Wastewater Infrastructure in the River Clun Catchment, An Assessment of Impact

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My final acknowledgement goes to Severn Trent Water Ltd for very kindly providing information to support the research.

Summary

The report investigates the impact of wastewater infrastructure on river quality in the upper Clun catchment, South Shropshire. At present a declining population of Freshwater Pearl Mussels *Margaritifera margaritifera* are located in the lower catchment of the River Clun. The potential translocation of the Freshwater Pearl Mussels, to the upper catchment, is therefore the basis of the study. The species are protected by European Law due to their decline over the last 60 years and are extremely sensitive to water chemistry; requiring the highest quality of water to survive. Therefore, if the translocation of the species is to take place in the River Clun, all areas of pollution must be examined.

Social research is used to gather information on typical usage techniques and methods of system management as well as the age and type of infrastructure in the area. The document also addresses the gap in knowledge and understanding of rural property owners in river quality and their potential impact on the local watercourse through wastewater. Recommendations and methods to improve these matters are addressed, with the hope to provide a suitable aquatic environment for Freshwater Pearl Mussels in the upper Clun catchment.

Contents

The EU Water Framework Directive (WFD) which came into force in December 2000 establishes an, integrated approach to the management and use of Europe's rivers, lakes, estuaries, coastal waters and groundwater. The directive sets 2015 targets for water quality throughout Europe by[1] and all surface and ground waters must achieve good status by this time. Since December 2000, greater emphasis has been made towards reducing the impact of agriculture and large-scale wastewater treatment plants on water quality. Ongoing water quality testing by the Environment Agency (EA) have shown a general improvement in water quality throughout the UK due, in part, to these improvements[2]. Less effort however has been shown to the possible impact small-scale wastewater systems (also referred to as on-site wastewater systems) have on water quality, despite evidence that these systems have the potential to discharge effluent highly concentrated in nutrients, including phosphorus and nitrogen[3].

In rural areas it is typical for a property to treat wastewater through an on-site system, such as a septic tank, and the catchment of the River Clun is no exception. The River Clun flows through Shropshire and Herefordshire, is part of the Teme Catchment and is a unit within the River Teme Site of Special Scientific Interest (SSSI). The source of the river is located on the English/Welsh border, near the settlement of Anchor, Shropshire and it joins the River Teme downstream at Leintwardine, Herefordshire[4].

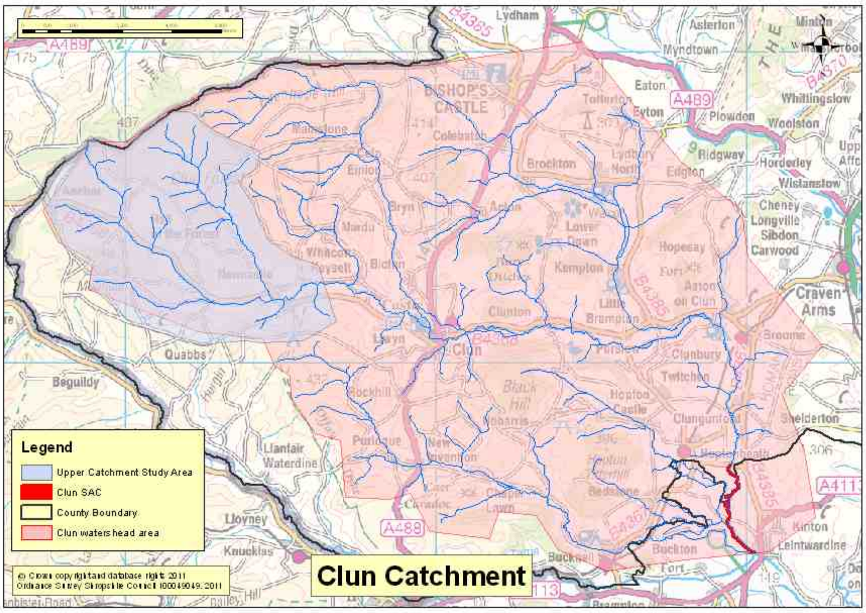

Figure 1. The River Clun and Catchment.

The River Clun is one of only four locations in England and Wales designated as a Special Area of Conservation for its Freshwater Pearl Mussels (*Margaritifera margaritifera*). The

[1] European Council (2000) *Water Framework Directive* (2000/60/EC), http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT
[2] Environment Agency (2011) *Freshwater Pearl Mussels*, http://www.environment-agency.gov.uk/homeandleisure/wildlife/116792.aspx
[3] Dudley and May (2007) *Estimating The Phosphorus Load to Waterbodies from Septic Tanks*, Centre for Ecology and Hydrology, NERC, 45pp. (CEH Project No: C03273, C01352) (Unpublished).
[4] Killeen, I. (2007) A Survey for the Freshwater Pearl Mussel *Margaritifera Margeritifera* (L., 1758) at 129 RHS Sites in the River Clun Catchment, Shropshire, Malacological Services.

Freshwater Pearl Mussel is included under the European Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive). The population of pearl mussels in Europe has declined rapidly over the last 60 years and in some parts of England and Wales, including the Clun River, they now face extinction[5]. Due to this decline, the species is included in Annex II of the Habitats Directive; 'animal and plant species of community interest whose conservation requires the designation of 'Special Areas of Conservation' and Annex V; 'animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures'[6]. The river is therefore internationally significant and protected under several areas of European Law.

At present the mussels are located in the lower reaches of the River Clun, which is subject to pollution from activities throughout the catchment, representing a relatively unstable aquatic environment. However, the translocation of the species to the upper Clun catchment imposes the question into the suitability of the area. A study conducted in 2009 by Killeen assessed risks associated with translocation, a recommended research topic from this study was the impact of wastewater. Therefore the aim of the report is to investigate the impact that wastewater treatment in the upper Clun catchment may have on water quality of the River Clun. Included in this aim are the following objectives:

1. To research the potential impact of wastewater infrastructure on water quality of the River Clun (with particular reference to phosphorus (P) and nitrogen (N) compounds).
2. To address issues linked to inefficient wastewater infrastructure and how this may be improved, and
3. With regard to wastewater, to investigate the suitability of the area for the translocation of Freshwater Pearl Mussels.

Before these issues are addressed a background to the study area is provided.

[5] Environment Agency (2011) Freshwater Pearl Mussels, http://www.environment-agency.gov.uk/homeandleisure/wildlife/116792.aspx
[6] European Council (1992) Habitat Directive

2.1 Water Quality

Concerns regarding water quality, pollution and supply are increasing throughout Europe and have led to water protection becoming a priority for the European Commission. Under the WFD, released in 2000, all coastal and inland waters within Europe must be classified as having good ecological and chemical status by 2015. Under this classification, surface water must display low levels of distortion from anthropogenic activity, including wastewater treatment. To achieve these standards, River Basin Management Plans have been created for each river catchment throughout Europe. The River Clun is included under the management plan for the River Severn basin. This management plan states that by 2015, 17% of surface waters (rivers, lakes, estuaries) will improve by at least one biological, chemical or physical element. This includes the improvement of 1860km of river in relation to fish, phosphate, specific pollutants and other elements[7].

Since the introduction of the directive in Europe, the Environment Agency has measured an improvement in water quality throughout the UK. Water quality is classified in the following way by the Environment Agency.

Nutrient Measures		
	Phosphate (ortho) (mg/l)	Nitrate (mg/l)
1. V.Low	0.02	5
2. Low	0.06	10
3. Moderate	0.1	20-30
4. High	0.2	40
5. V.High	1.0	>40
6. Excessively High	>1.0	

Figure 2. Nutrient measures applied by the Environment Agency towards measuring water quality[8].

The chemistry and biology of a watercourse are also measured, however these are ranked from A-very good to F-bad depending on a number of variables[8]. This system has been applied to over 6000 rivers throughout the UK, which have shown improvement over the last decade.

Nutrients are essential within aquatic ecosystems. An excess of nutrients however, particularly phosphorus and nitrogen, stimulate plant growth and can cause algal blooms, this process is called eutrophication. When the algae decompose it strips the aquatic ecosystem of oxygen resulting in biological decline. Sewage is one of the main sources of nutrient enrichment to watercourses throughout the UK. The nutrient composition of wastewater is readily available as it contains soluble nutrients, designed to dissolve in water, unlike nutrients in fertiliser which will often be bound to soil particles. Therefore effective wastewater infrastructure is essential to prevent eutrophic conditions and maintain water quality.

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[7] Environment Agency (2009) *River Basin Management Plan Severn River Basin District*, Environment Agency, Bristol, UK.
[8] Environment Agency (2011) River Quality, http://www.environment-agency.gov.uk/homeandleisure/37811.aspx

2.2 Wastewater Infrastructure

Small-scale treatment systems are considered to be an effective means of wastewater treatment in rural areas provided they are designed, located and maintained satisfactorily[9]. Since the year 2000, building regulations have aimed to ensure the installation of a wastewater treatment system is effective; having little impact on the surrounding environment. The regulations state the drainage field of the system must be 10 metres or more from a watercourse, 15 meters from a property and 50 metres from a point of water abstraction (ie. borehole or well). Provisions also include that the soakaway must be designed in accordance with British Standards (BS6297:2007) and a percolation test of the area must be conducted.

It is not only the installation of these systems that has developed over recent years in the UK and throughout Europe, but also regulations and standards towards manufacturing the systems. The Construction Products Regulations 1991, require sewage treatment plants to be watertight, structurally stable, durable, have sufficient treatment capacity and produce effluent which complies to the Environment Agency's consent standard. Package plants must also fall under the EN 12566-3 2005 European and British Standard to be legally sold in the UK (see figure 3 for effluent requirements under the European standard).

The most common method of on-site wastewater treatment is a septic tank and soakaway, which can still be purchased in the UK. However more modern treatment methods have been developed, such as bio-filters, bio-disks and bio-digesters, all of which aim to produce a higher level of effluent quality. The table shows the nutrient concentration of the effluent produced by a selection of systems available in the UK.

