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

Llywodraeth Cymru
Welsh Government

Objection Ref OBJ0077

WG/REB/OBJ0077 – Mr A. R. Pickup

Response to Objector's Evidence: A. R. Pickup

1. GROUNDS FOR OBJECTION

1.1. Details

1.1.1. A. R. Pickup has submitted a Statement of Evidence dated 24th January 2017 in relation to the draft statutory Orders associated with the Welsh Government's proposals for the M4 Corridor around Newport, which has been received via the Programme Officer.

1.1.2. The Welsh Government understands the evidence submitted within A. R. Pickup's Statement to be based on the following:

1. Concerns that the proposed water treatment systems are unlikely to function and would result in an impact on the water quality of the Gwent Levels SSSIs as a result of the Scheme.
2. Concerns that highway runoff could present a risk to the ecological interest of the Gwent Levels SSSI.
3. Concerns that reliance has been placed on uncertain climatological predictions (rainfall data).
4. States that the cleaning efficacy of the proposed water treatment elements does not accord with published information.
5. States that there is an admission that the quality of the runoff discharges are inadequate (not achieving ABCs) and this conflicts with DMRB Vol2, Sect 3, HD45/09, 2.13, which cites the obligations in relation to water quality discharge to special areas like SSSIs.
6. Concerns that there is a discrepancy between the known ability of grass-lined drainage channels to deal with dissolved contaminants and the data in the Environment Statement.
7. States that there is a conflict between the water quality of the discharge following treatment and the requirements of the SSSI water quality
8. Questions the proposed system's ability to produce adequate water quality run off for the SSSI and in heavy rain events.
9. States that there is over estimation of the effectiveness of reedbed treatment, particularly during high flow rates and phosphates.

10. Asserts that the reed beds will be rendered ineffective during extreme rainfall.

11. Concerns that there would be conflict between the design discharge rates and the water treatment systems under extreme conditions.

12. Concerns that discharge of contaminated water into the Gwent Levels presents a serious risk of eradication of populations of some species.

13. States that the designed system is inadequate; a simple safeguard to system failure is possible.

14. States that the design for dealing with surface water runoff from the highway is inadequate and should be amended. Highway runoff should only be discharged into 'main rivers' as discharging to the ‘IDB reens’ and not the ‘main rivers’ poses a significantly greater threat to the SSSIs.

15. Suggests that all channels designated for discharge water should be examined for the risk of over-topping as the black route traverse the lowest part of the Gwent Levels where the freeboard ditches are the smallest.

16. Suggests that where there is a risk of over-topping the channels should be embanked to ensure that contaminated water cannot overspill.

17. Suggests engineering alterations including embanking any Gwent Level watercourses.

2. REBUTTAL

2.1. Points Raised

2.1.1. Some of the above points have already been addressed in previous proofs of evidence. Others are dealt with by topic by the relevant witness in the following sections, in addition to their general proofs of evidence, to which readers should also make reference in their entirety for a full understanding of the Welsh Government's case. For ease of reference the places where the above points are addressed in this Rebuttal are listed in the table below:

Objector's point reference	Rebuttal paragraph reference	Objector's point reference	Rebuttal paragraph reference
1	2.2.1	9	2.2.8
2	2.2.2	10	2.2.9
3	2.1.2	11	2.2.10
4	2.2.3	12	2.2.11
5	2.2.4	13	2.3.1
6	2.2.5	14	2.2.12 & 2.3.1
7	2.2.6	15	2.3.2
8	2.2.7	16	2.1.2 & 2.3.2
		17	2.3.3

2.1.2. One of the Objector's points have already been covered in previous proofs of evidence as follows:

1. **Point 3** (Concerns that reliance has been placed on uncertain climatological predictions (rainfall data)) / The Proof of Evidence of Michael Vaughan WG 1.17.1 addresses this matter at paragraphs 4.2 to 4.14. Use of industry standard UK guidance, and available data, has been made with regards the flow estimation (hydrology).
2. **Point 16** (Suggests that where there is a risk of over-topping the channels should be embanked to ensure that contaminated water cannot overspill) / The Proof of Evidence of Michael Vaughan WG 1.17.1 addresses this matter at paragraphs 4.69 to 4.75.

2.1.3. The other points are responded to by specialist topic in turn in the sections following.

2.2. Richard Graham (Water Quality)

2.2.1. Response to **Point 1** (Concerns that the proposed water treatment systems are unlikely to function and would result in an impact on the water quality of the Gwent Levels SSSI as a result of the Scheme):

1. The Water Treatment Areas and the grass lined road side channels that intercept run off have been specified and designed to provide a very high likelihood that pollution to receiving reens within and beyond the SSSI can be minimised to an acceptable low level. All the components of the proposed run off treatment provisions are well documented and wholly appropriate for the reduction in potential pollutant levels through weather compensated capture (filtration and sedimentation), dilution, decay and controlled release.
2. These systems would be designed and constructed to sound engineering and environmental principals and be maintained by a regular inspection and maintenance schedule. Furthermore, every proposed discharge will be subject to a detailed programme of monitoring for both water quality and biological parameters to provide certainty of performance. Finally, a commitment will be made that water discharges to the SSSI will meet the requirements of the SSSI as required by NRW.
3. The use of grass lined channels, a pollution control lagoon, an attenuation lagoon and a constructed reed bed comprises a very high provision of run off treatment at a scale currently unmatched by similar systems in use within the UK serving roads or motorways.
4. Many of the treatment provisions found elsewhere in the UK comprise only one or two of the four systems proposed for the M4CaN and then only much smaller in size and hence a lower level of protection afforded than for the M4CaN scheme.

