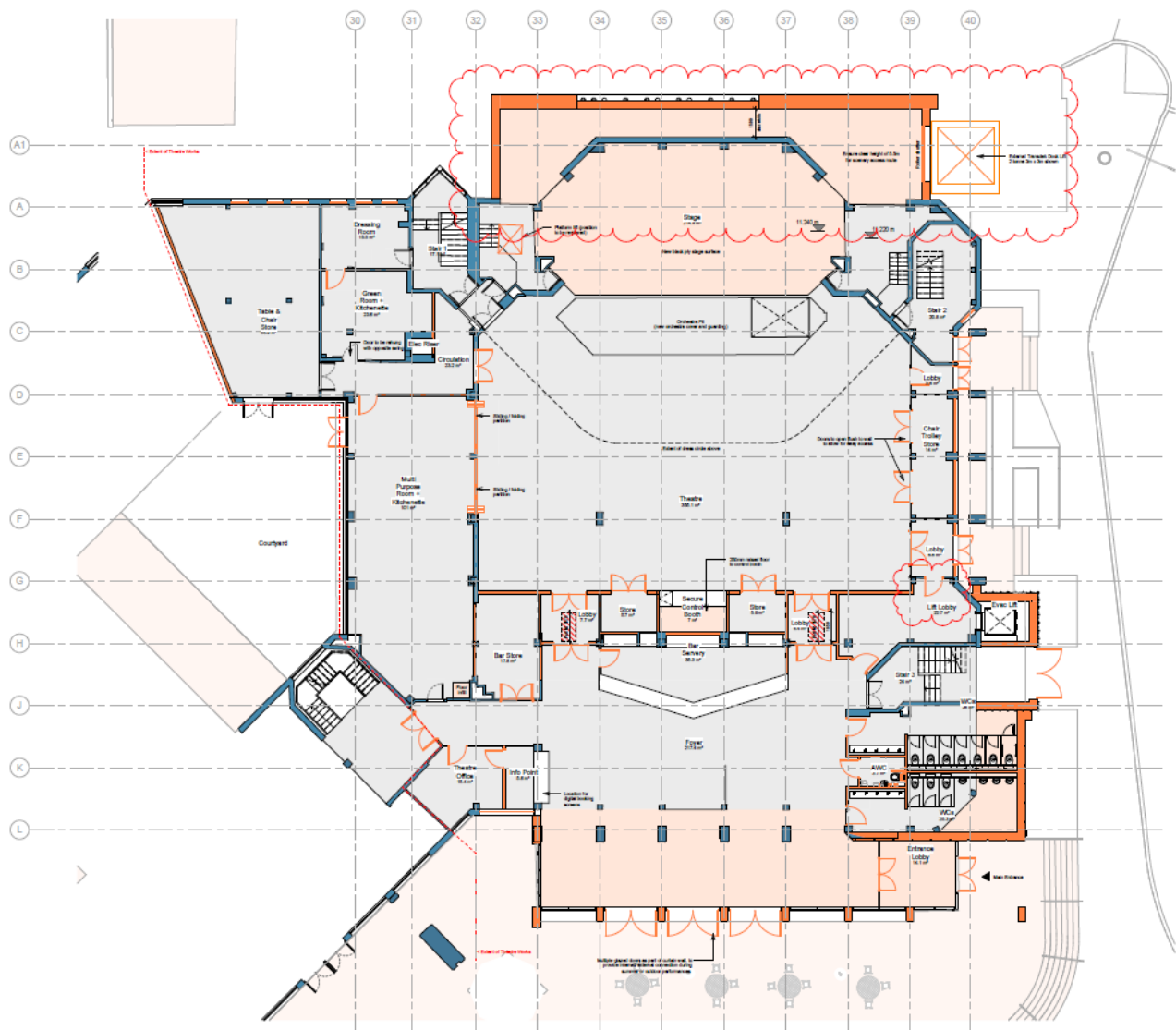
Figure 2-5 Watercourses and flood defences

2.5 Proposed development

Development proposals at the Princess Royal Theatre and Civic Square Redevelopment consist of both internal and external improvements to the building as well as changes to the site, the plans of which are provided in Appendix B. External improvements include landscape works, the removal of the central water feature and the addition of SuDS features.

The internal improvements will include the extension of the front of the building to provide a larger entrance space and the extension of the rear of the building to provide a wider stage area. Additional internal reconfigurations are also proposed, as shown in Appendix B. The front extension will have the same FFL as the existing building of 10.13mAOD. The rear stage extension will have a FFL of 11.24mAOD and will be elevated and cantilevered above the existing ground level. The basement levels will remain unchanged.

The works to the Port Talbot Town Centre Riverside Public Realm and Green Infrastructure include the refinement of landscaping areas and relocation of a proposed informal play area. No buildings will be constructed on the site.



3 Planning Policy and Flood Risk

3.1 Planning context

Planning Policy Wales (PPW) sets out the land use planning policies of the Welsh Government. It is supplemented by a series of Technical Advice Notes (TANs), Welsh Government Circulars, and policy clarification letters, which together with PPW provide the national planning policy and improve the social, economic, environmental, and cultural wellbeing of Wales as set out in the Wellbeing of Future Generations Act 2015.

Technical Advice Note (TAN-15) introduced by the Welsh Government in 2004, provides technical guidance relating to development planning and flood risk in Wales. The initial requirements of TAN-15 are to identify the vulnerability classification(s) and flood zones relevant to the proposed development, and to apply this information to the application of the justification tests.

An update for TAN-15 was released in October 2021. However, Welsh Government subsequently suspended this, and it is not currently known when the new TAN-15 will be published in its final form and implemented.

Although the draft update of TAN-15 is not a material consideration, Welsh Government and NRW advise that some consideration is given to the Flood Map for Planning (FMfP) as best available information³. Therefore, where a site is located in a FMfP flood risk zone it is recommended that an FCA is carried out.

As a result of the above, both the DAM and FMfP are considered as part of this FCA, although only the current TAN-15 has been applied to the assessment.

3.2 Vulnerability classification

TAN-15 assigns one of three flood risk vulnerability classifications to a development, as shown in Table 3-1. The Princess Royal Theatre and Civic Square Redevelopment is for use as a public building which is classified as **highly vulnerable development**. Development proposals at the site will not change the development use nor intensify the development.

The Riverside Public Realm will be public open space which is not explicitly classified in the flood risk vulnerabilities in TAN-15. Therefore, the development is classified as 'Other'. Section 5.3 and Section 9 of TAN-15 identifies that there are developments which do not fit into the three main vulnerability categories as shown in Table 3-1. Section 11.21 of TAN-15 states that:

'Proposals for public space, outdoor recreational uses and agricultural developments are likely to be acceptable in all areas where there is a risk of flooding. However ancillary buildings or structures required for these uses, which are subject to prior approval, may not be acceptable in accordance with Section 7'.

³ Chief Planner Letter, 15 December 2021. Ref. MA-JJ-3967-21

Table 3-1 Development classification defined by TAN-15

Development category	Types
Emergency services	Hospitals, ambulance stations, fire stations, police stations, coastguard stations, command centres, emergency depots and buildings used to provide emergency shelter in time of flood.
Highly vulnerable development	All residential properties (including hotels and caravan parks) public buildings, (e.g. schools , libraries, leisure centres), especially vulnerable industrial development (e.g., power stations, chemical plants, incinerators), and waste disposal sites.
Less vulnerable development	General industrial employment, commercial and retail development, transport and utilities infrastructure, car parks, mineral extraction sites and associated processing facilities, excluding waste disposal sites

3.3 Development Advice Map Classification

The Development Advice Map (DAM) is used to trigger different planning actions based on a precautionary assessment of flood risk. Figure 3-1 shows that the Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site are located in Zone C1, which is described as “areas of the floodplain with significant flood defence infrastructure”.

Development in DAM Zone C1 should be considered subject to application of the justification test, including acceptability of consequences.



Figure 3-1 Development Advice Map (DAM)

3.4 Flood Map for Planning Classifications

The Flood Map for Planning is used to trigger different planning actions in support of the new forthcoming TAN-15. Although the new TAN-15 is not a material consideration, the new Flood Map for Planning is useful in that it shows the flood risk allowing for climate change over a 100-year lifetime of development.

3.4.1 Flood Map for Planning - Rivers

The Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site are located within a TAN-15 Defended Zone for Planning for Rivers, as shown in Figure 3-2. TAN-15 Defended Zones shows areas that benefit from risk management authority owned flood defence infrastructure, that have a minimum, present day level of protection of 1% (1 in 100) annual event probability (AEP) for rivers.

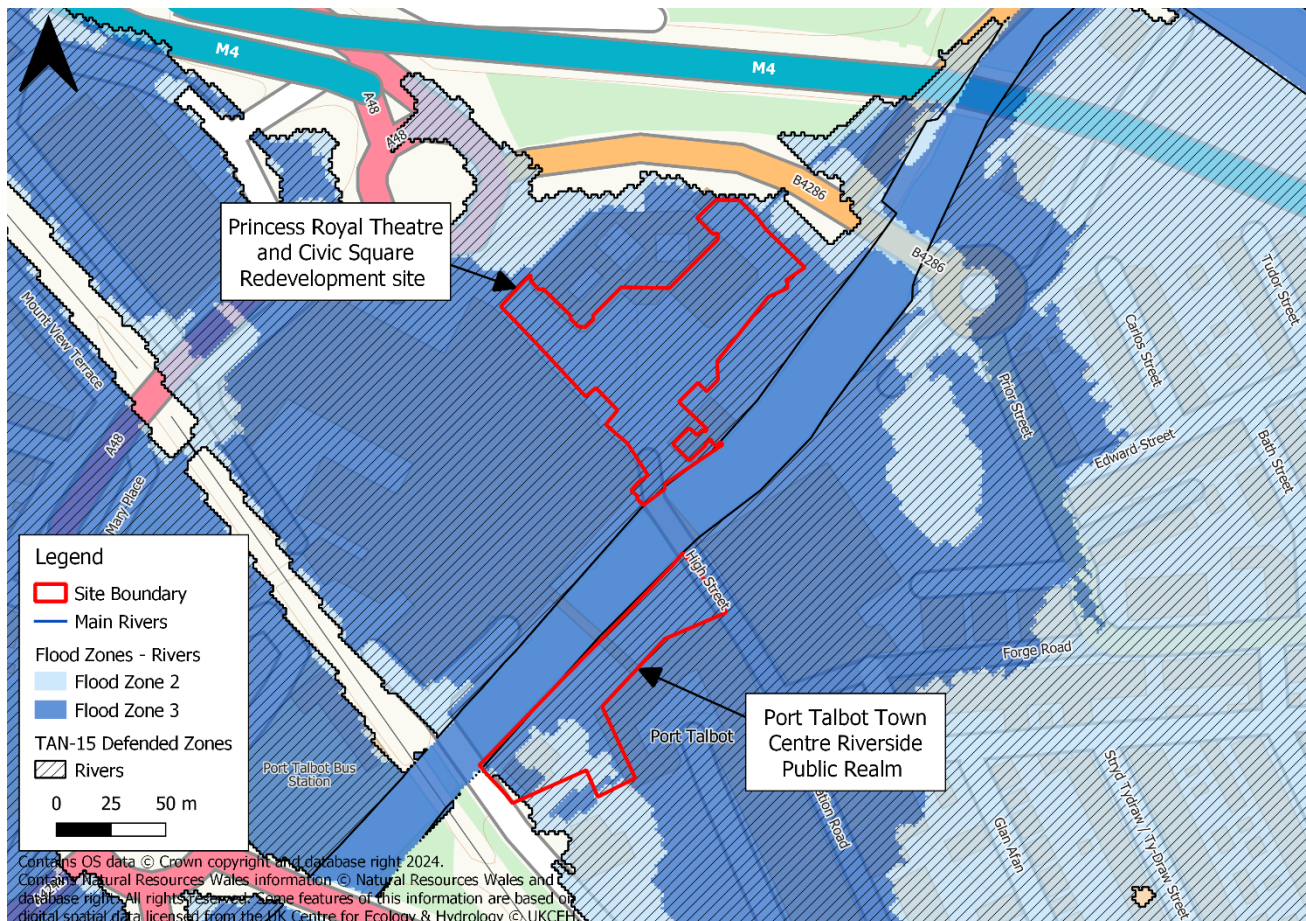


Figure 3-2 Flood Map for Planning – Rivers

3.4.2 Flood Map for Planning - Sea

The Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site are located within Flood Zone 1 of the Flood Map for Planning for the Sea. This area is shown as transparent in the Flood Map for Planning and has therefore not been represented graphically. Zone 1 represents areas that have less than a 0.1% AEP chance of flooding each year, including climate change.

3.5 Justification Test

TAN-15 does not clearly establish the policy requirements for modest non-residential building extensions, such as are being proposed at the Princess Royal Theatre and Civic

Square Redevelopment site. However, there is an overarching principal that new development should not unreasonably increase the vulnerability/intensity of development in a flood risk area. The proposed development at the site will not change the development use (ie. no change in vulnerability) and neither is it intended to intensify the development (ie. increase theatre capacity). Therefore, in relation to the theatre building works, we conclude that the Justification Tests are not applicable. We would however look to assess the requirements of the Acceptability Criteria, as discussed in Section 6.

As 'other' development the Justification Tests of TAN-15 do not apply to the Port Talbot Town Centre Riverside Public Realm site, and whilst consideration should be given to the Acceptability Criteria of TAN-15, the key consideration should be not to increase flood risk elsewhere.

4 Flood Risk Assessment

This section assesses the risk to both sites from all sources of flooding, the risk of increased flooding to others, and how flood risk can be managed. Information is taken from publicly available data sources.

4.1 Review of Existing Flood Risk Data

The latest available information on flood risk at the sites, published by NRW, is summarised in Table 4-1 below.

Table 4-1 Flood Risk Summary

Source of Flooding	Onsite Presence	Description
Flood Risk from Rivers	✓	The site is at low risk of fluvial flooding
Flood Risk from the Sea	✗	The site is at very low risk of tidal flooding
Flood Risk from Surface Water and Small Watercourses	✓	The site is at a low risk of flooding from surface water and small watercourses
Flood Risk from Groundwater	✓	The site is at a low risk of flooding from groundwater
Flood Risk from Reservoirs	✗	The site is at a very low risk of flooding from reservoirs
Flood Risk from Sewers	✗	The site is at a low risk of flooding from sewers

4.2 Historical Flooding

NRW's map of recorded flood extents does not show any evidence of historical flooding on the Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site.

The Neath Port Talbot County Borough Council (NPTC) Flood Risk Management Plan (FRMP) does not highlight flooding to the proposed development site. The Neath Port Talbot County Borough Council Local Flood Risk Management Strategy identifies flooding within Port Talbot. However, it is unknown if any flooding has taken place at either the Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site.

4.3 Flood Risk from Rivers

Both the Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site are at low risk of flooding from rivers, according to NRW's Flood Risk Assessment Wales (FRAW) Flood Risk from Rivers map, as shown in

Figure 4-1. This means there is between 0.1% and 1% chance of fluvial flooding in any given year. As noted in Section 2.4 above, both sites are protected by the presence of flood defences during a 1% AEP flood event.

To gain a better understanding of the flood risk to the site, further assessment of fluvial flood risk has been undertaken and is discussed in section 5.

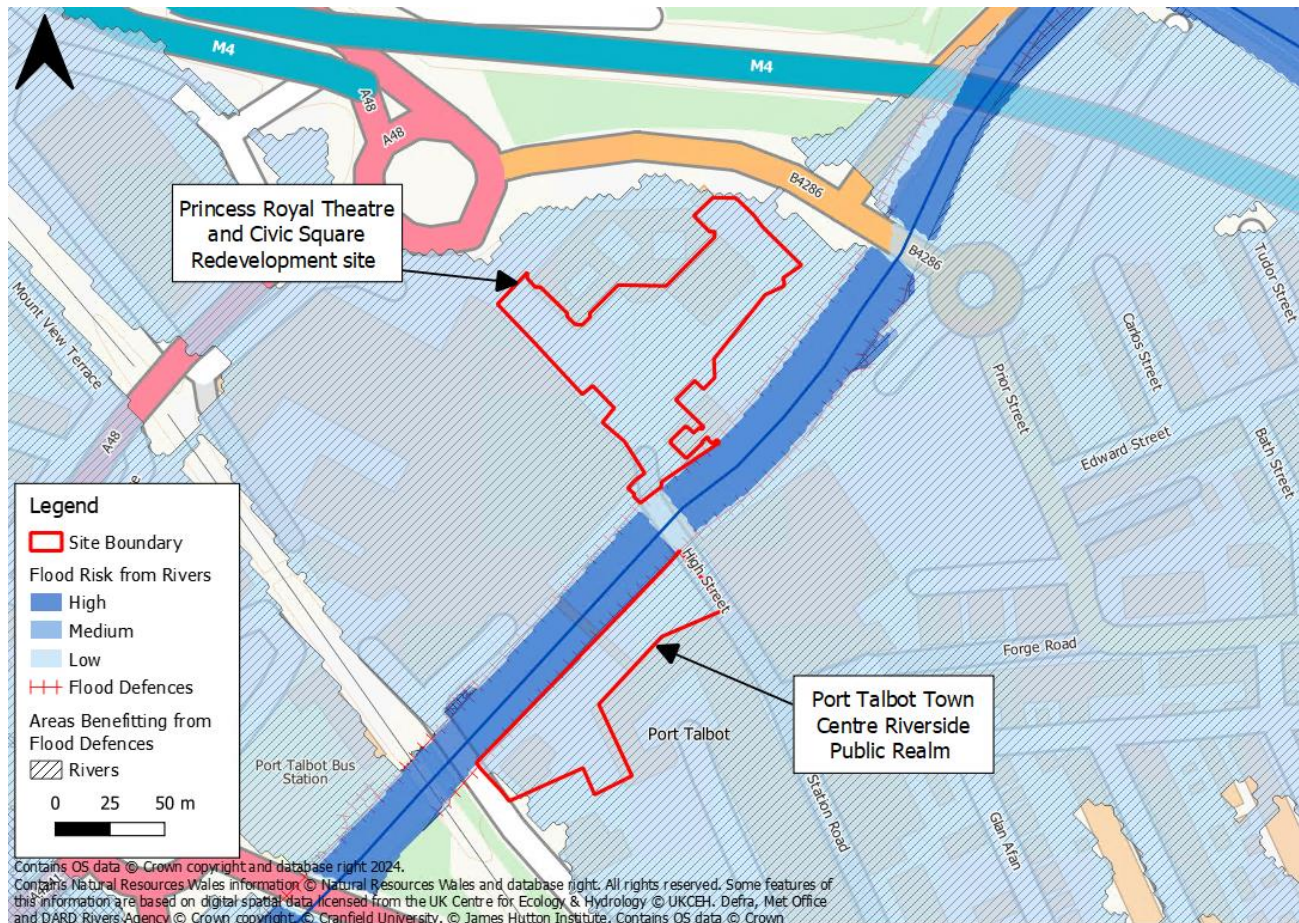


Figure 4-1 FRAW - Flood Risk from Rivers

4.4 Flood Risk from the Sea

Both sites are at a very low risk of flooding from the Sea according to NRW's FRAW Flood Risk from the Sea map. This means there is less than a 0.1% AEP chance of flooding from this source in any given year.

4.5 Flood Risk from Surface Water and Small Watercourses

The NRW FRAW flood risk from Surface Water and Small Watercourses mapping shows that the Princess Royal Theatre and Civic Square Redevelopment site are predominantly at very low risk of flooding from these sources, as shown in **Error! Reference source not found..** This means that there is a less than 1 in 1000 (<0.1% AEP) chance of flooding in any given year.

There are small areas at low to medium risk of surface water flooding, as shown in Figure 4-2. These areas are at risk of flooding there is between 1 in 1000 (0.1% AEP) and 1 in 100 (1% AEP) chance of flooding in any given year.

The Port Talbot Town Centre Riverside Public Realm site is at very low risk of flooding from these sources, as shown in Figure 4-2. This means that there is a less than 1 in 1000 (<0.1% AEP) chance of flooding in any given year.

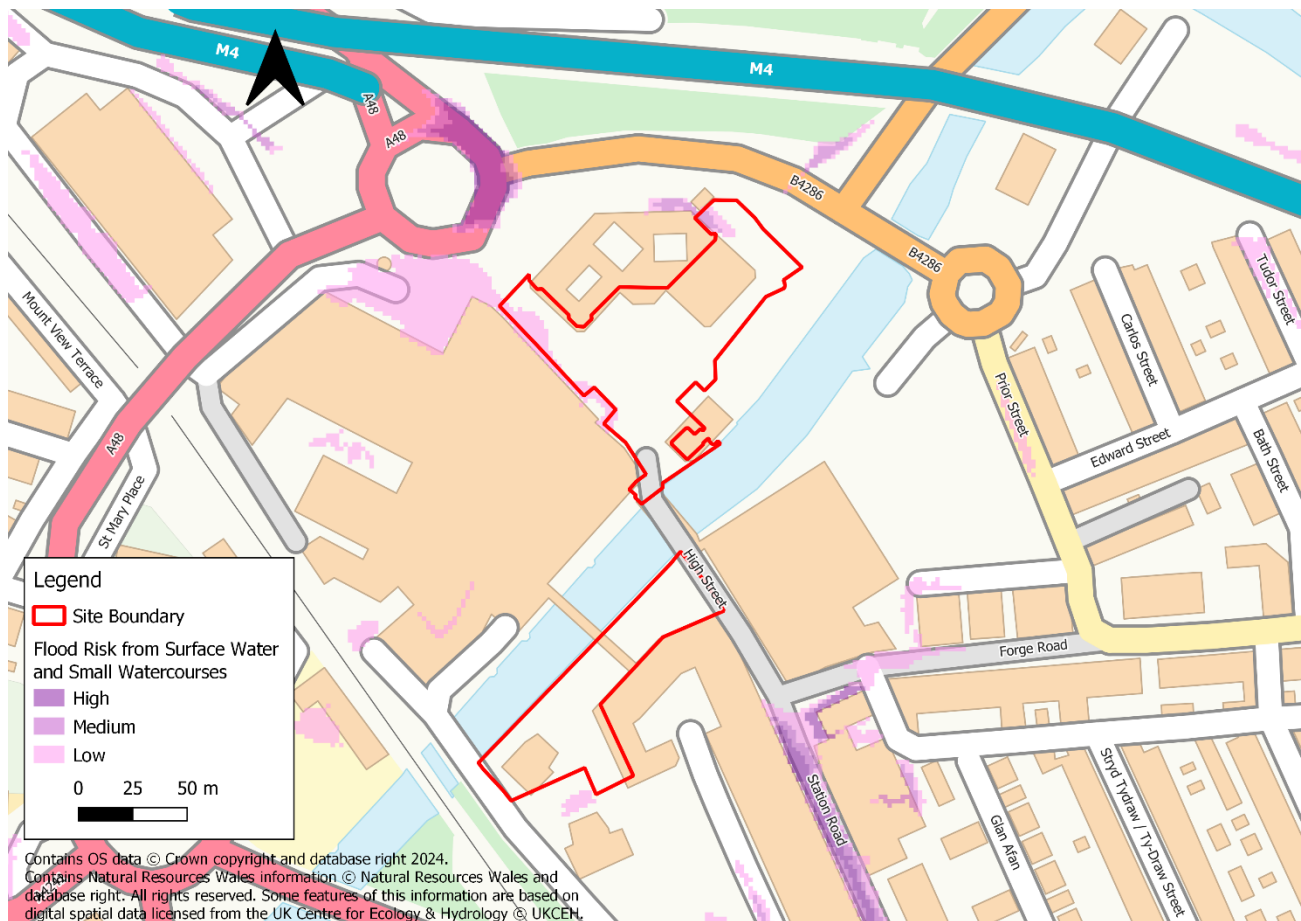


Figure 4-2 FRAW - Flood Risk from Surface Water

4.6 Flood Risk from Groundwater

Groundwater flooding is caused by unusually high groundwater levels. It occurs as excess water emerges at the ground surface or within manmade underground structures such as basements. Groundwater flooding tends to be more persistent than surface water flooding, in some cases lasting for weeks or months, and it can result in significant damage. The risk of groundwater flooding depends on the nature of the geological strata underlying the site, as well as on the local topography.

The NPTC Local Flood Risk Management Strategy (2013) states that “Historically, there are no specific areas of groundwater flooding recorded in the Neath Port Talbot area.”

The underlying superficial geology comprising Tidal Flat Deposits tends to be impermeable and therefore would not provide a pathway for groundwater to rise and impact the development.

From the information above, and our knowledge of the sites, the risk of groundwater flooding is assessed to be low.

4.7 Flood Risk from Reservoirs

The NRW FRAW Flood Risk from Reservoirs map illustrates that both sites are at **very low risk** of reservoir flooding, shown as a transparent layer on the FRAW mapping and has therefore not been represented graphically.

4.8 Flood Risk from Sewers

Flood risk from sewers is a result of excess surface water within the sewer drainage network. The NPTC Local Flood Risk Management Strategy (2013) states that 430 sewer events have been recorded by Dŵr Cymru Welsh Water. However, no sewer flooding issues are associated with the proposed development areas. Therefore, it's been assessed the risk of sewer flooding for this site is Low.

5 Detailed Fluvial Flood Risk Assessment

5.1 Hydraulic Modelling Availability

The following section sets out the detailed assessment of fluvial flood risk which is considered the primary source of flood risk to the site. This assessment is based on detailed flood modelling and considers the potential impact of climate change.

The existing flood modelling of Port Talbot has been developed over a number of years, with the current Natural Resources Wales product 7 dataset being most recently updated by JBA Consulting in October 2023 as part of a separate site-specific assessment. This version of the model has been used as the basis for the assessment of flood risk for the Princess Royal Theatre site. Appendix C details the updates that have been undertaken for the model.

For the site-specific assessment at the Princess Royal Theatre site, a further update has been applied to the model to incorporate site-specific topographic information by setting the existing finished floor level of the theatre building to an elevation of 10.13mAOD. This is based on the topographic survey provided by the client and found in Appendix A.

5.2 Baseline Flood Modelling

5.2.1 Baseline 1% AEP plus climate change event

During the 1% AEP plus Climate Change event, the Princess Royal Theatre and Civic Square Redevelopment site is shown to be inundated with varying levels of flood depths across the site as shown in Figure 5-2. Most of the site is modelled to have flood depths of less than 0.6m, with areas along the northern boundary and isolated areas towards the southeast of the site having modelled flood depths of >1.2m.