System	Effluent Nutrient Concentration (mg/l)			
	BOD	Ammoniacal Nitrogen (NH_3)	Suspended Sediment	Phosphate
Bio filter (Condor ECO)[10]	3.5	6.2	4.7	
Bio filter (Bio Rock)[11] Sgl Chamber Dbl Chamber	 7.9 3.5	 8.8 2.7	 7.7 2.9	
Bio disk (Klargester)[12]	15.0	15.0	25.0	
Biodigester (Pure Flo)[13]	11.0	7.0	16.0	
EU Standard Requirement (EN 12566-3:2005)	<25.0		< 35.0	<1.5
EU Elite Requirement (EN 12566-3:2005)	<10.0	<5.0	<15.0	<1.5

Figure 3. Effluent nutrient concentration of popular wastewater systems sold in the UK and effluent requirements under the European Standard (EN 2566).

[9] Withers, P.J.A, Jarvie.H.P, and Stoate, C. (2011) Quantifying the Impact of Septic Tank Systems on Eutophication Risk in Rural Headwater, *Environmental International*, 37. pp 644-653.
[10] WTE Ltd (n.d) *Condor ECO Non-Electric Sewage Treatment Plant,* Wastewater Solutions, WTE Ltd, http://www.wte-ltd.co.uk/condor_eco.html.
[11] BioRock (n.d) *Effluent Quality of BIOROCK Sewage Treatment Units*, BIOROCK UK, http://www.biorock-uk.com/biorock_test_results.html.
[12] Klargester (2010) *Klargester BioDisk BA-BD: High Performance Package Sewage Treatment Plants for Residential Applications*, Kingspan, Buckinghamshire, UK.
[13] WTE Ltd (n.d) *PureFlo Biodigester Sewage Treatment Systems*, http://www.wte-ltd.co.uk/pureflo_sewage_plant.html, WTE Ltd.

The table illustrates the variety of systems available on the UK market for small-scale wastewater treatment and the large variance in effluent quality. No data could be found on any available septic tank system. The majority of suppliers suggest a sewage treatment plant to obtain a better quality of effluent; therefore we can presume a septic tank would produce a poorer effluent quality than any of the systems indicated in the table. The data provided is a measure of effluent from the on-site treatment systems and therefore does not include biological treatment that occurs within a drainage field.

The data also provides an insight into the level of nutrient enrichment considered suitable for wastewater effluent. These figures are considerably higher than levels used by the Environment Agency to assess water quality (figure 2), especially for a water body containing Freshwater Pearl Mussels, due to the sensitivity of the species.

2.3 The Freshwater Pearl Mussel

The Freshwater Pearl Mussel [*Margaritifera margaritifera* (L.)] has been described as the most endangered aquatic organism in the world[14]. Within Europe the population has plummeted, with 90% of individuals being lost during the 20th Century[15]. The majority of *M. margaritifera* populations throughout England are now functionally extinct, meaning that the population is declining with little evidence of recruitment. Reasons for this decline include pearl fishing, a decline in host fish stocks, organic pollution and river degradation[16]. 'It is clear [however] that eutrophication is regarded as one of the main problems facing mussels'[17]. Due to this decline the species is included under the Habitats Directive in Annexes II and V which states the species' habitat must be managed as a Special Area of Conservation (SAC) and it is an offence to knowingly harm or kill the species[18]. Water quality improvement and river management of a watercourse containing Freshwater Pearl Mussels is associated to the Water Framework Directive and Habitats Directive, giving it local, national and international significance.

River quality is essential to assess habitat suitability for all freshwater species. The Freshwater Pearl Mussel is particularly sensitive to changes in river quality as it filters water to feed; an adult is able to filter around 50 litres of water a day[19]. The water quality requirements of the Freshwater Pearl Mussel is exceptionally high, of the 30 remaining pearl mussel rivers in England and Wales, only one is known to be recruiting juveniles ..

Quality Measures	**FWPM Requirements**				
	Killeen (2009) (River Ehen)	**WWF Sweden (2009)**	**Skinner *et al* (2003)**	**Oliver (2000)**	**Bauer (1988)**
pH	6.5-7	>=6.2	<7.5	6.5-7.2	

[14] Thomas, G.R. Taylor, J. and Garcia de Leaniz, C. (2010) Captive Breeding of the Endangered Freshwater Pearl Mussel Margaritifera Margaritifera, *Endangered Species Research*, Vol. 12, pp.1-9.
[15] Killeen, I. (2007) *A Survey For the Freshwater Pearl Mussel Margaritifera Margaritifera (L.,1758) at 129 RHS Sites in the River Clun Catchment*, Malacological Services, Ireland.
[16] Cosgrove, P.J. and Hastie, L.C. (2000) Conservation of Threatened Freshwater Pearl Mussel Populations: River Management, Mussel Translocation and Conflict Resolution, *Biological Conservation*, Vol.99, pp. 183-190.
[17] Young, M. (2005) *A Literature Review of the Water Quality Requirement of the Freshwater Pearl Mussel (Margaritifera margaritifera) and Related Freshwater Bivalves*, Scottish Natural Heritage Commissioned Report, No. 084.
[18] Cosgrove, P.J. and Hastie, L.C. (2001) Conservation of Threatened freshwater pearl mussel populations: Rover Management, mussel translocation and conflict resolution, *Biological Conservation*, Vol. 99, Issue 2, pp. 183-190.
[19] Scottish Natural Heritage (2009) Freshwater Pearl Mussel – A Species on the Brink, SNH, Perth, Scotland.

Total Phosphorus (mg/l)	<0.005	<0.005-0.015	<0.03	<0.03	<0.03
Nitrate (mg/l)	0.2-0.4 (TON)	<0.125	<1.0	<1.0	<0.5
BOD (mg/l)	<1			<1.3	1.4
Conductivity (µs/cm)	40-50		<100	<100	<70
Turbidity		<1 FNU			
Dissolved Oxygen				90-110%	
Water Temperature		<25°C			

Figure 4. Habitat needs of the Freshwater Pearl Mussel. Sources: Killeen (2009)[20] (TON= Total Oxidised Nitrogen), WWF Sweden (2009)[21], Skinner et al (2003)[22], Oliver (2000)[23] and Bauer (1988)[24].

When the requirements of the Freshwater Pearl Mussel are compared to the water quality measures of the Environment Agency (figure 2) it is clear that the species require a water quality similar to that of treated tap water, especially for a recruiting population. The difference between the habitat requirement of the Freshwater Pearl Mussel and the effluent quality provided in the previous section (2.2 Wastewater Infrastructure) illustrate the potential impact wastewater could have on the species and water quality through nutrient enrichment.

2.4 Relevant Literature

2.4.1. Case Study: Eutrophication of Loweswater Lake.

A study conducted in May 2010 in the Lake District, investigated possible contributors to the eutrophic conditions in Loweswater Lake. This involved research into land management techniques and wastewater treatment within the catchment[25]. A study was conducted into the influence small-scale wastewater treatment facilities may have on the phosphate concentration of the Loweswater Lake. The investigation found that due to phosphorous restrictions on detergent manufacturers in Europe the volume of soluble phosphorous in the lake from laundry detergents had reduced since 2006. Dishwasher detergents still contain phosphorous, however they were found to have a comparatively small impact (5% of total) towards the phosphorous load of wastewater.

The report found that organic matter from kitchen and lavatory wastewater contributed most to the phosphorous output of the domestic wastewater treatment systems. Of the 18 systems included in the study, the most common form of system used primary and secondary treatment (61%), with 7 of the 18 properties only using primary treatment in the form of a septic tank and all of the systems discharged through a soakaway. Despite the majority of properties having modernised systems with secondary treatment mechanisms (reed bed, bio-disk or bio-filter system) poor management, neglect and a low frequency of emptying meant that these systems were not producing a high quality effluent. Webb (2010) estimated that on average only 13% of phosphorous was removed during wastewater treatment, resulting in approximately 35 kg a year of phosphorus discharged

[20] Killeen, I. (2009) An Assessment of the Potential for the Restoration of the Freshwater Pearl Mussel Population in the River Clun, Shropshire, Malacological Services, Dublin, Ireland.
[21] WWF (2009) Restoration of Freshwater Pearl Mussel Streams, WWF Sweden, Solna, Sweden.
[22] Skinner, A. Young, M. and Hastie, L. (2003) *Ecology of the Freshwater Pearl Mussel*, Conserving Natura 2000 Rivers Ecology Series No.2 English Nature, Peterboroough.
[23] Oliver, G. (2000) *Conservation objectives for the freshwater pearl mussel* (Margaritifera margaritifera), Report to English Nature, Peterborough, UK.
[24] Bauer, G. (1988) Threats to the Fresh Water Pearl Mussel *Margaritifera margaritfera L.* in central Europe, *Biological Conservation*, Vol. 45, pp. 239–253.
[25] Webb, L. (2010) Survey of Local Washing Practices and Septic Tank Operation in Relation to Domestic Phosphorous Inputs to Loweswater, Loweswater Care Project.

to land by all 30 properties (18 systems). However under favourable conditions, such as high phosphate removal by vegetation, Webb (2010) estimates a removal rate of up to 30%, resulting in 28kg net phosphorus discharged to land per year. If even contribution occurred from each household within the study (30 households), we can use this figure to produce an estimated annual phosphorus load in the Clun catchment of 186.6 kg per year under favourable conditions (200 households) and 233.3kg per year in 'normal' conditions; a considerable annual volume of phosphorus discharge to land.

2.4.3 Previous Research

The contribution to eutrophication of surface waters from agricultural practices has been well researched and subsequent policy developments are in place to reduce the perceived impact on water quality. Sewage treatment works are currently subject to legislative pressures to improve treatment techniques. Whereas the potential impact of small-scale treatment systems to water quality is still relatively uncertain.

'The assumption [is] that agriculture is now the main source of P entering waterbodies in rural catchments. However, there is mounting evidence that...small point sources of P in [rural] areas, such as septic tanks, may also be important sources of P'[26]. This quote indicates the basis for the 2007 academic research by Dudley and May. They found that a sewage treatment system should remove the majority of P if 'sited, maintained and used properly'. They found that several factors impacted the effectiveness of a system, including the following:

- Soil grain size and chemical composition,
- proximity to the water table,
- proximity to surface water,
- capacity of the system in relation to the number of individuals using it,
- chemical composition of the sewage received by the system, and
- the frequency the system is emptied.

The report concludes that septic tank systems contribute a significant and underestimated source of phosphorus inputs to water bodies in rural catchments across the UK. A later paper by Edwards and Withers published in 2008 states, catchment observations suggest that small, low-order, headwater tributaries have only diffuse agricultural phosphate sources at first sight, but are being continuously impacted by other rural sources such as farmyard run-off and septic tank discharge[27].

