

FCA for WAST Development at Wrexham Maelor Hospital

Final Report

October 2013

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Contract

This report describes work commissioned by Arup, on behalf of BAM and WAST, by email dated 22nd May 2012. Arup’s representative for the contract was Poorav Chheda. Kevin Frodsham of JBA Consulting carried out this work.



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Purpose

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Acknowledgements

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Executive Summary

JBA Consulting has been commissioned by Arup, on behalf of BAM and ultimately WAST (the Welsh Ambulances Service NHS Trust), to undertake a Flood Consequence Assessment (FCA) for a site adjacent to Wrexham Maelor Hospital. The proposed development is a joint ambulance and fire services platform with fire training facilities that will occupy approximately 2.05 hectares of brownfield land on the left bank of the River Gwenfro. The River Gwenfro is currently the main source of flood risk to the site, parts of which currently lie within flood zone C2 as defined by Technical Advice Note 15 (TAN 15) Development and Flood Risk. The Natural Resources Wales (NRW) flood maps also show parts of the site to be within flood zone 3 (high probability of flooding) and/or flood zone 2 (medium probability of flooding). The principal aim of this FCA is to document the fluvial flood risk to the WAST site and demonstrate that the site can be developed to be safe from future flooding without adversely impacting on flood risk elsewhere. Minimising downstream impacts is especially important with respect to the WAST development since Wrexham Maelor Hospital, parts of which have flooded in the past, is situated immediately downstream of the WAST site.

The fluvial flood risk from the River Gwenfro has been analysed via hydraulic modelling. This comprised three key stages:

- A site-specific hydrology assessment.
- An assessment of the baseline (pre-development) risk.
- An assessment of the post-development risk.

Hydrology

A check was carried out on the hydrology since there have been a number of changes to the FEH guidelines since previous flows were calculated. The calculations produced a set of flows that were higher than the previous NRW Strategic Flood Risk Mapping (SFRM) estimates but were some 15% lower than those that had been used previously with the River Gwenfro hydraulic model. The revised flows were used in this FCA since they represent the most up-to-date assessment of the hydrology for this site.

Five flood events were modelled in this FCA; 5% AEP, 1% AEP, 1% AEP with climate change, 0.1% AEP and 0.1% AEP with climate change. Climate change was analysed, in accordance with FCDPAG3 guidance, as a simple 20% increase in fluvial inflows.

Baseline Risk

An important consideration of the baseline risk is that the development of the WAST site is dependent upon a new road scheme (the Western Gateway) that is currently being constructed near the western entrance to the site. The baseline risk to the WAST site was therefore analysed using a version of the River Gwenfro hydraulic model that had been created for the Western Gateway FCA in 2011. The Western Gateway scheme has previously been assessed by JBA to ensure no changes would result to the capacity and flow regime of the river upstream and downstream of the two bridges beneath the disused railway line.

The baseline model indicates that:

- The raising of the new spine road as part of the Western Gateway development would remove the flow route along the old railway line and through the WAST site that currently appears in Flood Zone 2.
- 79% of the WAST site would remain dry across the range of modelled events.
- The remaining 21% of the development (primarily in the east of the site) would remain at risk of flooding after the completion of the Western Gateway development.

Post-development Risk

To enable the WAST site to be safely developed whilst having no off-site impacts, it is proposed to develop the site on split levels with the majority of the site (including the key emergency response and fire training facilities) being developed to be above the future extreme {0.1% AEP} River Gwenfro flood level, leaving only a 'less vulnerable' overflow staff car park at a lower level.

To ensure that the core of the WAST development is safe from flooding and can remain operational at all times, it is proposed that ground levels across the majority of the site should be configured at a level that is, at a minimum, equal to the 0.1% AEP with climate change level in the adjacent River Gwenfro plus a 300mm freeboard. Access to and from the higher level of the site would be possible across the range of flood events studied and the residual risk from blockage and infrastructure failure to this part of the site is considered to be very low.

To prevent the development from having adverse off-site impacts, it is proposed to develop an overflow staff car park at a lower level. This part of the development would effectively be sited in the functional floodplain so would have to be appropriately designed and managed for the lifetime of the development via a suitable flood management plan. A number of potential design and operational requirements for the overflow car park are listed in Section 3.6.

Hydraulic modelling demonstrates that the new development would meet the requirements of TAN 15 regarding off-site impacts by having no significant adverse off-site impact. There would even be a small reduction (0.01 metres) in flood depth within the downstream hospital grounds during a 1% AEP event.

It is proposed to reduce surface water attenuation to Greenfield run-off rates by using suitable SUDS (Sustainable Urban Drainage System) methods.

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Abbreviations

AEP	Annual Exceedance Probability
FCA.....	Flood Consequence Assessment
JBA	JBA Consulting
m AOD	metres Above Ordnance Datum
TUFLOW	Hydraulic Modelling Software
WAST.....	Welsh Ambulances Service NHS Trust
Wrexham CBC	Wrexham County Borough Council

1 Introduction

1.1 Aims of the Flood Consequence Assessment (FCA)

JBA Consulting has been commissioned by Arup, on behalf of BAM and ultimately WAST (the Welsh Ambulances Service NHS Trust), to undertake a Flood Consequence Assessment (FCA) for a site adjacent to Wrexham Maelor Hospital. The proposed development is a joint ambulance and fire services platform with fire training facilities and the site is hereafter referred to as the 'WAST site'.

The construction of the WAST site is scheduled to follow the Western Gateway development that is currently being constructed by Wrexham County Borough Council (CBC) and which involves changes to the local road network in the vicinity of Wrexham Maelor Hospital (see Section 1.2). It is therefore a key assumption of this FCA that the Western Gateway development will be constructed according to the Western Gateway Flood Consequence Assessment (FCA) that was submitted to the Environment Agency, Wales (now NRW – Natural Resources Wales) in 2011.

The WAST site is located close to the River Gwenfro and part of the site is currently considered to be at risk from fluvial flooding since it lies within flood zone C2 as defined by TAN15 Development and Flood Risk. Since part of the site is potentially at a significant risk of flooding, a Flood Consequence Assessment (FCA) is required to accompany the planning application. This FCA has been written in accordance with the current Welsh Planning Guidance in relation to development and flooding i.e. TAN 15¹.

The primary objective of this FCA is to develop a full appreciation of:

- The consequences of flooding on the development, and,
- The consequences (i.e. the overall impacts) of the development on flood risk elsewhere within the catchment for a range of potential flooding scenarios up to that flood having a probability of 0.1%.

1.2 The WAST Development

1.2.1 Location and baseline conditions

The WAST site is located on brownfield land close to Wrexham Maelor Hospital in the west of Wrexham (Figure 1.1). The planned area of development occupies approximately 2.05 hectares² between a large hospital car park (which is partly situated along the route of a former railway line) and the left bank of the River Gwenfro. Figure 1.2 shows a recent (but pre-Western Gateway) aerial image of the WAST site.

Wrexham CBC has recently begun work on the Western Gateway development, which involves realignment of Croesnewydd Road just upstream from the WAST site and the construction of a new spine road along the course of the old railway (Figure 1.1). The spine road is to link with Croesnewydd Road just upstream of the WAST site. The Western Gateway development will also include redesigned culverts beneath both Croesnewydd Road and the spine road. The Western Gateway development has previously been shown to locally alter the flood risk from the River Gwenfro in the vicinity of the WAST site and these changes to the baseline flood risk were presented in a previous FCA³ prepared by JBA Consulting for Wrexham CBC. Since the WAST development is being designed to link into the proposed Western Gateway road configuration, it is a key assumption of this WAST FCA that Wrexham CBC will develop the Western Gateway configuration according to that documented in the Western Gateway FCA. The current FCA therefore uses the Western Gateway development as the baseline (existing) conditions when analysing the impact of the WAST development.

¹ Technical Advice Note 15: Development and Flood Risk, Planning Policy Wales, 2004.

² Note that this value is the area of the site polygon depicted in Figure 1.1 and not necessarily the maximum area of developable land.

³ River Gwenfro Western Gateway FCA Modelling, January 2011

Figure 1.1: Location of the proposed WAST development site.

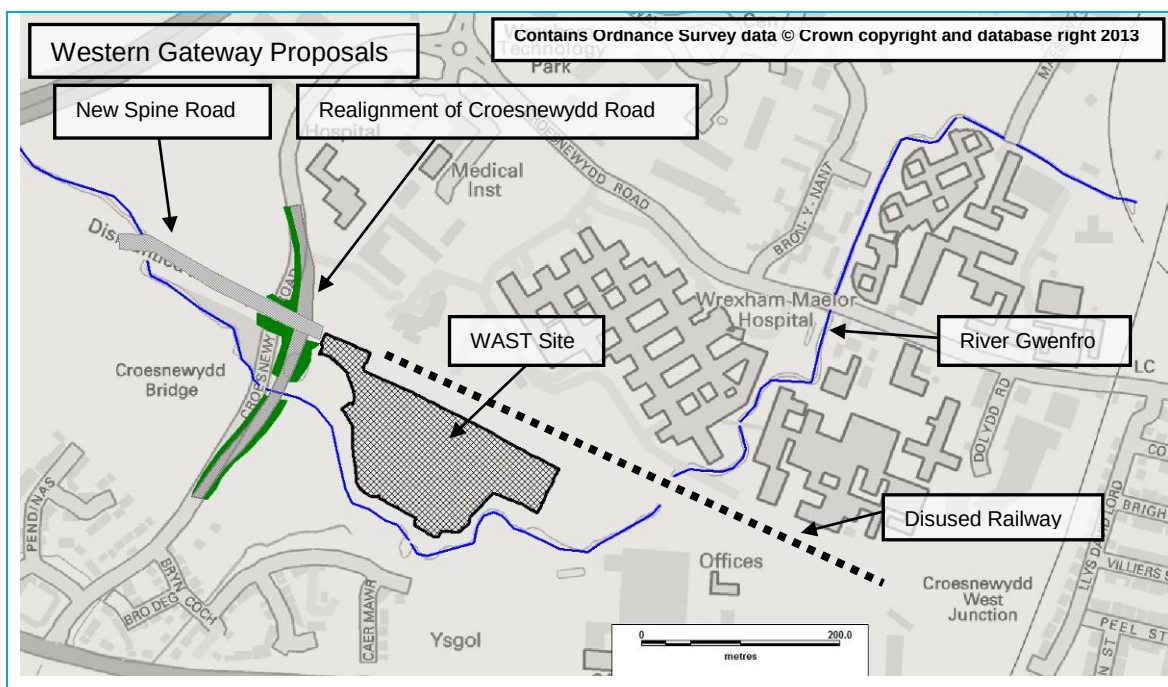


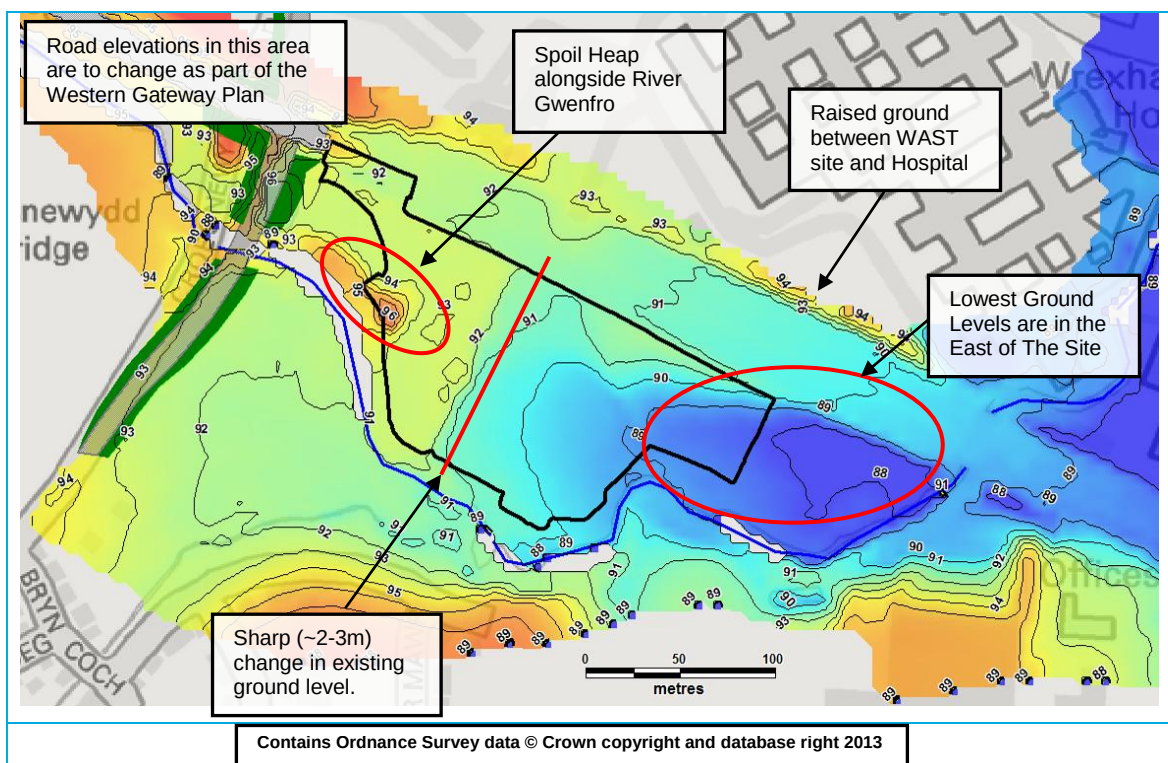
Figure 1.2: Aerial Image of the WAST site (from Bing Maps).



The topography of the WAST site, based largely on a ground survey of the site that was carried out in February 2011 by SUMO Services (Havant), is illustrated in Figure 1.3. This demonstrates that the main WAST site (on the left bank of the River Gwenfro) generally decreases in elevation from the north-west to the south-east with ground levels ranging from around 93.00m AOD in the north-west to 88.00m AOD in the south-east. Superimposed upon this general trend are the following noteworthy features:

- A sharp drop from 93.0 to 90.0m AOD across a NNE-SSW directed axis in the centre of the site.
- A spoil heap which rises to in excess of 95.0m AOD alongside the River Gwenfro near the western edge of the site.
- A broad embankment in excess of 93.0m AOD between the current car parking area along the old railway line and the main hospital buildings.

Figure 1.3: Current topography of the site (based primarily on the site survey).



1.2.2 Proposed Site Layout and Development Categories

The proposed layout of the main WAST site is shown in Figure 1.4⁴. This shows that the key emergency response part of the development (including the ambulance and fire services depot and the main site access/egress route) will occupy the western part of the site. The central part of the development will include the main ambulance and staff car parking areas with vehicle refuelling and washing areas whereas the eastern part of the site is proposed to be occupied by the fire training facilities and an overflow staff car park.

Figure 1.4: The proposed WAST site layout.

See the Figures Section at the back of the report.

The core of the WAST development would be categorised as 'Emergency Services' development according to TAN 15 since the ambulance and fire services platforms and several of the associated facilities would need to be operational and accessible at all times. Since usage of the fire training facilities would effectively be operated as commercial premises with only periodic usage, they could be regarded as a 'less vulnerable' type of development. Similarly, the overflow staff parking area at the very east of the site would not need to be operational at all times so would not be critical to the emergency response capability of the WAST site. Although, TAN 15 asserts that the vulnerability attributed to a mixed use proposal should be defined by the most vulnerable use, which is in this case 'the emergency services' facilities, in this particular case a pragmatic approach to each aspect of the proposed development has been taken in terms of flood risk owing to the site extent, the different proposed land uses and the proximity of the existing hospital.

⁴ Note that Wrexham CBC's attenuation ponds (shown on Figure 1-4) do not form part of the current WAST development proposal.