These flood depths are predicted based on a LiDAR derived ground model that is inherently unable to accurately describe the actual level of buildings. Therefore, to accurately assess the flood risk the modelled water level has been compared to the ground and FFL of the existing and proposed development, as shown in Figure 5-1.

The depths within the different areas of the site shown in Table 5-1.

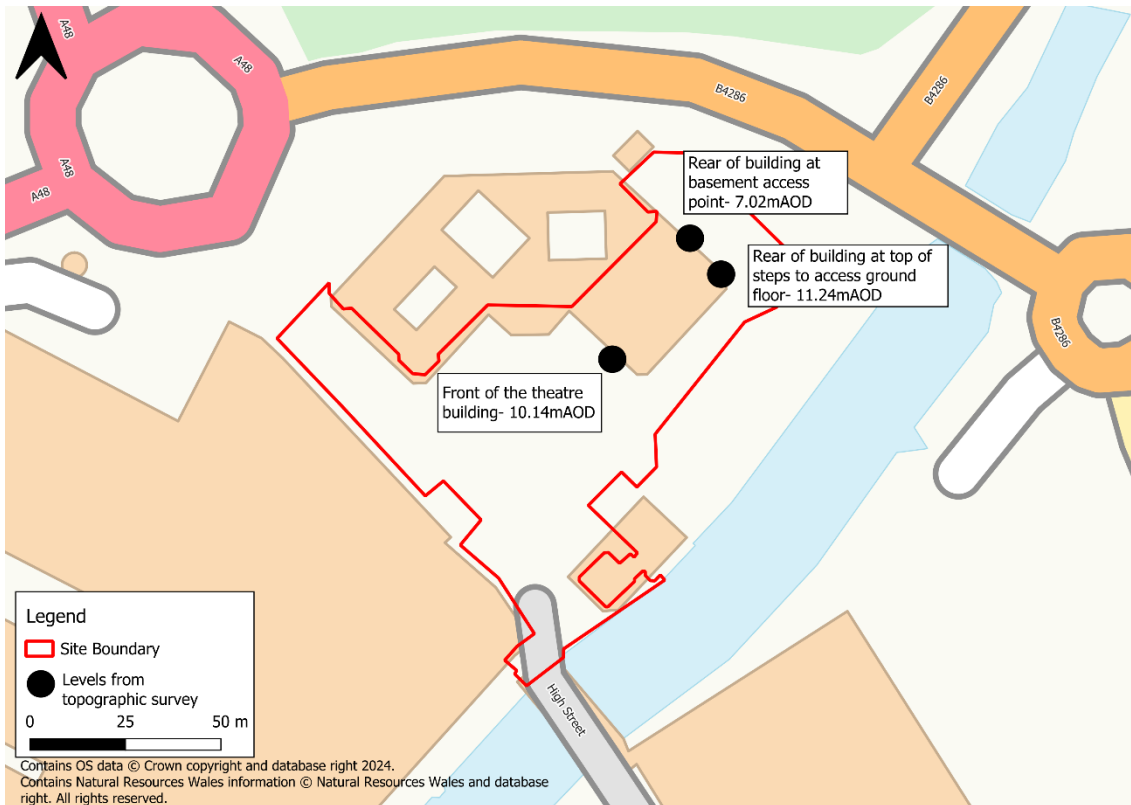


Figure 5-1 FFL and threshold levels from the topographic survey

Table 5-1 Potential flood depths in the 1% AEP plus climate change event

Area of the site	Finished Floor Level or threshold level (mAOD)	Flood Level (mAOD)	Maximum Flood Depth (m)
Front of the theatre building	10.14	10.08	Flood free
Rear of building at basement access point	7.02	10.20	3.18
Rear of building at top of steps to access ground floor	11.24	10.20	Flood free

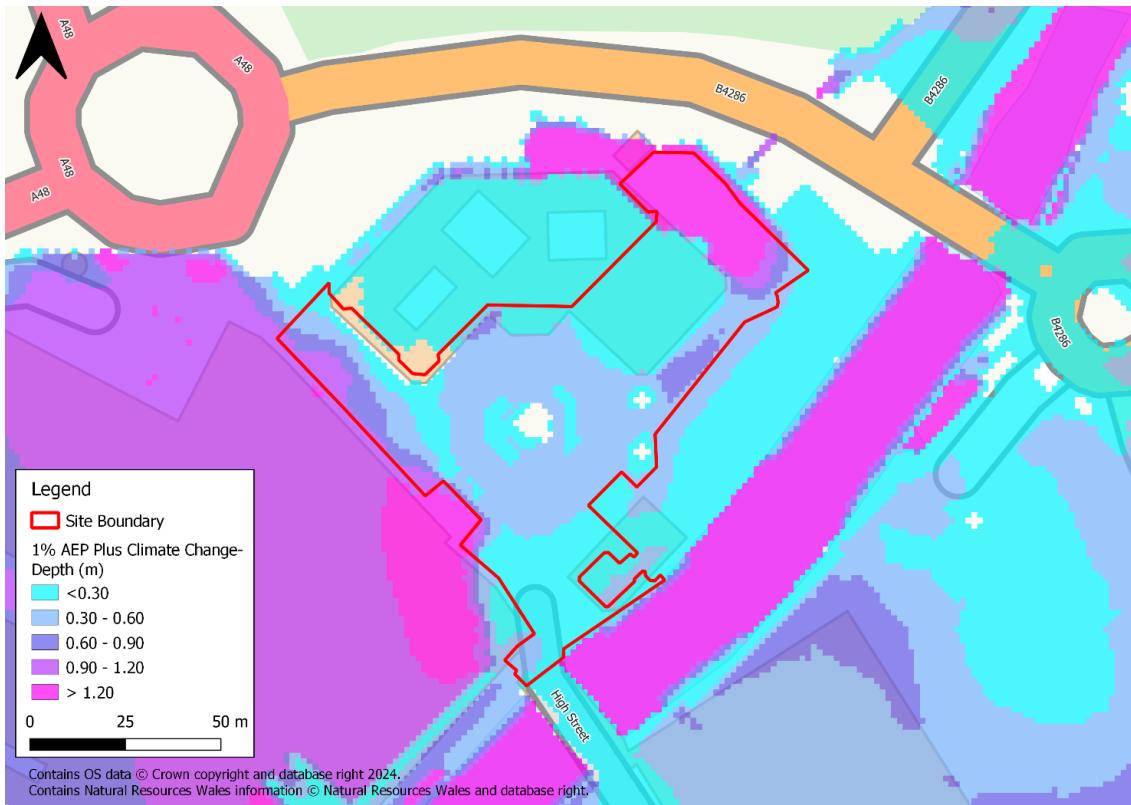


Figure 5-2 Baseline- 1% AEP Plus Climate Change flood depth (m)- Princess Royal Theatre and Civic Square Redevelopment site

The Port Talbot Town Centre Riverside Public Realm site is also shown to be inundated with varying levels of flood depths across the site, as shown in Figure 5-3. Most of the site is modelled to have flood depths of less than 0.6m, with an area in the south of the site predicted to flood to depths of less than 0.3m and an area in the north predicted to be between 0.6-0.9m.

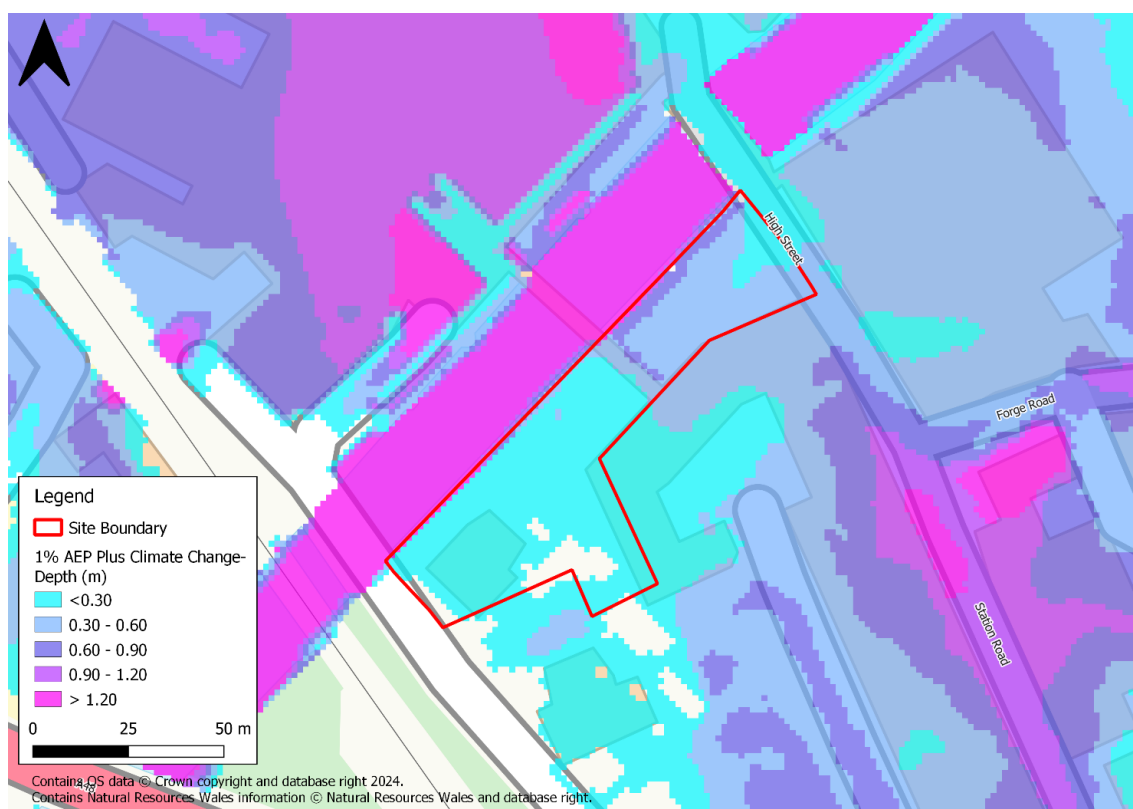


Figure 5-3 Baseline- 1% AEP Plus Climate Change flood depth (m)- Port Talbot Town Centre Riverside Public Realm site

5.2.2 Baseline 0.1% AEP event

During the 0.1% AEP event, the Princess Royal Theatre and Civic Square Redevelopment site is shown to be inundated with varying levels of flood depths across the site, as shown in Figure 5-4. As expected, flood depths are greater than those experienced during the 1% plus climate change AEP event, typically increasing by 0.4m.

In this design event, the modelled flood depths are predominantly between 0.3 and 0.9m, with areas in the north modelled to have maximum flood depths of greater than 1.2m.

To account for the proposed FFL's, the predicted flood depths are summarised in Table 5-2.

Table 5-2 Predicted flood depths in the 0.1% AEP event

Area of the site	Finished Floor Level or threshold level (mAOD)	Flood Level (mAOD)	Maximum Flood Depth (m)
Front of the theatre building	10.14	10.22	0.08
Rear of building at basement access point	7.02	10.58	3.56

Area of the site	Finished Floor Level or threshold level (mAOD)	Flood Level (mAOD)	Maximum Flood Depth (m)
Rear of building at top of steps to access ground floor	11.24	10.37	Flood free

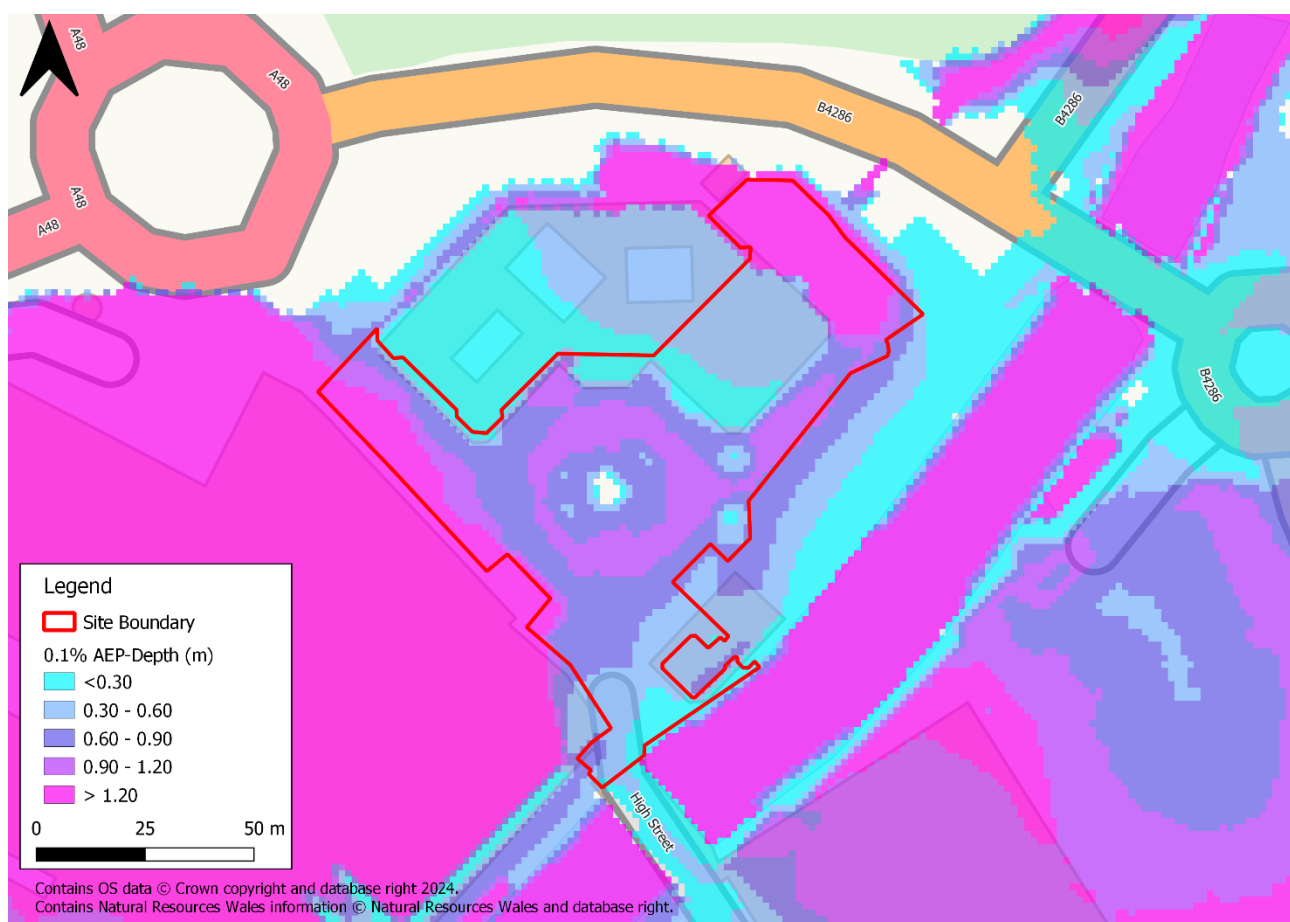


Figure 5-4 Baseline- 0.1% AEP flood depth (m)- Princess Royal Theatre and Civic Square Redevelopment site

The Port Talbot Town Centre Riverside Public Realm site is also shown to be inundated with varying levels of flood depths across the site, as shown in Figure 5-5. As expected, flood depths are greater than those experienced during the 1% plus climate change AEP event, typically increasing by 0.1m.

Most of the site is modelled to have flood depths of less than 0.6m, with an area in the south predicted to flood to depths of less than 0.3m and an area in the north predicted to be between 0.6-0.9m.

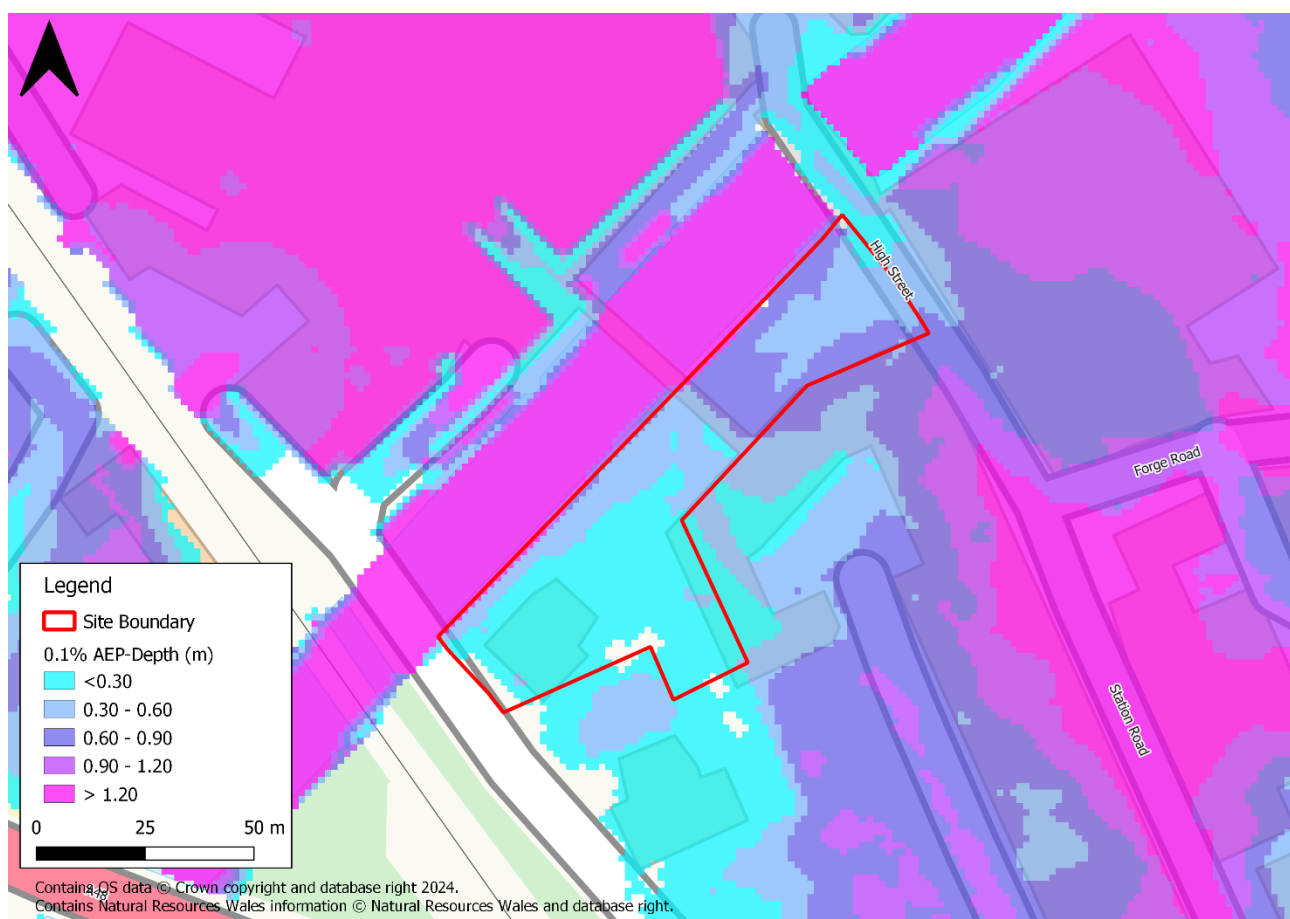


Figure 5-5 Baseline- 0.1% AEP flood depth (m)- Port Talbot Town Centre Riverside Public Realm site

5.3 Post-Development Modelling

5.3.1 Policy Requirements

Where development is justified, suitable mitigation measures can be incorporated within the design to ensure that development is as safe as possible, and there is (TAN-15, Para 7.3):

- minimal risk to life;
- minimal disruption to people living and working in the area,
- minimal potential damage to property;
- minimal impact of the proposed development on flood risk generally; and,
- minimal disruption to natural heritage.

Further guidance on assessing the above requirements is provided in Appendix 1 of TAN-15. Three requirements are particularly important concerning the proposed development and the flood mitigation required. These are:

1. **[A1.12]** No flooding elsewhere. The proposed development should have minimal impact of the proposed development on flood risk generally.
2. **[A1.14]** Commercial development should be flood-free in the 1% AEP plus climate change event. This is “indicative guidance”.

3. **[A1.15]** Beyond the threshold set by A1.14 flooding should be safe for site users and recommended values of maximum flood depths and velocity are provided. The maximum recommended flood depth for commercial development is 600mm. The figures provided are “indicative”; “Each site must therefore be considered individually, and a judgement taken in the context of the particular circumstances which could prevail at that site”.

5.3.2 Post-development model updates

The layout of the Princess Royal Theatre and Civic Square Redevelopment site, as shown in Appendix B, has been incorporated into the post-development model to understand the flood risk to the building and the potential to impact the flood risk to others.

In the post-development model, the new entrance extension has finished floor levels of 10.13mAOD to ensure it is able to tie into the existing building. The basement area below the proposed stage extension will remain as existing, with new columns supporting the extension floor. The extension of the building at the rear will tie into the existing stage level and will have a FFL of 11.24mAOD. This extension will be above the existing ground level to the rear of the theatre. Therefore, while the model changes have been applied for the entrance extension, no changes have been made to represent the rear extension.

As the development proposals on the Port Talbot Town Centre Riverside Public Realm site do not involve any changes in ground levels or any built development, the post development scenario has not been assessed as the development works will not result in any changes in flood risk.



Figure 5-6 Post-development model setup

5.3.3 Post-development 1% AEP plus climate change event

The predicted depths of flooding across the site are shown in Figure 5-7. To account for the proposed FFL's, the predicted flood depths are summarised in Table 5-3.

Table 5-3 Potential flood depths in the 1% AEP plus climate change post development event

Area of the site	Finished Floor Level (mAOD)	Flood Level (mAOD)	Maximum Flood Depth (m)
Front extension	10.13	10.16	0.03
Rear of building at basement access point	7.02	10.58	3.56
Rear of building at top of steps to access ground floor	11.24	10.37	Flood free

Area of the site	Finished Floor Level (mAOD)	Flood Level (mAOD)	Maximum Flood Depth (m)
Rear extension of the building	11.24	10.24	Flood free

The building extension is predicted to flood by 33mm which is an increase in risk from the baseline scenario however this increase in risk can be accepted by the developer.

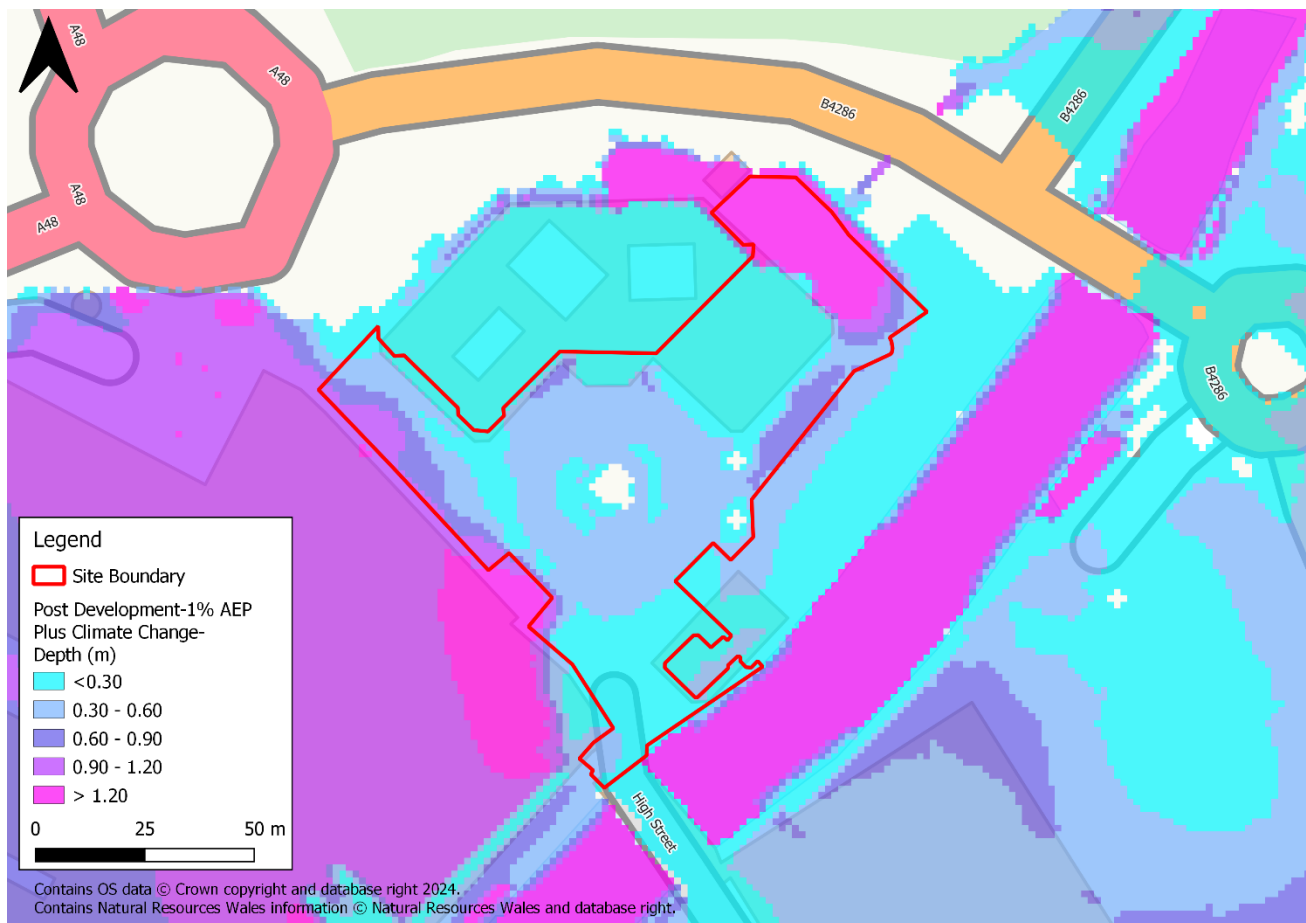


Figure 5-7 Flood depths in the Post Development 1% AEP plus climate change event

5.3.4 Post-development 0.1% AEP event

The flood depths predicted during the post-development 0.1% AEP event are shown in Figure 5-8.

To account for the proposed FFL's, the predicted flood depths are summarised in Table 5-4.