An increasing number of academic papers have been published that support this view; Withers *et al* (2011) state septic tank systems are a potential source of nutrient emissions to surface water but little data exists in the UK to quantify their significance for eutrophication[28]. With regard to groundwater, Gill *et al* (2009) states 'the protection of groundwater resources from contamination by domestic wastewater effluent is imperative'[29]. Arnscheidt *et al* (2007) investigated the correlation between nutrient transfers of septic tanks and water quality. The paper finds that for catchments with 'simple hydraulics' (houses located within a narrow catchment with a single channel) the

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[26] Dudley, B. And May, L. (2007) *Estimating The Phosphorus Load of Waterbodies from Septic Tanks*, NERC/Centre for Ecology and Hydrology, 45pp. (CEH Project No: C03273, C01352), (Unpublished).

[27] Edwards A.C. and Withers, P.J.A. (2008) Transport and Delivery of Suspended Solids, Nitrogen and Phosphorus from Various Sources to Freshwaters in the UK, *Journal of Hydrology*, Vol. 350, pp.144-153.

[28] Withers, P.J.A. Jarvie, H.P and Stoate, C. (2011) Quantifying the Impact of Septic Tank Systems on Eutrophication Risk in Rural Headwaters, *Environmental International*, Vol. 37, pp 644-653.

[29] Gill, L.W., O'Luanaigh, N., Johnson, P.M., Misstear, B.D.R and O'Suilleabhain, C. (2009) Nutrient Loading on Subsoils from On-Site Wastewater Effluent, Comparing Septic Tank and Secondary Treatment Systems, *Water Research,* Vol. 43, pp. 2739-2749.

total density of poorly maintained septic systems mirrored the magnitude of frequent total phosphorus concentrations, particularly at low-flow[30].

Wastewater treatment is an example of continuous pollution and can often be determined in river quality analysis as it will remain relatively consistent in storm events, assuming foul and rainwater are separate systems. Pollution from agricultural practices however will increase dramatically during storm events, as soil erosion and land drains allow sediment, organic matter and nutrients to be rapidly deposited to surface water. 'In rural catchments…semi-continuous discharges of nutrients from 'mini-point' sources such as... septic tank systems (STS) can also have a large impact on local stream chemistry and ecology during summer'[31]. This is particularly significant as eutrophication and pollutant concentration are more prevalent under low-flow conditions, having a greater impact on Freshwater Pearl Mussels.

Documents of particular significance include a risk assessment and malacological study of the River Clun, both conducted by Killeen in 2009 and 2010. The malacological study investigated the number of pearl mussels currently located in the River Clun and found over 2000 in continuous decline. The risk assessment then went onto address the issues that have the potential to severely impact the remaining population in the Clun River. These factors included sedimentation, habitat removal and nutrient pollution. Recommendations to improve the receptor sites in the upper Clun catchment for pearl mussel translocation included 'a survey of septic tanks and small effluent systems'[32], influencing and supporting the research conducted in this 2011 study.

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[30] Arnscheidt, J. Jordan, P. McCormick, S. McFaul, R. McGrogan, H.J. Neal, M. and Sims, J.T. (2007) Defining the Sources of Low-Flow Phosphorus Transfers in Complex Catchments, *Science of the Total Environment*, Vol. 382, pp.1-13.
[31] Withers, P.J.A. Jarvie, H.P and Stoate, C. (2011) Quantifying the impact of septic tank systems on eutrophication risk in rural headwaters, *Environment International,* Vol. 37, pp. 644-653.
[32] Killeen, I. (2009) An Assessment of the Potential for the Restoration of the Freshwater Pearl Mussel Population in the River Clun, Shropshire, Malacological Services, Dublin, Ireland.

3.0 Methodology

3.1 Site Description

The River Clun and tributaries totals 287 km of ordinary watercourse and main river, and flows from the Welsh/English border, near the settlement of Anchor, to Leintwardine in Herefordshire. The population of *M. margaritifera* are located in the lower catchment, therefore subject to pollution from the total catchment. To conserve pearl mussels in the River Clun, the suitability of the upper catchment as a receptor site is under consideration. The study therefore focuses on the upper catchment with regard to wastewater treatment.

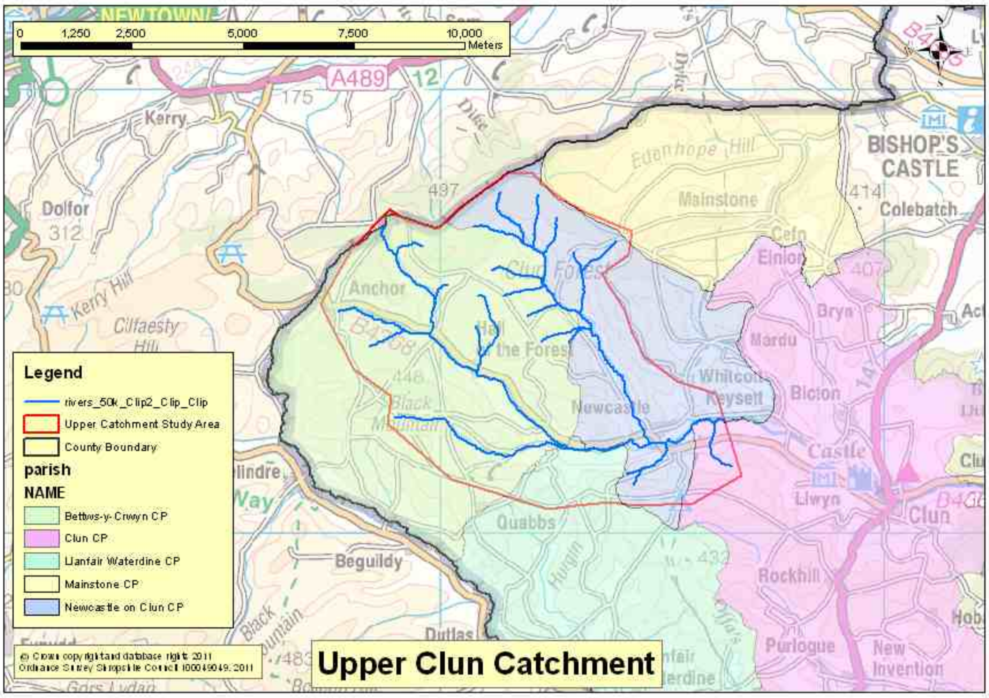

Figure 5. Map of Upper Clun Catchment.

The upper catchment covers 4,395 hectares of land with the entire catchment covering 27,200 ha. The area is predominantly rural with no towns and only one village (Newcastle). Despite the rural characteristic of the area, all properties within the upper catchment are within 1km of a watercourse. A database of 205 properties within the upper catchment were included in the study. This included non-domestic properties (5), farmers (35) and non-farming residents (165). According to the 2001 census, 204 households (481 people) are located within the parishes of Newcastle and Bettws-y-Crwyn, which represent the majority of the upper catchment. This suggests that the survey sample includes most, if not all, of the properties located in the upper catchment.

A Severn Trent Water treatment plant is situated within the upper catchment, in the village of Newcastle. The plant has a population capacity of 181 and its treatment area covers 101 ha of the surrounding area. Therefore the majority of the total population (481) of the two main parishes treat wastewater through small-scale systems. The properties within the sewered area were included in the survey as their wastewater will impact the quality of effluent discharged from the plant, representing a potential point source for pollution of the River Clun (albeit treated).

3.2 The Survey

Primary data was collected through social surveys. The survey was designed to collect information on the impact of each property, from their method of wastewater treatment. Due to the number of variables that can alter the impact a household can have on a surrounding watercourse, the survey had to include questions on the type of system, location, age, maintenance and usage (see appendix for full survey). To help increase the response rate, the survey was kept to less than 15 questions and all questions required only short answers. An incentive was also provided in the form of free ecological detergent samples and money-off vouchers. The surveys were distributed by post and a 23% response rate was achieved.

3.3 Secondary Data

Data was provided by the Environment Agency so that water quality could be assessed and the upper catchment compared to the current Freshwater Pearl Mussel location, upstream of the confluence with the River Teme. Data provided included orthophosphate, nitrate, pH and conductivity.

Severn Trent Water Ltd provided data on orthophosphate, total oxidised nitrogen, ammonia, pH, chloride, suspended sediment and BOD of the final effluent between 2006 and 2011. As none of the Environment Agency monitoring sites were in close proximity downstream to the treatment plant statistical associations could not be tested between the two data sets. However the effluent data from Severn Trent Water Ltd was compared with the final effluent quality of small-scale treatment systems and helped assess the potential impact of wastewater in the area. The data also contributed to assessing suitable receptor sites in the upper Clun catchment.

4.0 Results and Analysis

4.1 Survey Results

A total of 48 surveys were returned (23% response rate). Of these surveys, 2 were non-domestic properties. One of these properties was connected to mains drainage and the other had a sewage treatment system installed. As the results for these properties were very similar to the domestic results, due to the nature of the businesses, they have been included in the total calculations, unless specified otherwise.

4.1.1 Treatment Systems

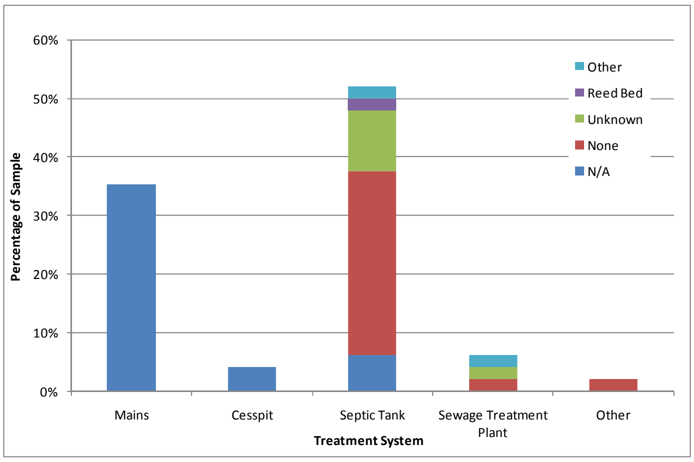

Figure 6. Percentage of households using each treatment system and the proportion of those systems with secondary treatment.

