An assessment into the potential impact of on-site wastewater treatment systems on surface water quality.

Summary Report

Valerie McCarthy, Eddy Minet, Patrick Rafferty, Jim O' Donohoe and Suzanne Linnane

The National Centre for Freshwater Studies, Dundalk Institute of Technology

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NATIONAL DEVELOPMENT PLAN

Introduction

In Ireland many people live in homes located in rural areas or small communities that are not connected to public wastewater treatment systems and are, therefore, reliant on their own private systems for wastewater treatment and disposal. Properly built and maintained on-site wastewater treatment systems (OSWTS) can treat effluent in an ecologically sound manner and return the water to the environment (Hill, 2004). However, inappropriately designed, installed and maintained OSWTS are among the many sources of nutrients to groundwater and surface water. Other major sources include agricultural fertilizers and livestock manure. Contamination of ground and surface water resources by effluent discharged from OSWTS is of critical concern owing to the potential health risks, and the degradation of recreational and drinking water resources as a consequence of increased nutrient inputs (Carroll *et al*., 2005). It is estimated that in Ireland 50 million gallons of effluent, from over 1.2 million people are produced by on-site systems (Daly, 2003).

On-site systems can be divided into two broad categories: septic tank systems and secondary treatment systems or proprietary systems and can include mechanical aeration systems, filter systems and constructed wetlands. A conventional septic tank system comprises a tank, which is designed for removal of solids followed by a soil percolation area. Most of the treatment of effluent takes place in the subsoil as it passes through the percolation area. Various physical, chemical and biological interactions occur in the subsoil which removes bacteria and other pollutants and renders the wastewater suitable for discharge. Aerobic treatment is the most complete treatment that the effluent can undergo in the subsoil, and this will only occur in layers that are not saturated with water.

There is increasing concern that failing or improperly installed and maintained OSWTS can cause contamination of ground and surface waters with pathogens, nutrients and biologically active compounds (Yates, 1985). In order to effectively treat the wastewater it is critical that effluent flows into the soil and remains in the soil until properly treated. The extent to which attenuation of the effluent takes place in the subsoil depends on the ion exchange capacity, permeability and texture of the subsoil, the depth of the unsaturated subsoil layer and depth to bedrock. In addition, the extent of the success of OSWTS at effectively treating effluent is dependant on a the capacity of the system in relation to the number of people in the household, the frequency at which the tank is desludged and the correct functioning of the various mechanical components of the system. Failure of any one of these components will reduce the efficiency with which the effluent is processed.

On-site wastewater treatment systems are considered to be one of the principal sources of groundwater pollution in rural areas (Daly *et al*., 1993). However, very little definitive work has been undertaken on the impact of OSWTS on surface water. Effluent from OSWTS can reach surface water through a number of pathways and usually occur in areas with low permeable soils overlying a poorly productive aquifer. Contamination can reach surface water via soil interflow and shallow groundwater or, particularly in karst areas, via deep groundwater flow which subsequently reaches surface water through a secondary rapid pathway such as an emerging spring. Effluent may also reach surface water directly overland where the soil is saturated or impermeable and effluent ponding at the surface is likely to occur.

Background to the study

The National Source Protection Pilot Project (NSPPP) was established by the National Rural Water Monitoring Committee and is based at the Milltown Lake catchment in Co. Monaghan, from which the Churchill and Oram group water scheme source their water. The project was set up in 2005 to co-ordinate efforts to monitor and assess water quality within the catchment, to identify reasons for its deterioration and to implement community led remediation measures to restore and maintain the quality of the raw water throughout the catchment. The catchment is monitored regularly for point and diffuse sources of contamination. In addition, the various land uses and activities which are potential sources of contamination have been identified within the catchment. The NSPPP aims to work with and through the local community to devise and implement environmentally sustainable mechanisms to deal with contamination at source.

On-site wastewater treatment systems were identified as a potential source of contamination within the catchment and as such they were characterised through a combination of household questionnaires and non-intrusive site inspections. A total of 154 households were surveyed in 2006 and homeowners were asked questions relating to the age and type of their system, the frequency of desluding, the number of occupants and the number of sinks, showers baths and toilets in the house. A subset of 42 of these systems were visually inspected to establish the materials used in the construction of the system, the type of effluent dispersal unit and the overall condition of the site. This work has been extended both in duration and activities in line with the requirements of the Unsewered Wastewater Treatment systems National Study as part of the field validation of the risk assessment methodology which was developed based on the pressure-pathway-receptor framework.

