Adran yr Economi a'r Seilwaith
Department for Economy and Infrastructure

Llywodraeth Cymru
Welsh Government

The M4 Motorway (Junction 23 (East of Magor) to West of Junction 29 (Castleton) and Connecting Roads) and The M48 Motorway (Junction 23 (East of Magor) Connecting Road) Scheme 201-

The M4 Motorway (Junction 23 (East of Magor) to West of Junction 29 (Castleton) and Connecting Roads) and The M48 Motorway (Junction 23 (East of Magor) Connecting Road) (Amendment) Scheme 201-

The London to Fishguard Trunk Road (East of Magor to Castleton) Order 201-

The M4 Motorway (West of Magor to East of Castleton) and the A48(M) Motorway (West of Castleton to St Mellons)(Variation of Various Schemes) Scheme 201-

The M4 Motorway (Junction 23 (East of Magor) to West of Junction 29 (Castleton) and Connecting Roads) and the M48 Motorway (Junction 23 (East of Magor) Connecting Road) and The London to Fishguard Trunk Road (east of Magor to Castleton) (Side Roads) Order 201-

The Welsh Ministers (The M4 Motorway (Junction 23 (East of Magor) to West of Junction 29 (Castleton) and Connecting Roads) and the M48 Motorway (Junction 23 (East of Magor) Connecting Road) and the London to Fishguard Trunk Road (East of Magor to Castleton)) Compulsory Purchase Order 201-

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Proof of Evidence

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Welsh Government, Flood Consequences Assessment

Document Reference WG 1.17.1

Contents

M4 Corridor around Newport
Proof of Evidence – Flood Consequences Assessment

1 Author

Personal profile and qualifications

1.1 My name is Michael John Vaughan. I am employed by Atkins Limited as a Principal Engineer. I have been instructed by Mr Martin Bates acting on behalf of Welsh Government to consider the fluvial and pluvial flood risk issues related to the proposed development of the M4.

1.2 I am a Chartered Civil Engineer and a Member of the Institution of Civil Engineers. I have over 21 years of professional experience, most of which has been in the fields of hydraulics, hydrology and land drainage. I have extensive experience in the preparation of hydraulic models and their use in the assessment of flood risk.

1.3 My qualifications include an honours bachelor's degree in Civil Engineering from the University of Exeter. I was registered as a Chartered Civil Engineer with the UK Engineering Council in 1998. In 2009 I became a member of the Chartered Institution of Water and Environmental Management, and qualified as a Chartered Water and Environmental Manager.

1.4 I have been employed by Atkins Limited since 2002. I am the regional team lead within our Flood Risk and Coastal management practice, covering the South West, as well as providing support to the national Atkins team. My responsibilities include management of modelling teams and projects, as well as being a technical lead on a range of projects.

1.5 My key competences include flood risk modelling; data analysis; scheme development and design; team and project management; and technical leadership. I provide expertise in river restoration and biodiverse habitat creation using bioengineering techniques.

1.6 I am a Reviewer for the Institution of Civil Engineers.

1.7 My first employment was with WS Atkins Consultants Limited, between 1994 and 1998. As a graduate engineer I gained experience in design and construction and undertook hydraulic modelling under the UK Governments Section 105 30/92 development and flood risk legislation.

1.8 I was employed by Parsons Brinckerhoff between 1998 and 2002. As a Chartered Civil Engineer I was involved in the developing a strategy for a National Flood Forecasting modelling system, as well as providing advice to the Environment Agency on matters of flood risk.

1.9 My consultancy experience has included commissions from many public and private organisations, such as developers, contractors, local authorities and Governmental clients, such as the Environment Agency, both in the UK and overseas.

1.10 I have worked on the following projects which have similarities or relevance to the M4 Corridor around Newport proposals:

a) HS2 Country North (HS2 Ltd) – I am the team lead undertaking detailed hydraulic modelling and flood risk assessment of the proposed scheme for the 64km of Country North. This covers 34 watercourse crossings including the rivers Tame, Cole and Avon. I manage staff across seven offices, interfacing with HS2 Ltd, project managing the inputs, as well as the budgets and programme on this section of the project.

b) HS2 hydraulic modelling review and specification (HS2 Ltd) – I was project manager and technical lead of a senior team reviewing the hydraulic modelling undertaken for the hybrid bill and submitted environmental statement. The team developed technical specifications for all future hydraulic modelling for HS2 Ltd, including the collection of topographic survey and hydrological studies.

d) HS2 Country South preliminary flood risk assessments (HS2 Ltd) - I lead the flood risk team for the rural South design package, evaluating and advising on matters of drainage and flood risk for the viaducts, bridges and drainage teams along some 90km of proposed new rail line. Work included outline design of river diversions and flood storage areas.

e) Glan Llyn development (Monks Ditch) (St Modwen) - I advised the land and drainage design team on matters of flood risk arising to and from the canalised watercourse through the site. This has required the development of hydraulic models and providing input on channel restoration.

f) A303, Ilchester Flood Study (Highways Agency) - I managed this project to investigate the cause of flooding of the A303 trunk road embankment over Christmas 2013. Hydraulic modelling was undertaken to establish the mechanism of flooding. Solutions for mitigation were developed and a preferred scheme presented to the client local area MP and community.

g) Olympic Park Site (Olympic Delivery Authority) – Over four years I led a team responsible for the master planning, design and implementation of the soft river edges and wetlands as integrated biodiverse habitats within the Olympic Park. This focussed on river restoration, bioengineering, and interfacing with landscape, utility, drainage and bridge teams. The work included the hydraulic modelling of the River Lee system under small floods and high flow conditions.

Personal Role on the Scheme

1.11 My evidence is being given on behalf of the Welsh Government. Atkins-Arup joint venture were appointed by the Costain Vinci joint venture to support the design of the proposed Scheme. The work was undertaken during 2015 and 2016. It is in this context I have written this Proof of Evidence.

1.12 I supported this project by reviewing the flood consequences assessment and overseeing a team of engineers, hydrologists and hydraulic modellers. The project developed a large 1D-2D hydraulic model for both the Caldicot and Wentlooge levels, to evaluate the impact of the Scheme on fluvial flood risk. I developed a separate much smaller 1D-2D model for the St Brides Brook to consider the impact of the Magor Junction.

1.13 The evidence which I have prepared and provided in this Proof of Evidence is true and has been prepared, and is given, in accordance with the guidance of my professional institution, and I confirm that the opinions expressed are my true and professional opinions.

2 Scope of Proof of Evidence

2.1 My evidence addresses the fluvial flood risk to, and from, the proposals for the M4 Corridor around Newport. That is matters of surface water flooding, and that from the watercourses.

2.2 My evidence to the Public Local Inquiry relates to the development of hydraulic models of the Gwent Levels (divided into, and more commonly known as, the Caldicot and Wentlooge Levels). These models have been used to predict the impact of the proposed Scheme on fluvial flood risk.

2.3 The evidence contained in this Proof of Evidence outlines the approach used in the development of the hydraulic models. It should be read in conjunction with:

a) The Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2)

b) The Flood Consequences Assessment supplement report at Appendix S16.2 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4)

c) The Reen Mitigation Strategy at Appendix 2.3 of the Volume 3 Environmental Statement (Document 2.3.2)

d) The Supplementary File Note on Reen Mitigation Strategy at Appendix S2.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4)

e) The Drainage Strategy Report at Appendix 2.2 in Volume 3 of the Environmental Statement (Document 2.3.2)

f) The Supplementary Drainage Strategy Report at Appendix S2.2 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4)

2.4 In this Proof of Evidence, I will describe the Scheme in general terms and how it relates to fluvial flood risk.

2.5 Then I will explain the procedures for assessing fluvial flood risk and outline the technical elements undertaken in:

a) The hydrology for flood risk and drainage design

b) The hydraulic modelling

c) The flood consequences assessment

d) The reen mitigation strategy

2.6 Finally I will respond to queries and objections received in relation to fluvial flooding and my considered opinion on the findings of the flood consequences assessment.

2.7 My evidence is herein presented in the following structure:

a) The Scheme in context of the fluvial features

b) Matters relating to fluvial flood risk

c) Hydrology

d) Hydraulic modelling of the Gwent Levels, drainage. Mill Reen, rivers Usk and Ebbw

e) Hydraulic modelling of the drainage scheme

f) The reen mitigation strategy

g) The flood consequences assessment;

h) General responses to queries and objections

i) Summary and conclusion.

2.8 My evidence does not address matters of tidal flooding. This specialist area is addressed by Dr Paul Canning, Chartered Civil Engineer in his Proof of Evidence (WG 1.16.1).

3 The Scheme proposal in terms of flood risk

The Scheme

3.1 The Scheme is described in Chapter 2 of the Volume 1 Environmental Statement (Document 2.3.2) and involves the construction of a new dual 3-lane motorway between Junction 29 at Castleton in the west and Junction 23 at Magor in the east.

