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An Investigation into the Performance of Septic Tank Soak-pit Systems and Alternative Infiltration Systems in Low Permeability Subsoils in Ireland

by

Mary Keegan

A Thesis Submitted for the Degree of Doctor of Philosophy

to the University of Dublin, Trinity College

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Department of Civil, Structural and Environmental Engineering,

University of Dublin,

Trinity College Dublin

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EXECUTIVE SUMMARY

In Ireland, domestic wastewater from over one-third of the population, or approximately 500,000 dwellings is discharged to on-site treatment systems. With over 25% of our water supplies provided by groundwater, the prevention of nutrient and pathogen migration to our water bodies is of paramount importance. Up until recently, research has focused on the threat to groundwater due to effluent application to relatively permeable subsoils. Ireland's Environmental Protection Agency (EPA) published a Code of Practice for Single Houses in 2009 which outlines the subsoil conditions that will provide an acceptable level of treatment for on-site wastewater in order to protect our water sources from effluent contamination. In more recent times however, the risk to both surface water and groundwater quality from effluent run-off as a result of inadequate percolation has been raised. Under the current Code on-site wastewater systems are not permitted in soils which return an on-site falling head percolation T-value of T > 75. Above this value, insufficient percolation to the subsoil is deemed to exist along with an increased probability of hydraulic failure in the form of surface ponding and effluent run-off. With approximately 40% of the country located in subsoil regions deemed to have inadequate percolation, either due to high water tables, low permeability subsoil, low permeability bedrock or all of the above, there are limited options available for householders in these areas. In conjunction with this, the recently published EPA National Inspection Plan has set about identifying problem sites in high risk areas across the country, including those in areas of inadequate percolation and as such, appropriate remediation options are required for such sites.

A three year field research study, funded by the EPA was undertaken to examine and compare the treatment performance of existing systems discharging into soak-pits, which do not meet current recommended guidelines across a range of subsoil permeabilities. The performance of six soak-pit systems in Ireland was assessed in terms of pollutant attenuation as well as their impact on downstream groundwater and/or surface water bodies. Following on from this, two sites, with failing systems in areas deemed to have inadequate percolation were upgraded to parallel alternative infiltration systems in the form of low pressure pipe systems and drip distribution systems. At one site septic tank effluent was applied to the system whilst at the second site secondary treated effluent was applied and the hydraulic and treatment capacity monitored over a 14 month period. To assess the temporal hydraulic conditions in the subsoil beneath each system's soil moisture probes, tensiometers and effluent measuring devices were installed at both sites. The treatment/attenuation of the effluent down through the soil was measured from soil moisture samples taken at a number of predetermined depths in the vadose zone by means of suction lysimeters. Sampling was carried out on a monthly basis for each site and included the sampling of groundwater samples from upstream and downstream boreholes. Chemical analysis of the

samples was carried out at the TCD environmental laboratory using EPA approved reagent kits for the following parameters: Chemical Oxygen Demand (COD), Total Nitrogen (TN), Ammonium (NH_4-N), Nitrite (NO_2-N), Nitrate (NO_3-N), Orthophosphate (PO_4-P) and Chloride (Cl). Bacteriological analysis for Total Coliforms and *Escherichia coli* was also carried out to determine the extent of pathogen migration in the receiving subsoil at each site. In conjunction with this, a once-off virus tracer study was performed at each site using a range of bacteriophage surrogates (MS2, ΦX172 and PR772). All three bacteriophages were grown on their host *Escherichia coli* lawns by the agar-overlay method while enumeration of the phages was performed by the plaque forming unit (PFU) method.

Results showed existing on-site wastewater treatment systems in the form of septic tanks discharging to soak-pits provided a considerable reduction in pollutant levels within all subsoil conditions. However, at both low permeability subsoil sites, the risk to human health and the environment was identified during the intermittent ponding of surface effluent above the soak-pits and the shallow lateral movement of effluent. At the four higher to moderate permeability sites the migration of pathogen and nutrients to groundwater was mitigated to a degree as a result of a soil clogging or biomat layer. The migration of enteric bacteria was found to be a much greater risk within the high permeability subsoil settings. Although migration via surface pathways was observed at the low permeability Site B, the maximum observed *E. coli* concentration was 22.9 MPN 100 mL^{-1}. In contrast to this, breakthroughs of magnitudes in excess of 1000 MPN 100 mL^{-1} were recorded at depths greater than 2.5 - 3 m beneath the high permeability systems. The migration of nutrients with depth was also found to be greater in the higher permeability subsoils, unlike the low permeability soils where the high clay fraction and slow draining conditions resulted in a much greater reduction in orthophosphate and inorganic-N.

Evaluation of the hydraulic performance of the low pressure pipe and drip distribution systems showed both maintained unsaturated conditions under normal operating conditions. Analysis of the treatment performance of both the LPP and DD systems receiving septic tank effluent was seen to be marginally greater than that of the systems receiving secondary treated effluent. Results of the bacteriophage study showed > 99% removal rates beneath both systems regardless of effluent quality. Overloading trials were carried out on each system during which time effluent was applied at double the design load for a period of four weeks causing subsoil saturation to occur intermittently but only a marginal increase in pollutant migration with depth was observed. Surface ponding was no longer observed at either of the low permeability sites following the upgrading of the soak-pit systems and an improvement in downstream groundwater quality was also recorded. A reduction in concentrations of enteric bacteria was observed in the downstream groundwater at both low permeability sites following the remediation works.

Overall the results highlight that the greatest risk to water quality in low permeability subsoils is through the potential lateral movement and run-off of ponded effluent to surface waters. In subsoils of higher permeability, there is a greater risk to groundwater due to the limited retention time of the percolate in the receiving subsoil. In low permeability areas, low pressure pipe and drip distribution systems are viable alternatives for both the remediation of existing systems and the construction of new developments.

ACKNOWLEDGEMENTS

I would like to acknowledge the help and support of a number of people without whom this would never have been written. First and foremost I would like to thank my supervisor Laurence Gill for his constant guidance, support and endless enthusiasm for all things effluent related. Over the past three years there wasn't a single moment when he wasn't available to give advice or answers questions. His constant availability and willingness to help, even when it meant climbing into a pump sump in Monaghan, is something I am truly grateful for.

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ACRONYMS

AET	Actual Evapotranspiration
BOD	Biochemical Oxygen Demand
BOD_5	Five-day Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CV	Coefficient of Variation
DDS	Drip Distribution System
EPA	Environmental Protection Agency (Ireland)
ERF	Effective Rainfall
ET_O	Reference Evapotranspiration
GSI	Geological Survey of Ireland
GWPS	Groundwater Protection Scheme
HLR	Hydraulic Loading Rate
IEP	Isoelectric Point
IS	Infiltrative Surface
LPPS	Low Pressure Pipe System
MPN	Most Probable Number
OD	Outside Diameter
OSWTS	On-site Wastewater Treatment System
PFU	Plaque Forming Units
ST	Septic Tank
STE	Secondary Treated Effluent
STU	Soil Treatment Unit

PEER-REVIEWED PUBLICATIONS

Keegan et al., 2014. Assessment of the impact of traditional septic tank soak-pit systems on water quality in Ireland. *Water Science and Technology*, 70, 634 - 641.

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Chapter 1 Introduction

1.1 BACKGROUND

Unlike other European countries, over one third of the Irish population lives in rural areas in areas not connected to public sewers. The most recent census (CSO, 2012) estimates that there are 497,000 on-site wastewater treatment systems operating in Ireland. The majority of these are conventional systems discharging septic tank or secondary treated effluent to a subsoil percolation area. These systems rely on the receiving subsoil to provide adequate pollutant attenuation prior to groundwater recharge. However, many regions in the country consist of subsoils unsuitable for the operation of these systems. As groundwater and surface waters are intrinsically linked this can have detrimental long-term effects on water quality.

In Ireland, the transport of contaminants from domestic sources has two primary pathways. Discharge of effluent to subsoils of insufficient depth and/or high permeability leads to the rapid transport of contaminants to groundwater (Figure 1.1a). Subsoils of very low permeability also pose a risk, discharge in these conditions leads to surface ponding of effluent creating a human health hazard as well as increasing the danger of run-off to surface waters (Figure 1.1b).

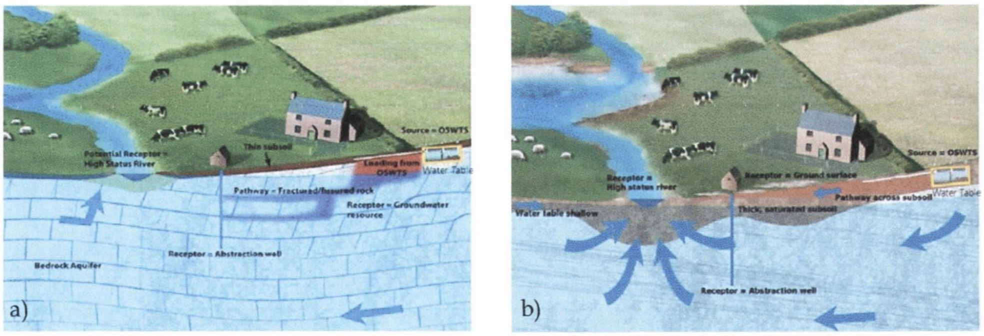


Figure 1.1 Transport of contaminants to groundwater and surface water bodies in a) areas of high permeability and b) areas of low permeability (EPA, 2012)

The source-pathway-receptor (S-P-R) model is a specifically design risk assessment methodology used by both the EPA and groundwater protection schemes in Ireland. It is based on the concept that for a risk to exist there must be a source of potential pollution (e.g. a discharge from an OSWTS), a receptor that may be impacted by that pollution (e.g. humans or the environment), and a pathway by which the pollution can get from the source to the receptor (e.g. through bedrock or soils) (EPA, 2012).

The degree of risk (low, moderate, high) is then assessed based on the following information:

- *Source characterisation*: How significant is the OSWTS discharge - the volume of wastewater, the pollutants of concern (nutrient, pathogens), the nature and condition of the system, the number of systems in the area;
- *Pathways analysis*: How and where the pollutants flow, to what extent the pollutants are expected to attenuate, whether there is a hydro-geological or hydrological link that can deliver a pollutant source to a nearby receptor;
- *Receptor identification*: Who or what potentially could be affected, taking account of appropriate environmental quality standards.

Several studies have highlighted the impact of OSWTS on groundwater quality. During the 3-year period 2007-2009, 35% of monitored groundwater sources (including public and private supplies) exhibited evidence of intermittent *Escherichia coli* contamination (EPA, 2010b). EPA (2009c) reported that between 1998 - 2008 33% of private wells showed evidence of faecal coliform presence. In Ireland, numerous studies have detailed a link between the consumption of water from private groundwater supplies and outbreaks of waterborne disease (Baldursson and Karanis, 2011, Mannix et al., 2007, Hynds et al., 2013).

Today guidelines are in place which provide instructions on the installation of on-site systems in Ireland and to ensure that these systems are sited in areas of suitable subsoil conditions thus reducing the risk to water quality (EPA, 2009a). However, a vast number of on-site systems were installed and have been in operation in Ireland prior to the introduction of these guidelines. Many of these sites are poorly constructed and maintained, do not meet current guidelines, and consequently have been highlighted as a potential risk to water quality in Ireland.

In areas where conventional systems are unsuitable, alternative systems may be appropriate, including advanced treatment by sand filter, packaged treatment plants or wetlands prior to discharge. However, despite the many options available as detailed by EPA (2009a), some on-site conditions have been identified as unsuitable for on-site discharge regardless of system configuration in particular, areas of low permeability subsoil where effluent percolation rates are too slow to cope with any additional hydraulic loading. In circumstances such as these, alternative systems are needed to provide remediation options for existing households as well as solutions that will allow further development in these regions.

1.2 RESEARCH CONTEXT

Up until 1991 in Ireland there was no standard in place to regulate the construction of on-site wastewater treatment systems. The introduction of SR6:1991 (NSAI, 1991) began the process of regulating these systems. Further guidelines were introduced by the Environmental Protection Agency (EPA) entitled *Wastewater Treatment Manual: Treatment Systems for Single Houses* (EPA, 2000). In order to develop these guidelines further, and to address information gaps identified since the publishing of the 2000 document, two research projects have been commissioned by the EPA and have been carried out by Trinity College Dublin:

(i) An investigation into the performance of subsoils and stratified sand filters for the treatment of wastewater from on-site systems

This project studied four separate sites with different subsoil permeabilities and found that the septic tank and gravity fed percolation system provided a comparable treatment performance with respect to groundwater protection to the packaged secondary treatment system with respective percolation area (Gill et al., 2005). The use of stratified sand filters was also studied, both as secondary treatment process and tertiary treatment process and appropriate design criteria were proposed. The sand filters performed slightly better compared to the percolation areas on both sites receiving septic tank and secondary treated effluent respectively (Gill et al., 2009a).

(ii) On-site wastewater treatment: investigation of rapid percolating subsoils, reed beds and effluent distribution

The second research project then went on to study three separate sites over a longer time interval (Gill et al., 2009b). Again, a significant reduction in biomat development was found on the trenches receiving secondary treated effluent and also some reduction in the biomat in the trenches receiving septic tank effluent due to the faster percolation characteristics of the subsoil. Indeed, a key finding from the overall field research has been higher nitrogen loading to the groundwater under secondary treated effluent fed percolation areas compared to septic tank fed areas due to significantly reduced biomat formation (Gill et al., 2009c). Finally, sub-surface horizontal flow reed beds were studied as both secondary and tertiary treatment processes (O'Luanaigh et al., 2007; 2010), from which design guidelines were derived.

Other smaller-scale projects have complemented this previous research into on-site systems such as looking at the fate of certain Endocrine Disrupting Chemicals in the on-site effluent (O'Súilleabháin et al., 2009; Gill et al., 2009d); comparison between sand and recycled glass as a filter media for on-site wastewater treatment (Gill et al., 2009e); and another relevant research activity, particularly in the context of percolation through low permeability subsoil, has been the development of a proposed methodology for estimating recharge to the underlying aquifers using this mapped data (i.e. vulnerability based on subsoil thickness and permeability) to calculate a recharge coefficient which is used in conjunction with annual effective rainfall across the country in order to produce a GIS-based recharge map (Misstear et al., 2009). In addition, joint research by TCD and the GSI considered the relationship between particle size distribution in subsoils and permeability values obtained from field tests (including slug tests) and laboratory tri-axial tests (Swartz et al., 2003).

Further work carried out by Trinity College Dublin was the field evaluation of a shortened percolation T-test method (devised by NUI Galway) for site assessments (O'Súilleabháin and Gill, 2006). The results of these research studies were used to develop a more comprehensive document, The EPA Code of Practice for Single Houses (EPA, 2009a) which was published in 2009 which legally replaces the SR6 document as the national standard for construction of these systems as it is called up in Part H of the National Building Regulations (NSAI, 1991).

Since the publication of EPA (2009a) further research into on-site wastewater systems has been carried out. One such project, funded by Wexford County Council, investigated the use of evapotranspiration systems (willow treatment) under Irish climatic conditions. As part of this project willow beds were constructed at 9 locations in 3 different counties. Results from the project, which was completed in 2012, have now been used to develop design guidelines for theses system in and Irish context which will soon be incorporated into the current Code of Practice.

A key driver for this research has been the recent European Court of Justice ruling against Ireland in relation to on-site wastewater treatment systems (ref. case C-188/08), finding that the State has failed to adopt the necessary legislation to comply with Articles 4 and 8 of European Directive 75/442/EEC. In response to this the EPA has published the National Inspection Plan: Domestic Waste Water Treatment Systems (EPA, 2013) under which domestic on-site systems will be inspected following a risk assessment based approached, with areas of insufficient percolation highlighted as posing a high risk to water quality due to surface run-off. The ruling by the European Court of Justice has brought national attention to the issue of on-site domestic systems and has heighten awareness of their importance in relation to groundwater and surface water quality.

1.3 Scope of Research

This project aims to address a number of issues which the EPA has recently identified as being of immediate concern in the field of on-site wastewater treatment. Many existing (or legacy sites)

built prior to 1991 do not comply with current standards. Many of these sites utilise soak-pits which are no longer a permitted form of effluent discharge.
For the purposes of this research a septic tank soak-pit system is defined as a septic tank from which effluent is discharged by gravity to a backfilled pit of stone/rubble in the subsoil. One of the most problematic issues arising from the operation of these soak-pits is the lack of design criteria during the installation and operation of the systems. Assessment of existing sites over the course of this project found that in general the dimensions of soak-pits increase as subsoil permeability decreases to allow for increased hydraulic capacity as the effluent percolates more slowly into the surrounding subsoil. However, overall the depth of effluent infiltration, dimensions and materials used to backfill soak-pits varied greatly from site to site and was dependent on the past experience of contractors hired to install it. Research carried out to-date has focused on constructed systems such as percolation trenches, sand filters and reed beds, however, the impact of these legacy systems has yet to be quantified.

In conjunction with this many systems across the country have been installed and are operating on sites unsuitable for wastewater discharge and as a result are urgently in need of remediation. However, under the current legislation, the only options available to householders in very low permeability areas is direct discharge of treated effluent to surface water under a discharge licence which is not permitted by any Local Authority at present. As a result alternative systems are required for discharge to ground. To date much of the research in Ireland on on-site systems has been carried out in high to moderate permeability subsoil. Although recent research into evapotranspiration systems may provide an option in low permeability areas, for some they require a large amount of space and are very costly.

The aim of this research project was therefore to carry out field assessments of existing soak-pit systems built prior to 1991 to determine their treatment performance and risk to water quality across a range of subsoils. A second aim was to evaluate the performance of two alternative infiltration systems in low permeability subsoils to determine their potential in other low permeability areas of Ireland.

These two main aims were achieved by targeting the following objectives:

- To determine the chemical and microbiological pollutant attenuation in the subsoil in six different existing septic tank soak-pits across a range of subsoils with different percolation rates with respect to groundwater pollution.

- To carry out field trials to assess the chemical and microbiological pollutant attenuation in the subsoil beneath the two different types of effluent dispersal systems (drip dispersal and low pressure systems) in low permeability subsoils with respect to groundwater and surface water pollution protection.

- To quantify the hydraulic infiltration of the effluent and rainfall throughout the year on both dispersal systems (drip dispersal and low pressure systems) and resulting soil moisture in the percolation areas.

- To produce appropriate design criteria for these different infiltration systems for different subsoil types, (based on percolation characteristics), to augment the national design legislation.

1.4 METHODOLOGY AND WORK PROGRAMME

To fulfil the objectives set out in Section 1.3, the project was divided into two distinct sub-projects. The sites were chosen according to the site assessment procedure as set out in EPA (2009a) and trials were designed to be a minimum of 12 months to capture seasonal variations. An overview of the project, as was carried out, is presented below:

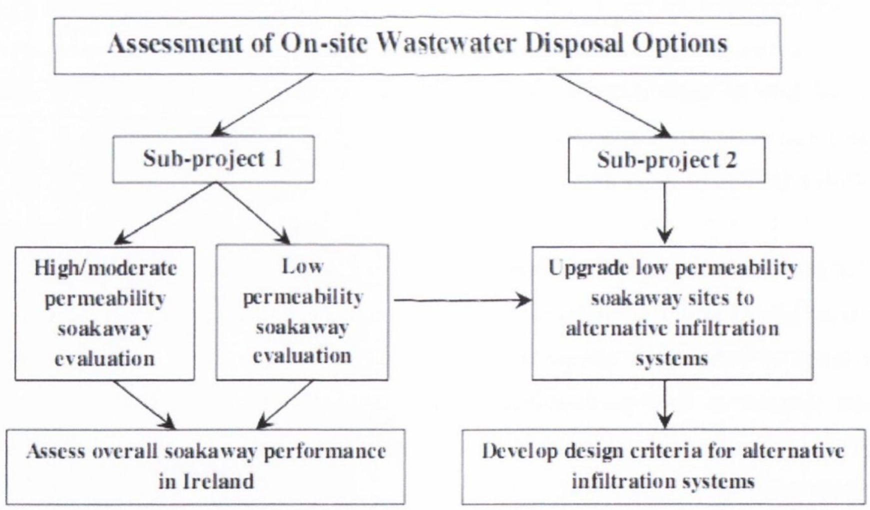


Figure 1.2 Project Overview

1.5 THESIS OUTLINE

Chapter 2 contains a literature review focusing on contaminant attenuation processes in the vadose zone with respect to substance levels found in primary and secondary treated domestic effluents that are of potential risk to groundwater and surface water bodies. One of the key aspects of the review is the potential for improved effluent treatment through the uniform pressure dosed application of effluent to a soil treatment unit.

Chapters 3 and 4 describe the site selection, construction and instrumentation processes as well as the sampling and analysis methodologies. Chapter 5 presents the on-site field results of pollutant and hydraulic loadings from the source unit treatment system on each site that provided the basis upon which the subsequent soil treatment performance was assessed. Chapter 6 presents analysis of the chemical and bacterial analysis results from the soak-pit systems monitored across a range of subsoil permeabilities. Chapter 7 details the results of the hydraulic, chemical, bacterial and viral analysis of the alternative infiltration systems installed in low permeability conditions.

In Chapter 8, the results from the comparable treatment systems are discussed and conclusions drawn while further observations together with recommendations for future research are included in Chapter 9.