Project Objectives

A major function of OSWTS is the removal of nutrients from wastewater before it reaches groundwater or surface water receptors. Diffuse run-off from agriculture is believed to be the principal source of nutrient input to water bodies in Ireland. Point sources, however, such as those from OSWTS are also likely to be an important source of nutrients to surface waters. In Northern Ireland, OSWTS have been estimated to contribute as much as 118 tonnes of total phosphorus to inland and coastal waters per year, which accounts for 7 % of the total phosphorus budget for Northern Ireland (Smith *et al.*, 2005). It is important to be able to quantify the effects of OSWTS on water quality in order to improve management of our water resources and to meet the requirements of the Water Framework Directive (WFD; 2000/60/EC), which aims to restore all surface waters to good ecological status by 2015. There is much anecdotal evidence suggesting that OSWTS may be a significant and underestimated source of nutrient input to water bodies in rural catchments (Beal *et al.*, 2004). However, the integrated management of water resources which will be inherent in the implementation of the WFD invokes a need to quantify the relative importance of point and diffuse sources of pollutants in catchments.

This project aims to develop an increased understanding of the risk posed by OSWTS to surface water and to provide quantifiable data on their contribution to nutrient loading within the study catchment. The field data generated in this study will be used to validate the risk assessment methodology developed by the Western Regional

Basin District Project on behalf of the Unsewered Systems Working Groups National Programmes of Measures as part of the implementation of the WFD in Ireland.

Methodology

Site Selection

Five OSWTS were selected for intrusive examination at varying distances from the nearest water course. Sites were selected based on their proximity to surface water (e.g. stream river, ditch), the absence of other potential sources of nutrients which could confound results (e.g. leaking slurry tank) and permission from the home owner. As a result of these constraints two of the study sites are located outside of the study catchment, but are nevertheless located adjacent to water courses which flow directly to Lough Muckno, from which the water supply to Dundalk, Co. Louth is sourced.

Installation of piezometers

At each site a varying number of piezometers were installed down gradient from each system depending on its proximity to the nearest water course. One control was also installed up gradient of the system. The piezometers were installed by drilling boreholes of varying diameters (5 cm, 6.3 cm and 7.5 cm) formed by window sampler gouges driven by a percussion hammer to a depth of approximately 1 – 2 m below the saturated zone (Plate 1).

Plate 1. Installation of piezometers.

Into these, rigid high-density 24 mm diameter polyethylene tubing was inserted. A closed point was fitted at the bottom and a removable cap at the top. The gap between the walls of the borehole and the perforated lower part of the tubing was filled with clean filter sand. The void around the upper portion of the tubing was sealed with bentonite to prevent the direct ingress of surface water through the borehole (Plate 2). The depth to the subsurface water was measured using an electronic dipper.

Plate 2. Piezometer at surface showing borehole packed with bentonite.

Field collection of subsurface and surface water samples began on the 15th of August 2008. Surface water sampling sites are located up and down stream of the OSWTS at each site. Samples are collected once every two weeks and are extracted from the piezometers using a peristaltic pump.

Laboratory Analyses

To ensure representative samples were obtained, all piezometers were purged prior to sampling. All water samples were analysed within 48 hours of collection. Dissolved nutrient analyses (soluble reactive phosphorus (SRP) and dissolved inorganic nitrogen (DIN; nitrate NO_3^--N + nitrite NO_2^--N + ammonia NH_3^+-N) were made on water filtered through 0.45 µm Whatman® membrane filters. Samples for total phosphorus (TP) and total nitrogen (TN) were analysed after digestion under pressure with potassium peroxide sulphate ($K_2S_2O_8$). Phosphorus and nitrogen analyses were carried out colometrically using a flow injection auto-analyser (Lachat Quickchem®, Lachat

Instruments, Loveland, Colorado, USA). Nitrate and nitrite, SRP and ammonia were determined following QuickChem® Methods 10-107-04-1-R, 10-115-01-1-V and 10-107-06-2-L, respectively.

Sulphate (SO_4^{2-}) and chloride (Cl^-) concentrations were determined by ion chromatography (Clesceri *et al*., 1989) using a Dionex® ICS-2000 system (electrochemical suppressed conductivity system with an anion exchange column). Sodium (Na^+) and potassium (K^+) concentrations were measured by atomic absorption (Clesceri *et al*., 1989). Samples for Biological Oxygen Demand (BOD) were collected in 300 ml Wheaton bottles. BOD_7 was calculated as the difference between initial dissolved oxygen concentration of the sample and that of the sample following incubation at 20 °C for seven days. Dissolved oxygen measurements were taken using a WTW® inoLab® BSB/BOD 740 meter with a StirrOX® G probe. Alkalinity was analysed on a 50 ml unfiltered sample of water by Gram titration according to Mackereth *et al.* (1978). Suspended solids and suspended particulate organic matter were obtained following Allen (1989). Conductivity was measured on-site using WTW® meters. Total coliforms and *E.coli* were enumerated from 100 ml of sample collected using sterile sample bottles according to the QuantiTray® 2000 (IDEXX Laboratories, Inc., Westbrook, Maine, USA) most-probable-number (MPN) format.

