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

Llywodraeth Cymru
Welsh Government

File Ref: WG/REB/OBJ6911- Louise Davies

Objection Ref OBJ6911

Response to Objector's Evidence: Louise Davies

1. GROUNDS FOR OBJECTION

1.1. Details

1.1.1. Louise Davies has submitted a Statement of Evidence 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 Louise Davies' Statement to be based on the following:

1. Suggested that the Scheme has an objectionable monetary cost which will take years to repay and could be better spent.
2. Suggested that funding could be better spent on flood defences.
3. Concerned that there would be a loss of fragile habitat, wildlife and tranquil green space.
4. Concerned about an increase in road death as evidenced by the comparable Newbury Bypass scheme.
5. Concerned that the scheme does not take into account the effect on mental health.
6. Suggested that there are other comparable case studies relating to chemical pollutants from road schemes, giving the example of Newbury Bypass, and specifically that the contamination effects on waterways has been referenced in this case. Outlined that Dr Neil I. Ward at the University of Surrey was responsible for evidencing the contamination effects related to Newbury Bypass and that he has published further research papers which evidence the contamination effects of motorways and in particular consider the effects of cadmium by thawing salt and effects of metal on human growth and development.

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	2.1.2	4	2.2.1
2	2.1.2	5	2.1.2
3	2.1.2	6	2.3.1

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

1. **Point 1** (Suggested that the Scheme has an objectionable monetary cost which will take years to repay and could be better spent) / The economic appraisal suggests that the Scheme would provide value for money. The core scenario for the Scheme is based on the central (or most likely) traffic growth forecasts and assumes that the tolls on the Severn Crossings are half their current level. Under this scenario, the Scheme has an initial benefit to cost ratio (Initial BCR) of 1.62. The initial BCR takes into account only the direct economic benefits of the scheme. If Wider Impacts (indirect economic benefits) are included in the assessment, the BCR for the Scheme is 2.23. In other words, the benefits of the scheme outweigh its costs by a ratio of over 2 to 1. How the Welsh Government allocates funding is not a matter for this Inquiry on the M4 Corridor around Newport.

2. **Point 2** (Suggested that funding could be better spent on flood defences) / Matthew Jones in Proof of Evidence WG1.1.1 at paragraph 13.5 explains that funding for the delivery of this project has been explicitly identified and provision set aside within the Welsh Government's published capital plans for the next four years. Allocations are not made beyond a 4 year period but suitable forecasts are in place to enable assurance to be given that the full funding requirements associated with the project are available within a reasonable timescale should the decision be taken to proceed. How the Welsh Government allocates funding is not a matter for this Inquiry on the M4 Corridor around Newport.

3. **Point 3** (Concerned that there would be a loss of fragile habitat, wildlife and tranquil green space) / The effect of building and operating the new section of motorway on the environment is set out in the Environmental Statement (Document 2.3.2) and its Supplements (Documents 2.4.4 and 2.4.14). The Environmental Statement acknowledges the importance of the Gwent Levels and clearly identifies the magnitude and significance of effects on a wide range of environmental features and assets.

1. **Point 5** (Concerned that the scheme does not take into account the effect on mental health) / A Health and Equality Impact Assessment has been undertaken and can be found at Environmental Statement Appendix 5.4 (Document 2.3.2). That report considers a range of likely impacts and benefits of Scheme on both physical and mental health. It concludes that overall, the Scheme is predicted to cause quantifiable but minor beneficial health outcomes due to a net reduction in residential noise and air pollutant exposure. Construction-stage employment, investment and training, and operational-phase improvements to the accessibility of services and reduced journey costs are predicted to have socio-economic health and wellbeing benefits. The impacts on physical fitness and permeability are on balance likely to be neutral.

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

2.2. Bryan Whittaker (Traffic)

2.2.1. Response to **Point 4** (Concerned about an increase in road death as evidenced by the comparable Newbury Bypass scheme):

1. Road traffic accidents are caused in the main by the behaviours of drivers and not directly by the vehicle except in rare instances. Other contributory factor are road alignment, both vertically and horizontally and road condition and in many cases the weather.
2. Motorways are inherently safe – at least 3 times safer than ordinary 2-way roads. This is achieved by a combination of high design standard and reducing vehicle conflicts.
3. Any shortfall in any of these aspects is a risk factor. In this respect, the M4 around Newport does not incorporate a high design standard – poor alignment, frequent junctions with many weaving sections over relatively short distances.
4. Some sections have a lower than average collision rate following the introduction of VSL, but two sections (24-25 and 26-27) remain higher than average.
5. Paragraph 4.6.5 of the 2016 Traffic and Collisions Report outlines the default average UK collision rate, and shows that some sections of the M4 (Junction 24 to 25 and Junction 26 to 27) remain above UK average, whereas the other sections comprising Junction 23 to 29 have benefited from the introduction of the Variable Speed Limit System in 2011 and are now below the UK default average rate. The TAG data book on the Department for Transport website is the source of the default accident rate for UK motorways.
6. Section 15 of Bryan Whittaker's Proof of Evidence (WG1.2.1) addresses accidents and concludes that there would be accident savings with the Scheme in place.