Chapter 2 Literature Review

2.1 INTRODUCTION

Over 40% of Ireland's population live outside of urban areas making the country one of the most ruralised in Europe (CSO, 2012). As a result, a large number of rural dwellings are not connected to a public sewer system, and hence require some form of on-site wastewater treatment before discharge to surface water or (more commonly) recharge to groundwater. A key driver for this research was a recent ruling by the European Court of Justice that found Ireland did not comply with the EU Waste Directive 75/442/EEC. Consequently, an on-site wastewater treatment system inspection plan has been put in place to identify potential sites that might fail to meet required standards. An estimated 39% of Ireland's subsoils are deemed as having inadequate percolation due to low permeability subsoils, high water tables and/or low permeability bedrock (EPA, 2012) and so it is feared that a large number of existing systems may fail to comply with the criteria set out in the new inspection plan. Therefore, alternative options for householders in these areas need to be assessed as a matter of urgency.

In a conventional on-site system (i.e. effluent discharged to a percolation area) there are only two routes by which a site's hydraulic load can be assimilated. One route is percolation down through soil beneath the distribution area resulting in groundwater recharge. In a properly functioning soil treatment unit the effluent will receive adequate treatment as it filters through the soil. Percolation of septic tank effluent through some minimum depth of unsaturated soil is the foundation of all regulations governing conventional on-site systems. The depth of unsaturated soil required for adequate treatment varies between countries, in Ireland it is 1.2 m for septic tank effluent and 0.9 m for secondary treated effluent (EPA, 2009a).

The second possible route is the loss of some of the hydraulic load to the atmosphere by evaporation. If the effluent infiltrative surface is shallow enough, or if roots of the above vegetation run deep enough, water held in the soil by matrix potential can be taken into the roots, to be lost to the atmosphere by transpiration out of the leaves. The combined action of surface evaporation and plant transpiration is called evapotranspiration (ET).

Other than nutrient uptake by plants, ET does not directly eliminate pollutants. If effluent water is retained in the soil for some time by matrix potential rather than percolating on through in short order, a number of biological and chemical mechanisms are given a better chance to remove pollutants from the water. This matrix potential is maintained by the soil moisture deficit created

by ET losses. The result is a lower mass loading of pollutants percolating down into the groundwater when ET is maximised.
Consequently, there are only two modes by which conventional systems fail in their function of effluent treatment and disposal. The first, and most commonly recognised, mode of failure is the appearance of effluent ponding above the percolation area, particularly prevalent during high intensity rainfall events, when water cannot percolate quickly enough due to low permeability soils or a clogged infiltrative surface. Apart from being a general nuisance for a householder, effluent ponding also poses a risk to human health particularly if children, household pets or rodents come into contact with it. Additionally, there is a risk to water sources when rainfall results in surface run-off from ponded effluent to nearby surface waters. The second mode of failure is more difficult to assess. It occurs in areas of insufficient subsoil depth or rapidly percolating subsoils allowing groundwater recharge of effluent without adequate treatment. This mode of failure can result in pollution of groundwater (and thereby also pollution of surface waters from baseflow discharges).

In areas where conventional systems have failed to provide adequate effluent treatment two potential solutions have been highlighted as a means of reducing the pollution risk. In areas of insufficient subsoil attenuation due to shallow or highly permeable subsoils the installation of secondary (or in some cases even tertiary) treatment systems reduce contaminant loading and risk of groundwater pollution. The second is the integration of alternative distribution of effluent which will maximise ET potential as well as the treatment capabilities of the available subsoil.

To-date, research conducted in Ireland into domestic on-site systems has focused on areas of higher permeability where recharge to groundwater prior to adequate treatment was of concern. This study focuses on the pollutant risk across a range of permeabilities with a special focus on alternative systems for areas of low permeability.

2.2 ON-SITE DOMESTIC WASTEWATER TREATMENT SYSTEMS

The standard arrangement for on-site wastewater treatment system (OSWTS) is a conventional septic tank (within which primary treatment is carried out) followed by discharge of the septic tank effluent (STE) to a subsurface disposal field or leach field but which, is commonly referred to as a percolation area in Ireland (Figure 2.1). The preferred international terminology for these systems is a Soil Treatment Unit (STU). At this stage of treatment the effluent infiltrates and permeates down through the vadose zone of the percolation area, undergoing physical, chemical and biological processes in the subsoil before recharge to groundwater.

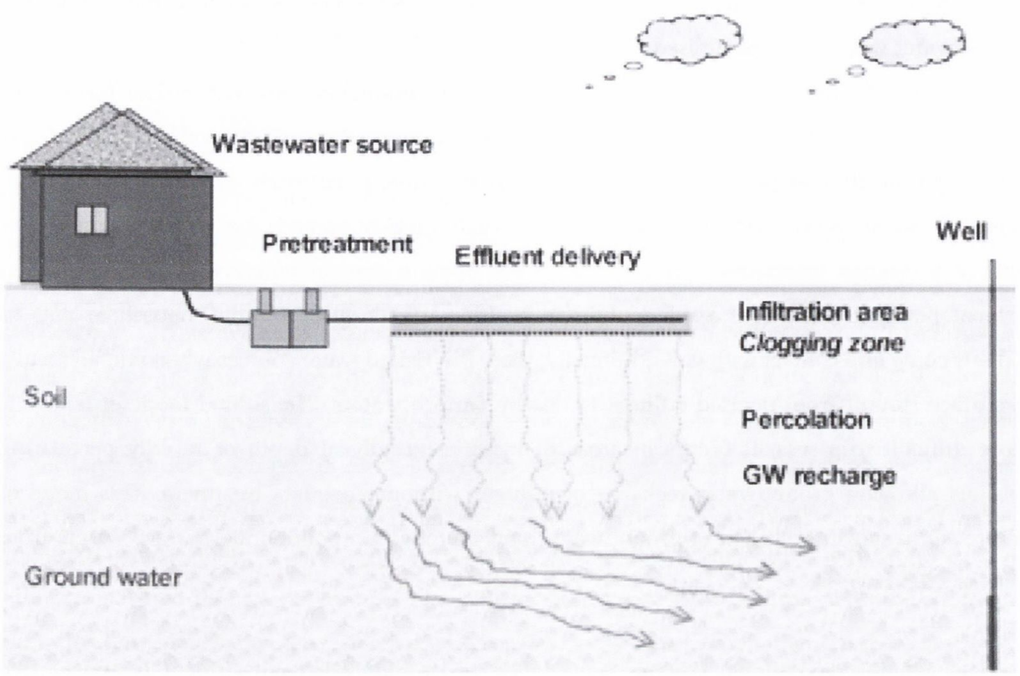


Figure 2.1 Conventional septic tank treatment system including percolation area with pathway for potential contaminant migration to groundwater (adapted fromVan Cuyk et al. (2001))

2.2.1 Septic Tank Design and Performance

In a conventional system, raw sewage from a household is generally discharged by gravity to a septic tank. It comprises of grey water (laundry, bath and kitchen sink) and black water (toilets) and as a result the nature of this discharge varies greatly depending on the source of the discharge at the time of sampling. As such, monitoring of these discharges is a complex process. One such study that went about quantifying these discharges was Canter and Knox (1985) who reported that on average, black water contributes approximately 30% of the Biochemical Oxygen Demand (BOD), 50% of the Suspended Solids (SS), 70% of the Total Kjeldahl Nitrogen (TKN), 17% of the Total Phosphorus (TP) and 30% of the flow from a household. However, characteristics of the remaining grey water loading vary greatly, in particular with respect to high concentrations of detergents and inorganic salts which may have a damaging effect on bacteria and hence treatment in the tank. However, Grant and Moodie (1995) reported that average concentrations of detergents and inorganic salts form a typical domestic dwelling will not detrimentally affect the functioning of the septic tank. Therefore, it is recommended that all wastes from the household be piped to the septic tank, but that water run-off (i.e. rain from roofs, footpaths, driveways) be diverted away to avoid dilution of the wastewater and hydraulic overloading of the system. The estimated biological and chemical characteristics of domestic wastewater in Ireland are shown in Table 2.1.

Table 2.1 Range of raw domestic wastewater influent characteristics (I.S. EN 12566-3:2005) (adapted from EPA (2009a))

Parameter	Typical concentration (mg/l unless otherwise stated)
Chemical oxygen demand (COD) (as O_2)	300-1000
Biochemical oxygen demand (BOD5) (as O_2)	150-500
Suspended Solids	200-700
Ammonia (as NH_4-N)	22-80
Total phosphorus (as P)	5-20
Total coliforms (MPN/100 ml)[1]	10^6-10^9

[1]Not from I.S. EN 12566-3:2005. (MPN, most probable number)

A properly functioning septic tank produces consistent effluent despite the variation in influent quality. A prefabricated tank is usually made from concrete or fibreglass that serves as a combined settling and skimming tank and as an unheated-unmixed anaerobic digester for wastewater (Metcalf et al., 1991).

Two-chamber septic tanks (Figure 2.2) are now the legislative standard in Ireland (EPA, 2009a) as they are superior to single-chamber tanks of the same size producing effluent with up to 50% less suspended solids and BOD (Laak, 1980). The main benefit is hydraulic isolation preventing short-circuiting and the reduction or elimination of inter-chamber mixing (Canter and Knox, 1985).

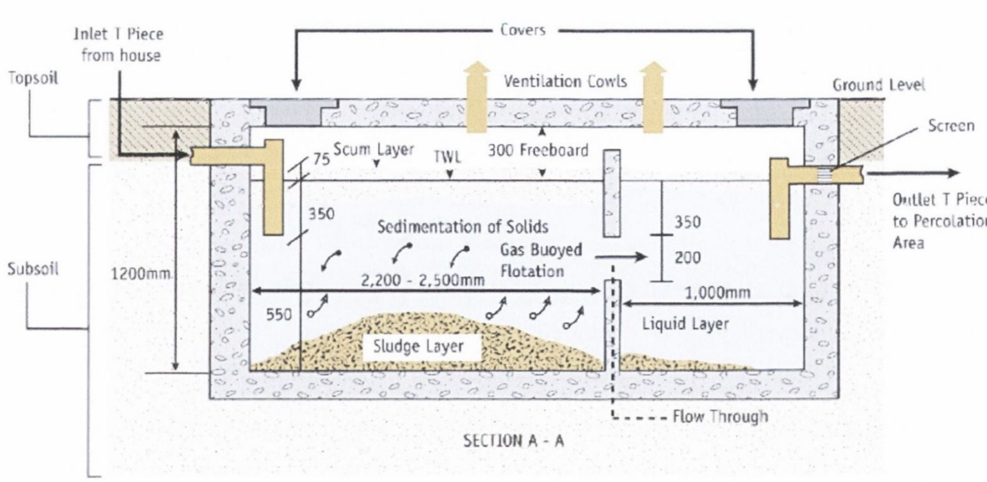


Figure 2.2 Longitudinal section of typical two-chamber septic tank (EPA, 2009a)

Septic tanks maintain stagnant conditions allowing the settlement of solids (both organic and inorganic) which in turn form a sludge layer at the bottom of the tank. This sludge layer is partially digested by anaerobic micro-organisms resulting in the liberation of gases, primarily carbon dioxide (CO_2) and methane (CH_4) (Diaz-Valbuena et al., 2011) Aided by these gases, a scum layer, consisting of greases, oils and gas-buoyed solids, forms above the liquid layer and provides and indicator that the tank is operating properly (Daly, 1993).

A properly constructed and maintained tank reduces BOD by approximately 15-30% and retains between 50-70% of the solids. Canter and Knox (1985) cite research carried out by Viraraghavan (1976) which found reduction rates of 50% for BOD and Chemical Oxygen Demand (COD) and less than 25% removal rates for total suspended solids. Lawrence (1973) reported less than a 15% reduction in BOD and a 34-35% reduction of suspended solids. In Ireland, the current Code of Practice (EPA, 2009a) does not specify an effluent quality for septic tanks but does detail the average influent quality (Table 1.1). Recent studies into septic tank effluent quality in Ireland have been carried out by O'Súilleabháin (2004) and O'Luanaigh (2009). Collectively these studies monitored the effluent quality from five two-chambered septic tanks resulting in mean COD effluent concentrations of 772 mg/l (Gill, 2007). This is comparatively high in contrast with the typical influent value detailed in Table 1.1.

The anaerobic environment within the septic tank is largely ineffective in reducing the nutrient loading of the wastewater. Nitrogen in the influent is largely in the form of organic nitrogen (org-N) and ammonia (NH_4), which together make up the total kjeldahl nitrogen (TKN). Under anaerobic conditions, much of this org-N is converted to readily oxidisable ammonium ions (NH_4^+). A typical wastewater influent TKN concentration is 38 mg/l [32% NH_4: 68% org-N] whilst average effluent TKN concentrations are recorded at similar levels of about 40 mg/l [75% NH_4: 25% org-N] (Bauer et al., 1979). However, O'Luanaigh (2009) reports STE with TKN of 106.1 mg/l for an Irish dwelling [approximately 70% NH_4: 30% org-N] which is considerably higher that these values. So, while the conversion of org-N to NH_4 is promoted in the septic tank environment, the overall removal of total nitrogen (TN) is generally negligible.

Most of the influent phosphorus is also converted in the anaerobic digestion process, from organic and condensed phosphate (polyphosphate) to soluble orthophosphate (Ortho-P) which passes out in the effluent. Wilhelm et al. (1994) reported that approximately 76% of the total phosphorus (TP) in the septic tank effluent (STE) was in its PO_4 form. Canter and Knox (1985) cite research carried out by (Bouma, 1979) which found an average TP concentration of 15 mg/l in the STE of which 85% is in PO_4 form. Research carried out by Salvato (1992) resulted in a similar concentration of 15 mg/l being found. In Ireland, two studies Gill et al. (2005) and Gill et al., (2009a) recorded average concentrations of 7.4 mg/l, 7.9 mg/l, 16.6 mg/l and 32.3 mg/l total phosphorus respectively for four different septic tanks.

2.2.2 SECONDARY TREATMENT SYSTEMS

A secondary treatment system can be installed as an alternative to a septic tank or to provide additional effluent treatment of STE before it is discharged to a STU. There are a wide variety of secondary treatment systems, both passive and mechanical. Some of the most popular secondary treatment units installed in Ireland include aeration systems, filter systems and constructed wetlands. The effluent produced by these systems has a reduced organic loading compared to STE and often provides a suitable environment for increased nitrification. A review of packaged wastewater treatment systems performance by Dubber and Gill (2012) reported that over 70% of package treatment units available in Ireland achieve BOD_5 concentrations of ≤12 mg/l during testing and SS ≤20 mg/l. Typically the systems reviewed achieved TN-removal of between 60% and 65% resulting in effluent concentrations of 12 - 24 mg/l. Most packaged treatment systems are not designed for significant P removal, however reductions of up to 15% are usually achieved through bacterial assimilation, precipitation and adsorption (Metcalf, 2003).

2.2.3 SOIL TREATMENT UNITS

In properly implemented STU, tertiary treatment and natural disinfection is possible in unsaturated subsoil with suitable permeability. Advanced treatment levels are possible due to the complex interactions of hydraulic and purification processes (Van Cuyk et al., 2001). STUs rely solely on the natural biogeochemical processes (Figure 2.3) that occur in soil to assimilate various effluent pollutants (Beal et al., 2005). These processes include removal (e.g. filtration of suspended solids or sorption of phosphorus), transformation (e.g. nitrification of ammonium or biodegradation of organic matter), and destruction processes (e.g. die-off of bacteria or inactivation of viruses) (Siegrist et al., 2000). Therefore, the STU is an integral part of OSWTS as it is here that the majority of treatment takes place.

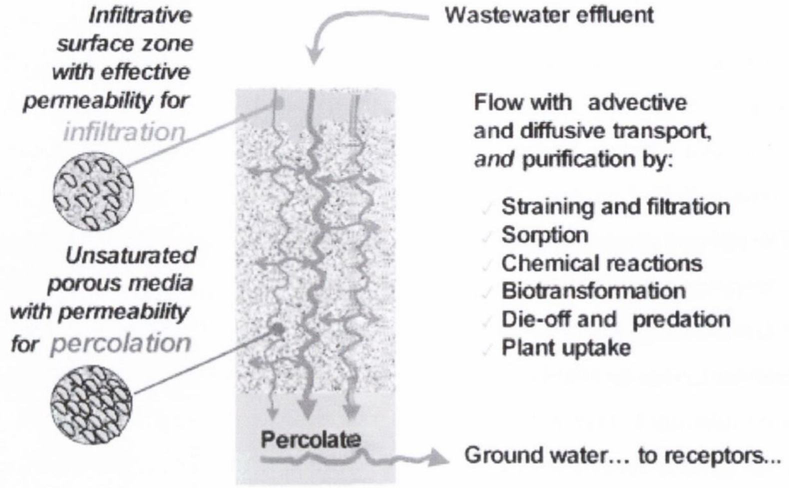


Figure 2.3 Illustration of hydraulic and purification processes operative during wastewater infiltration and percolation in soil-based systems (Van Cuyk et al., 2001)

Research has shown that for the most common effluent pollutants of concern such as BOD_5, COD and SS, purification efficiencies of >90% can be sustainably achieved in most STU settlings (Van Cuyk et al., 2001, Jenssen and Siegrist, 1990). Studies have also shown the near complete removal of faecal coliform bacteria and 99.99% or higher reduction in virus (Emerick et al. (1997), cited by Siegrist et al. (2000); Van Cuyk et al. (2001).

However, an array of older, pre-existing (or legacy) systems is operating across the country whose performance and reliability is unknown. A large number of these existing on-site systems (installed prior to the introduction of SR6:1991 Wastewater Treatment Systems for Single Houses) rely on soak-pits also referred to as seepage pits or soak-pit systems. Siegrist et al. (2000) describes these historical systems as open or lined pits into which pretreated wastewater discharges, their primary function being effluent disposal with limited treatment capacity. Soak-pits rely on a single gravity fed effluent distribution point discharging to a dug-out pit, which has been backfilled with large stones, resulting in highly concentrated STE being applied as a point load. Although the soak-pit aids with the effluent dispersal from this point source, these systems still rely on the properties of the surrounding subsoil. The aim of these soak-pits is effluent disposal rather than treatment and as such a number of key factors are not taken into account, such as the depth of unsaturated subsoil beneath the soak-pit or depth to groundwater. Research carried out by Gondwe et al. (1997) into the impact of lined septic tank soak-pits in shallow subsoils in Tanzania found that underlying groundwater was polluted by septic tank effluent as a result of poorly designed and maintained soak-pits. It was found that the sizing of soak-pits in the region were too small to allow reasonable pollutant attenuation resulting in continuous groundwater pollution.

There is a commonly held belief in Ireland that soak-pits operating in unsuitable subsoil conditions also pose a risk to water sources although to-date few studies have set-out to quantify their impact. One such study by McCarthy (2012) attempted to assess the impact of 5 OSWTS including 3 soak-pit systems, in low permeability settings, on surface water quality. Following extensive site inspections it was found that at two of the three sites, due to the inadequate permeability of the subsoil (T<80), direct discharge points were observed with pipes by-passing the soak-pit and discharging directly to nearby water courses. This highlights the unsuitably of soak-pit systems in these conditions. As such the treatment value of these systems and their impact on groundwater and surface water quality is unclear.

Another factor to be considered is that soak-pits no longer conform to current guidelines (EPA, 2009a). However, under current guidelines conventional percolation systems outline previously are also unsuitable in the low permeability conditions found in many parts of Ireland. Alternative options must therefore be considered to overcome these site limitations. One such solution is improved effluent distribution through the application of pressurised systems.

2.3 Pressurised Distribution and Hydraulic Loading

The importance of even effluent distribution for the successful operation of STUs, especially in slowly permeable conditions, cannot be over emphasised. Localised overloading, caused by poor distribution of effluent in a system, will result in saturated flow and probable poor purification of effluent (Converse, 1974). Many studies have documented the treatment benefits of uniform effluent dispersal within the soil infiltration area by means of pressurised distribution. The resulting uniform delivery of effluent to a soil absorption system gives better purification of effluent and reduces clogging in certain soils (Converse, 1974).

Certain soil conditions dictate that, regardless of effluent loading rates, traditional STU set-ups cannot function correctly. Site restrictions such as high/fluctuating water tables, layers of low permeability subsoil and shallow depth of subsoil above bedrock require alternative STU configurations in order provide appropriate groundwater protection.

As previously stated, one of the most common site restrictions in Ireland is the presence of low permeability subsoil either at or beneath the IS. Two alternative infiltration systems shown to overcome the above limiting factors are low pressure pipe (LPP) and drip distribution (DD) systems. The EPA Code of Practice currently permits the installation of both systems in line with manufacturer's guidelines. However, there are no specific guidelines in place for Irish subsoils at

this time. As such, design criteria are based on design specifications developed in other countries under similar subsoil settings and climatic conditions.
In Ireland, conventional percolation trenches are installed at depths of 850 mm below ground level (EPA, 2009a). This depth of IS greatly reduces the potential of water and nutrient uptake through evapotranspiration. As well as this, effluent applied to these systems is gravity dosed and distributed by means of distribution boxes. The effectiveness of this method in achieving uniform distribution has been highlighted as poor by numerous studies (Reneau et al., 1989, Otis et al., 1977, Otis, 1982, Gill et al., 2007). One of the key modifications proven to mitigate the issue of uneven distribution is pressurised effluent distribution.