Quality control

For all phosphorus and nitrogen analyses, quality control (QC) samples of known concentration were used to assess the performance of the analytical methods employed. Standard solutions for use as QC samples in N and P analyses were prepared with reagents which were independent to those used for the construction of standards, and therefore provided a degree of quality assurance as well as QC. For nitrate/nitrite analyses a QC with a concentration of 11.3 mg L^{-1} as N was prepared, for phosphorus analyses a QC concentration of 0.5 mg L^{-1} PO_4-P was used and for ammonia a QC with a concentration of 5 mg L^{-1} NH_3-N was used. All quality assurance values were within acceptable ranges (± 3 %).

Site Characterisation

Five sites were selected for intrusive survey work. Four of these sites currently have piezometers installed. Boreholes will be drilled at the fifth site in January 2009. Site characterisations were carried out at each site in November 2008 by Dr. Robert Meehan, Talamh Ireland. Percolation tests were carried out by Traynor Environmental. A full report of the site characteristics, based on a comprehensive desk study and geological field interpretation, has been complied by Dr. Robert Meehan and Traynor Environmental and are summarised here.

The soils at the majority of the sites are located in an area which is generally well drained where bedrock is at or near to the surface, but tend to have poor drainage on higher drumlin features. The GSI subsoil permeability map records the subsoil in this general area as 'low' permeability, meaning that runoff usually dominates over infiltration. However, as the area is in a locality mapped as 'X - Extreme' vulnerability, the soil on the sites may be relatively well drained.

Milltown Lake catchment is approximately 34 km^2 and is located in Co. Monaghan just north of Castleblayney town (Fig. 1). It is situated in a drumlin landscape and consists primarily of agricultural pasture. Miltown Lake has one outflow which flows directly into Lough Muckno.

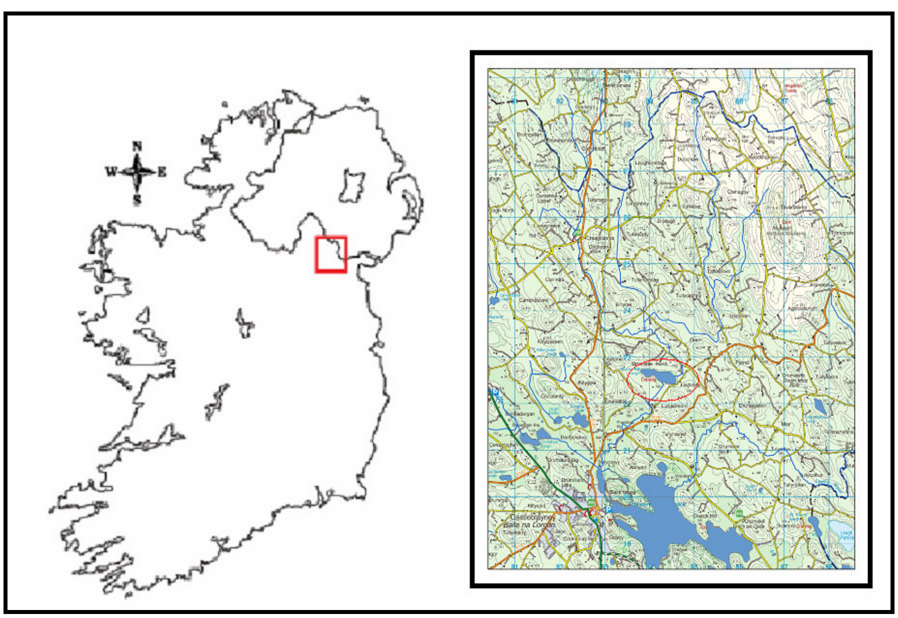

Fig 1. Milltown Lake and surrounding area.