3.2 From the westerly end of the Scheme, travelling east, and after the alignment crosses the mainline railway, the route passes on a low embankment across the Wentlooge Levels – an area identified as floodplain. As the route crosses the Levels, it bisects a number of reens (which are typically man made watercourses) and field ditches (which are smaller and non-regulated reens). These would be infilled under the footprint as part of the Scheme. Hydraulic connectivity will be maintained by the provision of culverts and implementation of the reen mitigation strategy, as detailed later.

3.3 The general design of the hydraulic connectivity is depicted in the Reen Mitigation Strategy at Appendix 2.3 of the Volume 3 Environmental Statement (Document 2.3.2), and the Supplementary File Note on Reen Mitigation Strategy at Appendix S2.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), comprising 16 drawings.

3.4 The new section of motorway would then cross the River Ebbw and pass to the south of the Docks Way Landfill site. The River Ebbw bridge would carry the new section of motorway over the River Ebbw.

3.5 To the east of the River Ebbw, the alignment would continue in a north easterly direction towards Newport Docks, passing to the south of the Docks Way landfill site.

3.6 The alignment will cross the Newport Docks between the South Dock and North Dock on a viaduct, before straightening out over the main bridge crossing of the Usk estuary. The bridge piers for the Usk crossing will be located outside the wetted channel (mean high water mark) of the River Usk.

3.7 To the east of the Usk crossing, the alignment will follow a general left hand curve across the Caldicot Levels. The highway will be supported on a low embankment as it runs eastwards over an area also identified as floodplain. As on the Wentlooge Levels the route bisects a number of reens and field ditches which will be infilled. Hydraulic connectivity will be maintained here, with the implementation of new culverts, and the reen mitigation strategy (new reens and field ditches).

3.8 The existing M4 will be re-aligned to the north, necessitating the widening of the existing embankment where it crosses the flood plain of the St Brides Brook. This will require the extension of the existing St Brides Road Underpass and the St Brides Brook/Mill Reen culvert.

3.9 It is forecast that construction of the whole Scheme will be completed by 2022. Technical Advice Note 15 - Development and Flood Risk, the national guidelines on flood risk, (Document 17.2.2) require that, “the development meets an acceptable standard of flood defence for the design life of the development.” The design life of the Scheme for flood risk is 100 years, and hence we have considered the flood risk for the year 2122.

Key matters relating to fluvial flood risk

3.10 The route passes across the Caldicot and Wentlooge levels (together known as the Gwent Levels) on a raised embankment. The area is identified as floodplain (predominantly Zone C1) in the Welsh Government’s Development Advice Maps (Welsh Government), based on the Natural Resources Wales’ extreme flood outlines. This indicates that the area is served by flood defences, but that development can take place subject to application of a justification test, including acceptability of consequences.

3.11 The Gwent Levels have a history of flooding, with areas such as the Broad Street Common road being flooded.

3.12 The Gwent Levels form a low lying area of land which generally sit below the high tide level, and are drained by an extensive network of freshwater drains, locally known as reens, and field ditches.

3.13 The network of reens discharge to the tidal estuary though a series of tide gates and sluices within tidal defences. During high tides, the reen network is tide locked and is unable to discharge. Tidal waters are, however, prevented from entering the reens and the levels. These outfalls maintain a freshwater habitat in the reen system within the Gwent Levels, yet requires them to store water, rather than discharge it, during high tide.

3.14 The water levels in the reen system are controlled by a series of sluice structures and are divided into winter penning levels and summer penning levels. Winter penning levels are kept lower to provide additional storage capacity. In summer, the penning levels are kept higher to provide a water source for agricultural purposes and wet fencing.

3.15 Natural Resources Wales may exercise their powers to undertake water management and maintenance of the watercourses classified as Main Rivers (the Main River reens generally running north to south). They now also maintain the other primary reens, knows as Internal Drainage District reens, within the Gwent Levels which were formerly maintained by the Caldicot and Wentlooge Internal Drainage Board (IDD), using powers prescribed under the Land Drainage Act 1991 and for the benefit of the landowners.

3.16 In my opinion the Scheme could have the potential to hold back flood water, arising from rainfall to the north or over the Gwent Levels themselves, given the nature of the raised motorway embankment. However, the Scheme has been designed with this in mind and, through the reen mitigation strategy, ensures the passage of floodwater under the embankment and to the coast.

4 Support of the Flood Consequences Assessment

Hydrology

4.1 Dr Yiwen Zhao of Atkins Consultants Limited made detailed estimates of the flows for the Gwent Levels as a results of intense or prolonged rainfall at a range of extremities, as contained in the Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2).

4.2 This hydrology was derived for the rainfall falling on the watersheds arising to the north of the Gwent Levels, and for the rainfall falling directly onto the Gwent Levels themselves.

4.3 Both assessments use data contained and generated within the Flood Estimation Handbook (Centre for Ecology & Hydrology, 1999), applying rainfall depth-duration-frequency data from the FEH CDROM v3.0 to the areas.

4.4 Runoff and flow estimates from the watersheds are based on UK industry standard methodologies. Specifically the Environment Agency's flood estimation guidelines (Document 17.2.10) have been followed, which use the Revitalised Flood Hydrograph (ReFH1) and Statistical approaches.

4.5 I note that a new set of flood Estimation guidelines for Wales has been published by Natural Resources Wales (Document 17.2.23). This refers to the Environment Agency's flood estimation guidelines (Document 17.2.10) but updates them and requires use of the second version of the Revitalised Flood Hydrograph model (ReFH2) in place of ReFH1 for deriving the extreme flood flows. I am of the opinion that in comparing the impact of the Scheme on fluvial flooding, any changes arising from this new approach will be negligible.

4.6 To test this I have had the largest inflow catchment examined and evaluated using the ReFH2 method. The approach reduces the estimate of the 1 in 1,000 year flow on the Monks Ditch from 26.7m^3/s to 26.5m^3/s and suggested rainfall depths are less too. Hence I infer that the extents of flooding at this location will be marginally smaller when using the new estimates. However, I consider that the actual change in fluvial flooding, for a given exceedance event, would be similar to that reported in the flood consequences assessment, and therefore the impact of the Scheme similar to that currently reported.

4.7 Consideration was given to the duration of rainfall generating floods, as well as its seasonality and frequency.

4.8 Climate change has been allowed for within the hydrological estimates in accordance with the Welsh Government's 2007 guidance (Document 17.2.20). A 20% increase in flows has been applied, with 30% applied to the direct rainfall intensity.

4.9 I am aware of the 2011 guidance, "Adapting to Climate change" as published by Welsh Government (Document 17.2.21). This document recommends a 25% flow change factor in the 2080s for the Severn river basin district, based on a 1961 - 1990 baseline, but is qualified in that it is not tailored for the land use planning system and advises continued use of the 2007 guidance (20% increase in flow). The guidance suggests using a 20% rainfall change factor which is less than has been applied in the hydraulic modelling for the flood consequences assessment

4.10 Most recently, in August 2016, Welsh government has published new advice, in its Guidance on Climate Change Allowances for Planning Purposes (Document 17.2.22). This should be incorporated into flood consequences assessments accompanying planning applications submitted from 01 December 2016. It is noted that this guidance advises use of a 75 year life for non-residential developments, and a 25% change factor for river flows in the 2080s, using a 1961 - 1990 baseline.

4.11 In this regard, the new 2016 guidance requires higher flows to be used in the testing of climate change. I am of the opinion that the change will

make little difference to the comparison of before and after Scheme, with the exception that predicted flood levels and extents will be greater in each case. For example, whilst a 20% increase has been added to the present day 1 in 100 year flow estimate for the Monks Ditch of 16.1m^3/s to obtain 19.3m^3/s, the 2016 climate change guidance would increase this to 20.1m^3/s. Then both the without, and with Scheme, conditions would be tested using that higher flow and the predicted flooding compared. I am of the opinion that this would not alter the relative impact of the Scheme: testing has already been undertaken using the higher 1 in 1,000 year flow of 27.2m^3/s which support this.

4.12 This recent guidance goes on to recommend use of the upper and lower end estimates (70% and 5% respectively) be used to assess risk, to inform mitigation measures to help ensure long term resilience. In my example, this would mean consideration, for resilience, of up to 27.4m^3/s in the Monks Ditch which is similar to the 1 in 1,000 year flow already tested and shown to not affect the Scheme.

4.13 It is noted that climate change advice for river flows is based on the 1961 to 1990 baseline. This might mean that climate change impacts have been overestimated by applying the 1990 related change factors to a present day baseline, although in my opinion it is more relevant that we now have a larger data record from which to make our present-day estimates. Should estimates have been made using only data from the years 1961 to 1990, it is likely our extreme event flow estimates would be different, higher or lower, than those presented in the Flood Consequences Assessment. However, the comparison of importance relates to the flood extents and depths with and without the Scheme, to which an identical flow has been applied.

4.14 This 2016 climate change guidance indicates no change factors for rainfall.

4.15 The impact of sea level rise on tide-locking is considered in the Flood Consequence Assessment and hydraulic modelling, and is described later.