An intricate part of any pressure distribution system is its utilisation of an effluent dosing cycle. These systems allow control of the volume and frequency of effluent dosing. This limits the amount of effluent applied to a STU at any one time to a pre-specified dose volume. This intermittent dosing has two primary benefits: it minimises the tendency toward continuous ponding in the trenches and subsequent severe clogging, especially in finer soils; it minimises the potential for development of saturated flow, especially in coarser soils, with consequently poor treatment of the percolating effluent (Reneau et al., 1989, Cogger and Carlile, 1984).

A further benefit of applying a dose/rest loading cycle is it allows the soil interface to aerate between doses. An effluent dose pumped to the STU is typically completely diffused into the soil before the subsequent dose is applied, allowing unsaturated conditions to return. Adoption of a pressurised dosing cycle has also been shown to influence the formation of a soil clogging layer at the IS by retarding the soil clogging process (Reneau et al., 1989). A marked reduction in infiltration rates is inevitable in a STU, regardless of soil type, assuming that the loading of STE is more or less constant. In this respect, intermittent dosing of STE has been shown to generate biomats of lower resistance than gravity distribution of STE (Beach et al., 2005). This is an important consideration in a STU where the native subsoil has a poor infiltration capacity and the development of a mature biomat layer can reduce hydraulic capacity of a subsoil even further resulting in surface ponding and system failure. Further discussion on the importance of this clogging layer is detailed in Section 2.4. Studies have also shown the application of SE (with a reduced organic loading) is also responsible for retarding the formation of a soil clogging layer (Gill et al., 2009) thus preserving the maximum hydraulic capacity of a low permeability subsoil.

Although pressurised distribution can improve the operation of traditional trench distribution, modification of these systems can maximise the potential benefits further, in particular the effects of ET. Two systems which employ pressurised effluent distribution as part of a modified distribution network are low pressure pipe (LPP) and drip distribution (DD) systems. Both of these alternative set-ups are outlined further in the following sections. The effluent loadings on a STU make a significant contribution to soil moisture levels. As such it is beneficial to apply reduced areal loading rates across a greater distribution area. As well as maximising ET losses, it provides conditions conducive to nitrogen uptake by overlying vegetation reducing the load that will percolate to groundwater. Overall pressurised distribution maximises a subsoils ability to treat percolate through a combination of the following key physical and biological processes:

2.4 BIOMAT DEVELOPMENT AND INFLUENCE

The biomat is a thin layer of an organomineral material that is deposited within and on top of the soil pore network at the infiltrative surface (IS) (McKinley and Siegrist, 2011). It is a zone of lower porosity than that of the native soil beneath the STU. It may develop at the IS from smearing and compaction of soil by machines, the impact of falling aggregate, dust from dirty aggregate, swelling of soil minerals, suspended solids (SS) from wastewater or biomass from organisms living on wastewater constituents (Tyler and Converse, 1994).

Siegrist and Boyle (1987) found that soil clogging can significantly affect the hydraulic and attenuation capacity of a STU. The permeability of a biomat layer is low, ranging from 0.6 mm/d to 2 mm/d depending on the soil type (Bouma, 1975) and so greatly influences the hydraulic capacity of a STU. A certain degree of soil clogging / biomat development can enhance wastewater treatment through physical, chemical and biochemical processes (McKinley and Siegrist, 2011, Siegrist, 1987). However, under some conditions excessive soil clogging can lead to hydraulic dysfunction, where the IS becomes so impermeable that the daily wastewater loading can no longer be fully infiltrated (McKinley and Siegrist, 2011, Siegrist, 1987, Siegrist et al., 2000).

Many studies have highlighted the importance in the formation and development of this "clogging layer", or biomat, at the infiltrative surface of a STU. The biomat layer is deemed to be a crucial factor in the retention of pollutants through processes such as enhanced sorption, nitrification and biological decay (McKinley and Siegrist, 2011). Biomat formation and development is a dynamic process influenced by the combination of physical, biological and chemical processes (Beal et al., 2005). Physical clogging of pores at the IS during effluent application usually occurs within the first months of operation. However, the greatest reduction in infiltration is thought to be due to biological clogging (Tyler and Converse, 1994). Stimulated by a favourable environment (e.g. anaerobic conditions, high humidity and moisture) in the initially clogged soil, biological activity then plays a significant role in long-term growth of the biomat zone (Bouma, 1979). The rate and extent of biomat development with time is thought to be dependent on several factors, namely the soil's morphology and temperature, the moisture content, the wastewater composition and hydraulic loading rate, and aeration status of the infiltrative surface.

Research into biomat development shows there are generally 3 phases of biomat formation (Jones and Lee, 1979, Otis, 1984, Siegrist, 1987). These phases consist of (I) an initial gradual decline in infiltration rate, (II) a rapid decrease in infiltration rate, and (III) a stabilization of infiltration rate at a low Long Term Acceptance Rate (LTAR) (McKinley and Siegrist, 2011). A general pattern of infiltration rate decline is presented in Figure 2.4. The LTAR ($l/m^2/d$) is the amount of pre-treated effluent which a STU can infiltrate during its lifetime. It is controlled by the permeability of the native subsoil as well as the development of a biomat or soil clogging layer.

Phase I of biomat development is generally attributed to the physical straining of organic materials and SS blocking pores as the IS and impeding flow rate to the underlying unsaturated zone. During Phase II biological activity, stimulated by changes to the soil environment created during Phase I, is considered the predominant clogging mechanism (Siegrist, 1987, Van Cuyk et al., 2001). A study by Vandevivere and Baveye (1992) found that cells, resulting from the biological processes of microorganisms, physically fill the pores in the soil reducing the porosity and hydraulic conductivity. The final phase of biomat formation is characterised by low infiltration rates where some researchers have observed an equilibrium state (i.e. LTAR) to evolve.

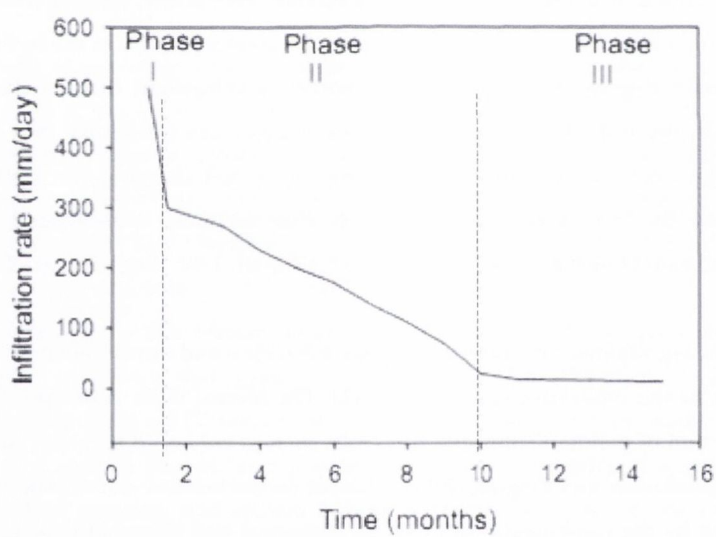


Figure 2.4 Typical schematic pattern of wastewater infiltration rate decline through infiltrative surface over time (Beal 2005 (from Otis 1984))

Severe soil clogging can result in system failure, however, the extent of a biomat formation can be reduced. Several researchers have suggested that biological clogging cannot predominate provided the STU remained at least intermittently aerobic (Jones and Taylor 1965, Thomas 1966). Lysimeter studies showed that the infiltrative capacity of the soil was reduced more slowly when periods of ponding were interrupted with periods of aeration (Thomas 1966). A study carried out by (Hargett et al., 1981) reported a reduction in the soil clogging rate provided the effluent application rate was not so high as to induce persistent ponding of the IS. The application of secondary treated effluent (SE) can delay or possibly even mitigate the formation of a soil clogging layer due to the reduced effluent concentration (Siegrist, 1987). This is of particular advantage in areas of slowly permeable subsoil where the formation of a significant clogging layer (biomat) could reduce the hydraulic capacity further, resulting in surface ponding and system failure.

2.5 SOIL WATER AND HYDRAULIC CONDUCTIVITY

Soils are permeable materials with water free to flow through the interconnected pores between the solid particles. Under saturated conditions (below the water table) the pores or voids within the soil are assumed to be filled with water. Above the water table (within the vadose zone) unsaturated or partially saturated conditions exist. Within this region water can be held at negative pressure by capillary tension in smaller pore spaces. Similarly, water percolating downward through a soil (for example rainfall) can be held by surface tension around the points of contact between soil particles (Craig, 2004). The resultant attractive force between particles is commonly referred to as soil moisture tension.

The rate at which effluent percolates through a STU is crucial to the treatment performance achieved. The hydraulic conductivity of a subsoil may be considered as a measure of the ease with which liquid pass through it and is dependent on the physical properties of the flowing liquid as well as the characteristics of the receiving subsoil. As the physical properties of domestic effluent (i.e. viscosity, density and specific weight) are practically constant, hydraulic conductivity is assessed as function of the permeability of the receiving subsoil. Laminar flow through a homogeneous isotropic saturated or unsaturated soil is described by the Darcy Velocity (Domenico and Schwartz, 1998):

$$(Darcy\ Velocity)v = -k\ \frac{dh}{dl} \qquad \text{(Eqn. 2.1)}$$

where,

$v = the\ volumeteric\ flow\ rate\ per\ unit\ surface\ area\ (m\ s^{-1})$
$k = the\ hydraulic\ conductivity\ (m\ s^{-1})$
$\frac{dh}{dl} = the\ hydraulic\ gradient$

However, for the determination of the convective transport of pollutants the seepage velocity (v') should be considered. Unlike the Darcy Velocity, the seepage velocity is a function of the available pore space within the soil medium through which water can move.

It is can be approximated as:

$$v' = \frac{v}{\eta} \qquad \text{(Eqn. 2.2)}$$

where, $v' = the\ seepage\ velocity\ (m\ s^{-1})$
$v = the\ Darcy\ Velocity\ (m\ s^{-1})$
$\eta = porosity\ of\ the\ soil$ (Craig, 2004)

Porosity (η) is defined as the fraction of the total volume of soil or rock that is empty pore space capable of containing water or air (Mihelcic, 1999) and is approximated as:

$$\eta = \frac{volume\ of\ pores}{total\ volume\ of\ soil} \qquad \text{(Eqn. 2.3)}$$

The degree of saturation of a soil medium is also crucial to its hydraulic conductivity. When a soil is fully saturated, all pore space is filled with water and conducting. The water phase is then continuous and the conductivity of the soil matrix is maximised. The return of unsaturated conditions results in some of the pores becoming air-filled so that the conductive portion of the soil's cross-sectional area diminishes. The first pores to empty are the largest ones (Hillel, 1998) which in turn regulates the remaining flow to the smaller pores. In conjunction with this the large empty pores, now acting as solid particles inhibiting flow, must be circumvented resulting in a overall decrease in hydraulic conductivity.

However, the conductive property of soil depends greatly on its texture and structure. At saturation, the most conductive soils are those whose overall pore volume consists of predominately large pore spaces, i.e. sands and gravels. In contrast to this, soils with a high proportion of fines (i.e. clays and silts) consist of numerous smaller pore spaces and are less conductive under saturated conditions. Under unsaturated conditions the reverse is true, with a rapid reduction in hydraulic conductivity in soils with large pores as it drains quickly and impedes flow. In finer soils, small pores retain and conduct water so that the hydraulic conductivity does not decrease as rapidly (Hillel, 1998).

The closer proximity of the percolating effluent to the solid phase in the unsaturated soil medium the longer the residence time that can be expected and the greater the potential for removal of pathogens and chemicals. Therefore, the correct sizing and effluent application rate to a STU is crucial in maintaining unsaturated conditions.
One drawback of conventional gravity fed systems is the shock loadings applied to a STU due to fluctuations in household discharge rates. This results in sporadic high effluent loadings to the STU increasing hydraulic conductivity over a short time frame. Intermittent effluent dosing has been identified as a means of combating these occurrences by allowing the regulation of effluent application. As outlined previously, gravity systems rarely achieve uniform effluent distribution across a STU. As a result, effluent discharges are concentrated within an area smaller than the design infiltrative area. This results in higher hydraulic loadings over the reduced surface area, increasing the likelihood of pollutant migration. The application of intermittent effluent has been identified as a key means of controlling the hydraulic conductivity in a STU and thus increasing the treatment performance.

2.6 SUBSOIL DESCRIPTION AND CHARACTERISTICS

Although biomat development plays a vital role in the treatment performance of STU, the characteristics of the native subsoil are also of critical importance with regards to the attenuation of contaminants and successful assimilation of the hydraulic loading.

2.6.1 BACKGROUND OF IRISH SUBSOIL

Irish subsoils were deposited during the Quaternary period of glacial history, which encompasses the last 1.6 million years and is sub-divided into the Pleistocene (1,600,000 - 10,000 years ago); and the more recent Holocene (10,000 years ago to the present day). During the Pleistocene, more commonly known as the 'Ice Age', glaciers and ice sheets laid down a wide range of deposits, which differ in thickness, extent and lithology. Material for the deposits originated from bedrock and was subjected to different processes within, beneath and around the ice. Some were deposited irregularly by ice and so are unsorted and have varying grain sizes, while others were deposited by water in and around the ice sheets and are relatively well sorted and coarse grained (Meehan, 2012). Mapping of subsoils in Ireland was undertaken by Teagasc in a project funded by the EPA during the period 1998 - 2006 (Figure 2.5).

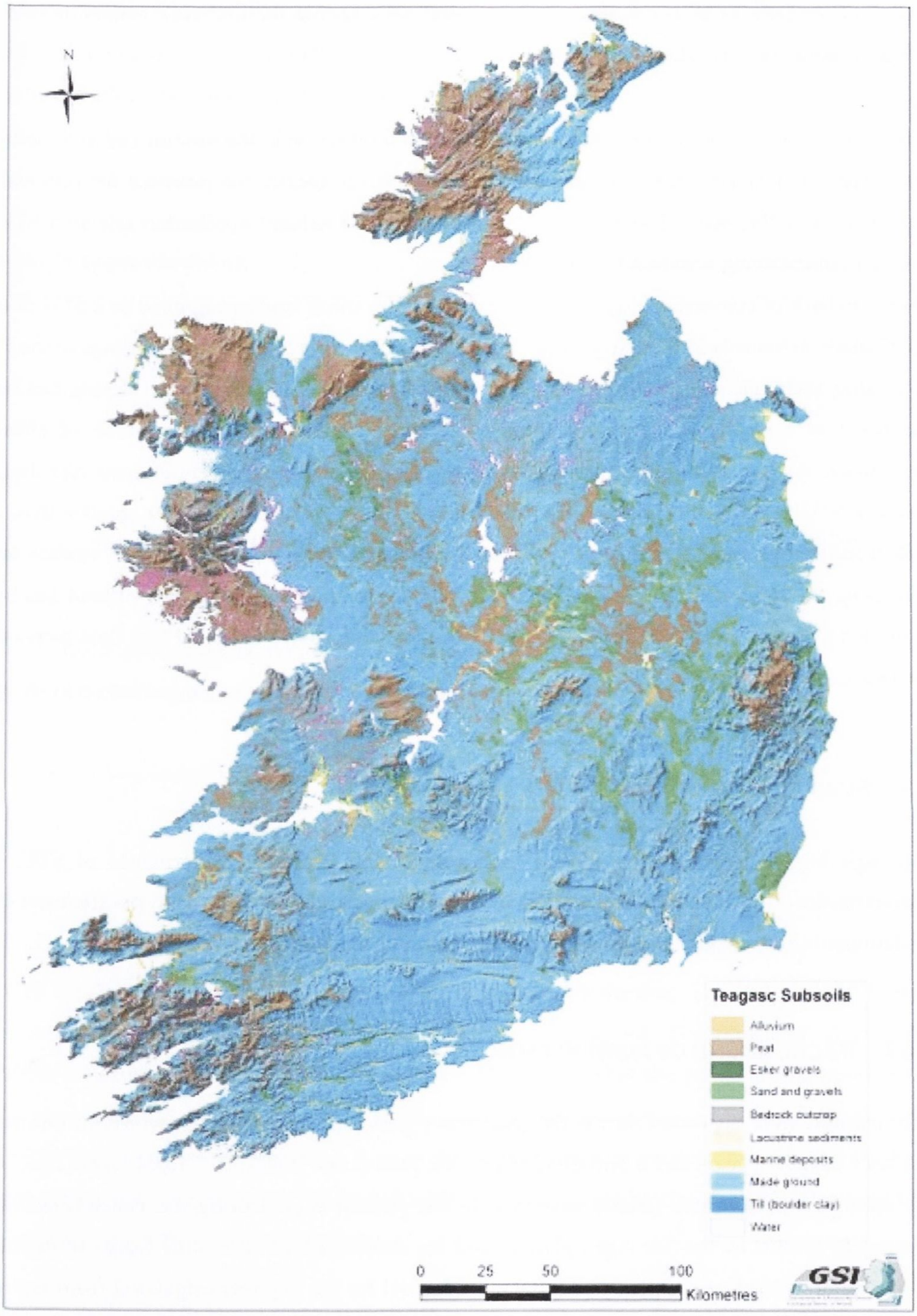


Figure 2.5 Subsoils map showing different subsoil types across the Irish landmass (Meehan, 2012)

In Ireland, the principal aquifers occur in fractured bedrock and in sand and gravel deposits. In general, little attenuation occurs in the bedrock because flow is almost wholly via fissures. Consequently, the subsoils act as a filter and protective cap for the underlying aquifers, and are therefore an important natural feature influencing groundwater vulnerability in Ireland (Swartz et al., 2003).

There are five main subsoil types in Ireland as shown in Figure 2.5:

- Till - often referred to as boulder clay is the most widespread subsoil across Ireland covering 43% of the country at surface level. Tills are often over-consolidated, or tightly packed, unsorted, unbedded and consist of many different particle sizes.
- Sand and gravels - these are either Glaciofluvial or Esker deposits and are usually loosely packed. Consequently sands and gravels usually have very high permeabilities.
- Lake deposits - consist of sorted gravel, sand, silt and clay.
- Alluvium - may consist of a variety of gravel, sand, silt or clay mixes along with a high percentage of organic carbon (10% - 30%).
- Peat - covering almost 20% of the country, these deposits mainly consist of partially decomposed vegetation often associated with poor drainage.

2.6.2 DESCRIPTION OF IRISH SUBSOILS

Subsoil is classified as the sediments present beneath topsoil and above bedrock. Topsoil is the uppermost layer of the earth in which plants grow and which is capable of supporting life. It is important to distinguish between the topsoil (the upper metre or so affected by biological and weathering processes) and the underlying subsoil, as the latter is of most relevance in attenuating contaminants from on-site wastewater treatment systems.

In Ireland the BS 5930 method (BSI, 1981) is used as a consistent and systematic method for the description of subsoils that also offers the advantage of being widely used by Civil Engineers and Hydrogeologists. Whilst the permeability and thickness of subsoils are the main factors used for determining vulnerability, it is recognised that other material factors such as particle size distribution, plasticity and dilatancy, and mass factors such as density/compactness, and discontinuities can influence the vulnerability at specific sites.

Particle Size Analysis

The particle size analysis of a soil sample involves determining the percentage by mass of particles within different size ranges (Figure 2.6). Particle size distribution is the most important factor influencing the permeability of, or percolation rate through subsoils. Subsoils consist of rock particles, mineral grains and sometimes organic matter, together with variable amounts of water and air. In general, fine-textured subsoils such as clayey and silty materials have more but smaller pore spaces for water to travel through, and therefore have a low permeability. Conversely, coarse grained subsoils have fewer but larger pore spaces that can transmit water quickly and thus have high permeability.

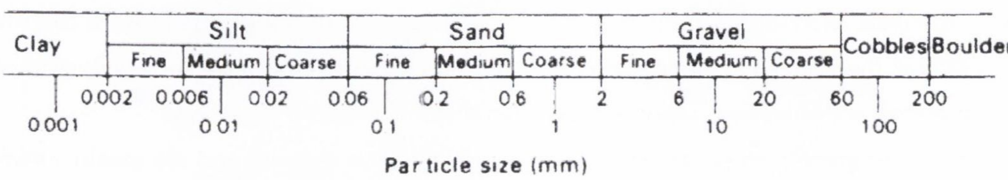


Figure 2.6 Particle size ranges (BSI, 1981)

Plasticity

Plasticity is an important characteristic in the case of fine soils, the term plasticity describing the ability of a soil to deform, or change shape, without breaking when subject to an external force of pressure. Plasticity is due to the presence of a significant content of clay mineral particles in a soil and as a result is usually an indication of low permeability. A thread test is carried out on-site during inspection of the trial hole to examine the soil plasticity. In summary, the longer the thread (~3 mm in diameter) can be rolled, and the more pressure it takes to break this thread (i.e. twisting it instead of just bending it), the higher the clay content of the sample.