Of the households that returned the survey 35.4% were connected to the local sewage treatment works and 4.2% used a cesspit or cesspool for wastewater disposal. A total of 29 of the 48 surveys included data on small scale treatment systems which would be managed by the property owner. Of these systems, 25 (86%) were septic tanks, 3 (10%) were sewage treatment plants (STP) and 1 system (4%) was categorised as other, as it was described as being a drainage field with no form of primary treatment. Of these systems 96% discharged effluent through a drainage field, with only one system (4%) discharging directly into surface water; a sewage treatment plant installed within that last 2 years.

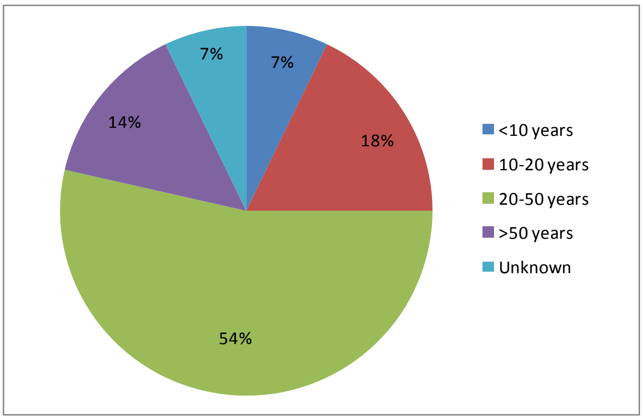

Figure 7. Percentage of small-scale treatment systems in each age category (septic tank, STP and other systems only).

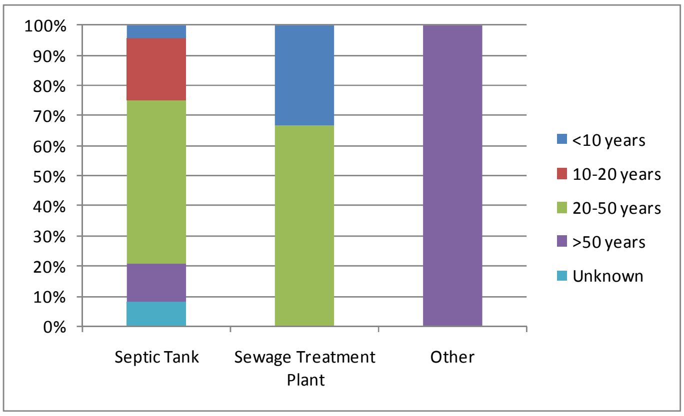

Figure 8. Age distribution of each system type. Total of 24 septic tanks (one recipient with a septic tank did not answer this question), 3 sewage treatment plants and 1 system with no primary treatment, classed as other.

The age of the small-scale wastewater infrastructure, indicated that 68% of the systems were over 20 years in age and 86% were installed over 10 years ago, meaning that the current, more stringent building regulations (SI 2000/2531 and BS 6297:2007) would not apply when the majority of systems were installed. Only 2 of the 28 systems were installed within the last 10 years (one septic tank and one sewage treatment plant, see figure 8), indicating an aging infrastructure in the upper Clun catchment.

The frequency of emptying these systems contributes greatly to the likely impact to local water bodies and contractors recommend annual de-sludging to maintain an efficient system. Of the small-scale systems 65% had been emptied within the last 3 years (36% of those were emptied within the last year). However this does mean that over a third of the systems (35%) had not been emptied within the last 3 years; including 3 of the total 28 (11%) having been last de-sludged or serviced over 10 years ago.

4.1.2 Usage

The frequency and method a small-scale wastewater system is used, is just as significant as the system itself, when calculating effluent quality. This section only includes domestic properties as although the wastewater infrastructure of commercial and domestic properties proved similar, the use of the systems did not.

All surveyed properties had a washing machine and 54% had a dishwasher. These appliances use detergents which can contain high levels of phosphate. Only 8% specified the use of environmental detergents for their washing machine and 9.5% for their dishwasher. Products which are sold for their environmental qualities are predominately made of “ecological” ingredients and do not contain inorganic phosphate, reducing the impact of nutrient enrichment a single property can have on local watercourses. The average household used the washing machine 2.96 times per week and the dishwasher 3.80 times per week.

Of all cleaning products, detergents contribute the most to the composition of domestic wastewater. However other cleaning products, depending on frequency of use, can impact the efficiency of a treatment system. Harsh substances such as anti-bacterial products and bleaches kill the bacteria needed to breakdown organic matter, therefore reducing the treatment capacity of a system. 20% of property owners used only environmental cleaning products (not including detergents), 32% did not use any and almost half used both conventional and environmental products. Cleaning products alone have not been found in previous research to have a direct impact on local watercourses but by altering the efficiency of a system they can contribute to the impact from detergents and organic matter.

4.2 Analysing Impact

4.2.1 Assessing Impact

The survey has highlighted examples of incorrect practice of wastewater management. The following flow chart provides a method of using this data, following guidelines in building regulations[33] and industry papers[34] to calculate the potential impact each property has on the watercourses in the upper Clun catchment.

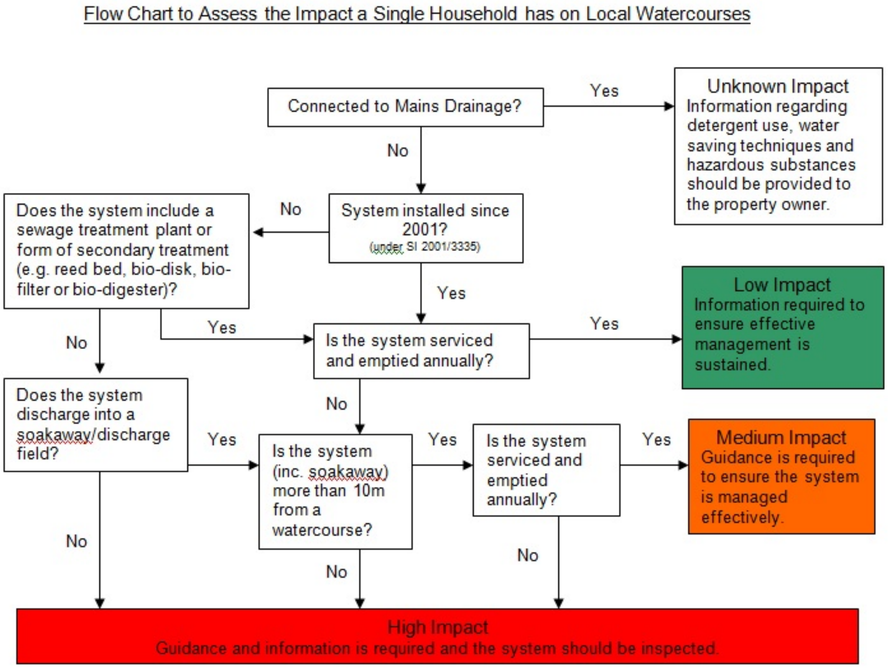

Figure 9. Flow chart to categorise the impact on water quality of a single domestic property.

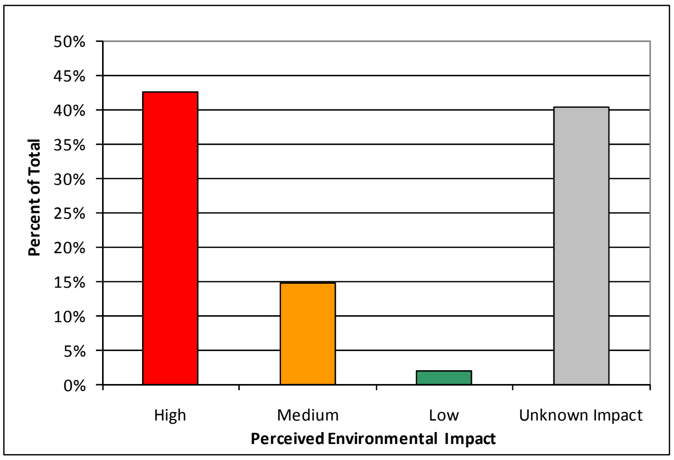

Figure 10. Graph of properties included in the survey, classified to show the potential environmental impact of each property.

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[33] NBS (2000) *Building Regulations 2000, Approved Document H: Drainage and Waste Disposal,* http://www.planningportal.gov.uk/uploads/br/BR_PDF_ADH_2002.pdf, Office of the Deputy Prime Minister.
[34] British Water (2011) *Publications*, http://www.britishwater.co.uk/Publications.aspx.

The flow chart allows the perceived impact of each recipient to be assessed, based on the system at each property and the level of management conducted. Of the properties surveyed, 43% were classified as having a high potential impact on local watercourses. This category indicates problems such as aging septic tanks, systems within 10 metres of a watercourse (no longer allowed under recent building regulations, SI 2001/3335) and a lack of annual de-sludging within the catchment. A large percent of the recipient responses were classed as having an 'Unknown Impact', this represents properties on mains drainage or using a cesspit or cesspool. These systems can impact local water bodies but the extent of which was not addressed within the study. Excluding this category, 71.4% of small scale systems were classified as having a potentially high environmental impact.

4.2.2 Catchment Phosphorus Load

Using the average phosphate concentration in detergents and the typical usage of domestic households of that area (according to the survey responses), an annual detergent derived phosphorus load can be estimated.

	Dishwasher	Washing Machine	Organic Matter [8]
Percent of Population With Appliance [1]	54%	100%	-
Percent of Pop Using Conventional Detergent [1]	90.50%	92%	-
Average Phosphate % in Conventional Detergents [2]	31%	5%	-
Average Domestic Weekly Usage [1]	3.8	2.96	-
Grams used Per Wash [3]	20	88	-
Grams of Phosphate per wash [4]	**6.3**	**4.4**	-
Phosphate Load/Week/Household (g) [5]	**23.75**	**13.02**	**23.47**
Annual Phosphate Load/Household (g) [6]	**1235.00**	**677.25**	**1220.44**
Annual Phosphorus Load in Catchment (kg) [7]	**120.71**	**124.61**	**244.09**

Total domestic households in Upper Clun catchment = 200

[1] Data based on survey responses

[2] Average P content of the conventional detergents included in the survey

[3] Based on Gilmour et al 2008

[4] Total grams per wash x Phosphate content (%)

[5] Grams of Phosphate per wash x Average weekly usage

[6] Phosphate load per week x 52

[7] Percent of households with appliance and which use conventional detergents x Annual Phosphate load per household

[8] Based on UKWIR 2008 and average household size form the 2001 Census.

Figure 11. An estimated phosphate load discharged within the Upper Clun catchment from appliances and organic matter.

