STORMWATER SHEPHERDS

Opinion piece: Design models for water quality treatment of highway runoff

We have three methods to design water quality treatment schemes for urban runoff in England and they differ significantly. Which one is properly protecting the environment? Are any of them properly protecting the environment?

Consider the runoff from a highway with a traffic density of approximately 50,000 annual average daily traffic movements (AADT). The highway outfall, in this instance, discharges to surface water. When it's raining, the runoff from the outfall looks like this.

The analysis of a sample from a road like this shows levels of polyaromatic hydrocarbons that exceed the Environmental Quality Standards and levels of the toxic metals, copper and zinc, that potentially exceed the EQS. The runoff also contains tyre-wear particles that leach out toxins, and very high levels of suspended solids that contaminate the bed of the watercourse.

To design a treatment scheme that reduces this pollution by capturing and retaining a proportion of the pollution, a designer might use one of three methods. Each will consider the risk of pollution; each will define the amount of treatment required, and yet each will give a significantly different answer. How can this be right? Which, if any, of these methods is delivering a treatment scheme that is adequate?

If the AADT is 50,000 or below, the designer can use the method set out in Chapter 26 of CIRIA C753, the SuDS Manual. If the AADT is 50,001 or above, the designer can use the method set out in the National Highways Risk Assessment Tool (HEWRAT) and then the design guidance in National Highways' Design Manual, DMRB. If the discharge contains Priority Hazardous Substances (PHS) in levels that exceed the Environmental Quality Standard (which we have illustrated that it does by sampling), the designer should use the Environment Agency Permitting Guidance for intermittent discharges to surface water containing PHSs.

So, what does Chapter 26 of the CIRIA C753 SuDS Manual say?

The Manual assigns a set of three Pollution Hazard Indices to the runoff, quantifying the anticipated level of pollution using factor-less indices. These signify the level of pollution for total suspended solids, metals and hydrocarbons.

For a highway with an AADT of between 300 and 50,000 those indices are:

- Total Suspended Solids 0.7
- Metals 0.6
- Hydrocarbons 0.7

The Manual then directs the designer to create a SuDS Treatment Train that contains adequate mitigation for that pollution hazard. Using the Manual, this Treatment Train could, for example, be

A bioretention system or raingarden;

A wetland with suitably sized upstream sediment capture;

A sediment separator followed by a pond;

A filter drain, followed by a basin pond or wetland;

A swale, followed by a basin, pond or wetland.

The Manual dictates that the selected Treatment Train should be sized to treat the runoff from a 1 in 1year, 15-minute rainfall event, and it provides the necessary treatment volumes for ponds, basins and wetlands.

It provides detailed design guidance too, setting out requirements for infiltration rates, depth of water, flow velocities etc.

The Manual also includes details of the necessary maintenance operations for each of these devices.

What do HEWRAT and the DMRB say?

The outfall in the photograph doesn't appear in the National Highways lists of high priority outfalls and must therefore be considered to be medium or low-risk, or the risk assessment hasn't been completed. But there is a recognised risk. We know from sampling that this outfall discharges runoff that exceeds the EQS for polyaromatic hydrocarbons. So surely the risk assessment must be completed and properly reflect the level of the risk of pollution. And the risk is measurable, so the assessment should quantify that risk.

If the HEWRAT risk assessment is carried out for these outfalls, and it identifies that an outfall poses a risk of pollution, it then quantifies the level of treatment required to reduce the pollution to an acceptable level.

So, for example, another highway outfall with similar traffic densities, for which a risk assessment has been completed, showed that treatment of the runoff **was** required to mitigate the risk.

The discharge was from a highway surface catchment area of 5.38ha draining into a watercourse with a Q95 flow of 0.001m3/sec. The risk assessment concluded that there was no risk of pollution from suspended solids or hydrocarbons, but that 60% of the dissolved metals need to be removed before the discharge into the Brook.

But remember that the CIRIA C753 SuDS Manual identified a pollution hazard for suspended solids and hydrocarbons that had to be mitigated, so how can the two methods deliver such different results? Which one is correct? Or perhaps neither of them are correct.