5. Each of the four components of the drainage treatment strategy afford significant and complimentary mechanisms for the entrainment and reduction in potential pollutants within highways drainage. By the interception, slowing and storage of road run off prior to cleansing through purpose built reed beds, water quality is released back to the SSSI at an acceptably slow rate and with reductions in concentrations of potential pollutants to levels that do not pose an unacceptable risk to reen water quality.
6. Whilst some short term rises (<24 hours) in concentrations are possible, these have been assessed using a site specific risk tool (HAWRAT) to be within acceptable limits for the protection of invertebrates. Furthermore, it is likely that longer term, baseline concentrations of pollutants within reens will not be affected.
7. It is also the case that the M4CaN is subject to a number of environmental commitments which make the contractor liable for meeting the water quality requirements of the proposed discharges to standards requested by NRW to protect the Gwent Levels SSSIs.

2.2.2. Response to **Point 2** (Concerns that highway runoff could present a risk to the ecological interest of the Gwent Levels SSSI):

1. The DMRB risk assessments undertaken for the proposed Scheme's treated drainage discharges have been undertaken using the Highways Agency Water Risk Assessment Tool (HAWRAT).
2. The Highways Agency (HA) has undertaken collaborative research in England with the Environment Agency (EA) to significantly improve the reliability and extent of existing data for pollutants and their concentrations found in road runoff from non-urban trunk roads and motorways (see attached EA Science Summaries SC020033 and SC020048).

3. The study identified those site characteristics that influence pollutant concentrations. The ‘significant’ pollutants of concern that are routinely found in road runoff and which pose a risk can be classified into two groups; those which affect water quality, and those which affect the aquatic habitat quality. In broad terms, the former are soluble metals which chemically impair biological functions due to short-term acute impacts and the latter are sediments which physically smother feeding and breeding grounds and when affected by sediment-bound pollutants produce long-term chronic impacts on ecosystems.

4. The pollutants modelled by HAWRAT fall within two groups – soluble metals and sediment bound metals and hydrocarbons as follows:

   a) Dissolved copper and zinc

   b) Total copper and zinc (adjusted for insoluble proportion)

   c) Total cadmium

   d) Total fluoranthene, pyrene, anthracene and phenanthrene

   e) Total PAHs

5. Depending on the type and form of the pollutant and its concentration and uptake by the organisms, the potential impact of the chemical pollutants can be either acute or chronic in nature. Acute effects are usually associated with certain metals and organic pollutants. Copper in a soluble form is particularly toxic and there are standards for concentrations in respect of general quality and sensitivity to fish. The more soluble or short chained organic pollutants such as herbicides may also cause acute effects.

6. Collaborative research has been undertaken by the Highways Agency and the Environment Agency to investigate the acute (short-term) effects of soluble pollutants on the ecology of receiving waters (see EA Science Summaries at Annex B to this rebuttal).

7. Using relevant toxicity data from tests on these organisms the results have been used to develop Runoff Specific Thresholds (RSTs) to protect receiving organisms from short-term exposure (six hours and 24 hours) to those significant pollutants identified in highway runoff. The RST 24 hour is designed to protect against worst case conditions whereas the RST 6 hour is designed to protect against more typical exposure conditions of aquatic organisms to soluble pollutants in highway runoff. For zinc, water hardness was found to have a significant effect on short-term toxicity such that toxicity values decreased with increasing water hardness. For cadmium and copper, water hardness was not found to have a significant effect on short-term toxicity.

8. Data from short-term toxicity tests carried out by Kings College London on a range of 13 algal, invertebrate and fish species (EA Science Summary SC020033) along with literature data for other relevant species, were used in the development of the RSTs. The species used in the RST derivation were largely UK resident species and included those with a range of sensitivities to the significant pollutants. The same taxonomic group proved not to be the most sensitive for all the pollutants of interest. In generating the RSTs a further assessment (safety) factor was applied to the no-effects threshold the study also looked at tissue metal contamination in native organisms captured downstream of outfall discharges as well as laboratory experiments on the effect on feeding rates of native organisms in contact with metal contaminated sediments.

9. The studies measured direct impacts on caged invertebrate populations deployed both up and down stream of each motorway discharge. In addition, caged bioassay invertebrate organisms were also deployed to measure impact on feeding rates either in-situ or pose exposures.

10. The organisms in question were:

    a) Sphaerium (pea mussel)

    b) Lymnaea (snail)

    c) Sericostoma (caddis)

    d) Wepobdella and Erpobdella (leeches)

    e) Gammarus (shrimp)

    f) Chironomus (midge larvae)

11. It is therefore the fact that ecological interest of the SSSI has been taken into account by both the scale and scope of the prosed run off treatment capability of the Scheme and the assessment of risk of the proposed treated discharges, which takes into account the potential harm to invertebrates being the most sensitive aquatic organisms representative of the SSSI ecological interest.

2.2.3. Response to **Point 4** (States that the cleaning efficacy of the proposed water treatment elements does not accord with published information):

1. The reduction of potential pollutant concentrations in run off prior to discharge to reens is based on DMRB guidelines on expected performance of each of the four stages of proposed run off treatment. Whilst pollution reduction efficacy of these systems is variable, the advice provided is based on sound knowledge of recommended typical performances informed from studies of road drainage schemes. Although there is a case to be made for using the upper bounds of the DMRB recommended efficacy figures, due to the robust design and scale of the proposed treatment systems, an assessment has been made on median (middle) figures to provide additional certainty of performance. I consider this is a reasonable approach which allows the risk to surface water quality from treated road run off to be soundly judged.

2. The original assessment provided in Appendix 16.3 to the March 2016 ES utilised DMRB and CIRIA suggested treatment efficacy values. However, the CIRIA SuDS document (C609) has since been re-issued and no longer provides such data and recommends assessment of road drainage SuDS using DMRB guidance.

3. For the purposes of this rebuttal, and to simplify the evidence provided, only DMRB provided figures have been utilised as these are the most appropriate for the M4CaN and supported by Welsh Government.