Dilatancy

Dilatancy describes the expansion in volume of a subsoil sample on shearing. When describing subsoils, shearing is caused by shaking the hand sample. If the sample volume expands upon shaking, the sample is said to be 'dilatant'. To assess the dilatancy of a hand sample, a saturated sample is held in the palm of the hand. Using the other hand, the hand holding the sample is tapped. Three terms are used to describe a sample's possible reaction: rapid, slow and done. A sample has a rapid reaction if water quickly rises to the surface, making the surface shiny and wet-looking. If the sample is subsequently squeezed, the shiny appearance disappears quickly. This occurs typically with sands and some silts with high permeability. Samples have a slow reaction if it takes vigorous shaking to notice a transformation, and there is little change after squeezing. Samples that show no change are simply noted as such. In clay, no response is typically observed due to the low permeability of the material.

Colour

Colour is a good indicator of the state of aeration of a subsoil. Well drained soils exhibit brown, reddish brown and yellowish brown colours. In the case of soils of limestone origin with deep water tables a grey colour is exhibited at depth due to the colour of the parent material. In contrast to this, saturated soils are dull grey or mottled. Mottling appears as a mix of grey and reddish brown/rusty staining and is a good indication of the height of a sites water table during winter.

Density/Compactness

Soil compactness or density refers to how tightly the soil particles are packed together and as such influences the permeability and percolation rate. The more dense or compact a particular soil, the more compressed the pore spaces are, and the lower the relative percolation rate.

Preferential Flow Paths

Preferential flow paths (PFPs) may form within subsoils due to biological, chemical and physical processes and their interactions. Far from being a uniform matrix, subsoil often contains beds, laminations for lenses of different sediments (O'Súilleabháin, 2004). Such variations can provide PFPs for percolating effluent to travel through the subsoil into the bedrock, thus reducing the attenuation capacity of the soil and increasing the likelihood of groundwater contamination. In particular, the occurrence of PFPs in the form of sand lenses within otherwise low permeability subsoils could permit the vertical migration of particular contaminants of concern (e.g. pathogens) of effluent to groundwater.

2.6.3 Low Permeability Subsoils

Previous research studies relating to OSWTS in Ireland (Gill et al., 2007, Gill et al., 2009, O'Luanaigh et al., 2012) have focused on higher permeability regions where the migration of contaminants such as nutrients and pathogens to groundwater has been of particular concern. However, STU operating in areas of lower permeability are also thought to pose a considerable risk of water pollution, particularly with respect to surface water run-off. This risk is reflected by the Figure 2.7b which shows the relative risk of water pollution from domestic wastewater sources via surface pathways. It is unsurprising therefore that the areas highlighted as most at risk correlate closely with those regions of low permeability highlighted by Figure 2.7a.

(a) (b)

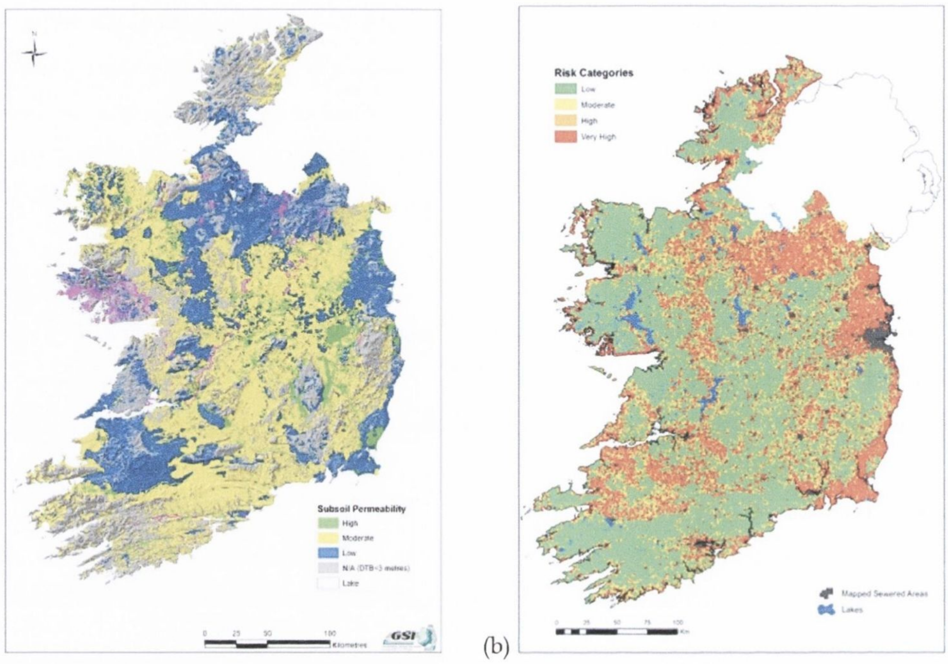


Figure 2.7 (a) Subsoil permeability map showing different permeability classes across the Irish landmass (Meehan, 2012); (b) Relative risk of water pollution (streams) from OSWTS via surface pathway (EPA, 2012).

2.6.4 DETERMINING SUBSOIL PERMEABILITY

The permeability of subsoil is largely a function of (a) the grain size distribution, (b) the amount (and sometimes type) of clay size particles present, and (c) how the grains are packed together (Meehan, 2012). In Ireland, the permeability of individual sites for wastewater discharge is assessed by means of a percolation test or T-test, the method for which is out-lined the EPA Code of Practice for Single Households (EPA, 2009a). This is the on-site standardised Irish falling head percolation test and is based on the average time for a 25 mm water drop (Mulqueen and Rodgers, 2001). The objective of the permeability test is to determine a subsoil's ability to hydraulically transmit applied effluent from the treatment system to the groundwater. For a subsoil to be effective as a medium for treating wastewater, it should be permeable enough to allow throughflow and remain unsaturated, whilst capable of retaining the wastewater for a sufficient length of time to allow attenuation in the aerobic conditions (EPA, 2009a). The results of the percolation test determine whether or not a site is suitable for construction of a STU and if so in what configuration. There are two types of percolation test used in Ireland, P-tests (at ground level) and T-tests (at depths greater than 400 mm). The procedures for both are detailed in Section 3.2.4.

The permeability of a subsoil, in conjunction with the extent of biomat development, control the LTAR of an existing or proposed STU. As such, determination of permeability is a critical step in the establishment of the suitability of a site for on-site wastewater treatment. The resultant T-value of a site following the completion of percolation testing determines the type of STU (if any) deemed suitable for that subsoil. Table 2.2 outlines the current options available for Irish householders as stated by the EPA Code of Practice.

Table 2.2 Interpretation of percolation test results (modified from EPA (2009a))

Percolation Test Result	Interpretation
$T > 90$[1]	Site is unsuitable for development of any on-site domestic wastewater treatment system discharging to ground.
$T < 3$[1]	Retention time in the subsoil is too fast to provide satisfactory treatment. Site is unsuitable for secondary-treated on-site domestic wastewater systems. However, if effluent is pretreated to tertiary quality then the site will be hydraulically suitable to assimilate this hydraulic load. P-test should be undertaken to determine whether the site is suitable for a secondary treatment system with a polishing filter at ground level or overground.
$3 \leq T \leq 50$	Site is suitable for the development of a septic tank system or a secondary treatment system discharging to groundwater.
$50 \leq T \leq 75$	Wastewater from a septic tank is likely to cause ponding at the surface of the percolation area. Not suitable for a septic tank system. May be suitable for a secondary treatment system with a polishing filter at the depth of the T-test hole.
$75 \leq T \leq 90$	Wastewater from a septic tank is likely to cause ponding at the surface of the percolation area. Not suitable for a septic tank system. Site unsuitable for polishing filter at the depth of the T-test hole. P-test should be undertaken to determine whether the site is suitable for a secondary treatment system with polishing filter, i.e. $3 \leq T \leq 75$, at ground surface or overground.
$P < 3$	Retention time in topsoil/subsoil insufficient to provide satisfactory treatment. However, if effluent is pretreated to tertiary state then the site will be hydraulically suitable to assimilate the hydraulic load. Imported suitable material may be deemed acceptable as part of site improvement works.
$3 \leq P \leq 75$	Site is suitable for a secondary treatment system with polishing filter at ground surface or overground

[1]Site is deemed suitable for treatment system discharging to surface water in accordance with Water Pollution Act licence however most local authorities do not grant these to single dwellings

2.7 FATE OF KEY POLLUTANTS FOUND IN DOMESTIC WASTEWATER

The performance of a STU is determined by the fate of a number of key pollutants originating from domestic effluent sources applied to it. The following sections examine the key mechanisms by which these pollutants are treated within a STU with a focus on the benefits of employing pressured effluent dosing and distribution.

2.7.1 ORGANIC CHEMICALS

Biodegradable organic chemicals in either dissolved or suspended form can be characterised by Biochemical Oxygen Demand (BOD) or Chemical Oxygen Demand (COD) which measure the amount of oxygen required for biochemical and chemical oxidation, respectively.

The formation of a soil clogging layer is critical to their effective removal in a STU with the biomat layer itself composed partly of organics and suspended solids (Van Cuyk et al., 2001). The biomat removes suspended solids including biodegradable organic and mineral matter through a combination of physical straining and biological degradation processes (Reed et al., 1995). Laboratory columns simulating the unsaturated zone often remove 80% to 90% of organic C in STE when aerobic conditions are maintained, suggesting aerobic oxidation and retention to be the main removal processes (Wilhelm et al., 1994). Gill et al. (2007) reported a 75% to 89% reduction in organics between the septic tank and a depth of 0.3 m below the IS with the author suggesting the COD attenuation occurred within the distribution gravel of the percolation trench rather than in the subsoil. A subsequent study by O'Luanaigh (2009) found a reduction of 61% to 83% within 0.35 m below percolation trenches treating STE and SE in highly permeable Irish subsoils. The main factors influencing the degree of organic matter removal achieved by a STU are presented in Table 2.3.

Table 2.3 Factors influencing fate of organic matter in the subsurface

	Influence on Migration
Temperature	The rate of decomposition of organic matter increases with temperature
Microbial activity	A biologically active soil improves the rate of organic matter removal through a combination of physical straining and biological degradation processes
Moisture content	Removal of organic matter is greatest under unsaturated conditions where aerobic oxidation and particle retention occurs

pH	Greatest removal in alkaline soils (pH > 6) where potential decomposition by microorganisms is at its highest
Soil properties	Greater organic matter migration in coarse-textured soils; there is a high degree of organic matter retention by the clay fraction of soil
Hydraulic conditions	Generally, organic matter migration increases with increasing hydraulic loads and flow rates

As noted previously, a dose/rest effluent loading cycle can also help to maintain unsaturated flow in an STU critical to the effective straining of wastewater and the removal of organic chemicals. A laboratory study carried out by Gross et al. (1990) compared the treatment performance of effluent application to sand filters by both pressurised and gravity distribution methods. It was found that the filter receiving STE by pressurised distribution consistently treated the WW to higher quality effluent than the filter receiving STE by gravity distribution. The pressurised distribution system reduced the BOD_5 concentration by an average of 85.5% compared to only 72.5 % reduction for the gravity fed system. SS removal efficiencies were 86.5% and 78.1% for the pressurised distribution and gravity distribution filters respectively. This suggests that the application of pressurised dosing has the potential to improve the likelihood of maintaining aerobic conditions, thus increasing a STU performance in the removal of organics. This is particularly applicable in low permeability areas where hydraulic overloading can quickly lead to the onset of anaerobic conditions, compromised effluent treatment and in some cases system failure.

2.7.2 NITROGEN

Of all the pollutants occurring in domestic wastewater one of the most problematic is nitrogen. The two forms of nitrogen (N) which are of most concern to the contamination of groundwater and surface water are ammonium and nitrate. Ammonium is toxic when present in high concentrations while nitrate presence in drinking water has been linked to methaemoglobinaemia (blue baby syndrome) in infants and it is also assumed to promote eutrophication in estuarine environments (Pepper et al., 2011) although some contemporary thinking disputes the link between drinking water and methaemoglobinaemia.

Ammonium is the main form of N in septic tank effluent which rapidly undergoes nitrification (converted to nitrate form) once applied to the unsaturated, aerobic zone of a STU. Nitrate is not readily removed from the percolate resulting in the potential transport to receiving waters. The fate of nitrogen in a STU is dependent on the presence of environmental conditions conducive to its removal through a combination of the potential pathways of fixation, adsorption, volatilization, biological uptake, and denitrification (Figure 2.8).

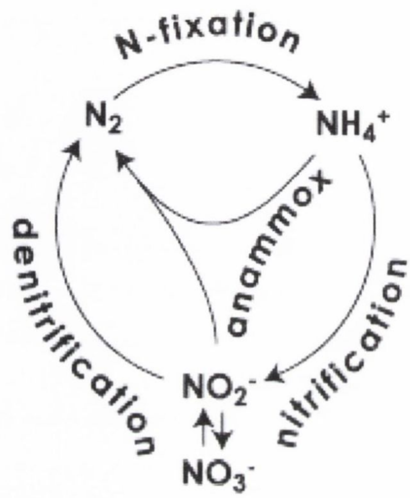


Figure 2.8 Nitrogen transformations during land disposal of wastewater

Table 2.4 details the conditions required for both nitrification and denitrification to occur within a STU. These are the key processes by which ammonium is transformed to nitrate and then leaches to groundwater or is removed through denitrification on the annamox process.

Table 2.4 Factors influencing the fate of nitrate and ammonium in the subsurface

	Influence on nitrification	Influence on denitrification
Temperature	Generally increases with an increase in temperature	Directly influenced by soil temperature with denitrification increasing rapidly from 2°C to 35°C with optimum temperature 25-35°C
Microbial activity	Controlled by autotrophic bacteria	Controlled by heterotrophic bacteria
Moisture content	Occurs rapidly under aerobic conditions	Occurs under anaerobic conditions provided a sufficient carbon source is available
pH	Occurs more rapidly at near neutral pH	Most denitrifiers show optimal growth at near neutrality (pH 6.0 to 8.0)
Soil properties	Generally occurs more readily in	Occurs in soils where both aerobic and

	aerobic well drained soils	anaerobic conditions occur
Organic matter		Readily decomposable organic matter required as heterotrophic bacterial are dependent on carbon availability

Fixation occurs when ammonium ions become trapped in the intermicellar layers of clay minerals, and fixation by organic components of the soil may also occur (Lance, 1972, Tyler et al., 1977). In most soils, the potential for ammonium fixation is limited, and this pathway is not likely to be important in the long-term nitrogen removal. Nitrogen loss through non-biological volatilization of ammonium to ammonia gas is even less of a factor due to the requirement for considerable air-water contact and high pH not afforded in STU (Lance, 1972).

In a properly installed and operating system, the predominant nitrogen retention reaction is ammonium adsorption while the major transformation reaction is nitrification (Siegrist et al., 2000). Any remaining N in the STE is generally in its organic form which is mineralised rapidly to ammonium in the upper layers of the soil system. Prolonged adsorption of NH_4-N appears most effective under anaerobic conditions where nitrification is inhibited, with Canter and Knox (1985) suggesting that in such an environment the ammonium ions are readily adsorbed onto negatively charged soil particles. After the adsorption capacity of the first few centimetres of soil is reached, the ammonium ions in the percolate will travel further to find unoccupied sites if anaerobic conditions persist. Cation exchange may also be involved along with adsorption in the retention of ammonium ions in the subsoil; however just as the adsorption capacity of the soil can be exceeded;, there are only a finite number of exchange sites available in the subsoil (O'Súilleabháin, 2004). In order for significant adsorption to occur anaerobic conditions must persist for a sufficient length of time as under aerobic conditions ammonium is readily nitrified (Tyler et al., 1977). In general, near complete nitrification should be achieved in properly installed systems with the process normally occurring very rapidly within the first 0.3 m of soil below the infiltrative surface (Siegrist et al., 2000). As a result the long-term removal of nitrogen by adsorption is limited.

In general, secondary treatment units produce a highly nitrified effluent. As a result in STU receiving SE the mechanisms of ammonium removal are relatively insignificant. Since nitrate is a negatively charged ion it is not attracted to the negatively-charged soil colloids and as such is readily discharged to groundwater. Harman et al. (1996) carried out research in a sandy subsoil receiving STE which showed nitrate concentrations increasing from less than 0.1 mg NO_3-N L^{-1} in the septic tank to 112 mg NO_3-N L^{-1} at the water table while ammonium concentrations decreased from 128 mg NH_4-N L^{-1} in the tank to less than 1 mg NH_4-N L^{-1} at the water table. In this case, as nitrate levels observed at the water table were similar to effluent ammonium levels, almost complete nitrification of ammonium appeared to occur with little ammonium being removed by other processes.

Biological uptake, denitrification and Anammox are the significant pathways for effluent nitrogen removal from a STU. Biological denitrification is the reduction of nitrate to nitrogen gas by bacteria that, in the absence of oxygen, use nitrate as an alternate electron acceptor.

Lance (1972) states that three conditions are necessary for denitrification to occur:

- oxidation of ammonium to nitrate
- passage through an anaerobic zone after nitrification has occurred
- provision of an adequate source of energy for the denitrifying bacteria in the anaerobic zone

However, as outlined previously, the organic matter content of STE is reduced rapidly beneath the IS whilst simultaneously undergoing nitrification. Therefore, at a point where denitrification reactions could remove significant quantities of nitrogen, little carbon remains in the water to feed the denitrifying bacteria. In a conventional system, where the IS is deep, effluent flows into the subsoil, where there is typically little soil organic matter present, and as such these optimal conditions for denitrification are generally limited to small anaerobic pockets in the vadose zone or the biomat itself (Wilhelm et al., 1994). However, near-surface disposal systems are located in higher soil horizons which contain the majority of soil organic matter increasing the denitrification potential. Beggs et al. (2011) also concluded that the light loading rate and resulting long effluent retention time in the upper soil zone associated with subsurface drip irrigation provide much greater opportunity for plant uptake than conventional deep leach field application of effluent. The author found conventional gravity STU depend more on dilution to reduce nitrogen concentrations as opposed to subsurface drip systems which provide more opportunity for plant uptake and denitrification. Hoover et al. (1991) also speculated that an increase in denitrification was the reason that little nitrogen was detected downstream of a low pressure trench system receiving sand filter effluent.

Anaerobic ammonium oxidation (Anammox) is a recently discovered component of the nitrogen cycle. It is a useful process in the treatment of wastewater as it reduces the need for aeration and carbon source. It has been proven to be an important mechanism for nitrogen removal in unsaturated subsoil conditions during the application of wastewater (Robertson et al., 2012)

2.7.3 PHOSPHORUS

In Ireland STE contains total phosphorus in the range of 5-20 mg/l mainly in the form of orthophosphate, dehydrated orthophosphate and organic phosphorus (Siegrist et al., 2000). Bouma (1979) reported on studies that found that more than 85% of total phosphorus in the STE was in the soluble orthophosphate (PO_4-P) form. Removal of PO_4-P from the percolate in the subsoil is typically due to a combination of soil adsorption and mineral precipitation processes. As it is difficult to distinguish between these two mechanisms the term 'sorption' is often used to describe the process where both absorption and precipitation are possible (White, 2009).

The availability of "sorption sites" to bind the phosphorus is dependent upon soil texture and the composition of the clay fraction (Griffin and Jurinak, 1974). While it is possible to exhaust these sites, most soils have a very high capacity for sorption of phosphorus. Sorption sites are provided by clay and organic fractions of the soil. Therefore, sandy soils typically have lower capacities than clayey soils (Sparks, 2003) however some sands have relatively high ferric contents which makes for a high rate of P sorption. Phosphate attenuation is generally considered in two general categories: initial adsorption reactions and much slower precipitation reactions the regenerate additional adsorptive surfaces occurring both from phosphate in solution and from phosphate previously absorbed (Lance, 1984).

Most studies indicate, however, that effective P immobilisation occurs in the soil (including those that are course-textured) within a few metres of the percolation trench and significant movement of P is therefore rare (Reneau et al., 1989, Harman et al., 1996).

While capacity for P sorption is finite, a given soil, however, does not have a fixed capacity to remove phosphorus as these reactions are dependent upon many factors such as the phosphorus concentration in the soil solution, soil pH, temperature, time and the concentration and type of ions in the STE (Lance, 1984). In contrast, precipitation may provide a higher capacity to fix phosphate, provided that the solution and soil chemistry is conductive to the reaction (Jones and Lee, 1979).

In research carried out on a system in operation for 44 years, it was concluded that the attenuation of phosphate in the subsoil was controlled by mineral precipitation rather than sorption (Harman et al., 1996). Analysis of the soil showed the P-sorption capacity had been reached. Also, the phosphate concentration recorded at the water table over a three year period was relatively constant and significantly lower than the STE phosphate concentration suggesting steady-state conditions. If adsorption was the main attenuation process, phosphate concentrations at the water would have been seen to increase as sorption sites are used up. The factors which determine the degree of P-sorption as percolate passes through a subsoil are outlined in Table 2.5.