The solution that was then designed using DMRB concluded that a swale or a filter drain and then a drainage basin would remove enough pollution to properly protect the environment. In this, the SuDS Manual would agree – a swale or filter drain, followed by a basin could adequately mitigate the pollution from this road.

But, in order to deliver the necessary mitigation, effective infiltration into the swale must occur, the swale must run the entire length of the highway drained, the filter drain must contain treatment media to capture dissolved pollutants, and the basin must be big enough to retain the design treatment volume, Vt, and to empty within 72 hours. It is not clear from the drawings if these design criteria have been met, and therefore it is possible that the treatment components will not actually deliver the required level of treatment to protect the stream from pollution.

And, although the HEWRAT risk assessment identifies no risk of pollution from sediment (total suspended solids), the samples of similar highway runoff contain very high levels of suspended solids and the CIRIA SuDS Manual identifies it as a significant risk of pollution from highway surfaces. So how can the two risk assessment processes differ so widely?

Where does the Environment Agency Permitting Guidance for intermittent discharges to surface water containing Priority Hazardous Substances (PHSs) fit in?

The Environment Agency in England provides details of how to carry out a risk assessment if you are applying for a bespoke permit that includes discharging hazardous chemicals and elements to surface water. The guidance is available here: https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit

Since we know that the discharge from the highway in question contains Priority Hazardous Substances in levels that exceed the EQS from the samples we have taken, theoretically, the highway authority should carry out this risk assessment.

Risk Screening: The first stage is a screening process. The screening process helps the applicant to decide whether the releases to water are a risk to the environment and whether they need to do a more detailed assessment of them. Assessing the impact of emissions which are not screened out and are a risk to the environment is known as 'detailed modelling'.

Risk Assessment: If the discharge 'fails' all four steps of the risk screening process, the Environment Agency should carry out the detailed water quality risk assessment for the discharge. They do this routinely for industrial discharges to the water environment. This risk modelling takes into account the level of pollution, the dilution provided in the receiving watercourse, mixing, the proximity to protected habitats and compliance with Statutory Standards. The output from this risk modelling will identify how much treatment the discharge must receive before it enters the water environment in order to prevent harmful levels of pollution.

It is unclear why the Environment Agency in England does not require the completion of these risk screening and risk modelling processes for discharges of highway runoff, when they know that they contain levels of PHSs that exceed the EQSs.

The same process should also be carried out for discharges to groundwater where one could argue that the need for good environment protection is even more urgent.

We have completed the four steps of the risk screening process for a highway outfall off a motorway in Preston and it failed all four steps. This means that the risk of pollution from that outfall should be modelled by the Environment Agency, and the level of treatment required to prevent pollution should be identified and delivered. This does not happen.

Do any of them work well?

The three risk assessments processes differ significantly. Are any of them adequate?

It can't be right that the three risk assessments say different things and have different outputs for the same discharge. The risk of environmental harm is measurable; the risk factors are known and the levels that must not be exceeded are published.

It is for the Environment Agency to unpick this problem and to state how the risk must be assessed. But it cannot be enough for them to refer back to an out-of-date risk assessment model, and to allow the polluter to run the model themselves under the auspices of a voluntary agreement. It is time that this pollution was brought into the formal Permitting process like other known sources of harmful pollutants, either using a new Standard Rules Permit process or bespoke Permits.

The CIRIA SuDS Manual

For our example of a road with approximately 50,000 AADT, the SuDS Manual can work well. However, this process misses the risk of harm to the natural environment **within the treatment train.** Because the runoff contains toxic, bioaccumulative pollutants such as copper, Benzo(a)pyrene and tyre-wear particles, it is unacceptable to expect nature to suffer this harm and to accumulate this load of pollutants.

It is fine to expect nature and natural processes to 'deal with' lower levels of pollution, where soil horizons and wetted environments provide micro-organic degradation, assimilation, precipitation, nutrient uptake and more. But for grossly polluted highway runoff, there must be pretreatment to remove some of the pollutant load before we ask nature to 'do its thing'. However, there are pre-treatment devices available already, and new ones are coming to market all the time; by including these upstream of the nature-based, vegetative devices, an effective treatment train can be designed and delivered for highways with traffic volumes up to 50,000 AADT using the SuDS Manual risk assessment and design details.