Site D:

Type of system	Proprietary system
Number of boreholes	8 down gradient, 1 control up gradient
Borehole depth	0.83 – 3.11 m
Average recovery	92%
Distance to watercourse	~105 m
Age of system	~ 5 years
Method of effluent dispersal	Percolation area
Frequency of desludging	every 2 years
Number of occupants	~ 5 adults

The site is located on the southeastern shoulder of a low ridge, within a hummocky area of an otherwise higher drumlin landscape. The site is adjacent to a relatively dense cluster of houses. The majority of land on and around the site is on a gradient. A fast flowing, meandering stream flows from east to west 105 m south-southeast of the site and Lough Muckno is located 460 m south-southwest of the site the site. A 2 m deep drain occurs along the hedgerow, 70 m southeast of the site, and channels surface water into the stream along a 65 m long stretch of land. The fields surrounding the site were found to be relatively firm and even during the site survey. The on-site system and percolation area are located in the garden at one side of the house. Some slight ponding was observed across the hedge from the site to the northeast, and some saturated ground also occurred in the flat, narrow floodplain of the stream located 130 m southeast of the site.

The trial hole characterisation (Fig. 2) suggests that the rainwater falling in this area infiltrates through 1.21 m of unsaturated topsoil and subsoil throughout the year, and is able to flow through this material vertically on the site into the fractured bedrock. As the top of the bedrock was noted to be mottled when the pit was excavated, the water is also likely to flow across the top of this during heavy rainfall. The area is dominated by bedrock within 3 m of the surface and would, therefore, be considered to be of 'extreme' groundwater vulnerability. Infiltration to the groundwater table and lateral flow across and through a relatively permeable uppermost bedrock surface dominates over overland flow in this locality.

The site is not considered suitable for a conventional septic tank, which requires 2 m of unsaturated soil and subsoil above bedrock and the water table, but is likely to be suitable for a mechanical aeration system and discharge to ground. An average 'T' value rating of 37.96 min/25 mm as recorded at this site and a 'P' value rating of 22.85 min/25 mm was observed.

Depth of trial hole (m):	1.29m	**Date and time of excavation:**	10/11/2008 10.30	**Date and time of examination:**	13/11/2008 10.15
Depth from ground surface to bedrock (m) (if present):	1.21m-1.29m				
Depth from ground surface to water table (m) (if present):	0.99m				

Depth	Soil/Subsoil Texture & Classification**	Soil Structure	Density	Colour ***	Preferential flowpaths
0.1 m – 0.2 m	*'A' horizon* Loam	Crumb	Variable compact to very soft	Dark brown (3/3, 10YR)	Abundant grass roots and rootlets
0.2 m – 0.6 m	*'B' horizon* sandy SILT with common gravels (2, 2, 2 threads; 60mm, 50mm, 50mm ribbons; dilatant, raspy)	Variable crumb to subangular blocky	Variable very soft to soft	Dark brown (3/3, 10YR)	Common roots and rootlets
0.7 m – 1.0 m	*'C' horizon* sandy SILT with common gravels (2, 1, 2 threads; 50mm, 70mm, 50mm ribbons; dilatant, raspy)	Massive, yet very fissile	Variable very soft to soft	Dark brown (3/3, 10YR)	Occasional rootlets Pods of silty GRAVEL in places Subhorizontal partings (shear structures)
1.1 m – 1.2 m	Water table				
1.3 m	Fractured shale bedrock				Base of hole
1.4 m – 3.0 m					

P1 & P2

T1 & T2

Other information							
Depth of water ingress:	0.7m and 1.25m	**Rock type (if present):**	Shale	**Plasticity and dilatancy results:**	As above under texture	**Likely T value:**	15-35

Fig. 2 Trial Hole at Site D

Site F:

Type of system	Single chamber septic tank
Number of boreholes	10 down gradient, 1 control up gradient
Borehole depth	1.44 – 5.17 m
Average recovery	57 %
Distance to watercourse	53 m
Age of system	Between 16 – 30 years
Method of effluent dispersal	Soakaway
Frequency of desludging	Unknown
Number of occupants	~ 2 adults

The site is located on the southern shoulder of a high ribbed moraine ridge located in a drumlin ribbed moraine landscape. The On-site system and soakaway are located in a field 25 m southwest of the house and farmyard. A fast flowing, well channelized stream flows from north to south 53 m southeast of the tank. Much of this flows over bedrock in the base of the channel. Two smaller streams flow into this from the east, 110 m northeast of the tank. Drainage ditches occur along most of the hedgerows surrounding the site, and channel water down slope during heavy rain. Agricultural pasture occurs in the surrounding fields, with some scrub also occurring alongside the stream, 50 m east of the tank. An extended area of bedrock outcrop is seen from 50 m east of the tank at the sides of the steep gully flanking the stream channel, and extending northwards on each side of the gully for a distance of over 200 m. The field immediately surrounding the tank is relatively firm and even, although directly up-gradient of the tank the land is completely saturated and it is likely that the inlet pipe is broken.