Table 2.5 Factors influencing fate of phosphate in the subsurface (Yates et al., 1988)

	Influence on Migration
Temperature	Generally, P-sorption increases as temperature increases
Salt species and concentration	Calcium and oxidized compounds of Fe and Al are known to be important agents for P-sorption in soils
pH	At low pH, soils have greater amounts of aluminium in the soil solution providing an increase in mineral precipitation
Soil properties	Sorption of phosphate is greater in soils with a high proportion of clay particles due to the increase in sorption sites
Organic matter	Organic matter can provide P sorption sites in the absence of a significant clay fraction, however, organic anions can also displace sorbed phosphate
Hydraulic conditions	Generally, P migration increases with increasing hydraulic loads and flow rates

Sawhney and Hill (1975) highlight the importance of the geometry of a STU on the sorption capacity of a soil, highlighting that a leaching pit (or soak-pit) provides less soil volume for sorption within a give distance from the pit than that of a percolation trench system. It therefore stands to reason that the improved effluent dispersal over a larger receiving area provided by pressurised distribution would further increase the available soil volume than that of conventional trench systems. Sawhney and Hill (1975) also state that deeper soil layers generally have a lower phosphorus sorption capacity, so phosphorus removal would be enhanced in shallow pressurised systems. In conjunction with this, organic matter can provide P sorption sites in the absence of a significant clay fraction. Therefore, in sandy soils the discharge of effluent into the near-surface soil horizons of higher organic content would theoretically increase the soils sorption capacity. Finally, as with nitrogen, P removal in shallow pressurised systems would be enhanced by plant uptake in the rhizosphere.

2.7.4 Pathogens

With an estimated 200,000 wells and springs in use in Ireland (Wright, 1999, cited by (Robins and Misstear, 2000)), the survival of pathogens under saturated and unsaturated conditions is a major concern in the protection of groundwater resources. The groundwater contaminants of primary concern in terms of human health are enteric pathogens including verotoxigenic E. coli (VTEC), Cryptosporidium spp., Giardia lamblia., and enteric viruses (rotavirus, adenovirus, norovirus, etc).

A range of symptomatic illnesses may result from direct consumption of one or more of these pathogens via groundwater (Hynds et al., 2013). Enteric pathogens, excreted in faecal matter, discharged via STE contaminate the environment and then gain access to new hosts through ingestion (i.e. the faecal-oral route). Consequently, private household wells may be more vulnerable to microbiological contamination as they are often located in close proximity to OSWTS. A study carried out during the period 1998 - 2008 found 33% or private group water schemes in Ireland showed evidence of faecal coliform presence (Hynds et al., 2013, EPA, 2009b).

Waterborne pathogens can be classified broadly into five groups of microorganisms according to their chemical, physical and physiological characteristics. Listed in order of increasing functional complexity the groups are viruses, bacteria, protozoa and helminths. Archaea are another group of organisms recently discovered that although share many similarities to the bacterial species have their own individual membrane structure and behaviour patterns. The different characteristics of each organism are shown in Table 2.6.

Table 2.6 Characteristics of waterborne pathogens (adapted from Pepper et al. (1996))

Organism	Size (μm)	Shape
Viruses	0.01 - 0.1	Variable
Bacteria	0.1 - 10	Rod, spherical, spiral, comma
Archaea	0.1 - 15	Rod, spherical, spiral, comma
Protozoa	1 - 100	Variable
Helminths	1 - 10^9	Variable

Gerba and Goyal (1985) report that septic tanks remove 50% to 90% of bacteria, none of the protozoan cysts and 50% to 90% of helminth eggs from domestic wastewater whilst viral numbers have been detected in concentrations in excess of 10^3 - 10^4 PFU L^{-1} in untreated wastewater (Toze, 1997). The large size of helminth ova would most likely retard their movement with water in a soil-pore matrix (Burge and Marsh, 1978) and are therefore not considered a threat to groundwater pollution. Concern surrounding public health in relation to waterborne pathogens is instead concentrated on the potential impact of bacterial, viral and protozoan species.

Bacteria

Bacteria are the most numerous of the microbial pathogens found in domestic wastewater (Pepper et al., 1996). Faecal pollution of a water body is determined by detection of indicator bacteria. The traditional faecal indicators monitored include *Escherichia coli* (*E. coli*) bacteria and intestinal enterococci.

The two mechanisms responsible for immobilisation of pathogens in wastewater moving through a porous media are straining and adsorption (Kristian Stevik et al., 2004). The straining capability of a soil is influenced by its grain size, the bacterial cell size and shape, the degree of water saturation and clogging of the soil. The extent to which bacteria are retained by straining is inversely proportional to the size of the soil particles which act as a filter media (Hagedorn et al., 1981). The influence of straining is of most importance when the average cell size of the bacteria is greater than the size of 5% of the soil particles (Updegraff, 1983). Unsaturated conditions are most conducive to straining as transport takes place in the smallest pores. In saturated conditions, flow is predominantly through macropores and as a result straining is less effective. The amount of effluent applied to a STU and the rate at which it is applied also affects the extent of bacterial migration (Yates et al., 1988). High loading rates cause effluent to percolate more rapidly through the soil, decreasing the time available for contact between the bacteria and soil, thus decreasing the probability of adsorption (Bouma, 1979).

Gannon et al. (1991) report that the transport of bacteria in a porous material is strongly correlated to the size and shape of the bacterial cell. The study examined the transport properties of 19 strains of bacteria, concluding that cells with a length <1 μm were transported more effectively than those >1 μm. Bacteria are also transported more effectively during high flow rates. As stated previously, saturated conditions result in greater transport through larger pores reducing the straining effect (Smith et al., 1985, Thomas and Phillips, 1979). A study by O'Luanaigh et al. (2012), on highly permeable soils in Ireland, found a greater instance of faecal contamination with depth as a result of a higher areal loading acting on the base of percolation trenches. Similar results were also reported by Gill et al. (2007). One way to mitigate such instances is through the application of effluent by means of pressurised dosing cycles. Studies by Bomblat et al. (1994) and Ausland et al. (2002) both report a higher removal of faecal coliform bacteria in filtration systems employing uniform pressure distribution compared to those employing gravity distribution. Smaller effluent doses, distributed evenly over a greater surface area reduces the likelihood of hydraulic overloading, thus increasing the effectiveness of straining.

The importance of the biomat in the prevention of pathogen migration cannot be overstated (O'Luanaigh et al., 2012). The development of a biomat restricts pore size and so enhances the effect of straining. Kristiansen (1981) found the highest concentrations of faecal coliforms in the effluent from sand filters with the least biomat development.

If the soil pores are larger than the bacteria the effect of straining is reduced and adsorption is the principal mechanism for bacteria retention (Sharma et al., 1985). The success of bacterial adsorption depends on a number of key factors. Physical factors of influence include the size, surface texture and charge of the particles present in the porous media to which effluent is applied. Smaller particle sizes result in the availability of a greater surface area compared to larger particles, this provides more adhesion sites increasing adsorption potential (Tan et al., 1991, Fontes et al., 1991). As such, the greater the proportion of clay particles in a soil the greater the adsorption of bacterial cells (Huysman and Verstraete, 1993b). The presence of organic matter is also thought to have an influence on adsorption in both a positive and negative manner. Organic matter attached to the filter media provides additional adsorption sites increasing bacterial retention (Huysman and Verstraete, 1993a). However, organic matter solution competes with bacteria for adsorption sites thus reducing the potential for bacterial retention (Harvey et al., 1989). Finally, temperature, pH, and effluent velocity affect the rate of bacterial adsorption. Fletcher (1977) reported a reduction in attachment was observed with a reduction in temperature. Studies have shown greater bacterial transport as a result of a higher rate of effluent application (Camper et al., 1993, Smith et al., 1985). As with straining, the application of effluent in reduced intermitted doses by means of pressurised distribution also has the potential to improve the immobilisation capacity of a soil by reducing the effluent application rate.

The rate of die-off of bacteria within a STU is influenced by abiotic factors (moisture content, pH, temperature and organic matter content) and biotic factors (bacterial species and predation). Several studies have shown connections between bacterial survival and temperature or water content (Young and Greenfield, 1923, Campbell and Biederbeck, 1976). Kibbey et al. (1978) examined the survival of *enterococci* (*faecal streptococci*), in five soils under various soil moisture contents and temperatures. The study showed longer bacterial survival times under cooler moister conditions irrespective of soil type. Prolonged bacterial survival has also been associated with the presence of organic matter as they require a nutrient source for survival (Tate, 1978). The survival rate is also dependant on the bacteria present, with the varying survival recorded between species (Rudolfs et al., 1950). A summary of the key factors which influence the survival and migration of bacterial when applied to an STU are illustrated in Table 2.7.

Table 2.7 Factors influencing bacteria fate in the subsurface (Yates et al., 1988)

	Influence on survival	**Influence on Migration**
Temperature	Bacteria survive longer at low temperatures	
Microbial activity	Increased survival time in sterile soil	
Moisture content	Greater survival time in moist soils and during times of high rainfall	Generally, migration increases under saturated flow conditions
pH	Increased survival time in alkaline soils (pH > 5) than in acid soils	Low pH enhances bacterial retention
Salt species and concentration		Generally, increasing the concentration of ionic salts and increasing cation valences enhance bacterial adsorption

Soil properties		Greater bacterial migration in coarse textured soils; bacteria are retained by the clay fraction of soil
Bacterium type	Different bacteria vary in their susceptibility to inactivation by physical, chemical and biological factors	Filtration and adsorption are affected by the physical and chemical characteristics of the bacterium
Organic matter	Increased survival and possible re-growth when sufficient amounts of organic matter are present	The accumulation of organic matter can aid in the filtration process
Hydraulic conditions		Generally, bacterial migration increases with increasing hydraulic loads and flow rates

As stated previously the traditional faecal indicators monitored include *Escherichia coli* (*E. coli*) bacteria and intestinal enterococci since they occur in human faeces. However, a few limitations of using these traditional indicators to represent pathogens in water include the fact that they have been shown to multiply in the environment, that they are not host specific, and that the absence of traditional faecal indicators is not necessarily evidence of pathogen absence (Schriewer et al., 2010, O'Flaherty et al., 2012).

In order to overcome these limitations, alternative indicators for faecal pollution have been developed. *Bacteroides* are found exclusively in the gastrointestinal tract and faeces of humans and animals and are among the most numerous bacterial populations in the human intestine. Over a decade ago, PCR-based assays were developed to detect *Bacteroides* in an effort to improve the monitoring of human faecal pollution in the environment (Kreader, 1998). These methods have been developed to target the host specific 16S rRNA gene markers for different faecal sources (Schriewer et al., 2010). For example, Kildare et al. (2007) developed universal (BacUni-UCD), ruminant-specific (BacCow-UCD) and human-specific (BacHum-UCD) *Bacteroidales* assays for water quality monitoring.

The analysis of *Bacteroidales* markers has been incorporated into microbial source tracking (MST) as a method used to identify the origin of faecal pollution in many parts of the world (Gourmelon et al., 2007, Reischer et al., 2008, Vogel et al., 2007). Strictly anaerobic members of the order *Bacteroidales* are used as faecal source identifiers in water and as a result they survive for only a few hours in oxygenated water (Fiksdal et al., 1985) making them a more useful indictor of recent faecal pollution than traditional faecal indicators. The main advantage however, is that they display a high level of host specificity. Many studies have shown the potential of *Bacteroidales* as faecal source trackers. Schriewer et al. (2010) demonstrated the high sensitivity of *Bacteroidales* as an alternative faecal indicator assay as both *Bacteroidales* and faecal indicator bacteria were detected in most surface waters sampled. Jenkins et al. (2009) used MST methods to detect universal, human-specific and cow-specific *Bacteroidales* genetic markers in water samples. Using qPCR assays they found that cows were a likely predominant source of faecal contamination. Studies to date support further research towards the use of *Bacteroidales* assays for water quality monitoring (Schriewer et al., 2010) however, no qPCR assay is 100% specific and sensitive for its intended target. However, occasional false negative as well as false positive amplifications can occur (Barrett, 2011).

Viruses

Viruses are among the most important and potentially the most hazardous of the pathogens found in domestic wastewater. This is due to their small size and therefore increased mobility, which ranges from 10 - 100 nm, in comparison to the other pathogenic groups. More than 100 types of human pathogenic viruses may be present in water containing faecal pollution (Toze, 1997). Viruses are not continuously present at high densities in domestic wastewater, but rather are shed during disease events and so there concentrations can vary greatly from non-existent to 10^6 organisms per L (Siegrist et al., 2000).

Viruses themselves are obligate intracellular parasites, which mean they cannot reproduce or express their genes without the help of a host cell (Withey et al., 2005). During what is termed the *lytic cycle* a virus adsorbs to the surface receptor of a host cell which may come in the form of animal or plant cells, bacteria, fungi or algae. The virus then penetrates the cell wall and injects its nucleic acid into the host. The reason for this is that viruses cannot synthesize proteins as they lack ribosomes and therefore must use the ribosomes of their host cells to translate viral messenger RNA into viral proteins. Also, viruses cannot generate or store energy, but have to derive their energy and all other metabolic functions, from the host cell. They also attack the cell for basic building materials, such as amino acids, nucleotides, and lipids (fats). Therefore, once a virus has infected a cell, it will assemble all the cell's ribosomes, enzymes and much of the cellular machinery before reproducing. The newly-formed viruses then break down the membrane in the cell wall and are released for the cycle to begin again.

In domestic wastewater, the most commonly detected pathogenic viruses are the enteroviruses, which belong to the family of enteric viruses. Enteroviruses are those that infect and multiply in the human intestines and are responsible for a wide-range of diseases including respiratory infections and hepatitis. During infection, large numbers of virus particles, up to 108 - 1012 per gram may be excreted in the faeces (Pepper 1996). These consist of small, single-stranded RNA viruses and include the poliovirus types 1 and 2, multiple strains of echovirus and coxsackievirus (International Nomenclature of Diseases, 1983). Such diseases that may be contracted from enteroviruses include poliomyelitis, upper respiratory infections, acute gastroenteritis, aseptic meningitis, pericarditis, myocarditis and viral exanthema, conjunctivitis, and hepatitis (International Nomenclature of Diseases, 1983). Hepatitis A virus (HAV) and Hepatitis E virus (HEV) are spread by faecally contaminated water and food and are very common in the developing world, where as much as 98% of the population may exhibit antibodies against HAV (Pepper 1996). Rotaviruses are the most infectious of all the enteric viruses (Gerba 1996) and thus can be considered to be a high health risk group if present in wastewater. Children under the age of two, the elderly and the immune-compromised have been identified as particularly vulnerable with acute gastroenteritis, the main symptom, attributing to millions of deaths every year in Africa, Asia and Latin America. Other viruses which have been detected in wastewaters include adenoviruses, reoviruses, noroviruses, astroviruses and other small round-structured viruses. In general, even low numbers of such viral pathogens in the environment represent a hazard as only a few viral particles can rapidly increase in the human body resulting in disease symptoms.

Viral contamination of the subsurface environment and groundwater is more difficult to study than bacterial contamination, partly because the principal water borne human viruses previously discussed are more difficult to assay (Sinton 1997). Viral indicator organisms, as such, have been considered (both successfully and unsuccessfully) as a guide to the presence of viral contamination. Coliform bacteria were once thought to be reliable viral indicators until several studies carried out worldwide on water samples ranging from groundwater to surface water to potable water showed that common faecal indicators were a poor maker as to the presence of viruses (Koot 1974, Marzouk 1980, Armon 1997, Scandura and Sobsey 1997).

Viruses that infect bacterial prokaryotic cells are termed Bacteriophages and it is these species that have been found to be most advantageous as surrogates for pathogenic viruses. Like all other viruses, they have no intrinsic metabolism and rely on the metabolic machinery of its host cell to support their reproduction (Withey 2005). These Bacteriophages that infect *E. coli* and other coliform bacteria are known as coliphages. Phages offer several advantages as surrogates for enteric viruses because they are constant inhabitants of the human intestinal tract, are non-invasive to humans and quantitative phage assays are inexpensive and rapid (Bales 1989). In addition they have similar physical properties in size, shape, morphology, physiochemistry and isoelectic points to enteric viruses (Table 2.8). Sizes may range from 20 to 350 nm, though some may have a total length of over 1000 nm. They are abundant in wastewater, ranging from 10^5 - 10^7 PFU m L-1 and up to about 108 g-1 in soil (Weinbauer 2004). Given their reliance on a bacterial host, phages are known to proliferate most effectively under optimum growth conditions for the host. In soils, nutrient content is generally low, which may also affect indigenous phage proliferation in this environment. This changes, however, with the addition of wastewater to soil. As bacterial activity is increased following wastewater infiltration into the soil, phages are consequently given more opportunity to increase in population.

Table 2.8 Characteristics of viruses and possible phage surrogates (adapted from Lytle 1991 and Collins 2006)

	Virus/Phage	Size (nm)	Symmetry	Isoelectric point[a]	Genetic material[b]
Phage	MS2	26	Icosahedral	3.5 - 3.9	ss-RNA
	PRD1	62	Icosahedral	4.2	ds-DNA
	ΦX174	25 - 27	Icosahedral	6.6	ss-DNA
Viral Pathogen	Adenovirus	80 -110	Icosahedral	N/A	ds-DNA
	Astrovirus	27 - 30	Polyhedral	N/A	ss-RNA
	Coxsackievirus	28 - 30	Icosahedral	4.8	ss-RNA
	Echovirus	28 - 30	Icosahedral	5.0 - 6.4	ss-RNA
	Hepatitis B	42	Icosahedral	N/A	ds-DNA
	Apthovirus (foot and mouth DV)	27 - 30	Icosahedral	N/A	ss-RNA
	Norovirus	35 - 39	Icosahedral	5	ss-RNA
	Poliovirus	28 - 30	Icosahedral	4.5 - 6.5	ss-RNA
	Rotavirus	80	Icosahedral	3.9	ds-DNA

[a]N/A = not available, [b]ss, single stranded; ds, double stranded

The three most common groups of bacteriophage are:

- F-specific (RNA or DNA) coliphages which infect Gram-negative bacteria
- Somatic coliphages (Bacteriophages which infect *Escherichia coli*)
- Bacteroides fragilis specific Bacteriophages

Male specific F-RNA coliphages and somatic coliphages in particular have been extensively used in survival and tracer studies (Jin et al., 1997, Woessner et al., 2001, Guan et al., 2003, Zhuang and Jin, 2003) as surrogates for viral pathogens (Table 2.9). Both have found to be in abundance in raw sewage and STE (DeBorde et al., 1998, Zhang and Farahbakhsh, 2007). The two families include the three phages MS2, ΦX174 and PRD-1 which have been most commonly employed as "models" for human enteric viruses in many groundwater transport studies due to their structural resemblance.

Table 2.9 Groupings and characteristics of bacteriophages (Adapted from Leclerc et al. (2000) and (IAWPRC, 1991))

Phage Type	Family Members	Host	Genetic Material	Tail Type	Size (nm)	Shape	Phage

Male-specific RNA	Leviviridae	*E.coli, salmonella*	Linear ss-RNA	No tail	20-30	Cubic capsid (isosahedral)	MS2, Qβ
	Inoviridae	*E.coli, salmonella*	Circular ss-DNA	No tail	810 x 6	Filamentous or rod-shape	SJ2, fd, M13
Somatic	Myoviridae	*E.coli, other Enterobactericea*	Linear ds-DNA	Long contractile	95 x 65	Cubic capsid (isosahedral or elongated)	T2, T4, T6
	Syphoviridae	*E.coli, other Enterobactericea*	Linear ds-DNA	Long non-contractile	54	Cubic capsid (isosahedral)	T5, λ
	Podoviridae	*E.coli, other Enterobactericea*	Linear ds-DNA	Short non-contractile	47	Cubic capsid (isosahedral)	T7, T3
	Tectiviridae	*E.coli, salmonella*	Linear ds-DNA		62	Cubic capsid (isosahedral)	PRD1
	Microviridae	*E.coli, other Enterobactericea*	Circular ss-DNA	No tail	25 - 30	Cubic capsid (isosahedral)	ΦX174, S13

Bacteriophage MS2 is a male-specific, unenveloped, single-stranded RNA phage (van Regenmortel et al., 2000) from the *Leviviridae* family, with a diameter of 26.0 to 26.6 nm (van Duin, 1988) and a low isoelectric point (IEP) of 3.9 (Zerda, 1982 as cited in Gerba and Bitton (1984)). The MS2 virus infects and replicates in *Escherichia coli* bacterial strains with sex pili. It has been used in a plethora of transport studies as a surrogate for poliovirus, coxsackievirus and norovirus given the similarities in structure and IEP.

Bacteriophage ΦX174 is a somatic, single-stranded DNA phage from the *Microviridae* family, with a diameter of 25 to 27 nm (Hall et al., 1959) and an IEP of 6.6 (Aach (1963) as cited by Ackermann and DuBow (1987)). It also infects and reproduces in *Escherichia coli* host. It is similar in size and shape to Hepatitis-C virus (HCV) (30 nm diameter) but also serves as a useful surrogate for Hepatitis-B (HBV) (42 nm diameter) and Human Immunodeficiency virus (HIV) (10 nm diameter). Results from Jin et al. (1997) also suggest ΦX174 is a good model for poliovirus because it has the same IEP value (~6.6) and exhibits similar attachment behaviour.