Table 5-4 Potential flood depths in the 0.1% AEP post development event

Area of the site	Finished Floor Level (mAOD)	Flood Level (mAOD)	Maximum Flood Depth (m)
Front extension	10.13	10.31	0.18
Rear of building at basement access point	7.02	10.58	3.56
Rear of building at top of steps to access ground floor	11.24	10.53	Flood free
Rear extension of the building	11.24	10.65	Flood free

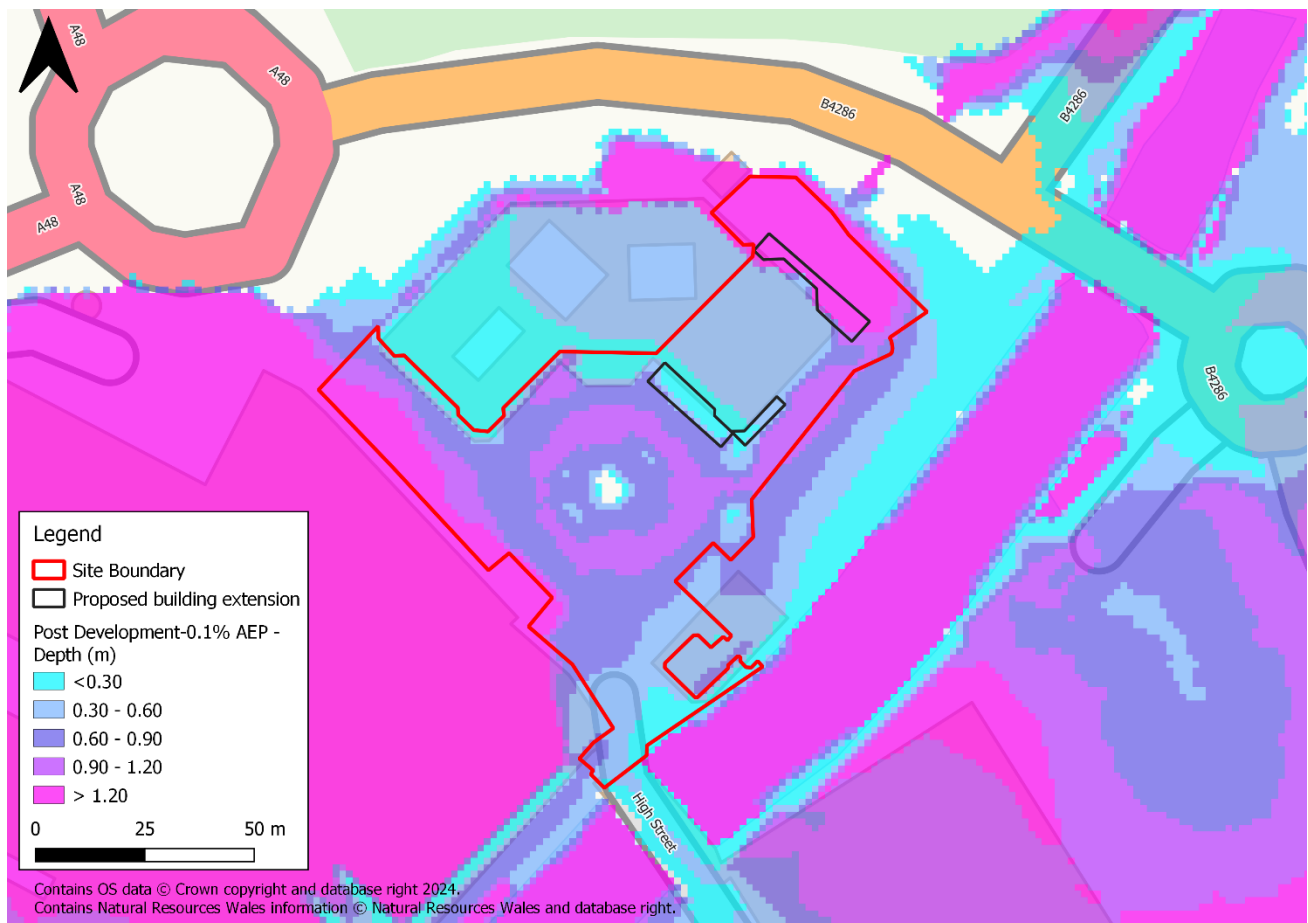


Figure 5-8 Flood depths in the Post Development 0.1% AEP event

5.3.5 Third-Party Impacts

Almost any new or extensions to development in the floodplain have the potential to change the flood risk to others. This can be caused by changes in the availability of flood storage or changes in how flood water can flow across a site (conveyance).

Paragraph 7.3 of TAN-15 states that development must have “minimal impact of the proposed development on flood risk generally”. Furthermore, the guidance in Section A1.5 of TAN-15 requires that an FCA should assess “the impact of the development in terms of flood risk on neighbouring properties and elsewhere on the flood plain”. Therefore, this matter is discussed in the following section.

To understand the potential change to the flood risk to others as a result of the development the pre- and post-development scenarios have been compared using GIS software. The 'detriment analysis' identifies areas where the flood depth has increased or decreased because of changes to the hydraulic model to represent the pre- and post-development scenarios.

5.3.5.1 1% AEP plus climate change event

The detriment analysis for the 1% AEP event plus climate change is shown in Figure 5-9.

Betterment is shown across the proposed development site as a result of an increase in building levels in the proposed development areas and changes in the flow conveyance. Depths decrease by 0.06-21cm to the east of the new entrance extension and to the south of the building with depths in the building predicted to increase in flooding by up to 0.05m.

Increases in water levels are limited to the wider site, including the car parking and surrounding area. Increases are up to 0.07m. However, no third-party areas are affected by the increase in flooding as all of these areas are under Neath Port Talbot Council's ownership. The owner of the building will be able to accept the increase in risk.

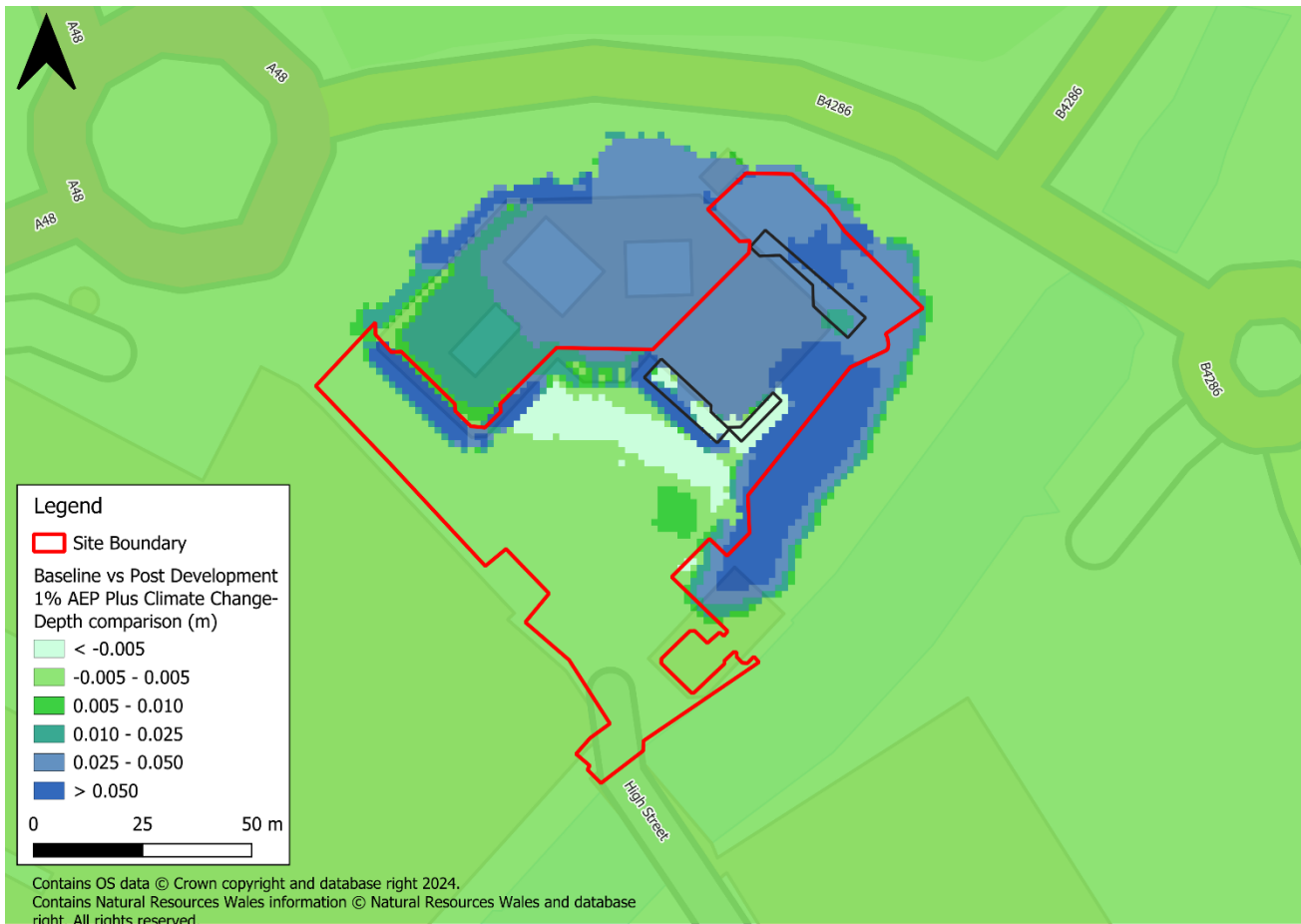


Figure 5-9 Flood depth comparison 1% AEP plus climate change event

5.3.5.2 0.1% AEP event

The detriment analysis for the 0.1% AEP event is shown in Figure 5-10. The results of the analysis are similar to that of the 1% AEP plus climate change event. The area of betterment in this event extends to a large area south of the site, where flood depths are reduced by 7mm. No third-party areas outside of the immediate site boundary are affected by the increase in flooding as this area is under Neath Port Talbot Council's ownership. A small area on the eastern bank is shown to have a minor increase in flooding however this appears to be linked to minor instabilities in the 2D water levels that propagating above the $\pm 5\text{mm}$ threshold. Following a careful review of the model setup and results, we are confident that this aberration is not indicative of an actual increase in flood risk elsewhere. This result highlights that complex flood models can have difficulties in accurately resolving change in flood levels to such small tolerances of just $\pm 5\text{mm}$.



Figure 5-10 Flood depth comparison 0.1% AEP event

5.4 Flood Mitigation Measures

The following measures are advised to enhance the site's resilience to flooding;

- Site management should sign up for the NRW flood warning service. The proposed development site is located entirely within the 'River Afan at Port Talbot' flood warning area and the 'Swansea Bay and Gower Coast' and the 'Rivers Afan and Kenfig' flood alert area.
- A Flood Emergency Plan should be developed and adopted so that occupiers and users are aware of the flood risk and know what action to take in the event of receiving a flood warning. At a minimum, the flood emergency plan should cover adequate flood warning, evacuation, and access/egress routes in the event of flooding for the lifetime of the development. NRW guide the production of flood emergency plans⁴. This guidance should be used to inform flood response procedures at the site.

⁴ Natural Resources Wales, How to prepare your home business or farm for a flood, retrieved from: <https://naturalresources.wales/flooding/preparing-your-home-business-or-farm-for-a-flood/?lang=en>

6 Assessment of Acceptability Criteria

Our assessment of the Acceptability Criteria, as set out in TAN-15, is summarised Table 6-1 below. These criteria must be satisfied for the proposed development to comply with all aspects of TAN-15.

Table 6-1 Assessment of Acceptability Criteria

TAN 15 Acceptability Criteria	Comments	Achieved
The developer is required to demonstrate that the site is designed to be flood-free for the lifetime [Ref: TAN-15 A1.5] of development for a 1 in 100 (1%) chance (fluvial) and 1 in 200 (0.5%) chance (tidal) flood event including an allowance for climate change in accordance with TAN-15 table A1.14.	The proposed front extension is predicted to flood to shallow depths in the post-development 1% AEP plus climate change flood event. However, as the entrance is required to be at the same level as the existing building, it is not possible to increase the finished floor levels.	No
The development should be designed so that in an extreme (1 in 1000 chance) event there would be less than 600mm of water on access roads and within the building.	During the 0.1% AEP event, flooding is predicted not to exceed 600mm within the front building extension as depths will be up to 180mm. To the rear, the extension will be on the ground floor and will be above the flood level, making it flood free.	Yes
No flooding elsewhere.	Detailed hydraulic modelling has shown that the proposed development will not increase flood risk to third parties, as detailed in Section 5. As Neath Port Talbot Council are the owners of the proposed site and the surrounding land, they are able to accept the consequences of a small increase in flooding as a result of the proposed development changes.	Yes
Flood defences must be shown by the developer to be structurally adequate, particularly under extreme overtopping conditions	The flood defences in Port Talbot are owned and maintained by NRW and are regularly inspected.	Yes

TAN 15 Acceptability Criteria	Comments	Achieved
(i.e. that flood with a 1 in 1000 chance of occurring in any given year).		
The developer must ensure that future occupiers of development are aware of the flooding risks and consequences	Site management should sign up to the NRW Flood Warning Service to provide adequate warning of flooding. A Flood Response Plan should be developed and adopted so that users are aware of the flood risk and know what action to take in the event of receiving a flood warning. At a minimum, the flood response plan should cover adequate flood warning, evacuation, and access/egress routes in the event of flooding for the lifetime of the development	Yes
Effective flood warnings are provided at the site	The site is located within NRW's 'River Afan at Port Talbot' flood warning area as well as the 'Swansea Bay and Gower Coast' and the 'Rivers Afan and Kenfig' flood alert area.	Yes
Escape/evacuation routes are shown by the developer to be operational under all conditions.	Considerable flood warning lead time (>24hrs) should provide plenty of time to evacuate the site safely and warn visitors to the building of the risk.	Yes
The development is designed by the developer to allow the rapid movement of goods/possessions to areas away from flood waters.	It has been recommended that resilience measures including the production of a flood response plan should be undertaken. An effective plan will facilitate rapid movement of goods/possessions away from the site or to higher levels within the building.	Yes
Development is designed to minimise structural damage during a flooding event and is floodproofed to enable it to be returned to its prime use quickly after the flood.	The proposed development would be unlikely to experience any structural damage during a flood event due to the shallow (<300mm) depths of flooding within the building.	Yes

7 Conclusion

JBA Consulting (JBA) was commissioned by Morgan Sindall Construction and Infrastructure Ltd to undertake a Flood Consequences Assessment (FCA) for the extension and redevelopment of the Princess Royal Theatre, and the enhancement of the riverside public realm in Port Talbot.

The proposed development areas are split into two sites, the Princess Royal Theatre and Civic Square Redevelopment site and the Port Talbot Town Centre Riverside Public Realm site. The Princess Royal Theatre and Civic Square Redevelopment site is approximately 0.68ha in size and is currently comprised of the theatre building, associated car parking and landscaping. The Port Talbot Town Centre Riverside Public Realm site is approximately 0.40ha in size and is currently comprised of landscaped land with pathways through the site connecting the surrounding roads, pedestrian bridge across the River Afan as well as the Riverside Baptist Church to the south.

Both sites are located in close proximity to the River Afan.

The Princess Royal Theatre and Civic Square Redevelopment is for use as a public building which is classified as highly vulnerable development. Development proposals at the site will not change the development use nor intensify the development. The Riverside Public Realm will be public open space which is not explicitly classified in the flood risk vulnerabilities in TAN-15. Therefore, the development is classified as 'Other'.

The site is located within Zone C1, as categorised by NRW's Development Advice Maps. Zone C1 is described as areas of the floodplain which are developed and served by significant infrastructure, including flood defences.

Both sites are within a TAN-15 Defended Zone of the FMfP for flood risk from Rivers.

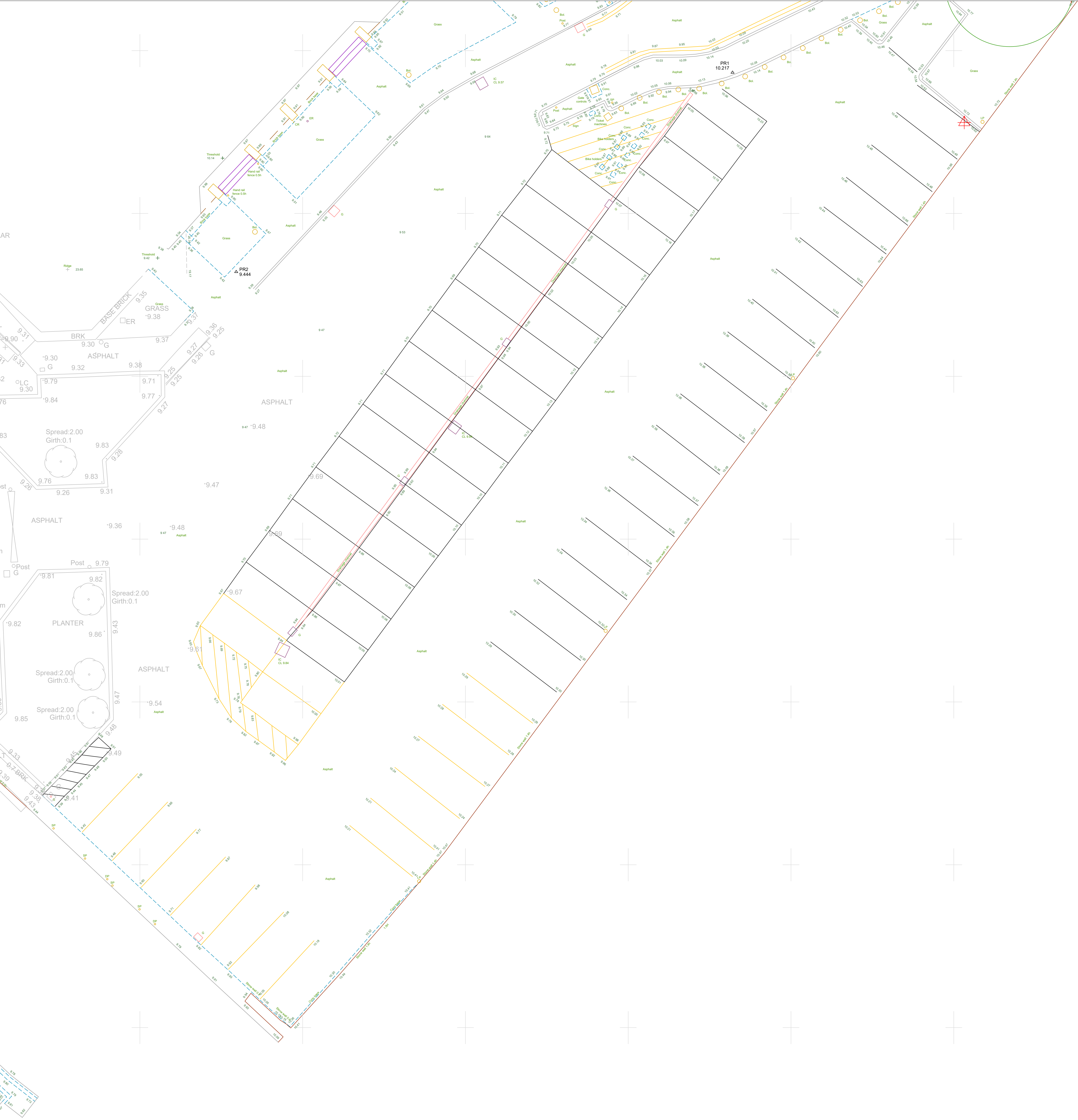
The site is at little or no risk of flooding from the sea, groundwater, or sewer flooding.

Detailed hydraulic modelling has been used to assess the risk of fluvial flooding to the site. This demonstrates that the proposed rear extension in the Princess Royal Theatre and Civic Square Redevelopment site will be flood-free in the post-development 1% AEP plus climate change and 0.1% AEP event fluvial event and the front extension will flood to shallow depths.

It is recommended that the building management sign up NRW's Flood Warning Service and that a Flood Response Plan is prepared to ensure that future occupiers of the site are aware of the flood risk and recommended flood risk management actions.

In conclusion, we find that the site satisfies all the requirements of the Acceptability Criteria in compliance with the aims and objectives of Planning Policy Wales and TAN-15.

A Topographic Survey



Coordinate System

This survey has been oriented to the Ordnance Survey (OS) National Grid and Datum using GPS observations and the OS Active Network.

A true OS coordinate was established near to the centre of the site. This survey has been correlated to this point. Further OS coordinates were established to create a true OS bearing for angle orientation.

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Notes

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Key to Abbreviations	
Inspection Covers & Chambers	Walls & Fence Types
AV Air Valve	BL Block Wall
BH Borehole	BR Brick Wall
CDP British Telecom Cover	BWF Barbed Wire Fence
CDV Cable Drove Valve	CB Close Boarded Fence
DW Combined Water	CIF Corrugated Iron Fence
D-CH Drainage Channel	CL Chain Link Fence
Ekc Electric Inspection Cover	CIP Concrete Post
ER Earth Road	GAB Gabion Wall
FH Fire Hydrant	HR Hand Rail
FW Foul Water	HR Iron Railings
GC Gas Cock	IR Iron
GG Gully	IRB Iron Railings
GV Gas Valve	IRB Iron Railings
IC Inspection Cover	IRB Iron Railings
KO Kerb Outlet	IRB Iron Railings
ME Manhole	IRB Iron Railings
RE Rodding Eye	IRB Iron Railings
SC Stop Cock	IRB Iron Railings
SV Stop Valve	IRB Iron Railings
SW Storm Water	IRB Iron Railings
TV Cable Television Cover	IRB Iron Railings
UL Up Lighter	IRB Iron Railings
UTL Unable to Lift	IRB Iron Railings
WMI Water Meter	IRB Iron Railings
WO Washout	IRB Iron Railings
Ground Surface Types	Street Furniture
Asp Asphalt	B Bolard
BIF Block Paving	BB Bellisha Beacon
Conc Concrete	DP Down Pipe
Pav Concrete Paving	EP Electricity Pole
Tac Tactile Paving	FB Flower Bed
	JP Junction Box
	LP Lamp Post
	MP Marker Post
	PS Post
	PS Post Box
	PS Post Sign
	RS Road Sign
	RWP Rain Water Pipe
	SR Sign Post
	SR Sign Post
	SVH Soil Vent Pipe
	TCH Telephone Call Box
	TL Traffic Light
	TP Telephone Pole
	VP Vent Pipe

Linetypes & Symbols

—	Banks	—	Banking
—	Buildings	—	Flow Direction
—	Building Overhead	—	Gate
—	Change of Surface	—	Survey Station
—	Fences	—	Tree
—	Kerbs	—	
—	Overhead Cables	—	
—	Ridges & Eaves	—	
—	Steps	—	
—	Walls	—	
—	Vegetation	—	
—	Tree Canopy	—	
—	Combined Water	—	
—	Foul Water	—	
—	Storm Water	—	

Sheet Layout

Rev	Date	Drawn	Details
A	22.03.24	CU	Survey updated.

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Title
Topographical Survey

Project
Princess Theatre

Client
Morgan Sindall

Drawn:	CU	Checked:	DR
Date:	18-03-2024	Scale:	1:100 @ A0
Drawing Number:	3348-T-02	Rev:	A



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CDP Cable Duct	CB Close Boarded Fence
OW Combined Water	CI Corrugated Iron Fence
D-CH Draining Channel	CL Chain Link Fence
Elec Electric Inspection Cover	CP Concrete Post
ER Earth Rod	Gal Galvanised
FH Fire Hydrant	HR Hard Rail
FW Four Water	IR Iron Railings
GC Gas Cock	Pat Palisade Fence
IC Inspection Cover	PR Post & Rail Fence
KO Kerb Outlet	PW Post & Wire Fence
MC Manhole	RE Retaining Wall
RE Redding Eye	St Stone Wall
SC Step/Cock	
SV Stop Valve	
SW Storm Water	
TV Cable Television Cover	
UL Up Lighter	
UUL Unable to Lift	
WM Water Meter	
WO Washout	
	Street Furniture
	B Bollard
	BB Bellisha Beacon
	DP Down Pipe
	EP Electricity Pole
	FB Flower Bed
	JB Junction Box
	LP Lamp Post
	MP Marker Post
	PP Post
	RS Road Sign
	RWP Road Water Pipe
	SP Sign Post
	SW Stop Wire
	SVH Sol Vent Pipe
	TCH Telephone Call Box
	TL Traffic Light
	TP Telephone Pole
	VP Vent Pipe

Measurement Descriptions

CL Cover Level
d Diameter (mm)
d Depth (m)
dia Diameter (mm)
FFL Finished Floor Level
h Fixture Height (m)
IL Invert Level
SL Sump Level
Soft Soft Level
WL Water Level

Ground Surface Types

Asp Asphalt
BFP Block Pavers
Conc Concrete
Pav Pavement
Tact Tactile Paving

LineTypes & Symbols

— Banks
— Buildings
— Building Overhead
- - - Change of Surface
- - - Fences
- - - Kerbs
- - - Overhead Cables
- - - Ropes & Cables
- - - Walls
- - - Vegetation
- - - Tree Canopy
- - - Combined Water
- - - Foul Water
- - - Storm Water

— Flow Direction
— Gate
— Survey Station
— Tree

Sheet Layout

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A	22.03.24	CU	Survey updated.