The soil sequences from the trial hole (Fig. 3) indicates that the rainwater falling in this area infiltrates through 0.55 /0.68 m of unsaturated topsoil throughout the year, and is capable of flowing through this material vertically as far as the subsoil layer. A small portion of this infiltrates, but most flows across the top of the impermeable subsoil layer as far as the stream during heavy rainfall, and during the winter months. The site is, therefore, not suitable for a conventional septic tank, but may likely be suitable for a mechanical aeration system and discharge to ground, the ‘T’ values are less than 90, and the ‘P’ values are less than 50. At this site an average ‘T’ value rating >98.26 min/25 mm indicating poor percolation of the subsoil materials and a P’ value rating of 24.79 min/25 mm, which would suggest good percolation characteristics of the topsoil material.

Plate 3. Trial hole, Site F. The well aerated topsoil material is visible and mottled and stiff to very stiff subsoil (photo: Robert Meehan).

The trial hole was located just outside an area dominated by bedrock outcrop/subcrop, in which infiltration to the groundwater table and lateral flow across and through the relatively permeable uppermost bedrock surface dominates over overland flow. The trial hole was, therefore, well drained owing more to the texture of the uppermost subsurface layers and the gradient on the site, than to the actual permeability of the subsoil. As the subsoil gets deeper away from the system and the area of bedrock outcrop and subcrop the subsoil is likely to be impermeable.

Depth of trial hole (m):	1.75m	Date and time of excavation:	10/11/2008 12.00	Date and time of examination:	13/11/2008 14.00
Depth from ground surface to bedrock (m) (if present):			>1.75m		
Depth from ground surface to water table (m) (if present):			>1.75m		

P1 & P2

T1 & T2

	Soil/Subsoil Texture & Classification**	Soil Structure	Density	Colour ***	Preferential flowpaths
0.1 m 0.2 m 0.3 m	*'A' horizon* Sandy loam with occasional gravels	Crumb	Compact	Dark brown (3/3, 10YR)	Abundant grass roots and rootlets
0.4 m 0.5 m 0.6 m	*'B' horizon* silty SAND with common gravels (1, 0, 0 threads; 30mm, 40mm, 30mm ribbons; cohesive, dilatant, very raspy)	Subangular blocky	Stiff	Dark yellowish brown (4/4, 10YR)	Occasional rootlets
0.7 m 0.8 m 0.9 m 1.0 m 1.1 m 1.2 m 1.3 m 1.4 m 1.5 m 1.6 m 1.7 m	*'C' horizon* slightly sandy SILT/CLAY with common gravels (4, 3, 3 threads; 70mm, 90mm, 110mm ribbons; slightly dilatant, raspy)	Massive, yet very fissile	Variable stiff to very stiff	Mottled light brownish grey (6/2, 10YR) with yellowish brown (5/4, 10YR) and brown (4/3, 10YR)	Pods of GRAVEL in places Subhorizontal partings (shear structures)
1.8 m 1.9 m 2.0 m 2.1 m 2.2 m 2.3 m 2.4 m 2.5 m 2.6 m 2.7 m 2.8 m 2.9 m 3.0 m	Base of hole				

Other information							
Depth of water ingress:	None	Rock type (if present):	None	Plasticity and dilatancy results:	As above under texture	Likely T value:	35-70 (or more owing to consolidation?)

Fig. 3 Trial Hole at Site F

Site K:

Type of system	Single chamber septic tank
Number of boreholes	4 down gradient, 1 control up gradient
Borehole depth	0.11 – 0.17 m
Average recovery	41 %
Distance to watercourse	12 m
Age of system	Between 16 – 30 years
Method of effluent dispersal	Soakaway
Frequency of desludging	> 5 year intervals
Number of occupants	2 adults

The site is on the northeastern lower backslope of a low drumlin ridge, within a drumlin landscape. The tank is situated in a field approximately 15 m from the house. A fast flowing stream flows from northwest to southeast 12 m from the tank. The surrounding land consists of agricultural pasture. The fields surrounding the site to the south and west are relatively firm and even. Across the stream to the northeast, the fields are softer, wetter and are commonly poached.

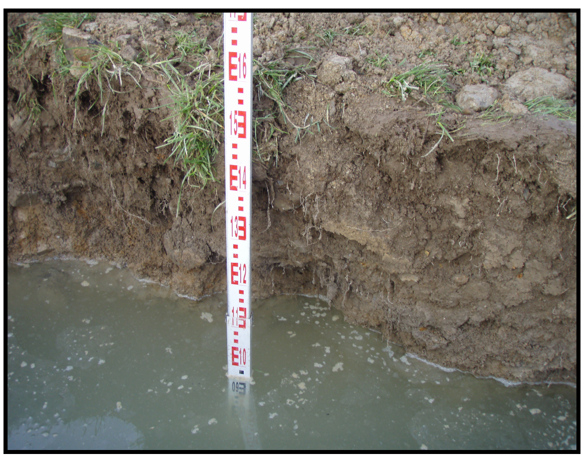

Plate 4. Trial hole, Site K. Note the mottled nature of the material above the perched water table (photo: Robert Meehan).