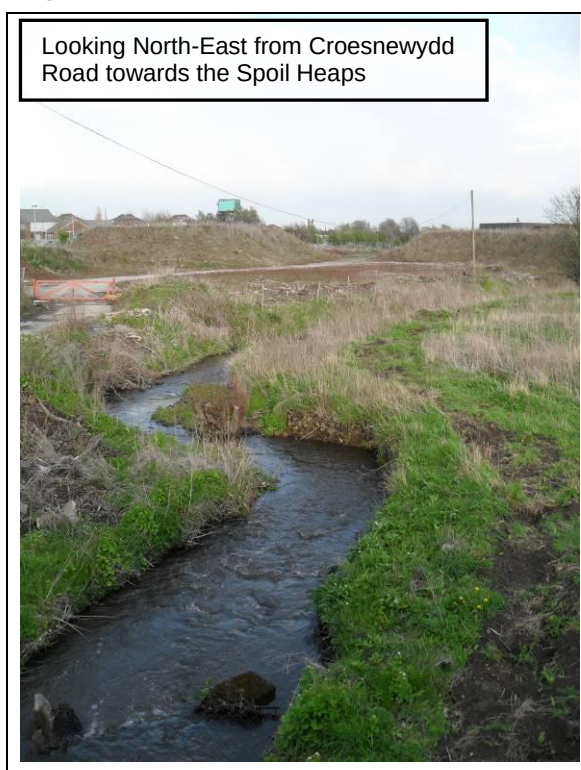
1.3 Potential Sources of Flooding

An FCA should consider all potential sources of flooding to the site. This section lists the results of a preliminary investigation into the likely role of each of these sources at the WAST site. Further information on the fluvial flood risk forms the core of this FCA and is provided in Sections 2 and 3. Further information on the surface water risk is provided in Section 4.

1.3.1 Fluvial Flood Risk

The River Gwenfro is a relatively small watercourse that is typically less than 5.0 metres wide adjacent to the WAST site (Figure 1.5). The Gwenfro catchment upstream of the site is approximately 10.0km² in size and predominantly rural.

Figure 1.5: View of the River Gwenfro and WAST site (April 2012).



Flooding has been recorded from the River Gwenfro at a number of different locations in Wrexham on a number of occasions⁵. Since the WAST site lies upstream of these known flood risk locations (including part of Wrexham Maelor Hospital), it will be important to minimise and control any potential impacts of the WAST development as part of this FCA. Anecdotal evidence suggests that the low-lying eastern part of the WAST site was flooded in November 2012 at the same time as the severe flooding in Ruthin St. Asaph. It should be noted that flooding of the eastern part of the site is in accordance with the lower existing risk threshold that has been predicted by the hydraulic modelling (presented in Section 2). There are no other reports of the WAST site having flooded in the past but since the site occupies a derelict brownfield location, it is by no means certain that flooding of the site would always be recorded to enable a picture of the frequency of flooding to be assembled.

The Development Advice Map for the WAST site made available by the Welsh Assembly⁶ is included as Figure 1.6. This classifies a significant part of the WAST site as Zone C2 (defined as an area of the extreme floodplain without significant flood defence infrastructure). The latest flood map maintained by National Resources Wales (NRW) is shown in Figure 1.7.

⁵ Afon Gwenfro Flood Risk Mapping Study, Modelling Report, February 2009.

⁶ <http://data.wales.gov.uk/apps/floodmapping/>

The NRW flood map implies that:

- The eastern part of the WAST site is potentially at a high (<1% AEP) risk of flooding.
- Some of the western part of the WAST site is potentially at risk from an extreme (0.1% AEP) flood event.

The current NRW Flood Map does not, however, take account of the predicted changes to the local flood risk that will result from the Western Gateway development. Raising the course of the old railway to form part of the new spine road was predicted (in the Western Gateway FCA) to restrict flow along the route of the old railway line, therefore, removing the western part of the main WAST site out of the extreme flood extent (and hence Zone C2). These impacts were demonstrated in the Western Gateway FCA and since the Western Gateway development has been incorporated into the baseline conditions for the current WAST FCA, the extreme flood risk presented in this FCA (Section 2) does not include the flow route along the disused railway. The post-Western Gateway flood risk maps are provided in Section 2.

Figure 1.6: Development Advice Map for the WAST site.

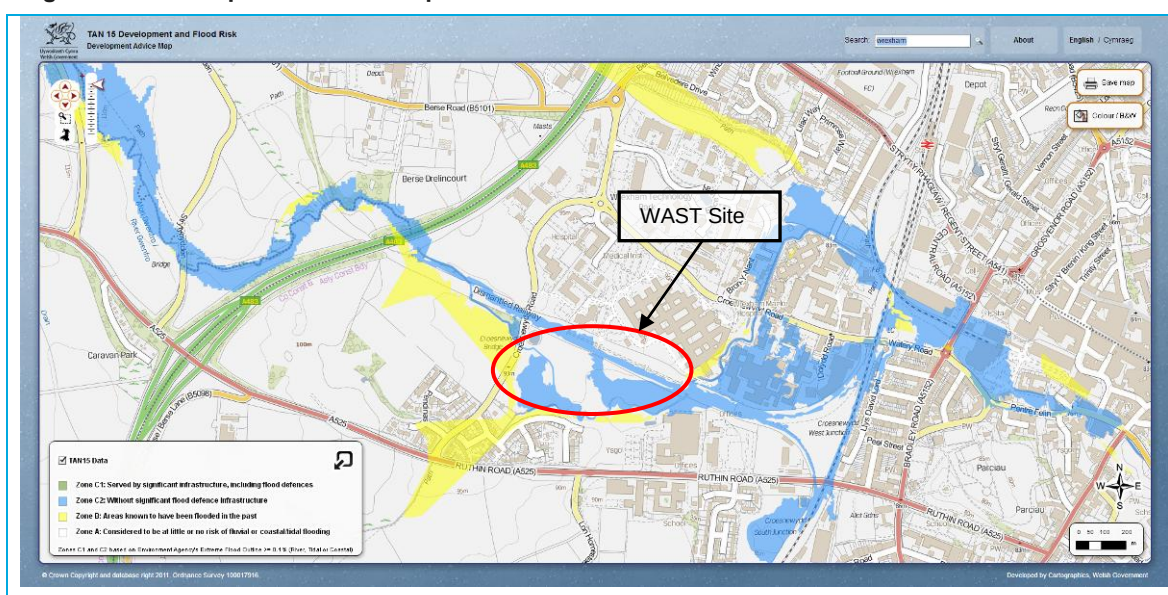
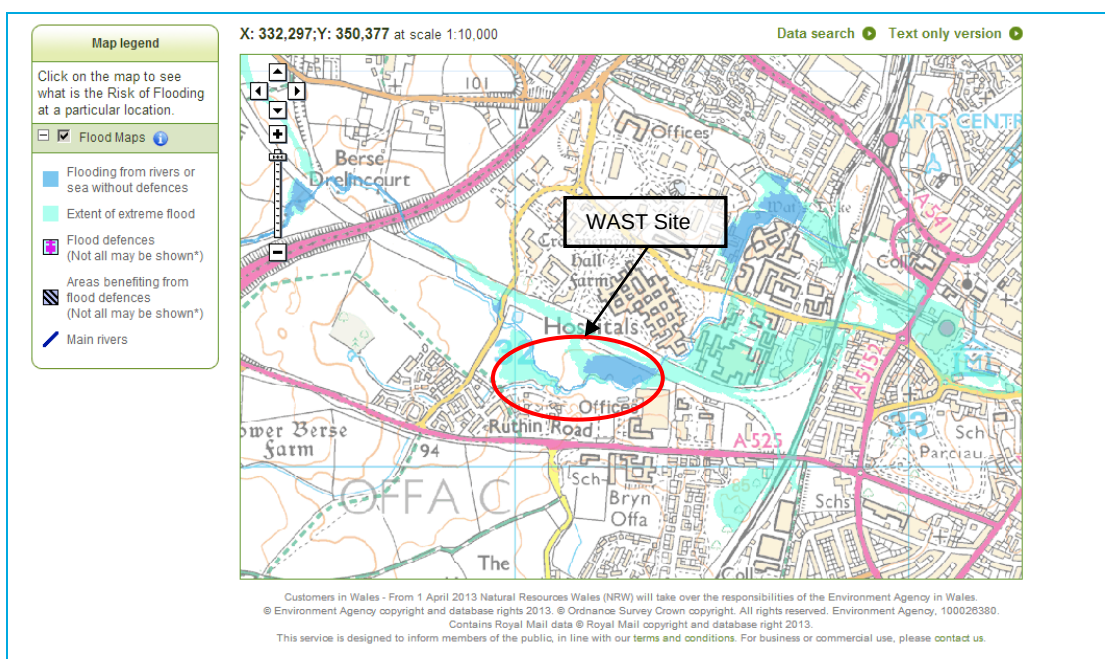


Figure 1.7: The Environment Agency's Flood Risk Maps for Wrexham (reproduced from the Environment Agency's website - June 2012).



Properties alongside the River Gwenfro in Wrexham are subject to NRW issued Flood Alerts but flood levels are not currently monitored along the Gwenfro as part of a more defined Flood Warning scheme.

1.3.2 Other potential sources of flooding

Surface Water

Surface water issues are addressed in Section 4.

Groundwater

A preliminary screening of the potential groundwater risk (supplied by JBA Risk Management) reveals that the WAST site is not considered to be at a significant risk of groundwater flooding from either underground aquifers or a raised water table.

Infrastructure failure

- There are no flood defences in the vicinity of the WAST site so defence failure will not be a consideration for this site.
- Consideration should be given to the possibility and consequences of culvert blockages on a development in an FCA. There are a number of bridges and culverts along the WAST study reach at blockage could exacerbate the fluvial flood risk to the site. The potential impact of blockages is investigated as part of the residual risk to the site in Section 3.4.2.
- NRW Reservoir Risk maps reveal that the WAST site is not at risk from any nearby reservoir failure.

2 The Baseline (post-Western Gateway) Fluvial Flood Risk

The assessment of the fluvial flood risk from the River Gwenfro to the WAST site was principally carried out by hydraulic modelling. This phase of the work consisted of:

- An update on the hydrology of the Gwenfro model.
- The evaluation of the baseline risk using Wrexham CBC's Western Gateway FCA model with some local modifications appropriate to a site-specific FCA.
- The evaluation of the post-development risk (i.e. with the ambulance platform and any mitigation measures in place).

This Section outlines the baseline risk and how this was evaluated for the WAST site and nearby (off-site) receptors. The post-development risk is evaluated in Section 3.

2.1 Fluvial Hydrology

2.1.1 Revised FEH Calculations

The hydrology in the Western Gateway FCA model was based on calculations undertaken in 2008 and there have been a number of revisions to the FEH methodology since the Gwenfro hydrology was last calculated in Wrexham. A hydrology check was, therefore, carried out to ensure that the flood risk to the site was modelled with the most up-to-date hydrology. These calculations are reproduced in Appendix A (the FEH Calculation Record) and the calculated peak flows for a range of return periods for a location just upstream from the WAST site are shown in Table 2-1.

Since the peak flows were found to decrease (slightly) in magnitude downstream through Wrexham (as a consequence of changes in the FEH catchment descriptors), it was decided to use the flows shown in Table 2-1 to evaluate the fluvial flood risk at the WAST site. The flows in Table 2-1 represent an increase on the values that were calculated for the Gwenfro FRM study in 2008 (e.g. 1 in 100 flow = 6.8m³/s) but a decrease on the values that were previously included in the Gwenfro model (e.g. 1 in 100 flow = 9.9m³/s); since a decision had been made during the FRM study to stick with a set of flows that had previously been calculated for a design scheme in Wrexham. Since the latest calculations (reproduced in Appendix A) represent the most up-to-date flows estimation, it is considered that these values best represent the flood risk at the WAST site.

Table 2-1: Flood peak flows (m³/s) for the following return periods (in years)

2	5	10	20	50	75	100	200	1000
3.2	4.4	5.2	6.4	7.4	8.1	8.6	9.9	15.0

Flood events modelled for the FRA include:

- 5% AEP (annual Exceedance probability) equivalent to a 1 in 20 year return period.
- 1% AEP (annual Exceedance probability) equivalent to a 1 in 100 year return period.
- 0.1% AEP (annual Exceedance probability) equivalent to a 1 in 1000 year return period.

The 1% and 0.1% AEP events were modelled both with and without a climate change factor (as documented in Section 2.1.2).

2.1.2 The Application of Climate Change in this FCA

TAN15 recognises that climate change could be a key factor affecting the flood risk over the lifetime of any new development and requires that climate change is included in any analysis of the flood risk at a new development. While the approach towards analysing climate change is generally becoming more sophisticated, the most recent guidance⁷ regarding adapting to climate

⁷ Adapting to climate change: Guidance for Flood and Coastal Erosion Risk Management Authorities in Wales, December 2011

change in Wales released for Flood and Coastal Erosion Risk Management Authorities notes that: “This advice *has not yet been tailored for the land use planning system. Local planning authorities and developers should continue to use the allowances in the Welsh Government FCDPAG3 Economic Appraisal Supplementary Note, July 2007, as directed within Technical Advice Note 15, (TAN15).*”

FCDPAG3 notes that for events more than 20 years into the future, climate change should be incorporated into fluvial flood risk assessments via a 20% increase in fluvial inflows. This approach has been used in this FCA to analyse both the future 1% AEP and 0.1% AEP fluvial flood events but is anyway equivalent to the mean climate change factor for the Dee and its tributaries proposed in the more recent ‘Adapting to climate change’ guidance.

2.2 Existing (Baseline) Flood Risk

2.2.1 Hydraulic Modelling

Following an agreement between WAST, NRW and Wrexham CBC, Wrexham CBC’s Western Gateway FCA model was used to evaluate flood risk at the WAST site. This model was developed by JBA for the Western Gateway FCA in 2011 from NRW’s Flood Risk Mapping (FRM) model of the River Gwenfro (2009).

The changes made to NRW’s Gwenfro FRM model when developing the Western Gateway FCA model are documented in detail in the Western Gateway FCA. In summary, changes were made to the local level and alignment of Croesnewydd Road and the disused railway line (which is to become the new spine road) and the culverts beneath both of these structures were upgraded to ensure no increase in downstream impacts during flood events.

To determine the baseline risk to the WAST development for this WAST FCA, a small number of changes were made to the Western Gateway FCA model. These were:

- The model inflows were scaled to reflect the peak flows shown in Table 2-1.
- Topographic survey was used where available to define the baseline elevation around the WAST site since a detailed topographic survey was supplied by the client and topographic survey is generally considered more accurate than the LIDAR, upon which the original (NRW) model topography was built⁸.
- A small number of changes (primarily adjusting the 1D section width) were made to the study reach between the two Croesnewydd Road Bridges to improve model stability and enable the impact of development to be better evaluated downstream of the site.

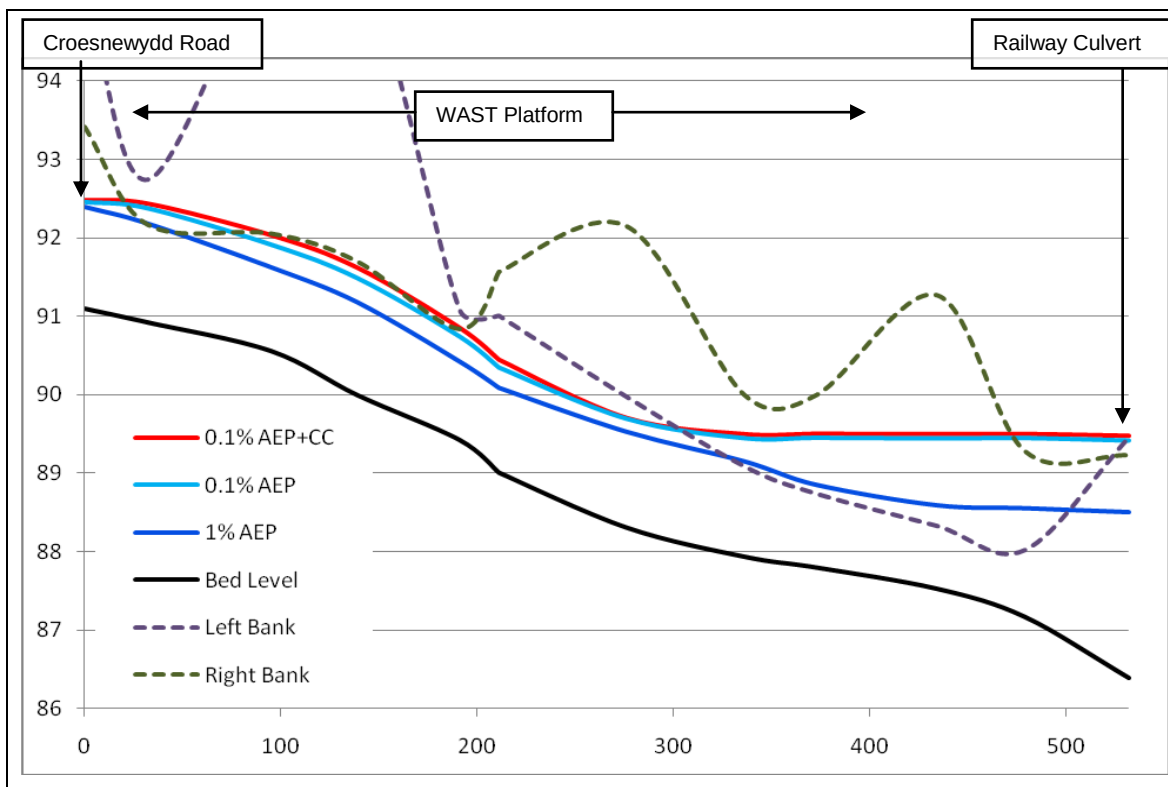
2.2.2 Predicted Baseline (Existing) Risk

Figure 2.1 shows the peak modelled flood levels in the River Gwenfro alongside the WAST site between Croesnewydd Road and the downstream railway culvert. This shows that flood levels would remain below the left bank crest for the initial 300 metres downstream of Croesnewydd Road⁹. Overtopping of the left bank would, however, occur in the 230 metre reach immediately upstream of the railway culvert. Figure 2.1 also shows the flood profiles flattening out in the downstream part of this reach, presumably as a consequence of the limited capacity of the culvert beneath the disused railway line.