4. The one aspect of the CIRIA SuDS guidance that has been retained for the purposes of assessing likely water environment impact is the use of the cumulative assessment methodology whereas only the first treatment stage efficacy data is used as recommended, with all subsequent stages using only half the recommended efficacy values. This approach ensures multiple treatment stages are assessed realistically by reducing expected performance by a factor of 50%, which I consider a significant factor of safety for the assessment of potential impact to the SSSI.

5. The assessment of the multi-stage water treatment utilising DMRB median efficacy data applied using the CIRIA cumulative methodology is provided as Annex A to this rebuttal. The two principal groups of contaminants assessed are total suspended solids (TSS) and dissolved metals. The former group includes, in addition to suspended sediment, non-dissolved heavy metals and Polynuclear Aromatic Hydrocarbons (PAH).

6. The results of this revised assessment of likely cumulative efficacy show that prior to discharge of road run off to reens, suspended solids and non-dissolved pollutants will be reduced by a median value of 94.4% and that dissolved metals would be reduced by a median value of 83.5%. These are not absolute predictions but the results of the prescribed and reasonable approach used for the numerical calculation of pollutant reducing efficacy properly taking into account likely variability and performance of a series of individual treatment systems.

7. I am therefore content that the cleaning efficacy of the proposed water treatment elements does accord with published information.

2.2.4. Response to **Point 5** (States that there is an admission that the quality of the runoff discharges are inadequate (not achieving ABCs) and this conflicts with DMRB Vol2, Sect 3, HD45/09, 2.13, which cites the obligations in relation to water quality discharge to special areas like SSSIs):

1. The HAWRAT risk assessment is a tool for identifying whether a proposed drainage discharge is of an unacceptable risk to water quality based potential for ecological harm. The purpose of risk assessment is to identify whether unacceptable water quality impacts could result. The approach requested by NRW to achieve this within the Gwent Levels SSSI is the use of predominantly Water Framework Directive (WFD) compliant quality criteria referred to as Trigger Levels. These criteria are the concentrations, expressed either as maximum allowable concentrations or annual average concentrations, required to achieve good ecological status and are prescribed by NRW specifically for the proposed Scheme for the protection of the Gwent Levels SSSI.
2. The need to maintain baseline water quality (otherwise known as the Ambient Background Concentration or ABC) is not a requirement of the DMRB assessment methodology nor of NRW in seeking to determine whether the proposed treated run off discharges are acceptable. The assessment undertaken within Appendix 16.3 of the March 2016 ES provided, for completion, the likely treatment efficacy required to both preserve the ABC and additionally to remain within the WFD water quality thresholds since adopted by NRW as trigger levels. Paragraph 4.5.6 of this report states:

   "*It can be seen that the proposed WTA treatment train, whilst not achieving reen ABC within discharge waters, is likely to maintain reen conditions within the WQS/PNEC at the point of discharge.*"
3. The risk assessment therefore is supportive of the conclusion that the proposed provision of run off treatment systems is capable of protecting surface water quality to avoid pollution in accordance with the requirements of the Waster Framework Directive and NRW. This conclusion is also supported by NRW in the evidence of Dr Hatton-Ellis.
4. This conclusion, which is supported is therefore in accordance with DMRB Vol.2, Sect 3, HD45/09, 2.13.

2.2.5. Response to **Point 6** (Concerns that there is a discrepancy between the known ability of grass-lined drainage channels to deal with dissolved contaminants and the data in the Environment Statement):

1. The Environmental Statement water environment assessments as presented in Appendix 16.3 of the March 2016 ES utilised water treatment efficacy data provided DMRB and by CIRIA. Since the completion of this assessment, CIRIA have reissued this guidance and no longer recommend such data and state that assessment of road drainage should utilise DMRB methodology.

2. There is also the issue of swales and grass lined channels being interchangeable terms. Whilst grass lined channel can be considered a type of swale, the type proposed for the Scheme differ from generic description of swales in the following key areas:

   a) The proposed grass lined channels are impermeably lined so that run off water is retained in the channel. Conversely, swales often are designed to permit infiltration to collect in a buried carrier pipe to permit piped flow once percolation has taken place. This limits the residence time of water within the swale.

   b) The cross sectional area and length of the proposed grass lined channels are larger than typical swales more routinely incorporated into road drainage schemes. The larger size and length prevents overtopping during high rainfall storm events and thus promotes contact time with the grass lining and thus treatment potential.

   c) Due to the larger cross sectional area, the gradient of the proposed grass lined channels has been kept very low to allow their use on the flat embankments crossing the SSSIs. Such low gradients promote very slow water conveyance whilst preventing overtopping under all storm rainfall events within a 100 year return period allowing for 30% climate change.

   d) The proposed grass lined channels are designed with gradients of approximately 1 in 200 falls meaning that the velocity of draining water never exceeds a rate that would cause erosion, even during storm events. Calculations for the drainage design show that this maximum rate to be approximately 0.1 m/s. To put this velocity in context, typical walking speed is about 15 times faster. Put another way, a 1,000 metre section of grass lined channel would carry run off for over 167 minutes or 2¾ hours. The majority of grass lined channel are located at a greater flow distance than 1,000 metres prior to reaching a water treatment area. It is apparent that under typical rainfall events, potential pollutants in run-off will not flow directly to a WTA but in stages following larger rainfall events.

e) Such high residence times and staged flow along a grass lined channel toward WTA increases the treatment process for dissolved metals as these contaminants need the presence of free flowing water to exist. Once water percolates into the topsoil or evaporates due to the action of sun and wind, dissolved metals precipitate and become undissolved and typically form relatively insoluble compounds such as oxides and carbonates. In this way, larger and longer grass lined channels, and by necessity, all those serving longer sections of main roads, have an increased capacity to attenuate dissolved metals than more conventional swales serving smaller sustainable drainage systems as described by CIRIA. Indeed, CIRIA considers a SuDS swale to have an optimum minimum length of just 60 metres. This compares to a proposed grass lined channel provision of typically larger than 1,000 metres.

f) The very slow design rate of water movement through the proposed grass lined channels will not result in remobilisation of sediment bound metals leading to a re-release of soluble metals, which is a concern in higher flow swales particularly following higher rainfall events.