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

2.3. Richard Graham (Water Quality)

2.3.1. Response to **Point 6** (Suggested that there are other comparable case studies relating to chemical pollutants from road schemes, giving the example of Newbury Bypass, and specifically that the contamination effects on waterways has been referenced in this case. Outlined that Dr Neil I. Ward at the University of Surrey was responsible for evidencing the contamination effects related to Newbury Bypass and that he has published further research papers which evidence the contamination effects of motorways and in particular consider the effects of cadmium by thawing salt and effects of metal on human growth and development):

1. It is acknowledged that recently constructed road schemes in the UK have included systems design to treat road run off prior to discharge to water courses. In particular, the Newbury A34 bypass incorporates 9 water treatment areas of varying designs along the 13.5km section of dual carriageway, each with different catchments and specifications that include similar treatment systems to those proposed for the scheme including oil interceptors, sediment traps, grass channels, lagoons and reed beds. I attach a useful publication at Annex A[1].
2. There is a difficulty in making comparisons with these and other roads. Two principal differences are present when making such a comparison.
3. Firstly, these existing water treatment systems do not match those proposed in scale and design, particularly in respect to the grass lined channels, attenuation lagoons and reed beds. A number of the WTAs for the M4CaN Scheme include the use of grass lined channels as a method of conveyance to the WTA. The use of the grass lined channels of the length proposed for each WTA (up to a maximum length of 3,600m, with an average of 1,550m) offers a number of benefits:
   a) settling and trapping of sediment in vegetation;
   b) adhesion of sediment and pollutants to plants;
   c) filtering and adsorption in the underlying soils and plant roots;

[1] Constructed Wetlands for the Treatment of Runoff from the Newbury Bypass (2001). H. Pontier, BSc, E. May, BSc, PhD and J. B. Williams, BSc, PhD, MIBiol, CBiol

d) nutrient uptake by plants;

e) provide storage to capture and immobilise spills on the highway; and

f) convey runoff from extreme rainfall events through the swale at low velocities without significantly remobilising sediment or causing erosion.

4. The Newbury bypass treatment areas only include grass slopes for water to flow down prior to entry into the main lagoon. The maximum length of the grass slopes is approximately 10m. The capacity for water treatment of the proposed scheme's grass lined channels is substantially larger in comparison.

5. The Newbury bypass treatment areas provide a single 'biofiltration' lagoon which is designed to provide simultaneous storm water volume balancing and biological treatment by reeds or other aquatic plants. Such biofiltration lagoons have reduced treatment efficacy due to compromised design requirements making them of considerably smaller volume and surface area of the separate lagoons and reed beds respectively as proposed for the M4CaN scheme. As an example, the Newbury bypass treatment area 'C' is reported to have a drained area of 1.6Ha and a pond storage volume of 1,050 m^3 (Pontier et al., 2001). The ratio of these properties of a treatment area is a factor for the comparison of designs. Pond C therefore has a ratio of approximately 650 m^3/Ha. The ratios for the proposed M4CaN WTAs range from approximately 800 to 3,500 m^3/Ha and provide on average approximately five times this normalised storage volume provision than that the reported Newbury bypass lagoon. This results in the proposed M4CaN lagoons providing greater dilution, lower flow velocities, increased sedimentation residence times and provides volume for sediments to settle and be retained.

6. The proposed M4CaN WTAs incorporate separate reed bed systems designed to ensure satisfactory functionality and treatment efficacy. The use of a separate, bespoke reed bed sized to optimise the residence times of water according to design standards results in a far higher performance than the planted reeds will achieve within a biofiltration pond. Furthermore, the biofiltration ponds contain standing open water where

the majority of water during storm events is not in contact with reed roots and will receive no water quality benefit as a result.