Examination of the trial hole (Fig. 4) indicates that the rainwater falling in this area infiltrates through only 0.14/0.15 m of unsaturated topsoil throughout the year, and is able to flow through this material laterally on the site above the impermeable subsoil. The rainwater can infiltrate the subsoil in summer, when the material dries out, but 'fills' with water again in winter, when a perched water table forms. On the day of excavation the hole was dry, but water began infiltrating immediately. At this site little rainfall infiltrates to groundwater and the majority runs off the site.

The site is, therefore, not suitable for a conventional septic tank or for a mechanical aeration system as the average 'T' value recorded at this site was >82.06 min/25 mm. In addition a 'P' value rating of 50.04 min/25 mm was measured indicating poor percolation characteristics in the topsoil material. It should be noted that the soakaway on the site has been by-passed and a pipe discharges directly from the septic tank to the stream.

Depth of trial hole (m):	1.85m	**Date and time of excavation:**	10/11/2008 13.00	**Date and time of examination:**	14/11/2008 09.30
Depth from ground surface to bedrock (m) (if present):	>1.85m				
Depth from ground surface to water table (m) (if present):	0.68m				

P1 & P2

T1 & T2

	Soil/Subsoil Texture & Classification**	**Soil Structure**	**Density**	**Colour *****	**Preferential flowpaths**
0.1 m 0.2 m	*'A' horizon* Clay loam	Crumb	Compact	Dark brown (3/3, 10YR)	Abundant grass roots and rootlets
0.3 m 0.4 m	*'Bg' horizon* CLAY with occasional gravels (4, 4, 5 threads; 100mm, 120mm, 110mm ribbons; non-dilatant)	Subangular blocky	Variable very soft to soft	Mottled dark yellowish brown (3/4, 10YR) with light grey (7/1, 10YR)	Common rootlets
0.5 m 0.6 m 0.7 m	*'Cg' horizon* CLAY with common gravels (6, 5, 6 threads; 120mm, 140mm, 120mm ribbons; non-dilatant)	Massive, yet fissile	Variable very soft to firm	Mottled yellowish brown (5/6, 10YR) with grey (6/1, 10YR) and strong brown (5/6, 7.5YR)	Occasional rootlets
0.8 m 0.9 m 1.0 m 1.1 m 1.2 m 1.3 m 1.4 m 1.5 m 1.6 m 1.7 m 1.8 m 1.9 m	Water table				
2.0 m 2.1 m 2.2 m 2.3 m 2.4 m 2.5 m 2.6 m 2.7 m 2.8 m 2.9 m 3.0 m	Base of hole				

Other information							
Depth of water ingress:	0.8m and 1.2m	**Rock type (if present):**	None	**Plasticity and dilatancy results:**	As above under texture	**Likely T value:**	>90

Fig. 4 Trial Hole at Site K

Site S:

Type of system	Single chamber septic tank
Number of boreholes	12 down gradient, 1 control up gradient
Borehole depth	1.93 – 3.08 m
Average recovery	69 %
Distance to watercourse	> 200 m
Age of system	Between 16 – 30 years
Method of effluent dispersal	Soakaway
Frequency of desludging	> 5 year intervals
Number of occupants	2 adults

The site is located on a southeastern mid-backslope of a high drumlin ridge, within a drumlin landscape. The tank is situated in a field 25 m south of the house. A fast flowing stream has been channelled under and alongside the laneway flanking the site. This is at the base of a 0.8 – 1.3 m cutting. Agricultural pasture around the site and the fields to the south and east are relatively firm and even. The fields to the north, northwest and west are softer and are commonly poached. Drains are relatively common in this area, but are absent from the area immediately east and south of the site. This may be owing to the steeper gradients in that area.