⁸ Except where the survey picked up spoil heaps, the surveyed ground levels across the WAST site were typically (up to 0.20m) lower than were apparent in the Gwenfro SFRM model DEM that (based on old LIDAR). The spoil heaps were included in the baseline model since checks revealed that their current location on the raised part of the site would not be expected to influence the modelled flood risk.

⁹ This plot includes the spoil heaps that currently lie alongside the western part of the site (see Figure 1.3) but even discounting the spoil heaps, ground levels, which are typically around 93.00m AOD this area, would remain above the modelled flood levels in the River Gwenfro.

Figure 2.1: Maximum predicted flood levels (m AOD) in the River Gwenfro alongside the WAST site.



Overtopping of the right bank is limited to two short reaches; one immediately downstream of Croesnewydd Road Bridge and the other just upstream of the railway culvert. Overtopping in this latter location would only occur during an extreme event and is modelled to lead to flow across the old railway line and flooding of the hospital grounds on the right bank downstream of the old railway line.

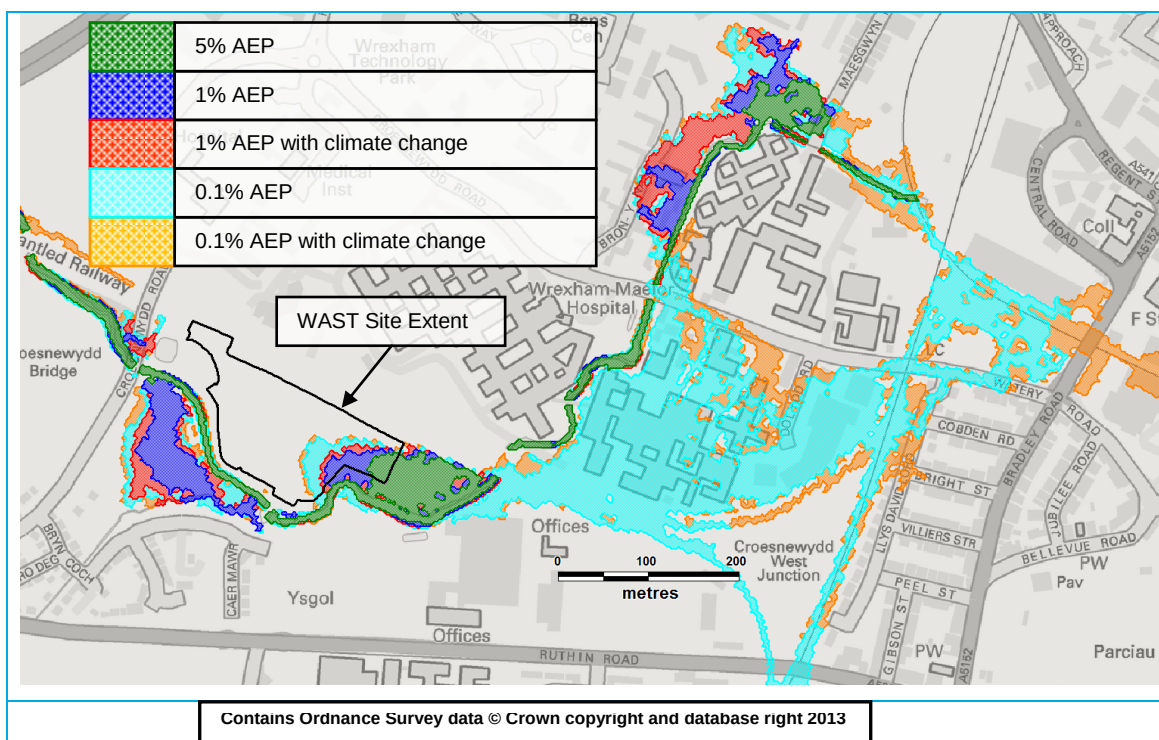
Figure 2.2 shows the modelled baseline flood outlines for the range of modelled events. This demonstrates that approximately 79% (1.62Ha) of the proposed WAST site (2.05Ha) is predicted to remain dry across the range of modelled flood events and that the fluvial flood risk is restricted to 21% (0.43Ha) of the proposed development area in the east of the WAST site¹⁰. Flooding of this eastern area is modelled to occur by direct overtopping of the left bank of the River Gwenfro and is a consequence of low ground levels and the limited capacity of the culvert beneath the old railway line. Figure 2.2 shows that the eastern part of the WAST site is modelled to flood with a threshold as low as 5% AEP¹¹ and that the flooded area on-site increases (albeit not greatly) with event magnitude.

Elsewhere in Wrexham part of Wrexham Maelor Hospital downstream of the WAST site, in the vicinity of Bron-y-Nant, is predicted to flood during a 1% AEP event. The extent of flooding to the hospital grounds is predicted to increase significantly during an extreme (0.1% AEP) event as a consequence of floodwater overtopping the old railway line at the downstream end of the WAST site. These results highlight the fact that there is highly vulnerable development already at flood risk just downstream from the WAST site. The FCA must therefore ensure that there is a 'minimal' downstream increase in flood risk in response to the development of the WAST site.

¹⁰ Note that these areas and percentages are based on the site polygon depicted in Figure 1-1.

¹¹ Note that 5% AEP was the lowest magnitude modelled for this FRA so the threshold could be lower still.

Figure 2.2: Modelled baseline flood outlines.



The modelled flood depth maps across the site for each event are shown in Figure 2.3 and this flood depth information is summarised in Table 2-2¹². These demonstrates that flooding would likely be quite deep (>1.0m) across the eastern-most part of the WAST site during an extreme 0.1% AEP event; potentially making it difficult to safely develop this part of the site at current ground levels.

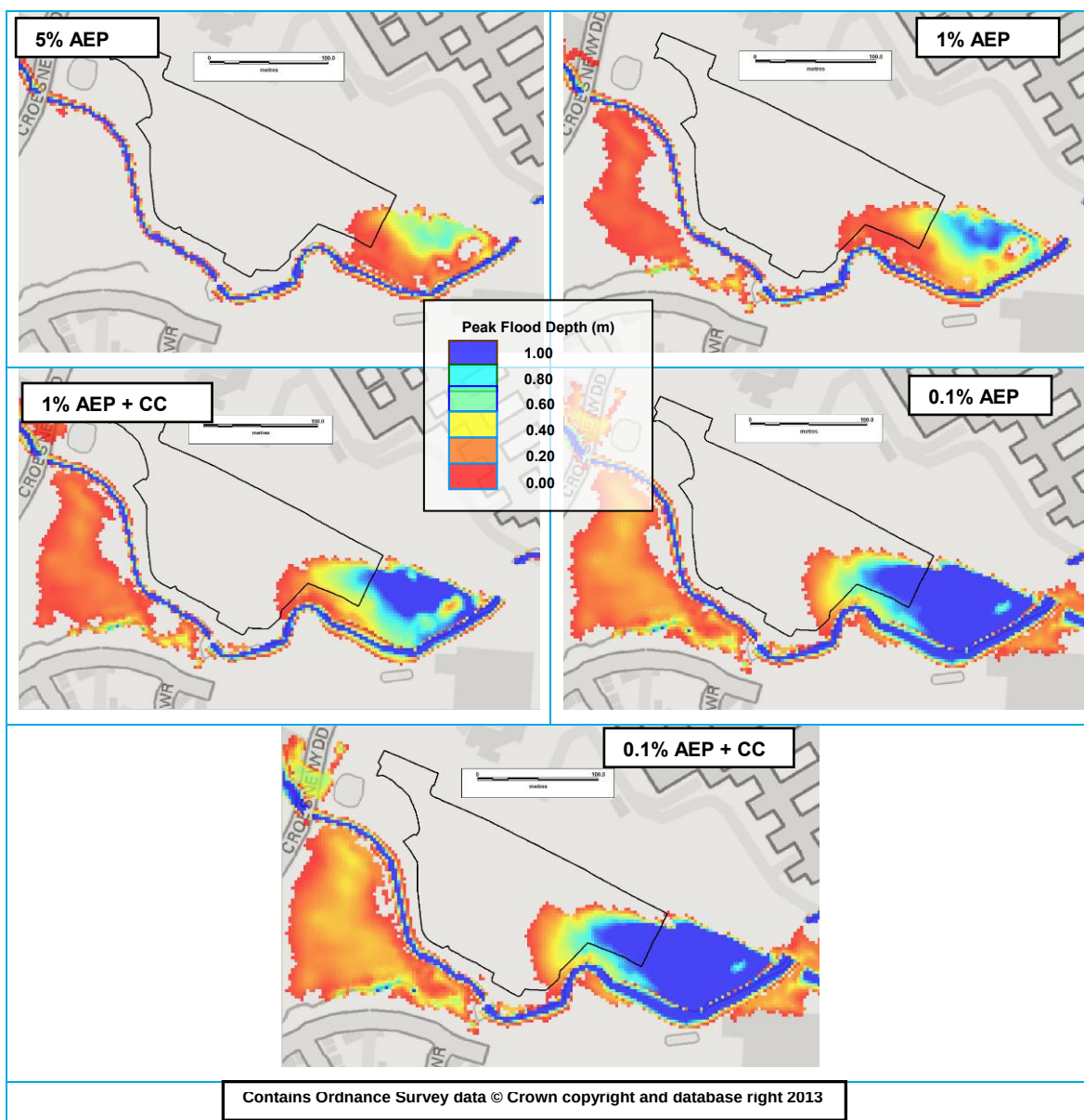
Table 2-2: Modelled extent and depth of flooding at the WAST site for a range of flood events.

	5% AEP	1% AEP	1% AEP+CC	0.1% AEP	0.1% AEP+CC
Area of Flooding (hectares)	0.07	0.17	0.23	0.39	0.43
Mean Flood Depth ¹³ (m)	0.10	0.17	0.38	0.60	0.60
Maximum Flood Depth (m)	0.41	0.67	1.06	1.55	1.60

¹² Note that the tabulated depths and volumes are based on the site polygons shown in Figure 2.3.

¹³ This is the mean flood depth across the flooded area (shown in Figure 2.3) and not the mean depth across the whole of the WAST site.

Figure 2.3: Baseline Flood Depths



Floodwater which overtops the left bank near the downstream end of the WAST site is modelled to follow a simple curved (north-easterly, easterly, then south-easterly) path before rejoining the River Gwenfro just upstream of the old railway culvert (Figure 2.4). Flood velocities are predicted to peak at between 0.6m/s to 0.8m/s across this part of the WAST site during initial wetting, although they are generally lower at the peak of the event when the railway culvert tends to limit the magnitude of forward flow along the Gwenfro.

Flood hazard (evaluated using a conservative debris factor) is modelled to peak at around 1.3 during a 1% AEP event increasing to 1.8 in the eastern part of the site during a 0.1% AEP event. This can be broadly categorised as danger for most (including the general public).

Figure 2.4: Modelled flood velocities (magnitude and direction) at the peak of a 0.1% AEP event.

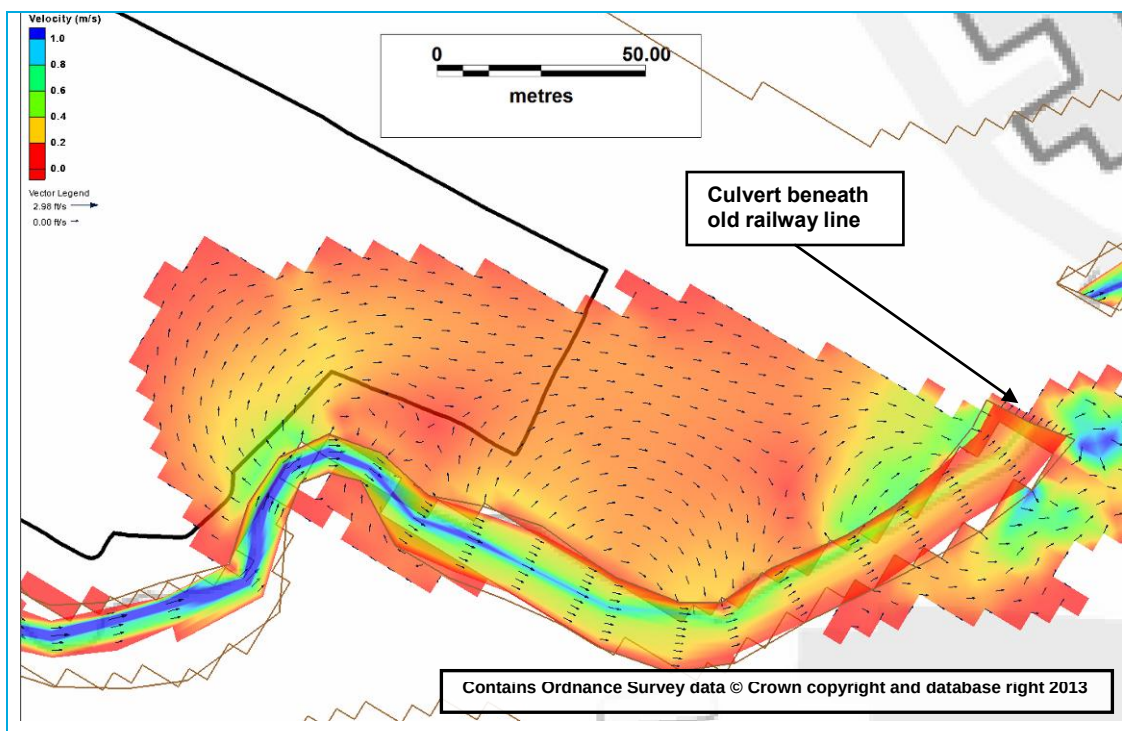
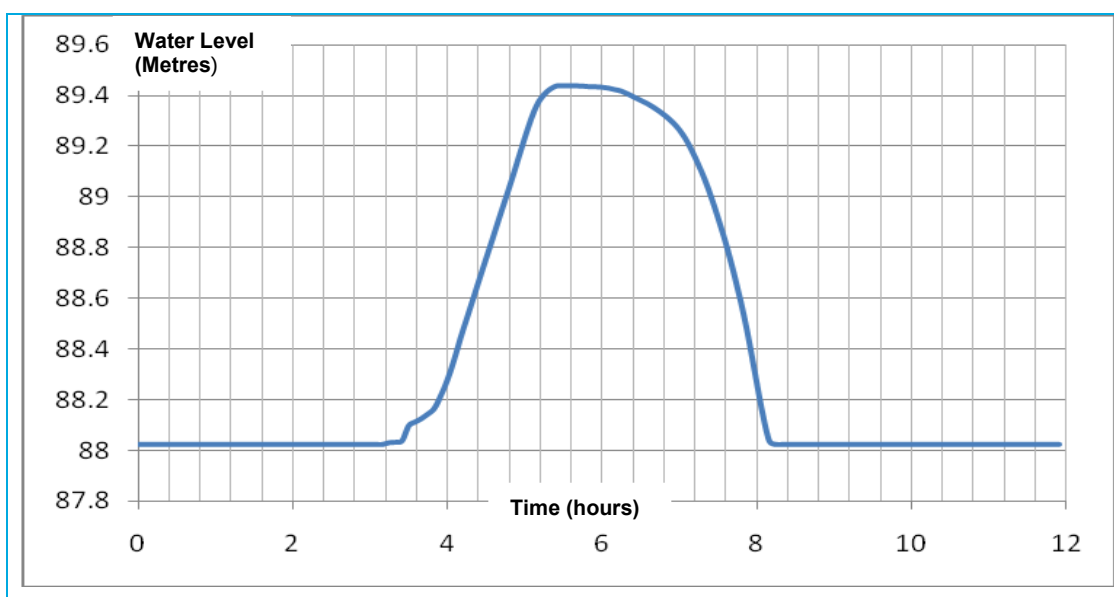


Figure 2.5 shows the modelled water level time series during a 0.1% AEP event for a point in the east of the WAST site. This demonstrates that once local overtopping of the left bank of the River Gwenfro occurs, inundation would likely be quite rapid (at a constant rate of approximately 0.3mm/s i.e. close to 1m/hr) but of short duration (4.5 hours based on the modelled storm duration). Flood water would not be stored for a long period on the local floodplain following an event since drainage of floodwater back into the River Gwenfro would be relatively unhindered by the floodplain topography.