Legislation on detergent manufacturing has altered the industry in recent years, as by 2015 inorganic phosphates will be banned from washing detergents (<0.4% of ingredients by weight). Until this date however a product is able to contain phosphorus as long as it equates to less than 5% of the total ingredients. Without the limits in phosphate, washing detergents used to contain similar levels to that of current dishwasher detergents; up to and above 30% of the weighted ingredients. Using this percentage a phosphate load prior to the current regulations (effective since April 2010) can be estimated, assuming the socioeconomic profile of the area has not changed. This gives a total phosphate load per year in the area of 748kg, compared to 125kg now. From 2015, when phosphates are effectively banned (<0.4% P), the phosphate load from washing machines in the upper catchment could be reduced to 10kg a year; illustrating the vital role of effective legislation.

	Pre-2010	Now	Post-2015
Average Phosphate % in Conventional Detergents	**30%**	**5%**	**0.4%**
Average Domestic Weekly Usage (based on survey responses)	2.96	2.96	2.96
Grams used Per Wash	88	88	88
Grams of Phosphate per wash	**26.4**	**4.4**	**0.352**
Phosphate Load/Week/Household (g)	78.14	13.02	1.04
Annual Phosphate Load/Household (g)	4063.49	677.25	54.18
Annual Phosphorus Load in Catchment (kg) (Total households in catchment = 200, but with only 92% using conventional washing detergents, based on survey responses)	**747.68**	**124.61**	**9.97**

Figure 12. Change in annual phosphorus load in catchment from development of detergent legislation[35].

The detergents for dishwasher appliances have not yet received such strict measures as an alternate ingredient has not yet been developed[36], which means many products are still made up of over 30% phosphate. This explains why the phosphate load from dishwasher use is almost equal to that of washing machine use, despite the difference in the proportion of households that own each type of appliance; all residents within the survey had a washing machine and 54% had a dishwasher. There is a rising trend in dishwasher use, if we presume 100% of households use a dishwasher and all only use conventional detergents (typically containing 30% phosphate) the phosphorus load could reach 247kg each year; a greater phosphorus load than organic matter. Therefore long-term focus should be upon improving the detergents used in dishwashers within the catchment.

Although these calculations can only be taken as estimates, they provide an insight into the contribution of each appliance to domestic wastewater (figure 11). Within the upper Clun catchment (presuming the survey sample is representative of the whole population) it can be estimated that the annual phosphorus load from dishwasher use and washing machine use is almost equal and approximately half the volume of phosphate contributed by organic matter (faeces and urine).

4.3 Social Response

Many factors influence choices made towards wastewater treatment techniques and cleaning regimes used within domestic properties. Some of these, which arose during the study, included a lack of knowledge of effective system management, insufficient information and understanding of effective detergent use and the perceived cost associated to both. When distributing samples of an ecological brand a typical response for not purchasing the product was cost. If more affordable ecological products are available, it would result in less damaging products being discharged within the catchment. With regard to poor management techniques it is clear that if information was provided to property owners within the catchment and in rural communities throughout the UK, the impact of domestic wastewater to ground and surface water quality could be reduced. Key areas of understanding that need to be developed include emptying requirements, impact of using conventional washing and cleaning products, information

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[35] HSE (2010) *The Detergents Regulations 2010*, Consumer Protection, Environmental Protection, Public Health, Secretary of State, http://www.detergents.gov.uk/detergents_home.asp?id=&link=%2Fuploadedfiles%2FWeb_Assets%2FPSD%2FDetergentsRegs2010.pdf.

[36] EC (2010) *Proposal for amending Regulation (EC) No 648/2004 as regards the use of phosphates and other phosphorus compounds in household laundry detergents*, European Council, 2010/0298 (COD).

into the different systems available and the significance of an efficient system for sustaining a clean environment.

4.4 Wastewater and River Quality

4.4.1 Water Quality of the River Clun

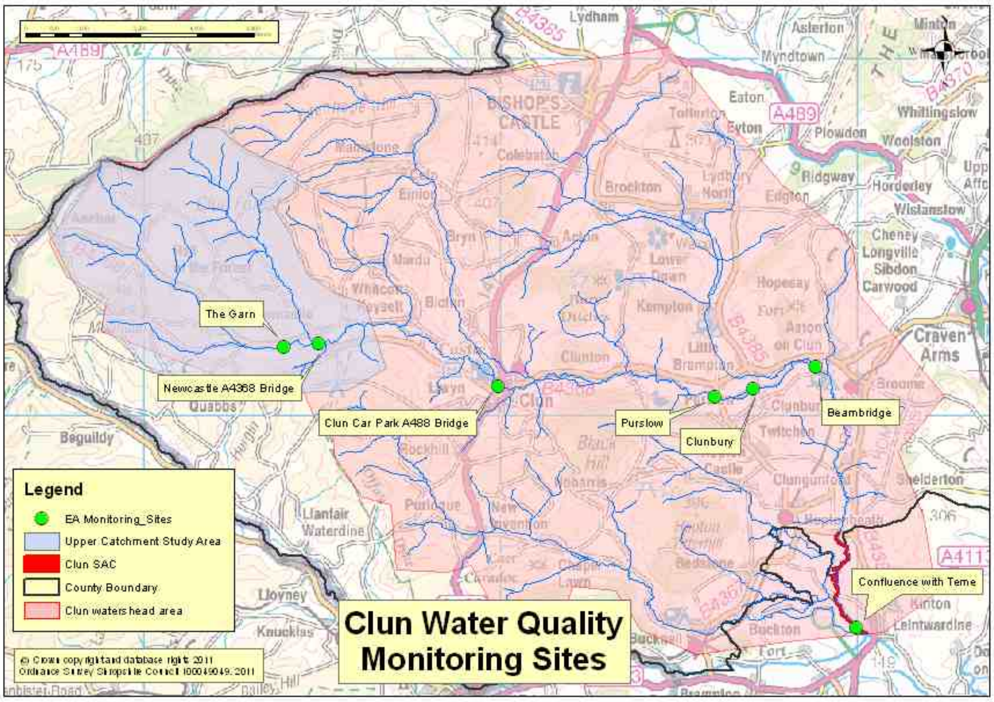

Figure 13. Environment Agency water quality testing sites.

Long term monitoring of orthophosphate by the Environment Agency shows a decline between 2002 and 2010 at all of the monitoring sites. The decline has been most dramatic at Purslow and the confluence (where the River Clun meets the Teme). The decline in orthophosphate at these two sites is not entirely reliable however, due to the extreme values between July and August 2003.

The Newcastle site, within the upper catchment, showed a steady and comparatively low level of orthophosphate between 2002 and 2010. The consistency of the Newcastle site data represents a site that does not suffer 'extreme' events. Therefore despite a greater concentration of orthophosphate measured in 2010 compared to other sites, the area still represents a more stable habitat for the translocation of *M. margaitifera* with regard to the orthophosphate data provided.

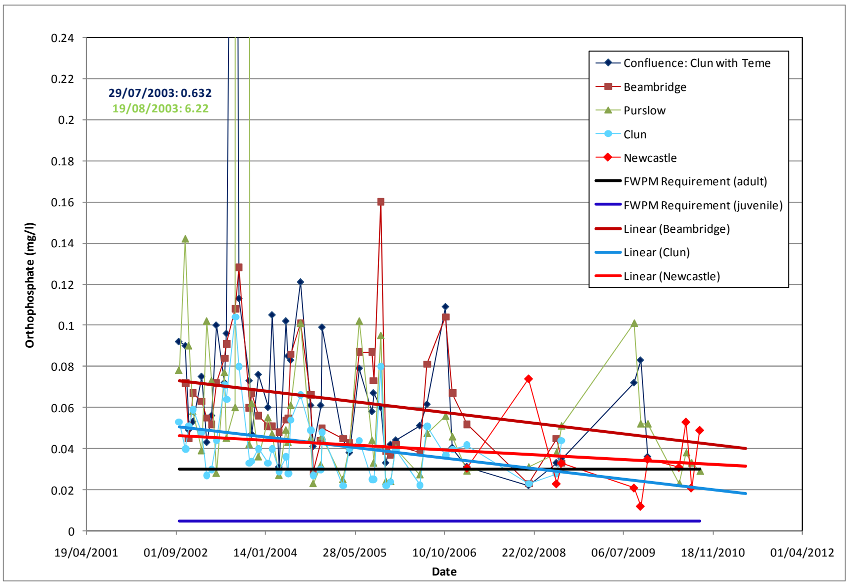

Figure 14. Time series of Orthophosphate monitoring. (FWPM = Freshwater Pearl Mussel).

The site titled Confluence Site is located in the River Clun, directly upstream from the confluence with the River Teme. This area is the current location of the pearl mussel population. The nitrate data provided by the Environment Agency indicates a difference in nitrate concentration between the current pearl mussel site and the possible translocation site within the upper catchment. An ideal aquatic habitat for a Freshwater Pearl Mussel has a nitrate concentration of <1mg/l [37]. The current location of this species and the translocation area (upper catchment) are therefore both unsuitable with regard to the concentration of nitrate.

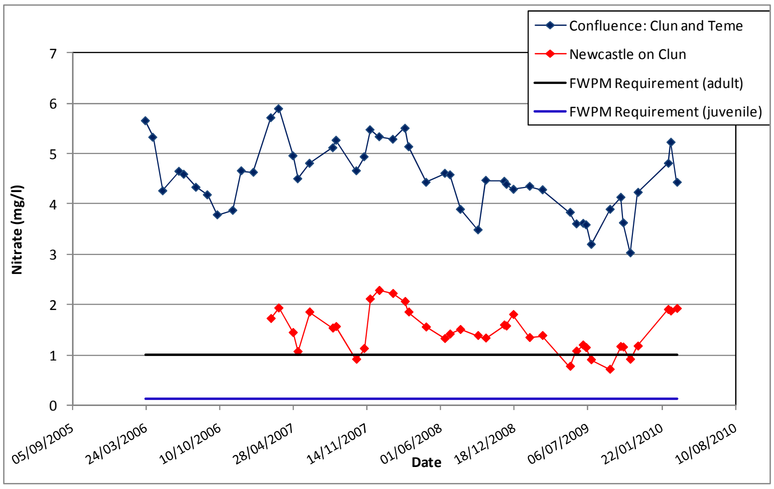

Figure 15. Nitrate Levels for the current Freshwater Pearl Mussel Site (Confluence of the Clun with the Teme) and the potential site (Newcastle on Clun); the lower and upper catchment.