Bacteriophage PR772, a double-stranded DNA phage from the *Tectiviridae* family, is only a recently isolated phage upon which little research has been carried out to date. It has been used in some filtration studies as a surrogate for mammalian viruses of around 50 to 60 nm (Lute et al., 2004). A study by O'Luanaigh et al. (2012) used PR772 as an indicator of human enteric viruses in and unsaturated, freely draining subsoil. Originally isolated from a wastewater treatment system in Pretoria, South Africa, less is known about PR772, although it is thought to be highly similar to PRD1 on the basis of its overall similarity of *Tectiviridae* family phages (Coetzee and Bekker, 1979). However, Lute et al., (2004), in an in-depth study on the comparison of the two phages discovered

PR772 and PRD1 were structurally very similar and the genomes revealed their DNA sequences to be 97.2% identical. PRD1 is an icosahedral double-stranded DNA somatic *Salmonella typhimurium* phage fromthe *Tectiviridae* family with diameter 62 nm and and IEP of between 3 and 4 (Powelson et al., 1993). It is therefore modeled on the larger enteric viral pathogens, e.g. rotoviruses (80 nm diameter) and adenoviruses (80 - 110 nm), although it may differ to the latter in surface charge. Unlike other members of the familty *Tectiviridae* (e.g., PRD1, which is usually propagated on *Salmonella enterica serovar Typhimurium*), production of PR772 has the benefit of not involving the handling of pathogenic host bacteria. It is grown on non-pathogenic *Escherichia coli*.

Table 2.10 Factors influencing virus fate in the subsurface (Yates et al., 1988)

Factor	Influence on survival	Influence on Migration
Temperature	Viruses survive longer at lower temperatures	Unknown
Microbial activity	Some viruses are inactivated more readily in the presence of certain microorganisms; however, adsorption to the surface of bacteria can be protective	Unknown
Moisture content	Some viruses persist longer in moist soils than in dry	Generally, virus migration increases under saturated flow conditions
pH	Most enteric viruses are stable over a pH range of 3 to 9; survival may be prolonged at near-neutral pH values	Generally, low pH favours virus adsorption and high pH results in virus desorption from soil particles
Salt species and concentration	Some viruses are protected from inactivation by certain cations; the reverse is also true	Generally, increasing the concentration of ionic salts and increasing cation valencies enhance virus adsorption
Virus association with soil	In many cases, survival is prolonged by adsorption to soil; however the opposite has also been observed	Virus movement through the soil is slowed or prevented by association with soil
Virus aggregation	Enhances survival	Retards movement
Soil properties	Effects on survival are probably related to the degree of virus adsorption	Greater virus migration in coarse-textured soils; there is a high degree of virus retention by the clay fraction of soil
Virus type	Different virus types vary in their susceptibility to inactivation by physical, chemical, and biological factors	Virus adsorption to soils is probably related to physicochemical differences in virus capsid surfaces
Organic matter	Presence of organic matter may protect viruses from inactivation; others have found that it may reversibly retard virus infectivity	Soluble organic matter competes with viruses for adsorption sites on soil particles
Hydraulic conditions	Unknown	Generally, virus migration increases with increasing hydraulic loads and flow rates

Numerous studies have demonstrated that soils can effectively remove viruses from water (Yates et al., 1988, Lance and Gerba, 1984, Jin et al., 1997, Van Cuyk and Siegrist, 2007, O'Luanaigh et al., 2012). One of the most important processes for virus removal in soils is adsorption of viruses on solid surfaces. Virus particles may be removed by soil adsorption to clay, organic matter and other negatively charged material such as iron and aluminium (Al) oxides. The availability of sorption sites is undoubtedly influenced by the textural components of a soil (Gerba and Bitton, 1984). It is generally agreed that soils with a greater proportion of fines retain viruses more effectively than sandy soils since the clay mineral fraction increases the sorptive capacity as a result of its high surface area and high cation exchange capacity. It should be noted however that the adsorption of viruses is not permanent and can be reversed by the ionic characteristic of the percolating effluent (Bales et al., 1993); this process is known as desorption. Heavy rainfall events have also been found to cause desorption of viruses from soil particles by changing the ionic strength of the soil water (Lance et al., 1976).

Virus adsorption is also influenced by the pH of a soil. Numerous studies have reported a reduction in adsorption levels the higher the pH (Goyal and Gerba, 1979, Sobsey et al., 1980, Grant et al., 1993). As the pH increases, the charge on the virus becomes less positive and adsorption is reduced. The pH at which the charge of the virus is neutral is termed the *isoelectric point* (IEP). The importance of pH on virus transport in the subsurface cannot be overestimated. Goyal and Gerba (1979) reported that among several soil characteristics including soil texture, organic matter content, soil, pH, resin-extractable phosphorous, Total Al, and exchangeable Al contents, soil pH was the most significant factor affecting virus sorption.

Soil moisture content also influences virus persistence in soils. It has generally been observed that virus inactivation rates are greater in more rapidly drying soils (Yates et al., 1988). Unsaturated flow increases the efficiency of virus removal by reducing the pore water velocity and restricting flow to the smaller pore spaces, surface contact time is increased as is the potential for adsorption. Lance and Gerba (1984) reported on a column study which found that poliovirus penetrated to a depth of 0.4 m under unsaturated conditions compared with 1.6 m under saturated conditions. Another column study carried out by Powelson and Gerba (1994) found that unsaturated flow of effluent resulted in removal rates of MS2, PRD1 and polioviruses three times higher than compared with saturated flow. The rate at which effluent is applied to the soil has also been shown to affect virus adsorption rates. Lance and Gerba (1984) found that increasing the application rate from 0.6 to 1.2 m/day caused an increase in the virus transport. In contrast to this a column study carried out by Van Cuyk and Siegrist (2007) found a higher hydraulic loading rate lead to greater removal rates of both MS2 and PRD1. The study also observed no differences in removal rates by columns dosed four times a day and those dosed 24 times a day.

Organic matter (dissolved and/or suspended) tends to compete with viruses for attachment sites on the soil surface and thereby reduce virus attachment (Gerba, 1984). Dizer et al. (1984) showed that virus adsorption rates were lowest for SE when compared with groundwater, tertiary effluent and distilled water. A field study carried out by O'Luanaigh et al. (2012) in unsaturated conditions found greater removal of MS2, PRD1 and ΦX174 by a depth of 0.35 m within a system receiving SE than compared to a system receiving STE. The STE contained an organic (COD) load nine times greater than that of the SE and the authors concluded that the higher organic matter content facilitated an increase in vertical transport over the first 0.35 m of unsaturated soil.

It is difficult to consider the factors influencing virus removal and retention separately as interactions between them undoubtedly occur as well as alter under changing environmental conditions.

Protozoa

Protozoa are unicellular, eukaryotic organisms that range up to 5.5 mm in length, although most are much smaller. (Pepper et al., 2011). Protozoa are found in nearly all terrestrial and aquatic environments and are thought to play a valuable role in ecological cycles by in part controlling bacterial populations. As a result, the protozoan population of a soil is often correlated with the bacterial population, which is the protozoan's major food source. Because of their large size and requirement for large numbers of smaller microbes as a food source, protozoa are removed more efficiently in the soil and high populations are found in the biomat layer and close to the soil surface. The two most common species which cause waterborne enteric diseases in humans are Giardia lamblia and Cryptosporidium. They are a topical issue in relation to the treatment of drinking water although little has been written on their presence in the subsoil or the threat they pose to contamination of groundwater resources (O'Súilleabháin, 2004).

2.8 CURRENT OSWTS REGULATIONS IN IRELAND

In Ireland the governing legislation for OSWTS is The EPA Code of Practice for Single Houses (EPA, 2009a). It sets out a methodology that should be followed to allow site conditions to be assessed, and an appropriate wastewater treatment system to be selected, installed and maintained.

As outlined previously, the standard arrangement for on-site wastewater treatment systems is a conventional septic tank followed by discharge to a subsurface disposal to a percolation area. The sizing of the tank is critical to its treatment performance with larger tanks providing greater hydraulic retention and therefore greater settlement of solids and sludge storage capacity. The volume required for sludge storage is the determining factor in the sizing of a septic tank. In Ireland, EPA (2009a) states that the septic tank must be of sufficient volume to provide a hydraulic retention time of at least 24 hours at maximum sludge depth and scum accumulation to facilitate BOD and solids removal from the wastewater.

The degree of sludge accumulation is dependent on the number of occupants in the household, and consequently it is recommended that the tank capacity be calculated using the following-equation:

$$C = 150P + 2000 \qquad \text{(Eqn. 2.4)}$$

where C = capacity of the tank (litres)

P = design population

This equation assumes that the tank is desludged at least once every 12 months. In Ireland a minimum capacity of 2600 litres should be provided (EPA, 2009a), which corresponds to a design for a minimum population of 4 people.

In Ireland, existing OSWTS comprise of various configurations of percolation areas or STU located in varied site conditions with different environmental sensitivities. Today the standard STU consists of percolation pipes installed in gravel trenches above a sufficient depth of unsaturated subsoil (Figure 2.9).

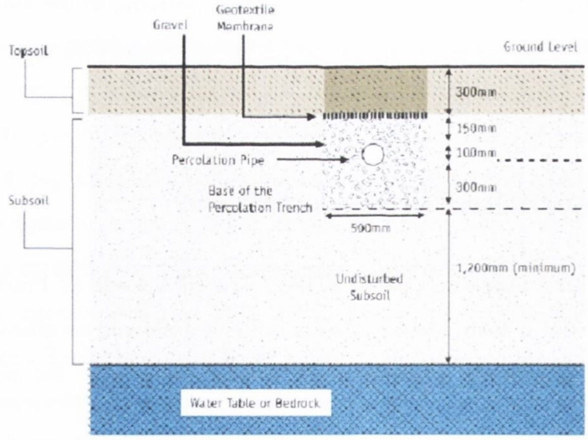


Figure 2.9 Section of a conventional percolation trench receiving STE (EPA, 2009a)

Although the current regulations permit the installation of alternative infiltration systems (i.e. low pressure pipe systems and drip distribution systems) in line with manufacturer's guidelines there are currently no specific guidelines for Irish soils. The design and operation of these alternative systems is discussed further in the following sections.

2.9 ALTERNATIVE INFILTRATION SYSTEMS

Conventional STUs rely on the presence of subsoil of sufficient depth and permeability. However, as outlined previously, a large proportion of sites in Ireland do not meet these criteria. Alternative systems for on-site effluent disposal have been developed to overcome problem sites where the following restrictions may exist:

- Insufficient subsoil depth
- Insufficient subsoil permeability
- High water table

One of the most employed alternatives for these problem sites is the mound system. Imported fill is used to create a bed of suitably permeable material to which effluent can be applied. The mound allows the sufficient depth of effluent percolation prior to reaching bedrock/groundwater. Mound systems also incorporate pressurised effluent distribution and have been successfully installed and operated on problem sites (Converse et al., 1978). The standard arrangement for a mound system is a conventional septic tank followed by a pumping chamber. Effluent is pumped to the elevated mound allowing the pressurised distribution across the soil adsorption system. Typically, a mound consists of the fill material, an absorption area, a cap and topsoil. The distribution network is a series of perforated pipes installed in gravel trenches as with conventional percolation areas. The cap, usually silt or clay, provides a barrier to infiltration, retains moisture for vegetation and promotes runoff of precipitation (Converse et al., 1978).

Figure 2.10 illustrates a cross-section of a typical mound system. Effluent is pumped into a pressurised distribution system. In slowly permeable soils, the effluent moves laterally away from the mound, while in the more permeable soils, it moves downwards (Converse et al., 1978).

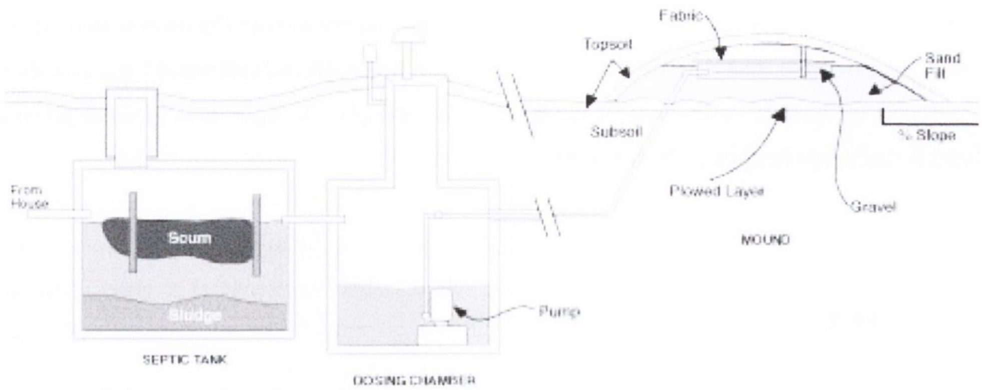


Figure 2.10 Cross-section of a septic tank mound system for on-site wastewater disposal (adapted from Converse et al. (1978))

However, construction of mound systems is expensive due to the costs associated with importing and constructing fill of sufficient depth and permeability in order to achieve adequate percolate treatment. An alternative method of achieving sufficient subsoil depth on restricted sites is the application of effluent at a shallow depth in the receiving subsoil. This maximises the existing subsoil depth and promotes evapotranspiration of the applied effluent. Two systems which utilise pressurised effluent dosing at shallow depths are DD and LPP systems. The development, design features, construction, operation and maintenance of both systems are detailed in the following sections.

Research concerning DD systems for on-site wastewater treatment has occurred during the past decade and has been undertaken primarily in the United States. To date, most research has focused on effluent dispersal hydraulics (Berkowitz, 1999, Persyn et al., 2007) including modelling (Berkowitz and Mancl, 2001, Beggs et al., 2004, 2011) dispersal effects on soil hydraulic properties (Jnad et al., 2001); comparisons of DD systems receiving different effluent qualities (Bohrer and Converse, 2001); and comparisons of DD systems with other soil infiltration technologies (Costa et al., 2002). Design and operation guidelines for DD systems in the United States have now been published (NOWRA, 2006). Despite this few DD systems have been installed and limited field scale research has been carried. One such study (Siegrist et al., 2014) carried out a ^{15}N isotope study beneath a DD system which had been in operation for approximately one year in order to provide an insight into nitrogen movement and fate. Effluent applied to the system was spiked with 99.9% ^{15}N ammonium chloride ($^{15}NH_4Cl$). The DD system was then divided into two separate distribution zones with effluent applied to each at different hydraulic loading rates; 5 L d^{-1} per m^2 (Zone 1) and 10 L d^{-1} per m^2 (Zone 2). Results of the study showed on a portion of the effluent applied migrated downward in the soil profile (approximately 34% in Zone 1 and 64% in Zone 2). The study concluded that an estimated 51% of the applied N was removed by plant uptake and denitrification confirming the rationale behind the shallow place of effluent distribution networks in the biologically active root zones. Beggs et al. (2011) concluded that the light loading rate and resulting long effluent retention time in the upper soil zone associated with subsurface drip irrigation provide much greater opportunity for plant uptake than conventional deep leach field application of effluent. The author found conventional gravity STU depend more on dilution to reduce nitrogen concentrations as opposed to subsurface drip systems which provide more opportunity for plant uptake and denitrification.

Numerous studies have been carried out on the performance of pressurised effluent distribution in relation to mound systems, however field scale studies of the performance of LPP systems installed directly into the native subsoil are a more recent occurrence. One such study carried out by Ijzerman et al. (1992) used bacterial tracers to evaluate the suitability of a shallow-placed LPP system as a remediation option in an area where conventional OSWTSs had failed. During the study the LPP system was evaluated under four different loading rates in varying climatic conditions. Soil matrix potentials were determined for each loading rate and showed the system maintained unsaturated conditions throughout the study. The bacterial tracer study, carried out using spontaneously-resistant mutants of an *E. coli* (American Type Culture Collection ATCC 25922) recorded removal rates of >99% beneath the system regardless of effluent loading rates.

A field study on the nitrogen removal capacity of LPP systems carried out by Hoover et al. (1991) speculated that an increase in denitrification beneath the shallow system was the reason that little nitrogen was detected downstream of a low pressure trench system receiving sand filter effluent. Sawhney and Hill (1975) found that deeper soil layers generally have a lower phosphorus sorption capacity, so phosphorus removal was be enhanced in shallow LPP system. A laboratory scale study (Gross et al., 1990) compared the treatment performance of effluent application to sand filters by both pressurised and gravity distribution methods. It was found that the filter receiving STE by pressurised distribution consistently treated the WW to higher quality effluent than the filter receiving STE by gravity distribution. The pressurised distribution system reduced the BOD_5 concentration by an average of 85.5% compared to only 72.5 % reduction for the gravity fed system. SS removal efficiencies were 86.5% and 78.1% for the pressurised distribution and gravity distribution filters respectively.

2.9.1 Drip Distribution Systems

During the last three decades subsurface drip irrigation has advanced significantly as a technology. A review by Camp (1998) stated that the use of wastewater with subsurface drip irrigation offered great potential. However, there is still a slow rate of application in Ireland and to-date no design guidelines for Irish soils have been published.

Background

The concept of subsurface drip irrigation (SDI) began in the 1860s in Germany as a successful method for subsurface irrigation and drainage ((Keller, 2000) cited by Lamm et al. (2012). However, this method did not become economically feasible until after World War II with the development of polyethylene.

SDI consists of small diameter, flexible polyethylene tubing with holes, or emitters, and spaced equal distances apart along the length of the tubing. The main objective is to place the emitters at the plant root zone in order to maximise the potential influence of evapotranspiration. This relies on soil capillary action to transport the water horizontally between the emitters, as well as gravity to pull the water downward toward the lower roots.

SDI became a favourable method of irrigating vegetable crops in arid regions, as well as areas with high competition for water resources (Lamm et al., 2012). In the 1970s, SDI was no longer viewed as just an efficient method of irrigating crops. It was also seen as an efficient method of delivering nutrients directly to the plant root zone. During this same time period, research began on the use of treated wastewater for irrigation. This appeared to be another solution for regions with limited water resources because it uses non-potable water in situations that previously had to rely on potable water sources. This reserved more of the potable water resources for human consumption. The successful use of SDI of reclaimed water led to their uses as an alternative disposal method for on-site septic systems. In the instance of on-site disposal, the wastewater is being disposed of as needed by the homeowner. For this reason, it is more appropriate to refer to this method as drip distribution (DD) rather than SDI.

DD systems have been used in the U.S. for dispersal of wastewater onto soil infiltrative surfaces since the 1980s. This technology is commonly used at sites where conventional soil treatment areas are not appropriate such as shallow soils above a limiting condition (heavy clay, rock or groundwater) (Duan et al., 2007). DD systems have been used successfully in Colorado in areas with deep clay soils as well as in mountainous regions of the state to overcome problems with uneven sites since 1994 (Church, 1997). The successful use of DD systems has also been shown along lake and coastal lots in Texas (Carlile, 1994). DD systems were an ideal option for these areas because they maximised the space utilization on the lot and offered a maximum separation distance between driplines and groundwater.

System Components

A DD system is a low-pressure, high efficiently method of effluent distribution. Compared to other on-site distribution technologies DD requires a relatively high cost investment. In order to ensure the longevity of the system proper materials, design, construction and maintenance are paramount. There are several components to DD systems including: supply and return manifolds, driplines with engineered emitters, a pump, a filter, air release valves and controls. The selection and layout of the system components is dependent on the nature of the wastewater (STE or SE) and the soil/site conditions. Figure 2.10 illustrates a typical on-site DD system for a single household.

Supply and Return Manifolds

DD systems consist of both supply and return manifolds. Supply manifolds fed effluent from the pump sump to the distribution network. The return manifold allows periodic flushing out of the distribution system. Flushing removes any sediment or clogging material that may have accumulated within the laterals and returns it to the septic tank or secondary treatment unit for treatment.

Driplines and Emitters

Driplines for wastewater are made of 13 mm (1/2") diameter flexible polyethylene. The typical emitter spacings for wastewater is 0.6 m, however spacings from 0.15 m to 1.2 m are available for a variety of site conditions. The emitters contain very small holes (1200 - 2000 microns) that are engineered to dose a specific amount of wastewater at a time (Ruskin, 1992). There are two main types of emitters available: pressure compensating and turbulent flow. Pressure compensating emitters are the preferred form as they allow an equal amount of wastewater to be dosed from each emitter over a range of pressures. This ensures an equal delivery of effluent across the entire distribution network even on sloping sites.

Filters

Filters are an integral part of a DD system. The narrow diameter of the emitters means particles as small as 1200 microns can cause clogging leading to a reduction in distribution or eventual system failure. The most common types of filters in use today are disk filters or spin (screen) filters. Disk filters consist of many small discs stacked together with very small spaces (100 - 150 microns) between them (Converse, 2000). The wastewater flows from the outside, through the disks and into the hollow, centre core. The filtered particles remain on the outside of the disks. As the filter is automatically backwashed, these particles are washed back into the septic tank/secondary treatment unit.

A spin filter consists of a screen cylinder with openings of 100 - 150 microns through which the wastewater flows at an angle so as to produce turbulence (Converse, 2000). This turbulent flow helps to maintain a clean filter. These filters can be backwashed automatically or manually. If STE is being filtered it is essential that the filter be automatically backwashed on a regular basis. If the filter receives highly pretreated effluent (aerobically treated), periodic flushing can be either automatic or done manually, with automatic flushing preferred.

Air Release Valves

Air release valves are installed at the high points of a DD system. They allow the system to break the vacuum that is created in the driplines at the end of a dose event. This prevents soil from being pulled into the emitters due to back-siphoning or back-pressure (Geoflow, 2007).