4.16 To summarise my evidence here, it is UK practice to estimate flood flows which are based on statistical methods and correlations. The design flows applied are by nature, estimates. It should be remembered that the evaluation of impact should look at change arising from the Scheme, and not the absolute prediction of inundation.

Hydraulic modelling - Gwent Levels

4.17 Detailed hydraulic modelling has been undertaken to support the flood consequences assessment of the proposed Scheme.

4.18 The modelling uses the industry standard software package ESTRY-TUFLOW.

4.19 TUFLOW is a powerful computational engine that provides one-dimensional (1D) and two-dimensional (2D) solutions of the free-surface flow equations to simulate flood and tidal wave propagation.

4.20 The 1D solution is used to predict flood levels and velocities within watercourse channels and is based on the WBM software ESTRY.

4.21 This software is used by consultants worldwide and it is a preferred tool of Natural Resources Wales and has been benchmarked and approved against UK standard software tests by the Environment Agency (Document 17.2.7) and (Document 17.2.11).

4.22 Combined 1D/2D hydrodynamic models of the Gwent Levels were developed using ESTRY and TUFLOW software packages. The 1D-2D models are dynamically linked to model the interaction of water between the two domains.

4.23 The baseline model was developed to assess the current flood risks to the Gwent levels. Two separate models were developed: of the Caldicot levels east of the River Usk; and of the Wentlooge levels west of the River Ebbw.

4.24 The model uses Light Detection and Ranging data (LiDAR) in the form of a digital elevation model (bare earth). Due to the extents of the model, and LiDAR dataset coverage, LiDAR data originating from 2010, 2011,

2012, 2013 and 2015 was combined, using both 1m and 2m resolution data. A 5m model grid was developed from the LiDAR.

4.25 This was supplemented with a cross section survey by Azimuth Surveys in 2015, Ordnance Survey Mastermap data, GIS information from Natural Resources Wales, and railway structure information from Network Rail.

4.26 The baseline model has been developed to allow representation of the key hydraulic features dominating the Gwent Levels system. That is the major outfalls are included with tidal flap valves, and the key bridges and culverts added to represent the constraints on the system.

4.27 The hydrology is applied to the hydraulic model as a series of inflow boundaries, either as flow-time boundaries or rainfall-time boundaries.

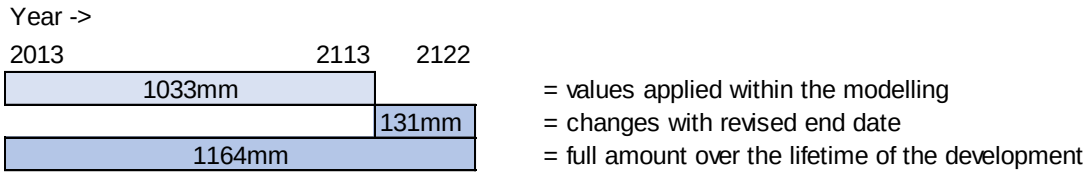
4.28 The downstream boundary for the model was applied as a mean high water spring tide (MHWS) covering several days of tides representative of the state in the Severn Estuary at each outfall. The MHWS tidal curve was derived from work undertaken in the Severn Estuary Flood Risk Management Strategy (Document 17.2.16) and varies spatially with a peak level of 6.0m AOD at the mouth of the Rhymney and 6.8m AOD at the toll at Sudbrook.

4.29 Climate change allowances for sea level rise between the year 2013 and 2113 were included in the hydraulic modelling, adding 1033mm to the peak tides, based on the 2007 climate change guidance (Document 17.2.20).

4.30 The 100 year design life for the road, should be taken from the estimated construction completion in 2022. This requires us to consider any impact in the year 2122. This adds a further 9 years of sea level rise, or 131mm, to the peak tide in comparison to the year 2113 used in the hydraulic modelling. This is based on the 2007 climate change guidance (Document 17.2.20).

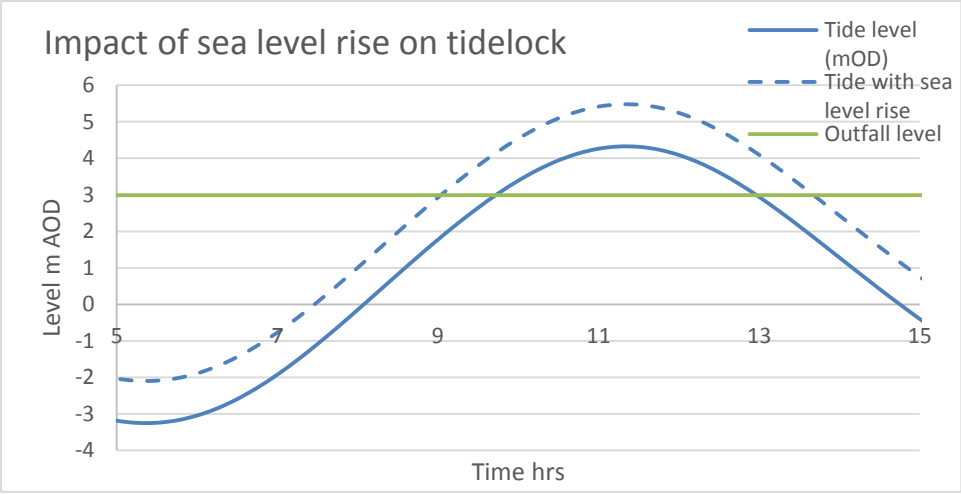
4.31 This would be a total sea level rise of 1164mm from the year 2013 to the year 2122. Figure 1 shows this graphically.

Figure 1 – 2007 sea level rise allowances



4.32 This sea level rise (modelled as 1033mm or now assessed as 1164mm) has a negligible impact on the inland fluvial regime as it applies to both the 'with', and 'without Scheme', conditions. For fluvial flood risk as modelled, sea levels affects only tidelock across the Gwent Levels. This manifests as a marginal change in the length of time that an outfall cannot discharge to sea. Figure 2 presents this graphically.

Figure 2 – impact of sea level rise on tidelock

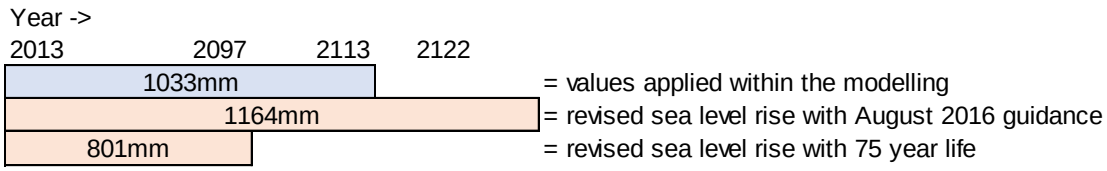


4.33 I have considered from the most recent climate change advice from Welsh Government (Document 17.2.22). The new recommended allowance for overall sea level rise from the year 2013 to 2122 remains the same, at 1164mm.

4.34 It is noted that the new 2016 guidance suggests an assessment lifetime of 75 years for climate change. The appropriate sea level rise over that timeframe (75 years after the year 2022, being the year 2097) would then be less, at 801mm (using a baseline of 2013). This is described in Figure 3.

4.35 The assessment has, however, maintained a more precautionary lifetime of 100yrs throughout, and applied the 2007 guidance.

Figure 3 – 2016 sea level rise allowances



4.36 I am of the opinion that the variations in guidance on sea level rise, alongside the inevitable uncertainty in predicting this into the future, have little impact on the predictions of fluvial flood levels in this tidelocked system where it is the period of tide lock that has the impact rather than absolute tide level. The impact of sea level rise will be a longer period of tide lock as I have just described. Hence there would be a negligible change when comparing fluvial flood risk with and without the Scheme.

4.37 A sensitivity test was undertaken to check the impact of the relative timing of the high tides against the rainfall. The work indicated negligible impact. As such, the modelling was continued with a high tide arriving at the same time as the peak of the rainfall representing a worst case scenario.

4.38 Tests were undertaken with the model to evaluate the effect of different storm durations, storm frequencies and storm profiles.

4.39 The work identified that a 12hr storm generated the greatest depth of flooding across most of the levels (as opposed to 3hr, 6hr or 24 hrs tested). This was evaluated with a corresponding present day MHWS tide.

4.40 The result of flood seasonality was mixed, although the winter storm profile appeared to cause the greatest flooding on the majority of the Levels.

4.41 The models have been run with an initial water level across the Gwent Levels of 4.5m AOD in both the 1D and 2D models. The level of 4.5m AOD reflects average winter penning levels across the Gwent Levels, as supplied by Natural Resources Wales. This correlates with the worst case being a winter storm.

4.42 The penning levels do vary across the Gwent Levels, and the impact of modelling an initial condition of 4.5m AOD means that the model will slightly overestimate the storage capacity in the reens. However, as the flooding impact is a measure of a comparison of 'with' and 'without' Scheme, I consider that the modelling assumption made is valid.

4.43 The hydraulic model for the proposed Scheme is derived from the baseline model by applying the Scheme plans to the model. As such, it includes a linear raised embankment with the new culverts underneath. The reen mitigation works were included, in the 1D model, as new lengths of watercourse to convey water to the culverts. The highway drainage ponds and treatment areas were included to recreate the changed topography.