Remember that the polyaromatic hydrocarbons have biodegradation rates in the order of months to years, and that they bioaccumulate within organisms, so to assume that they simply 'degrade away' in vegetative treatment devices is untrue. The soils within a swale may be 'dosed' with highway runoff over 150 times a year, so the levels can remain high and the harmful effects persist.

The SuDS Manual provides detailed information on the design and sizing of the treatment devices so, coupled with the broader information about the risk of pollution, a designer can use the Manual to design a robust and effective treatment train.

Remember, however, that the groundwater risk assessment in the SuDS Manual is not necessarily enough to assess the risk from highway runoff, and a qualified hydrogeologist must assess the risk and identify the appropriate risk assessment process.

For highways with a traffic density above 50,000 AADT, the risk assessment procedure in the SuDS Manual is too crude, and a comprehensive water quality assessment and design process must be employed, based on site specific pollution source data and receptor details.

HEWRAT and the DMRB

For the example described above, HEWRAT does not measure the risk of pollution from the highway runoff effectively. It concludes that there is no unacceptable risk of pollution from suspended solids from the discharge, but we know that is not true. A sample from a highway with a similar traffic density contained a level of suspended solids in the runoff that will cause pollution. And we know that the suspended solids contain most of the metals pollution and the hydrocarbon pollution. We also know that the runoff contains high levels of microplastic tyre-wear particles. HEWRAT assumes that suspended solids and the associated pollutants can be 'washed away' if the watercourse has adequate flow, but some of these are bioaccumulative pollutants, so they remain in the sediment and exert their toxic, harmful effects wherever they settle out. So the pollution and its harmful effects are not 'washed away'; they are moved downstream but remain harmful. The tyre-wear particles end up in our oceans and myriad international research papers have shown that they cause harm to marine life. So to use a model that assumes that the pollution 'washes away' is out-of-date and out-of-touch with the real-World implications.

The HEWRAT model was built before the EQS for polyaromatic hydrocarbons were published and before we had the laboratory techniques to properly measure the very-low, but harmful levels of these toxins. EQSs were created for polyaromatic hydrocarbons because of their harmful effects; for example, Benzo(a)pyrene is listed because of its carcinogenic, mutagenic, reprotoxic, very persistent, very bioaccumulative and very toxic properties. National Highways has a statutory duty to prevent pollution from its network and that includes compliance with the EQS in the rivers downstream of their discharges. Because HEWRAT does not properly account for PAH pollution, and it was built on pollution source data that is now out-of-date, the model cannot reliably assess the risk of this pollution.

Once the HEWRAT risk assessment is complete and it has suggested the level of treatment that is required to control pollution, the design manual isn't sufficiently detailed to ensure that the designer delivers a robust treatment scheme. The devices must be big enough to treat all sub-annual rainfall events, at least. To do this a swale, for example, must be the length of the road it is treating, and allow the runoff from the sub-annual events to be properly treated. This means that the runoff must be able to infiltrate into the soil horizons beneath the grass sward, because the microbial degradation of hydrocarbons and the assimilation of metals take place in the soil horizons. For this to be effective, the runoff must enter the soil, and the soil must be properly specified and have the relevant hydraulic properties to be effective. If the runoff simply runs along the swale, with little or no infiltration, or if the designer specifies a grassed-surface water channel where infiltration is

not included, then only a limited amount of sedimentation will occur and the assigned/ assumed pollution mitigation will not be delivered.

DMRB also relies on a Table of treatment efficiencies for different treatment devices that is incorrect and out-of-date. This Table differs significantly from the Table 26.3 in the CIRIA SuDS Manual which leads to confusion amongst designers. The two tables should be aligned, taking the one in the SuDS Manual to be more accurate, and the treatment efficiencies reconsidered and updated.

So the model is flawed, and one hopes that the review of the model will repair these flaws. But the design guidance is incomplete too, and it is essential that the guidance is improved to close these gaps. A good designer can deliver effective treatment schemes using these processes, but a less experienced designer with incomplete training can deliver schemes that will not prevent pollution.