3. I therefore remain satisfied that the data used within the Environmental Statement is both consistent with the DMRB methodology and reasonably representative of the performance of grass lined channels in the specific setting proposed for the scheme.

2.2.6. Response to **Point 7** (States that there is a conflict between the water quality of the discharge following treatment and the requirements of the SSSI water quality):

1. As stated for point 5 above, I am satisfied that the risk assessments for the proposed treated drained discharges will be, for the potential run off derived pollutants of concern generated by the scheme, within water quality criteria prescribed by NRW for the protection of the Gwent Levels SSSI, which are also largely consistent with Water Framework Directive requirements for good ecological status. This is a conclusion also reached by NRW's water quality expert witness, Dr Hatton Ellis as stated at 6.11 in his Proof of Evidence.

2.2.7. Response to **Point 8** (Questions the proposed system's ability to produce adequate water quality run off for the SSSI and in heavy rain events):

1. The drainage for the proposed scheme has been designed to accommodate all rainfall events within a 100 year return period with a 30% additional provision to account for climate change. The grass lined channels have been designed to convey drainage flows within this annual event probability at very slow rates of approximately 0.1 m/s regardless of storm rainfall intensity or duration.
2. The water treatment areas contain an appropriately sized attenuation ponds sized to contain the volume of water associated with the most significant storm event (the design storm). Storm water volumes received by the attenuation lagoon from the grass lined channels (via the pollution control lagoon) are flow controlled to the equivalent green field run off rate prior to discharge to the constructed reed bed. The pollution control lagoon acts as a protection of the lagoon to ensure higher storm water volumes do not cause disturbance of the attenuation lagoon and remobilise accumulated sediments contained therein.
3. It can be appreciated then that these drainage design features have water treatment functions that are resilient of heavy and/or long duration rainfall events. Accordingly, I am satisfied that the proposed system's ability to produce adequate water quality run off for the SSSI will be unaffected by such rainfall events.

2.2.8. Response to **Point 9** (States that there is over estimation of the effectiveness of reed bed treatment, particularly during high flow rates and phosphates):

1. As described in the response to Point 8, the reed bed is design protected from variation in flows due to storm events as a consequence of the proposed design of the water treatment areas. The reed beds are located as the final stage of treatment as they function best where pollutant levels are lower as a consequence of the previous treatment systems efficacy, and less vulnerable to significant flow variation. The purpose of the reed bed is to filter out potential pollutants by a number of chemical processes that occur within the root zone, including the conversion of remaining soluble metals to insoluble compounds that remain within the root zone. Over time, accumulation of heavy metals will occur, which is entirely in accordance with the understood functioning of reed beds. A programme of inspection and maintenance is therefore essential to ensure the long term performance of these treatment systems. To this end, a commitment will be made by Welsh Government to undertake such inspections and maintenance according to DMRB requirements. This would include in time, the staged removal and replanting of reeds, which would be disposed of as necessary according to their waste classification.
2. As explained for Point 4, the treatment efficacy for reed beds is taken as a median value from the range prescribed by DMRB. The constructed design and scale of reed beds proposed takes account of Environment Agency guidance to ensure good functionality – a feature not commonly present for most road drainage scheme where reed beds are typically under sized or poorly maintained. I am therefore satisfied that a median value for treatment efficacy is appropriate.
3. Phosphate, which is a primary constituent of domestic waste, and in addition to ammonia, a pollutant of concern within the Gwent Levels SSSI owing to their affect as nutrients and the cause of eutrophication of reens, is not a pollutant produced by road traffic and is therefore of no relevance to the assessment of reed beds as water treatment systems for road run off.

2.2.9. Response to **Point 10** (Asserts that the reed beds will be rendered ineffective during extreme rainfall as a consequence of inundation):

1. Further to the description of reed bed resilience to intense rainfall events provided in the response to Point 8, the reed beds proposed for the scheme comprises sub-surface flow wetlands. These are designed to pass water via the root zone only to ensure high treatment efficacy. In comparison to surface flow wetlands, standing water is not present and the issues associated with inundation on treatment efficacy, e.g. water being allowed to flow above the level of the rooting medium.
2. Accordingly, the proposed reed bed design ensures adequate functionality under all rainfall events within a 1 in 100 year return period with an additional 30% accommodation for climate change.

2.2.10. Response to **Point 11** (Concerns that there would be conflict between the design discharge rates and the water treatment systems under extreme conditions):

1. It is apparent from previous responses to points regarding treatment functionality under extreme conditions that the proposed water treatment areas are designed to capture, store and discharge storm water at an appropriate rate (as agreed with NRW) whilst maintaining treatment efficacy to ensure no conflict is present between the design discharge rates and the water treatment systems under extreme conditions.

2.2.11. Response to **Point 12** (Concerns that discharge of contaminated water into the Gwent Levels presents a serious risk of eradication of populations of some species):

1. It has been demonstrated in the responses to previous points that the proposed scheme's drainage design and water treatment provision has adequate resilience to extreme rainfall. Furthermore, the functionality of water treatment is adequate to lower potential pollutants in discharges to acceptably low concentrations that are protective of sensitive aquatic species.

2.2.12. Response to **Point 14** (States that the design for dealing with surface water runoff from the highway should only be discharged into 'main rivers' as discharging to the ‘IDB reens’ and not the ‘main rivers’ poses a significantly greater threat to the SSSIs):

1. The drainage design has responded to and therefore constrained by the need to maintain embankment heights through the Gwent Level SSSIs at the lowest height possible to minimise land take as well as reducing other environmental impacts, i.e. landscape impact and construction material volumes.
2. The consequence of such a design is that gravity falls are constrained by summer penning levels within reens and therefore the proposed new section of motorway cannot be drained solely to Main River reens (formerly IDB reens). I accept that such water courses would provide higher flows, there would be a greater drained area of motorway discharging to a smaller number of watercourses. This would require potentially larger scale treatment provision leading to greater land take. Also, if higher embankments are to be avoided and the associated SSSI land take, reliance would be needed on non-gravity drainage systems incorporating some degree of pumping. This would not comprise a fail-safe design and subsequently increase the risk of uncontrolled discharges of potentially untreated road run off to reens within the SSSIs.
3. The drainage design proposing discharge of treated road run off to Internal Drainage District (IDD) maintained reens as well as Main River reens has been accepted in principal by NRW.