The pH of the River Clun has remained relatively stable since 1999 throughout the catchment. At all sites monitored by the Environment Agency an elevated pH was measured (7.4 is neutral). The data also shows that all sites have exceeded the

[37] Skinner, A. Young, M. and Hastie, L. (2003) *Ecology of the Freshwater Pearl Mussel*, Conserving Natura 2000 Rivers Ecology Series No2. English Nature, Peterborough.

requirement for a Freshwater Pearl Mussel habitat, which is a pH between 6.2[38] and 7.5[39]. Of the sites, the upper catchment showed preferred water quality with an average pH of 7.65, compared to 7.72 at the confluence and Clun sites, and 7.82 recorded at Purslow.

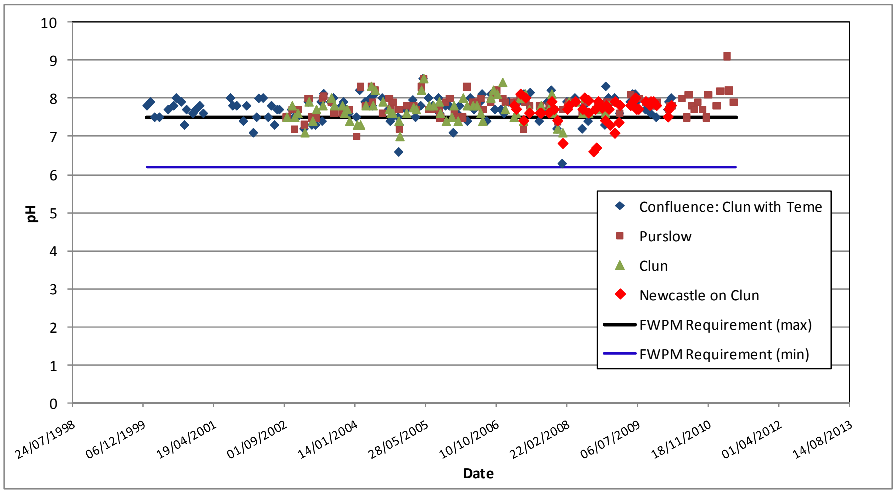

Figure 16. Time series of pH measures at four monitoring sites on the River Clun.

The requirements of the *M.margaritifera* are understood to be oligotrophic conditions; 'poor in nutrients, pH 7.5 or less and low overall conductivity'[40]. The conductivity requirement for an adult Freshwater Pearl Mussel population is less than 100µS/cm, which all monitoring sites exceed. The lowest conductivity was measured in the upper catchment (monitoring site: Newcastle on Clun), whereby an average conductivity of 154.05µS/cm was recorded between October 2007 and March 2010. The average conductivity in the lower catchment, where the pearl mussel population are currently located was far greater at 308.69µS/cm over the same time period.

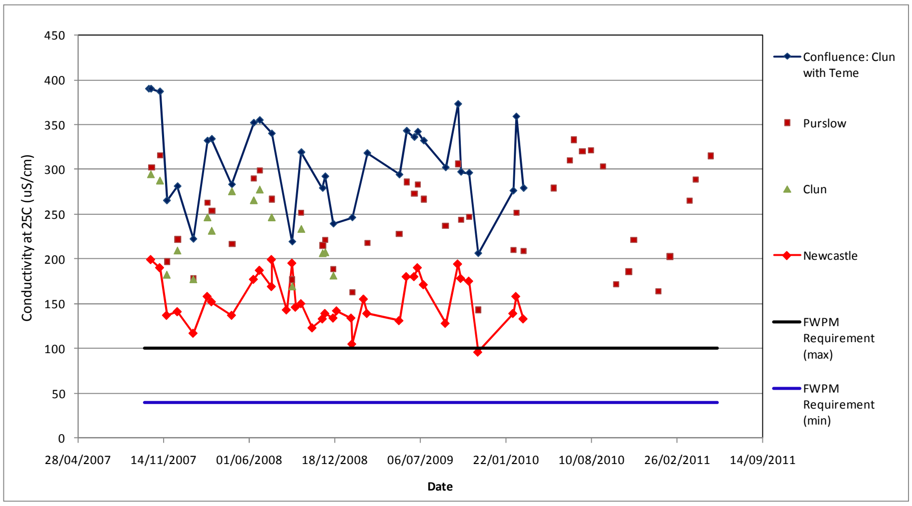

Figure 17. Conductivity time series from four sites on the River Clun and requirement (max and min) of Freshwater Pearl Mussels.

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[38] Degerman, E., Alexanderson, S., Bergengren, J., Henrikson, L., Johansson, B-E., Larsen, B.M. & Söderberg, H. (2009) *Restoration of freshwater pearl mussel streams.* WW F Sweden, Solna.
[39] Skinner, A. Young, M. and Hastie, L. (2003) *Ecology of the Freshwater Pearl Mussel*, Conserving Natura 2000 Rivers Ecology Series No2. English Nature, Peterborough.
[40] Skinner, A. young, M. and Hastie, L. (2003) *Ecology of the Freshwater Pearl Mussel*, Conserving Natura 2000 Rivers Ecology Series No2. English Nature, Peterborough.

4.4.2 The Sewage Treatment Plant

Data for the treatment plant located in Newcastle, in the upper Clun catchment, was provided by Severn Trent Water Ltd. The data included measures of final effluent quality between 2006 and 2011. Using this data a comparison can be made with effluent quality of small-scale treatment systems, according to the test results under the European Standard for package sewage treatment plants (EN12566-3). The European standard for packaged treatment systems (EN 12566-3) is an effluent quality of 20mg/l Biological Oxygen Demand (BOD), 30mg/l Suspended Sediment (SS) and 20mg/l Ammonia (NH_4), expressed as BOD:SS:NH_4. If a plant does not reach this standard it is illegal for it to be sold in Europe. A septic tank is believed to only reach an effluent quality of 120:180:80[41], far greater than modern small-scale systems and the treatment plant.

The average effluent quality discharged from the Severn Trent sewage treatment works was a better quality than that of a selection of small-scale treatment systems. The sewage treatment plant located in Newcastle on Clun produced an average effluent quality that was lower in Biological Oxygen Demand, Ammoniacal Nitrogen and Suspended Sediment.

System	Effluent Quality Measures (mg/l)				
	BOD	Ammonia	Suspended Sediment	Total Oxidised Nitrogen	Phosphate
Bio filter (Condor ECO)[42]	3.5	6.2	4.7		
Bio filter (Bio Rock)[43] Sgl Chamber Dbl Chamber	 7.9 3.5	 8.8 2.7	 7.7 2.9		
Bio disk (Klargester)[44]	15.0	15.0	25.0		
Biodigester (Pure Flo)[45]	11.0	7.0	16.0		
Sewage Treatment Plant: Newcastle on Clun (average measures of the final effluent provided by Severn Trent Water Ltd, for 2006 to 2011).	**2.208**	**0.378**	**2.885**	**4.099**	**1.704**

Figure 18. Effluent Quality of small-scale systems and the Severn Trent Treatment Plant.

The comparison of these values is not straight forward. The data for small-scale systems does not include treatment that occurs within a drainage field through biological activity. The values also presume effective system management for this effluent quality to be sustained. However as many of the manufacturers state that the effluent can be discharged directly to surface water (subject to approval by the Environment Agency), the values can still be classed as final effluent. It must be considered however that if proper management or a drainage field with good percolation is applied the final effluent of these systems can be improved.

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[41] BioRock (n.d) *Effluent Quality of BIOROCK Sewage Treatment Units*, BIOROCK UK, http://www.biorock-uk.com/biorock_test_results.html.
[42] WTE Ltd (n.d) *Condor ECO Non-Electric Sewage Treatment Plant,* Wastewater Solutions, WTE Ltd, http://www.wte-ltd.co.uk/condor_eco.html.
[43] BioRock (n.d) *Effluent Quality of BIOROCK Sewage Treatment Units*, BIOROCK UK, http://www.biorock-uk.com/biorock_test_results.html.
[44] Klargester (2010) *Klargester BioDisk BA-BD: High Performance Package Sewage Treatment Plants for Residential Applications*, Kingspan, Buckinghamshire, UK.
[45] WTE Ltd (n.d) *PureFlo Biodigester Sewage Treatment Systems*, http://www.wte-ltd.co.uk/pureflo_sewage_plant.html, WTE Ltd.

As the sewage treatment plant is able to produce a better final effluent quality than small-scale systems, properties in the mains drainage area should be encouraged to connect. Particularly if they currently have an inefficient small-scale system as this will help improve the wastewater quality from that household.

Effluent quality at the treatment plant has varied over time but has shown a linear decline in nutrient levels (orthophosphate and nitrate and nitrite as total oxidised nitrogen) and therefore an improvement in effluent quality. The effluent of the treatment plant is likely to continue to improve due to strict legislation and development within the water industry. Although dilution when discharged to surface water will reduce these levels further, they are currently greater then those required for a Freshwater Pearl Mussel habitat (maximum of 0.03mg/l P and 1mg/l N). It is therefore suggested that only translocation sites upstream of the treatment plant outfall are considered.

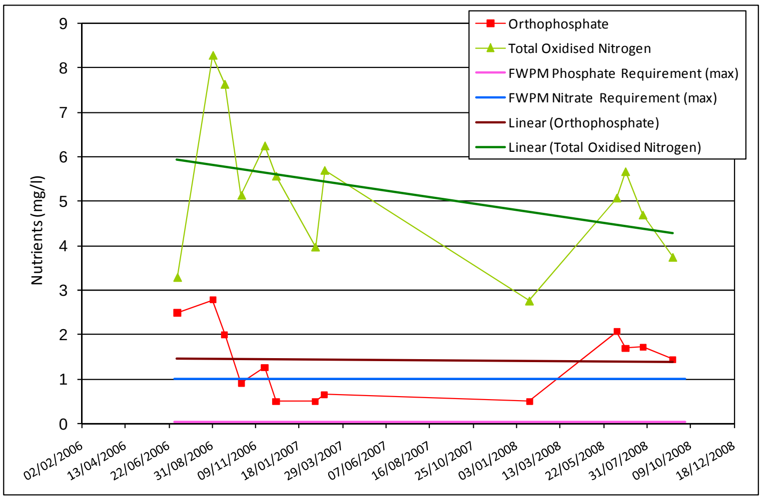

Figure 19. Time series showing Orthophosphate and Total Oxidised Nitrogen of the final effluent at the Newcastle Treatment Plant. Source: Severn Trent Water Ltd.