Figure 2.5: Modelled rate of water level rise and duration of flooding during a 0.1% AEP event in the east of the WAST site.



3 Managing the Fluvial Flood Risk

The hydraulic modelling of the baseline (post Western Gateway) risk, reveals that 79% of the area of the proposed WAST platform would be above flood levels during a 0.1% AEP with {20%} climate change flood event. The majority of the WAST site would therefore appear to be at a low flood risk and outside of Zone C. However, Figure 2.2 and Figure 2.3 show that the eastern part of the WAST site would flood (under baseline conditions) down to a threshold of approximately 5% AEP. The flooded area would amount to approximately 21% of the area proposed for development¹⁴ in a 0.1% AEP event with climate change. Therefore, approximately one fifth of the site could be defined as (future) Zone C.

A key part of developing in line with TAN 15 is that any development, which is potentially at risk from flooding under existing conditions, should be designed to be safe whilst having no adverse off-site impacts on flood risk. In the case of the WAST development, the safety aspect is particularly important since the critical 'emergency response' facilities would need to remain operational during times of flooding. Off-site impacts would also need to be minimal due to the fact that parts of the hospital grounds downstream of the site are already at flood risk. A solution for developing the WAST site is presented in this FCA within, which the majority of the site, including all of the critical emergency response facilities, will be developed above predicted flood levels, the only exception being an overflow staff car park which will be developed at a lower level in order to prevent any off-site impact from the development.

3.1 Developing the WAST site to be safe from flooding

The WAST development includes a joint ambulance and fire services depot that would need to be operational and accessible at all times (including times of flooding). The most critical parts of the development would equate to 'Emergency Service' development according to TAN 15. TAN 15 seeks to direct new development away from Zone C (the extreme flood outline) and states that 'Emergency Service' development should not be permitted in Zone C2. The WAST development has been therefore been designed so that the most critical parts of the emergency response facilities (the emergency services apron and main building) will be developed at a sufficient elevation to keep them above the future predicted 0.1% AEP flood levels (i.e. outside of the future Zone C2)¹⁵. The ambulance and staff car parking areas, the vehicle refuelling, vehicle wash-down and fire training facilities, which are not necessarily critical for maintaining an emergency response, will also be maintained above the future 0.1% AEP flood levels. This leaves the overflow staff car parking area in the east of the site, which should be considered as 'less vulnerable' from the viewpoint of TAN15, as the only part of the development that will remain at risk of flooding from the River Gwenfro.

To ensure that the WAST site is safe from flooding, it is proposed to ensure that ground levels across the development are placed at suitable levels as follows.

- Since NRW indicated in preliminary discussions that any critical 'Emergency Response' facilities should be placed above the 0.1% AEP with climate change flood levels, it is proposed that ground levels across the majority of the site should be set at a minimum of the modelled 0.1% AEP with climate change flood levels plus a 300mm freeboard allowance. A freeboard of 300mm is considered justified on the basis of model sensitivity testing, which is presented in Appendix C.
- In order to avoid adverse off-site impacts, especially to the hospital grounds downstream, it is proposed to develop the 'less vulnerable' overflow staff car park at a similar elevation to existing ground levels with a small volume of additional excavation alongside the disused railway line. These facilities would therefore remain at flood risk (as outlined in Section 3.3) and a flood management plan would be needed to enable the safe operation of this car park over the lifetime of the development.

The proposed development levels are shown in Figure 3.1 and two cross-sections through the development are shown in Figure 3.2. A 15 metre wide green corridor that includes for NRW access to the watercourse is to be retained between the WAST site and the River Gwenfro.

¹⁴ Based on the site outline included in Figure 1.1.

¹⁵ This will hold true once the Western Gateway development is completed, which is a key pre-condition of this FRA.
2012s5958 - FCA for WAST Development at Wrexham Maelor Hospital - Final Report - Oct 2013.doc

Figure 3.1: Proposed post-development ground levels (m AOD) for the WAST platform.

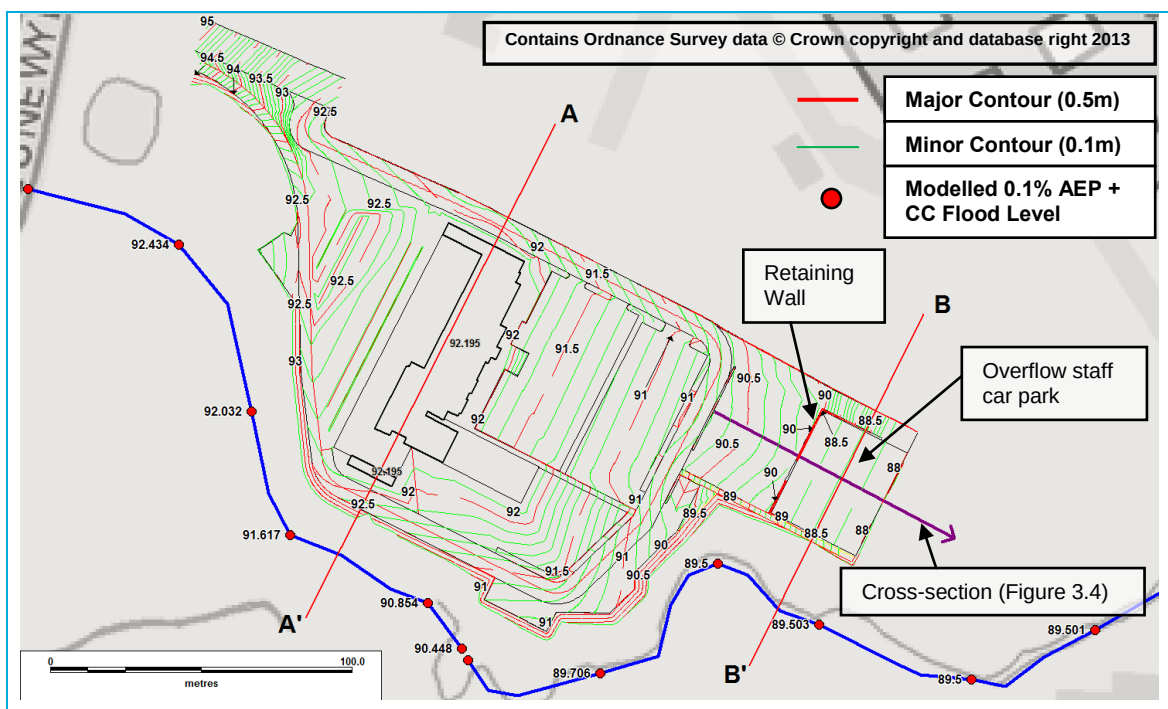
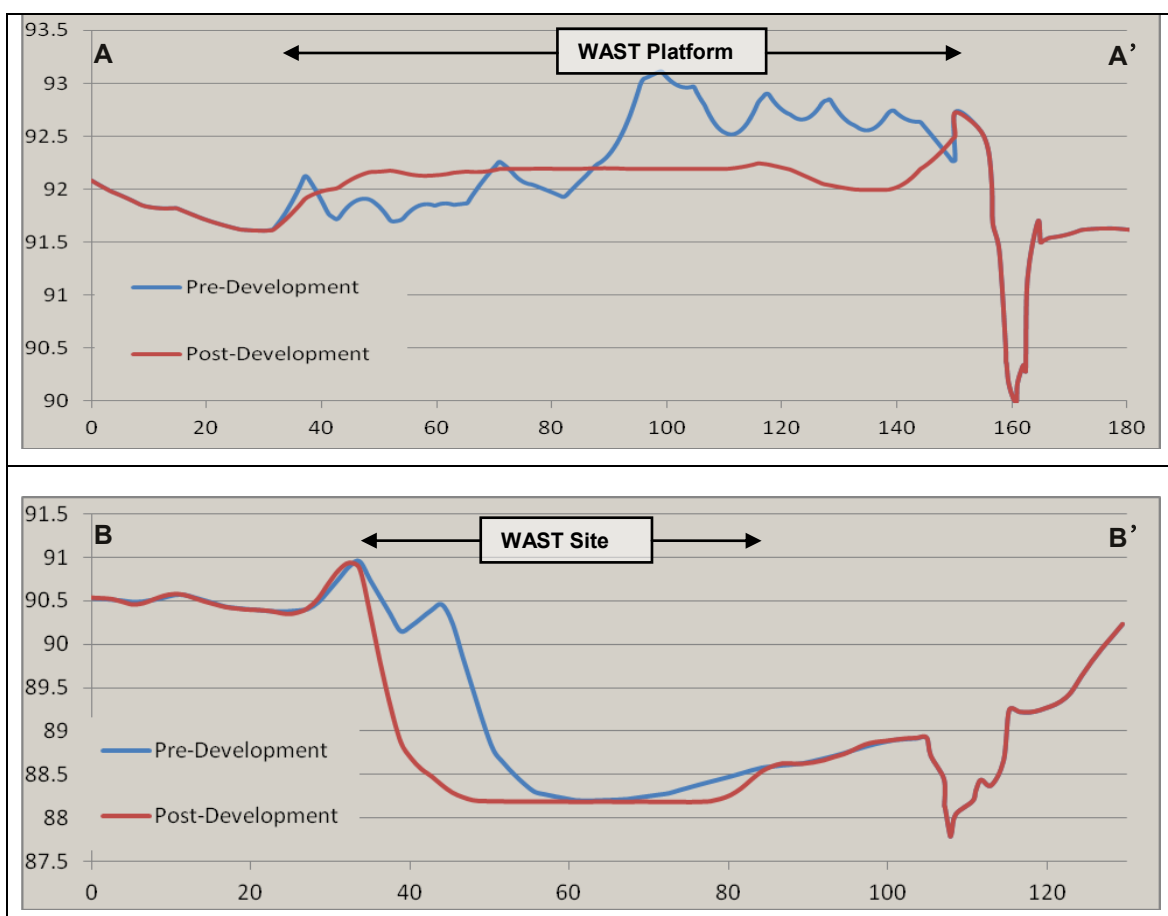


Figure 3.2: Indicative cross-sections through the proposed WAST development (see Figure 3-1 for location).



3.2 Modelled post-development flood risk

The modelled post-development flood outlines for the WAST development are shown in Figure 3.3. These show that the majority of the site would remain dry and a dry access route to the hospital grounds would be retained across the range of modelled flood events up to and including the future 0.1% AEP event. Thus, the majority of the site would be suitably safe to meet the requirements of TAN15. The only area that is modelled to be at flood risk is the staff overflow car park at the eastern end of the site and several flood risk issues need to be considered in relation to the development of this car park:

- The staff overflow car park is modelled to flood at a threshold as low as 5% AEP so would effectively be located in the functional floodplain.
- The modelled post-development flood levels across the staff overflow car park are illustrated in Figure 3.3 by reference to a WNW-ESE cross-section (location shown in Figure 3.2) and the peak modelled flood depths across the parking area are listed in Table 3-1. These illustrate that the car park would be flooded to depths that could be potentially damaging to people and vehicles during major flood events on the River Gwenfro.
- Since the overflow car park would need to flood to prevent the WAST site from having an adverse impact on the hospital grounds downstream, the car parking area would need to be allowed to flood unimpeded. Therefore, planting or fencing of a type that might collect debris should not be permitted within this part of the site.
- Since the staff overflow car park would be at risk of flooding, a Flood Management Plan (Section 3.5.4) would be needed to define procedures to be followed in the operation of the car park particularly in the event of heavy rainfall and/or a flood alert.
- Any evacuation of the overflow staff car park would be best undertaken on a precautionary basis since there might be little lead time between the onset of overtopping and potentially damaging flooding of the car park. Based on the results of the 0.1% AEP model, flood water would likely reach the car park within about 15 minutes of overtopping commencing along this reach of the Gwenfro. Flood depths could then increase in proportion to the rise in flood level shown in Figure 2.5 *i.e.* floodwater could exceed 0.5m depth within half an hour of overtopping commencing. Given these rates of water level rise, it would be wise to place an egress route (e.g. steps) up the 1.5 metre high retaining wall to enable safe escape from the car park in the event of rising flood water.

Figure 3.3: Modelled post development flood outlines alongside the development.

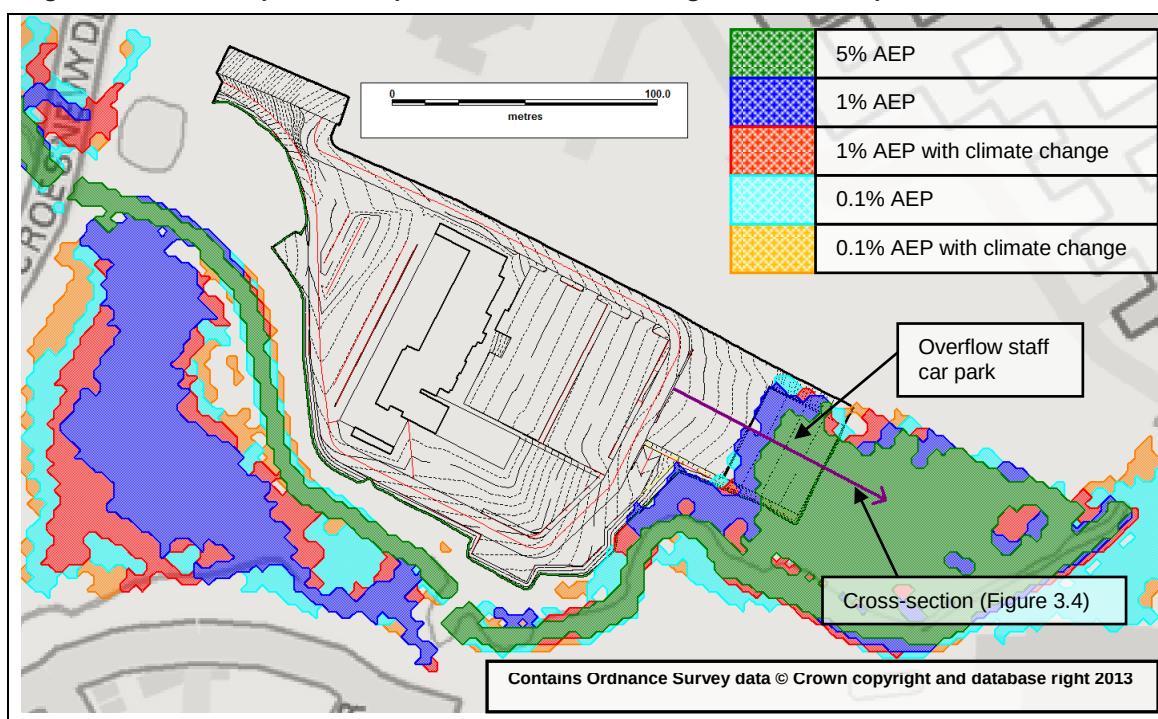


Figure 3.4: Modelled flood and proposed ground levels (m AOD) in the eastern part of the site (cross-section location shown in Figure 3.3.)