2.3. Michael Vaughan (Flood Consequences)

2.3.1. Response to **Point 13 & 14** (States that the designed system is inadequate; a simple safeguard to system failure is possible):

1. The Proof of Evidence of Michael Vaughan WG 1.17.1 addresses this matter at paragraphs 5.5 to 5.38.
2. An option to route highway discharge directly to the sea was considered at an early stage within the KS3 design process. However this was rejected in favour of attenuating and treating highway run-off and discharging to the local reen system.

3. The option to discharge highway runoff to the sea would have to include 10 new major outfalls. As the ground has little, if any, gradient towards the coast, it would not be possible to utilise pipes to convey water to the sea. New reens or ditches (open channels) would have to be used.
4. Those channels would need to be hydraulically independent from the rest of the reen/ditch network to ensure that untreated highway runoff was prevented from entering that system. The new highway ditches would need to cross a large number of the existing reens and field ditches. To maintain connectivity in the existing reen system, the new highway ditches would need to be siphoned under each crossing point. Siphon structures are dangerous and are maintenance liabilities. They are very much last resorts on new drainage systems and are avoided if at all possible. The alternative would be to separate the Gwent Levels into 10 hydraulically independent reen systems. This was also considered unacceptable.
5. The new highway ditches would also need to be embanked to prevent flood water from the Gwent Levels and reens entering the new highway ditches, and vice versa.
6. Given the shallow gradient on these channels, and the fact that ground levels often rise towards the sea, the stand alone drainage channels could be as deep as 3m in places. The top width could be as much as 10m. This option would fundamentally change the hydraulic behaviour of the existing system, and would impact on land take, cost and the SSSI.
7. An additional 10 outfalls would need to be constructed through the existing sea defences on the Gwent Levels. The construction of these outfalls introduces additional risks of tidal flooding to the Gwent Levels.
8. An alternative would be to introduce 10 major pumping stations to pump water to the estuary. It was not considered sustainable to pump all the surface water landing on the highway to the Severn Estuary in perpetuity. In addition, pumping stations are prone to failure increasing the risk of spilling untreated highway runoff to the Gwent Levels
9. The preferred scheme includes the discharge of attenuated and treated highway water to existing or new reens. Overtopping of these reens during flood is a risk under the present day conditions.

10. The Scheme has mitigated the risk of additional flooding, rather than by embanking those receiving watercourses to contain the runoff, by:

    a. ensuring that the drainage system is designed to accept flows up to the 1 in 100 year return period event with a 30% allowance for climate change. Whilst this does not remove the risk of the system failing, it reduces the risk to less than 1% per annum.

    b. restricting discharges from the water treatment areas to a ‘greenfield’ rate of 3.5l/s/ha, providing both volumetric and peak rate attenuation. The peak flow being passed in to the receiving reen system is somewhat less than might arrive under the current conditions. This in itself will reduce the risk of overtopping of the reens and ditches.

11. This scheme is defined in Table 1 in the Drainage Strategy Report in the Environmental Statement (Document 2.3.2), Volume 3 Appendix 2.2. For the reasons listed above this option is preferred to either dedicated channels or pumping stations to convey flow directly to the estuary.

2.3.2. Response to **Point 15 & 16** (Suggests that all channels designated for discharge water should be examined for the risk of over-topping as the black route traverse the lowest part of the Gwent Levels where the freeboard ditches are the smallest):

1. We can consider a response for all channels:, the grass lined channels as part of the drainage Scheme, the water treatment areas; and the receiving watercourses.

2. The grass lined channels conform with the UK SuDS standard, as described in the 2015 CIRIA SuDS Manual (C753), with flow velocities of 0.1m/s.

3. The lagoons are designed to attenuate the 1 in 100 year flood with 30% allowance for climate change to a runoff rate of 3.5 l/s/ha, and each lagoon includes a measure of freeboard in its design. The risk of overtopping will be less and 1% per annum. This storage and attenuation will be achieved through use of a vortex flow regulator, which will pass forward the design flow, at 3.5 l/s/ha, at the specific design head.

4. UK SuDS guidance as described in the 2015 CIRIA SuDS Manual (C753) describes the use of long term storage which is intended to provide a volumetric restraint, as opposed to flow control. Your suggested release rate of 2l/s/ha is intended to mimic the natural percolation of water through the soils. It is this volume that should be prevented from leaving the site (via infiltration or harvesting) or where this is not possible, controlled so that it discharges at very low rates that will have negligible impact on downstream flood risk. The guidance requires that only the greenfield runoff volume should be allowed to discharge at greenfield rates. However, the full guidance requires us to restrict all runoff to the maximum of either 2 l/s/ha or QBAR greenfield runoff.

5. Using the same guidance, the greenfield runoff rates for the Scheme are 3.7 l/s/ha for the 1 in 2 year storm, and 8.1 l/s/ha for the 1 in 100 year storm. Hence the design could either attenuate runoff during the 1 in 2 year event to 3.7 l/s/ha, and the 1 in 100 year event to 8.1 l/s/ha; or to attenuate all flows to 3.7 l/s/ha. In fact, the hydraulic design approach has been to attenuate the permitted pass-forward flow to a lower 3.5 l/s/ha. Hence, both flow and volumetric storage are suitably provided for.