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Title: Topographical Survey

Project: Princess Theatre

Client: Morgan Sindall

Drawn: CU	Checked: DR
Date: 18-03-2024	Scale: 1:100 @ A0
Drawing Number: 3348-T-03	Rev: A

Coordinate System

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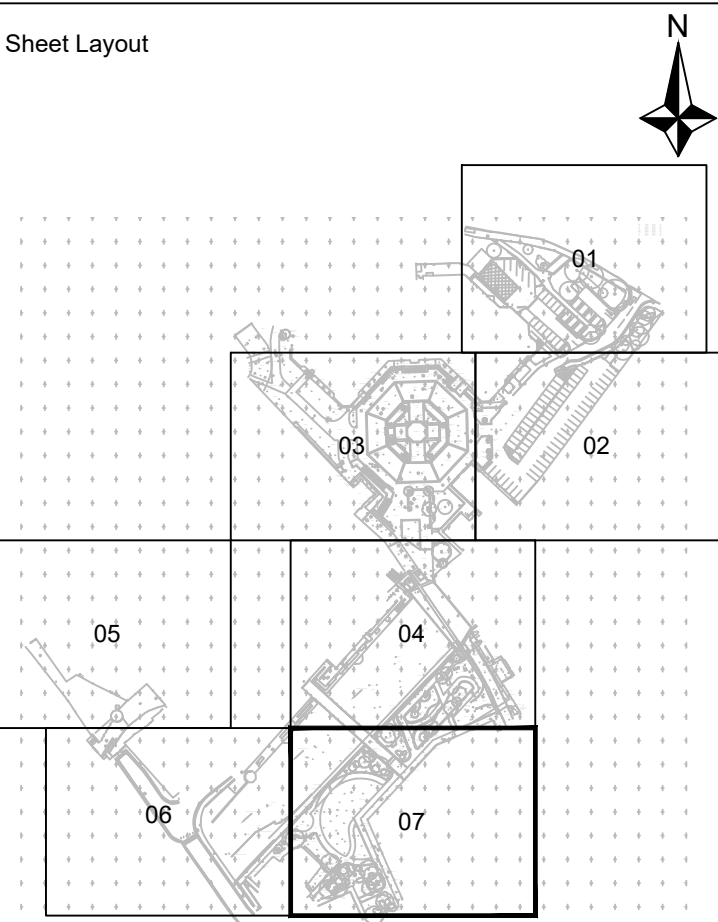
Key to Abbreviations

[illegible]

Linetypes & Symbols

	Banks		Banking
	Buildings		Flow Direction
	Building Overhead		Gate
	Change of Surface		Survey Station
	Fences		Tree
	Kerbs		
	Overhead Cables		
	Ridges & Eaves		
	Steps		
	Walls		
	Vegetation		
	Tree Canopy		
	Combined Water		
	Foul Water		
	Storm Water		

Sheet Layout



A	22.03.24	CU	Survey updated.
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Title: **Topographical Survey**

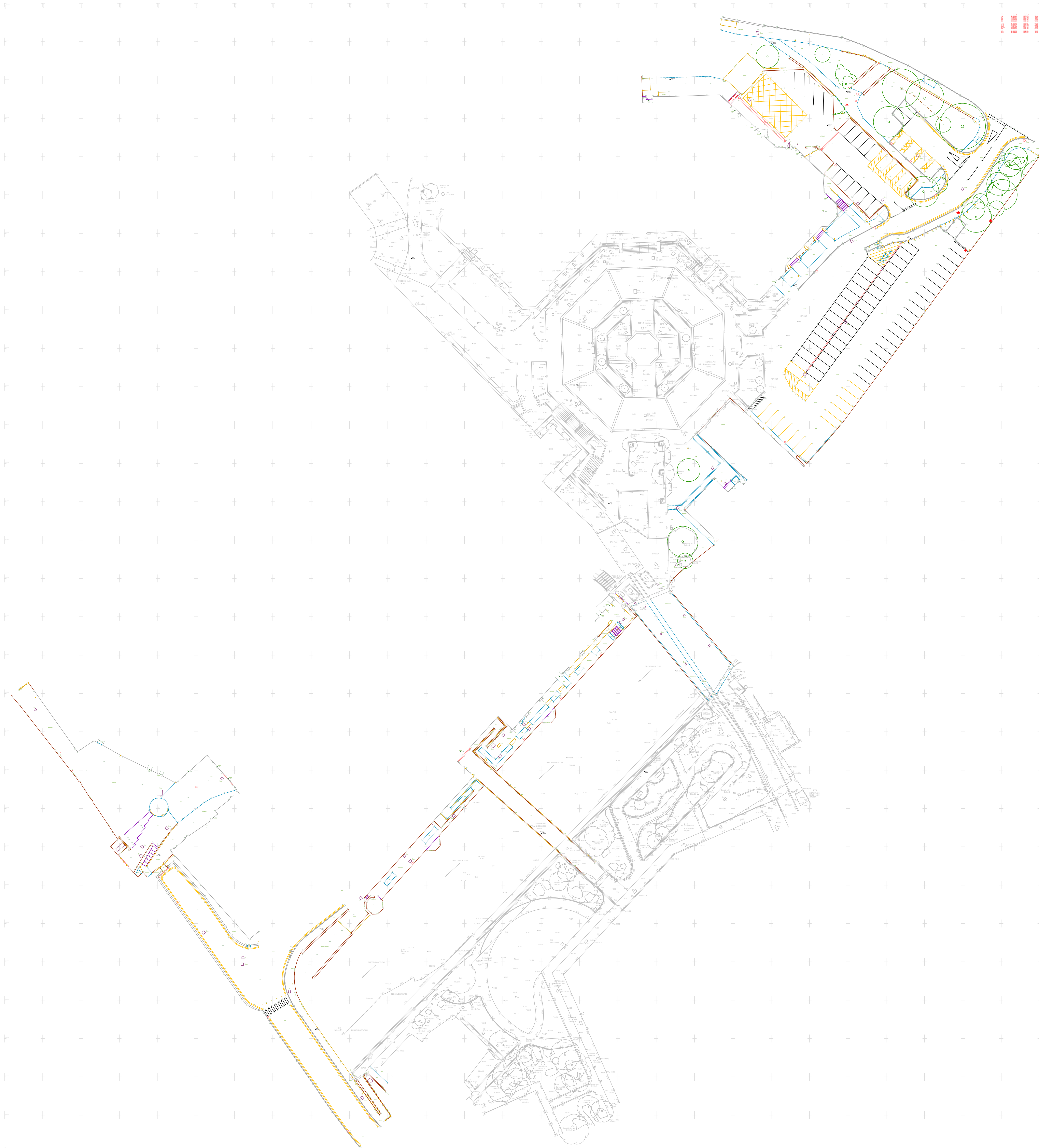
Project: Princess Theatre

Client: **Morgan Sindall**

Drawn:	CU	Checked:	DR
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Date: 18-03-2024	Scale: 1:100 @ A0
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UTL Unable to Lift	JB Junction Box
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Conc. Concrete	SP Sign Post
Pav. Concrete Paving	SW Stop Sign
Tac. Tactile Paving	SVR Soil Vent Pipe
	TCH Telephone Call Box
Measurement Descriptions	TL Traffic Light
CL Cover Level	TP Telegraph Pole
d Depth (m)	VP Vent Pipe
d/s Diameter (mm)	
FFL Finished Floor Level	
h Feature Height (m)	
IL Invert Level	
SL Sump Level	
Soft Soft Level	
WL Water Level	

Linetypes & Symbols

— Banks	— Banking
— Buildings	— Flow Direction
— Building Overhead	— Gate
— Change of Surface	— Survey Station
— Fences	— Tree
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— Overhead Cables	
— Pipes & Eaves	
— Steps	
— Walls	
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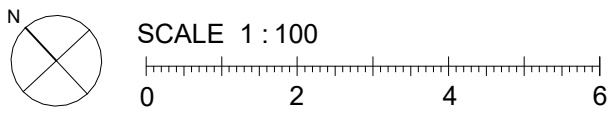
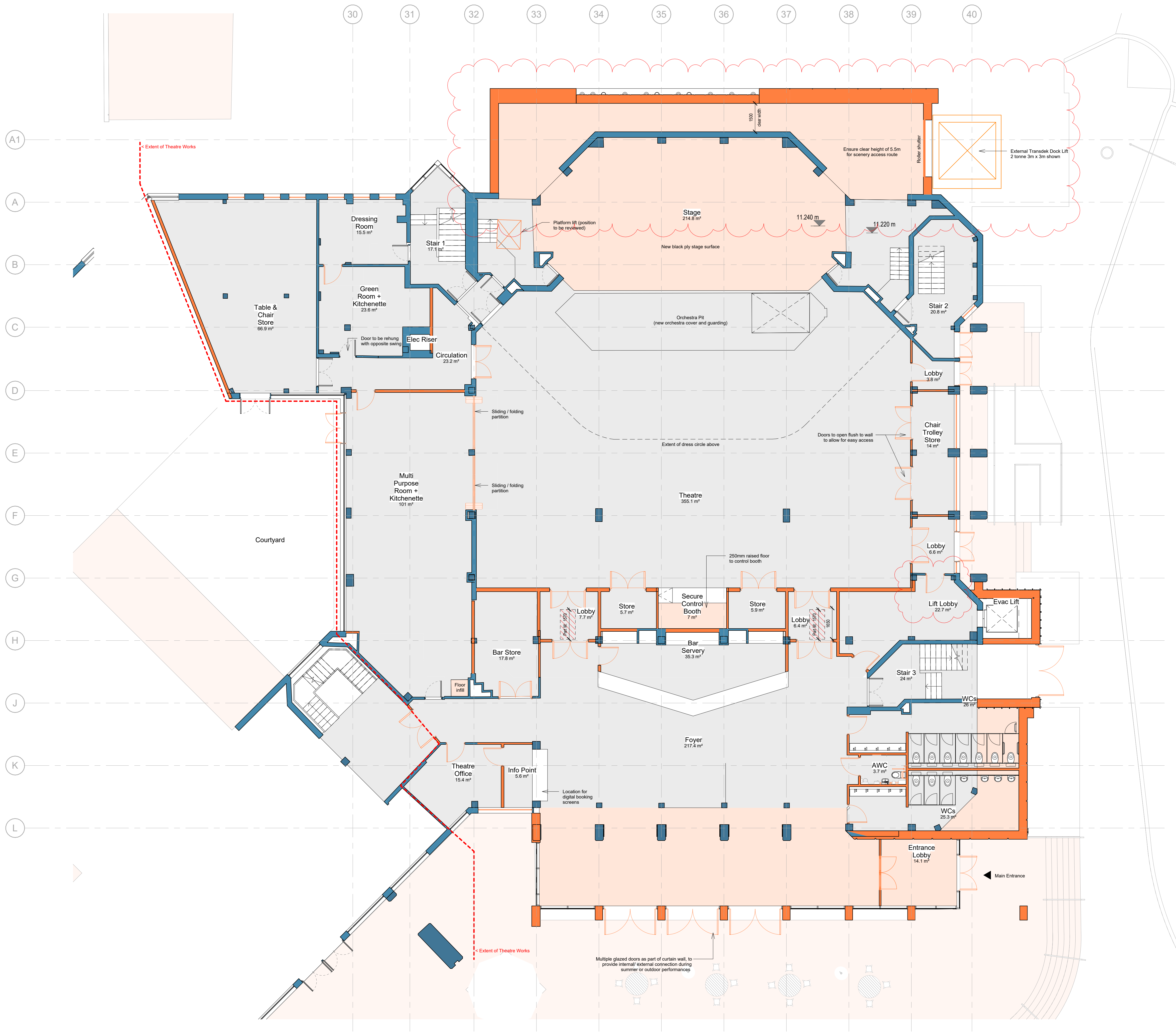
Title
Topographical Survey

Project
Princess Theatre

Client
Morgan Sindall

Drawn: CU	Checked: DR
Date: 18-03-2024	Scale: 1:100 @ A0
Drawing Number: 3348-T Overview	Rev: A

B Development Plans



Key	
---	Works boundary line
■	Retained Walls/ Doors
■	Retained Floor / Roof
■	Proposed Walls/ Doors
■	Proposed Floor
■	Proposed Roof

General Note:
Contractor to verify dimensions on site prior to undertaking any work or manufacturing items

Existing Building Information:
The revit model is based on the received survey data, therefore any liability for the accuracy of the survey data will remain with the surveyor.
3348-F Floor Plans rev - dated 20.03.24
3348-E Elevations rev - dated 20.03.24
3348-S Sections rev - dated 27.03.24

As the following key items are awaited from the surveyors, the interim use of assumptions and historical information has been made for the following:

Roof plan
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Civic centre plans
Soffit heights
Theatre reflected ceiling plan

Site Plan & Landscape:
Existing plans awaited from Landscape Architect. Topographical survey has been used for the existing ground and basement plans to provide context.
3348-T Topographical Survey rev A dated 18.03.24
Proposed landscape is as provided by Urbanists RE22-URB-ZZ-ZZ-M3-L-9999-
LandscapeModel (2024-05-17)

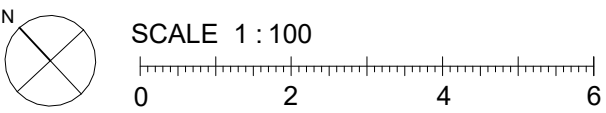
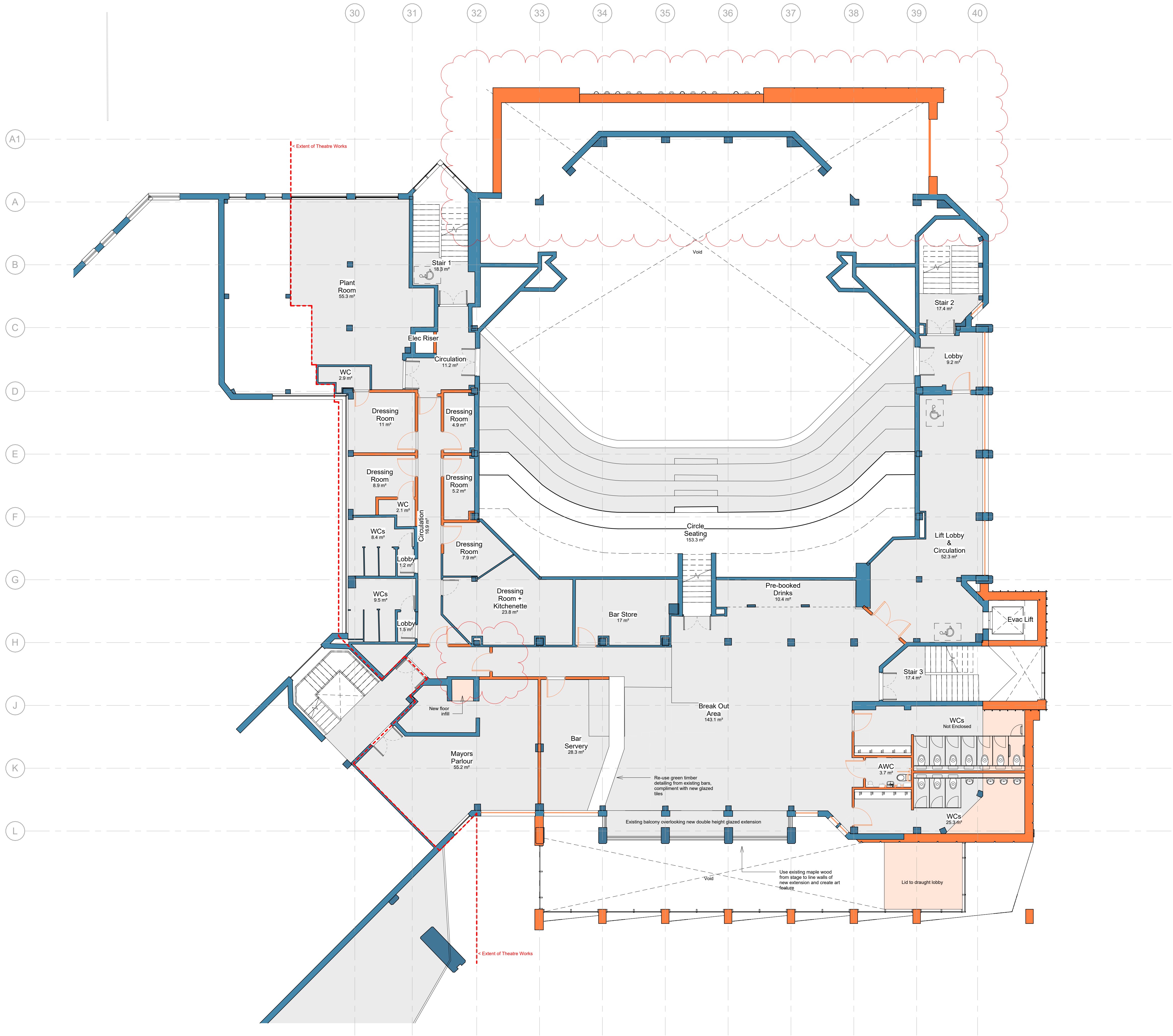
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P04	(S4) Stage 2 Issue	09.05.24	HT	HT
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P02	(S0) General updates	15.04.24	HT	HT
P01	(S0) Initial issue	08.04.24	HT	HT
Rev	Description	Date	Dr by	App by
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Author	04/05/24	Approver		

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client name	Morgan Sindall		
project	Princess Royal Theatre		
drawing	Proposed - Ground Floor		
computer file	110.32.1110EM_Profile_Folder_redaction\hra\Documents\Revit_Files\Local Floorplan 2024050303-AHR-ZZ-ZZ-M3-A-2000_ArchModel_hra.txd	plot date	
project number	2022.00734.000	scale	1 : 100 @A1
drawing number	26CC03-AHR-ZZ-00-DR-A-20050	rev	P05
		issue status	S1

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Key

- Works boundary line
- Retained Walls/ Doors
- Retained Floor / Roof
- Proposed Walls/ Doors
- Proposed Floor
- Proposed Roof

General Note:
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Existing Building Information:
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3348-F Floor Plans rev- dated 20.03.24
3348-E Elevations rev- dated 20.03.24
3348-S Sections rev - dated 27.03.24
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3348-T Topographical Survey rev A dated 18.03.24
Proposed landscape is as provided by Urbanists RE22-URB-ZZ-ZZ-AG-4-9999- LandscapeModel_2024-05-17

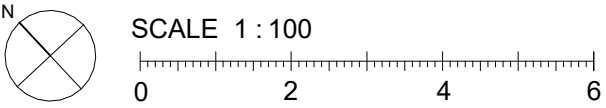
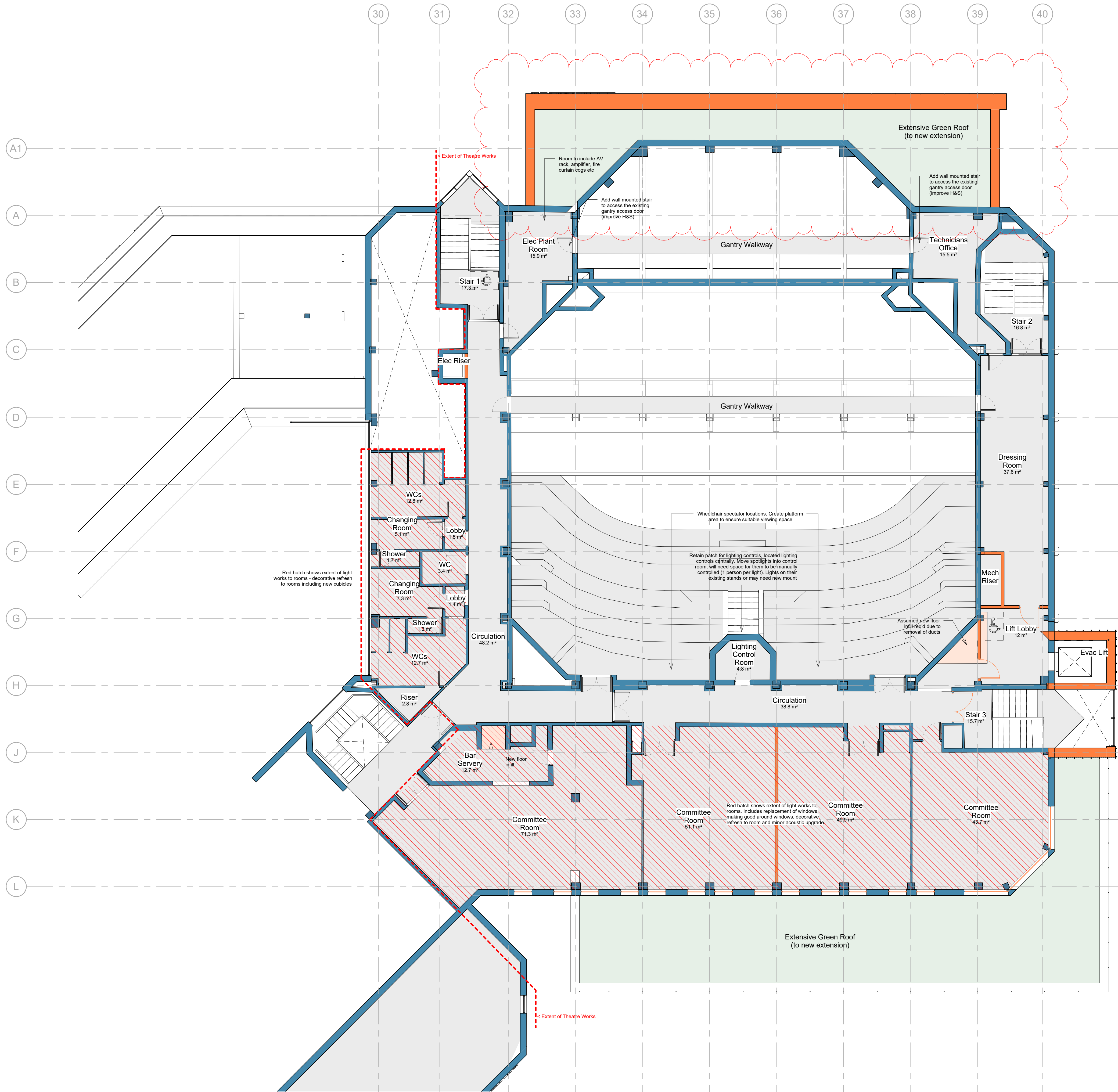
P05	(S1) Rear extension update to suit client change. Update to suit F1Eng input	19.06.24	HT	HT
P04	(S4) Stage 2 Issue	09.05.24	HT	HT
P03	(S0) General updates	24.04.24	HT	HT
P02	(S0) General updates	15.04.24	HT	HT
P01	(S0) Initial issue	08.04.24	HT	HT
Rev	Description	Date	Dr	App
original by	date created	approved by		
Author	04/05/24	Approver		



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client name	Morgan Sindall
project	Princess Royal Theatre
drawing	Proposed - First Floor
computer file	110.32.1110EM_Profile_Folder_redactorhrya.tammy/Documents/Realt FieldUseFloorPlan20240503-AHR-ZZ-ZZ-AG-A-2000 ArchModel_hrya.tammy.rvt
project number	2022.00734.000
scale	1 : 100 @A1
drawing number	26CC03-AHR-ZZ-01-DR-A-20050
rev	P05
issue status	S1

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3348-S Sections rev - dated 27.03.24
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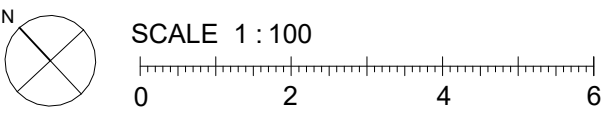
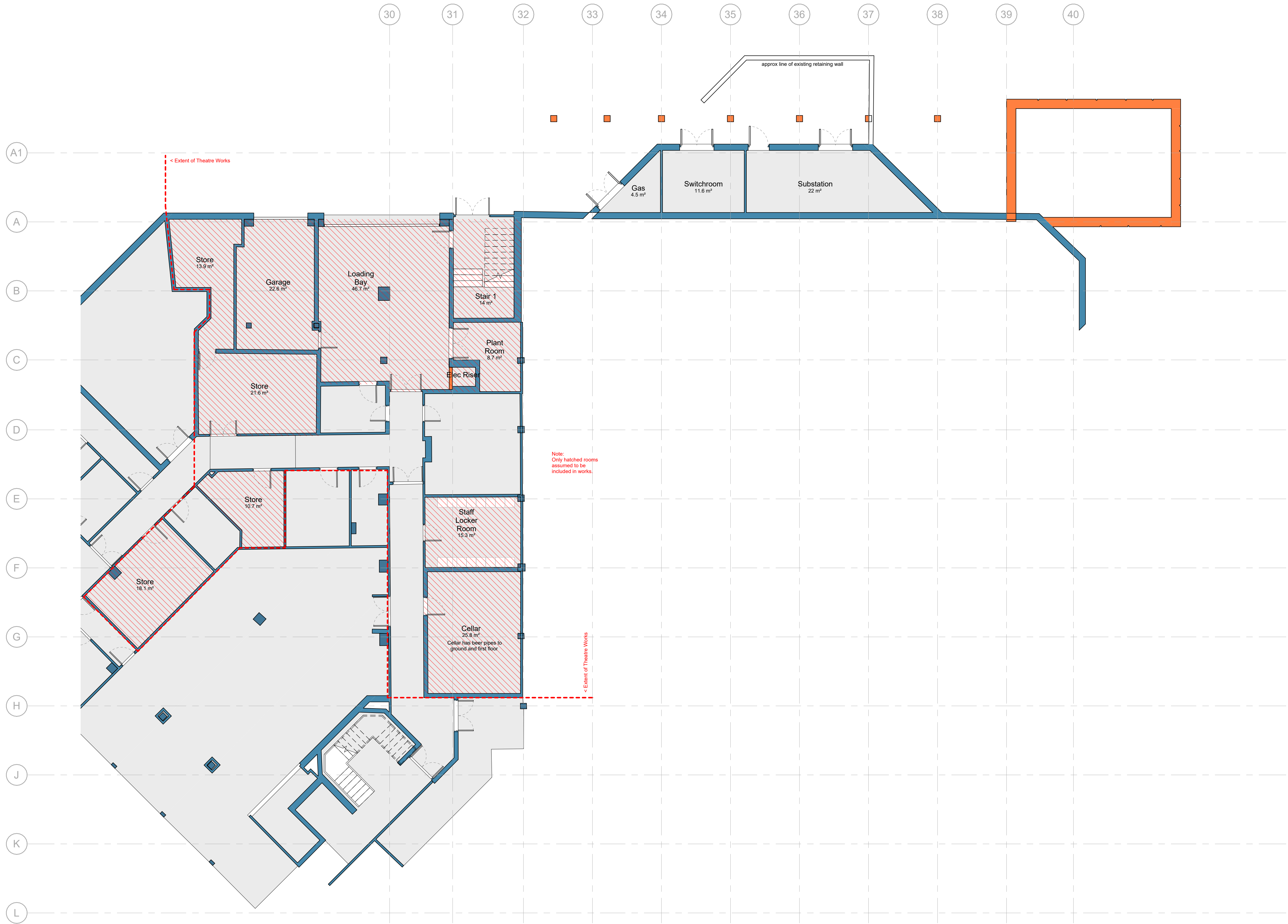
Site Plan & Landscape:
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3348-T Topographical Survey rev A dated 18.03.24
Proposed landscape is as provided by Urbanists RE22-URB-ZZ-ZZ-M3-9999-
LandscapeModel_ (2024-05-17)