4.44 The data for the Scheme was sourced from design drawings in early October 2015, applying the ground models representing the earthworks, including water treatment and attenuation areas. Sensitivity testing has since been undertaken on the evolving design, which has indicated little effect on fluvial flood risk.

4.45 The with-Scheme model has an additional set of hydrological boundaries: the outputs from the drainage models, described in the next section of this evidence, were used as inflows to the flood model, representing the discharges from the various attenuation ponds. No rainfall input was applied to the motorway carriageway itself, as this would drain to the attenuation ponds, and was dealt with by the drainage models.

4.46 Under the design conditions all runoff passes through the water treatment areas and is attenuated to a restricted discharge into the reens.

4.47 The 1D-2D models were simulated for flood events occurring 1 in 100 years with climate change, and 1 in 1000 years, in accordance with TAN15 (Document 17.2.2). The 1 in 5 year event was also simulated for comparison with known conditions across the Gwent levels.

4.48 The results from the modelling have been presented as a series of plans, which are contained within the Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2). These indicate the magnitude of change in flood levels.

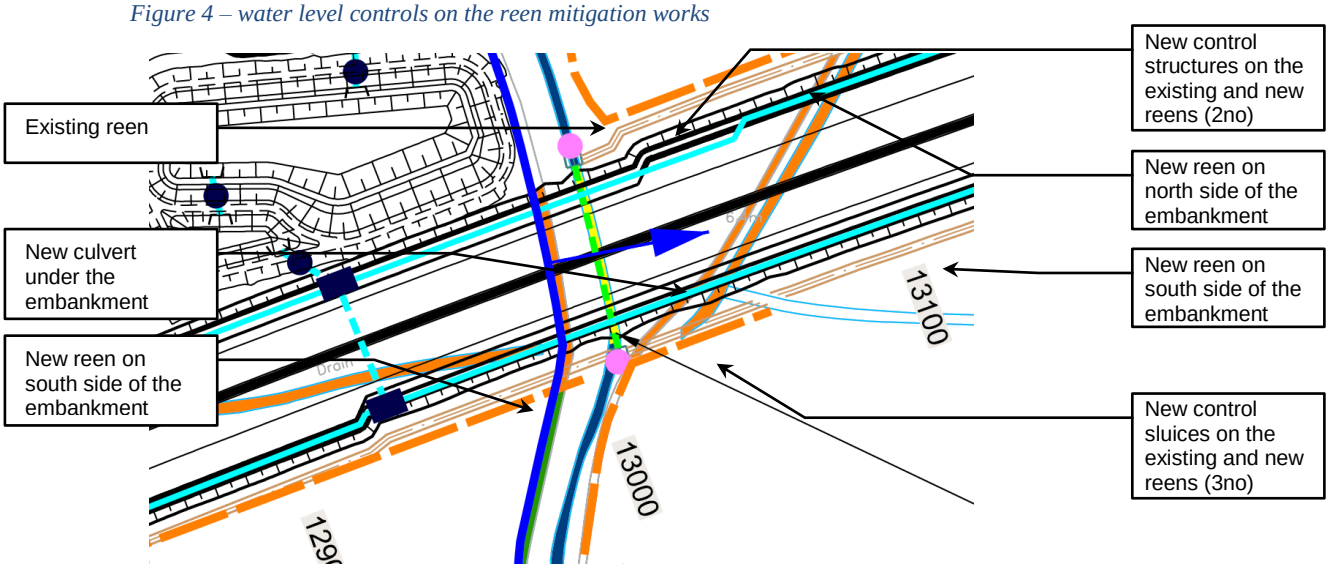
4.49 Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2), and the Flood Consequences Assessment supplement report at Appendix S16.2 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), report that no residential or industrial property would experience an increased risk of fluvial or pluvial flooding as a result of the Scheme. This is borne out by the hydraulic modelling, which demonstrates a typical change in peak flood level in the range of -10mm to +10mm.

4.50 Small areas of increased water levels, up to 100mm higher, were predicted on agricultural land immediately south of the Scheme. Consequently the model also predicted a reduction in peak water levels to the north of the Scheme by up to 100mm.

4.51 The Scheme design includes a new set of control sluices, or tilting weirs, at each reen crossing. These controls are not included in the hydraulic model as they would be manually operated and subject to site feedback.

They will allow fine control of water levels on the Gwent Levels, providing flexibility to better manage water levels in the locality of each crossing. These controls will be able to mitigate the areas of predicted downstream detriment, by balancing the upstream and downstream levels.

Figure 4 – water level controls on the reen mitigation works



Hydraulic modelling - drainage

4.52 The engineering of the drainage design is described in the Proof of Evidence on engineering, by Mr Ben Sibert, Chartered Civil Engineer (WG 1.5.1), and documented in the Drainage Strategy Report at Appendix 2.2 in Volume 3 of the Environmental Statement (Document 2.3.2), with updates in the Supplementary Drainage Strategy Report at Appendix S2.2 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4).

4.53 Mr Richard Graham also describes the drainage system in his Proof of Evidence on Water Quality (WG 1.15.1), and how that drainage system addresses matters of pollution control and treatment.

4.54 The construction drainage is described in the Proof of Evidence on Construction, by Mr Barry Woodman, Chartered Civil Engineer (WG 1.6.1).

4.55 The drainage system will include features to address risk of pollution and reduced water quality to the Gwent Levels SSSIs especially during periods of heavy rainfall. This is described in the evidence of Mr Richard Graham, Hydrogeologist, on Water Quality (WG 1.15.1). The drainage system also addresses matters of surface water flood risk.

4.56 Each drainage run will comprise a drainage channel or pipework, passing into a lined pollution control forebay, and then into an attenuation lagoon. The lagoons will pass a regulated flow of water into a reedbed which discharges into a receiving watercourse.

4.57 The starting point for the design of each drainage run was the summer penning level in the receiving watercourse, be it a Main river, IDD reen or Ordinary watercourse. The summer penning levels are higher than the winter penning levels and so this provides a precautionary case.

4.58 An allowance has been made for the hydraulic gradients through the outfalls, working upstream through the reedbed treatment area, the attenuation lagoon, the forebay and the drainage channels or pipes. The overall fall across the drainage system guides the carriageway design levels and hence the height of the Scheme embankments.

4.59 The hydraulic design of the drainage system has been developed using the industry standard MicroDrainage software, version 2015.1.

4.60 Using this software, the full suite of drainage infrastructure has been designed and tested, applying a variety of storm events of differing depths, durations, frequencies and seasonality.

4.61 These analyses use UK standard approaches to drainage modelling, based around the modified rational method from the Wallingford procedure, and applying rainfall from the Flood Studies Report (Institute of Hydrology, 1975) for preliminary sizing. A suite of 1 in 100 year return period events, with allowance for climate change, were then simulated through the designs to prove them under the range of conditions.

4.62 A 30% allowance for climate change was applied to rainfall intensity. This originates from the 2007 Welsh Government climate change guidance (Document 17.2.20).

4.63 I note that the 2011 guidance, “Adapting to Climate Change” as published by Welsh Government (Document 17.2.21) recommends only a 20% rainfall intensity change factor which is less than the 2007 guidance applied to the Scheme. However, that 2011 guidance is qualified in that it is not tailored for development, and instead advises continued use of the 2007 guidance.

4.64 The most recent 2016 guidance on climate change allowances (Document 17.2.22) makes no comment on how rainfall might change into the future.

4.65 The Scheme has been designed to convey flows from the more intense (short duration) 1 in 100 year storm, with climate change, to the water treatment areas. Longer duration storms of the same frequency were also tested. These are, by nature, less intense and generate smaller flows, but sustain them over a longer period of time and develop greater volumes. Hence the longer duration storms are also accommodated by the Scheme.

4.66 It is notable that the applied design standard exceeds that usually applied to road schemes, where the Design Manual for Roads and Bridges (Document 13.2.6, 2016) design standard is 5 years for carriageway flooding. This exceedance has been for both environmental and flood risk reasons, driven by the sensitivity of the SSSIs and compliance with the requirement of Natural Resources Wales for attenuation to greenfield runoff.

4.67 Highway drainage systems are typically designed to intercept and remove rainfall from short duration, high intensity events with return periods of 1 in 1 year (for no surcharge of piped systems or road-edge channels) or 1 in 5 years for no flooding of the carriageway.

4.68 The design of the channels is governed by the shallow longitudinal gradients along the Scheme, particularly across the Gwent Levels. These shallow gradients mean that the grassed channels are relatively large: the channels are trapezoidal, having a 0.6m wide base and being typically 2.1m wide across the top and 0.5m deep, although the largest are 3m wide and 0.8m deep.

4.69 The attenuation lagoons have each been sized to store the excess water arising from the carriageway whilst limiting the pass forward flow to the reedbed. This restriction has been applied during all events, up to and including the 1 in 100 year storm (with allowance for climate change), to a maximum of 3½l/s/ha. This is the greenfield runoff rate applied by Natural Resources Wales to all developments across the Gwent Levels.