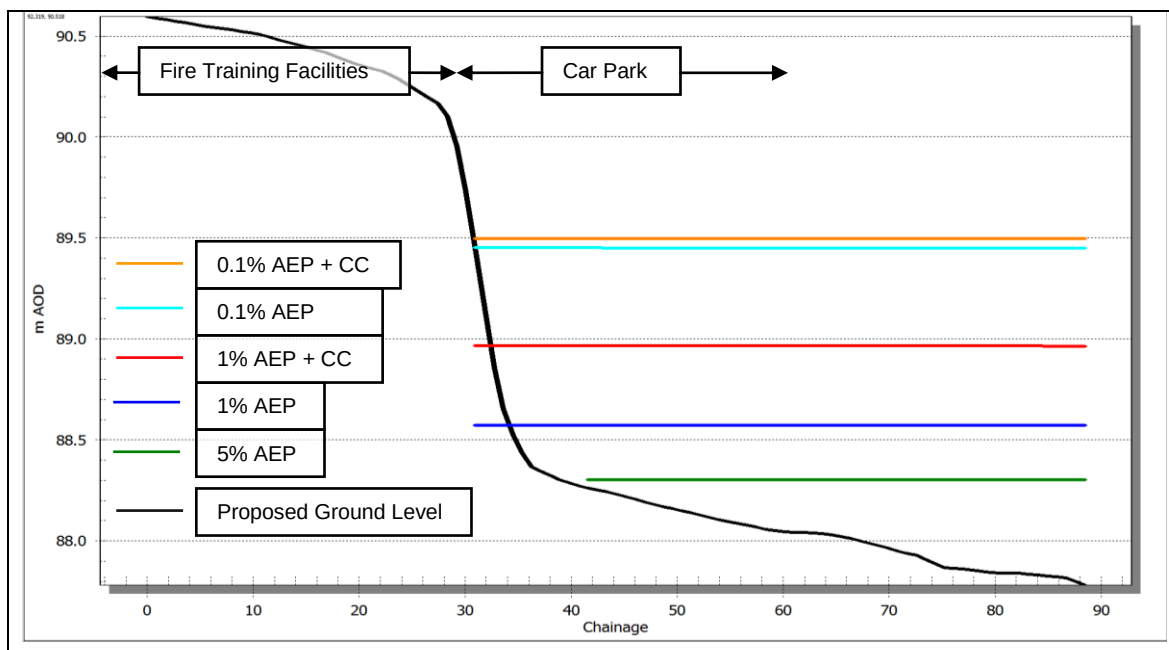


Table 3-1 : Predicted peak flood depths across the staff overflow car park.

	5% AEP	1% AEP	1% AEP + CC	0.1% AEP	0.1% AEP + CC
Flood Depth (m AOD)	0.26	0.53	0.92	1.41	1.46

3.3 Off-site impacts

In order to meet the conditions of TAN15, the modelled off-site impacts should be negligible. This section summarises the modelled impact of developing the proposed WAST site. This illustrates that the WAST development is predicted to have no significant adverse impact on the off-site flood risk and would also produce a small reduction in risk to the hospital grounds during the key 1% AEP event.

3.3.1 Peak River Levels in the River Gwenfro

Figure 3.5 shows the peak river level profiles in the vicinity of the WAST site (i.e. between the two Croesnewydd Road bridges upstream and downstream of the site). The peak river levels downstream of the site are also summarised in Table 3-2.

In combination the modelled, pre- and-post development, peak river levels imply that:

- The proposed WAST development would produce a small local increase in the peak (in-channel) river level alongside the WAST site. This would reach a maximum of 0.01m during a 1% AEP event and 0.04m during a 0.1% AEP event.
- The proposed development would have no significant impact on peak river levels upstream of the development site.
- The proposed development would have no significant impact on the peak river levels downstream of the development site including the hospital grounds.

Figure 3.5: Modelled pre and post development peak (in-channel) river levels in the River Gwenfro.

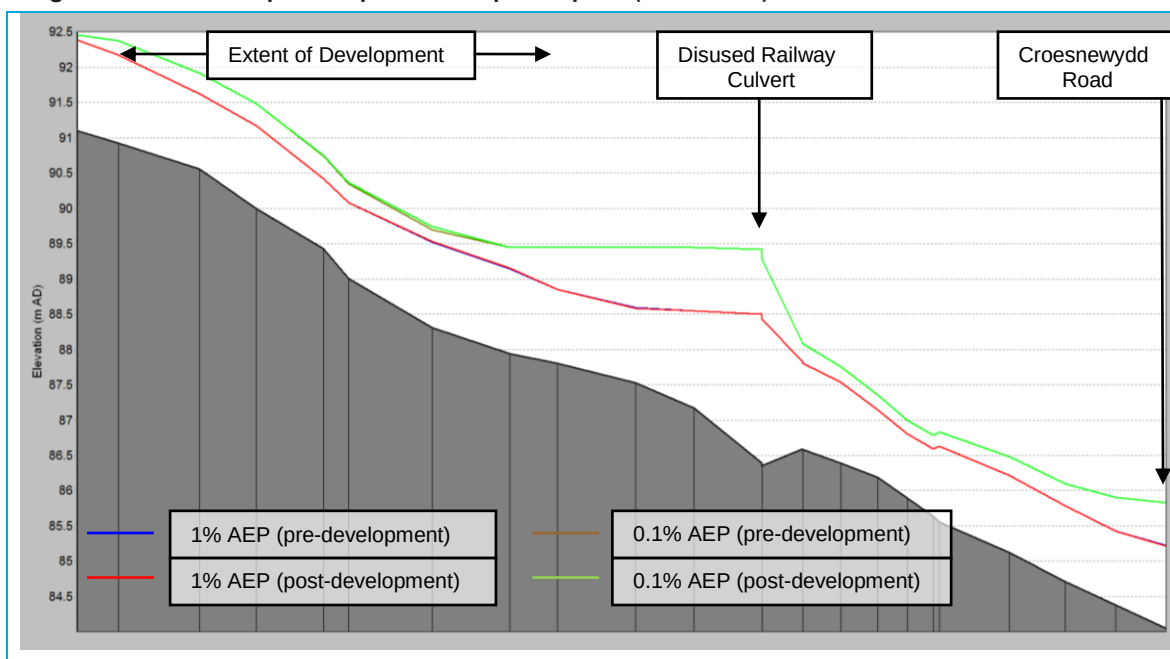


Table 3-2: Modelled peak (in-channel) flood levels (m AOD) on the River Gwenfro downstream of the site at Croesnewydd Road Bridge¹⁶.

	5% AEP	1% AEP	1% AEP + CC	0.1% AEP	0.1% AEP + CC
Pre-Development	85.00	85.22	85.40	85.83	86.11
Post-Development	85.00	85.22	85.40	85.83	86.11
Net Change (metres)	0.00	0.00	0.00	0.00	0.00

3.3.2 Floodplain extents and depths

In addition to the peak river levels, the hydraulic model directly outputs the extent and depth of flooding across the floodplain and this information can provide a direct assessment of the impacts of development on the adjacent floodplains. The pre- and post-development flood outlines from key flood events are shown in Figure 3.6. These show that there is no significant change to any of the design flood extents downstream of the site due to the proposed WAST development.

Figure 3.7, Figure 3.8 and Figure 3.9 show the change in the depth of flooding on the floodplains that is modelled due to the proposed WAST development during the 1%, 1% with climate change and 0.1% AEP events, respectively. Adverse impacts have been represented by warm colours (orange and red colours) whereas a reduction in risk has been represented by cold colours (light and dark blue); yellows and greens represent neutral impacts of $\leq \pm 0.005\text{m}$. These depth difference plots reveal that most of the floodwater displaced by the raising of the main WAST platform is accommodated within the car park area on-site. In summary:

- There is no significant (i.e. $>0.005\text{m}$) increase in off-site, floodplain flood depth during a 1% AEP event (Figure 3.7). In fact downstream of the site there is a small (0.01m) reduction in the flood depth in the Bron-y-Nant area, where modelling for this FCA has shown adjacent properties to be very sensitive to changes in the 1% AEP river level.
- There are no significant (i.e. $>0.005\text{m}$) increases in off-site, floodplain flood depths during a 1% AEP event with climate change (Figure 3.8).
- There are no significant (i.e. $>0.005\text{m}$) increases in off-site, floodplain flood depths during a 0.1% AEP event (Figure 3.9).

¹⁶ These flood levels are reported from model node GwenWr_4077 and have been rounded to the nearest centimetre with the implication that impacts of less than 5mm may be considered minimal.

Figure 3.6: Modelled changes in Flood Extent due to the proposed WAST development.

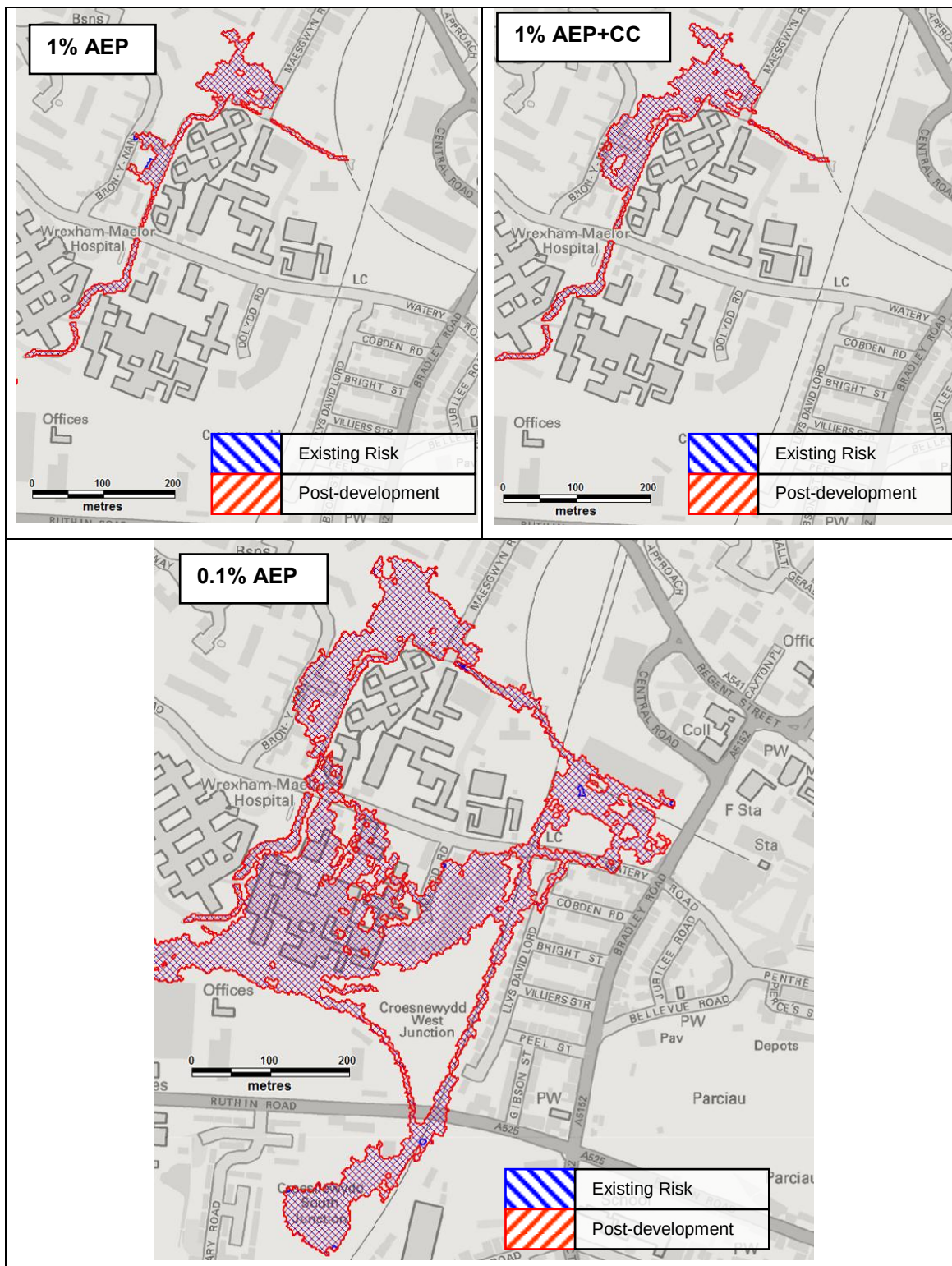


Figure 3.7: Modelled changes in 1% AEP flood depth due to the proposed WAST development.

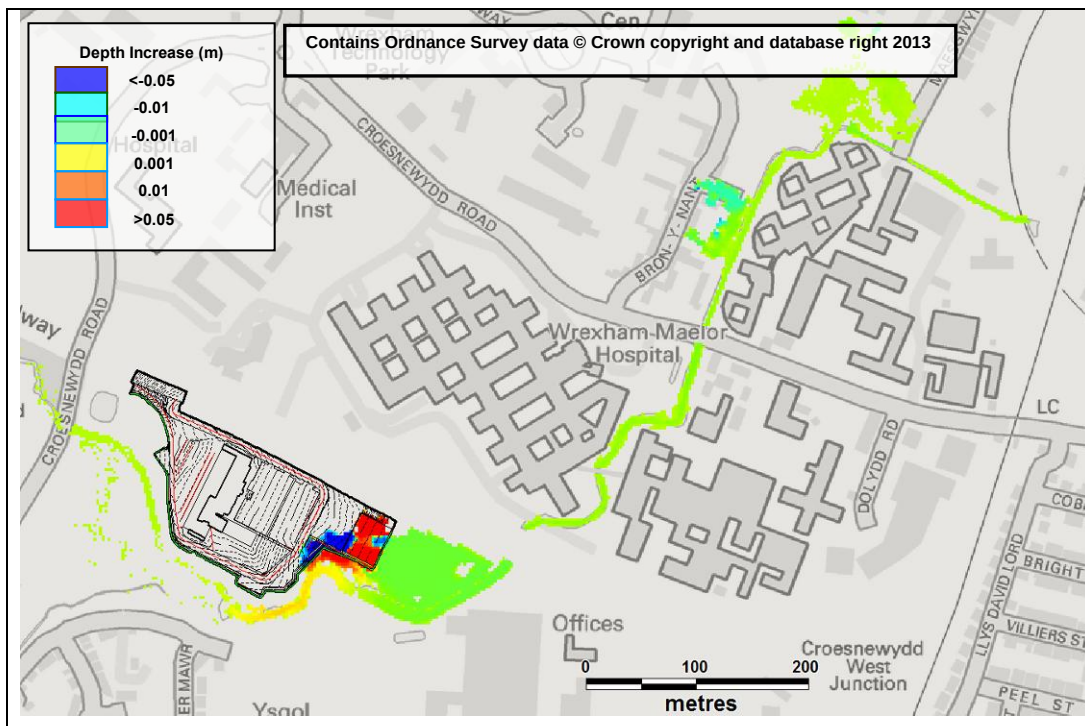


Figure 3.8: Modelled changes in 1% AEP + climate change flood depth due to the proposed WAST development.