P06	(S1) Rear extension update to suit client change	19.06.24	HT	HT
P05	(S4) Minor update. Stage 2 issue	13.05.24	HT	HT
P04	(S4) Stage 2 issue	09.05.24	HT	HT
P03	(S0) General updates	24.04.24	HT	HT
P02	(S0) General updates	15.04.24	HT	HT
P01	(S0) Initial issue	08.04.24	HT	HT
Rev	Description	Date	Dr by	App by
original by	Author	date created	04/05/24	approved by
				Approver



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client name	Morgan Sindall
project	Princess Royal Theatre
drawing	Proposed - Second Floor
computer file	110.32.1110EM_Profile_Folder - redactor\hrya\temey\Documents\Revit File\Local FloorPlan\2024\02\03-AHR-ZZ-ZZ-M3-A-2000 ArchModel_hrya.temey.rvt
project number	2022.00734.000
scale	1 : 100 @A1
drawing number	26CC03-AHR-ZZ-02-DR-A-20050
rev	P06
issue status	S1
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3348-S Sections rev - dated 27.03.24
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Site Plan & Landscape:
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Topographical survey has been used for the existing ground and basement plans to provide context.
3348-T Topographical Survey rev A dated 18.03.24

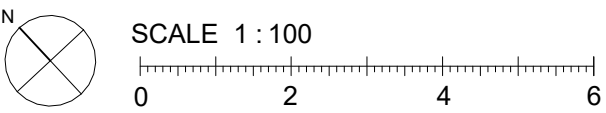
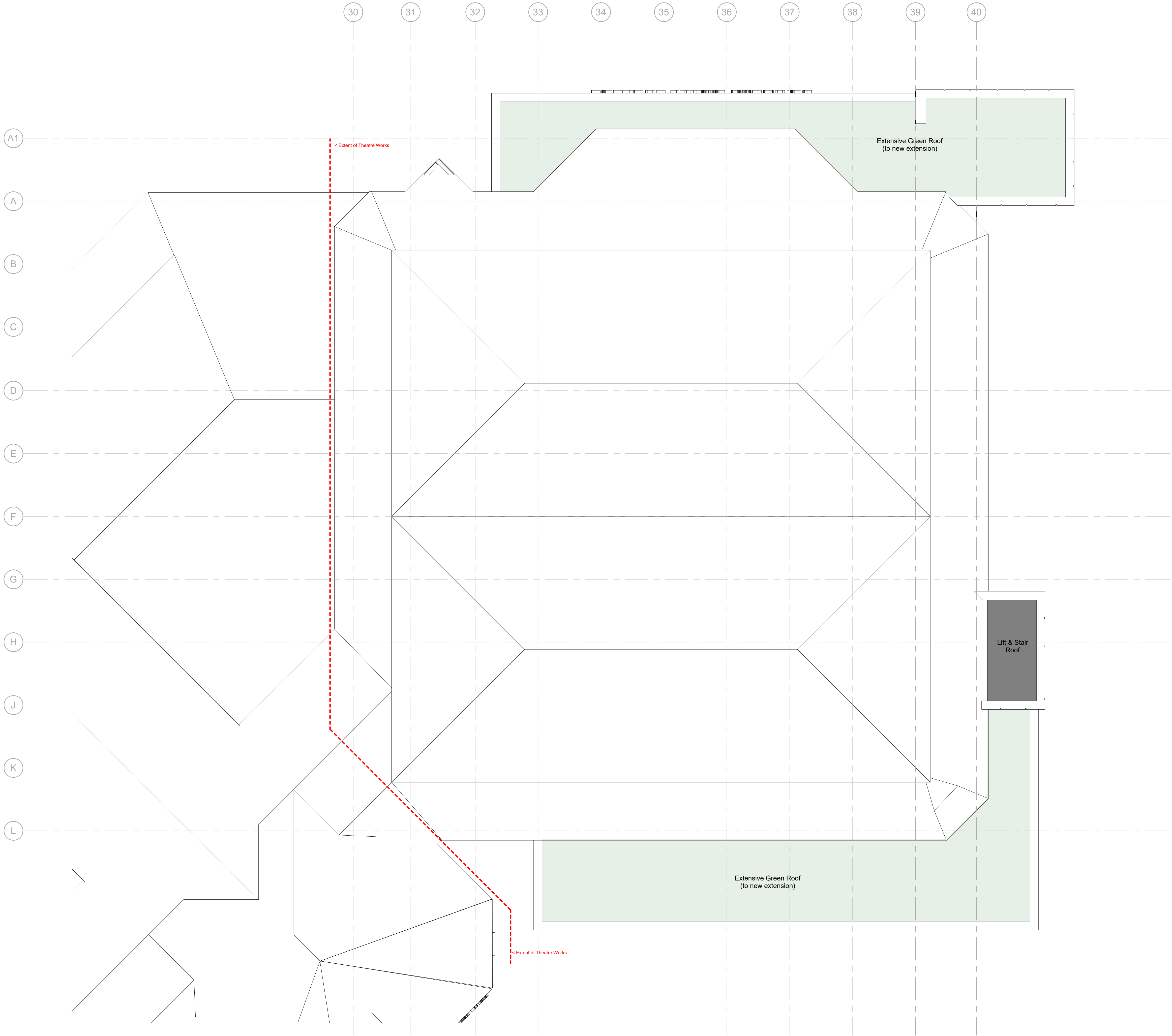
P03	(S4) Stage 2 Issue	09.05.24	HT	HT
P02	(S0) General updates	15.04.24	HT	HT
P01	(S0) Initial issue	08.04.24	HT	HT
Rev	Description	Date	Dr	App
Author		04/05/24	by	by
			Approver	

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client name	Morgan Sindall		
project	Princess Royal Theatre		
drawing	Proposed - Basement		
computer file	\\10.32.1.110\EM_Profile_Folder_redactor\hrya\mexy\Documents\Revit_Files\Useful Files\Revit\2020\000003-AHR-22-22-03-A-2000_ArchModel_hrya\mexy.rvt		plot date
project number	2022.00734.000	scale	1 : 100 @A1
drawing number	26CC03-AHR-ZZ-B1-DR-A-20050	rev	P03
		issue status	S4

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Topographical survey has been used for the existing ground and basement plans to provide context.

3348-T Topographical Survey rev A dated 18.03.24

P01	(S4) Stage 2 Issue	09.05.24	HT	HT
Rev	Description	Date	Dr	App
by	by		by	by
original by	date created		approved by	
Author	04/05/24		Approver	



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client name

Morgan Sindall

project

Princess Royal Theatre

drawing

Proposed - Roof

computer file	110.32.1110EM_Profile_Folder - redactor\hira.tamey\Documents\Revit File\Local Floor\Revit 2024\000003-AHR-ZZ-22-M-A-2000 ArchModel_hira.tamey.rvt	plot date	
project number	2022.00734.000	scale	1 : 100 @A1
drawing number	26CC03-AHR-ZZ-RF-DR-A-20050	rev	P01
		issue status	S4

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C Flood modelling

TECHNICAL NOTE

JBA Project Code	2024s0465
Contract	Princess Royal Theatre FCA Flood Risk Modelling
Client	Morgan Sindall Construction & Infrastructure Ltd
Date	July 2024
Author	Paul Redbourne BSc PGCert, MCIWEM, C.WEM
Reviewer / Sign-off	George Baker BEng AEMA CEnv IEng MCIWEM C.WEM
Subject	Hydraulic Modelling Documentation

1 Baseline flood modelling

To provide an improved understanding of flood risk for the extension and redevelopment of the Princess Royal Theatre, a detailed flood modelling exercise has been completed. NRW's product 7 model of Port Talbot has been licensed and used for this assessment with a series of updates applied to align the model with current best practice and methods. This section of the technical note summarises the updates applied to produce a new baseline model scenario.

1.1 General Schematisation

The model has been updated to use the TUFLOW executable 2023-03-AA. There have been subsequent software releases by TUFLOW but there is a known bug issue in these versions associated with water level lines incorrectly projecting results within the channel. This has been discussed with NRW on other studies and agreed that the 2023-03-AA version should be used in preference.

The model grid resolution and model timesteps have been retained from the original model as these are considered appropriate and provide an acceptable balance between model run times and providing a detailed representation of overland flow routes.

New LIDAR data has been collected for much of Wales and consideration has been given for including this data within the new model. This analysis found that the new LIDAR had significant inaccuracies that incorrectly influenced the overland flow routes throughout the modelled study area. The limitations associated with the new LIDAR data have been discussed with NRW and it has been agreed that the older LIDAR data (collected in March 2014) should be used in preference for the Port Talbot model.

1.2 Hydrological Assessment

A new hydrological assessment has been completed to derive new peak flow estimates and inflow hydrographs for the Port Talbot model. Full details of this can be found in the FEH Calculation Record as part of the FCA report appendices.

The hydrological assessment has produced new inflows for all three watercourses within the modelled study area (Afon Afan, Ffrwd Wylt, and Baglan Brook). The FEH Statistical method has been used for the Afon Afan, and the ReFH2 method has been used for the Ffrwd Wylt and the Baglan Brook. For the Afon Afan inflows, the ReFH2 ratio method has been used to derive the peak flow estimate for the 0.1% AEP event in line with NRW's flood estimation guidelines¹.

The previous NRW modelling applied individual storm durations to each of the three catchments, and it was decided to retain this approach. The Afon Afan has adopted a storm duration of 10.5 hours, the Ffrwd Wylt has adopted a storm duration of 5.25 hours, and the Baglan Brook has adopted a storm duration of 4.25 hours. Model testing was completed to understand the impact of using a uniform storm duration across the model, but this showed only negligible differences to model flood extents and flood depths. Therefore, individual durations for each catchment have been used to ensure consistency with previous studies in Port Talbot.

Climate change has been applied to the model for the 1% AEP event. In line with Welsh Government's Flood Consequences Assessments climate change guidance², an uplift of 30% has been applied to each of the model inflows.

¹ Flood estimation – technical guidance – GN 008. November 2021. Natural Resources Wales.

² Flood Consequences Assessments: Climate change allowances. September 2021. Welsh Government. LINK

TECHNICAL NOTE

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Subject	Hydraulic Modelling Documentation

The peak flow estimates applied to the model are provided in Table 2-1 and a map showing the locations of the model inflows is provided in Figure 1-1.

Table 1-1: Fluvial peaks for annual exceedance probabilities

Site code	AEP events (%)			
	50%	1%	1%+CC	0.1%
AFAN02	99.32	206.9	268.97	339.03
AFAN01_IA	5.58	12.46	16.19	21.30
BAG_01	0.77	1.95	2.53	3.88
BAG_02	0.86	2.10	2.73	4.02
BAG_03	0.42	1.08	1.41	2.20
BAG_04	0.49	1.12	1.99	2.59
FF_01	4.79	10.99	14.28	19.38
FF_02	3.28	7.59	9.87	13.45
FF_03	11.94	26.89	34.95	46.70

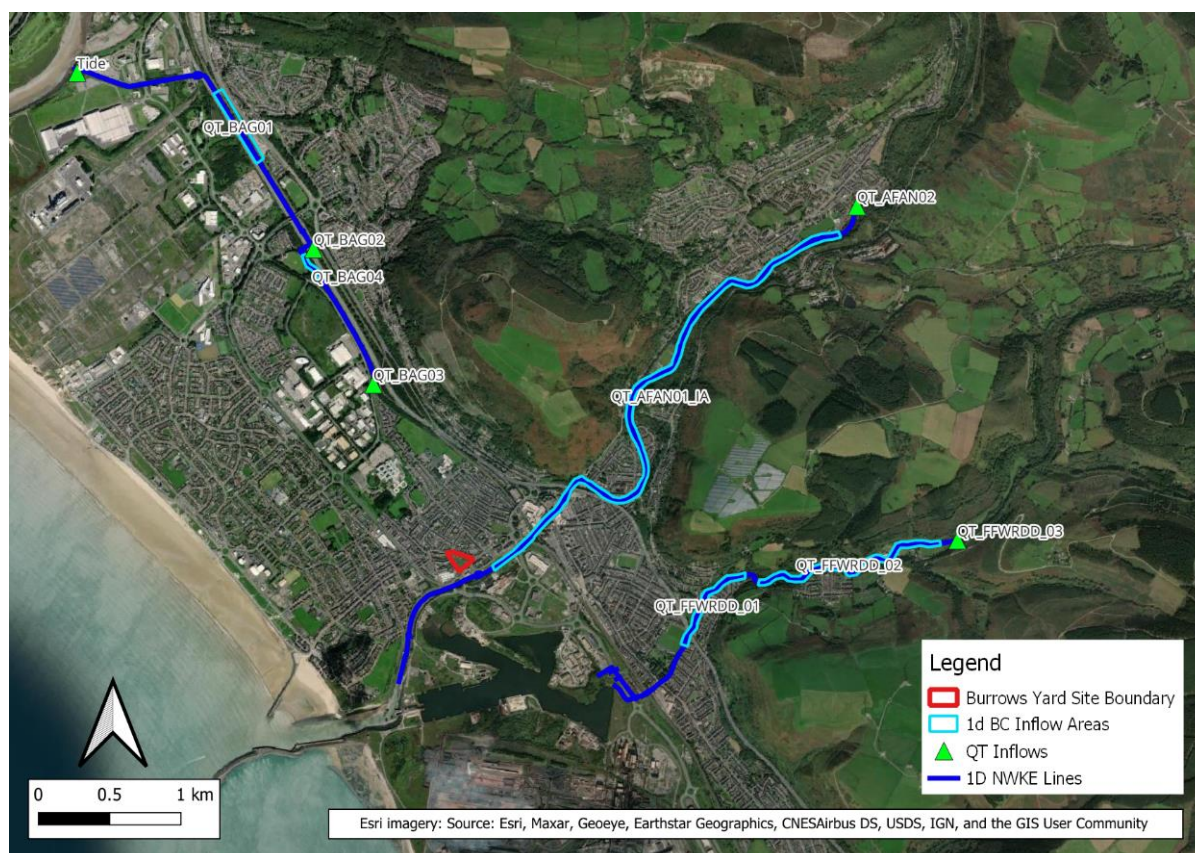


Figure 1-1: Map of 1D fluvial boundaries

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Subject	Hydraulic Modelling Documentation

1.3 Tidal Boundary Conditions

The Port Talbot model is a fluvial – tidal model that can represent both sources of flooding. Since the construction of the original model, the extreme sea level coastal flood boundary (CFB) dataset³ and the Welsh government climate change guidance² for sea level rise have been updated and therefore the tidal boundary conditions applied to the model have been amended accordingly.

The CFB data node point 480, located in the mouth of the Afon Afan estuary has been used to extract the extreme sea levels for use within the hydraulic model. The CFB data has a base year of 2017 and therefore this has been uplifted to 2023 to represent present day conditions.

In line with Welsh Governments climate change guidance, the UKCP18 user interface has been used to generate new tidal boundary conditions for the epochs 2023 and 2098. A climate change epoch of 2098 has been adopted to represent the 75-year design life of the proposed development. The RCP 8.5 scenario has been used to download the projected sea level rise estimates with the 70th percentile (higher central allowance) estimates used to uplift the tidal boundary conditions for the required epochs.

The updated present day and climate change maximum tidal levels are shown in Table 2-2 and the model implementation is shown in Figure 2-4.

For reference, the fluvial design event simulations use the Mean High Water Spring tide curve for the downstream boundary conditions, and the tidal design events use the QMED inflows as the fluvial inflow boundary conditions. For climate change simulations, climate change has been applied to both the fluvial and tidal boundary conditions.

Table 1-2: Extreme sea level estimates

	MHWS	T0200	T1000
2017	4.49	6.37	6.69
2023	4.52	6.40	6.72
2098	5.23	7.11	7.43

³ Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018). December 2023. Environment Agency.

TECHNICAL NOTE

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Subject	Hydraulic Modelling Documentation



Figure 2-4 Map of 1D and 2D tidal boundaries

1.4 Improvements to 1D Schematisation

The 1D domain has been updated to provide an improved representation of key structures on the Afon Afan watercourse. The following sections discuss the updates that have been made to these 1D elements.

1.4.1 Green Park Weir

Green Park weir was rebuilt in 2017 to strengthen the degraded structure and provide additional water security to Port Talbot dock which is fed by the Afon Afan.

The weir is made up of three components, the north weir acting as a crump weir, the south weir acting as stepped revetment, and a fish pass. The previous NRW model adopted a simplistic approach to modelling the structure with a single 1d_nwke line representing the full weir crest. Following construction of the new weir, it was deemed appropriate to update the representation of this structure within the model. The updated representation of Green Park weir has been completed using the 'as built' design drawings.

The model now uses three separate 1d_nwke lines to represent the three core elements of the weir, as discussed below:

North weir: A 'WW' weir unit has been used to represent the north weir (AFAN0867N) with an XZ table used to specify the weir crest geometry and an ESTRY weir factor of 1.19 has been specified to represent the efficient crump structure type. The smolt chute that is located between the north and south weir has been represented within the north weir XZ table.

TECHNICAL NOTE

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Client	Morgan Sindall Construction & Infrastructure Ltd
Date	July 2024
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Reviewer / Sign-off	George Baker BEng AEMA CEnv IEng MCIWEM C.WEM
Subject	Hydraulic Modelling Documentation

South weir: This has been modelled using the 1d_nwke line AFAN0867S. The 1d_nwke line has been used to represent the smolt screen structure. This has been given an invert level of 6.36mAOD and weir crest width of 18m. An ESTRY weir factor of 0.69 has been used to represent the inefficient nature of the smolt screen.

Fish pass: The fish pass is located at the most northerly part of Green Park weir and has been represented within the model using an open channel section with an XZ table to represent the opening geometry. The structure is very challenging to model accurately due to the presence of baffles within the structure. To account for the turbulence expected within this structure, a high roughness value of 0.8 has been specified within the 1d_nwke layer.

1.4.2 Newbridge Weir and Bridge

The new flood modelling of Port Talbot has updated the representation of the Newbridge weir and Newbridge bridge structures which are located near to the downstream model extent of the Afon Afan.

The Newbridge weir schematisation has been amended using the new river channel survey data collected by Storm Geomatics in May 2023. The weir has been represented within the model using a 'WW' weir unit and an XZ table to represent the weir crest. An ESTRY weir factor of 0.88 has been used to represent the uneven nature of the weir crest due to the presence of the concrete pillars.

Upstream of Newbridge weir, there is the Grade II listed Newbridge bridge which has also been updated. The 2023 Storm Geomatics survey included this bridge structure and therefore this data has been incorporated into the model. The model has represented this structure using three 1d_nwke 'BB' Bridge units with Height-Width (HW) tables used to specify the geometry for each of three openings. A skew angle of 41° has been applied to this structure as specified in the survey data deliverables. The bridge length is 11.6m and therefore, overtopping of this structure has been modelled in the 1D domain using a separate 1d_nwke 'WW' weir unit. The bridge parapet has been represented using an XZ table and an ESTRY weir factor of 0.88 has been specified to represent the inefficient nature of bridge deck overtopping.

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Reviewer / Sign-off	George Baker BEng AEMA CEnv IEng MCIWEM C.WEM
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2 Model performance, assumptions, and limitations

2.1 Model performance

The model exhibits 1D negative depths in each of the design event simulations. In the fluvial scenarios, there are 387 and 391 1D negative depths for the 1% AEP plus climate change and 0.1% AEP events respectively. For the tidal scenario these increase to 1158 in the 0.5% AEP plus climate change event and to 1295 in the 0.1% AEP plus climate change event. These are located at AFAN0197.1 on the Afon Afan watercourse which is approximately 50m upstream of Newbridge bridge. Attempts have been made to address these using interpolate sections and improved initial conditions, but the negative depths remain.

Analysis of the model outputs shows that the negative depths are occurring at a range of different times throughout the simulation, but importantly they are not influencing the peak water levels, as shown in Figure 2-1.

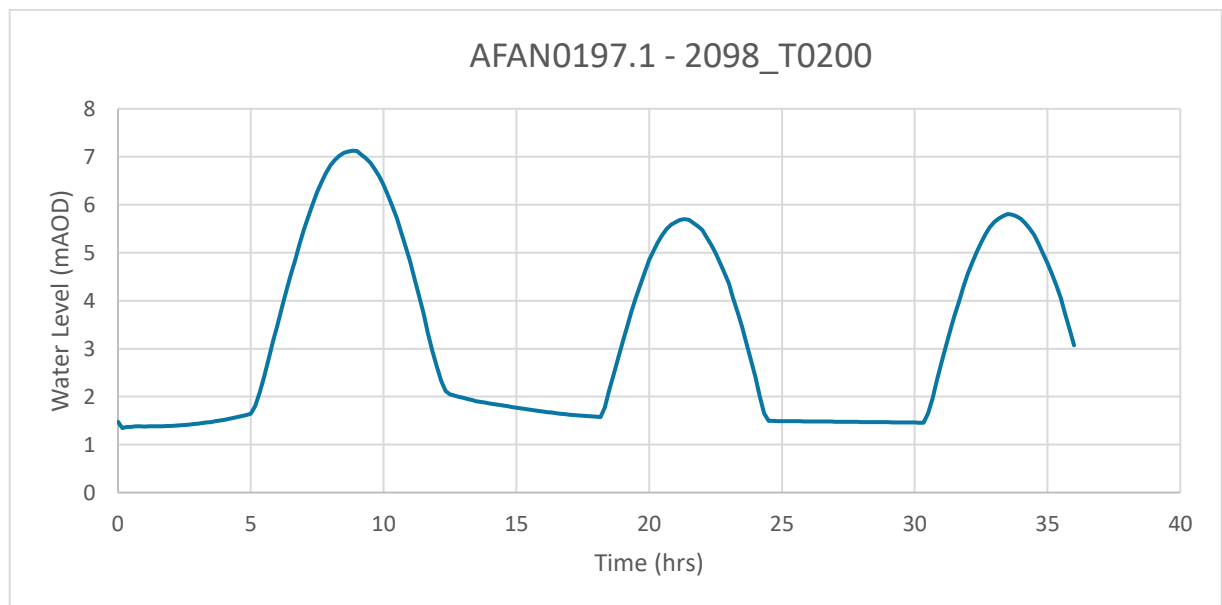


Figure 2-1: 1D water level at Afan_0197 for the 2098T0200 event

There are no 2D negative depths present in any of the design event simulations and the mass error is within the recommended $\pm 1\%$ tolerance for all design events. This indicates that the 2D model is stable, and the outputs can be used with confidence.

2.2 Assumptions and limitations

Developing a hydraulic model requires the application of simplifications and generalisations. As such, several assumptions were made when building the model. This can lead to model uncertainties and subsequent limitations in the results. Some of the key assumptions, limitations, and uncertainties specific to this study are listed below:

- A new hydrological assessment has been completed that adopts the latest available data and uses the latest methods. A hybrid approach has been used with the FEH statistical estimates used on the Afon Afan and ReFH2 used on the Ffrwd Wylt and Baglan Brook watercourses. The new hydrology is considered an improvement on the previous inflow estimates and inflow hydrographs but it should be noted that the hydrology typically accounts for the largest uncertainty with the model outputs.

TECHNICAL NOTE

JBA Project Code	2024s0465
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- The decision to not adopt the new LIDAR data is a limitation as it means that any areas of new development may not be accounted for within the model topography. However, the new LIDAR data within Port Talbot was found to inaccurately represent key overland flow paths and therefore its inclusion could not be justified. Previous discussions with NRW have indicated that they are happy with this approach and any future users of the model should consider the merits of using the new LIDAR data.

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Reviewer / Sign-off	George Baker BEng AEMA CEnv IEng MCIWEM C.WEM
Subject	Hydraulic Modelling Documentation

3 Model runs

3.1 Baseline model scenario

Run reference	Baseline - PTH_~s1~_~s2~_~e1~_~e2~_240_Indiv_SD_~s4~
Purpose of runs:	To model required TAN15 design storms for flood depth and hazard maps
TUFLOW file names:	PTH_~s1~_~s2~_~e1~_~e2~_240_Indiv_SD_~s4~.tcf PTH_~s1~_~s2~_~e1~_~e2~_240_Indiv_SD_~s4~.ecf PT_240.tgc PT_191.tbc
Run time:	Fluvial: 28 hours
AEP events:	1% AEP fluvial event plus climate change 0.1% AEP fluvial for present day conditions
Boundary conditions:	bc_dbase_PT_Indiv_SD_101.csv
Run settings:	TUFLOW version: 2023-03-AA-iSP-w64

3.2 Post-development model scenario

Run reference	Post-dev - PTH_~s1~_~s2~_~e1~_~e2~_250_Indiv_SD_~s4~
Purpose of runs:	To model required TAN15 design storms for the post development scenario for flood depth, depth change and hazard maps
TUFLOW file names:	PTH_~s1~_~s2~_~e1~_~e2~_250_Indiv_SD_~s4~.tcf PTH_~s1~_~s2~_~e1~_~e2~_250_Indiv_SD_~s4~.ecf PT_250.tgc PT_191.tbc
Run time:	Fluvial: 28 hours
AEP events:	1% AEP fluvial event plus climate change 0.1% AEP fluvial for present day conditions
Boundary conditions:	bc_dbase_PT_Indiv_SD_101.csv
Run settings:	TUFLOW version: 2023-03-AA-iSP-w64

Flood estimation report: Port Talbot Flood Modelling

Introduction

This report template is a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations, and decisions made during flood estimation and the results.

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Approval

Revision stage	Analyst / Reviewer name & qualifications	Date
Method statement preparation	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM	31/03/2023
Method statement sign-off	Vicky Shackle BSc PhD MCIWEM C.WEM	11/04/2023
Calculations preparation	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM	31/03/2023
Calculations sign-off	Vicky Shackle BSc PhD MCIWEM C.WEM	11/04/2023

Revision History

Revision reference	Date issued	Amendments	Issued to
V1.0	23/01/2024	-	NRW

Abbreviations

AEP	annual exceedance probability
AM.....	annual maximum
AREA	catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
BGS	British Geological Survey
CPRE	Council for the Protection of Rural England
FARL.....	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
GEV	Generalised Extreme Value (distribution)
GL	Generalised Logistic (distribution)
HOST	Hydrology of Soil Types
KAP3.....	Kappa 3 (distribution)
NRFA	National River Flow Archive
NRW	Natural Resources Wales
OS.....	Ordnance Survey
P3	Pearson Type 3 (distribution)
QMED	median annual flood
ReFH2	Revitalised Flood Hydrograph 2 (method)
SAAR	standard average annual rainfall (mm)
Tp	time to peak of the instantaneous unit hydrograph
URBEXT ₂₀₀₀	index of urban extent
WINFAP-FEH	Windows Frequency Analysis Package

1 Summary of assessment

1.1 Summary

This table provides a summary of the key information contained within the detailed assessment in the following sections.