6. The reedbed designs are based on the attenuated flows form the attenuation lagoons, at 3.5 l/s/ha.

7. The drainage design is based on the higher summer penning levels, in the receiving reens, as their discharge levels. As the existing reen network is heavily regulated and controlled, it is assumed that, with the natural baseflow contributions, the summer penning level would be held during any future drought periods. This is precautionary. Winter penning levels are lower and as such the design assumption is again precautionary.

8. Discharges from the Scheme are minimised through the releases being restricted to 3.5 l/s/ha for all events up to the 1 in 100 year storm with 30% allowance for climate change. The drainage and attenuated discharges have been included in the hydraulic modelling. The results from this modelling process demonstrate that the proposed drainage causes no detriment to fluvial or surface water flood risk. This may even reduce flood risk form those reens. The risk of overtopping within the receiving watercourses will be unchanged from the present day.

9. The Proof of Evidence of Michael Vaughan WG 1.17.1 also addresses similar matters at paragraphs 4.69, 5.6 to 5.14.

2.3.3. Response to **Point 17** (Suggests engineering alterations including embanking any Gwent Level watercourses):

1. As described above, the risk of overtopping in the receiving channels will not increase as a result of the Scheme, where all runoff rate and volume are restricted to 3.5l/s/ha. This was proven through the hydraulic modelling.

2.3.4. I confirm that the statement of truth and professional obligations to the inquiry from my main proof still applies.

Annex A

4 Stage	Input	GLC	Output	Pond Forebay	Output	Sedimentation Pond	Output	SFF Wetland	Output	4 Train efficiency %
TSS	100	80	20.0	45	15.5	80	9.3	80	5.6	94.4
Heavy Metals - dissolved	100	65	35.0	15	32.4	30	27.5	80	16.5	83.5
Oil & Grease	100	80	20.0	45	15.5	45	12.0	80	7.2	92.8

3 Stage		100		50		50		
	Input	Pond Forebay	Output	Sedimentation Pond	Output	SFF Wetland	Output	3 Train efficiency %
TSS	100	45	55.0	80	33.0	80	19.8	80.2
Heavy Metals - dissolved	100	15	85.0	30	72.3	80	43.4	56.7
Oil & Grease	100	45	55.0	45	42.6	80	25.6	74.4

		%		%		%		%					
	AF reduction factor (%)	100		50		50		50					
Stage percentile	Input	Stage 1 Grass Lined Channels	Stage 1 Output	Stage 2 Balancing Pond (Forebay)	Stage 2 Output	Stage 3 Sedimentation Pond	Stage 3 Output	Stage 4 SSF Wetland	Stage 4 Output		Percentile	4 train AF	3 train AF
Min TSS	100	60	40.0	30	34.0	60	23.8	60	16.7	TSS	0	**83.3**	
25th %ile TSS	100	70	30.0	37.5	24.4	70	15.8	70	10.3		25	**89.7**	
50th %ile TSS (median)	100	80	20.0	45	15.5	80	9.3	80	5.6		50	**94.4**	**80.2**
75th %ile TSS	100	90	10.0	52.5	7.4	90	4.1	90	2.2		75	**97.8**	
Max TSS	100	100	0.0	60	0.0	100	0.0	100	0.0		100	**100.0**	
Min Dissolved Metals	100	30	70	0	70.0	0	70.0	60	49.0	Dissolved metals	0	**51.0**	
25th %ile Dissolved Metals	100	47.5	52.5	7.5	50.5	15	46.7	70	30.4		25	**69.6**	
50th Dissolved Metals (median)	100	65	35	15	32.4	30	27.5	80	16.5		50	**83.5**	**56.7**
75th %ile Dissolved Metals	100	82.5	17.5	22.5	15.5	45	12.0	90	6.6		75	**93.4**	
Max Dissolved Metals	100	100	0	30	0.0	60	0.0	100	0.0		100	**100.0**	
Min PAHs	100	60	40	30	34.0	30	28.9	60	20.2	PAH	0	**79.8**	
25th %ile PAHs	100	70	30	37.5	24.4	37.5	19.8	70	12.9		25	**87.1**	
50th %ile PAHs (median)	100	80	20	45	15.5	45	12.0	80	7.2		50	**92.8**	**74.4**
75th %ile PAH	100	90	10	52.5	7.4	52.5	5.4	90	3.0		75	**97.0**	
Max PAHs	100	100	0	60	0.0	60	0.0	100	0.0		100	**100.0**	

	Total Suspended Solids (TSS)		**Dissolved Metals**		**PAHs**	
	Min	Max	Min	Max	Min	Max
1 Grass Lined Channels	60	100	30	100	60	100
2 *Balancing Pond*	30	60	0	30	30	60
3 Sedimentation Pond	60	100	0	60	30	60
4 SSF Wetlands	60	100	60	100	60	100

Annex B

science summary

Environment Agency

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Highway runoff: Effects of soluble pollutants on the ecology of receiving waters

Science Summary SC020033

A tool to assess the risks to aquatic organisms from highway runoff has been developed by scientists from WRc and King's College London, working with the Environment Agency and Highways Agency. Using this tool, engineers can assess the environmental aspects of new road projects whilst Environmental Agency staff can advise on the risks from highway runoff and pinpoint sites of particular concern.

After a period of rain, surface water from highways is often drained into nearby streams and rivers. However, we know that this runoff can contain pollutants, either in solution or bound to sediment particles. The Highways Agency has embarked on a programme to improve its methods for predicting the ecological impacts of new or modified highway drainage schemes. This would be used to highlight those schemes where risk reduction steps might be necessary to ensure they would not affect local ecology. Schemes should also satisfy the chemical requirements of the Water Framework Directive in the receiving water by not breaching Environmental Quality Standards (EQSs).

The research programme comprises three projects:

- *Improved determination of pollutants in highway runoff*
- *Effects of insoluble pollutants on the ecology of receiving waters*
- *Effects of soluble pollutants on the ecology of receiving waters*

This summary refers to the last project, carried out in collaboration with the Environment Agency.