4.70 As water levels rise in the attenuation lagoon the discharge to the reedbed increases up to the point of the restriction at 3½l/s/ha.

4.71 The design considers a range of storm durations to determine the critical event specific to storage. That is the storm which, over time, contributes the greatest flow to the attenuation lagoon with the lowest discharge to the reedbed.

4.72 The attenuation lagoons have been sized for much longer duration storms than the channels and pipe networks. This is as expected because of the need to balance the inflow with the restricted outflow, and account for the volume held in storage. This is supported by the drainage modelling, which indicates a critical duration storm in excess of 24 hours for the lagoons.

4.73 In general the attenuation lagoons are designed to accept the required volume with a rise in stored water level up to a depth of about 1.4m. Hence a theoretical storage requirement of 10,000m^3 would require an average plan area of 7,142m^2. However, as the height of the proposed embankment is driven, in part, by the hydraulic gradients in the drainage system, some of the attenuation lagoons on the Gwent Levels are sized with a smaller design rise in stored water level. This means that the plan areas of those lagoons are, by comparison, larger than the others. For example, the theoretical storage requirement of 10,000m^3 might be limited with a 0.5m rise in stored water level and hence then require an average plan area of 20,000m^2.

4.74 Each attenuation lagoon is designed with a 200mm freeboard, or factor of safety.

4.75 Flows from the attenuation lagoon into the reedbed area would be regulated by use of a vortex flow control device, or other suitable method. These devices are widely used in the drainage industry.

4.76 Flows leaving the reedbed are piped and pass through a non-return valve into the receiving watercourse. This prevents water from the reens passing back into the reedbed during times of high water level across the Gwent Levels.

4.77 The impact of higher water levels in the receiving watercourse has been considered to determine the sensitivity of the drainage system to this boundary condition.

4.78 High water levels within a receiving watercourse will affect the water treatment area, reducing the discharge from the outfall or preventing discharge altogether. In such conditions water would be held within the reedbed, by virtue of the hydraulic gradient, until flood levels in the receiving watercourse drop, or stored water levels rose sufficiently, whereupon discharges would resume.

4.79 Any flooding from the receiving watercourse will be prevented from entering the water treatment area by virtue of the localised ground levels forming the internal access road.

4.80 Data on the attenuated volumes and allowable pass forward flows, are contained in the Drainage Strategy Report at Appendix 2.2 in Volume 3 of the Environmental Statement (Document 2.3.2). Table 1 of that document demonstrates that all water treatment areas attenuate their outflow to the required greenfield runoff.

4.81 The largest attenuation lagoon holds 13,000m^3 and a corresponding peak discharge to the receiving watercourse (in this case the Middle Road Reen diversion) of 55.3l/s.

Hydraulic modelling - Mill Reen

4.82 The Mill Reen (St Brides Brook) lies inland from the Gwent Levels and is not part of the hydraulic modelling described before, being somewhat distant from them.

4.83 The watercourse is classified as a Main river, although it is a small brook where it passes underneath the existing M4 motorway at the existing Magor junction. South of the M4 motorway the brook passes through the village of Magor before eventually merging with the Gwent Levels reen system and discharging to the Severn Estuary.

4.84 The proposed Scheme sees the culvert under the existing M4 motorway lengthened by 72½m, from 61½m to 134m, in order to carry the new Magor junction. As this lengthening has the potential to increase flood levels upstream, additional hydraulic modelling was carried out to investigate the impacts.

4.85 A standalone model was developed using the Flood Modeller software. Flood Modeller is developed and marketed by CH2M from their UK operation.

4.86 A 1D-2D model was developed from LiDAR data, generating cross sections at 50m intervals over 2km of the watercourse. A 3m grid was used to form the floodplain areas. The existing culvert under the M4 was modelled using record drawings of the structure supplemented by local survey from 2015.

4.87 Flows were generated from the Revitalised Flood Hydrograph (ReFH) model. The downstream boundary was tested but based on predictions from the downstream Gwent Levels model described previously.

4.88 A with-Scheme application of the model was developed by changing the culvert and motorway embankment in accordance with the Scheme drawings of October 2015. The proposed surface water drainage pond was also included to represent the loss of floodplain arising at that site.

4.89 The results of the modelling indicated that the proposed Scheme could increase water levels in the farmland to the north-east of the Magor junction. Increases of up to 350mm were predicted at the culvert entrance during the 1 in 1,000 year flood. The impact on flood levels extends approximately 600m upstream through farmland towards, but not as far as, the culvert below St Bride's Road, although no properties would be affected.

4.90 The land predicted to suffer increased flooding has been included in the Compulsory Purchase Order as with Rights to discharge surfacewater and floodwater (shown for plots 19/5a, 19/5b and 19/6). This is scheduled in the Compulsory Purchase Order (Document 2.1.5) sheet 19 of 23. This approach is understood to have been used elsewhere on Welsh Government projects.

4.91 In my opinion it is not sustainable to excavate into the hillside here to provide new floodplain to offset this detriment, as the scale, cost and impact of the excavation would be significant when compared the impact of the additional floodwater.

4.92 The 350mm predicted increase in peak flood level, during the 1 in 1,000 year event, elevates floodwater at the inlet to 10.99m AOD. This would be insufficient to initiate a new flood route along the St Bride's Road underpass into Magor, whose threshold is much higher at 12.60m AOD.

4.93 Downstream a reduction in flood risk was predicted, with marginally lower flows (less than $1m^3/s$ change) being carried forward.

Reen mitigation strategy

4.94 The water quality aspects of the reen mitigation strategy are described by Mr Richard Graham in his evidence on water quality (WG 1.15.1).

4.95 Similarly, the ecological aspects of the reen mitigation strategy are described by Dr Keith Jones in his evidence on ecology and nature conservation (WG 1.18.1).

4.96 The Scheme will require numerous reens to be infilled, where they run across or along the alignment. Severance of these reens, without any mitigation, could alter the way that water moves across the Gwent Levels, blocking overland flow paths during flooding, concentrating flows in certain areas and removing water from others.

4.97 The reen mitigation strategy is included in the design to ensure the hydraulic connectivity of water across the Gwent Levels, specifically considering the reens, and smaller field ditches.

4.98 Hence the mitigation strategy is to:

a) Collect water from the north side of the embankment in a new reen running parallel to the alignment on the north side

b) Pass it through a series of culverts under the embankment

c) Spread the water out via a new reen parallel to the alignment on the south side

4.99 The Supplementary File Note on Reen Mitigation Strategy, at Appendix S2.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) revises the lengths of reens and ditches.

4.100 Some 2,755m of reen will be infilled as part of the Scheme. These will be replaced by some 2,826m of new reen.

4.101 Some 9,373m of field ditches will be infilled as part of the Scheme. These will be replaced by some 10,594m of new field ditches.

4.102 The replacement reens will be constructed with larger dimensions than those being lost. The existing reens currently vary in width and depth although are typically 1m wide at the base and 3m wide at the top. The replacement reens will excavated with a depth of 2m, a base width of 1m, and a 700mm wide ledge (berm), giving a wider overall top-width of 5.7m.

4.103 The replacement field ditches will also be cut nominally larger than the existing ditches, to be 1m deep, with a base width of ½m and overall top-width of 2.5m.

4.104 In this way the mitigation will provide similar conveyance and flood storage capacity present today. With an increase in overall replaced lengths, the reen mitigation strategy will increase the volume available for flood storage.

4.105 The Scheme includes for the design of side roads and will ensure that maintenance routes are available for Natural Resources Wales to access and maintain the reens. The new reens will be placed 3m from the embankment fence line, and provide a 7m easement for maintenance at Natural Resources Wales' request.

4.106 The existing Internal Drainage District reens are heavily managed across the Gwent Levels by Natural Resources Wales, both in terms of water level management and vegetation control. There is currently a seven year rolling programme of dredging and vegetation clearance on the existing reens, although this is dependent on their funding.

4.107 To assist the regulation of water levels during the defined summer and winter penning seasons, the Scheme includes up to three control structures on each side of the embankment. The inclusion of these was established through discussions with Natural Resources Wales.

4.108 These manually operated tilting weirs, sluices, or valves, will provide opportunity for Natural Resources Wales to regulate the passage of water under the embankment and the ability to apply different penning levels on both the new and existing reens. Water level management across the Gwent Levels will not rely on these structures and will remain possible with or without their use.

4.109 Hydraulic connectivity across the embankment, new access roads and other infrastructure will be maintained by forty one culvert crossings, installed as concrete box culverts. Those nine culverts conveying watercourses defined as main rivers, herein known as reen bridges, will be 1.8m high and 4.2m wide. Those thirty two reens conveying smaller flows will be 1.8m high and 1.8m wide. These are listed in the Drainage Strategy Report at Appendix 2.2 in Volume 3 of the Environmental Statement (Document 2.3.2), and updated in the Supplementary Drainage Strategy Report at Appendix S2.2 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4)

4.110 The hydraulic performance of the reen mitigation strategy was tested in the hydraulic model that I have previously described, as reported on in the Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2). That work determined that the Scheme would have no impact on fluvial flood risk to property, and only localised and minor adverse impacts on the agricultural land.