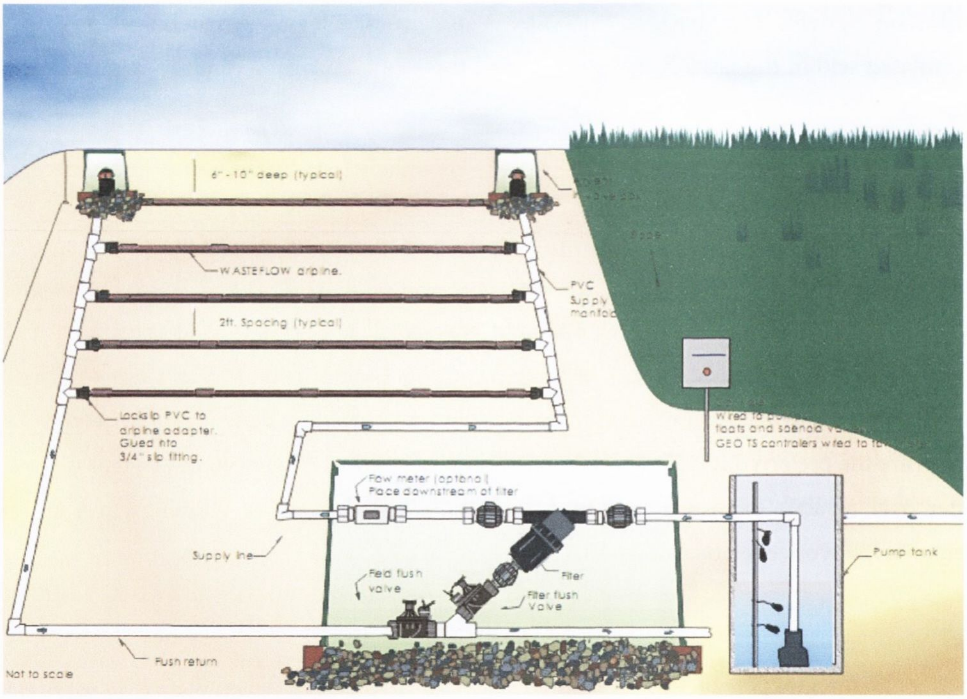


Figure 2.11 Typical drip field layout for a individual instalment (Geoflow, 2007)

Design Loading Rates

Determination of site criteria for DD systems is carried out in the same manner as for conventional systems. Characterisation of the soil permeability, structure and assessment of groundwater levels is required to adequately size the DD system for a given effluent loading.

Although drip dispersal systems are permitted under the current EPA Code of Practice (EPA, 2009a), design guidelines are not yet included for Irish subsoil, as such manufacturer's instructions should be followed. This is similar to the NOWRA (2006) guidelines which recommend that drip systems are designed according to the manufacturer recommended hydraulic loading rates which are expressed as an aerial loading rate. For example, Geoflow Inc. recommends rates of 57 $l/m^2.d$ for coarse sandy soil down to 12.2 $l/m^2.d$ for poor clays. Most research has been carried out in the US, for example drip dispersal systems were tested in sandy conditions (Parzen et al., 2007) at loading rates 10 to 20 $l/m^2.d$.

Table 2.11 details the loading rates for drip distribution systems receiving SE based on the subsoil classification and structure. Flow rates as low as 3 $l/ m^2.d$ are also appropriate based on increased sizing of the distribution network. These low rates are also applicable for LPP systems again depending on the native subsoil characteristic and sizing of the distribution area.

Table 2.11 Recommended drip loading rates adapted from (Geoflow, 2007)

Soil Texture	Soil Structure	Maximum Monthly Average BOD_5 < 30 mg/l TSS < 30 mg/l Litres/m²/day
Course sand or coarser	N/A	65.2
Loamy coarse sand	N/A	57.0
Sand	N/A	48.9
Loamy sand	Weak to strong	48.9
Loamy sand	Massive	28.5
Fine sand	Moderate to strong	36.7
Fine sand	Massive or weak	24.4
Loamy fine sand	Moderate to strong	36.7
Loamy fine sand	Massive or weak	24.4
Very fine sand	N/A	24.4
Loamy very fine sand	N/A	24.4
Sandy loam	Moderate to strong	36.7
Sandy loam	Weak, weak platy	24.4
Sandy loam	Massive	20.4

Loam	Moderate to strong	32.6
Loam	Weak, weak platy	24.4
Loam	Massive	20.4
Silt Loam	Moderate to strong	32.6
Silt Loam	Weak, weak platy	12.2
Silt Loam	Massive	8.1
Sandy clay loam	Moderate to strong	24.4
Sandy clay loam	Weak, weak platy	12.2
Sandy clay loam	Massive	0.0
Clay loam	Moderate to strong	24.4
Clay loam	Weak, weak platy	12.2
Clay loam	Massive	0.0
Silty clay loam	Moderate to strong	24.4
Silty clay loam	Weak, weak platy	12.2
Silty clay loam	Massive	0.0
Sandy clay	Moderate to strong	12.2
Sandy clay	Massive to weak	0.0
Clay	Moderate to strong	12.2
Clay	Massive to weak	0.0
Silty clay	Moderate to strong	12.2
Silty clay	Massive to weak	0.0

2.9.2 Low Pressure Pipe Distribution Systems

Background

Pressure distribution of effluent has been used for more than 40 years to apply domestic effluent to STU's. A paper published by Converse (1974) documents the application and performance of pressure distribution systems particularly in sandy soils. Today the benefits of pressurised systems for the delivery of effluent to STU have been widely acknowledged.

In the 1970's designers and researches began developing better wastewater distribution systems as a result of continued failings of traditional gravity fed systems to evenly distribute the applied effluent load (Gross et al., 1990). One such system is the LPP distribution system. Originating in North Carolina and Wisconsin (USEPA, 1999) LPP systems are used extensively across the US, however in Ireland the technology is still in its infancy.

System Components

The main components of a LPP system (Figure 2.11) include the following:

- A septic tank or secondary treatment unit
- A pumping/dosing chamber containing a submersible effluent pump, level controls, high water alarm and a supply manifold
- A network of small diameter perforated distribution laterals

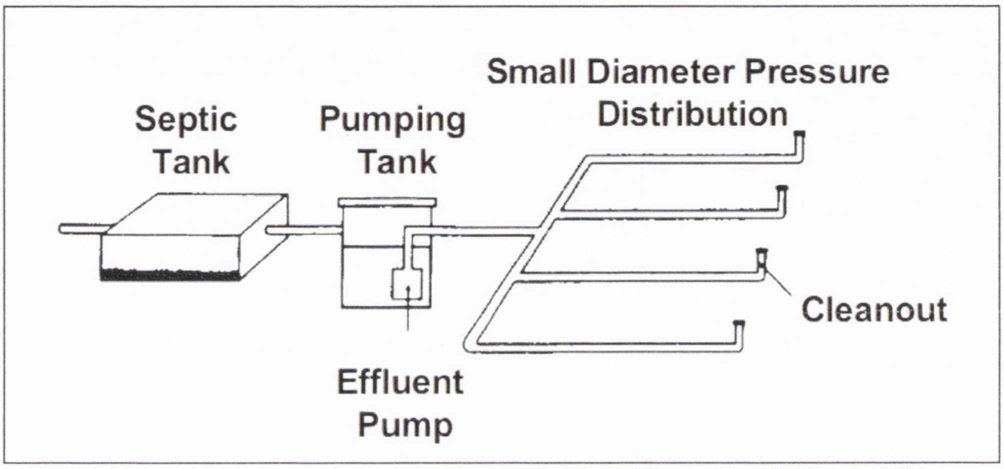


Figure 2.12 Low pressure pipe system (USEPA (1992); cited by USEPA (1999))

Advantages of Low Pressure Distribution

LPP distribution is now commonly recognised as an alternative for overcoming soil and site restrictions that do not allow conventional gravity systems to function properly (Perkins, 1989). These pressurised systems differ in design to conventional systems as outlined in Table 2.12.

Table 2.12 Comparison of design features of conventional trench system and LPP systems

Design Features	Conventional STU[1]	LPP System[2]
Depth of IS	850 mm	250 - 450 mm
Dimension of trench	450 mm	300 - 450 mm
Diameter of percolation pipes	100 mm	25 mm
Distribution of effluent	Gravity fed	Pressurised uniform distribution
Effluent application rate	Continuous gravity feed	Intermittent dosing

[1]Based on design criteria outlined in (EPA (2010a))
[2]Based on design criteria outlined in (USEPA (1999))

The alternative configuration and location of LPP results in it having the following advantages over conventional systems:

- Shallow placement of trenches in LPP installations promotes evapotranspiration and enhances growth of aerobic bacteria
- Absorption fields can be located on sloping ground or uneven terrain that are otherwise unsuitable for gravity flow systems
- Improved distribution through pressurised laterals disperses the effluent uniformly throughout the entire drain field area
- Periodic dosing and resting cycles enhance and encourage aerobic conditions in the soil
- Shallow, narrow trenches reduce site disturbances and thereby minimise soil compaction and loss of permeability
- LPPs allow placement of the drain field area upslope of the home site
- LPPs have reduced gravel requirements
- There is a significant reduction in land area required for the absorption system
- Costs are comparable to other alternative typical distribution systems
- LPPs overcome the problem of peak flows associated with gravity-fed conventional septic systems

Construction and Design Criteria

Determination of site criteria is carried out in the same manner as for conventional systems. LPP systems should be installed in soils that have a suitable texture, depth, consistence, structure and permeability. A minimum of 0.3 m of unsaturated subsoil must be available between the adsorption trenches and any underlying restrictive horizons (USEPA, 1999). The recommended design loading rate is 5 $l/m^2.d$ but systems could be designed at lower rates for low permeability subsoils (as applied for the Chatham County, North Carolina case study (USEPA, 1999)) how loading rates detailed in Table 1.7 are also applicable based on the subsoil characterisation.

Chapter 3 Site Selection and Description

3.1 INTRODUCTION

At the outset of the project the first objective was to identify six existing sites with OSWTSs which had been in operation for a minimum of 20 years and consisted of a traditional septic tank followed by a soak-pit. Sites of this age and configuration were selected as this meant they would have been installed prior to the introduction of the first design regulations for OSWTSs (NSAI, 1991). These sites (legacy sites) represent a large proportion of OSWTSs in Ireland today and are thought to pose significant pollution risk to our water supplies. By selecting systems of this age, within which mature biomats had developed, the long term pollution attenuation capacity of these legacy systems could be determined.

The aim was to identify these systems in areas of varying subsoil permeabilities in order to assess their treatment performance under different conditions. The six different sites would have the following site characteristics:

- 2 sites of high permeability (T<10) subsoil
- 2 sites of moderate permeability (10 <T<50) subsoil
- 2 sites of low permeability (T>70) subsoil

Initially the selected sites were to have a minimum of 3 PE (population equivalent) to ensure an adequate effluent loading and a water supply from an on-site well to allow the assessment of local groundwater conditions at each location. Following a sufficient period of monitoring the existing soak-pit systems at both sites of low permeability subsoil would be upgraded to alternative infiltration systems and monitored to determine if they provided improved effluent treatment in these areas.

Site assessments were carried out in line with the EPA Code of Practice for Single Houses (EPA, 2009a). The three key stages of site assessment and selection are outlined below.

3.2 SITE SELECTION PROCESS

3.2.1 DESK STUDY

The main aim of the desk study was to identify potential areas across the country whose subsoil properties fell into the above soil permeability categories. This was carried out in conjunction with the soils expertise of Dr. R. Meehan. Hydrological, bedrock, soil and subsoil data in potential regions highlighted by Dr. Meehan was assessed. Suitable areas were then targeted by means of a media campaign, door-to-door leaflet drops and the assistance of Local Authorities. In total 161 householders across the country responded to the call for suitable sites. However, following further consultation with the respondents only 129 sites were confirmed as consisting of a septic tank and soak-pit configuration as set out by the project criteria. The most critical sites were the 2 low permeability sites (as they were to be upgraded) and so these areas were targeted first. Of the 129 remaining sites 30 were identified as likely to consist of low permeability subsoils. These sites were visited and visual assessments carried out as outlined below.

3.2.2 VISUAL ASSESSMENT

The initial stage of every site visit was a visual assessment of the OSWTS and surrounding area. This was a very valuable stage of the site selection process and enabled a prompt decision on whether or not a site would meet the project criteria prior to any further investigation. The key factors considered during this visual inspection included the location of the systems with respect to nearby water courses and site boundaries, the slope of the site and the expected direction of the effluent plume as well as the house holder's knowledge of the system. Further conditions also considered as per the EPA Code of Practice are outlined below in Table 3.1.

Table 3.1 Factors to be considered during visual assessment (adapted from (EPA, 2009a))

Factor	Significance
Water level in ditches and wells	Indicates depth of unsaturated subsoil available for treatment or polishing of wastewater
Landscape position	May indicate whether water will collect at a site or flow away from the site
Slope	Pipework, surface water run-off and seepage. Influence the design of the system
Presence of watercourses, surface water ponding	May indicate low permeability subsoil or a high water table
Presence and types of bedrock outcrops	Insufficient depth of subsoil to treat wastewater allowing it to enter the groundwater too fast
Proximity to existing adjacent percolation areas and/or density of houses	May indicate a high nutrient-loading rate for the locality and/or potential nuisance problem
Land use and type of grassland surface	Suggests rate of percolation or groundwater levels

Vegetation indicators	Suggests rate of percolation or groundwater levels. The presence of indicator plants should not be taken as conclusive evidence that the site is suitable for a drainage system, but they might indicate where any subsequent soil investigations could take place
Proximity to wells, water supply sources, groundwater, streams, ditches, lakes, surface water ponding, beaches, shellfish areas, springs, karst feature, wetlands, flood plains and heritage features	Indicates targets at risk

As the sites being assessed were installed prior to the introduction of legislation no records of installation or construction were available. In many cases key details were unclear including location of septic tank, location/direction of effluent discharge, depth of effluent discharge. In many cases septic tanks had been in operation without desludging since their installation and access covers were not accessible. This meant that of the 30 low permeability sites identified 11 were immediately ruled out following a visual assessment.

3.2.3 TRIAL HOLE

Further investigations were then carried out at the remaining 19 potential sites in low permeability areas. The first stage of assessment was to use a hand auger to determine the subsoil characteristics at each site as well as the depth of unsaturated subsoil. This stage also gave an indication if the site would be suitable for monitoring purposes as the instrumentation was to be installed by hand using hand augers (see Chapter 4). As such, the presence of numerous stones in the subsoil would make the installation process extremely difficult. If a sufficient depth of unsaturated subsoil was identified a trial hole was excavated in order to get a better understanding of the soil and subsoil characteristics. It was essential that this trial hole was not located within the boundaries of the existing effluent plume or within the area where the potential upgraded system would be constructed as this could create preferential flowpaths within the subsoil matrix potentially altering the balance of the existing system.

The subsoil characteristics of each site (soil texture, structure, preferential flowpaths, soil density, colour, layering) were also examined in line with BS5930 (BSI, 1999) as part of the on-site assessment process (Table 3.2). This provided a better understanding and description of the subsoil matrix and insight into the future behaviour of the soil on receipt of wastewater effluent.

Table 3.2 Subsoil characteristics considered during trial hole inspection (O'Súilleabháin, 2004)

Characteristic	Importance
Soil texture	Affects physical and chemical processes
Structure	Influence pore space, aeration and flow conditions
Preferential flowpaths	Influence the percolation rate of effluent, level of treatment and subsequently risk to groundwater
Soil density	Influence percolation rate
Colour	Indicative of state of aeration of soil
Layering	Affects percolation rate

3.2.4 PERCOLATION TEST

As detailed in Chapter 2, a falling head percolation test, labelled the 'T-test', is carried out as part of the Irish on-site assessment to evaluate the hydraulic assimilation capacity of subsoils. In summary, the test consists of the excavation of a percolation test hole located adjacent to, but not within, the proposed percolation area. As detailed below in Figure 3.1 the depth of the top of the percolation hole should be located as closely as possible to the depth of effluent infiltration.

There are two types of T-test; the standard method and the modified method. As outlined in the EPA Code of Practice three percolation holes are excavated adjacent to the existing or proposed percolation area. Each hole should be 300 mm x 300 mm x 400 mm deep. The bottom and sides of the hole should be scratched with a knife or wire brush to remove any compacted or smeared soil surfaces caused during the excavation. Each hole is filled to the 400 mm height with clean water early in the morning and again that evening to provide pre-soaking. After the hole has been pre-soaked overnight it is filled once again to the 400 mm mark with clear water and the time is recorded. The water level is then allowed to drop to the 300 mm mark and the time is again recorded, this time determines how the remainder of the test is to be carried out.

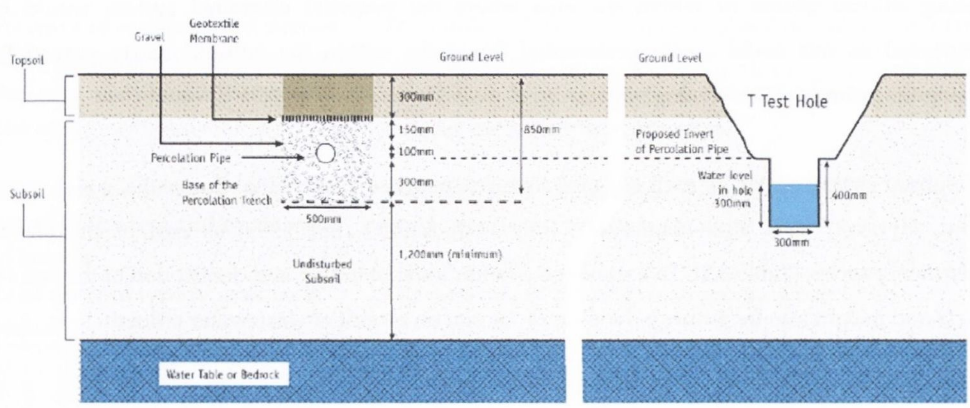


Figure 3.1 Cross-section of a T test hole (EPA, 2009a)

If the 400 mm to 300 mm drop takes more than 5 hours then the site is deemed to have failed the test as the T-value will be greater than 90. At this point the test is discontinued.

If the initial drop takes less than or equal to 210 minutes then the standard T-test method is applied. This is done by allowing the water to drop to the 200 mm depth, the time is noted and the test hole is refilled to the 300 mm depth and the water level is allowed to drop again. This procedure is repeated until the water level has been allowed to drop from the 300 mm depth to the 200 mm depth four times with the time required for each drop being recorded. The average time for all 4 drops is then divided by 4 giving the T-value for that percolation hole. The average T-value for all 3 test holes is taken as the T-value for the site.

If the 400 mm to 300 mm drop takes more than 210 minutes but less than 5 hours then the modified T-test method is applied. This is done by allowing the water level to drop from the 300 mm depth to the 100 mm depth recording the time at the 250 mm, 200 mm, 150 mm and 100 mm depths. A time factor is then applied to each drop to give the modified hydraulic conductivity value. This is divided by 4.45 to give the equivalent T-value. As with the standard test the average T-value for all 3 test holes is taken as the T-value for the site.

A site whose T-value is less than 3 or greater than 50 is be deemed to be unsuitable for a standard percolation area. However, if the T-value is greater than 3 and less than or equal to 75, the soil may be used as a polishing filter following secondary treatment. T-values greater than 90 indicate that the site is unsuitable for discharge to ground.

3.3 Low Permeability Site Selection

Of the 30 potential low permeability sites assessed only 2 were deemed suitable for the project and were selected for monitoring. One of the greatest difficulties faced was that although traditional soak-pit systems had been installed at many low permeability sites, they had proved unsuitable over the years in many areas resulting in surface ponding and system failure. As such, many of the sites visited had been modified in some way to help the effluent disposal process. In some cases this was through the installation of percolation trenches, in extreme circumstances effluent was piped straight to nearby streams and ditches. Table 3.3 outlines main reasons for site reject of low permeability sites following visual assessments whilst Figure 3.2 details the decision process during visual assessments and trial holes during the site selection phase.

