Flood Consequence Assessments of Critical Assets

Dŵr Cymru Welsh Water's assessments of eight infrastructure assets in Wales

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The Welsh Government's Technical Advice Note 15: Development and Flood Risk (TAN15) gives indicative guidance that the annual probability of flooding of general infrastructure from fluvial events should be no greater than 1% AEP (annual exceedance probability) and no greater than 0.5% AEP from tidal events. This paper presents the reasons for the detailed flood risk assessment of eight water assets in Wales in 2011 and also includes the approach, methodology and findings of the hydraulic modelling which formed a key part of the assessments. Brief details are presented of two of the hydraulic models. Reference should be made to the separate paper published in UK Water Projects 2012 for further details of the mitigation measures implemented.

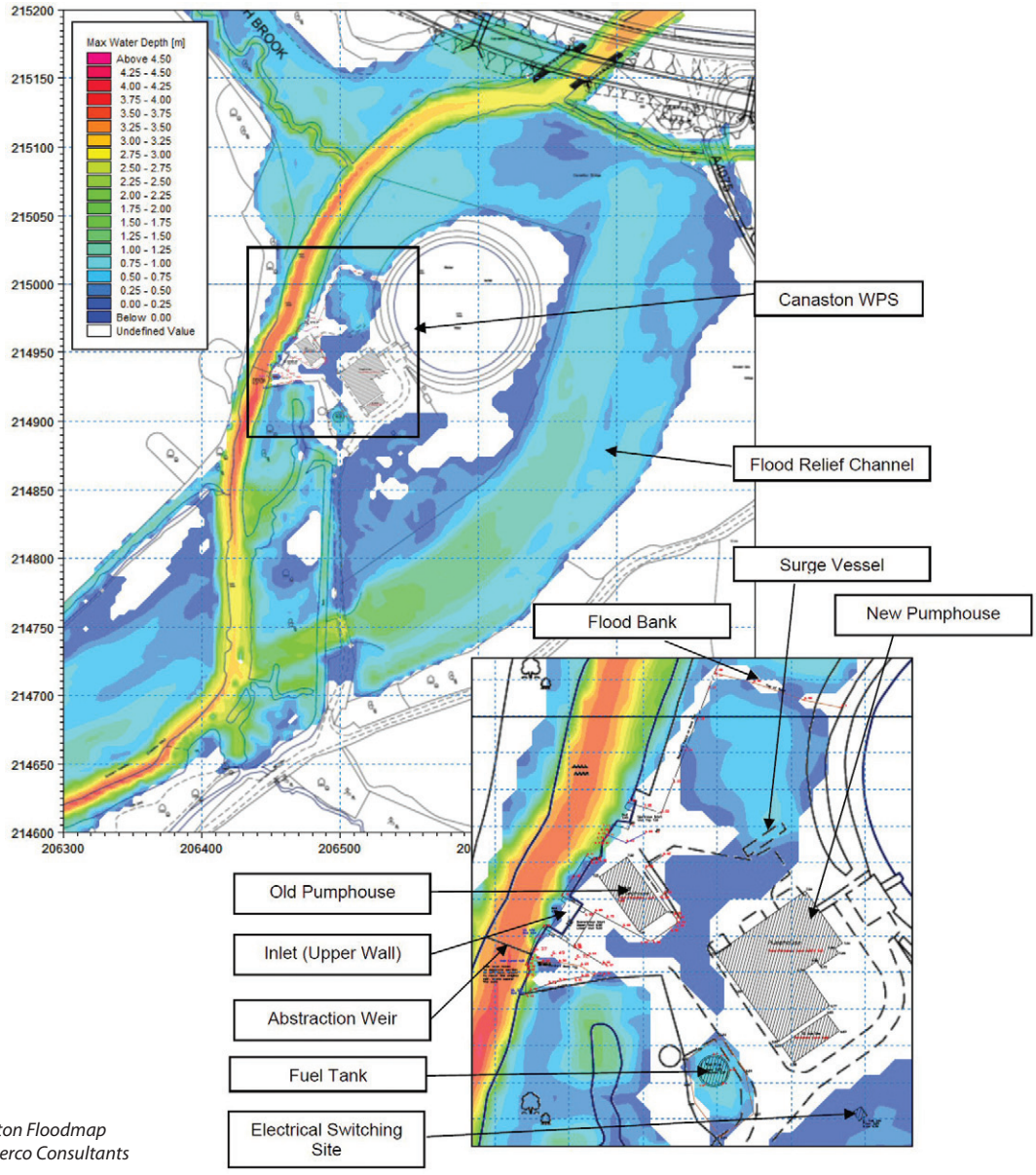

Figure 1 - Canaston Floodmap
Courtesy of Waterco Consultants

Background

In line with Dŵr Cymru Welsh Water's commitment to respond to climate change and to protect public water supplies, the company undertook to assess the risk at sites which may be vulnerable to flooding and to provide mitigation if necessary. The first stage, undertaken in 2008, was a review of all potable water sites located within Environment Agency's (EA) zones of flooding, with the output being a prioritised list based on previous flooding experiences and a flood analysis report for each site. These reports outlined the risks and provided recommendations for further investigation.

Welsh Water received funding to provide mitigation at a number of the sites considered at risk. The eight sites listed below were packaged together as a single tender, as detailed hydraulic

Site name	Description	Available data
Bryn Aled	Water Pumping Station	J Flow
Bryn Cowlyd	Water Treatment Works	ISIS
Canaston	Water Pumping Station	HEC-RAS
Crowhill	Water Treatment Works	J Flow
Llannerch	Boreholes	J Flow
Llechryd	Water Pumping Station	HEC-RAS
Nantgaredig	Water Pumping Station	HEC-RAS
Pontsticill	Water Treatment Works	ISIS

modelling had been recommended to substantiate the risk of flooding at all eight. In January 2011 Welsh Water appointed Waterco Consultants to undertake this package of work.

Existing Flood Risk Data

As shown above, the type of data provided in the 2008 flood analysis reports varied across the sites, with some having hydraulic models of adjacent watercourses, while others only had coarse resolution 'J Flow' data available.