The first step was to develop runoff-specific thresholds (RSTs). These are water quality benchmarks designed to protect organisms from short-term (six and 24 hour) exposure to substances which have previously been measured in the dissolved phase of highway runoff at significant concentrations (such as cadmium, copper, zinc, fluoranthene and pyrene). Although EQSs are already available (or are near completion) for these substances, they protect against long-term exposure and do not adequately account for the very short periods of exposure typically seen with highway runoff (where the average duration is four hours).

RSTs were derived by analysing published ecotoxicity data from experiments carried out over short periods or studies initiated by Kings College London for this project. Thresholds were generated using a probabilistic or deterministic approach depending on the quantity and quality of available short-term (six and 24 hour) toxicity data. Two RSTs were developed for each substance: the RST_{24h} is a stringent threshold below which aquatic organisms are not expected to be at risk. In contrast, exceeding an RST_{6h} would mean receiving water organisms are probably at risk. Where samples have concentrations between the RST_{24h} and RST_{6h} values the receiving water organisms are probably not at risk, but this requires confirmation. Metals are problematical because their toxicity is affected by water hardness, so the effects of hardness need to considered.

Chemical analyses of sampled highway runoff showed that mean concentrations for cadmium, fluoranthene and pyrene were always markedly lower than the derived RSTs, and so these substances are not likely to pose a risk. Only the RSTs for copper and zinc are required to assess the impact of highway runoff on receiving water communities. For these substances, the RSTs are more likely to be exceeded in undiluted highway runoff when traffic density is high (band 5: AADT 80,000 to 119,999 and band 6: AADT 120,000 to 200,000). However, we saw no effect of climatic zone. For both copper and zinc, more than 97 per cent of runoff samples posing a potential risk would require less than five times dilution to satisfy the RST_{6h} values, but a small group of samples contained high dissolved zinc concentrations that would need greater dilution.

We validated this approach using previously collected chemical and biological data. Information on pollutant concentrations in highway runoff and biological survey data from a previous project were used to compare predicted and measured effects of a range of runoff events on the receiving water organisms.

The tool uses a two-tier approach. In the first tier, levels of substances in highway runoff (before and after treatment) at several sites are compared with RSTs to assess whether there is a potential for ecological impact. The second tier focuses on locations where pollutant concentrations in untreated and/or treated runoff have exceeded one or more RST. The method determines whether the RST exceedance(s) would be removed by dilution downstream of the runoff or by local water quality conditions (such as hardness).

We were concerned not to propose thresholds that were too precautionary (which might prompt unnecessary action) or which were not stringent enough (and thus fail to protect aquatic organisms). Therefore, we compared our predictions with the results of biological surveys (*in situ Gammarus* deployments) carried out at the Voss Stream site, near Plympton, Devon which receives runoff from the A38. The available evidence was limited but there was no indication that the RSTs were too precautionary. We could not tell from the limited data whether or not they were under-precautionary.

To summarise, RST_{24h} values are derived using 24-hour exposure data for soluble pollutants. This is precautionary because 24 hours is longer than the average exposure of four hours that organisms are likely to experience in receiving waters during highway runoff events. RST_{6h} values for copper and zinc are more realistic thresholds for assessing risks.

If the design process shows that the RST_{24h} will be achieved, it is predicted that highway runoff (either before or after treatment) will not cause short-term adverse effects in a receiving water.

If the design process shows that the RST_{24h} will not be met, there is a possibility of short-term adverse effects in the receiving water. The tool uses a graded classification: 'not at risk', 'probably not at risk' and 'probably at risk' using RST_{24h} and RST_{6h} values for copper and zinc.

Based on these principles, we have developed an assessment tool to predict the impact of highway runoff discharges on the ecology of receiving waters. This can be used by engineers and by Environment Agency staff to assist in the future design of highway drainage schemes. It will help focus attention on those sites where there is a risk from pollutants in road runoff and, also, to avoid investing resource in situations where there is no risk to ecology.

The tool: (1) predicts the range of concentrations of copper and zinc in untreated undiluted highway samples over a long release period (ten years); (2) identifies how frequently (and for what duration) the RST_{24h} and RST_{6h} for copper and zinc may be exceeded at a given site; and (3) identifies the level of treatment and/or dilution required to achieve the RSTs in the receiving water.

In Tier 1 of the tool's approach, RST_{24h} values are used as stringent design standards and these can be compared to predicted runoff concentrations of zinc and copper in undiluted highway runoff at a location (effectively a "worst case" scenario). Further precaution is provided by setting the frequency of exceedance at a stringent level (such as only once per year) so that non-risky schemes can quickly be screened out.

In Tier 2, the assessment becomes more realistic and includes the use of RST_{6h} values which are designed to protect receiving water organisms against exposure to copper and zinc over timescales typically found during highway runoff events. It also takes into account factors such as treatment prior to discharge, available dilution in the receiving water as well as the physico-chemical characteristics of the receiving water (like hardness).

This summary relates to information from Science Project SC020033, reported in detail in the following output(s):

Science Report published by the Highways Agency:
Title: Highway Runoff: Effects of soluble pollutants on the ecology of receiving waters

Internal Status: Released to all regions
External Status: Publicly available

Project manager: Paul Whitehouse, Environment Agency Science Department

Research Collaborator: Highways Agency

HIGHWAYS AGENCY

Research Contractor: WRc, Kings College London

This project was part-funded by the Environment Agency's Science Department, which provides scientific knowledge, tools and techniques to enable us to protect and manage the environment as effectively as possible.