7. In comparison, the proposed M4CaN WTA reed beds are sub surface flow systems which results in 100% of water flowing through the root zone of the reed bed ensuring maximum filtration potential for solids and conversion of metals from dissolved to non-dissolved forms. As this reed bed is not acting as a balancing pond as is the case for the Newbury bypass treatment areas, water flows at a slow and uniform rate ensuring long residence tiles as required by guidance on the construction of wetlands. This is simply not achievable given the design compromises inherent in a dual purpose biofiltration pond as used more commonly on the highways estate.

8. I am of the opinion that biofiltration ponds as employed on the Newbury A34 bypass and the M25 motorway at Oxted and Leatherhead, whilst achieving good levels of road run off attenuation have a reduced treatment efficacy than separate lagoons and reed beds and are as such incomparable with the M4CaN WTA, which will provide far higher treatment provision.

9. Secondly, the primary issues considered responsible for unfavourably low treatment efficacy identified in many road run off treatment systems is the low residence times afforded to drainage water within the treatment and the lack of maintenance to ensure long term functionality.

10. To achieve good levels of water treatment efficacy, water residence times need to be appropriate for the systems employed. Low residence times limit the opportunity for filtration, dilution, stilling, sedimentation, biodegradation of organic substances and chemical transformation of metals from soluble to non-dissolved forms.

11. Typically, low residence times are a consequence of inappropriate or compromised sizing of treatment areas, for example as a consequence of limited land provision for such systems that require large areas. The design of the M4CaN WTA has been undertaken from the outset by the project team given the sensitive setting of the proposed discharges thus ensuring appropriate design and associated high functionally. The provision of systems capable of accommodating a 1 in 100 year extreme

rainfall event including a 30% additional provision for climate change has ensured that the grass lined channels, attenuation ponds and reed beds are of a size capable of delivering high treatment efficacy. This is particularly important within the grass lined channels and attenuation lagoon where higher residence times result in the removal of sediments and within the reed beds where higher residence times within the root zone of reeds allows a higher degree of potential water pollutant removal to occur.

12. Water treatment systems designed for road run off require regular inspection and maintenance to ensure long term viability and treatment efficacy. This is recognised by DMRB and guidelines are provided (see Table 6.1 in DMRB Volume 4 Section 2 Part 1 HA103/06) to achieve this. Insufficient or untimely maintenance for such systems is identified as a contributing factor for many road treatment systems with the highway estate. A principal requirement of road scheme water treatment areas is to capture and retain suspended solids as these are associates with the majority of potential pollutants in run off and can cause impact to rivers from smothering of plants and river beds. It is therefore important that sediment accumulation and recovery/disposal is undertaken as accumulation of sediment reduces filtration potential of grass lined channels and reed beds as well as increasing the risk of remobilising sediment within lagoons. Sediment accumulation also reduces storm water storage volumes and thus compromises the functionality of treatment areas for flood risk mitigation following extreme rainfall events.

13. The M4CaN scheme will therefore be subject to appropriate inspection and maintenance to DMRB standards and also to NRW requirements to be included within the Register of Commitments for the scheme. This includes requirements for grass lined channel mowing and sediment management as well as lagoon and reed bed de-silting.

14. I am of the opinion that the scope of the inspection and maintenance schedule proposed will ensure the proposed WTA will be able to function at an acceptably high standard and thus maintain the necessary standard of treatment to afforded protection to the Gwent Levels SSSIs.

15. Cadmium is a potential pollutant of concern present in low concentrations within road run. The DMRB guidance on road run risk assessment (HAWRAT) states an average Event Mean Concentration (EMC) for total cadmium of 0.63 ug/L. The prescribed annual average Gwent Levels SSSIs NRW trigger level for cadmium is aligned with that of the Water Framework Directive at 0.15 ug/L. To reduce this cadmium EMC concentration to the prescribed NRW Trigger Level concentration would require a treatment attenuation factor of approximately 76%. I am satisfied that the proposed water treatment areas are capable of delivering this annual average magnitude of efficacy for the removal of cadmium, which will comprise both soluble and non-dissolved forms.

16. To determine compliance of the proposed WTA with the NRW trigger levels, long term monitoring is proposed to determine any impact on water quality arising from proposed discharges. This will form part of the Register of Commitments for the scheme. In addition to this commitment, further commitments have been provided to ensure that all water discharges from the proposed WTA will meet WFD and SSSI requirements prior to entering the reen network.

17. Regarding road salt application and effect on salinity on waters discharging from WTA and the effect on sensitive ecology within reens, the use of ecologically appropriate, non-chloride based road treatment agents is being discussed with NRW to be implemented in March each year.