'J Flow' is the national generalised broad-scale modelling approach, which often takes little or no account of local structures and topographical features. As such, the model outputs cannot be used as the basis for detailed assessment of flood depths. Where the existing models were in either HEC-RAS or ISIS software format, these provided the foundation for more detailed modelling with supplementary survey data being added as appropriate.

Modelling Methods

Flood modelling methods currently in use in the UK can be divided into 1D and 2D approaches. HEC-RAS and ISIS models are one-dimensional (1D) in nature. 1D models are based on a form of the St-Venant, or shallow water, equations. By definition the direction of flow is restricted to one dimension, with vectors being aligned with the centre line of the river channel. Within such models lateral movement of the flow across the channel is considered negligible, relative to the longitudinal direction. Simulation run times are relatively quick, with the approach being ideal for the replication of flows that remain within the channel banks. During high flow events (banks overtopping) the representation of out of channel flow paths across the floodplain are limited.

2D models use the two-dimensional shallow water equations in conjunction with a numerical grid configuration, allowing flow to move between adjacent cells in two directions. 2D models, often known as digital terrain models, are derived from a combination of high resolution LiDAR data and topographical survey information.

Although good at simulating multi-directional overland flows, these models require significant amounts of input data and longer computational run times to accurately represent low flows. Modelling of rivers using 2D only is rare in the UK.

In order to utilise the advantages of both approaches, a 1D river network model can be joined to a 2D floodplain grid using a series of lateral link structures – a combined 1D/2D approach. This provides improved representation of out of channel flows (floodplains) whilst maintaining reasonable run times. Lateral link structures are a mathematical representation of the way in which water is exchanged between the 1D and 2D elements, based on the hydraulic gradient at a given time step. Note that 3D modelling is different again and is used, primarily, in water quality modelling.