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science summary

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Environment Agency

Accumulation and dispersal of suspended solids in watercourses

Science Summary SC020048

A novel risk assessment procedure to prioritise sites likely to be affected by highway-derived sediment is outlined in a new report. A five-year research programme jointly funded by the Highways Agency and the Environment Agency included three projects which assessed the ecological impacts of highway storm runoff,

- *Effects of insoluble pollutants on the ecology of receiving waters*
- *Improved determination of pollutants in highway runoff*
- *Effects of soluble pollutants on the ecology of receiving waters*

This project, on insoluble pollutants, identifies the scenarios under which contaminated sediment in runoff would be likely to have a negative impact on receiving-water ecology.

Key findings and recommendations of the report:

- Total mass of sediment discharged during the monitoring programme was highly variable between sites.
- The concentration of contaminants in runoff sediment samples did not vary greatly between different field sites.
- Damage to biological communities was observed downstream of some runoff outfalls and highway-derived contamination was measured in animal tissue.
- Highway-derived sediment that had accumulated in a receiving watercourse was toxic to selected invertebrates in lab tests.
- Sites at which the receiving watercourse flowed too slowly to disperse sediment were particularly prone to negative ecological impacts.

Risk assessment procedures should therefore take account of the mass of sediment discharged annually as well as the concentration of contaminants associated with that sediment. Most importantly though, the propensity of the receiving watercourse to accumulate or disperse sediment must be assessed.

In the study, the effects of sediment in runoff were investigated at six highway outfalls using both field and laboratory investigations. Native invertebrate communities were monitored upstream and downstream of each outfall. Sediment toxicity was assessed in both laboratory and field "in situ" tests with five species of aquatic invertebrate. The field sites were selected from a potential pool of approximately 1,800 known sites and were short-listed according to desirable characteristics including: a traffic flow greater than 30,000 vehicles per day, a relatively diverse watercourse community and minimal or no treatment of highway runoff. Field sites were restricted to relatively small receiving watercourses. The overall approach was to represent realistic worst case conditions. Site selection was done in 2003.

The six field sites were Penrith (M6/River Petteril), Newton Aycliffe (A1/River Skerne), Sheffield (M1/Pigeon Bridge Brook), Birmingham (M5/River Salwarpe and M42/River Arrow) and Stowmarket (A14/River Sapiston trib). Receiving watercourses at three sites were fast-flowing and dispersed sediment away from the point of discharge (M6, M5 and A14). The remaining three sites were slow-flowing and accumulated sediment. Field investigations were carried out every three months for a period of two years (2004 and 2005) and laboratory investigations were completed by the end of 2006.

As well as intensive monitoring and investigation of impacts at field sites, the inputs of sediment material and the quality of that sediment were assessed during ten storm events at each site. Properties such as contaminant loading and particle size distribution were compared between samples of storm runoff and samples of accumulated bed sediment. Rainfall and river depth/velocity were continuously monitored by data loggers at each site during 2005 and 2006.

Following the field and laboratory investigations, a risk assessment procedure for insoluble contaminants was developed in 2007. This uses predictions of contaminant concentrations resulting from a separate modelling project. (Crabtree, B. "Improved Determination of Pollutants in Highway Runoff – Phase 2: Final Report" WRc Report UC7697, 2008). Predicted sediment contamination is compared to trigger values at which toxicity is expected (derived from extensive literature review). Subsequently, the prediction of toxicity may be refined by considering local conditions that may remove toxicity (binding phases in sediment that can sequester contaminants). If sediment is predicted to be hazardous, the ability of the receiving watercourse to disperse sediment is assessed. Finally, at sites that are predicted to accumulate sediment, the potential extent of annual sediment coverage is estimated.

After designing the risk assessment procedure, it was applied to a further six field sites and the outcomes were compared to actual field conditions. These sites incorporated three watercourses that were predicted to disperse sediment (Penrith M6/Gill Beck, Leeming Bar A1/Bedale Beck and Lockerbie M74/Dryfe water) and three that were predicted to accumulate sediment (Sheffield M1/Rockley Dike, Worcester M5/Spetchley Brook and an unnamed watercourse crossing the A14 at Huntingdon).

At all sites, highway-derived particulate material was predicted to exceed the trigger values at which toxicity is expected. The risk assessment procedure successfully identified sites that dispersed and accumulated sediment. Assessment of ecological impact was complicated by the extensive flooding that occurred in 2007, and dramatic changes in the habitats at all sediment-accumulating sites were observed. Nevertheless, it proved possible to use data collected during the 2003 site selection procedure as a comparator. Overall, the sites predicted to be impacted by accumulated sediment were observed to be impacted. But some evidence of community impacts were also found at two of the dispersing sites (M6/Gill Beck and M74 Dryfe Water). Observed impacts may therefore be a result of soluble contaminants present in the water column and this highlights the need for separate assessment of soluble contamination. (reported in: Johnson, I and Crabtree, B. "Effects of Soluble Pollutants on the Ecology of Receiving Waters – Final Report" WRc Report UC7486/2, 2008).

This report is relevant to highway designers and environmental regulators responsible for the assessment, design and management of highways.

The Highways Agency's research programme (Crabtree et al, 2006) identified that some aspects of its guidance for assessing the impacts of highway runoff was based on data that may not be representative of the pollutants and concentrations currently found in highway runoff under UK conditions. The focus of the Highways Agency's ongoing research programme, in partnership with the Environment Agency, is to collect data to better understand the nature and impacts of pollutants in highway runoff.

The key aims of this research programme are to develop a model to predict pollutant concentrations in highway runoff and to develop ecologically based standards for receiving waters in order to control the impact of soluble and insoluble pollutants in highway runoff. The research outputs will be taken into consideration by the Highways Agency in future revisions of the Design Manual for Roads and Bridges, specifically HA216 *Road Drainage and the Water Environment*.

This summary relates to information from Science Project SC020048 reported in detail in the following output(s):

Science Report produced by the Highways Agency: Y91925, May 2008

Title: Accumulation and dispersal of suspended solids in watercourses

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Project manager: Phil Chatfield, Science Department

Research Collaborator: Highways Agency

Research Contractor: ECUS, University of Sheffield, University of Warwick

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