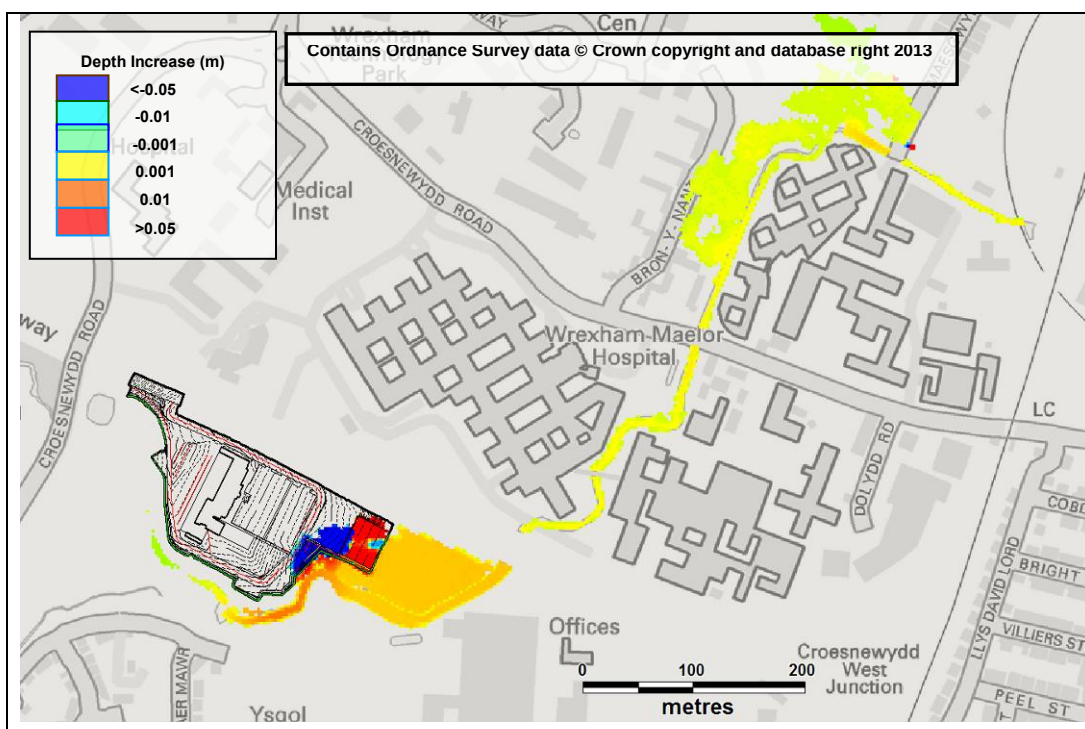
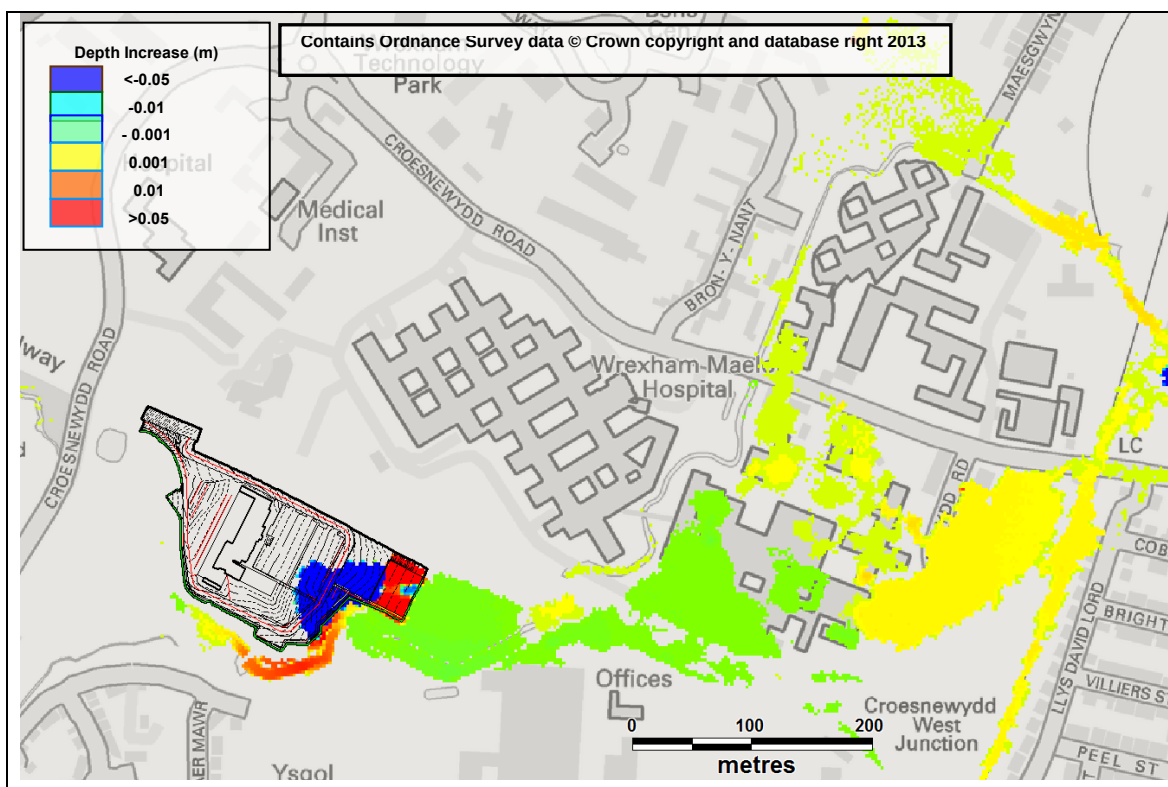


Figure 3.9: Modelled changes in 0.1% AEP flood depth due to the proposed WAST development.



3.4 Calculated flood storage volumes

In order to achieve minimal off-site impacts, it is usually necessary to show that there is a minimal net reduction in the on-site flood storage capacity following development. Table 3-3 summarises the calculated, peak, pre- and post-development, flood storage, volumes for the WAST development¹⁷. This demonstrates that there would be no loss of floodplain storage for events of up to and including 1% AEP with climate change and, although, there would be a small reduction in storage during the more extreme events (0.1% AEP), these are modelled to be insufficient to bring about any adverse off-site impacts. Therefore it is considered unlikely that the current scenario would need to be accompanied by any additional flood storage.

Table 3-3: Modelled peak, pre- and post-development, flood storage volumes (m³) for the WAST site.

Scenario	5% AEP	1% AEP	1% AEP + CC	0.1% AEP	0.1% AEP + CC
Pre-Development	82	331	982	2,516	2,759
Post-Development	132	437	980	1,754	1,832
Net Change	+50	+106	-2	-762	-927

Although, Table 3-3 implies that less storage may be available during extreme (0.1% AEP) events after development, the hydraulic modelling implies that this small, on-site, storage deficiency does not lead to any significant adverse impact in flood risk. There is no reason to doubt the findings of the hydraulic modelling since there are a number of reasons why no significant impact should be predicted during an extreme event.

- The change in storage volume is very small (almost insignificant) compared to the volume of the 0.1% AEP event and any displaced storage volume would be spread across a very wide area during this event once the disused railway line is overtopped and the hospital grounds become extensively flooded.

¹⁷ Calculated across the site polygon shown in Figure 3.1.

- The new site design may be more efficient in storing floodwater than under baseline conditions since there will be a topographic step along the part of access ramp to the overflow car park which could partially obstruct the direct flow of floodwater across this part of the site during an event.

3.5 Other Factors

3.5.1 Emergency Access/Egress

It is being proposed to elevate all of the facilities on the WAST site with the sole exception of the overflow staff car park in the east above the predicted 0.1% AEP with climate change flood level in the adjacent River Gwenfro. The results of the hydraulic modelling show that access to and from the site to the following locations would not be hindered by flooding from the River Gwenfro during this extreme event:

- Wrexham Maelor Hospital.
- The A483 (via the new spine road once this has been constructed as part of the Western Gateway development).
- Croesnewydd Road both south to Ruthin Road and north to Berse Road.

Eastward progress from Croesnewydd Road onto Watery Road could, however, be hindered by floodwater during extreme (0.1% AEP) events, which the modelling results predict may locally exceed 0.5m depth.

Access/egress to the overflow staff car park would need to be considered as part of the site Flood Management Plan (Section 3.5.4).

3.5.2 Blockage

The flood risk to the WAST site could be influenced by blockage of one or more of the culverts along the adjacent River Gwenfro. Since the capacity of the culvert located beneath the disused railway line at the downstream extent of the site is somewhat smaller than the culverts located immediately upstream of the site, the risk of blockage to this downstream culvert is likely to be higher than to the upstream culverts. In addition, since blockage of this culvert was considered likely to have the greatest impact on flood levels at the WAST site, the post-development model was also run with a 33% blockage applied to the old railway culvert. This blockage scenario was run under two events (a 1% AEP event and a 0.1% AEP with climate change event) with the following outcomes:

- The 1% AEP blockage run predicted a flood level 89.05m AOD across the flooded part of the site (i.e. the overflow staff car park). This represents an increase of around 0.48 metres, which implies that the risk to the overflow staff car park could be significantly increased if the downstream culvert was to be blocked.
- The future 0.1% AEP blockage run, by contrast, did not predict a significant increase in the peak flood level at the WAST site. This is because floodwater is anyway modelled to overtop the old railway line during this magnitude of event so blockage merely reduces the time at which overtopping commences rather than leading to an increase in peak upstream flood levels.

In view of the potential consequences of blockage to the downstream culvert, the WAST site should be managed to reduce the risk of site debris entering the floodplain. This is particularly pertinent to the overflow car park which would need to be designed (operated) to prevent cars from floating and blocking the downstream culvert in the event of a flood. This would likely require suitable single strand wire fencing that would not collect finer debris and hence prevent the car park from functioning as a flood storage area.

3.5.3 Residual Risk

Since the majority of the WAST site is being designed to be safe from a future 0.1% AEP event, the residual risk to the site from extreme events is only relevant to the design and operation of the low-level overflow staff car park in the east of the site. During an extreme (0.1% AEP) event, flood depths across the overflow staff car park are modelled to be in the order of 1.0 to 1.4 metres (Figure 3.4). These depths are potentially damaging and would likely cause parked vehicles to float downstream during extreme events. Therefore, a suitable flood management

plan (Section 3.5.4) would be needed to safeguard this part of the site against future flood events.

There are no raised defences in the vicinity of the site so there is no flood risk from defence failure. Infrastructure failure of Croesnewydd Road embankment would likely be a negligible risk since the road is new and there will also be a culvert of similar capacity in place beneath the new spine road further upstream (currently the old railway embankment).

3.5.4 Site management

Since the overflow staff car park would remain at flood risk, a suitable flood management plan, including acceptance of liability issues, would need to be drawn up to ensure that the flood risk to this part of the site is successfully managed throughout the lifetime of the development. This would need to address such issues as:

- The development of a suitable flood warning procedure to follow in the event of adverse weather forecast and/or flood alerts. This would require a suitable evacuation plan to ensure that any staff and vehicles could be safely evacuated from the overflow staff car park.
- Consider whether a suitable monitoring system (e.g. gated access) to the car park should be installed to regulate access and enable the site management company to determine ownership of any vehicles parked in this area.
- Maintaining adequate drainage of the overflow staff car park.
- Define maintenance procedures to be carried out to ensure that the flood risk continues to be manageable in the future (e.g. ensure that the railway culvert is maintained free from blockage).

3.6 Summary of proposed WAST development

The majority of the WAST site can be developed at a safe elevation above flood levels. However, in order to minimise off-site impacts, it is proposed to include an overflow staff car park at a lower level. Since this overflow car park will flood with a frequency as low as 5% AEP, it will effectively be on functional floodplain so will have to be suitably designed and maintained for the lifetime of the development. The development of the overflow car park would need to consider a number of design and operational issues.

The car park should be designed:

- To not impede flooding (e.g. via the planting of trees or fences that could collect debris) in order that the full WAST development has no off-site impact.
- To allow surface and/or floodwater to drain at a suitable rate.
- To include steps up the retaining wall at the end of the car park to enable rapid egress.
- With suitable (single strand wire) fencing to prevent cars from floating off-site in the event that full evacuation of vehicles was not possible during a flood.

The daily operation of the car park would require the developer to accept liability for the risk to the car park and produce a suitable flood management plan for the operation of the car park. This would likely require a number of the following issues to be addressed:

- The development a suitable flood warning procedure to follow in the event of adverse weather forecast and/or flood alerts. The site might also benefit from having a local level gauge installed in the River Gwenfro.
- Consider whether a permit system with gated access should be installed, which would allow the developer to monitor the ownership of any vehicles in the car park in the event that an evacuation may be required.
- Define maintenance procedures to be followed to ensure that the flood risk continues to be manageable both now and in the future (e.g. avoiding blockage of the downstream culvert).

4 Managing the Surface Water Flood Risk

4.1 Risk of Flooding From Surface Water

A preliminary screening of the surface water risk to the site (supplied by JBA Risk Management) reveals that risk of surface water flooding would largely be limited to the eastern part of the site (Figure 4.1). Indicative surface water flood depths based on the surface water maps are also included as Table 4-1. As with the fluvial risk, once the Western Gateway development is in place the existing flow route along the old railway line which is evident in the 1 in 1000 year surface water outline will not be a viable flow route. The baseline surface water risk would therefore be restricted to the ponding of floodwater in the eastern part of the WAST site. The post-development surface water risk to this area would be reduced by the ground raising of this area provided suitable drainage measures were built into the site design.

Figure 4.1: Map showing surface water flooding at the WAST site.

See the Figures Section at the back of the report.

Table 4-1 : Indicative flood depths for surface water flooding at the WAST site.

Design Event	Surface Water Depths (m)		
	Estimated Minimum Depth	Estimated Maximum Depth	Estimated Mean Depth
Q75	0.0	0.7	0.0
Q200	0.0	1.0	0.1
Q1000	0.0	1.1	0.1

4.2 Managing the Site Discharge

An additional surface water consideration for the site is that the run-off from the site should not increase relative to existing conditions. Since the site is currently undeveloped, it is proposed to restrict the surface water run-off to the following calculated Greenfield run-off rates:

- Q1 = 4.8 l/s/ha
- Q30 = 9.6 l/s/ha
- Q100 = 11.9 l/s/ha

The calculation record for these calculations is included as Appendix C.

It is proposed to supply details of how these run-offs will be achieved (including elements of SUDS design and storm water storage volumes) at the detailed design stage. However, it is envisaged that a surface water drainage network to the River Gwenfro will not be adopted and that storage will be provided for up to and including a Q100 + 20%CC event in the form of below ground attenuation tanks (cellular storage) as opposed to oversized pipes.

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Introduction

This document is a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

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3	STATISTICAL METHOD ----- 7
4	REVITALISED FLOOD HYDROGRAPH (REFH) METHOD ----- 10
5	DISCUSSION AND SUMMARY OF RESULTS ----- 11
6	ANNEX - SUPPORTING INFORMATION ----- 13

Approval

	Name	Qualifications
Calculations prepared by:	Kevin Frodsham	BSc MSc PhD
Calculations checked by:	Chris Smith	BSc PhD CEnv CWEM MCIWEM MCMI
Calculations approved by:	Chris Smith	BSc PhD CEnv CWEM MCIWEM MCMI

ABBREVIATIONS

AM	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
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
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: - Purpose of study - Approx. no. of flood estimates required - Peak flows or hydrographs? - Range of return periods and locations - Approx. time available	The purpose of this study is to estimate suitable design flows for an FCA for a development site adjacent to Wrexham Maelor Hospital. The flows in the current River Gwenfro model have been retained from a Flood Mapping Study that was carried out in 2008, in which the flows were calculated using Hi-Flows UK Version 1.1, August 2005. It was considered prudent to check these flows before proceeding with the FCA. Hydrographs already exist in the model. It is envisaged that the existing hydrographs will be scaled to the Statistical estimated peak. 4%, 1% and 0.1% AEP flows will be needed for the FCA. QMED is required for surface water calculations. One day has been set aside for these calculations.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	TBC – in FCA.