Catchment location	Port Talbot, South Wales
Purpose of study and scope	Flood modelling to provide an improved understanding of flood risk throughout Port Talbot. The existing NRW hydraulic model, including the hydrological assessment, will be updated for the purposes of this study. This model also includes the Ffrwd Wylt and Baglan Brook watercourses. The hydrology for these watercourses will be updated, as well as the hydrology for the Afon Afan. Moderately complex hydrological assessment.
Key catchment features	The lower parts of the catchments are urbanised and generally very flat. There are large areas of forestry / woodland and the catchments have been historically mined / quarried. It is not within the scope of the study to investigate the impact that these features have on the catchment hydrology. For the Afon Afan, the gauge data at Marcroft Weir may, to some degree, account for this influence.
Flooding mechanisms	Peak flows exceeding channel capacity is likely to be the predominant source of flood risk to Port Talbot. Tide-locking at the outfall into the Afon Nedd may increase flood risk from Baglan Brook and flood volumes may be important on this watercourse. Sewer flooding and surface water flooding could also contribute to flood risk in the urban areas. Only fluvial flooding is being considered for this study.
Gauged / ungauged	Good quality flow gauge (Marcroft Weir) on the Afan within the model reach plus two other level / daily flow gauges. Two level gauges on the Ffrwd Wylt.
Final choice of method	Afon Afan – FEH Statistical. Ffrwd Wylt and Baglan Brook – ReFH2.
Key limitations / uncertainties in results	The complex drainage system for Baglan Brook leads to difficulties in accurately defining the catchment boundary. There are no flow gauges on the Ffrwd Wylt and Baglan Brook with which to improve and / or verify estimates.

1.2 Note on flood frequencies

The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.

Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval.

The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

Annual exceedance probability (AEP) and related return period reference table

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.0133	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2 Method statement

2.1 Requirements for flood estimates

Overview	Updates will be made to the existing Natural Resources Wales (NRW) flood model of Port Talbot, developed by JBA in 2016. This will require a range of amendments to the hydrology and hydraulic model to bring it in line with current guidance and good practice. The study will look at both fluvial and tidal sources of flooding to provide an improved understanding of baseline flood risk to the study area. The existing NRW model includes the Afon Afan, Ffrwd Wyllt, and Baglan Brook watercourses. This document details the hydrological assessment completed to update the hydraulic model inflows. The hydrology undertaken to provide inflows to the existing NRW model dates from 2016 / 2017. Due to the time which has elapsed since the previous hydrological assessments were completed, new datasets, methods, software, and guidance have been released and the calculations require updating to use these. Design event peak flow estimates and hydrographs are required for the following annual exceedance probability (AEP) events: 50%, 3.33%, 2%, 1.33%, 1% and 0.1%. However, peak flow estimates for the full suite of design events (also including 20%, 10%, 5% and 0.5%) are presented within this document, for reference. The effects of climate change will be assessed by applying an increase of 30% to the 3.33%, 1% and 0.1% AEP events, as per the latest guidance¹ and requested by the Client. This represents the change factor / central estimate for the 2080s epoch for the West Wales River basin district.
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2.2 The catchment

Description	Afon Afan The Afon Afan is a medium-sized watercourse (approximately 90km²) which drains from Werfa, to the west of Treorchy, to discharge into Swansea Bay at Port Talbot. It has two key tributaries, Afon Corrwg Fechan, which joins at Cymer and Afon Pelenna which joins at Pontrhydyfen. Several smaller tributaries join the Afan along its length. The catchment topography is steep with generally limited floodplain extent even in the lower reaches. Throughout the catchment there is a significant amount of forestry and some rough grazing. The catchment has been historically mined. There are several small settlements in the upper and mid-catchment (Blaengwynfi, Croeserw, Cymer, Glynccorwg, Tonmawr, Pontrhydyfen) and in the lower catchment the larger settlements of Cwmafan and Port Talbot. There is an offtake to Port Talbot Docks a short distance upstream of the Afan Way roundabout (approximate grid reference: 276034, 189697). The British Geological Survey (BGS) website 1:625,000 mapping shows the catchment to be underlain by the South Wales Upper Coal Measures Formation which consists of mudstone, siltstone, sandstone, coal, ironstone and ferricrete. There are some superficial deposits of peat and till. Soils were assessed using the Soilscales website. Over the upland area there are slowly permeable, wet, upland soils with a peaty surface. Freely draining loamy soils over rock overlie the rest of the catchment, with loamy and clayey soils at the coast. Ffrwd Wyllt The Ffrwd Wyllt rises near Bryn to the north-east of Port Talbot and flows in a south-westerly direction to Port Talbot Docks. The catchment area to the upstream extent of the docks is approximately 24km². The docks discharge to
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¹ Welsh Government. September 2021. Flood Consequences Assessments: Climate change allowances. 2024s0465 - Hydrology_Report_v1.0

the Afon Afan just upstream of the entrance to Swansea Bay.

The catchment topography is steep, with generally limited floodplain extent. There is a significant amount of forestry throughout the catchment and some rough grazing. The catchment is predominantly rural with only the village of Bryn located in the upper catchment. The lower catchment includes the village of Goytre and the eastern part of Port Talbot, including the docks, industrial estates, and steelworks.

The BGS website 1:625,000 mapping shows the catchment to be underlain by the South Wales Upper Coal Measures Formation and Pennine Middle Coal Measures Formation. There are some superficial deposits of till in the upper catchment, and sand and gravel and river terrace deposits in the lower catchment. In the upper catchment soils are loamy upland with a peaty surface, and slowly permeable wet upland with a peaty surface. Freely draining loamy soils over rock, and loamy and clayey soils of coastal flats with naturally high groundwater, overlie the lower catchment.

Baglan Brook

Baglan Brook is the smallest of the study watercourses, with a catchment area of about 6.5km² at the downstream extent. The catchment characteristics are complex due to significant human alteration including mining, urbanisation, and industrialisation. It rises to the east of Baglan and flows towards the M4 motorway. The watercourse follows the M4 north for about 1.4km, before passing beneath it to discharge into the Afon Nedd, just upstream of the entrance to Baglan Bay. The Baglan Moors area to the west of the M4 also drains into Baglan Brook where it reaches the M4.

The catchment topography is steep to the east of the M4, with limited floodplain extent. West of the M4, the topography is much shallower, forming coastal flats. The upper catchment is rural, with areas of forestry. However, most of the catchment is urbanised, covering Baglan and Sandfields.

The underlying geology is the same as for the Ffrwd Wyllt catchment. There are some superficial deposits of alluvium (clay, silt and sand) and blown sand (sand and gravel) to the west of the M4. In the upper catchment (most of the catchment east of the M4) soils are slowly permeable and seasonally wet loamy and clayey, and freely draining loamy over rock. In the lower catchment (generally west of the M4), soils are loamy and clayey of coastal flats with naturally high groundwater, and sand dune soils.

Figure 2-1 provides an overview of the study area, including the modelled reaches and locations of Newbridge Weir and hydrometric gauges. Full catchment boundary extents are provided in Figure 2-2, which also shows the catchment topography.

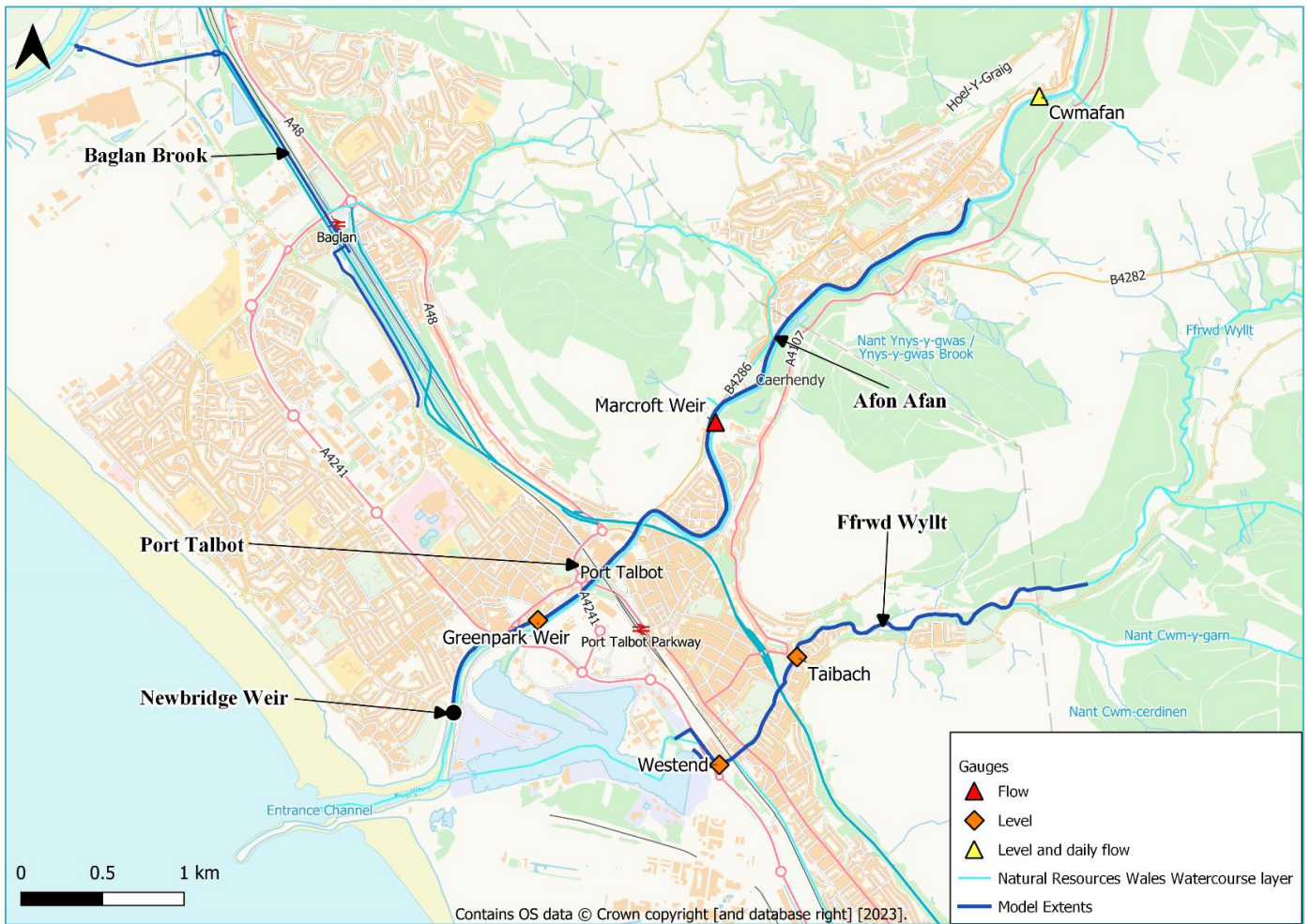


Figure 2-1: Study area overview map

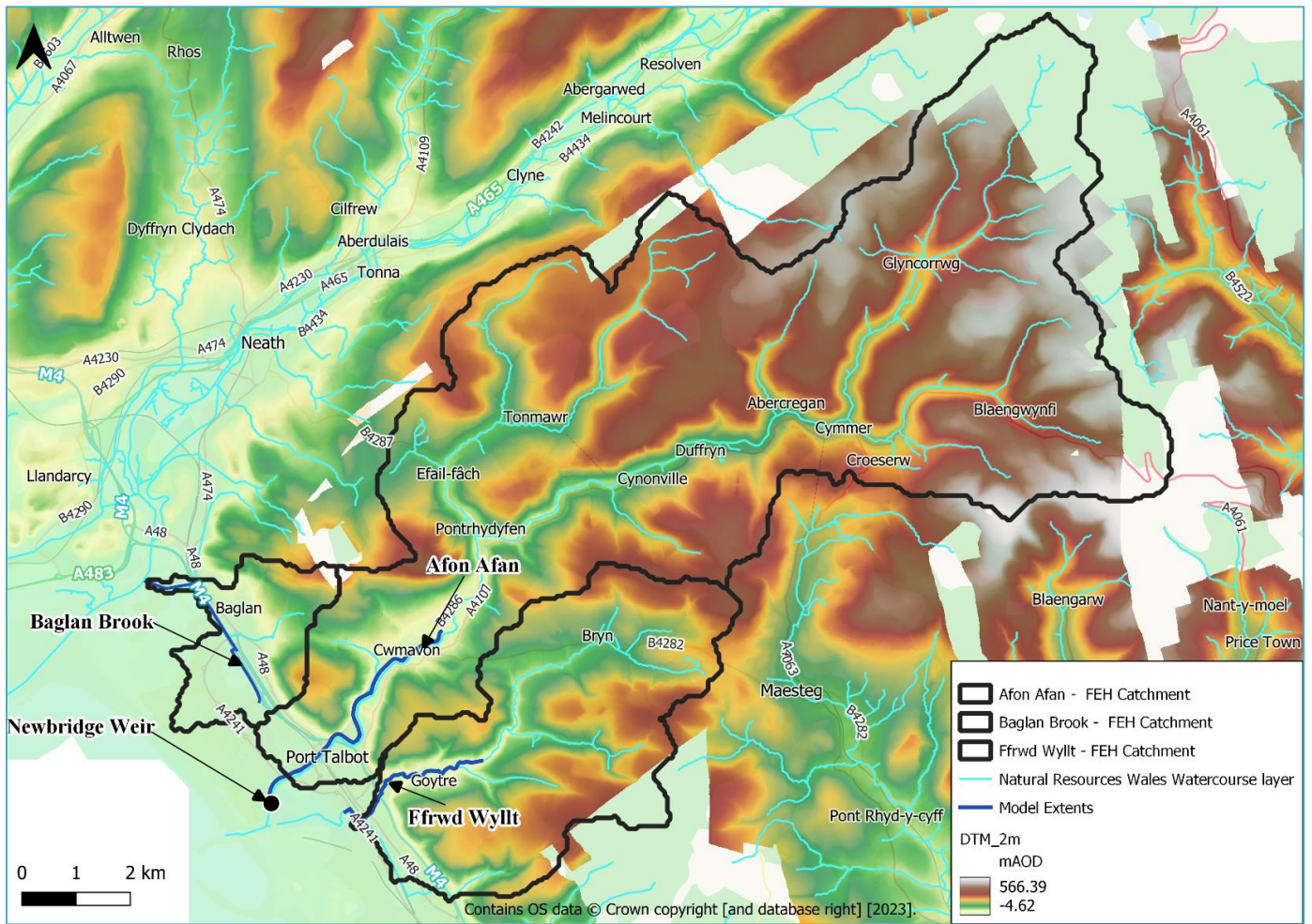


Figure 2-2: Catchment topography

2.3 Source of flood peak data

Source	National River Flow Archive (NRFA) peak flows dataset, Version 11, released September 2022. This contains data up to water year 2020-21. * Note: The FEH Statistical method assessment was completed prior to the release of NRFA v11.1 on 6 th March 2023. The newer version of the dataset represents only a minor update.
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2.4 Gauging stations (flow or level)

Watercourse	Station name	Gauging authority number	NRFA number	Catchment area (km ²)	Type	Start of record and end if station closed
Afon Afan	Greenpark Weir	Unknown	N/A	91.4	Level	08/2013 - Present
Afon Afan	Marcroft Weir	058012	58012	89.7	Rated	10/1977 – Present
Afon Afan	Cwmafan	058S0014W	58004	81.5	Level (and daily flow)	09/1989 - Present
Ffrwd Wylt	Westend	Unknown	N/A	24.2	Level	07/2015 - Present
Ffrwd Wylt	Taibach	058S0667W	N/A	19.7	Level	05/2000 - Present

2.5 Data available at each flow gauging station in Table 2.4

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED ?	OK for pooling ?	Data quality check needed ?	Other comments on station and flow data quality
Marcroft Weir	1977-2020	No	Yes	Yes	No	High velocities due to steep gradients. Weir refurbishment 03/09/2012 – 01/07/2013, data infilled using data from upstream gauging station Cwmafan. Gaugings have confirmed no significant impact of refurbishment on the rating. Weir remains modular to at least 2.5m (AMAX1 at the time of writing). Not gauged to within 30% of QMED but Crump weir expected to perform well at QMED and beyond AMAX3. All flows have been contained within bank and the channel profile remains consistent to top of bank.

2.6 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data	Details
Check flow gaugings	No	N/A	N/A	Rating review / development is not within the scope of this study.
Historical flood data	Yes	No	N/A	An Internet search revealed no readily available information on flooding in Port Talbot from the study watercourses. It is thought that flood defences in the town were constructed in response to flooding from the Afan in December 1979 (AMAX1), however no information could be found on the impacts of this event on the town.
Flow or river level data for events	No	N/A	N/A	See Section 2.8.
Rainfall data for events				
Potential evaporation data				
Results from previous studies	Yes	Yes	JBA Consulting	Afon Afan FEH Calculation Record ² Ffrwd Wyllt & Baglan Brook Calculation Record ³
Other data or information	No	N/A	N/A	N/A

2.7 Hydrological understanding of catchment

Conceptual model	Peak flows in the three study watercourses exceeding channel capacity is likely to be the predominant source of flood risk to Port Talbot. Tide-locking at the outfall into the Afon Nedd may increase flood risk from Baglan Brook and flood volumes may be important on this watercourse. Sewer flooding and surface water flooding could also contribute to flood risk in the urban areas. It should be noted that only fluvial flooding is being considered for this study.
Unusual catchment features	The lower parts of the catchments are urbanised and generally very flat. There are large areas of forestry / woodland and the catchments have been historically mined / quarried. It is not within the scope of the study to investigate the impact that these features have on the catchment hydrology. For the Afon Afan, the gauge data at Marcroft Weir may, to some degree, account for this influence. Defining the catchment boundary accurately for Baglan Brook will be difficult due to the complex drainage system.

2.8 Initial choice of approach

Is FEH appropriate ?	Yes
Initial choice of	Both the ReFH2 method and the FEH Statistical method are suitable for flood flow estimation for the study catchments. For the previous hydrological

² JBA Consulting. February 2017. 2016s4827 - FEH calculation record_Afon Afan_v2.0 (Feb 2017).pdf

³ JBA Consulting. October 2016. 2016s4827 - FEH Calculation Record_v3.0 (Feb 2017).pdf
2024s0465 - Hydrology_Report_v1.0

method(s) and reasons	assessments peak flow estimates were derived using both methods and compared to determine the most suitable method. The FEH Statistical method estimates were taken forward as the preferred peak flow estimates for the Afon Afan. For Ffrwd Wyllt hydraulic model results showed the Statistical method peak flow estimates to be substantially overestimating flooding. Due to this the ReFH2 method peak flows were taken forward as the preferred estimates. The ReFH2 method peak flows were also selected for Baglan Brook due to catchment characteristics which lead to this approach being favoured. For the current study both methods will be applied for all catchments for completeness and comparison with the previous study estimates. The intention would be to retain the preferred approaches taken forward for the previous hydrological assessments. However, the updated results will be checked to confirm that this is still appropriate. Surface water sewer network details will not be used to define catchment and sub-catchment boundaries in the urban parts of the catchments. One of the simplest approaches (and the published approach) for urban catchments is to assume that there are no 'sewers in' or 'sewers out', i.e., all runoff from the topographic catchment reaches the watercourse for all design events and no additional water enters from outside the catchment. This approach is supported by the Environment Agency Flood Estimation Guidelines⁴ which state that unless there is a major export of water from the catchment via urban drainage systems, it may be simpler to assume that exports and imports roughly balance. In addition to this the process for deriving catchments / sub-catchments from the surface water sewer network and the approach for generating peak flow estimates is complex and time-consuming, and the study scope does not allow for this. There may also be little benefit in undertaking a detailed analysis of the sewer network for the purposes of generating fluvial peak flow estimates when there is no flow gauge data against which to verify the results and / or where there is uncertainty about the capacity of the sewer network. The hydrograph shape will be derived using the ReFH2 method. Catchment descriptors for the intervening areas between flow estimation points will be generated using a back-calculation of the area-weighting method derived in the FEH Volume 5. These will be used within the ReFH2 method to generate lateral inflows to be applied to the hydraulic model. It is not within the scope of this study to undertake a detailed flood history investigation for the purposes of incorporating historical information into frequency analysis at the Marcroft Weir gauge. Analysis of river gauge data to improve rainfall-runoff model parameters is also not within the scope of the study. In addition to this it would be unlikely to significantly improve confidence in the results. There is no recording raingauge within the Ffrwd Wyllt catchment which could be used as part of a lag analysis to improve the Tp model parameter estimate. This means that confidence in any results of the lag analysis would be reduced. Although there are recording raingauges in the Afon Afan catchment, the Statistical method will be preferred to estimate peak flows for this watercourse due to the availability of a peak flow record at Marcroft Weir. Estimating Tp from lag analysis could be used to adjust the hydrograph shape, but this is thought unlikely to have a substantial impact on the hydraulic model results. It should be noted that FEH22 rainfall statistics are now available (released December 2022), although it is not possible to use them within the current version of the ReFH2 software. The ReFH2 model is currently being updated to use FEH22 and is expected to be released in early Spring 2023 (after completion of this assessment). The Environment Agency position statement on this is that there would be no expectation that calculations submitted up to and including 31st August 2023 would need to be updated to use FEH22. There is no known
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⁴ Environment Agency. December 2022. Instruction: LIT 11832. Flood Estimation Guidelines. 2024s0465 - Hydrology_Report_v1.0

	formal equivalent guidance issued by NRW. As such, as hydrology calculations are programmed to be submitted well before this date, and for the project to be completed by mid-September, it has been assumed that there will be no requirement for FEH22 rainfall statistics and the new version of the ReFH2 software to be used in this study.
Software to be used	FEH Web Service ⁵ / WINFAP 5 ⁶ / ReFH2.3

⁵ CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.

⁶ WINFAP 5 © Wallingford HydroSolutions Limited 2021.
2024s0465 - Hydrology_Report_v1.0