The soil sequences from the trial hole (Fig. 3) suggests that the rainwater falling in this area infiltrates through only 0.25/0.32 m of unsaturated topsoil throughout the year, and is able to flow through this material laterally on the site above the impermeable subsoil. The rainwater infiltrates the subsoil in summer, when the material dries out, but ‘fills’ with water again in winter, when a perched water table forms. On the day of excavation the hole was dry, but water began infiltrating immediately. This site is in an area dominated by relatively deep subsoils, little rainfall infiltrates to groundwater and the majority runs off the site. The site is, therefore, not suitable for a conventional septic tank or for a mechanical aeration system with discharge to ground as the ‘T’ value was > 100.00 min/25 mm and the perched water table rises to within 0.15 m of the surface during winter. The ‘P’ value rating of 63.25 min/25 mm suggests poor percolation of the topsoil material. It should be noted that the soakaway on the site may have been by-passed by a pipe discharging directly from the septic tank to the surface water drain under the road.

Depth of trial hole (m):	1.75m	Date and time of excavation:	10/11/2008 14.15	Date and time of examination:	14/11/2008 11.30
Depth from ground surface to bedrock (m) (if present):	>1.75m				
Depth from ground surface to water table (m) (if present):	1.05m				

P1 & P2

T1 & T2

	Soil/Subsoil Texture & Classification**	Soil Structure	Density	Colour ***	Preferential flowpaths
0.1 m	*'A' horizon* Clay loam	Variable crumb to subangular blocky	Variable very soft to soft	Dark yellowish brown (3/4, 10YR)	Abundant grass roots and rootlets
0.2 m 0.3 m	*'B' horizon* CLAY with occasional gravels (6, 6, 6 threads; 140mm, 150mm, 140mm ribbons; non-dilatant)	Subangular blocky	Variable soft to firm	Mottled dark brown (3/3, 10YR) with light grey (7/1, 10YR)	Common roots and rootlets
0.4 m 0.5 m 0.6 m 0.7 m 0.8 m 0.9 m 1.0 m 1.1 m	*'Bg' horizon* gravelly CLAY (6, 5, 5 threads; 140mm, 150mm, 150mm ribbons; non-dilatant)	Massive, slightly fissile	Variable firm to stiff	Mottled light brownish grey (6/2, 10YR) with light grey (7/1, 10YR) and dark brown (3/3, 10YR)	Occasional rootlets
1.2 m 1.3 m 1.4 m 1.5 m 1.6 m 1.7 m	Water table				
1.8 m 1.9 m 2.0 m 2.1 m 2.2 m 2.3 m 2.4 m 2.5 m 2.6 m 2.7 m 2.8 m 2.9 m 3.0 m	Base of hole				

Other information							
Depth of water ingress:	1.0m	Rock type (if present):	None	Plasticity and dilatancy results:	As above under texture	Likely T value:	>90

Fig. 5 Trial Hole at Site S

<u>Site M</u>:

Piezometers have not yet been installed at this site.

Type of system	Single chamber septic tank
Number of boreholes	N/A
Borehole depth	N/A
Average recovery	N/A
Distance to watercourse	15 m
Age of system	Between 16 – 30 years
Method of effluent dispersal	Soakaway
Frequency of desludging	Unknown
Number of occupants	2 adults

This site is located on the northeastern footslope of low drumlin ridge, within a drumlin landscape. The septic tank is in a field adjacent to the house site. A fast flowing stream flows from northwest to southeast 15 m northeast of the tank. The surrounding fields were dominated by agricultural pasture, with an area of mature forestry approximately 22 m from the tank. Some slight ponding was observed in the flat area 25 m north of the tank across the stream. One disused well occurs 40 m to the north-northwest and is used for livestock.

Based on the examination of the trial hole (Fig. 6) the rainwater falling in this area infiltrates through only 0.12/0.17 m of unsaturated topsoil for part of the year, and is able to flow through this material laterally on the site above the impermeable subsoil. The rainwater infiltrates some of the subsoil in summer, but in the winter 'fills' with water. On the day of excavation the hole was dry, but water began infiltrating immediately. Little rainfall infiltrates to groundwater and the majority runs off the site. The site is, therefore, not suitable for a conventional septic tank or a mechanical aeration system as the 'T' value is > 90.00 min/25 mm and the water table rises to within 0.12 m of the surface during winter. The 'P' value also indicates poor percolation characteristics of the topsoil and is 65.21 min/25mm. It should also be noted that the soakaway on the site has been by-passed by a pipe discharging directly form the septic tank to the stream 15 m away.