Although the models were not subject to EA approval they were built to EA standards for completeness. All 1D/2D modelling was completed using the MIKEFLOOD software package (DHI).

Hydrology

The input flow hydrographs were either extracted direct from the existing model data or calculated using the most appropriate methods eg. FEH Statistical, ReFH etc. As none of the original modelling took account of climate change, the fluvial flows in the detailed models were increased by 20% to provide a Climate Change Allowance (CCA).

Canaston WPS

This works is located near Canaston Bridge to the east of Haverfordwest, Pembrokeshire, on the banks of the Eastern Cleddau River from which raw water is extracted. There are two sets of pumps which supply raw water to Bolton Hill WTW and Green Hill raw water storage reservoir.

The WPS facility sits within a known floodplain, just downstream of the confluence between the Eastern Cleddau and two smaller tributaries; Narberth Brook and Toch Brook.

Under normal flow conditions the combined flow remains within channel, flowing along the western boundary of the site through the extraction weirs. However, under high flow conditions there is a high probability that the channel capacities of the Eastern Cleddau and Narberth Brook are exceeded causing the facility to be surrounded on all sides by the flood plain.

To protect against this, a low level flood protection bank around pumping stations was installed, in addition to a flood alleviation channel bypassing flow from Narberth Brook around the eastern boundary of the WPS. The main objectives of the detailed modelling at the Canaston site was to determine if the flood bank and relief channel provide the required standard of protection i.e. 1% AEP + CCA.

A relatively recent HEC-RAS model of the local river system was made available by the Welsh Government which had been updated to include the new A40 trunk Road layout upstream of the site. Following a detailed review of the model it was decided that supplementary survey data was required specifically around the flood relief channel and throughout the site.

The 1D river network was converted from HEC-RAS to MIKE11 so that it could be coupled to a 2D digital terrain model of the local