4.111 In my opinion, the reen mitigation strategy suitably addresses the potential hydraulic issues that a raised embankment and reen severance could cause.

Flood Consequences Assessment

4.112 The policy application of TAN15 (Document 17.2.2) is described in the evidence of Mr John Davies on planning and sustainable development (WG 1.23.1).

4.113 As reported in the Environmental Statement (Document 2.3.2) and the Flood Consequences Assessment in Appendix 16.1 of its Volume 3, and the supplements (Document 2.4.4), no residential or industrial property would experience an increased risk of fluvial or pluvial flooding as a result of the Scheme.

4.114 The Scheme is not predicted to flood from surface water or the reen network during the 1 in 100 year event, over the lifetime of the project.

4.115 The Scheme is not predicted to flood from surface water or the reen network during the 1 in 1,000 year event.

4.116 At Mill Reen, there is minimal impact of the proposed development on flood risk generally, which is included as part of a right to flood agreement.

4.117 Consequently, the evidence demonstrates that the Scheme satisfies the acceptability criteria laid out in TAN15 (Document 17.2.2) for fluvial and pluvial flooding (A1.12, A1.14 and A1.15), and that it would not cause any unacceptable impacts from fluvial flooding elsewhere. Those criteria are:

a) Flood defences must be shown to be structurally adequate particularly under extreme overtopping conditions. [There are no flood defences used to protect the Scheme from fluvial flooding]

b) The cost of future maintenance for all / new approved flood mitigation measure, included defences must be accepted by the developer and agreed with the Environment Agency [sic]. [The exact mechanism is to be agreed by Welsh Government and its agencies but Commitments 98 and 101 in the Register of Environmental Commitments Update, Appendix R18.1 in Volume 3 of the

Environmental Statement Supplement (Document 2.4.4) document this].

c) *The developer must ensure that future occupiers of development are aware of the flooding risk and consequences*. [The fluvial flood risk information is part of the Scheme and will be retained with the health and safety file for the project]

d) *Effective flood warnings are provided at the site*. [This is not required as the carriageway or its associated infrastructure is not at risk of fluvial or pluvial flooding]

e) *Escape / evacuation routes are shown by the developer to be operational under all conditions*. [The road remains operational during the 1 in 1000 year rainfall allowing evacuation of the area].

f) Flood emergency plans and procedures produced by the developer must be in place. [Such will form part of the management and maintenance plan for the Scheme].

g) The development is designed by the developer to allow the occupier the facility for rapid movement of goods / possessions away from the floodwaters. [This does not apply to general infrastructure].

h) Development is designed to minimise structural damage during a flood event and is flood Proof of Evidence to enable it to be returned to its prime use quickly in the aftermath of the flood. [Whilst the carriageway will not suffer from fluvial or pluvial flooding, the embankment and infrastructure is structurally designed to withstand flooding].

i) *No flooding elsewhere*. [The Flood Consequences Assessment demonstrates the impact of the Scheme on fluvial flooding elsewhere. The detriment identified alongside the Mill Reen has been addressed in the CPO by application of Rights to discharge surfacewater and floodwater].

j) Flood free at the 1 in 100 year fluvial flood in any year. [The Flood Consequences Assessment demonstrates this].

k) *Within tolerable conditions during extreme events*. [The Flood Consequences at Appendix 16.1 of the Volume 3 Environmental Statement Assessment (Document 2.3.2) demonstrates that the carriageway does not flood from fluvial or pluvial events during the 1 in 1,000 year event, and hence the criteria on maximum depth of flooding, maximum rate of rise of floodwaters, maximum speed of inundation of flood risk area, and maximum velocity of floodwaters are all met].

4.118 I can report that the Scheme will be free from fluvial flooding during the 1 in 100 year event over the lifetime of the development, and the consequences of fluvial flooding under extreme conditions are acceptable in accordance with the TAN15 (Document 17.2.2) guidelines.

4.119 The hydraulic modelling in the Flood Consequences Assessment, Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2) has been reviewed by Natural Resources Wales. The acceptance of this flood consequence assessment is described in the developing Statement of Common Ground between Welsh Government and Natural Resources Wales.

5 General responses to queries and objections

5.1 My review of the work undertaken has led me to my opinion that the Scheme will not increase fluvial or pluvial flood risk across the Gwent Levels. However, I have seen 1

5.2 5 specific objections with comments and queries to the Scheme, citing fluvial flood risk and related matters as a cause for concern: Objections 0013, 0020, 0077, 0083, 0125, 0145, 0149, 0150, 0185, 0195, 0206, 0216, 0250, 0260, 0268, 0270, 0310, 0314,

5.3 The objections appear to cover 6 main themes:

a) Runoff

b) Drainage

c) Reen mitigation

d) Water level management;

e) Maintenance and access

f) General flooding.

5.4 I will address each of these separately.

Runoff

Objections 0020, 0150, 0195, 0310, 0314

5.5 Chapter 16 of the Environmental Statement (Document 2.3.2) provides a detailed and comprehensive assessment of the effect of the Scheme on the water environment.

5.6 The surface water runoff from the Scheme is captured by a new highway drainage system and routed to various water treatment areas. The run-off from the highway is firstly attenuated to a ‘greenfield’ run-off rate, being held in attenuation pond and released at a controlled rate into new reedbeds for quality polishing.

5.7 A greenfield run-off rate is the rate of flow from an existing catchment, considered to be in its present state and contributing runoff without influence of the Scheme. For much of the Scheme, the greenfield runoff relates to a natural farmland state representative of the Gwent Levels today.

5.8 The rate of run-off from the existing catchments has been set by Natural Resources Wales at 3½ l/s/ha for all events up to and including the 1 in 100 year rainfall with 30% allowance for climate change. This is a given value for the wider area, and applied by Natural Resources Wales to all developments across the Gwent Levels. The Scheme will comply with this requirement for attenuation.

5.9 The fixed 3½ l/s/ha value compares to a theoretical value for the Gwent Levels of 3.7 l/s/ha for a more common 1 in 2 year event, and 8.1 l/s/ha for a present day 1 in 100 year event (HR Wallingford, 2015).

5.10 In context, a 3½ l/s/ha runoff rate compares to a range across Wales of ½ l/s/ha on the Gower to 70 l/s/ha in Snowdonia.

5.11 Higher greenfield runoff rates mean that a development will be permitted to pass higher flows into a receiving watercourse. Lower greenfield runoff rates mean that a development has to limit its discharge, passing smaller flows into a receiving watercourse and storing the rest in designated ponds.

5.12 During the extreme rainfall events, I consider that the Scheme will supply less than half the peak runoff currently being supplied by the land, releasing a peak flow of only 3½ l/s/ha from the lagoons during the 1 in 100 year storm. Thus I consider that the design of the drainage applies a precautionary approach on this Scheme.

5.13 The overall volume of water discharged by the Scheme would be similar to, if not marginally higher than, the present day, but discharging over a longer period of time. The reduced peak flow rate will provide betterment risk: this is because the Scheme will be permitted to release far less water to the reen network during the peak of a storm than the existing land

currently does, so reducing the peak flows arising in the reens and thus reducing flood risk.

5.14 The design and restrictions on discharge mean that the drainage works associated with the Scheme will not increase the risk of flooding. This is covered by Commitment 5 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) , "*Scheme design will provide mitigation for both water quality and water volume*".

Drainage

Objections 0077, 0250

5.15 The Drainage Strategy Report at Appendix 2.2 in Volume 3 of the Environmental Statement (Document 2.3.2), and the Supplementary Drainage Strategy Report at Appendix S2.2 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) provides details on the hydraulic design of the drainage system.

5.16 The drainage strategy for the Scheme provides for both water quality and water quantity control on discharges to the reen network. The water quality aspects of the drainage strategy are described by Mr Richard Graham in his evidence on water quality (WG 1.15.1).

5.17 The engineering and land required for the drainage, is described in the Proof of Evidence on engineering, by Mr Ben Sibert, Chartered Civil Engineer (WG 1.5.1).

5.18 I have reviewed the objections that cite drainage as a concern with regards to its hydraulic performance.

5.19 The Scheme conveys all runoff from the proposed carriageway to the twelve water treatment areas. The system of grass and concrete lined channels, supported by pipework are sized to ensure that a 1 in 100 year storm event, with a 30% allowance for climate change, can be collected and taken to a treatment area. This accords with the 2007 climate change guidance (Document 17.2.20).

5.20 The runoff is taken to a lagoon forebay which is sized, in each case, to accommodate a minimum of 50m^3 of runoff.

5.21 Runoff is then taken into the main attenuation lagoon. Each lagoon is designed to attenuate the pass forward flow to the maximum greenfield runoff allowance of 3½ l/s/ha. The outlet is controlled by a vortex regulator. The attenuation manifests as a rise in water levels within the lagoon.