Key Findings:

- Settlement pattern shows close association with river
- 35.4% of households are connected to Severn Trent Treatment Works at Newcastle
- Of the properties off–mains
    - 86% are septic tanks
    - 10% are sewage treatment plants (4% other)
- Aging off-mains infrastructure - 68% are over 20 years old
- 36% are serviced/de-sludged annually
- 35% over 3 years since last service/ de-sludge
- 11% over 10 years since last service/ de-sludge
- Poor maintenance and lack of awareness means that 71.4% of off-mains systems considered to have a potentially high environmental impact
- Some residents within Newcastle village choose not to be connected to mains sewage
- 20% solely use "environmentally friendly" laundry products
- High cost of "environmentally friendly" products deters use
- Estimated annual domestic phosphate load to septic tanks and treatment works from detergents and human waste is 489.41 kg
- Expected to drop further post 2015 with legislation requiring laundry detergent P to reduce to 0.4% of weighted ingredients
- Post 2015 dishwasher detergent will be the main contributor of detergent derived phosphate in the catchment

5.0 Discussion

5.1 Wastewater Infrastructure

The evidence collected through the social survey provided an insight into the type, age and location of the wastewater infrastructure throughout the upper Clun catchment. Of the properties located out of the mains drainage area (and some within but not connected), 86% had a septic tank. These systems do not typically have a form of secondary treatment (only 4% had secondary treatment) and are no longer recommended on the market due to the poor effluent quality they discharge: septic tanks 'offer very limited biological sewage treatment and the effluent from a correctly sized tank still contains about 70% of the original polluting matter'[46]. The survey results also indicate an aging infrastructure in the area, with 68% of the systems having been installed more than 20 years ago, and 11% of the systems over than 50 years ago. Building regulations have developed over the last decade to focus upon reducing the potential impact a wastewater treatment system can have on local watercourses, making the age of a system significant when assessing the impact on water quality. The location of a system is also relevant and has now been included under recent building regulations (SI 2001/3555), whereby a drainage field should not be within 10 metres of a watercourse.

The age, location, type and management of each system, included in the survey, has been used to predict a potential impact on local watercourses, using the flow chart introduced in section 4.2.1. By using this method 43% of the total sample (including properties connected to mains drainage) were classed as having a high potential impact on the local water quality. Of the properties with a small-scale system, 71.4% were classified as having a high potential impact on the local watercourses, which is comparable to predictions made be May et al (2010) that over 80% of septic tank systems in the UK are working inefficiently and are a significant and underestimated source of phosphorus to nearby watercourses[47]. A study conducted by Dudley and May in 2007, investigated the proportion of phosphorus in surface water attributable to septic tanks. Of 18 catchment areas, the average phosphorus load attributed to septic tank use alone was 12%. The potential impact of septic tanks included in this report is not quantifiable at this stage but a problem with old, inefficient wastewater systems has been demonstrated in the area (as noticed in many rural areas in the UK) and a large margin for improvement which could help reduce nutrient levels, sedimentation and eutrophication of the River Clun.

The data provided by Severn Trent Water Ltd on the effluent quality at the Newcastle Treatment Plant, enables a comparison to be made with manufacturer standards of small-scale systems. It is evident that the treatment plant is able to produce a better quality wastewater than any of the small-scale systems (excluding treatment in the drainage field). This suggests that encouraging households to connect to mains drainage, that are within a treatment plant area and are classed as having a high potential impact on the local environment, would help to improve the water quality of the River Clun. However there is only one treatment plant in that area which has a population capacity of 181, approximately 38% of the total population of the upper catchment and is located at the bottom of the upper catchment. It therefore would not improve the habitat of the potential receptor sites upstream (Folly Brook and the Garn) and would not act as a short-term solution for sites downstream. It is therefore important to focus upon improving the small-scale systems which are prevalent in the upper catchment. This could be achieved through updating the infrastructure but also through improved management.

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[46] WTE Ltd (N.d) *Sewage Treatment: Options for Rural properties Which Conform to Current UK Regulations*, http://www.wte-ltd.co.uk/sewage_treatment_options.html, WTE Ltd.
[47] May, L. Place, C. O'Malley, M.O. and Spears, B. (2010) *The Impact of Phosphorus Inputs From Small Discharges on Designated Freshwater Sites*, A Report to English Nature and Broads Authority, 130pp.

5.2 Management and Social Awareness

Effective management of a wastewater system and frequent de-sludging is one of the main indicators of an effective system and the main reason that small-scale systems incur problems[48]. The majority of the households included in the survey had had their system de-sludged within the last 3 years. However over a third had not, and 11% had not had their system emptied for over 10 years. Such poor management can have detrimental effects on water quality, of ground and surface water, as once a system reaches capacity it is no longer able to effectively treat the effluent that passes through it.

Another factor to influence the impact of a single wastewater treatment system is the products that are used within the property. The products of particular relevance are washing machine and dishwasher detergents. Only 8% of properties with a washing machine and 9.5% with a dishwasher used a detergent free of phosphates. Using results of the social survey and the typical volume of detergent used in each wash, an annual phosphate load could be estimated for the entire upper catchment. The annual phosphate load from each appliance was calculated to be almost equal: 120.71kg from dishwasher use and 124.61kg from washing machine use within the catchment. Only 54% of the population were believed to use a dishwasher (based on survey results) and 100% a washing machine so the results illustrate the significance limiting the percent of phosphorus in each product. Washing machine detergents will be limited at 0.4% phosphate of the total weight from January 2015. Dishwasher detergents have not yet been given such a restriction as an economically and technically feasible alternative for phosphate has not yet been developed and products still contain >30% phosphate. To improve the water quality and reduce nutrient levels in the upper Clun catchment the use of dishwasher products should be improved. This is more economically viable for homeowners, as it avoids the need to update infrastructure. It is therefore an achievable option with short-term benefits; saving the environment of the upper Clun up to 120.71kg of phosphorus a year.

A gap in householder knowledge and awareness was visible when completing the social surveys, especially regarding the management of wastewater treatment systems. There are also few opportunities to obtain guidance and information as the Local Authorities no longer offer support on sewage treatment. This means that new people to the area are unable to gain guidance on best practice of small-scale wastewater treatment; representing an increasing problem. Another issue that arose during the survey was the cost of ecological cleaning products. Ecological cleaning products not only reduce the impact on watercourses but improve the efficiency of the treatment process as they help maintain the bacteria in the tank, reducing the frequency of emptying and the likelihood of future problems and therefore reducing cost. Such issues are generally unknown but would help improve local rivers, reduce contamination risk and enhance potential receptor sites in the upper Clun catchment for the Freshwater Pearl Mussel.

5.3 Water Quality and the Freshwater Pearl Mussel

A phosphorus load to sewer, derived from detergent and organic matter, has been estimated in section 4.2.2 (figure 11). These calculations provide an insight into the volume of phosphate in wastewater of the upper catchment. These values only represent crude effluent as treatment capacity must be considered for the quality of final effluent to be estimated. In a survey conducted at Loweswater in the Lake District (more information on the survey in section 2.4.1) a treatment capacity of 13% was measured under normal conditions and 35% under favourable conditions (good maintenance and use of drainage

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[48] WTE Ltd (N.d) *Septic Tank Problems and Solutions*, http://www.wte-ltd.co.uk/septictank.html, WTE Ltd.

field)[49], which is comparable to levels considered on the market for septic tanks[50]. Using these values of treatment capacity an annual phosphorus load of final effluent in the upper Clun catchment can be calculated.

Source of Phosphorus	Total Annual P Load of Final Effluent Discharged in the Upper Clun Catchment.	
	Normal Treatment Capacity (13%)	Favourable Treatment Capacity (35%)
Dishwasher	105.02 kg	78.46 kg
Washing Machine	108.41 kg	81.00 kg
Organic Matter	212.36 kg	158.66 kg
Total	**425.79 kg**	**318.12 kg**

Figure 20. Annual phosphorus load of wastewater in the upper catchment post-treatment.

When treatment values are included, the total annual phosphate load in wastewater discharged to the local environment is estimated to be between 318kg and 426kg. The small-scale treatment systems of the upper Clun catchment were predominately septic tanks and 71.4% of on-site systems were classed as having a potentially high environmental impact, suggesting the 'normal treatment capacity' is more representative of the sample. Nutrient enrichment of this level is likely to cause eutrophication of surface water within the catchment, particularly as all domestic properties within the upper catchment are within 1km of a watercourse (most are within a few hundred metres). Eutrophication is believed to be one of the main contributors to the decline in Freshwater Pearl Mussel populations throughout Europe. The nutrient enrichment that wastewater contributes, within the upper catchment of the River Clun, indicates an issue requiring improvement if the translocation of pearl mussels is to be successful.

From the water quality data provided by the Environment Agency it is clear that the upper catchment has a better quality water; with consistently lower levels of orthophosphate, nitrate and conductivity from 2007-2010 than sites downstream. However none of the seven monitoring sites reached the requirements for a healthy Freshwater Pearl Mussel population. Therefore although the upper catchment represents a more suitable habitat, work is still necessary to ensure the water quality reaches and sustains the levels required.

[49] Webb, L. (2010) *Survey of Local Washing Practices and Septic Tank Operation in Relation to Domestic Phosphorus inputs to Loweswater,* Loweswater Care Project.
[50] WTE-Ltd (n.d) *Sewage Treatment*, www.wte-ltd.co.uk/sewage_treatment_options.html, WTE Ltd.

6.0 Conclusion

The aim of the report was to investigate the possible impact of wastewater infrastructure on water quality of the River Clun. From this information a potential effect to the Freshwater Pearl Mussel species can be assessed.

The majority of households included in the survey with a self managed treatment system were classified as having a high potential impact on local water quality. The main reasons for this were poor management and an aging and inefficient infrastructure. The impact of wastewater on the River Clun could therefore be reduced by increasing the knowledge and understanding of efficient system management and development of the current infrastructure in place.