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

ANNEX A

Constructed Wetlands for the Treatment of Runoff from the Newbury Bypass

H. Pontier, BSc, E. May, BSc, PhD and J. B. Williams, BSc, PhD, MIBiol, CBiol *(Member)**

Abstract

The A34 Newbury bypass crosses sensitive watercourses and incorporates runoff-control systems. The series of treatment stages of each system comprises an oil interceptor, silt trap, grassy slope and constructed wetland. In December 1998, a monitoring programme was initiated for one of the systems to evaluate the removal and behaviour of pollutants, and this paper presents the initial results. Future work will examine the mechanisms involved in metal removal and the fate of other pollutants.

Key words: **Constructed wetlands; metal partitioning; Newbury bypass; runoff.**

*Department of Civil Engineering and School of Biological Sciences, University of Portsmouth, Portsmouth, UK.

Introduction

Recent controversy about the impact of road development on the environment has included concern about pollutants entering sensitive watercourses. The high-profile A34 Newbury bypass crosses several rivers with sensitive ecosystems and, for their protection, runoff-control systems were designed according to the best available guidance[1,2].

For safety reasons, the primary objective of highway drainage is to remove water from the road surface as quickly as possible. The rapid variations in flow can hydraulically overload local watercourses, causing flooding and ecological damage. Pollutant concentrations may also fluctuate significantly[1,3]. The 'first flush' after a dry period, especially where gully pots have been used, has been considered to be the most polluting runoff event[1,2]. The pollutants of concern include particulates, metals such as zinc and iron (from tyre and mechanical wear), and hydrocarbons (from oil residues and combustion by-products)[1,2].

A significant proportion of pollutants in road runoff is associated with particles[1,2,4], therefore sedimentation can provide treatment – provided that a long enough retention period is incorporated. Silt traps can be used to separate out the largest particles, but long retention periods can give rise to putrefaction. Grass swales can provide physical and biological filtration[2,5].

Reed-beds, or constructed wetlands, have been successfully used to treat sewage and other wastewaters. The simplest reed-bed installations are surface-flow systems where there is an exposed water surface, but there are many gravel beds which provide sub-surface flow[6]. Wetland plants can (a) provide a stilling effect in surface systems, (b) maintain the hydraulic conductivity of subsurface systems, and (c) promote aerobic treatment processes[7,8]. Constructed wetlands have also been used for road runoff treatment; however, despite some promising findings as yet, there are no specific design and operating codes for this application.

Pond Design

The design concept for the Newbury bypass was to use a series of treatments to give progressive pollutant removal with minimum maintenance. The series consists of five components, commencing with the road surface and ending with a constructed wetland (Figs. 1 and 2).

Porous Asphalt

The porous asphalt road surface provides noise abatement, and also gives some pollution control because soluble contaminants, particulates and water become trapped and retained. The runoff is conveyed through pipes to collection points along the road.

Oil Interceptor

The Klargester bypass oil separators are designed to trap oils and grease from the 'first flush' after a storm event.

Sediment Trap

The rectangular reinforced concrete sediment traps are designed to allow settlement of larger particles (>80 μm), and removal rates of 60–80% have been reported[2].