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Yes – v3.1.2. (July 2011).
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1.4 Gauging stations (flow or level)

(at the sites of flood estimates or nearby at potential donor sites)

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catchment area (km ²)	Type (rated / ultrasonic / level...)	Start and end of flow record
Clywedog	Clywedog @ Bowling Bank	067025	67025	SJ 396483	98.6	Rating	1975-2011
Alyn	Alyn @ Pont Y Capel	067008	67008	SJ335540	227.1	Rating	1965-2011
Alyn	Alyn @ Rhyd ymwyn	067009	67009	SJ206667	77.8	Rating	1957-2011

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK*	Update for this study?	Suitable for QMED?	Suitable for pooling?	Other comments on station and flow data quality – e.g. information from HiFlows-UK, trends in flood peaks, outliers.
Clywedog at Bowling Bank	WY1975 – WY2009	No	Yes	No	Some works carried out in 2002/3 to attempt to contain the peak flows. The June 2007 event was almost contained, with barely a trickle bypassing the station. Before 2002/3 works, thought to bypass from approx the ten-year event. Sand and gravel deposits (in central part of catchment) overlying Carboniferous strata. Land use is >10% urban or industrial, with a significant amount of mining in the catchment. Run-off influenced by groundwater abstraction/recharge. Mine drainage and abstraction in upper catchment. 50% of low flow was treated effluent from Wrexham until 7/10/92 when this discharge was piped directly to the R. Dee.
Alyn @ Pont Y Capel	WY1965 – WY2009	No	Yes	Yes	Ill-defined catchment boundary to north-east and south-east. 25% Carboniferous Limestone. Major loss of water from upper 70 sq km into limestone swallow holes and mine drainage tunnels. Extensive glacial deposits over Coal Measures. Small reservoirs in catchment may affect flows. Abstraction from catchment for industry/agriculture. Loss of flow to mine drainage tunnels. Some effluent returns.
Alyn @ Rhydyrmwyn	WY1957 – WY2009	No	Yes	Yes	Trapezoidal flume in concrete trapezoidal channel. Flow frequently zero due to river entering swallow holes in limestone u/s of site. Accurate at low flows. Data prior to 1968 suspect - loaded into the database but not included in the analysis. Geology in the west is made up of impermeable Silurian rocks covered with Boulder Clay and Drift, and to the east lies Carboniferous Limestone escarpment. Swallow holes frequent between Maeshafn and Rhydyrmwyn, substantial losses of river flow through percolation to mine drainage tunnels. Loss of flow to mine drainage tunnels.

* If a detailed hydrological study was undertaken, it may be useful to obtain the last few Water Years not included on the HiFlows UK website.

1.6 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	There are no known unusual catchment characteristics so the FEH Statistical approach would appear valid for the study catchment for events of up to 0.5% AEP. However, the ReFH Method will be more appropriate to estimate the peak 0.1% AEP flow (via the Q1000:Q100 ReFH ratio).
Outline the conceptual model, addressing questions such as: - Where are the main sites of interest? - What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides...) - Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? - Is there a need to consider temporary debris dams that could collapse?	The main site of interest is the WAST site adjacent to Wrexham Maelor hospital. Other sites that are being checked are the upstream extent of the hydraulic model and the downstream road culvert at Maesgwyn Road (to enable the downstream impact of development to be suitably dealt with). We are primarily interested in fluvial flooding from the River Gwenfro during high flow events. Surface water and groundwater flooding will be dealt with separately in the FCA.
Any unusual catchment features to take into account? e.g. - highly permeable – avoid ReFH if BFIHOST>0.65, use permeable catchment adjustment for statistical method if SPRHOST<20% - highly urbanised – avoid ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives - pumped watercourse – consider lowland catchment version of rainfall-runoff method - major reservoir influence (FARL<0.90) – consider flood routing - extensive floodplain storage – consider choice of method carefully	None known.
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	FEH Statistical because there are no known unusual properties for the Gwenfro catchment and there are potential donor sites on adjacent watercourses. ReFH to help determine the Q1000 inflows relative to the Q100 Statistical estimates as per current guidance.
Software to be used (with version numbers)	FEH CD-ROM v3.0 ¹ WINFAP-FEH v3.0.002 ² / ReFH spreadsheet / ReFH Design Flood Modelling Software

¹ FEH CD-ROM v3.0 © NERC (CEH). © Crown copyright. © AA. 2009. All rights reserved.

² WINFAP-FEH v3© Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

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

2.1 Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km ²)*	Revised AREA if altered
GW_6534	Gwenfro	Model u/s extent	331050	350850	9.06	
GW_4391	Gwenfro	Wrexham Maelor Hospital	332350	350250	10.05	
GW_3771	Gwenfro	Maesgwyn Road	332750	350600	13.85	
Reasons for choosing above locations		The FCA development at Wrexham Maelor hospital is the key site. However, upstream and downstream sites were also checked to enable the hydraulic model inflows to be consistent.				

* For the hydrology check, the area draining to each estimation point has been estimated from FEH only. If a more detailed hydrological study was undertaken, it is recommended that the catchment boundaries are checked against other tools such as Arc Hydro, a water resource tool (that uses LIDAR data to define catchment boundaries based upon topography), United Utilities surface water sewer records and/or British Waterways records etc.

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

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 2000	FPEXT
GW_6534	0.991	0.51	0.508	3.61	87.9	908	35.69	0.106	0.0310
GW_4391	0.992	0.51	0.542	5.08	82.8	898	34.41	0.099	0.0357
GW_3771	0.973	0.51	0.630	4.95	91.1	877	31.08	0.124	0.0432

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	FEH CD-ROM V3 has been used to derive catchment boundaries. These have been checked to ensure there are no obvious erroneous boundaries.
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	Kjeldsen (2009)

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Method	Initial estimate of QMED (m ³ /s)	Data transfer						Final estimate of QMED (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Weight	Distance between centroids d _{ij} (km)	Power term, a	Moderated QMED adjustment factor, (A/B) ^a	Final adjustment factor	
GW_6534	CD	3.0	67025	1	3.81	0.51	0.954	0.954	2.9
GW_4391	CD	2.9	67025	1	3.51	0.53	0.952	0.952	2.8
GW_3771	CD	2.5	67025	1	3.31	0.54	0.951	0.951	2.3
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?					QMEDs decrease downstream most probably in response to the variation in catchment descriptors BFIHOST and FPEXT. This prediction can be evaluated against the hydraulic model.				
Notes Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone. When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below. When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050 ^{Error! Bookmark not defined.} should be used. If the original FEH equation has been used, say so and give the reason why. The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This 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 estimate from catchment descriptors. If more than one donor has been used, give the weights used in the averaging.									

3.2 Search for donor sites for QMED

Comment on potential donor sites Mention: - Number of potential donor sites available - Distances from subject site - Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors - Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	Three potential donor gauges have been assessed for the ungauged sites on the Gwenfro. HI-Flows UK considers all three to be suitable sites to act as potential QMED donors. 67025 was used to calculate the final donor adjustment factor since it is the closest potential donor site (it lies on the River Clywedog downstream of Wrexham and the Gwenfro confluence) and appears the most hydrologically similar to the study sites. (NB although AREA is notably different, most of the other key catchment descriptors incl. FARL, BFIHOST, URBEXT ³ are similar to the subject catchment). In addition, since the other two potential donor sites produced an adjustment factor ~0.8 (possibly based on the more permeable nature of these two catchments), using 67025 as a donor site produced more conservative flow estimates for the study sites.
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It should be noted that the distance from subject site described above is based on the catchment centroid.

³ Although the URBEXT of 67025 is too high for this catchment to be recommended as a donor in most cases, it is in this case considered acceptable since it lies within the same catchment as the subject site and the adjustment factor is relatively minor.

3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B)*
67025	Accepted – see 3.2	AM		19.7	19.4	0.954
67008	Rejected - see 3.2	AM		21.9	35.7	0.809
67009	Rejected - see 3.2	AM		8.6	15.3	0.813

*NB: this is not just A/B but also includes an Urban Adjustment Factor (UAF) and the distance of the donor site from the subject site.

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Refer to the back of this report for the gauging stations included in each pooling group.

Target return period (years) for all pooling groups			100	
Name of group	Site code for which group derived	Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	Distribution and reason for choice	Parameters (before urban adjustment) Note any permeable catchment adjustments
GW_4391_p01	GW_4391*	A number of sites (26802, 44006, 44008, 44009 & 44809) were removed on the basis of SPRHOST <20. 32029 was removed on the basis of a short (5 year) record.	GL = best and acceptable fit	1.000; 0.215; -0.208

Note: Pooling groups were derived using the revised procedures from Science Report SC050050 (2008).
 * Note that pooling groups were initially generated for all three subject sites but due to the overall similarity of the pooling groups, only one group (based on the key FCA site location) was used to generate the growth factors for all three sites.

3.5 Flood growth curves at subject sites

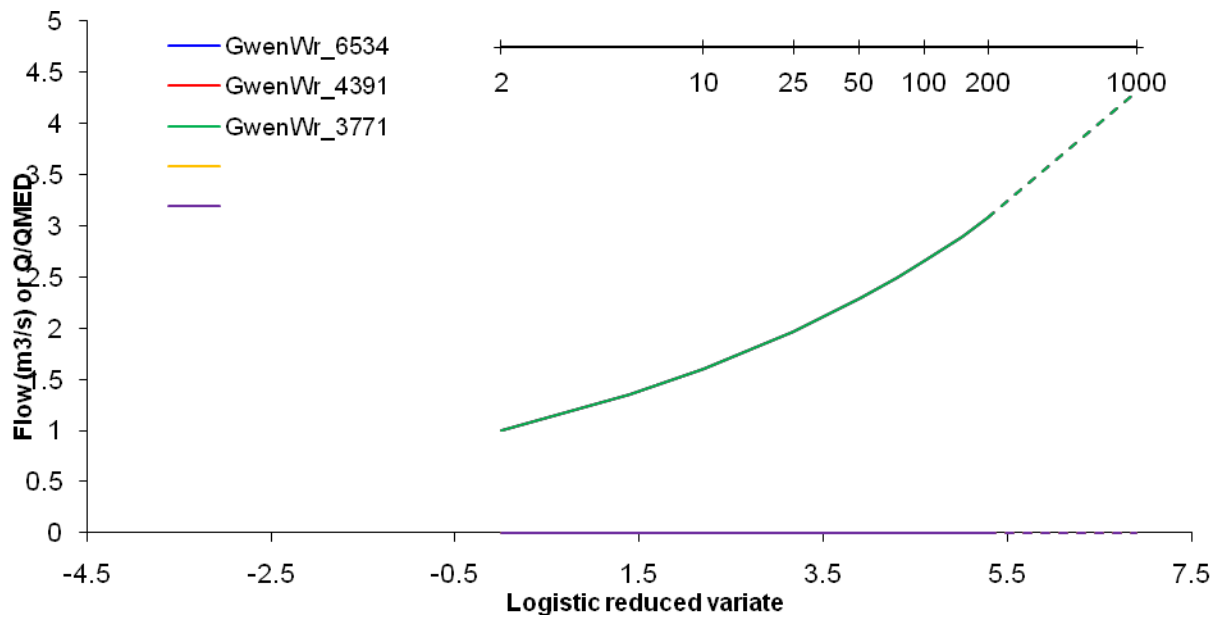
Site code	Method: SS – Single site P – Pooled J – Joint analysis	If P or J, name of pooling group (3.4)	If SS, distribution used and reason for choice If J, details of averaging	If SS, parameters of distribution (location, scale and shape)	Growth factor for 100-year return period
GW_6534	P	GW_4391_p01			2.65
GW_4391	P	GW_4391_p01			2.65
GW_3771	P	GW_4391_p01			2.65

Note: Growth curves were adjusted for urbanisation using the "v3" method published by Kjeldsen (2010).

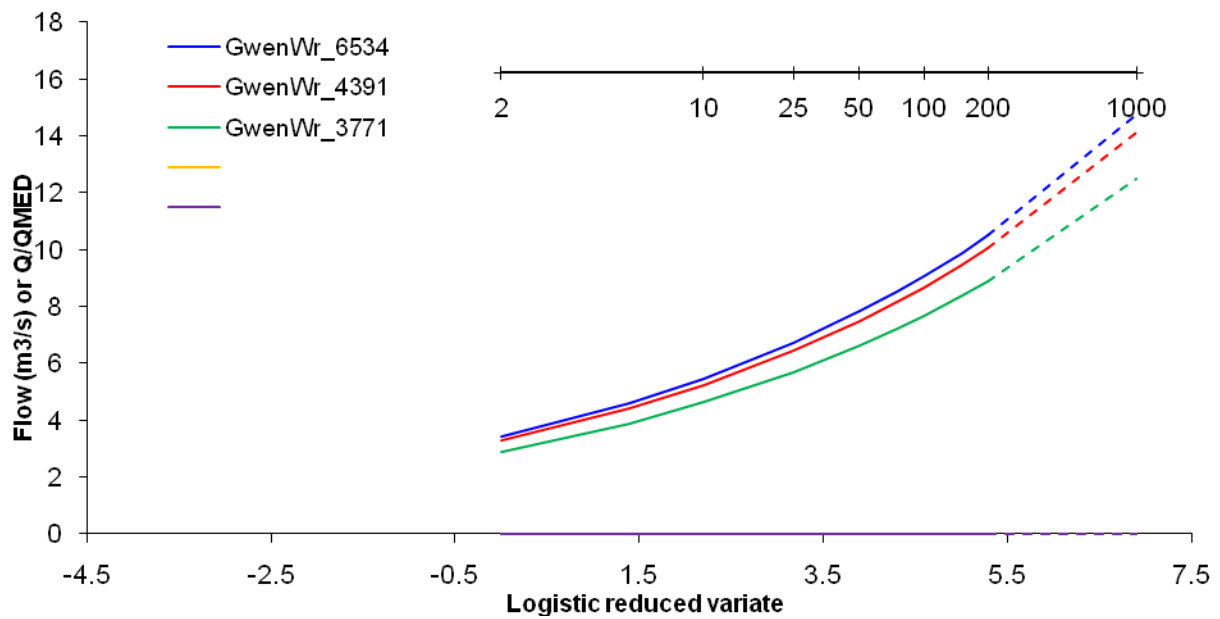
3.6 Flood estimates from the statistical method

Site code	Flood peak (m³/s) for the following return periods (in years)								
	2	5	10	20	50	75	100	200	1000
GW_6534	3.2	4.4	5.2	6.4	7.4	8.1	8.6	9.9	13.9
GW_4391	3.1	4.2	4.9	6.1	7.1	7.7	8.2	9.5	13.3
GW_3771	2.7	3.7	4.4	5.4	6.2	6.8	7.2	8.4	11.8

Growth Curves



Flood Frequency Curves



4 Revitalised flood hydrograph (ReFH) method

4.1 Design events for ReFH method

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
GW_4391	Urban	Winter (= default)	3.9	-
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			No. This is just a quick check on the Q1000:Q100 ReFH ratio to determine the Q1000 design flow.	

4.2 Flood estimates from the ReFH method

Site code	Flood peak (m ³ /s) for the following return periods (in years)		Q1000:Q100 ratio
	100	1000	
GW_4391	11.15	19.4	1.74

5 Discussion and summary of results

5.1 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	The Statistical flows will be used in the FCA with the exception of the extreme (0.1% AEP) event, for which the hybrid method (i.e. scaling the 1% AEP flow by the Q1000:Q100 ReFH ratio) will be used to generate suitable peak flows. Since the estimated flows diminish downstream, it is possible that lateral inflow units may not be needed along the key study reach.
--	---

5.2 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	FEH Statistical methodology is appropriate for flood estimation on the ungauged River Gwenfro. The gauge at Bowling Bank on the River Clywedog is a suitable donor site for QMED estimation. The assembled pooling group generates an appropriate growth factor for the subject sites.
Discuss any particular limitations , e.g. applying methods outside the range of catchment types or return periods for which they were developed	None known once it is assumed that the Statistical approach is suitable for the subject catchment.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH 3 12.5 or the factorial standard error from Science Report SC050050 (2008).	QMEDs are from catchment descriptors with donor adjustment from a larger downstream catchment. Confidence in QMED at these sites is therefore not high.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	These calculations should provide suitably up-to-date flow estimates for any up and coming studies on the River Gwenfro in Wrexham.
Give any other comments on the study, for example suggestions for additional work.	

5.3 Checks

Are the results consistent, for example at confluences?	There are no tributaries in the study reach. The calculations do predict a downstream reduction in peak flows along the study reach, which may need to be validated by the hydraulic model.
What do the results imply regarding the return periods of floods during the period of record?	TBC
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	2.65 seems realistic for this catchment.