Depth of trial hole (m):	1.5m	Date and time of excavation:	10/11/2008 16.00	Date and time of examination:	14/11/2008 13.30
Depth from ground surface to bedrock (m) (if present):			>1.5m		
Depth from ground surface to water table (m) (if present):			0.88m		

P1 & P2

T1 & T2

	Soil/Subsoil Texture & Classification**	Soil Structure	Density	Colour ***	Preferential flowpaths
0.1 m	'A' horizon Clay loam	Variable crumb to massive	Very soft	Grey (4/1, 10YR)	Abundant grass roots and rootlets
0.2 m					
0.3 m	'Bg' horizon gravelly CLAY (6, 6, 6 threads; 150mm, 150mm, 150mm ribbons; non-dilatant)	Massive, slightly fissile	Variable firm to stiff	Mottled light brownish grey (6/2, 10YR) with lgrey (6/1, 10YR) and dark brown (3/3, 10YR)	Occasional rootlets
0.4 m					
0.5 m					
0.6 m					
0.7 m					
0.8 m					
0.9 m					
1.0 m	Water table				
1.1 m					
1.2 m					
1.3 m					
1.4 m					
1.5 m					
1.6 m	Base of hole				
1.7 m					
1.8 m					
1.9 m					
2.0 m					
2.1 m					
2.2 m					
2.3 m					
2.4 m					
2.5 m					
2.6 m					
2.7 m					
2.8 m					
2.9 m					
3.0 m					

Other information							
Depth of water ingress:	0.9m and 1.3m	Rock type (if present):	None	Plasticity and dilatancy results:	As above under texture	Likely T value:	>90

Fig. 6 Trial Hole at Site M

Biological and chemical parameters

A brief summary of biological and chemical parameters measured ate each sites since sampling began in August 2008 are briefly summarised below:

- **Site D:** Mean SRP and ammonia (± SE) concentrations of 3.28 ± 0.82 mg L^{-1} (n = 54) and 33.74 mg L^{-1} (n = 61) respectively were recorded across all piezometers since sampling began in August 2008. Maximum values of both SRP and ammonia were recorded at a distance of between 18.7 and 21.7 m from the on-site systems and reached peaks of 21.4 mg L^{-1} of SRP and 160 mg L^{-1} of ammonia. Maxima in nitrate concentrations occurred in the piezometers located between 60 - 100 m from the on-site system with the maximum *E. coli* values recorded as high as 98,040 MPN[1]/100 ml in November. A proprietary system is installed at this site, but is not operating correctly.

- **Site F:** Mean (± SE) ammonia concentration of 4.4 ± 1.2 mg L^{-1} (n = 78) has been calculated for the period of sampling to date. Maximum concentrations occur at piezometers located approximately 12 m from the tank, with the highest value of 54 mg L^{-1} recorded in November. Ammonia concentrations decline with distance from the tank, however, nitrate concentrations peak at piezometers located approximately 40 m from the tank, with mean nitrate (± SE) concentrations recorded for the period of 14.1 ± 1.0 mg L^{-1} (n = 78) across all piezometers at the site. A mean SRP (± SE) value of 0.03 ± 0.001 mg L^{-1} (n = 70) was recorded and maximum *E. coli* numbers of 2419 MPN/100 ml in the piezometers closer to the tank. However, *E. coli* numbers of 1986.3 MPN/100 ml were recorded in the piezometers located within 2 m of the stream bank. The ground is completely saturated directly upgradient of the tank and it appears that the inlet pipe to the tank is broken.

- **Site K**: The soakaway area at this site has been by-passed completely by a pipe which discharges directly to the nearest water course, which in this case is 12 m from the on-site system. In both of these sites the 'T' and 'P' test values were high indicating poor percolation characteristic of the subsoil and topsoil material. In addition, the perched water table was found to rise to within 0.14 m of the surface during winter. Faecal bacteria measurements in the nearby stream were between 272.3 – 1986.3 MPN/100 ml for total coliforms and 37.9 – 870.4 MPN/100 ml for *E. coli*. It is important to note, however, that cattle have direct access to the streams throughout the catchment, and as yet no differentiation has been made between animal and human sources of faecal bacteria.

[1] MPN = most probable number

- **Site S**: Mean ammonia and SRP (±SE) values of 0.07 ± 0.01 mg L^{-1} and 0.04 ± 0.006 mg L^{-1} were recorded for all piezometers over all samples collected since August 2008. Maximum concentrations were recorded just down gradient from the soakaway area, but decline to relatively low levels thereafter. There is some suggested that the soakaway on the site may have been by-passed by a pipe discharging directly from the septic tank to the surface water drain under the road.

Conclusion and further work

Sampling at the five sites will continue until March 2008. The preliminary results to date, however, have indicated that the on-site systems at all of sites are either poorly maintained, non operational or poorly installed. The majority of sites are unsuitable for conventional septic tanks. Three of the five sites have perched water tables and are thus unlikely to be suitable for a mechanical aeration system with discharge to the ground. Although work is continuing, preliminary results do provide indications of potential risk of contamination to surface water.

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