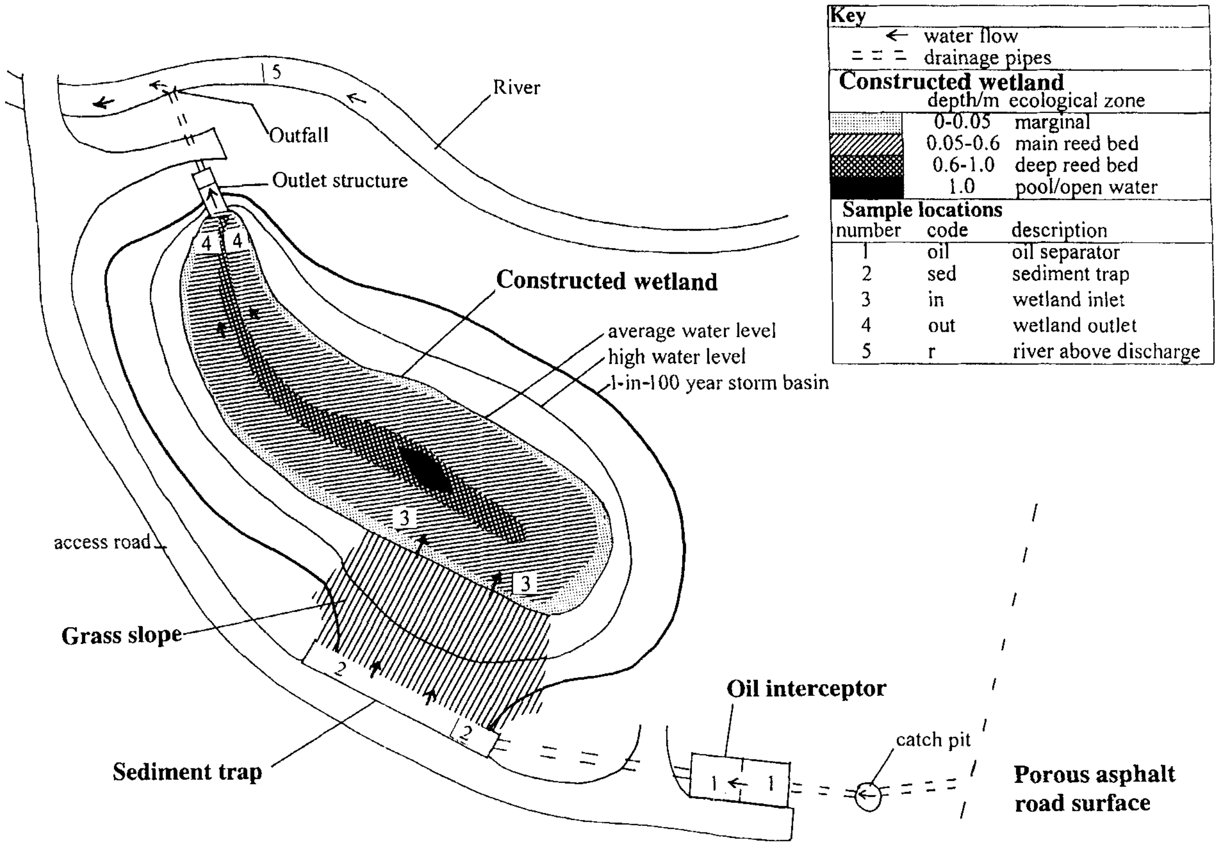

Fig. 1. Diagram of Pond C showing typical design features and sampling locations

Grassy Slope/Swale

This reduces the flow velocity and prevents damage to the wetland plants, while giving a degree of particulate removal by filtration.

Constructed Wetlands

The wetlands are effectively balancing ponds enhanced with wetland plants. The pond systems are designed to attenuate peak flows up to a design storm varying from a 1-in-25 year to a 1-in-100 year storm and are lined, where necessary, to protect groundwater.

Different types of macrophytes were planted at various depths. The plants for inclusion in the design are pollutant tolerant, and may take up metals and other pollutants. The design includes a permanent standing water body to sustain the plants, improve sedimentation, and prevent re-suspension of settled material. The water leaves the ponds via a circular orifice plate to the receiving watercourse.

There are nine systems along the 13.5 km bypass, each with different catchments and specification. One installation has been converted to a sub-surface flow gravel reed-bed and is being considered in a complimentary study by Middlesex University. Pond C is the subject of this paper, and the design characteristics are given in Table 1.

Thirteen species of macrophytes were planted in the pond but the main plant was the reed sweet grass, *Glyceria maxima*.

Fig. 2. View of Pond C (March 1999)

Table 1. Catchment and design characteristics of Pond C

Catchment area (m^2)	16 000	Length of planted zone (m)	47
R (coefficient of runoff)	0.75	Width of planted zone (m)	13
Tc, time of concentration (min)	12	Catchment geology	Clay/river gravel
Peak inflow		Receiving water	Stream to River Enborne
1-in-1 year (l/s)	190		
1-in-5 year (l/s)	318	Maximum depth to outlet invert (m)	1
Storage volume (m^3)	1050		

Fringing plants were included in the shallows, and submerged species were planted in the open water of the pool. The ponds were planted in November 1998 (a year before the road opened) to allow establishment of the biological components and development of wetland conditions which promote the treatment mechanisms of the ponds.

Materials and Methods

Pond C (Fig. 2) was selected for multi-variate sampling because of the ease of access, and samples (of water and sediment) were taken at 30–40 day intervals from the duplicate sampling points numbered in Fig. 1.

Water samples were separated on-site into particulate and soluble components by filtration of 200–250 ml samples through a series of Whatman filters. The metal content of suspended solids (SS) was determined from the residues on GF-C filters (1.2 µm pore size). Dissolved metals were analysed in filtrates passing through 0.45-µm pore size cellulose nitrate filters and the filtrate was preserved by the addition of 1 ml of concentrated nitric acid (HNO_3). Ultra-fine suspended metals were determined from the residues retained by these filters.