Environment Agency Permitting Guidance for intermittent discharges to surface water containing Priority Hazardous Substances (PHSs)

This risk assessment is the most robust and would be completed using site-specific pollution source data, river flow data and knowledge of designated protected habitats and sites. If it were completed for runoff from highways with traffic densities that exceed 50,000 AADT that would quickly allow us to better understand the risks associated with these discharges. However, at the moment, the Agency will not complete these assessments for pollution from highway runoff and the risk from the Priority Hazardous Substances remains unquantified.

The Agency do not complete hydrogeological risk assessments for discharge of highway runoff to ground either, and this may be a significant risk of long-term groundwater pollution. Without adequate sampling, monitoring and risk assessment, we cannot know what risk these discharges are posing to the health of aquifers and to water supply security in the future.

Conclusion

The three risk assessment processes are very different, and the outputs from them differ widely. That cannot be acceptable. We know roughly what levels of pollution are found in highway runoff, and we know what levels of pollution can be tolerated by the environment and the creatures living within it. Comprehensive risk assessment models exist in the Environment Agency and it is their statutory duty to measure and control these known discharges of Priority Hazardous Substances. By working with National Highways and other highway authorities, it would be possible to create a much better risk assessment process for discharges of runoff from highways with a traffic density that exceeds 50,000 AADT. Professional water quality modellers and Permitting teams complete similar tasks for industrial discharges, contaminated land sites and wastewater treatment works all the time.

It is time that discharges of highway runoff with a comparable risk of pollution were assessed in the same way.

For lower trafficked roads, discharging to surface waters, the SuDS Manual can remain effective, but there needs to be proper recognition of the need to provide pre-treatment for busy roads and to protect nature-based solutions from gross pollution.

The current situation is confused and confusing and does not protect the environment from pollution.

Proposed next steps

- National Highways, the Agency and highway authorities need to collect more data from highway discharges, particularly where they are designing retro-fit treatment schemes. Without proper source pollution data, no risk assessment will properly represent the risk of harm.
- These datasets will allow HEWRAT to be reviewed to see if it can be upgraded to properly assess the risk from PAH pollution.
- HEWRAT needs to be upgraded to recognise that polluted sediment cannot be assumed to 'wash-away'. The capture and removal of micro-plastic tyre-wear particles is essential if we are to protect marine life, and that starts with the treatment of highway runoff. The model must also recognise that the toxic effects of the sediment will be exerted wherever the sediment is deposited and that is unacceptable. Many of the outfalls are upstream of protected estuaries where wildfowl live, feed and breed, and those habitats must be protected as well as the river or stream receiving the runoff.
- If that cannot be done, HEWRAT needs to be replaced.
- The design guidance needs to be aligned so they all say the same thing, and the details about soil specification, infiltration capacity, device size, detentions time and more must be strengthened so that all designers can do a good job, regardless of their level of experience or training.
- Training for designers needs to be delivered and updated across the industry. Too many designers are being left to work it out for themselves, and, in the absence of good design guidance, that isn't working.
- Groundwater risk assessments for pollution from highway runoff need to be reviewed and updated; there is too little understanding of the risk of pollution from the infiltration of highway runoff to ground.
- The Environment Agency needs to find the time & resources to carry out site specific risk assessments, using comprehensive water quality modelling, for the highest risk sites as a start.

NOTE: the 'cut-off' at 50,000 AADT to identify high-risk roads for the purposes of pollution control is largely arbitrary; it is possible that the cut-off should be as low as 30,000 AADT. This will become clearer as more water quality samples are collected and, for now, it seems a sensible figure to use. However, it may have to be changed in the future.

I welcome your thoughts and any additions that you may suggest for this piece. You can e-mail me at jo.bradley@stormwatershepherds.org

Refs: Polycyclic aromatic hydrocarbons (PAHs): sources, pathways and environmental data. Environment Agency. 2019. Available here: https://consult.environment-agency.gov.uk/environment-and-business/challenges-and-choices/user_uploads/polycyclic-aromatic-hydrocarbons-rbmp-2021.pdf

Jo Bradley | Stormwater Shepherds UK | March 30th 2026