5.22 Each lagoon has been sized to hold its critical volume: that is the worst case volume arising from the storm that provides the longest duration of high rainfall runoff, for a given frequency of event, whilst accounting for the permissible outflow through the control. This was derived through computational modelling, and varies for each water treatment area.

5.23 Each attenuation lagoon is designed with a minimum of 200mm of freeboard. The volume due to the freeboard amounts to between 15% and 30% extra above that required total 1 in 100 year with climate change inflow. This further reduces the possibility of the water treatment areas being bypassed, or overtopped, to well beyond the 1 in 100 year event with climate change allowance.

5.24 The regulated flow from the attenuation lagoon passes into the reedbed. This feature provides further attenuation, before eventual discharge into the receiving watercourse.

5.25 The final discharge is made from the reedbed via a piped outfall. The outfall will be fitted with a non-return value to prevent water in the receiving watercourse backing up into, and flooding, the water treatment area.

5.26 I have reviewed the drainage design for its ability to operate during periods of tide lock or flooding across the Gwent Levels.

5.27 The tide lock of the tidal outfalls requires water to be held within the reens for periods of the tide cycle. This means that discharge from the reens to the sea may be prevented under certain conditions.

5.28 During periods of tide lock water levels in some reens will temporarily rise, until the tide drops and discharge is possible.

5.29 Where the resulting rise in water levels affects the reens that will receive discharges from the water treatment areas, the new reedbed outfalls will be submerged and could be prevented from discharging.

5.30 In such situations the hydraulic performance of the new outfalls may be reduced. The impact of fluvial flooding will have a similar effect, submerging the new outfall and affecting the ability to discharge.

5.31 The influence of this effect on the water treatment areas is small. I have checked all the reedbeds in the Scheme, and determined that should any reedbed outfall be prevented from discharging for 6 hours, either by a high tide or fluvial flood, then water levels in the reedbed will rise by a worst case of 140mm. This will be contained within the area of the reedbed, and not cause any spillage of the runoff.

5.32 The drainage can still operate when water levels in the reens are elevated for longer periods due to flooding. To do so water levels in the water treatment areas will need to rise slightly, to generate a small head of water, to flow against the flood level in the receiving watercourse.

5.33 I have checked the required head to operate the discharge pipes against the 1 in 100 year with climate change flood level in the reens. In all cases the required water level will be still contained within the water treatment area.

5.34 As such, the drainage system will be capable of not only attenuating runoff in the 1 in 100 year with climate change event, but also in discharging the controlled runoff during times of flooding and tide lock on the Gwent Levels.

5.35 I have noted that the 1 in 100 year flood level, with allowance for climate change, already inundates the land around the water treatment areas. The predicted depths of flooding vary, although the maximum depth is 560mm. This floodwater will be prevented from filling the attenuation

lagoons and reedbeds by the design levels of the access around the water treatment areas.

5.36 All the receiving watercourses are new engineered highway ditches or existing reens.

5.37 Commitment 100 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), provides for ongoing liaison and design development with Natural Resources Wales on the drainage, "*Welsh Government and the M4CaN contractor will continue to liaise with NRW on the development of the Drainage Strategy (including, but not confined to* phasing *of reen replacements, detailed culvert designs, use of tilting weirs) and NRW's drainage requirements will be addressed to NRW's satisfaction*".

5.38 The design and restrictions on discharge mean that the drainage works associated with the Scheme will not increase the risk of flooding. This is covered by Commitment 5 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), "*Scheme design will provide mitigation for both water quality and water volume*". However, this should be interpreted to mean water discharge rates rather than water volume.

Reen mitigation

Objections 0260, 0268, 0270, 0185

5.39 The Reen Mitigation Strategy at Appendix 2.3 of the Volume 3 Environmental Statement (Document 2.3.2) and the Supplementary File Note on Reen Mitigation Strategy at Appendix S2.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) provides details on the reens and ditches to be infilled and replaced by way of compensation.

a) The commitment to implementing the Reen Mitigation Strategy is documented as Commitment 136 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the

Environmental Statement Supplement (Document 2.4.4): "*The Reen Mitigation strategy will be implemented to minimise impacts on the Reens*."

5.40 The new watercourse channels to be provided, in place of those removed, add a further 71m of reen and 1,221m of field ditch. This provides additional flood storage capacity and is documented as Commitment 6 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4): "*Provision of new reens will provide replacement water storage capacity*."

5.41 The inclusion of new water level control structures, through new tilting weirs or similar, at culverts under the Scheme, will provide opportunity for additional control on the reen network and will lead to enhanced water level management.

5.42 I have reviewed the flow predicted in the hydraulic model as heading towards the Collister Pill pumping station. I can confirm that the flood flows, in both the 100 year with climate change and 1 in 1,000 year floods, are unchanged by the Scheme and hence no additional pumping costs will be incurred by Natural Resources Wales.

5.43 I have reviewed the discharge points for the various water treatment areas and I can confirm that all discharge into reens or new engineered highway ditches. None of the water treatment areas discharge into existing, or replacement, field ditches.

5.44 Commitment 100 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) provides for ongoing liaison and design development with Natural Resources Wales, "*Welsh Government and the M4CaN contractor will continue to liaise with NRW on the development of the Drainage Strategy (including, but not confined to phasing of reen replacements, detailed culvert designs, use of tilting weirs) and NRW's drainage requirements will be addressed to NRW's satisfaction*".

5.45 I am of the opinion that the documented reen mitigation strategy will address the adverse impacts on fluvial flood risk and local hydraulics on the Gwent Levels, as it will ensure hydraulic connectivity of the surface water features and overcome the issue of severance.

Water level management

Objections 0145, 0149, 0150, 0206, 0216, 0310

5.46 Chapter 16 of the Environmental Statement (Document 2.3.2) provides a detailed and comprehensive assessment of the effect of the Scheme on the water environment.

5.47 The Scheme has been designed with a series of forty-one culverts to ensure hydraulic connectivity of the reens across the proposed motorway embankment. These culverts are typically 1.8m wide × 1.8m high, except where the flows in the principal reens necessitate a wider product – those are typically 4.2m wide. The culverts are all connected into the new reens. There are also some 50 new pipe culverts for the field drains.

5.48 The reen mitigation is designed to collect water from the north of the Scheme, convey it under the embankment, and then spread the water to south of the Scheme. It ensures continuance of the reens and field ditches on the Gwent Levels.

5.49 The reen mitigation strategy provides new reens parallel to the Scheme, on both sides of the embankment. These will collect water from the fields and ditches and route it to the nearest culvert under the embankment and then distribute it back along the other side.

5.50 The new culverts can be isolated by a pair of control structures, one at each end of the culvert. This will permit the culvert to be maintained. Furthermore, the sluices will enable the ability to provide water level management to be undertaken on those reens, which is a key criterion in the determination of whether a Flood Risk Activity Permit (for Main or IDD rivers), or Ordinary Watercourse Consent (for non-Main rivers) for the structures can be granted.

5.51 Item 100 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) describes how the design will be developed with Natural Resources Wales in order to reach an agreeable conclusion, particularly with regards to water level management, "*Welsh* Government *and the M4CaN contractor will continue to liaise with NRW on the development of the Drainage Strategy (including, but not confined to phasing of reen replacements, detailed culvert designs, use of tilting weirs) and NRW's drainage requirements will be addressed to NRW's satisfaction*".

5.52 The new reens feeding, or draining, the new culverts will be fitted with small gates or modern tilting weirs. These will allow enhanced operation of the reen and ditch network by enabling a fully variable control on water levels in those watercourses. This would facilitate additional penning zones; the supply or drain of water; and maintenance of the system in the vicinity of the Scheme.

5.53 This is documented as Commitment 108 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) "*The phasing of the construction of new* reens*, ditches and culverts, and the infilling of existing reens and ditches (including ecological issues) will be discussed with NRW, documented and implemented to their satisfaction".*

5.54 It is recognised that the Scheme will require the removal of some 2,755m of existing reen, and 9,373m of field ditches. In compensation, the reen mitigation will provide 2,826m of new reen and 10,594m of new field ditch, as described in the Supplementary File Note on Reen Mitigation Strategy at Appendix S2.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), giving an overall increase in storage capacity.

5.55 The Scheme-wide assessment of fluvial flood risk is based on flood modelling of the Gwent Levels and around the wider corridor of the new section of motorway. This assessment involved representation of the new

reens. The increase in field ditches was not included given their limited size.

5.56 In my opinion the increase in the overall length of field ditches would actually provide a slight reduction in flood risk, the system then being able to hold a greater volume of water during times of flood and nominally reducing the rate of rise or onset of flooding. The amount of rain landing on the Gwent Levels, and being drained by the ditches, will remain the same.

5.57 The Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2) concluded that the construction of the new section of motorway will have no significant adverse effect on fluvial and pluvial flood risk within the locality.

5.58 I am also of the opinion that the reen mitigation strategy will enhance the ability of the various parties to manage water levels on the Gwent Levels, by enabling new conveyance routes for both feed water and drainage.