Sediment samples were taken from pond-bed deposits using a scoop, and the settled solids were collected using 95-mm ID catch traps, placed just above the sediment surface. After removal of large objects and invertebrates, the samples were separated into two fractions by wet sieving through a stainless-steel 63 µm sieve using water from the sampling location[9]. The <63 µm size fraction includes silt and clay, and can also contain the bulk of the pollutants in road runoff[1,4,9]. The sediment fractions were dried at 100°C and weighed. After the analysis of the metal concentration in the separate fractions, the proportion (by mass) of each grain-size fraction was used to calculate the size-weighted metal content of the fractions in whole sediments.

The residues from water filtration and the sediment fractions were dissolved in hot concentrated HNO_3 (analytical grade) and analysed for metals (Cd, Cu, Pb, Zn and Fe).

Results

Table 2 shows the variation in water quality in Pond C, from 6–8 samples taken during January to May 1999.

The most significant change was found in the total suspended solids (TSS) which showed about 40% reduction across the silt trap and a further 50% reduction across the wetland. The pH of runoff entering the system decreased from 9.0 to 7.0 between the oil separator and wetland outlet.

The total metal content of the input runoff was highly variable, with wide differences in concentrations between sampling occasions. Most of the metals were associated with the solids (only Zn and Fe occurred in the dissolved phase at detectable levels). The April result for the partitioning of Fe (the most common metal) between solid and dissolved phases is shown in Fig. 3. The solid phase dominates with less than 10% being found in the aqueous phase, and there were reductions in the total Fe concentration – mainly due to the removal of iron in the solid phase from the water column, across the silt trap and wetland. The concentration of Fe in the larger suspended solids (>1.2 µm) increased from 31 µg/mg in the oil separator to 40 µg/mg in the wetland inlet waters and to 57.9 µg/mg in the

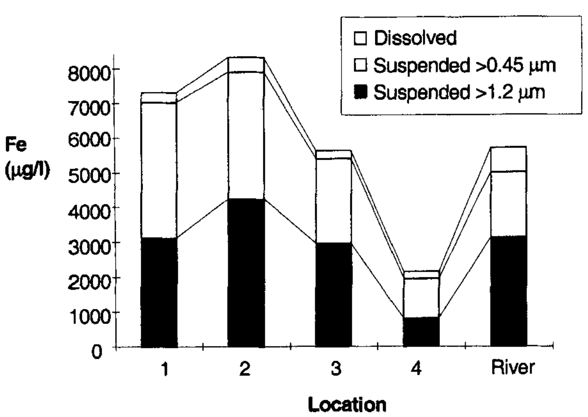

Fig. 3. Partitioning of iron between dissolved and particulate forms, Pond C (April 1999)

*Table 2. Water-quality changes in pond C (n=8, *n=6)*

Location	COD (mg/l)	BOD (mg/l)	TSS (mg/l)	Iron (µg/l)	Copper (µg/l)
1. Oil separator*	29.7 (±4.1)	2.22 (±0.38)	65.1 (±22.0)	4286 (±1541)	15.6 (±1.3)
2. Sediment trap	44.9 (±13.8)	4.40 (±1.47)	65.1 (±19.3)	5456 (±1246)	22.9 (±5.5)
3. Wetland inlet	24.6 (±7.0)	2.57 (±0.41)	40.5 (±10.3)	2997 (±765)	17.8 (±2.8)
4. Wetland outlet	32.9 (±10.6)	3.52 (±0.50)	19.1 (±1.40)	2665 (±921)	15. 0 (±0.92)
5. River	35.4 (±6.0)	1.55 (±0.37)	24.6 (±14.3)	5079 (±800)	12.3 (±3.6)

Figures in brackets denote 'standard error of the means'