The effluent quality discharged from the sewage treatment works in the upper catchment was better than that tested by manufacturers of small-scale systems. However this effluent is discharged to surface water, unlike a typical small-scale system, so for the translocation of Freshwater Pearl Mussels it is advisable to translocate upstream from the treatment plant. This will ensure a better aquatic habitat and avoid impact from treatment changes or technical errors from the site. As the treatment plant is able to produce a better quality effluent, it is also suggested that properties within the mains drainage area, which currently have an inefficient treatment system, are connected to the treatment plant.

The influence of legislation and the benefit of regulations applied to washing detergents has been evident on a local scale. All of the surveyed residents owned a washing machine, so the regulations to reduce phosphate content of washing machine detergents, has helped considerably in reducing the amount of phosphate discharged to wastewater in the upper catchment. At present an economically and technically feasible alternative to phosphate used in automatic dishwasher detergents is not available. If this can be improved the contribution of detergents to the phosphate load of domestic wastewater will be dramatically reduced.

It can therefore be concluded that domestic wastewater has the potential to impact the local environment including watercourses and subsequently effect the survival of Freshwater Pearl Mussels but this is dependant on many influencing factors. The main factors that must be considered for short-term water quality improvement in the Upper Clun catchment, include improving the general understanding and knowledge in system management and correct automatic dishwasher detergent use. To ensure this is utilised it must be readily available and ecological products must be affordable. For long-term improvement wastewater infrastructure must be developed, households connected to mains drainage where feasible and other systems improved. Such development will help avoid fines under the European Water Framework Directive and Habitats Directive, which suggests government funding should be made available for such work especially for high profile and protected sites such as the River Clun.

7.0 Recommendations

Key Recommendations:

- Undertake effluent quality testing across a range of off-mains systems to accurately assess impact on water quality
- Follow-on survey to accurately determine the number, location and type of off-mains treatment in the upper catchment
- Identify high risk installations (age, servicing, proximity to river etc.)
- Study of a small number of locations close to septic tanks to monitor nutrient fluxes to soil, groundwater and surface water
- Undertake survey to identify misconnections (rain to foul) mains and off-mains
- Undertake awareness raising campaign to:
  - Encourage better maintenance,
  - Promote upgrading of old systems
  - Encourage the use of low impact products
- Provision of grant for householders wishing to upgrade old/inefficient systems
- Remove disincentives to connect to mains treatment works
- Set discharge limits at sewage treatment works consistent with a recruiting pearl mussel river

7.1 Further Research

The report has indicated many topic areas that could be taken further in future research. An area of particular relevance would be the possible correlation between effluent quality and river quality. This could be done using the effluent quality data of a treatment plant and the river quality and velocity downstream of the plant. If a link can be made between effluent quality and discharge volume from a treatment plant and the subsequent impact to river quality, the required effluent quality when discharged to a river containing freshwater pearl mussels could be established.

The impact of activities within the home on wastewater is not quantifiable without testing under controlled conditions. Testing would need to be conducted whereby the substances and volume of wastewater was controlled. This would allow the influence of different contributors to wastewater (such as detergents, organic matter, bleach etc) to be tested. The impact of these activities on river quality could then be tested by monitoring water quality downstream (if the system discharged directly to surface water). For systems that discharge to a drainage field, soil testing could be conducted. Core samples could be taken to allow nutrient levels through a soil profile to be tested. These techniques could also be used to compare the treatment capacity of an aging septic tank with a modern sewage treatment plant (similar to that tested by Gill *et al* in 2009[51]). The findings of such research would contribute to creating a more accurate flow chart to assess impact. Once more information is available such as the impact of system age, type, treatment techniques and soil type, a flow chart could be created and used as a standard for assessing the potential environmental impact of each system, locally but also nationally if successfully developed.

An approach has been designed by UK Water Industry Research (UKWIR), Scotland & Northern Ireland Forum for Environmental Research (SNIFFER) and the UK Technical Advisory Group (UKTAG), which incorporates the methods mentioned here. The approach involves a behaviour questionnaire, sewer sampling and flow monitoring to assess the

[51] Gill, L.W., O'Luanaigh, N., Johnson, P.M., Misstear, B.D.R and O'Suilleabhain, C. (2009) Nutrient Loading on Subsoils from On-Site Wastewater Effluent, Comparing Septic Tank and Secondary Treatment Systems, *Water Research,* Vol. 43, pp. 2739-2749.

impact of source control on the quality of wastewater received at treatment works. This approach could therefore be adapted and applied locally to provide a more accurate measure of 'impact'.

7.2 Provision of Information and Support

At a local scale several improvements can be made to reduce the impact wastewater can have on the water quality of the River Clun. This includes research into suitable environmental products. A trial could be conducted by local people into a selection of different ecological products. The aim of this is to encourage people to use ecological products (particularly dishwasher detergents) by increasing their interest and knowledge of the products available.

Information into system management is also required in the area to ensure systems are emptied and serviced regularly. This has the potential to dramatically improve the impact a household can have on river quality from their wastewater. It also has benefits for the householder as regular de-sludging and servicing reduces the risk of future system failures. A portal is required however for such information to be provided and made available, especially as the Local Authorities no longer provide this service.

For long-term improvement in river quality and to ensure a sustained aquatic habitat for Freshwater Pearl Mussels within the upper catchment the wastewater infrastructure of the area would require development. This should be focussed at households within close proximity to a watercourse. Grants could be made available for this improvement to encourage homeowners to conduct such costly changes, especially as such actions will help avoid fines from Europe under the Habitats and Water Framework Directives. These efforts will only be successful if management techniques are improved. The provision of local support and information is therefore vital for wastewater to be eradicated as an environmental issue. An effective way to implement this would be through a local community catchment scheme, such as the Dee Catchment Partnership, who aim to support and promote fully integrated catchment management.

7.3 Registration

During the research project, the Environment Agency encouraged home owners to register small-scale treatment systems. The Environment Agency is now reviewing this requirement in England. If this is put in place, work is required in the upper Clun catchment and all rural communities in the UK, to increase peoples understanding and awareness of the registration.

7.4 Connection to mains drainage

Over 70% of properties with small-scale treatment systems were classed as having a high potential impact on the local environment; it is therefore recommended that properties are connected to mains drainage where possible and if appropriate. This is particularly relevant if a property has a septic tank over 20 years in age or if effective management of the system is not conducted by de-sludging the system regularly.

7.5 Implication to the Freshwater Pearl Mussel

The report highlights one of many factors that need to be considered within the upper catchment of the River Clun, particularly if the translocation of pearl mussels is conducted. The water quality data measured at Newcastle indicated that even the upper Clun is not suitable as a receptor site at present. An increase in effective water quality monitoring is required, to include a continuous data record for sites upstream of Newcastle (such as that introduced in the Killeen (2009) report). The quality measures should be relevant to the known requirements of Freshwater Pearl Mussels, to provide an applicable method of assessing habitat quality. An increase and consistency to water quality monitoring in the catchment will also help address other factors that are influencing habitat quality, with the aim to reach a clean and sustainable catchment.

Appendix 1: Domestic Survey

Working to conserve and enhance the landscape

Shropshire Hills
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Domestic Wastewater Survey

A well managed wastewater treatment system can prove cost effective, reliable and help protect your local environment.

Aim of the survey:

- To gather information from homeowners in the Clun Valley with regard to the treatment of wastewater.
- The information provided will only be used by the Shropshire Hills AONB Partnership as a means to increase our understanding of wastewater treatment in the area so that we can provide relevant information and contacts to local homeowners, to help you maintain a clean and healthy local environment.
- No personal information is required, only a postcode to allow mapping of the surveyed area.

The Survey:

Postcode: ……………………………….

Domestic Water System:

1. What type of treatment system do you have for your domestic wastewater (sewage)?

☐ Mains drainage (Skip to question 8)
☐ Cesspool or cesspit (Skip to question 8)
☐ Septic tank Model…………………… Size (litres)....…………
☐ Sewage treatment plant Model: ……………………. Size (l)……....……………...

Other (please specify)…………………………………………………………………………………

2. What type of secondary treatment does your system have?

☐ None ☐ Bio-disks ☐ Bio-filter ☐ Reed bed ☐ Don't Know ☐ Other …..…………..

3. Method of discharge?

☐ Ground water (soakaway) ☐ Surface water (pipe to river, stream etc.)

4. Do you have sole use of this system?

☐ Yes ☐ No

If you have answered **no**, how many properties in total use the system?
……………………

5. Age of the system?
   ☐ < 10 year ☐ 10-20 years ☐ 20-50 years ☐ > 50 years

6. How close is your system to a watercourse (stream , river, ditch etc.)?
   ☐ Less than 10 metres ☐ More than 10 metres

7. When was the last time the system was emptied or serviced?
   ☐ <1 year ☐ 1-3 years ☐ 3-6 years ☐ 6-10 years ☐ >10 years

Usage:

8. Which of these appliances do you have in your home? (tick all that apply)
   ☐ Washing Machine ☐ Dishwasher ☐ Power Shower ☐ Dual-flush Toilet

9. As a household, how many times a week do you use these appliances? (**if N/A leave blank and skip to question 11**)
   ☐ Washing Machine ☐ Dishwasher

10. What brand of detergent do you usually use for the following appliances? (e.g. Persil, Aerial etc.)

    Washing Machine ____________________
    Dishwasher ____________________

11. Do you use 'environmentally friendly' cleaning products in the home (washing up liquid, toilet cleaner, all purpose cleaner, bathroom cleaner etc.)? (e.g. Ecover)
    ☐ Yes: All ☐ No: None ☐ Some

12. Do you dispose of any food waste into your wastewater system (eg. pouring food substances down the drain or using an electronic food waste disposer)?
    ☐ Yes ☐ No

13. Are the rainwater drainage pipes (down-pipes) of your home connected to your wastewater treatment system?
    ☐ Yes ☐ No ☐ Don't know

Any comments:
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………………………………………………

Thank you for your time.

If you would like any more information on the study please do not hesitate to contact the Shropshire Hills AONB Partnership:

Rosanna Fildes
Research Intern (temporary)
Tel: 01588 674087
Email: rosanna.fildes@shropshire.gov.uk

Or alternatively,

Mike Kelly
River Valleys Officer
Tel: 01588 674091
Email: mike.kelly@shropshire.gov.uk

By returning the survey before 20th July 2011, you will receive a free sample of washing up liquid or detergent, which is less damaging to your local watercourse and will help your wastewater treatment system run efficiently.

Simply fill in the slip attached and return it with your survey.