3 Locations where flood estimates required

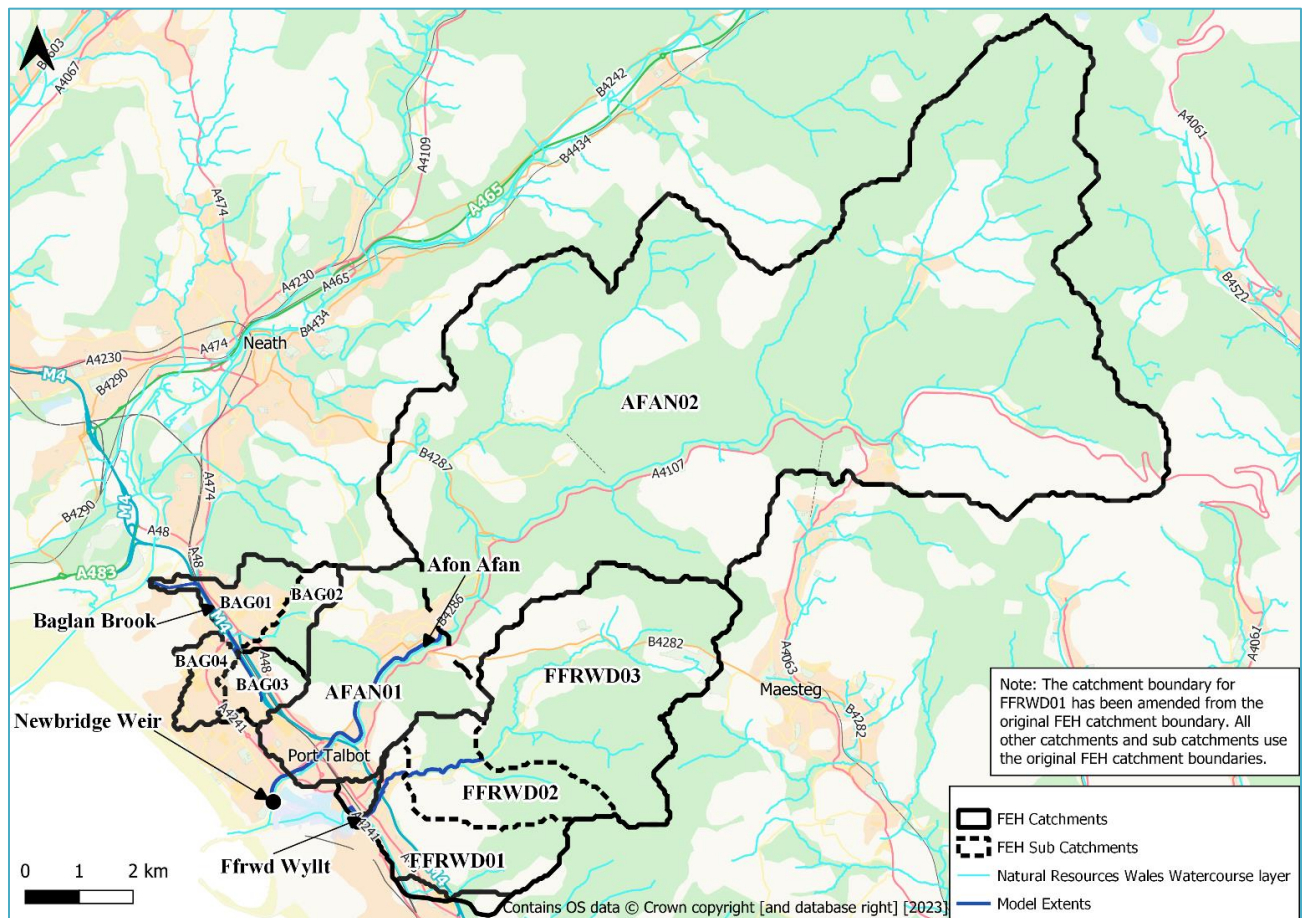


Figure 3-1: Flow estimation point catchments

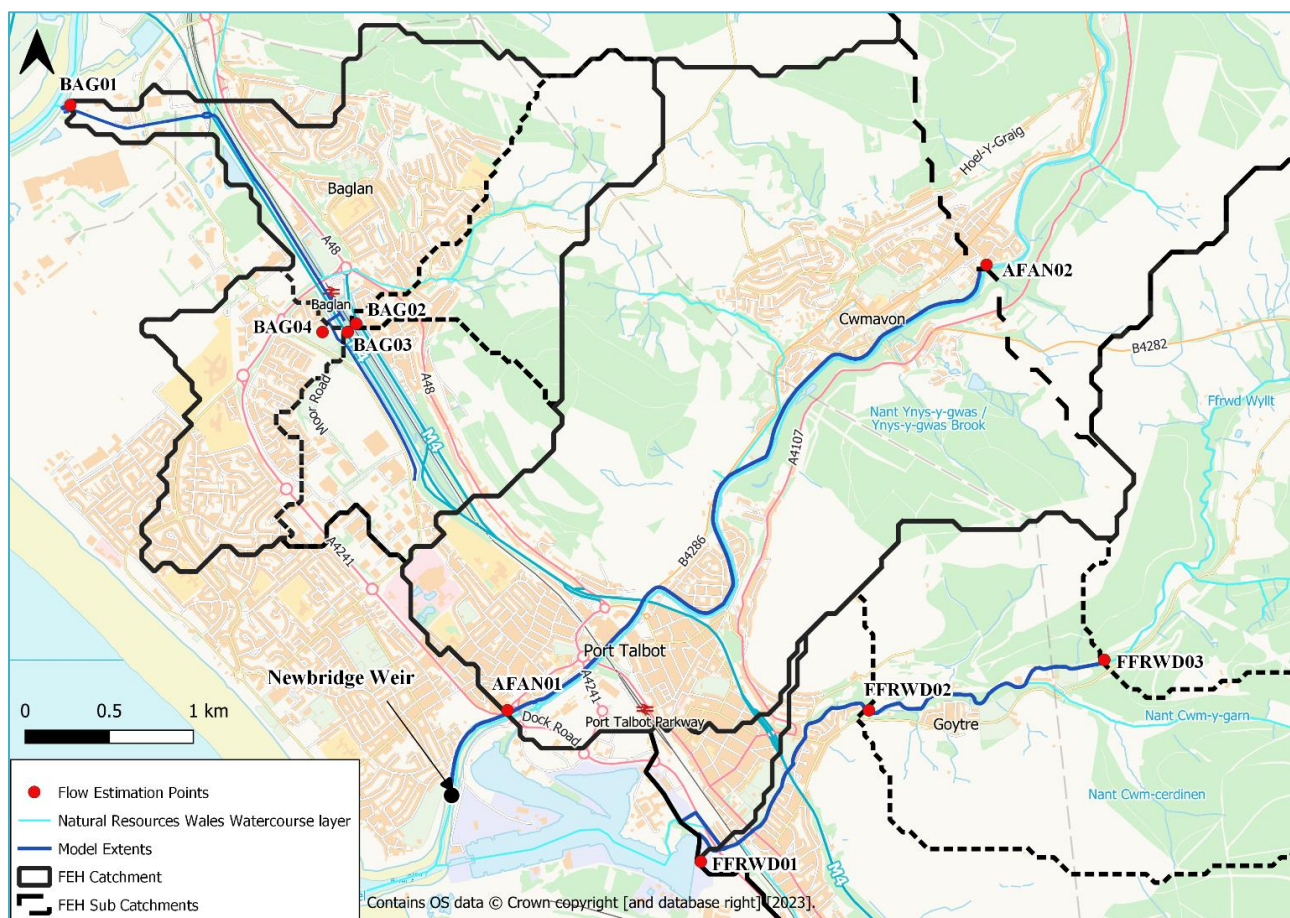


Figure 3-2: Flow estimation point locations

The flow estimation points selected for the previous study were reviewed and retained for Ffrwd Wylt and Baglan Brook. It should be noted that the FEH Web Service watercourse lines for Baglan Brook do not match those on Ordnance Survey (OS) mapping. Therefore, flow estimation points were selected to represent approximate areas draining to these locations for the purpose of deriving hydrographs to add flow to the hydraulic model.

For the Afon Afan flow estimates were previously made at the location of Greenpark Weir and input at the upstream model extent. As part of the current study, it was decided to amend the catchment schematisation for the Afon Afan. Flow estimates were made at the upstream model extent and at the tidal limit defined by the FEH Web Service, with an intervening area between the two flow estimation points.

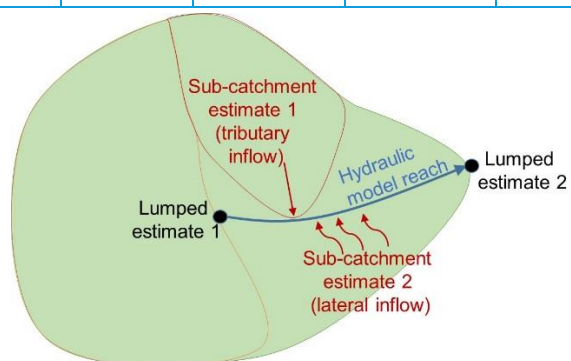
Figure 3-1 shows the full catchments draining to the flow estimation points. In Figure 3-2 the map is zoomed in on the flow estimation points to show their location more clearly. These figures show the adjusted FFRWD01 catchment boundary rather than the FEH Web Service boundary (see Section 3.3). The table in Section 3.1 lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

3.1 Summary of subject sites

Site code	Type of estimate	Watercourse	Name or description of site	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA (km ²) if altered
FFRWD01	L	Ffrwd Wylt	Confluence with Docks	277000	188800	24.2	25.2
FFRWD02	L	Ffrwd Wylt	Start of urban area	278000	189700	19.3	-

Site code	Type of estimate	Watercourse	Name or description of site	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA (km ²) if altered
FFRWD03	L	Ffrwd Wylt	Upstream model extent	279400	190000	14.5	-
BAG01	L	Baglan Brook	Confluence with Afon Nedd	273250	193300	6.4	-
BAG02	L	Baglan Brook	Confluence with BAG03 and BAG04 tributaries at Baglan Moors	274950	192000	1.4	-
BAG03	L	Baglan Brook	Confluence with Baglan Brook at Baglan Moors	274900	191950	1.6	-
BAG04	L	Baglan Brook	Confluence with Baglan Brook at Baglan Moors	274750	191950	1.3	-
AFAN01	L	Afon Afan	FEH tidal limit	275850	189700	93.0	-
AFAN02	L	Afon Afan	Upstream model extent	278700	192350	83.2	-
FFRWD01_IA	S	Ffrwd Wylt	Intervening area between FFRWD01 and FFRWD02	-	-	-	5.9
FFRWD02_IA	S	Ffrwd Wylt	Intervening area between FFRWD02 and FFRWD03	-	-	-	4.8
BAG01_IA	S	Baglan Brook	Intervening area between BAG01, BAG02, BAG03 and BAG04	-	-	-	2.1
AFAN01_IA	S	Afon Afan	Intervening area between AFAN01 and AFAN02	-	-	-	9.7

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required. Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced. The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



3.2 Important catchment descriptors at each subject site

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT ₂₀₀₀	FPEXT
FFRWD01	1.000	0.52	0.482	5.90	201.5	1,596	0.0439	0.031
FFRWD02	1.000	0.52	0.465	4.78	201.5	1,651	0.0134	0.010
FFRWD03	1.000	0.52	0.440	4.04	194.9	1,703	0.0080	0.008
BAG01	0.908	0.52	0.678	3.53	114.9	1,276	0.2463	0.317
BAG02	1.000	0.52	0.545	1.51	176.8	1,386	0.0692	0.037
BAG03	1.000	0.52	0.715	1.18	132.4	1,229	0.1846	0.486
BAG04	1.000	0.52	0.826	1.71	8.5	1,170	0.4589	0.682
AFAN01	1.000	0.53	0.393	14.99	208.3	2,008	0.0364	0.029
AFAN02	1.000	0.53	0.367	11.66	211.1	2,083	0.0155	0.014
FFRWD01_IA	-	0.52	0.538	1.38	201.5	1,416	0.1437	-
FFRWD02_IA	-	0.52	0.541	1.19	221.5	1,493	0.0298	-
BAG01_IA	-	0.52	0.651	1.17	124.8	1,301	0.2820	-
AFAN01_IA	-	0.53	0.615*	1.57	184.4	1,367	0.2149	-

Note: FARL and FPEXT values are not provided for the intervening areas. These areas only require the generation of hydrographs and not peak flow estimates, and the ReFH2 model does not use these descriptors. Any descriptors which were adjusted from the FEH Web Service values are given in red text. URBEXT₂₀₀₀ was updated to the current year at the time of the study (2023).

* The AFAN01_IA BFIHOST19 value perhaps seems a little high given the lumped catchment values. However, the calculation is correct. This anomalous value may be due to the limitations of the back-calculation of the area-weighting method for smaller intervening areas. It is thought unlikely that this will have a substantial effect on the hydraulic model results, but modelled flows will be checked and reconciled to target flows, where necessary.

3.3 Checking catchment descriptors

Catchment boundary checks	Afon Afan The previous study found only minor discrepancies between the FEH Web Service catchment boundary and contours, spot heights and watercourse lines from mapping. No changes were made to the catchment boundary. Checks undertaken as part of the current study showed this decision to be reasonable and the FEH Web Service catchment boundary and area was retained without amendment. Ffrwd Wylt A detailed assessment of the Ffrwd Wylt catchment boundary was carried out for the previous study, making use of sewer network information. This found that the boundary for the lower part of the catchment, affecting FFRWD01 only, looked incorrect in several locations. The catchment boundary was amended accordingly. As this made a relatively small difference to the catchment area only this descriptor and DPLBAR were updated. DPLBAR was calculated using the UK average power term given in Volume 5 of the FEH. The adjustments made to the FFRWD01 boundary were checked as part of the current study. Part of the amendment assumes that Arnallt Brook drains to Ffrwd Wylt, following the railway line from Margam north to join the Ffrwd Wylle just upstream of the Docks. It is difficult to tell from mapping if this is the case, but it seems a reasonable assumption and the adjustments are conservative as
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	the catchment area is increased. Therefore, the adjusted catchment boundary from the previous study was taken forward for the current study. A figure showing the FEH Web Service and adjusted catchment boundary is provided in Section 7.1, for reference. As for the previous study, only DPLBAR was updated in addition to catchment area. However, for the current study, rather than using the UK average power term, the value was derived by the simple approach of applying an area-weighting (new AREA / old AREA) to the 'old' DPLBAR value. This approach was deemed reasonable for the scope of the study and uses 'local' information rather than a generalised power term. In this case the derived DPLBAR was very similar to that used in the previous study. Baglan Brook No changes were made to the Baglan Brook catchment boundary in the previous study. For the upper and rural parts of the catchment the FEH Web Service was deemed reasonable, with only minor discrepancies compared to contours, spot heights and watercourse lines. The boundary is difficult to verify in the lower part of the catchment as it lies on a flat coastal area and is predominantly urbanised. The channels appear to have been substantially changed from the natural drainage. Due to all other uncertainties in flood flow estimation for this catchment, the FEH Web Service catchment boundary was accepted as reasonable. Checks undertaken as part of the current study verified these findings, and no changes were made to the catchment boundary or area.
Other catchment descriptor checks	The FEH Web Service BFIHOST19 values show the Ffrwd Wyllt catchment to be moderately impermeable, with values increasing from upstream to downstream, showing a slight increase in permeability. This seems reasonable given the changes in soils described in Section 2.2. BFIHOST19 values for the Afan catchment follow a similar trend, although values are slightly smaller than for Ffrwd Wyllt, indicating a more impermeable catchment. This seems reasonable based on the soils and geology. The Baglan Brook BFIHOST19 values are much larger than for the other two watercourses. BAG01, BAG03 and BAG04 have BFIHOST19 ≥ 0.65, indicating highly permeable / groundwater-dominated catchments. This ties in with soils developed from sand dunes becoming dominant in the parts of the catchment closest to the coast. No changes were made to any of the BFIHOST19 values. FARL values are 1.000 at all flow estimation points except BAG01. This indicates no attenuation due to lakes and reservoirs, which is supported by mapping. For BAG01 the FEH Web Service shows a 'lake' area along Baglan Brook downstream of the A4241 road. There is a small reservoir shown on mapping in this area to the west of the M4, although it is not as extensive as the lake area shown on the FEH Web Service. The reservoir is not directly online but OS MasterMap mapping indicates that there may possibly be both an inflow from and outflow to Baglan Brook. The previous study amended the FARL value to 1.000 for BAG01. However, due to the potential for the reservoir to have an influence on flood attenuation it was deemed preferable to retain the FEH Web Service value for the current study. In addition to this, ReFH2, which was the preferred method in the previous study, does not utilise the FARL descriptor. Urban coverage shown by the FEH Web Service URBEXT₂₀₀₀ layer was compared to current OS mapping. This showed that there are no significant developments unaccounted for by the URBEXT₂₀₀₀ layer. No changes were made to the URBEXT values except to update them to the current year (2023). Catchment descriptors for the intervening areas were derived using a back-calculation of the area-weighting approach described in Volume 5 of the FEH. DPLBAR was derived using the same approach detailed for updating the FFRWD01 DPLBAR value following catchment boundary amendment.

Source of URBEXT	URBEXT ₂₀₀₀
Method for updating URBEXT	CPRE formula from 2006 CEH report on URBEXT ₂₀₀₀

4 Statistical method

4.1 Overview of estimation of QMED at each subject site

Site code	QMED (rural) from CDs (m ³ /s)	Final method	Data transfer			Urban adjustment factor UAF	Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 4.3)	Distance between centroids d _{ij} (km)	Moderated QMED adjustment factor, (A/B) ^a		
FFRWD01	19.6	DT	58012	7.35	1.004	1.050	20.6
FFRWD02	17.0	DT		6.69	1.004	1.015	17.4
FFRWD03	14.8	DT		6.04	1.004	1.008	15.0
BAG01	1.6	DT		10.31	1.003	1.479	2.4
BAG02	1.2	DT		9.31	1.003	1.090	1.3
BAG03	0.55	DT		10.59	1.003	1.390	0.77
BAG04	0.25	DT		11.46	1.003	2.756	0.70
AFAN01	96.1	DT		0.35	1.008	1.036	100
AFAN02	96.1	DT		0.64	1.007	1.014	98.2
Are the values of QMED spatially consistent?				Yes, QMED increases downstream for the Afon Afan and Ffrwd Wyllt. QMED at BAG01 is less than the sum of the upstream flows even though there is about a 50% increase in catchment area to BAG01. However, the characteristics of each catchment are very different, and this result may be expected.			
Method used for urban adjustment for subject and donor sites				WINFAP v4 ⁷			
Parameters used for WINFAP v4 urban adjustment if applicable							
Impervious fraction for built-up areas, IF			Percentage runoff for impervious surfaces, PR _{imp}		Method for calculating fractional urban cover, URBAN		
0.3			70%		From updated URBEXT ₂₀₀₀		
Notes							
Methods: DT – Data transfer (with urban adjustment).							
The QMED adjustment factor A/B for each donor site is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is (A/B) ^a times the initial (rural) estimate from catchment descriptors.							

4.2 Search for donor sites for QMED

Station 58012 Afan at Marcroft Weir was selected as the donor for the AFAN flow estimation points. The gauge lies within the modelled reach and will be highly representative of the flow estimation points. The moderation term was retained as the distance between catchment centroids is small and QMED at the flow estimation points remains consistent with QMED at the gauge.

The small catchment procedures recommend that for catchments <25km², the single closest donor station should be used to adjust QMED. This recommendation was accepted for this study for Ffrwd Wyllt and Baglan Brook; this is proportionate to the scale of the study. In addition, there is only a small reduction in uncertainty for ungauged sites when donors are used. This will particularly be the case when the donor is on a different watercourse.

For the Ffrwd Wyllt flow estimation points there is a difference in the closest donor station

⁷ Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.
2024s0465 - Hydrology_Report_v1.0

when a threshold of $URBEXT_{2000} < 0.03$ and < 0.30 is used. See discussion in Section 4.4 regarding selection of this threshold.

- Threshold < 0.03 : 58012 Afan at Marcroft Weir is the closest donor station, with 6.0km to 7.4km between catchment centroids, $QMED_{ObsDeurbanised} / QMED_{CDRural} = 1.004$.
- Threshold < 0.30 : 58007 Llynfi at Coytrahen is the closest donor station, with 5.2km to 6.0km between catchment centroids, $QMED_{ObsDeurbanised} / QMED_{CDRural} = 0.966$.

Catchment descriptors for Station 58007 are, generally, more similar to those of Ffrwd Wylt than Station 58012. Consideration was given to using this station as a donor for the FFRWD flow estimation points. However, both stations only result in a small change to the catchment descriptor QMED estimate, particularly 58012. Use of either station could be justified and, due to the difference in trend between $QMED_{Obs}$ and $QMED_{CD}$ at the two stations (58012 > 1 and 58007 < 1), using an average of the two adjustments is not sensible. Therefore, 58012 was selected for consistency with the AFAN and BAG flow estimation points.

4.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)
58012	AM	N/A	97.6 (99.6)	96.8	1.009

The deurbanised value of QMED from flow data was used in this calculation, which is derived by dividing QMED from observed data (given in brackets in the table) by the urban adjustment factor (UAF) which is 1.020 for the gauge.

4.4 Derivation of pooling groups

Where there are multiple flow estimation points the Environment Agency Flood Estimation Guidelines⁴ identify that it is good practice to apply one pooling group to several points along a river. This helps to promote spatial consistency. The key area of interest is Newbridge Weir, within the tidal reach of the Afon Afan. Therefore, the AFAN01 pooling group was selected to provide the growth curve for both Afan flow estimation points. FFRWD01 is within the urban area of Port Talbot and this pooling group was selected to generate the growth curve for all three Ffrwd Wylt flow estimation points. BAG01 was selected to generate the Baglan Brook flow estimation points growth curve. The other flow estimation point catchments are very small and the best estimate of flow is most likely to be derived at the downstream extent.

Small catchment procedures were used to generate the pooling groups for FFRWD01 and BAG01. This was not compared to a 'standard' pooling group for BAG01 as the catchment is $\leq 25\text{km}^2$ and the small catchment pooling group should, in theory, be more appropriate. As the catchment for FFRWD01 is 25km^2 a standard pooling group was also generated for comparison. There was little difference between the growth factors for the small catchment and standard pooling groups, and it was decided to take forward the small catchment pooling group for FFRWD01.

Pooling groups were generated using the default $URBEXT_{2000}$ threshold of 0.03 and a threshold of 0.30. The latter is recommended by NRW⁸ even where the subject site is not urbanised. Growth factors only change by a small amount when using the different thresholds, decreasing when the higher threshold is used. The 0.30 threshold pooling group was selected for this analysis as it follows NRW guidance.

⁸ Natural Resources Wales. November 2021. GN 008. Flood estimation – technical guidance. 2024s0465 - Hydrology_Report_v1.0

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged?	Changes made to default pooling group	Weighted average L-moments
FFRWD01	FFRWD01	No	None. Checks undertaken on: - Highest ranked three stations: 25012, 49003, 48009. - Stations with FARL <0.95: 48001. - Stations with URBEXT₂₀₀₀ >0.03: 57010, 46006. - Stations with slightly different L-moment ratios to others in the group: 48009, 57010, 206006. There was no strong reason to remove any of these stations from the pooling group and all were retained.	L-CV: 0.200 L-skew: 0.204
BAG01	BAG01	No	None. Checks undertaken on: - Highest ranked three stations: 45816, 28033, 47022. - Stations with FARL <0.95: 47022, 69047, 18014, 48007. - Stations with URBEXT₂₀₀₀ >0.03: 69047, 84035. - Stations with slightly different L-moment ratios to others in the group: 44008, 49005. There was no strong reason to remove any of these stations from the pooling group and all were retained.	L-CV: 0.240 L-skew: 0.239
AFAN01	AFAN01	No	None. Checks undertaken on: - Highest ranked three stations: 58012, 57006, 58005. - Stations with FARL <0.95: 96004, 73017. - Stations with URBEXT₂₀₀₀ >0.03: 57006, 58005. - Stations with slightly different L-moment ratios to others in the group: 73017, 46008, 58006. There was no strong reason to remove any of these stations from the pooling group and all were retained.	L-CV: 0.174 L-skew: 0.151
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008). Weighted average L-moments quoted above are the 'deurbanised' values.				

4.5 Derivation of flood growth curves at subject sites

Site code	Method	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution	Growth factor 1% AEP
FFRWD01	P	FFRWD01	Generalised Logistic (GL), Generalised Extreme Value (GEV)	Urban adjustment applied. No adjustment for non-flood years applied. Ratio of	Location: 1.000 Scale: 0.194 Shape: -0.212	2.51

Site code	Method	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution	Growth factor 1% AEP
FFRWD02	P		and Kappa 3 (KAP3) distributions all had an acceptable fit to the data. GL z-value was closest to zero, indicating the best fit. This is also the recommended distribution for UK catchments.	total non-flood years to total station years is <0.05. This is likely to have an insignificant effect on the growth curves, particularly as the adjustment generally has a fairly small impact on them.	Location: 1.000 Scale: 0.198 Shape: -0.206	2.52
FFRWD03	P				Location: 1.000 Scale: 0.199 Shape: -0.205	2.52
BAG01	P	BAG01	GL, GEV and KAP3 distributions all had an acceptable fit to the data. GL z-value was closest to zero, indicating the best fit. This is also the recommended distribution for UK catchments.		Location: 1.000 Scale: 0.200 Shape: -0.284	2.89
BAG02	P				Location: 1.000 Scale: 0.228 Shape: -0.251	2.97
BAG03	P				Location: 1.000 Scale: 0.209 Shape: -0.272	2.92
BAG04	P				Location: 1.000 Scale: 0.169 Shape: -0.323	2.79
AFAN01	P	AFAN01	GEV and Pearson Type 3 (P3) distributions give an acceptable fit to the data. GEV z-value was closest to zero, indicating the best fit. There was a relatively small difference between the GEV and GL growth factors.		Location: 1.000 Scale: 0.263 Shape: 0.020	2.06
AFAN02	P				Location: 1.000 Scale: 0.267 Shape: 0.026	2.06

Notes

Methods: P – Pooled

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

For the GEV distribution, WINFAP uses a different parameterisation for the location parameter and growth curve equation compared to the equations given in Section 15.4 of FEH Volume 3 (which are used to derive the values presented above). The two methods are algebraically equivalent, giving the same resultant growth curve.

4.6 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
FFRWD01	20.6	27.1	31.8	36.9	40.2	44.8	48.7	51.7	72.0	83.1
FFRWD02	17.4	22.9	26.9	31.3	34.1	37.9	41.2	43.7	60.7	69.9
FFRWD03	15.0	19.8	23.3	27.1	29.5	32.8	35.7	37.8	52.5	60.5
BAG01	2.4	3.2	3.9	4.6	5.1	5.8	6.5	7.0	10.6	12.7
BAG02	1.3	1.8	2.1	2.6	2.8	3.2	3.5	3.8	5.7	6.7
BAG03	0.8	1.0	1.3	1.5	1.7	1.9	2.1	2.2	3.4	4.0
BAG04	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	3.1	3.8
AFAN01	100	130	149	167	177	190	200	207	245	261
AFAN02	98	127	146	164	174	186	196	203	239	255

5 Revitalised flood hydrograph 2 (ReFH2) method

5.1 Parameters for ReFH2 model

All catchments				
Site code	Method	C _{max} (mm)	Tp _{rural} (hours)	BL (hours)
FFRWD01	CD	356.41	2.07	39.61
FFRWD02	CD	341.02	1.84	37.02
FFRWD03	CD	319.57	1.68	34.51
BAG01	CD	593.02	1.84	43.55
BAG02	CD	419.78	1.00	31.70
BAG03	CD	652.84	1.00	35.41
BAG04	CD	871.02	2.78	41.91
AFAN01	CD	281.71	3.42	42.52
AFAN02	CD	263.32	2.95	38.62
FFRWD01_IA	CD	356.41	1.00	28.85
FFRWD02_IA	CD	415.44	1.00	29.96
BAG01_IA	CD	552.85	1.00	33.39
AFAN01_IA	CD	501.48	1.00	34.10
Link to details of any lag or flood event analysis		N/A		
Version of the ReFH2 model applied		ReFH2.3 using the water balance option. This treats BR (baseflow recharge) as a state variable rather than a parameter, setting it automatically in order to conserve volume. The values of BR vary with return period and so are not reported here.		
Parameters for urban runoff model		Impervious fraction of urban areas (IF): default value of 0.4 retained. Impervious runoff factor (IRF): default value of 0.7 retained. Depression storage: default value of 0.5mm retained. Tp for runoff from areas modelled as positively drained was calculated as 0.75 times Tp _{rural} .		
Methods: CD: Catchment descriptors				

5.2 Design events for ReFH2 method: Lumped catchments

Note: Allocation of urban / rural and the season of the design event is based on the definition in the Environment Agency's Flood Estimation Guidelines⁴. A winter storm is assigned unless $URBEXT_{2000} \geq 0.30$ or $URBEXT_{2000} \geq 0.15$ and $BFIHOST19 \geq 0.65$. All catchments with $URBEXT_{2000} < 0.30$ are treated as rural and the rural results used rather than the urban results. The rural results assume no influence of urbanisation, i.e., $URBEXT_{2000} = 0$. Guidance recommends that for catchments with $0.15 < URBEXT_{2000} \leq 0.30$ a T_p scaling factor of 1 should be used. However, if rural results are used, as per the guidance, the T_p scaling factor is not relevant. Due to this the T_p scaling factor has been left as default for all sites.

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
FFRWD01	Rural	Winter	5.50
FFRWD02	Rural	Winter	4.75
FFRWD03	Rural	Winter	4.75
BAG01	Rural	Summer	4.25
BAG02	Rural	Winter	2.30
BAG03	Rural	Summer	2.30
BAG04	Urban	Summer	6.50
AFAN01	Rural	Winter	10.50
AFAN02	Rural	Winter	9.50

5.3 Design events for ReFH2 method: Sub-catchments and intervening areas

Different storms are applied for each watercourse in the existing hydraulic model as an accepted simplification of the modelling. There is little interaction between the watercourses, except for a slight meeting of floodplain flows. It is proposed to retain this approach for the current study.