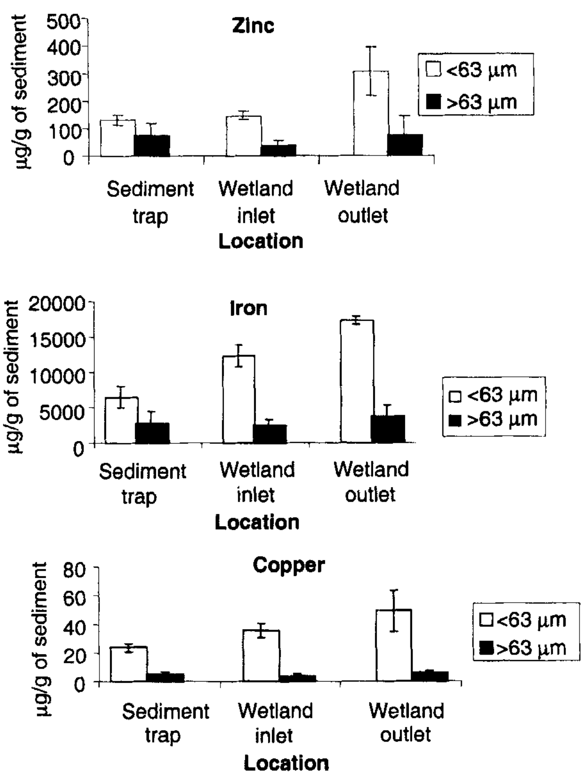

Fig. 4. Concentrations of metals associated with size fractions in whole sediment (weighted according to metal content and proportion by mass of each size fraction)

wetland outlet waters. A similar enrichment pattern was observed on each sampling occasion.

Fig. 4 shows the metal composition of settling solids which were caught in the catch traps. All three metals are predominantly associated with particles <63 μm grain size. There is a trend for the concentrations of all three metals to increase in this fraction, especially across the wetland. The larger particles are more consistent.

Discussion

The road runoff entering the treatment system is characterised by a COD:BOD of about 10:1 (Table 2) which is similar to other studies[2]. This indicates that the pollutants are either mainly inorganic or of low biodegradability.

Although there was little or no change in the BOD and COD across the system, the concentrations were generally low, with the pond effluent containing 3.5 mg/l BOD. This is likely to have little impact on the oxygen balance of the receiving water which has a water-quality guideline of 4 mg/l BOD.

The BOD, COD and TSS of the runoff were low compared to other studies, which have recorded concentrations 5–25 times higher[1,2,10]. As the road surface matures, accumulation of nutrients, pollutants, litter and debris can stimulate microbial activity and result in higher organic loads. The reduction in suspended solids across the system is probably due to sedimentation of solids in the sediment trap and in the quiescent conditions provided by the permanent pool and vegetation in the wetland[8]. The absence of a resulting decrease in BOD and COD indicates that these particles are relatively inert.

The basic pH of the runoff is expected to promote partitioning of metals from the soluble phase, due to the precipitation of insoluble salts or the attraction to cation-exchange sites on solids[3,9].

Normally the metal results are similar to another study[11]. Some removal of metals occurred as water passed through the pond (Table 2), but this was variable (as shown by the 'standard error of the means'). The most variable metal was Zn (results not shown), which has previously been shown to have a complex behaviour in runoff ponds[12]. Cu removal has been linked to its interaction with organic material[9] and with settling planktonic algae[15]. Plant litter and algal growth was observed in Pond C.

Most of the Fe load entering the system was associated with particulates, and has been reported in other studies[1,3]. The TSS removals (Table 2) could account for the overall reduction of Fe, but the solids showed an increasing Fe concentration. The reduction in concentration of different phases of Fe across the system (Fig. 3), coupled with the observed enrichment of the large suspended solids, could provide an ideal scenario for metal removal by subsequent sedimentation of enriched particles. Such enrichment may occur by partitioning because many metals are readily absorbed onto solids which are found in runoff and wetland systems[9,13,15,16]. Other enrichment processes may involve degradation of metal-organic sorbent material complexes[9,14,15].

Metal concentrations in settling solids were comparable to other studies[15,16]. The partitioning of metals between the < and > 63 μm size fractions in sediments caught by the catch traps in Fig. 4 shows that metal concentrations increase predominantly in the finer fraction. Other studies have identified that the bulk of metal loads in road runoff is associated with <63 μm grain-size particles[1,4] and reported metal enrichment[13,15,16]. Transport of these small particles is governed by hydrological conditions; the particles are easily washed from road surfaces and have relatively high surface areas for pollutant attachment[1,2].

The apparent metal enrichment of the fine settling solids across the wetland (Fig. 4) could be due to metal removal from the water column by partitioning and degradation of organic complexes as described elsewhere[13,15,16]. Metal-partitioning mechanisms such as sorption, co-precipitation, complexation by ligands, and microbial interactions might be involved. Changes in conditions (such as pH, redox potential, ionic concentrations, salinity, and oxygen availability) in the drainage system and across the treatment system could influence partitioning[9,13]. Water storage in the system between storms might allow time for changes in the partitioning equilibrium to occur in response to prevalent conditions. The particles which are involved in the partitioning might originate in the road runoff or within the treatment system – especially in the wetland component where algae, plant litter and re-suspension of deposited sediments can contribute to suspended particles.