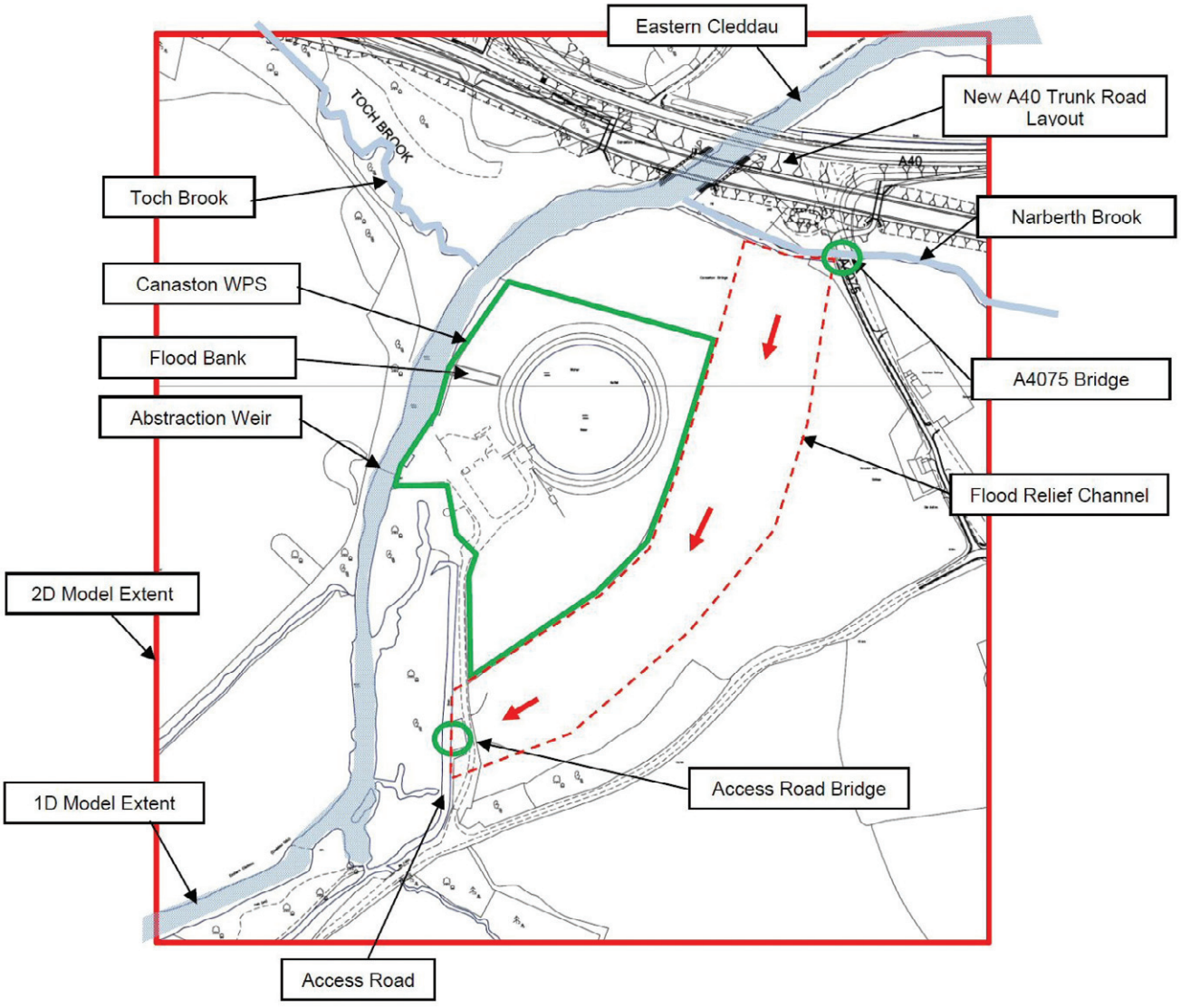

Figure 2 - Canaston Layout - Courtesy of Waterco Consultants

floodplain. Unlike the original model, it was decided that the flood relief channel be represented within the 2D model area rather than the 1D network. This provided a more accurate simulation of the overland flow route and improved representation of the flooding mechanism.

In line with the objectives of the study, the model was used to simulate the 1% AEP + CCA and 0.1% AEP (1 in 1000) fluvial events. The combined peak flow for the 1%AEP + CCA was 223 m^3/s.

With the site being located approximately 300m upstream of the normal tide limit of the Eastern Cleddau, the influence of the tide was a key consideration. Although peak tide levels provided by the EA showed the site not to be at direct risk of tidal flooding, the influence of the tide combined with fluvial flood events needed to be considered. Therefore 'tidelock' scenarios were considered i.e. each fluvial event coinciding with a MHWS tide cycle.

Given the extent and importance of the overland flow routes, the roughness value chosen for the terrain model was considered very important. A range of Manning's n values was chosen depending on the terrain type. Based on OS Masterlap layers, values ranging from 0.02 to 0.3 were allocated for roads, wooded areas, grass, brush and buildings.

Each simulation considered an event duration of approximately 35 hours with a fixed time step of 1 second. In addition to the primary simulations, additional models were run which considered other potential scenarios including partial blockage of the flood relief channel and a breach of the flood embankment.

Flooding during the 1% + CCA throughout the floodplain was shown to be extensive with the flood relief channel being fully utilised. Some shallow depth flooding (<300mm) was predicted at the pumping stations. Upon inspection it was shown that this flooding was caused by a localised low spot in the low level flood embankments which was overtopped at the event peak.

Having identified the potential weaknesses in the defences, mitigation measures could be prescribed. Although a number of buildings housing electrical equipment were found to be at risk, it was found that the critical equipment was high enough. No contract works were therefore required.

Pontsticill WTW

Located in the Brecon Beacons National Park, this WTW is sited immediately downstream of the Pontsticill Reservoir alongside the Taf Fechan watercourse. The watercourse ordinarily only carries compensation flows, but it also receives overspill from the reservoir during extreme rainfall events and previous experience and past modelling works have shown that risk of flooding from this source is significant.