It should be noted that this is not normal practice. It is usual to apply the same storm duration, areal reduction factor (ARF) and season to all model inflows within the same hydraulic model. Therefore, when looking at the hydraulic model results the watercourses should be considered in isolation. For example, the results for the Afan and Baglan Brook are for different storms which are critical to each catchment, and it would not be expected to see these results occur at the same time on the watercourses.

Site code	Season of design event	Storm duration (hours)	ARF	Reason for selecting storm
All FFRWD	Winter	5.25	0.936	Based on FFRWD01 which is the location in the main area of interest in terms of flood risk. Adjusted slightly from the recommended duration to enable a shorter time interval to be used and produce a finer resolution hydrograph. This storm duration and ARF will be applied for all FFRWD model inflow hydrographs.
All BAG	Summer	4.25	0.956	No specific site of interest for this watercourse for the current study. Recommended storm duration for BAG01 was used as this covers the whole catchment. This also lies between the recommended durations for the other locations. This storm duration and ARF will be applied for all BAG model inflow hydrographs.
All AFAN	Winter	10.5	0.923	Recommended duration for AFAN01 which is the closest location to the site of interest. This storm duration and ARF will be applied for both AFAN model inflow hydrographs.

5.4 Flood estimates from the ReFH2 method

Results provided in the table are rural for all sites except BAG04 where $URBEXT_{2000} > 0.30$, as per guidance. These results are based on the recommended storm duration for individual locations, as detailed in Section 5.2.

Dark red text indicates that the AFAN02 (upstream site) peak flows are larger than those for AFAN01 (downstream site). This may be due to the proportionally small change in catchment area between the two locations and proportionally larger change in other catchment descriptors. The Flood Estimation Guidelines note that the FEH methods are not guaranteed to give spatially consistent results if applied to multiple sites along a river system.

Peak flows for BAG03 and BAG04 are given to two decimal places to better show changes between design events. This does not imply any greater degree of confidence in these results.

Site code	Flood peak (m^3/s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
FFRWD01	15.1	19.4	22.5	25.5	27.4	29.9	32.0	33.7	38.4	59.0
FFRWD02	13.2	17.1	19.8	22.6	24.3	26.5	28.5	29.9	34.1	52.4
FFRWD03	11.8	15.3	17.8	20.3	21.8	23.8	25.5	26.8	30.5	46.7
BAG01	1.5	2.0	2.3	2.6	2.9	3.2	3.5	3.7	4.4	7.3
BAG02	0.7	1.0	1.2	1.4	1.5	1.6	1.8	1.9	2.2	3.4
BAG03	0.39	0.54	0.64	0.76	0.83	0.93	1.01	1.08	1.3	2.2
BAG04	0.52	0.66	0.76	0.85	0.92	1.00	1.08	1.14	1.3	2.0
AFAN01	81.0	102	116	131	139	150	160	168	189	276
AFAN02	87.9	111	127	143	153	166	176	185	208	303

6 Discussion and summary of results

6.1 Comparison of results from different methods

Site code	Ratio of peak flow to FEH Statistical peak	
	50% AEP	1% AEP
	ReFH2	ReFH2
FFRWD01	0.73	0.65
FFRWD02	0.76	0.69
FFRWD03	0.78	0.71
BAG01	0.62	0.53
BAG02	0.58	0.49
BAG03	0.50	0.48
BAG04	0.74	0.58
AFAN01	0.81	0.81
AFAN02	0.90	0.91

6.2 Final choice of method

Choice of method and reasons	Afon Afan FEH Statistical is the preferred method to generate peak flow estimates for the Afon Afan. This is consistent with the previous study. QMED has been improved by using a local donor located within the model reach; the ReFH2 results are based on catchment descriptors alone. The Statistical method is also based on a much larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments. NRW guidance recommends that a ratio derived from the ReFH2 method results is used to adjust Statistical method peak flow estimates for design events less frequent than the 1% AEP event. For example, the ratio between the ReFH2 method 0.1% AEP and 1% AEP event flows is applied to the Statistical method 1% AEP event flow to generate an adjusted 0.1% AEP event estimate. This was applied for the AFAN flow estimation points (also consistent with the previous study) and the final peak flow estimates with this adjustment applied are given in Section 6.5. Ffrwd Wyllt The reasons for preferring the FEH Statistical method over the ReFH2 method are the same for the Ffrwd Wyllt as those described for the Afan, except that the QMED donor is located on an adjacent watercourse. Section 6.1 shows that the ReFH2 method peak flow estimates are substantially smaller than the Statistical method estimates. Potentially the catchment drainage network geometry descriptors (DPLBAR and DPSBAR) are influencing the ReFH2 method results; these are not used within the Statistical method. A similar difference in the results was found in the previous study and both sets of peak flow estimates were tested using the hydraulic model. This showed that the Statistical method overestimated flooding based on historical flooding evidence (or absence of it). The ReFH2 method results also generated more flooding than expected but to a lesser extent than the Statistical method estimates. It was recommended that the ReFH2 method results were taken forward as the model inflows. This recommendation was retained for the
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	current study as the differences between the method results are similar to those for the previous study. Baglan Brook There is little to choose between the FEH Statistical and ReFH2 methods for Baglan Brook, as both use catchment descriptors only. For all sub-catchments except BAG02 there are very large floodplain extents and no flood peak data to implicitly account for the effects of storage. Flood volumes may be more important than peak flows for this watercourse. Therefore, a rainfall-runoff approach may be favoured in this case. Comparison of 50% and 1% AEP event flows in Section 6.1 shows that the ReFH2 method flows are substantially smaller than the FEH Statistical method flows. Adjustment to the 50% AEP event for the Statistical method using the donor led to a minimal change to catchment descriptor values, so it is not this that is leading to the difference between the two methods. At this stage, it is recommended that the ReFH2 method flows are taken forward as inflows to the hydraulic model and the model results sense-checked to ensure that flood extents and levels are realistic. It should be noted that permeable urban catchments are outside the range of most catchments from which the FEH methods were developed. For such catchments the only reliable flood estimates are likely to be derived from local flow data. This is consistent with the previous study.
How will the flows be applied to a hydraulic model?	The ReFH2 model will be used to supply the hydrograph shape for the Afon Afan model inflows. A scaling factor was derived for the upstream inflow (AFAN02) and applied to the ReFH2 hydrograph. The ratio between the Statistical peak flow estimate and the ReFH2 peak flow estimate (based on the recommended storm duration for AFAN02 (9.5hr)) was calculated and applied to the selected 10.5hr duration hydrograph. There was only a small deviation in the scaling factor between the design events and it was decided to apply the 50% AEP event scaling factor to all design event hydrographs. If necessary, the intervening area hydrograph will be adjusted to approximate the lumped Statistical peak flow estimate at AFAN01. The lumped catchment FFRWD03 ReFH2 hydrograph will be applied at the upstream extent of the Ffrwd Wylt model. The intervening area catchment hydrographs (FFRWD02_IA and FFRWD01_IA) will be distributed along the relevant model reaches. For Baglan Brook the previous model had BAG02 and BAG03 applied as point inflows. BAG04 was distributed over a short reach just downstream of the BAG02 and BAG03 point inflows. The intervening area inflow was distributed over the reach downstream of the A4241 Seaway Parade to the small reservoir to the west of the M4. It is anticipated that the same approach will be used to apply the ReFH2 hydrographs derived for the current study. Details of how the model inflow hydrographs were generated are provided in Section 7.3.

6.3 Assumptions, limitations, and uncertainty

Assumptions	The main assumptions are: • The ReFH2 method peak flow estimates are more appropriate for the Ffrwd Wylt than the Statistical method estimates, based on testing undertaken in the previous study. • Based on catchment characteristics the ReFH2 method is more appropriate than the Statistical method for Baglan Brook.
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	- Using the unamended FEH Web Service FARL value for BAG01 is reasonable, rather than amending to 1.000 as was done in the previous study. - Selecting the geographically closest (and rural) donor for Ffrwd Wylt and Baglan Brook is appropriate (follows guidance). - Use of the small catchment pooling approach is more appropriate than using a 'standard' pooling group for Ffrwd Wylt and Baglan Brook. - Generating pooling groups using an URBEXT₂₀₀₀ threshold of 0.30 rather than 0.03 is reasonable to increase the number of stations from which the pooling groups are drawn. - It is reasonable not to adjust pooled L-moments to account for non-flood years as these account for <5% of the total station years and are likely to have little impact on the results.
Limitations	The main limitation is: There is no flow gauge on the Ffrwd Wylt and Baglan Brook which can be used to adjust QMED at the flow estimation points or against which to check other design event peak flow estimates.
Uncertainty	It is not possible to directly quantify uncertainty for the ReFH2 method. A UK average measure of uncertainty is presented in a technical guidance report⁹ generated by a R&D project which considered use of local data in reducing uncertainty in flood frequency estimation. The 95% confidence limits for the 1% AEP event, with donor adjustment of QMED (one donor) are: - Rural catchment (URBEXT₂₀₀₀ < 0.03), relevant to FFRWD02, FFRWD03 and AFAN02: 0.47 – 2.12 times the best estimate. - Moderately urbanised catchment (0.03 ≤ URBEXT₂₀₀₀ < 0.15), relevant to FFRWD01, BAG02, and AFAN01: 0.34 – 2.94 times the best estimate. Confidence intervals for heavily urbanised catchments URBEXT₂₀₀₀ > 0.15 are not provided because there are not enough suitable catchments with flood peak data to provide reliable statistics. It may be assumed that the confidence intervals will be somewhat wider than those for moderately urbanised catchments.
Suitability of results for future studies	The design event peak flow estimates and hydrographs were derived for the purposes of this modelling study. If peak flow estimates and hydrographs are required for a different purpose it is recommended that, at a minimum, a review of the results is carried out.

6.4 Checks

Are the results consistent?	Yes, for the FEH Statistical method and for the Ffrwd Wylt and Baglan Brook for the ReFH2 method. Peak flow estimates decrease downstream on the Afon Afan for the ReFH2 method. It is thought that this may be due to a small proportional increase in catchment area and a somewhat larger proportional increase in other catchment descriptors. ReFH2 has only been used to provide the hydrograph shape for the Afan, therefore this is not a concern.
What do the results imply regarding the frequency of	There are no flow gauges at the flow estimation points on any of the watercourses. However, Marcroft Weir lies between the two Afan flow estimation points. The design event peak flow estimates at AFAN01 were area-weighted to Marcroft Weir and compared to the AMAX series. AMAX1

⁹ Environment Agency. 2017. Technical guidance 12_17: Using local data to reduce uncertainty in flood frequency estimation.

floods during the period of record?	(the largest peak flow at the gauge) is 157m ³ /s (27/12/1979). This equates to between the 10% and 5% AEP events from the area-weighted peak flow estimates for the FEH Statistical method. This estimate may seem too frequent given the gauge has a 42-year record, suggesting that the peak flows may be too high. However, it must be remembered that the observed peak flow could also have a high degree of uncertainty associated with it. The ReFH2 method results suggest an AEP of around 1.33%. As no reports of flooding in Port Talbot could be found for the December 1979 event from a brief Internet search this estimate potentially seems too infrequent. It would generally be expected that at least some flooding would be noted for an event of this frequency.
Range of 1% AEP growth factors	The 1% AEP event growth factors are: • FFRWD ◦ FEH Statistical: 2.51 - 2.52 ◦ ReFH2: 2.23 - 2.28 • BAG ◦ FEH Statistical: 2.79 - 2.97 ◦ ReFH2: 2.19 - 2.79 • AFAN ◦ FEH Statistical: 2.06 ◦ ReFH2: 2.07 - 2.10 The typical range is 2.1 - 4.0. Values are generally towards the lower end of this range, with the growth factor for the Afan nodes falling just below the lower end of the range for both methods. Although the values are low this is characteristic of generally impermeable, wet, and steep catchments. Baglan Brook, which has more permeable geology and soils, has slightly larger growth factors than the other catchments.
Range of ratios for 0.1% AEP flow over 1% AEP flow	The 0.1% / 1% event ratios are: • FFRWD ◦ FEH Statistical: 1.60 - 1.61 ◦ ReFH2: 1.74 - 1.75 • BAG ◦ FEH Statistical: 1.76 - 1.92 ◦ ReFH2: 1.75 - 2.02 • AFAN ◦ FEH Statistical: 1.26 ◦ ReFH2: 1.64 - 1.65
How do the results compare with those of other studies?	Peak flow estimates from the current study and 2016 studies are compared in Table 6-1 for the downstream flow estimation points on each watercourse for selected design events. This shows that the current study peak flow estimates for the Afon Afan and Ffrwd Wyllt are up to 10% larger than those from the 2016 study. For Baglan Brook the current study peak flow estimates are around half those from the 2016 study. This is predominantly due to the use of the rural results for the current study (which follows guidance for locations where URBEXT₂₀₀₀ is ≤0.30), whereas urban results were used for all Baglan Brook locations in the 2016 study. It should be noted that these large differences are only seen at BAG01 and BAG03. At BAG02 and BAG04 the differences are within 10%. This is due to BAG02 having a much smaller URBEXT₂₀₀₀ value than the other locations, hence the rural and urban results do not differ as much, and urban results being used for BAG04 in the current study as URBEXT₂₀₀₀ is >0.30.

Table 6-1: Comparison of 2023 & 2016 peak flow estimates

Site code (and method)	AEP (%) event	2023 study (m ³ /s)	2016 study (m ³ /s)	Ratio (2023 / 2016)
AFAN01 (Statistical)	50	100	98	1.02
	1	207	189	1.09
	0.1*	340	313	1.09
FFRWD01 (ReFH2)	50	15.1	13.8	1.09
	1	33.7	30.6	1.10
	0.1	59.0	53.7	1.10
BAG01 (ReFH2)	50	1.5	3.0	0.49
	1	3.7	6.9	0.54
	0.1	7.3	12.4	0.59

* ReFH2 0.1% / 1% AEP event ratio applied to Statistical 1% AEP event peak flow.

The current study results are preferred as they use the latest methods, datasets, and guidance. Due to the large differences seen between the studies for some of the Baglan Brook flow estimation points, hydraulic model results for the current study will be checked to ensure predicted flooding looks sensible and not underestimated.

Are the results compatible with the longer-term flood history?	Investigation of longer-term flood history was not within the scope of the study.
Describe any other checks on the results	Hydraulic model results will be sense-checked to ensure that flood extents / depths appear reasonable when compared to reported flooding. However, there is limited detailed historical flooding information on which to base this assessment.

6.5 Final results

For the AFAN flow estimation points the results are those from the Statistical method. The 0.5% and 0.1% AEP event values were derived by applying the ReFH2 0.5%:1% and 0.1%:1% AEP event ratios to the Statistical method 1% AEP event peak flow estimates.

For the FFRWD and BAG Brook flow estimation points the results are from the ReFH2 method using the individual storm duration, ARF and season for each location. Flow reconciliation between hydraulic model flows and target flows (shown in this table) should be undertaken for FFRWD01 and BAG01, the locations for which critical conditions were applied when deriving the hydraulic model inflows.

Site code	Flood peak (m ³ /s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
FFRWD01	15.1	19.4	22.5	25.5	27.4	29.9	32.0	33.7	38.4	59.0
FFRWD02	13.2	17.1	19.8	22.6	24.3	26.5	28.5	29.9	34.1	52.4
FFRWD03	11.8	15.3	17.8	20.3	21.8	23.8	25.5	26.8	30.5	46.7
BAG01	1.5	2.0	2.3	2.6	2.9	3.2	3.5	3.7	4.4	7.3
BAG02	0.7	1.0	1.2	1.4	1.5	1.6	1.8	1.9	2.2	3.4
BAG03	0.39	0.54	0.64	0.76	0.83	0.93	1.01	1.08	1.3	2.2
BAG04	0.52	0.66	0.76	0.85	0.92	1.00	1.08	1.14	1.3	2.0

Site code	Flood peak (m ³ /s) for the following AEP (%) events									
	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AFAN01	100	130	149	167	177	190	200	207	233	340
AFAN02	98	127	146	164	174	186	196	203	228	333

6.6 Uncertainty bounds

This table reports the flows derived from the uncertainty analysis detailed in Section 6.3. The 'true' value is more likely to be near the estimate reported in Section 6.5 than the bounds. However, it is possible that the 'true' value could still lie outside these bounds.

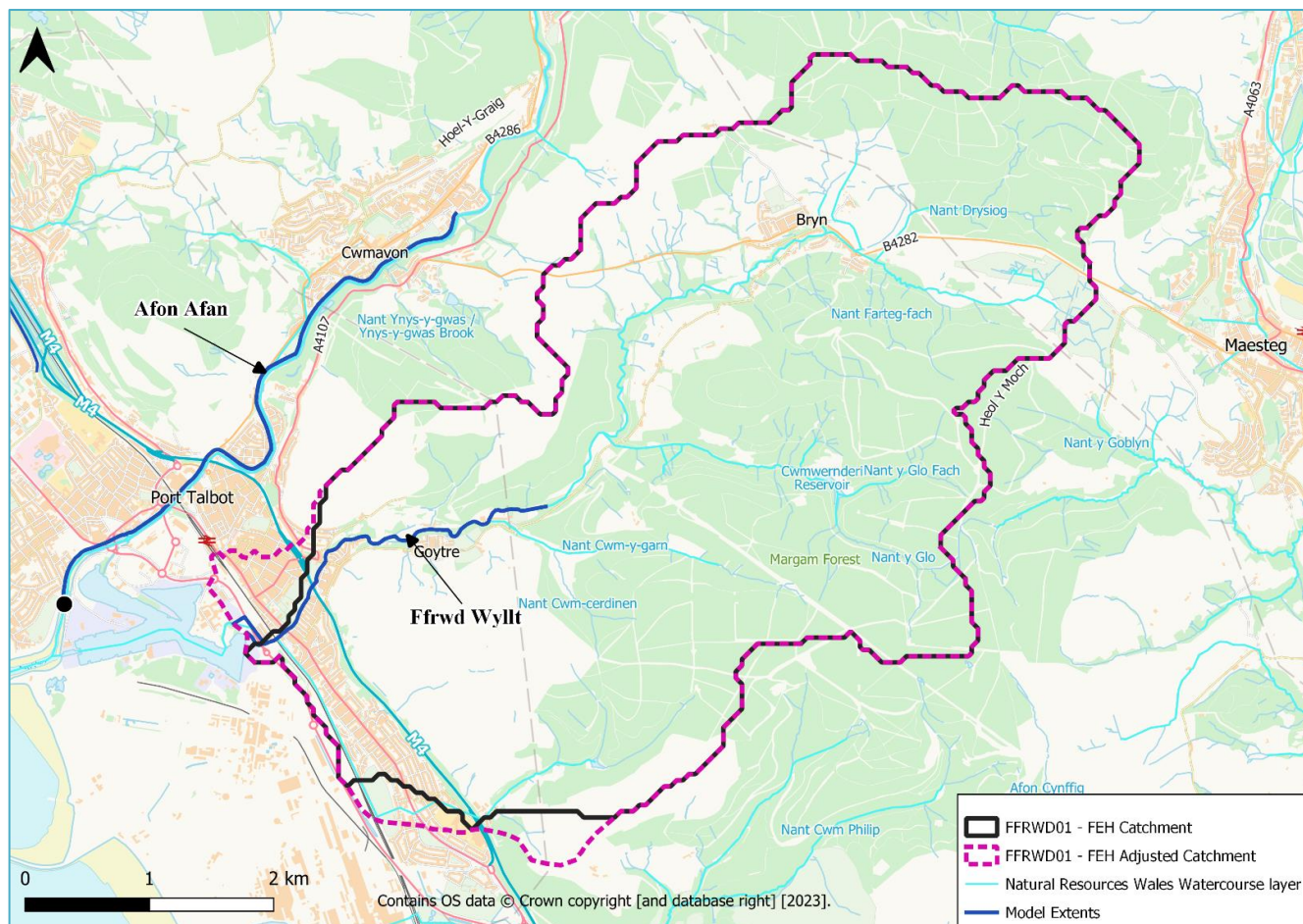
This assessment can only be undertaken for the AFAN flow estimation points. Uncertainty bounds are not provided for the 0.1% AEP event as these were adjusted using the ReFH2 ratio. It is not possible to directly quantify uncertainty for the ReFH2 method, which has been used to supply the final peak flow estimates for the FFRWD and BAG flow estimation points.

Site code	Flood peak (m ³ /s) for the following AEP (%) events			
	50		1	
	Lower	Upper	Lower	Upper
AFAN01	40.1	252	70.2	607
AFAN02	49.1	198	95.2	429

If flood hydrographs are needed for the next stage of the study, where are they provided?	Hydrographs for model.zip The above zip file is located in the 'Supporting file' folder issued with this report. The zip file contains separate folders for each watercourse which, in turn, contain .csv files for six AEP events.
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7 Annex

7.1 FFRWD01 FEH Web Service & adjusted catchment boundary



7.2 Final pooling groups

7.2.1 FFRWD01

Station	Distance (SDM)	Years of data	QMED AM	L-CV Deurbanised	L-SKEW Deurbanised	Discordancy
25012 (Harwood Beck @ Harwood)	0.040	52	33.4	0.184	0.223	0.368
49003 (De Lank @ De Lank)	0.134	55	13.7	0.213	0.165	1.512
48009 (St Neot @ Craigshill Wood)	0.173	12	8.5	0.245	0.372	1.619
48004 (Warleggan @ Trengoffe)	0.285	52	10.0	0.252	0.257	1.185
48001 (Fowey @ Trekeivesteps)	0.306	52	17.3	0.216	0.275	0.279
27032 (Hebden Beck @ Hebden)	0.324	53	4.1	0.197	0.202	0.270
57010 (Ely @ Lanelay)	0.346	22	39.7	0.152	0.130	2.092
76023 (Dacre Beck @ Dacre Bridge)	0.397	21	35.9	0.189	0.213	0.992
21017 (Ettrick Water @ Brockhoperig)	0.418	56	59.8	0.175	0.220	0.685
47014 (Walkham @ Horrabridge)	0.462	47	40.5	0.219	0.210	0.256

206006 (Annalong @ Recorder)	0.479	48	15.3	0.189	0.052	2.243
46006 (Erme @ Ermington)	0.480	46	47.0	0.170	0.153	0.498
Total		516				
Weighted means				0.200	0.204	

7.2.2 BAG01

Station	Distance (SDM)	Years of data	QMED AM	L-CV Deurbanised	L-SKEW Deurbanised	Discordancy
45816 (Haddeo @ Upton)	0.159	28	3.4	0.294	0.423	1.109
28033 (Dove @ Hollinsclough)	0.225	46	4.1	0.223	0.379	1.091
47022 (Tory Brook @ Newnham Park)	0.643	26	6.6	0.252	0.146	0.688
25011 (Langdon Beck @ Langdon)	0.670	35	15.6	0.226	0.324	0.796
69047 (Roch @ Littleborough)	0.679	25	9.5	0.236	0.138	0.467
84035 (Kittoch Water @ Waterside)	0.790	30	20.0	0.156	0.015	1.281
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	0.925	11	5.8	0.263	0.206	2.575
27032 (Hebden Beck @ Hebden)	1.037	53	4.1	0.197	0.202	0.220
206006 (Annalong @ Recorder)	1.047	48	15.3	0.189	0.052	1.541
18014 (Bannock Burn @ Bannockburn)	1.093	29	16.6	0.225	0.160	0.174
48009 (St Neot @ Craigshill Wood)	1.118	12	8.5	0.245	0.372	0.638
44008 (South Winterbourne @ Winterbourne Steepleton)	1.123	30	0.5	0.422	0.289	3.531
27010 (Hodge Beck @ Bransdale Weir)	1.124	41	9.4	0.224	0.293	0.219
48007 (Kennal @ Ponsanooth)	1.133	53	4.3	0.191	0.212	0.337
48004 (Warleggan @ Trengoffe)	1.140	52	10.0	0.252	0.257	0.333
Total		519				
Weighted means				0.240	0.239	

7.2.3 AFAN01

Station	Distance (SDM)	Years of data	QMED AM	L-CV Deurbanised	L-SKEW Deurbanised	Discordancy
58012 (Afan @ Marcroft Weir)	0.140	42	99.6	0.153	0.040	1.114
57006 (Rhondda @ Trehafod)	0.248	49	115.4	0.171	0.099	0.171
58005 (Ogmore @ Brynmenyn)	0.319	52	53.0	0.203	0.148	0.761
74001 (Duddon @ Duddon Hall)	0.341	54	120.9	0.149	0.228	0.699
47024 (Tavy @ Tavistock Abbey Bridge)	0.361	27	92.6	0.200	0.089	0.915
55004 (Irfon @ Abernant)	0.374	45	56.5	0.160	0.254	0.735

58006 (Mellte @ Pontneddfechan)	0.518	50	89.4	0.177	0.120	0.646
46008 (Avon @ Loddiswell)	0.520	41	63.1	0.172	0.101	2.666
96004 (Strathmore @ Allnabad)	0.593	19	198.5	0.183	0.234	0.505
73017 (Kent @ Bowston)	0.622	22	66.3	0.207	0.354	2.386
60006 (Gwili @ Glangwili)	0.646	53	83.1	0.176	0.158	0.062
47020 (Inny @ Bealsmill)	0.667	38	34.5	0.201	0.109	0.724
79004 (Scar Water @ Capenoch)	0.722	58	140.4	0.122	0.152	1.616
Total		550				
Weighted means				0.174	0.151	

7.3 Model inflow derivation metadata

Table 7-1 provides details of the storm duration, ARF and season used to generate the hydraulic model inflows. It also identifies whether rural or urban results were used – as URBEXT₂₀₀₀ is >0.30 only for BAG04 all other inflows use rural results.

Table 7-1: Model inflow derivation metadata

Inflow	Duration (hr)	ARF	Season	Rural or Urban results
FFRWD01_IA	5.25	0.936	Winter	Rural
FFRWD02_IA	5.25	0.936	Winter	Rural
FFRWD03	5.25	0.936	Winter	Rural
BAG01_IA	4.25	0.956	Summer	Rural
BAG02	4.25	0.956	Summer	Rural
BAG03	4.25	0.956	Summer	Rural
BAG04	4.25	0.956	Summer	Urban
AFAN01_IA	10.5	0.923	Winter	Rural
AFAN02	10.5	0.923	Winter	Rural

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