Over the next two years, the monitoring will be continued to (a) study the development of the ponds, and (b) examine seasonal differences in runoff and treatment. Further studies of the fate of metals will examine their interactions with adsorbent solids. The fate of hydrocarbons and PAHs will also be examined. An important aspect of the work being developed is the use of flow-gauges and tracer studies to gain an understanding of the hydrology of the pond systems and the response of the road catchment to precipitation events.

Conclusions

1. The levels of contamination of the runoff monitored at Newbury were normally lower than those reported in other runoff studies, and the wetlands effectively removed TSS.

2. Metals were mainly associated with particulates, with only Fe and Zn being detected in the aqueous phase. The removal of TSS in the pond therefore promoted the removal of metals.
3. These early results indicate two treatment mechanisms: 'sedimentation of solids' which occurs predominantly in the sediment trap and wetland inlet, and 'enrichment of settling particles' which occurs across the system.
4. Further work will investigate the partitioning behaviour of metals and factors favouring the retention of metals by sediments.

Acknowledgements

This research is carried out under the joint funding of Mott MacDonald, the University of Portsmouth and the Highways Agency. The authors wish to thank Peter Wilson of the Highways Agency, Colin Walker of Mott MacDonald, Cath Mant, Mike Woodhatch and Michele Pontier.

References

(1) LUKER, M. AND MONTAGUE, K. Control of Pollution From Highway Discharges. CIRIA Report No. 142, 1994.

(2) ELLIS, J. B. AND REVITT, D. M. *Drainage from Roads Control and Treatment of* Highway Runoff. Report NRA 43804-MID.012, 1991, NRA Reading.

(3) HARRISON, R. M. AND WILSON, S. J. Chemical composition of highway drainage waters: II. Chemical associations of metals in the suspended sediment. *Sci. of the Total Envir.*, 1985, 43, 79.

(4) STONE, M. AND MARSALEK, J. Trace metal composition in street sediment: Sault Ste Marie, Canada. *Wat. Soil and Air Pollut.*, 1994, 87, 149.

(5) BARRETT, M. E., WALSH, P. M., MANILA, J. F. AND CHARBENEAU, R. J. Performance of vegetative controls for treating highway runoff. *J. Envir. Engng.*, 1998, **124**, (11), 1121.

(6) NUTTALL, P. M., BOON, A. G. AND ROWELL, M. R. *Report No. 180.* Review of the Design and Management of Constructed Wetlands. CIRIA, 1997.

(7) WILLIAMS, B. J., MAY, E., FORD, M. G. AND BUTLER, J. E. Nitrogen transformations in GBH systems used as a tertiary treatment stage for sewage effluents. *Wat. Sci. Technol.*, 1994, **29**, (4), 29.

(8) BRIX, H. Functions of macrophytes in constructed wetlands. *Wat. Sci. Technol.*, 1994, **29**, (4), 71.

(9) FORSTNER, U. Contaminated sediments. Lecture notes in: *Earth Sciences*, 21, 1989.

(10) ELLIS, J. B., REVITT, D. M. AND LLEWELLYN, N. Transport and the environment: effects of organic pollutants on water quality. *J. Ch. Instn. Wat. and Envir. Mangt.*, 1997, **11**, (3), 170.

(11) SCOLES, L., SHUTES, R. B. E., REVITT, D. M., FORSHAW, M. AND PURCHASE, D. The treatment of metals in urban runoff by constructed wetlands. *Sci. of the Total Envir.*, 1998, 214, 211.

(12) MARTIN, E. H. Effectiveness of an urban runoff detention pond-wetlands system. *J. Envir. Engng.*, 1998, **114**, (6), 810.

(13) YOUSEF, Y. A., HVITED-JACOBSEN, T., HARPER, H. H. AND LIN, L. Y. Heavy metal accumulation and transport through detention ponds receiving highway runoff. *Sci. of the Total Envir.*, 1990, 93, 433.

(14) JACKSON, T. A. Biogeochemistry of heavy metals at Flin Flon (Canada): a proposed method of limiting heavy metal pollution of natural waters. *Envir. Geol.*, 1978, **2**, (3), 173.

(15) LEE, P. L., TOURAY, J., BAILLIF, P. AND ILDEFONSE, J. Heavy metal contamination of settling particles in a retention pond along the A71 motorway in Sologne, France. *Sci. of the total Envir.*, 1997, 201, 1.

(16) LEE, P. K., BAILLIF, P. AND TORAY, J. C. Geochemical behaviour and relative mobility of metals (Mn, Cd, Zn and Pb) in recent sediments of a retention pond along the A71 motorway in Sologne, France. *Envir. Geol.*, 1997, **32**, (2), 142.