A detailed review of the catchment hydrology was completed as part of the preliminary works with the additional 20% climate change allowance being considered. A bellmouth weir some 5m in diameter forms the reservoir overflow which is regularly monitored. As such, a head-discharge relationship was available from Welsh Water which formed the basis of the model input hydrology.

An ISIS model, developed as part of the 2008 initial investigations, was available and, following a detailed review, was used as the basis for more detailed 1D/2D modelling. Due to limited data availability, this original 1D model utilised a 'glass wall' approach preventing water leaving the channel and flowing across the site: a conservative approach.

To provide more realistic flood levels and indeed to more accurately establish the overland flow routes through the site, the model was upgraded to a 1D/2D model using MIKEFLOOD. Similar to the Canaston model the model was run for the 1% and 0.1% AEP fluvial events. Given the geographical location, tidal influence was not a factor. An additional return period of 2% AEP (1 in 50) was also carried out to calibrate the model against a previous historical event, believed to be of that severity.

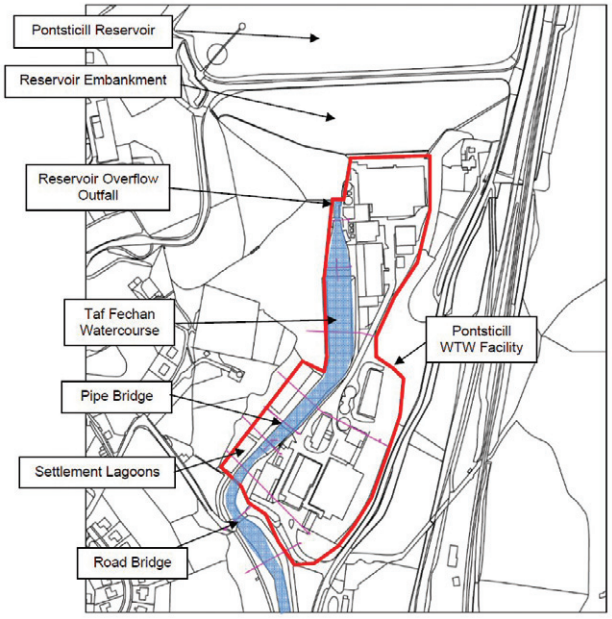

Figure 3 - Pontsticill Layout - Courtesy of Waterco Consultants

During the 1% + CCA event the existing low level banks were shown to be overtopped, leading to extensive flooding through the lower section of the WTW with a predicted flood depth of 800mm. Upon review, a number of factors were identified to have a significant influence on the amount of overtopping; namely the restrictions caused by a low-level upstream pipe bridge, an EA gauging weir and an historic listed stone bridge approximately 150m downstream of the works.

Various flood mitigation concepts were developed, simulated and analysed including: construction of a flood protection wall; relocation of the gauging weir; and provision of a weir bypass channel.

Following cost-benefit analysis, the final option was the recommended solution. The bypass channel would only operate during extreme event flows allowing the weir measurement function to continue during normal flows.

Conclusion

For completeness, a Flood Consequences Assessment (FCA) Report compliant with TAN15 was produced for each site. The project successfully met Welsh Water's objectives; either confirming in the FCA that the asset was not at risk during a 1% + CCA event; or providing a supplementary package of information for the subsequent detailed design of the flood alleviation solution determined by the hydraulic modelling.

A separate paper on the flood alleviation works arising from the flood risk assessment detailed above will be published in UK Water Projects 2012 and at www.WaterProjectsOnline.com.

The editor & publishers would like to thank the following for providing the above article for publication:

Chris Lewis, Senior Engineer with Waterco Consultants; Peter Jones, Managing Director of Waterco Consultants and Laura Howe, Hydraulic Modeller with Waterco Consultants.