Maintenance and access

Objection 0268

5.59 Maintenance of the existing water level and flood defence assets will need to continue over the construction period and during the life of the Scheme.

5.60 Item 98 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), describes the commitment from Welsh Government to this effect, "*The existing and replacement reens and field ditches would be maintained on a regular basis including clearing out of debris bi-annually*."

5.61 Natural Resources Wales are able to exercise their powers to maintain the Main River reens, and now also operate with powers under the Land Drainage Act 1991 to maintain, improve or construct works required for land drainage in the Internal Drainage District.

5.62 I understand that Natural Resources Wales has agreed, in principle, to use its powers to access and maintain the Main River reens, and also the

other Internal Drainage District reens within the former Caldicot and Wentlooge Internal Drainage Board area, provided that it is adequately compensated.

5.63 Item 101 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) refers specifically to the management and maintenance of the new infrastructure being provided, "*Welsh Government will discuss and agree with NRW management responsibility of the new reens, ditches, culverts and water control devices*."

5.64 The land required for the design, its access, and future ownerships and responsibilities are described in the Proof of Evidence on engineering, by Mr Ben Sibert, Chartered Civil Engineer (WG 1.5.1).

5.65 The construction programme requires implementation of the reen mitigation and construction drainage works prior to development of the embankment and related infrastructure. This is described in the Proof of Evidence on Construction, by Mr Barry Woodman, Chartered Civil Engineer (WG 1.6.1). This approach will enable the relevant parties to gain a knowledge and experience of the new assets, and their possible functions, early in the programme.

5.66 During the course of construction the Welsh Government's contractors will be managing and securing the construction site 7 days a week, 24 hours a day, and access to the culverts, tilting weirs, and reen mitigation will be permitted to the future owners and operators where required. Commitment 22 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4), refers to this, "*The main compound and strategic satellite compounds would have 24-hour security. The compounds would be manned during the day to manage the entry/exit of site vehicles and personnel. At night, the compounds would be secured and patrolled by security guards and/or CCTV*".

5.67 New access routes have been designed into the Scheme and are shown on the highway drainage and reen mitigation plans – contained in the

Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2). Furthermore, Commitment 106 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) relates to arrangements to be in place to ensure access for Natural Resources Wales, "*Before the commencement of any construction works discussions will take place with NRW and access arrangements agreed whereby NRW can continue to undertake, but not be limited to:*

a) Routine reen, ditch and flood risk management structure management and maintenance

b) Emergency works, such as blockage removal and repairs to defences

c) Wider compliance and enforcement work within NRW's remit, not directly related to the M4 construction works"

5.68 The access routes are the suggested means for Natural Resources Wales, using current field accesses etc. There is no specific provision within the Orders for these access routes (as it will be for Natural Resources Wales to use its powers to access the Main River reens and Land Drainage powers to maintain the Internal Drainage District reens). However, the Welsh Government easements would give Welsh Government and their agents, including Natural Resources Wales, access rights to the reens and field ditches, during and after construction so ensuring the ability to manage and maintain these assets.

5.69 It is recognised that, during the construction phase, health and safety matters may prevent safe access to various assets. During this time arrangements will be made with Natural Resources Wales and other relevant parties: this may include having operatives from Natural Resources Wales being inducted to the construction site. The need to access site will need to be notified in advance (and hence the site made safe), and that any plant brought onto site would need to be inspected

prior to its use as it would have to fully comply with the site procedures and systems.

5.70 Alternatively, it may be possible to have Natural Resources Wales trained construction operatives who could undertake asset management during the works.

5.71 Whenever necessary, construction activity could be stopped temporarily at a location to permit safe access.

5.72 The Scheme will sever some access routes north-south that currently provide access for maintenance. However the reen mitigation along with new tilting weirs and sluices will provide the opportunity to manage water levels from either side of the embankment.

5.73 The tilting weir on either side of the embankment will also enable the culverts to be closed, so enabling inspection of the culvert, removal of sediment, or other maintenance.

5.74 Routes will be available north-south using new overbridges, although these may not be in the same locations as today.

5.75 The evidence of Mr Ben Sibert (WG 1.5.1) covers the access for maintenance and inspection along the River Ebbw under the proposed bridge.

5.76 Commitment 107 in the Register of Environmental Commitments Update, in Appendix R18.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) relates specifically to the Ebbw access, "*Vehicular access would be provided for NRW along the length of the River Ebbw affected by the works, including beneath the west bank under River Ebbw bridge*."

5.77 In my opinion the change in access caused by the motorway embankment, supplemented with new water level controls and Natural Resources Wales access routes, will not inconvenience maintenance activities, as the new controls will enable water level management from either side of the route.

General flooding

5.78 Objections 0013, 0083, 0125, 0150

5.79 Chapter 16 of the Environmental Statement (Document 2.3.2) provides a detailed and comprehensive assessment of the effect of the Scheme on the water environment, including a flood consequences assessment.

5.80 This assessment considers the flood risk effects that are associated with the construction of the Scheme and over its lifetime into the next century.

5.81 The assessment of fluvial flood risk is based on extensive flood modelling of the Gwent Levels and around the wider corridor of the new section of motorway. This accounts for the impacts of climate change on fluvial flows and sea level rise over the next 100 years.

5.82 The Scheme drainage has been designed to accommodate a 1 in 100 year storm plus a 30% climate change allowance. The drainage infrastructure is capable of capturing, conveying and releasing surface water run-off from the new highway within a 3.5 l/s/ha restriction as applied by Natural Resources Wales. This will reduce the flow of water draining from the Scheme such that it is less than the contribution the land makes today.

5.83 The Supplementary File Note on Reen Mitigation Strategy at Appendix S2.1 in Volume 3 of the Environmental Statement Supplement (Document 2.4.4) provides a greater length of reen and field ditch than is removed by the Scheme, allowing more conveyance and storage across the Gwent Levels.

5.84 The water level controls for the new culverts and reens provides new opportunities for water level management, with even greater control on water levels than the aging system currently affords.

5.85 The result of the design and restrictions on discharge mean that the drainage works associated with the Scheme will not increase the risk of flooding.

5.86 The flood consequence assessment made for the St Brides Brook at Magor in Appendix 16.1 of the Volume 3 Environmental Statement

(Document 2.3.2) tested the impact of the widened motorway culvert, widened embankment, and creation of the water treatment area.

5.87 The results from the hydraulic modelling indicated a 250mm increase in flood levels in the farmland immediately upstream of the Scheme, as a result of the 1 in 100 year flood with allowance for climate change, which extended approximately 550m upstream and certainly no further than the existing St Brides Road bridge.

5.88 In the extreme event tested (the 1 in 1,000 year flood), the increase in peak flood level adjacent to the existing M4 was 350mm. The predicted flood level is significantly less than that required to initiate a flow path through the existing St Brides Road underpass and the impacts diminish to zero some 750m upstream, which is not as far north as the St Brides Road crossing of this watercourse.

5.89 The Flood Consequences Assessment at Appendix 16.1 of the Volume 3 Environmental Statement (Document 2.3.2) has concluded that the construction of the new section of motorway will have no significant adverse effect on fluvial or pluvial flood risk within the locality.

6 Summary and Conclusion

6.1 My Proof of Evidence provides a detailed description of the hydraulic modelling undertaken on the Gwent Levels and demonstrates that the Scheme addresses matter of fluvial and pluvial flood risk.

6.2 The proposed Scheme is represented within a set of hydraulic models to enable the impacts of the Scheme on flood risk issues to be assessed. The hydraulic models are used as a tool to assess the before and after conditions and evaluate any change arising.

6.3 The hydraulic models are based on well-founded science and industry standard methods. The input data is suitable for this assessment and uses published sources as well as project specific information. Whilst the UK guidance on hydrology and climate change continues to be updated, the comparative impact of the Scheme on baseline conditions will be unchanged. I am of the opinion that ongoing design development of the Scheme will continue to have negligible impact on fluvial and pluvial flood risk, so long as the number of culverts under the embankment does not reduce, and the ability to manage water levels through the new tilting weirs is included.

6.4 In my opinion whilst the Scheme could locally modify the flood response, the impacts will be minor, and can be managed.

6.5 The Gwent Levels are a heavily managed network of reens and ditches and its response to rainfall is complicated. The Scheme includes additional water level controls that will aid longer term management and provides opportunities with the landowners to refine it.

6.6 My Proof of Evidence includes all facts which I regard as being relevant to the opinions which I have expressed, and the Public Local Inquiry's attention has been drawn to any matter which would affect the validity of that opinion. I have expressed my opinions and supported them with evidence and example.

6.7 This evidence represents my true and professional opinion and is given in accordance with the Institution of Civil Engineer's Rules of Professional Conduct.

6.8 I understand my duty to the Public Local Inquiry to assist it with matters within my expertise and I believe that I have complied with that duty.

7 References

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Document 13.2.6. (2016). *Design Manual for Roads and Bridges.* Highways Agency et al.

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Document 17.2.20. (2007). *Climate Change Supplement.* Welsh Government.

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8 Appendix

None used.