If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	Only estimated for one subject site at 1.74. This appears realistic.
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	100 year specific run offs decrease downstream from 9.47 to 5.22 l/s/ha (being 8.15 at the FCA site).
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	The flow estimates in Table 5.4 represent a small increase on those calculated during the Gwenfro 2009 SFRM study. However, the flows in the current Gwenfro model were calculated by Halcrow prior to the FRM study and retained on the basis that they had previously been used for a design scheme alongside the Gwenfro. The flows presented in Table 5.4 therefore represent a reduction in the flows that are currently being modelled along the study reach by the existing River Gwenfro hydraulic model. The 1% and 0.1% AEP flows at the upstream extent of the existing model are 9.9m³/s and 17.3m³/s, respectively; although attenuation does seem to have reduced the 0.1% AEP flow to 11.6m³/s near the FCA site. The flow estimates in Table 5.4 are intermediate between the two previous sets of calculations. Since they have been calculated using a more up-to-date approach than the previous estimates they are considered to be more valid for modelling flows at the subject site.
Are the results compatible with the longer-term flood history?	TBC.
Describe any other checks on the results	Hydraulic modelling has been used to determine the validity of the flow estimates and their variation along the study reach. This shows that, providing no additional lateral inflows are put into the study reach, a single inflow at the upstream extent of the model corresponding to the peak flow estimated for site code GW_6534, produces peak flows at the FCA site that closely match those of the corresponding flow estimation point at GW_4391.

5.4 Final results

Site code	Flood peak (m ³ /s) for the following return periods (in years)								
	2	5	10	20	50	75	100	200	1000
GW_6534	3.2	4.4	5.2	6.4	7.4	8.1	8.6	9.9	15.0
GW_4391	3.1	4.2	4.9	6.1	7.1	7.7	8.2	9.5	14.3
GW_3771	2.7	3.7	4.4	5.4	6.2	6.8	7.2	8.4	12.5

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)	Design Hydrographs are available within the hydraulic model inflow files (i.e. ISIS IED files).
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6 Annex - supporting information

6.1 Pooling group composition

GW_4391_p01

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
27051 (Crimple @ Burn Bridge)	0.4	37	4.514	0.22	0.133	1.028
25019 (Leven @ Easby)	0.616	31	6.088	0.355	0.396	0.671
45816 (Haddeo @ Upton)	0.835	16	3.539	0.331	0.427	0.45
28033 (Dove @ Hollinsclough)	0.9	30	4.654	0.257	0.403	0.632
27010 (Hodge Beck @ Bransdale Weir)	0.945	41	9.42	0.224	0.293	0.113
25011 (Langdon Beck @ Langdon)	1.026	23	15.362	0.247	0.399	0.871
50009 (Lew @ Norley Bridge)	1.126	21	19.025	0.147	-0.249	2.995
22003 (Usway Burn @ Shillmoor)	1.178	13	16.17	-0.282	-0.311	4.23
203046 (Rathmore Burn @ Rathmore Bridge)	1.235	27	10.996	0.126	0.125	0.424
206006 (Annalong @ Recorder 1895)	1.323	48	15.33	0.189	0.052	0.985
27032 (Hebden Beck @ Hebden)	1.433	43	3.793	0.22	0.274	0.189
25003 (Trout Beck @ Moor House)	1.45	36	15.105	0.173	0.328	0.86
48009 (st Neot @ Craigshill Wood)	1.531	12	8.469	0.246	0.372	0.417
203049 (Clady @ Clady Bridge)	1.564	27	22.742	0.197	0.123	0.077
48004 (Warleggan @ Trengoffe)	1.579	40	9.604	0.245	0.197	0.121
49003 (de Lank @ de Lank)	1.593	43	13.055	0.227	0.246	0.582
36010 (Bumpstead Brook @ Broad Green)	1.63	42	6.795	0.428	0.223	2.356
Total		530				
Weighted means				0.215	0.208	

6.2 Additional supporting information

None.

NOTE TO FILE

JBA Project Code 2012s5958
Contract River Gwenfro Flood Modelling to Support WAST Development
Client Arup
Day, Date and Time 24 July 2012
Author Kevin Frodsham
Subject Freeboard Analysis



1 Freeboard Analysis

Section 3 of the FCA proposes that ground levels for the WAST platform should be set at 0.1% AEP with climate change levels plus a 300mm freeboard. This note summarises the rationale behind a 300mm freeboard margin.

The freeboard was assessed following an assessment of the model sensitivity alongside the WAST site; specifically the variation in the peak 0.1% AEP flood level due to the following model configurations:

- 20% increase in flow
- 33% blockage of the downstream (old) railway culvert
- 20% increase in channel roughness
- 15%¹ decrease in channel roughness

The freeboard was assessed using the following formula:

$$y = \sqrt{\sum (\sigma_2 - \sigma_1)^2}$$

for all sensitivity tests in which $\sigma_2 - \sigma_1$ is positive

where σ_2 = the peak flood level from each sensitivity test

and σ_1 = the peak 0.1% AEP flood level from the baseline model

This calculations was performed for three model nodes at the upstream (GwenWr_4891), centre (GwenWr_4784) and downstream (GwenWr_4489) parts of the WAST platform. The results are shown in Table 1. This shows that the peak flood level alongside the platform is relatively insensitive to changes in these key model parameters giving rise to freeboard margins (y) of between 0.04 and 0.16m; the most sensitive location being alongside the centre of the site.

In view of these calculations it is proposed that a 300mm freeboard margin should be sufficient to cover the uncertainty in the modelled flood levels alongside the WAST site.

Table 1: Modelled flood levels and calculated freeboard margins from the sensitivity tests.

	Baseline	33% Blockage	+20% Flow	CR+20%	CR-15%	y
GwenWr_4891	92.37	92.37	92.43	92.42	92.33	0.08
GwenWr_4784	91.49	91.49	91.62	91.58	91.40	0.16
GwenWr_4489	89.48	89.49	89.50	89.45	89.43	0.04

¹ Note that a 20% decrease caused the model to go unstable. However, since a reduction in channel roughness causes a reduction in peak flood level, this particular test is not counted in the final freeboard calculation.

Ove Arup & Partners International Ltd		Page 1
The Arup Campus Blyth Gate Solihull B90 8AE		
Date 23/03/2012 14:06 File	Designed by sion.will... Checked by	
Micro Drainage	Source Control W.12.6.1	

IH 124 Mean Annual Flood

Input

Return Period (years) 1 Soil 0.450
Area (ha) 50.000 Urban 0.000
SAAR (mm) 840 Region Number Region 9

Results	l/s	DEVELOPMENT RESULTS (2.3 Ha)
QBAR Rural	271.9	
QBAR Urban	271.9	
Q1 year	239.3	
Q1 year	239.3	$Q_{1YR} \times (A/50) = 11.0 \text{ l/s}$
Q2 years	252.5	
Q5 years	329.0	
Q10 years	386.1	
Q20 years	443.4	
Q25 years	463.3	
Q30 years	479.4	$Q_{30YR} \times (A/50) = 22.1 \text{ l/s}$
Q50 years	526.4	
Q100 years	592.7	$Q_{100YR} \times (A/50) = 27.3 \text{ l/s}$
Q200 years	671.6	
Q250 years	698.7	
Q1000 years	867.3	

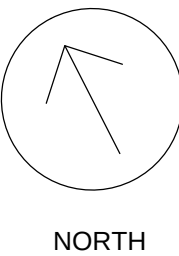
DEVELOPMENT AREA EXC. PUBLIC OPEN SPACE (A) = 2.3 Ha

PEAK DISCHARGE RATE OF RUN-OFF PER UNIT AREA:

- $Q_{1YR} = 4.8 \text{ l/s/HA}$
- $Q_{30YR} = 9.6 \text{ l/s/HA}$
- $Q_{100YR} = 11.9 \text{ l/s/HA}$



SCALE (METRES)



- LEGEND**

 - MACADAM ROAD SURFACE
 - MACADAM PAVEMENT SURFACE
 - NATURAL FINISHED CONCRETE SURFACE
 - 15m WIDE ECOLOGICAL CORRIDOR RETAINED
 - REFER TO LANDSCAPE PROPOSALS DRAWING
 - DESIGNATED PEDESTRIAN & CYCLE WAY (MACADAM PAVEMENT SURFACE)
 - EXISTING TREES RETAINED
 - FOR NEW PLANTING PROPOSAL, SIZES AND LOCATIONS REFER TO DRAWING AR-ARC-00-PL-100-024
 - BOLLARD LOCATIONS SUBJECT TO FURTHER DESIGN (20 No. TOTAL)
 - AREAS NOT COLOURED TO BE MADE GOOD AROUND SITE WORKS WHERE NECESSARY/ RETAINED IN EXISTING CONDITION
- LEGEND**

 - INDICATES LINE OF 15m WIDE ECOLOGICAL CORRIDOR FROM LINE OF RIVER BANK
 - SITE BOUNDARY
 - NEW SECURITY FENCE TO SITE BOUNDARY AND WITHIN SITE AS INDICATED
 - SECTION OF NEW SECURITY FENCE TO INCLUDE OTTER PROOF MESH AND BASE
 - RIVER BANK TAKEN FROM SITE SURVEY AND PRECISE LINE TO BE USED WILL REQUIRE MARKING OUT ON SITE TO ESTABLISH ACTUAL ECOLOGICAL CORRIDOR LINE TO SATISFACTION OF ENVIRONMENT AGENCY AND PLANNING OFFICERS
 - INDICATES MINIMUM 800mm DEEP x 1200mm WIDE (ACTUAL WIDTH TO MATCH PAVING IF WIDER) AREA OF COLOUR CONTRASTING 'BLISTER' TACTILE PAVING COMPLETE WITH DROP KERBS AND TRANSITION KERBS
 - INDICATES COLOUR CONTRASTING HAZARD WARNING 'CORDUROY' TACTILE PAVING MINIMUM 800mm DEEP WHERE INDICATED

VEHICLE AREAS

- STAFF CAR PARKING:
85 STANDARD SPACES (4.8m x 2.4m)
- PLUS 2 ACCESSIBLE SPACES
(4.8m x 2.4m WITH 1.2m MARGIN TO TWO SIDES)
- PLUS OVERFLOW PARKING FOR VISITORS
(UP TO 50 SPACES)
- PARKING AREA FOR 20 BICYCLES
PARKING AREA FOR MOTORCYCLES
- WAST AMBULANCE VEHICLE PARKING:
45 SPACES (7.2m x 3.3m)
- WAST AMBULANCE VEHICLE EXTERNAL CHARGING:
6 No. POINTS IN FRONT OF AMBULANCE GARAGE
30 No. POINTS TO AMBULANCE VEHICLE PARKING
(LOCATIONS AND DISTRIBUTION TBC)
- VEHICLE REFUELING AREA:
10,000 ltr DIESEL TANK (ABOVE GROUND)
WITH INTEGRAL BUND (MIN 10% OF INNER TANK)
L3800mm x W3840mm x H2200mm
ONE FUEL DISPENSING PUMP WITH 4m HOSE
CONCRETE BASE TO EXTEND MIN 300mm BEYOND
MAXIMUM DIMENSIONS OF THE TANK TO BS 5410
BOLLARDS TO PREVENT VEHICLE IMPACT
SCREEN FENCE TO BE AGREED
- BUND BETWEEN REFUELING AND WASH AREA
REFUELING AREA TO BE AT LOWER LEVEL
TO PREVENT CROSS CONTAMINATION
- VEHICLE WASH AREA:
ONE WASH POINT WITH SCREEN, GRP HOUSING
AND BELOW GROUND WATER RECYCLING TANK
- NWFRS ROAD TRAFFIC COLLISION TRAINING AREA:
AREA PROVIDED FOR TRAINING INCLUDING MOCK UP
OF ARTICULATED LORRY REAR, MOTORWAY BARRIER,
REMOVABLE BOLLARDS AND CONCRETE RAMP
- WAST FLEET SERVICE YARD AND SECURE COMPOUND:
VEHICLE DELIVERY BY RAMPED LOW LOADER TRUCK
- WORKS TO HOSPITAL CAR PARK:
REALIGNMENT OF KERBS AND ROAD LAYOUT TO
PROVIDE NEW VEHICULAR ACCESS AND EGRESS
REQUIRING LOSS OF APPROX 14 CAR PARKING BAYS
SUBJECT TO FURTHER DETAIL DESIGN

NOTES
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ANY DISCREPANCIES OR CHANGING TO BE REPORTED TO NIGHTINGALE ASSOCIATES
DO NOT MODIFY DIMENSIONS
USE DRAWING ONLY FOR PURPOSES ISSUED

No	Design Risk Register	
M 080912	ROADSABOUT REMOVED, FIRE TRAINING FACILITY MOVED TO FLOOD SAFE AREA, PARKING AREAS AMENDED, TO REQUIREMENTS OF MEETING ON 7th AUGUST 2012	
L 080212	RAMPS AND ONEWAY SYSTEM TO FIRE TRAINING FACILITY ADDED	
K 240112	VEHICLE REFUELING AND WASH DOWN CHANGED TO FINISHED CONCRETE SURFACE FINISH	
J 080112	REVISIONS TO SITE PLAN, ROAD LAYOUT REVISED, AMBULANCE BAYS REMOVED FROM MAIN STAFF CAR PARK, VEHICLE REFUELING ADDED BACK	
H 070912	REVISIONS TO SITE PLAN, ROAD LAYOUT REVISED AS CURRENT ARUP DRAWINGS, GRAPHICAL AMENDMENTS TO COLOUR CODING, ROAD, BOUNDARY LINE, HARDSTANDING AND STORAGE COMPOUND PARKING BAYS ALL AMENDED	
G 170912	REVISIONS TO SITE PLAN FOR PLANNING: GRAPHICAL AMENDMENTS TO COLOURS, ROAD, BOUNDARY LINE, HARDSTANDING AND STORAGE COMPOUND PARKING BAYS ALL AMENDED	
F 110712	REVISIONS TO SITE PLAN FOR PLANNING: MATERIALS CLARIFIED, REVISIONS INSTRUCTED BY MACE, TRANSITION PAVING ADDED, OIL STORE ADDED, HOSPITAL ENTRANCE REVISED, COVERED PARKING BAYS OMITTED, NOTES REVISED TO SUIT REVISIONS	
E 260612	REVISIONS TO SITE PLAN AS AGREED AT MEETING WITH WAST AND NWFRS 1406012 INCORPORATING ADDITIONAL WAST VEHICLE PARKING, 15M ECO CORRIDOR, RELOCATED SECURE COMPOUND WITH STAFF PEDESTRIAN ACCESS, REDUCED REFUELING AND WASH AREAS, MRB AND FLEET GARAGE REVISED DESIGN	
D 220612	SITE ENTRANCE REVISED AS ARUP DESIGN	
C 190602	VEHICLE WASH AND REFUELING AREAS AMENDED AS INSTRUCTED BY BAM 190602, NOTES UPDATED	
B 010512	PROJECT TITLE REVISED TO CLIENT REQUIREMENTS CONFIRMED 11.05.12 NO CHANGES TO SITE LAYOUT	
A 300412	REVISED AS AGREED 25.04.12, RELOCATION OF BUILDING AND ADJACENT DELIVERY BAYS/PARKING, SITE ENTRANCE RATIONALISED AND CYCLE ROUTE/PEDESTRIAN ROUTES REVISED, FIRE TRAINING AREA MOVED	
Rev	Date	Revision Notes
		Client / Contractor Wrexham Ambulance Services NHS Trust North Wales Fire and Rescue Services BAM Construction Limited

NIGHTINGALE
associates

Project
AMBULANCE AND FIRE SERVICES
RESOURCE CENTRE
WREXHAM

Drawing Title
PROPOSED SITE PLAN

Job No
09044

Date
17/04/12

Scale@A0
1:500

Status
PLANNING

Drawing No
AR-ARC-00-PL-100-021

Rev
M

Caution Note: This map is intended to be a preliminary screening tool only and should not be relied upon for any other purpose or in isolation. It provides an approximate guide to areas which may be at risk of flooding. The map, including the key, and information derived therefrom is not a substitute for detailed modelling or risk assessment, which you are strongly advised to consider in every case. Neither should it be used in the design or production of any flood mitigation or defence works. A detailed Flood Risk Assessment is recommended to confirm the likely extent and depth of flooding, to establish flow routes and to demonstrate the impact of any development on flood risk.