Table 3.3 Primary reasons for rejection of low permeability sites following site visits

Reason for site rejection	No. of sites
T-value too high	9
Presence of too many stones (preventing installation of monitoring instrumentation)	3
Incorrect/unknown system setup	7
Insufficient space for upgrade	5
Insufficient depth of unsaturated subsoil	4

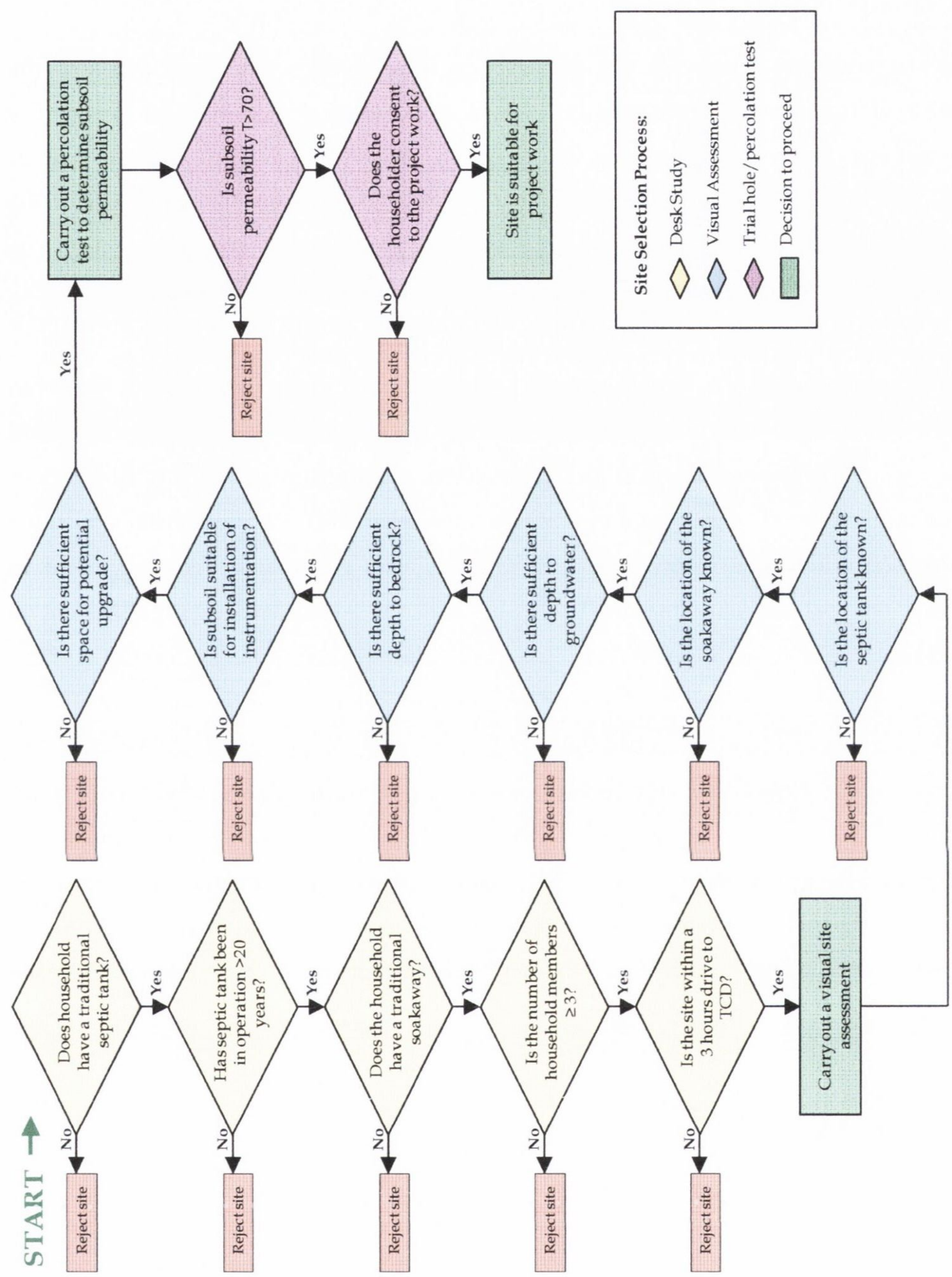


Figure 3.2 Site selection process for low permeability soak-pit sites

3.4 Moderate and High Permeability Site Selection

Following the selection of the two low permeability sites attention was then turned to the identification of the remaining four sites in areas of moderate/high permeability. Households identified as being located in higher permeability areas who had responded to the initial call for low permeability sites were contacted to see if they would still be interested in taking part in the project. Unfortunately, as the aim was to monitor these sites (without the potential for a site upgrade) many respondents where no longer interested in taking part in the project.

Of the remaining 99 households only 61 were still interested in taking part in the project. However, a further 14 were excluded due to their distance from the TCD laboratory and 28 sites were found to have an incorrect or unknown system configuration. As with the low permeability sites, lack of knowledge and a wide variation of system setups was observed. This was unsurprising given the absence of design criteria and/or guidelines prior to 1991 when these systems were constructed. In total only 19 were identified as potentially suitable and site assessments were carried out as outlined in Figure 3.3.

The greatest difficulty in locating suitable sites of higher permeability was caused by sites with insufficient depth of subsoil above the bedrock or a large percentage of gravel/boulders present making manual installation of monitoring equipment impossible. Due to time constraints it was agreed that the best way to precede would be to enlist the help of a hammer rig to allow the monitoring instrumentation to be installed at sites were manual augering was unsuitable. With this agreed four final sites were identified and instrumented following the completion of site assessments.

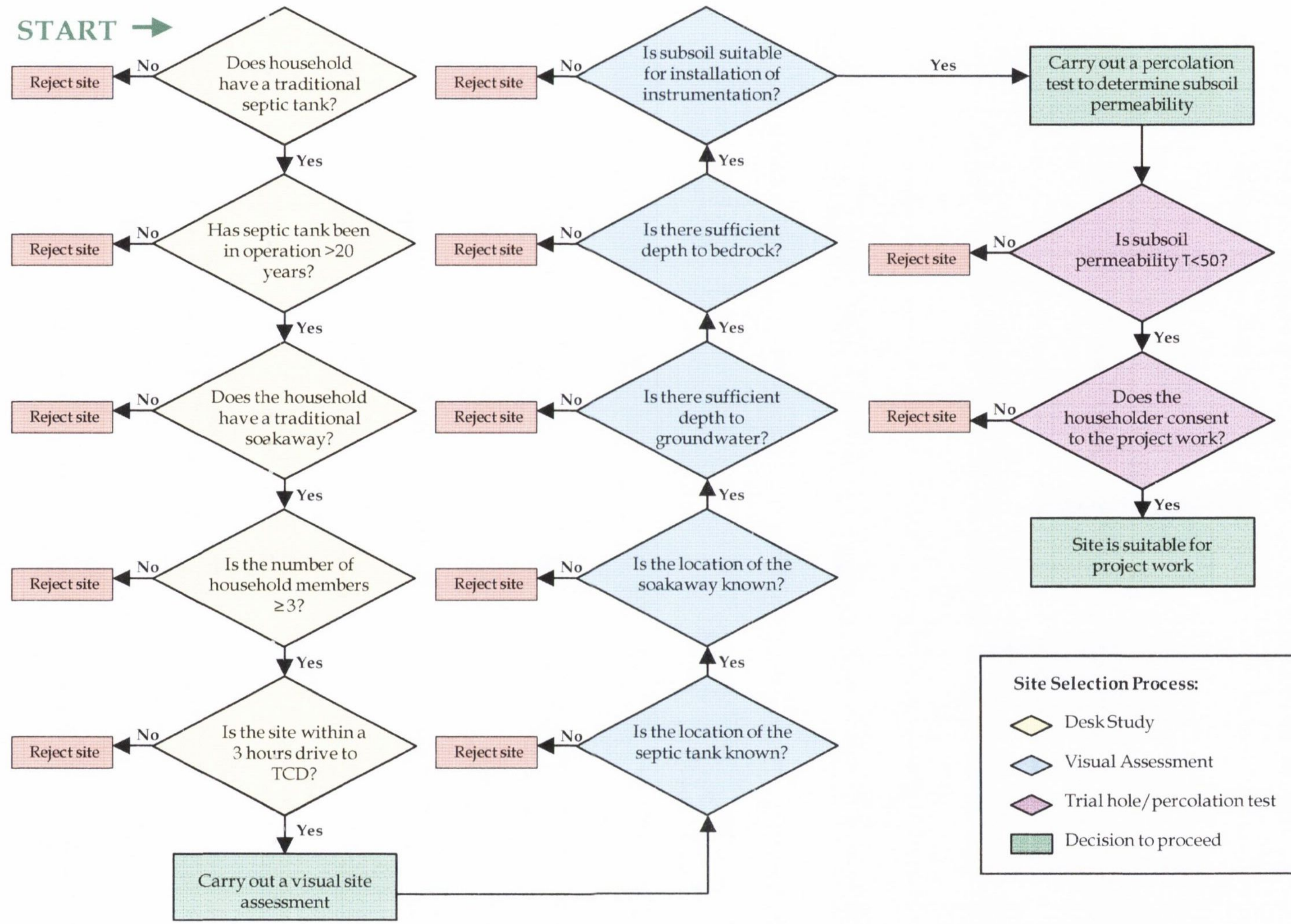


Figure 3.3 Site selection process for high/moderate permeability soak-pit sites

3.5 OVERVIEW OF SELECTED PROJECT SITES

Figure 3.4 shows the location of the final six sites chosen for the project work in relation to the TCD environmental laboratory. A comprehensive description of each site is detailed in the following sections.

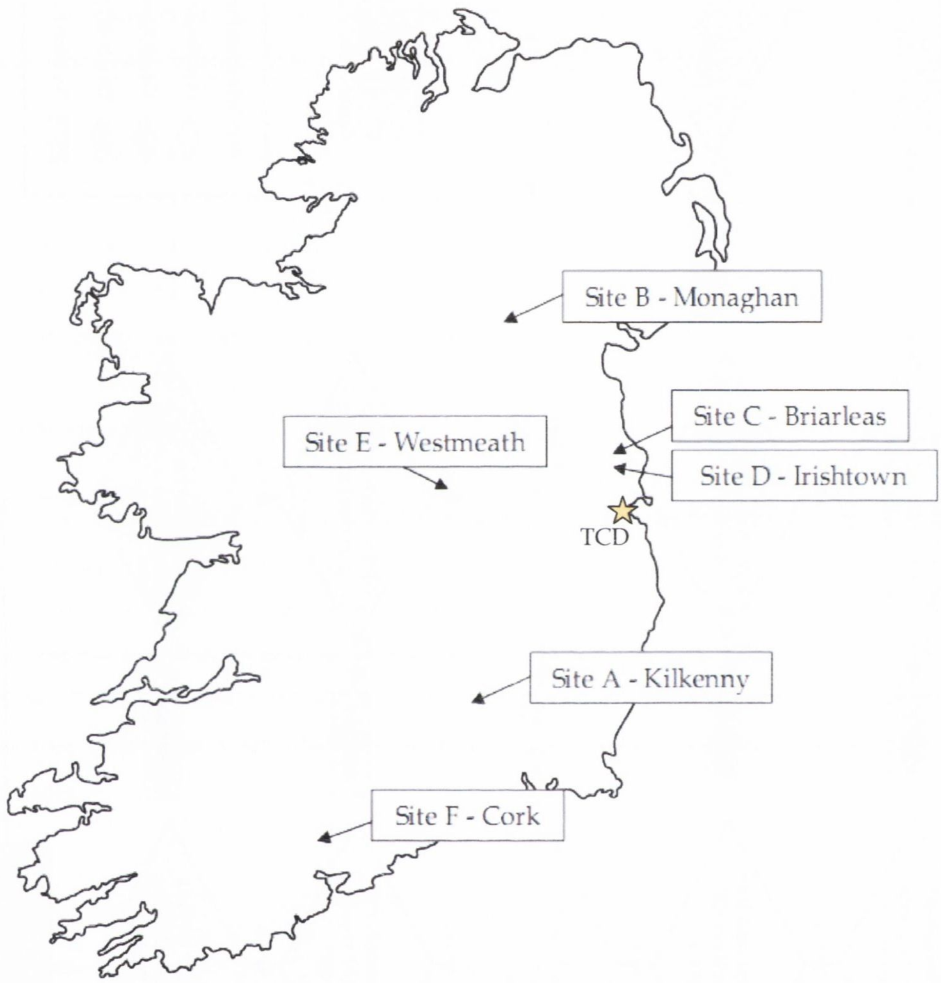


Figure 3.4 Location of selected project sites

3.5.1 SITE A: KILKENNY

The existing system at Site A, located approximately 10 km south of Kilkenny City consisted of a septic tank and soak-pit which had been in operation since the houses construction in the 1980's. Although the system was still functioning in its role of effluent disposal, on closer inspection it became apparent that the drainage ditch adjacent to the soak-pit was providing a vital discharge point for the effluent load, compromising the quality of treatment being achieved. The septic tank was desludged regularly (1 - 2 years).

A desk study of the site location was carried out. Subsoil examination of Site A, through GSI groundwater mapping, showed the site lies within a region containing a mixture till derived chiefly from Namurian rocks and alluvium. The sites bedrock consists of Dinantian upper impure limestone, however in the areas surrounding the site Dinantian dolomitised limestone and Dinantian pure bedded limestone are also present. Site A lies on a locally important aquifer but is adjacent to a regionally important aquifer and is located in an area of moderate groundwater vulnerability. Maps of the region and further details are included in Appendix A.

Following the desk study a site visit was carried out. An investigation into the depth of unsaturated subsoil was initially carried out by means of a hand auger at the site. This test indicated >1.8 m of unsaturated subsoil. As existing depth of effluent infiltration at the site was unknown two modified T-tests were carried out, outside of the soak-pit area, at depths of 0.7 and 0.8 m giving a final T-value of 75. Particle size analysis of borehole samples taken at the site was carried out at intervals to a depth of 3.0 m. A sedimentation test was also carried out at the 1m sample depth to determine the silt and clay content of the subsoil. Soil/subsoil texture classification was carried out accordance with BSI (1999) through the aid of a flowchart produced by the Groundwater section of the GSI and included in Appendix C of EPA (2009a). The overall site characteristics are shown in Table 3.4.

Table 3.4 Site A - Site characteristics

Site Details	
Site Location	Kilkenny
PE	3
T-Value	75
K_{fs} (m/d)	0.059
Depth to bedrock (m)	5
Subsoil Classification	Sandy SILT/CLAY (8 threads, ~140mm ribbon, not dilatant)

Particle Size Analysis				
Depth (m)	*Clay/Silt*		*Sand*	*Gravel*
	Clay	*Silt*		
1.0	20%	25%	33%	22%
1.5	39%		38%	23%
2.0	41%		37%	22%
2.5	43%		38%	19%
3.0	44%		36%	20%

3.5.2 SITE B: MONAGHAN

The existing system at Site B, located approximately 5 km West of Monaghan town consisted of a septic tank and soak-pit which had been in operation for over 20 years. After the initial 10 years (approximately) of operation the soak-pit backed up and surface ponding occurred. In order to remedy the situation a second larger soak-pit was dug out in a field adjacent to the site and effluent was diverted from the old soak-pit to the new soak-pit. This second soak-pit had operated satisfactorily for another few years however at the time of the project site assessment it too was showing signs of hydraulic failure with surface ponding over the soak-pit during rainfall events. Access to the septic tank was achieved by digging down to a concrete lid approximately 0.5 m below ground level. Desludging of the tank had not taken place since the installation of the second soak-pit approximately 10 years previously.

A desk study of the site showed the site lies within a region of till derived from mixed Devonian and Carboniferous rocks. The sites bedrock consists of Dinantian (early) sandstones, shales and limestones, however in the areas surrounding the site Dinantian lower impure limestones are also present. Site B lies on a regionally important aquifer and is located in an area of moderate groundwater vulnerability.

At Site B the initial auger test was again carried out following completion of the desk study and indicated >1.3 m depth of unsaturated subsoil. The presence of larger stones and boulders throughout the site prevented further investigation using this method. As the existing depth of effluent infiltration at the site was unknown two modified T-tests were carried out, outside of the soak-pit area, at depths of 0.8 m giving a final T-value of 73. Particle size analysis of borehole samples taken at the site was carried out at intervals to a depth of 2.5 m. A change in subsoil was noted at a depth of approximately 2.2 m when a layer of dense boulder clay was reached. Sedimentation tests were carried out at the 1 m and 2.5 m sample depths to determine the silt and clay content of the subsoil. Soil/subsoil texture classification was carried out in accordance with BSI (1999) through the aid of a flowchart produced by the Groundwater section of the GSI and included in Appendix C of EPA (2009a). The overall site characteristics are shown in Table 3.5 whilst the collated desk study data is included in Appendix A.

Table 3.5 Site B - Site Characteristics

Site Details	
Site Location	Monaghan
PE	4
T-Value	73
K_{fs} (m/d)	0.061
Depth to bedrock (m)	10
Subsoil Classification	SILT/CLAY (9 threads, ~135mm ribbon, not dilatant)

Particle Size Analysis				
Depth (m)	*Clay/Silt*		*Sand*	*Gravel*
	Clay	*Silt*		
1.0	24%	12%	32%	32%
1.5	39%		31%	31%
2.0	27%		38%	34%
2.5	32%	15%	30%	23%

3.5.3 SITE C: MEATH (BRIARLEAS)

Site C is located along a stream and has two very distinct subsoil layers, a high permeability layer of with a high percentage of sand and gravel to a depth of approximately 2 m at which point the subsoil changes to lower permeability subsoil with a high clay fraction. It is unsurprising that the examination of the sites subsoil through GSI groundwater mapping shows the site lies in an area divided into two distinct subsoil types: Glaciofluvial sands and gravels and alluvium. The sites bedrock consists of Silurian metasediments and volcanics close of a region of Dinantian pure bedded limestone. Site C lies on a poor aquifer region and is located in an area of high to moderate groundwater vulnerability.

At Site C, two distinct soil layers were found to be present. The upper horizon, approximately 1.4 m in depth consisted of well drained gravelly SAND. Underlying this was a low permeability SILT/CLAY layer of approximately 0.4 m in depth. Below this depth the subsoil consisted of gravelly SAND to a depth of > 2.75 m. A T-test carried out at a depth of 0.5 m at the site indicated the high permeability of the upper soil horizon (T = 21). Particle size analysis of borehole samples taken at the site was carried out for both distinct soil horizons. A sedimentation test was also carried out at the 1.5 m sample depth. Soil/subsoil texture classification was carried out accordance with BSI (1999) through the aid of a flowchart produced by the Groundwater section of the GSI and included in Appendix C of EPA (2009a). The overall site characteristics are shown in Table 3.6.

Table 3.6 Site C - site characteristics

Site Details				
Site Location	Meath			
PE	3			
T-Value	21			
K_{fs} (m/d)	0.21			
Depth to bedrock (m)	3 -10			
Subsoil Classification	Upper horizon is a gravelly SAND (0 threads, 0 ribbons) Lower horizon is a SILT/CLAY (2 threads, ~85mm ribbon, dilatancy uncertain)			
Particle Size Analysis				
Depth (m)	*Clay/Silt*		*Sand*	*Gravel*
	Clay	*Silt*		
1.0	16%		55%	30%
1.5	28%	58%	12%	2%

3.5.4 Site D: Meath (Irishtown)

Subsoil examination at Site D through GSI groundwater mapping shows the site lies in a high permeability area of Glaciofluvial sands and gravels close to the coast at Benhead. The sites bedrock consists of Silurian metasediments and volcanics close of a region of Dinantian pure bedded limestone. Site D lies in a poor aquifer region and is located in an area of high groundwater vulnerability. Maps of the region in which Site C and D are located are presented in Appendix A.

At Site D, a T-test was carried out at a depth of 0.5 m below ground level. During preparation of the test hole the presents of a large number of boulders within the subsoil was noted. It was unsurprising therefore that the site was found to be well drained with at T-value of 12. Particle size analysis of borehole samples taken at the site was carried out to a depth of 2 m. A sedimentation test was also carried out at the 1.5 m sample depth. Soil/subsoil texture classification was carried out accordance with BSI (1999) through the aid of a flowchart produced by the Groundwater section of the GSI and included in Appendix C of EPA (2009a). The overall site characteristics are shown in Table 3.7.

Despite the close proximity of Site C and Site D, the subsoil characteristics of the sites were found to be considerably different. This highlights the variation in subsoil conditions which exist in areas deemed to be of similar conditions.

Table 3.7 Site D - site characteristics

Site Details	
Site Location	Meath
PE	3
T-Value	12
K_{fs} (m/d)	0.37
Depth to bedrock (m)	5
Subsoil Classification	Gravelly SAND (0 threads, 0 ribbons)

Depth (m)	*Clay/Silt*		*Sand*	*Gravel*
	Clay	*Silt*		
1.0	39%		27%	34%
1.5	1%	6%	28%	65%
2.0	43%		35%	22%

Particle Size Analysis

3.5.5 SITE E: WESTMEATH

Site E is located in Westmeath and lies in a high permeability area consisting till derived chiefly from limestone. A desk study revealed the region is characterised as an area of high groundwater vulnerability. The sites bedrock consists of Dinantian Upper Impure limestones and is located above a locally important aquifer.

At Site E particle size analysis of borehole samples taken at the site was carried out to a depth of 2 m. A sedimentation test was also carried out at the 1.5 m sample depth. Soil/subsoil texture classification was carried out accordance with BSI (1999) through the aid of a flowchart produced by the Groundwater section of the GSI and included in Appendix C of EPA (2009a). The overall site characteristics are shown in Table 3.8.

Table 3.8 Site E - site characteristics

Site Details				
Site Location	Westmeath			
PE	3			
T-Value	3.2			
K_{fs} (m/d)	1.39			
Depth to bedrock (m)	4			
Subsoil Classification	Gravelly SAND (0 threads, 0 ribbons)			
Particle Size Analysis				
Depth (m)	*Clay/Silt*		*Sand*	*Gravel*
	Clay	*Silt*		
1.0	5%		23%	72%
1.5	1%	4%	19%	76%
2.0	5%		42%	53%

3.5.6 SITE F: CORK (CASTLELYONS)

Site F is located approximately 6 km from the town of Castlelyons and lies in a high permeability area consisting till derived chiefly from Devonian sandstones. The region is characterised as an area of high groundwater vulnerability. The sites bedrock consists of Devonian old red sandstones and is located above a locally important aquifer.

At Site F, a T-test was carried out at a depth of 0.8 m below ground level with a resultant T-value of 8 indicating the site was highly permeable. During the installation of instrumentation at the site, fractured bedrock was reached at a depth of approximately 3 m. Particle size analysis of the borehole samples taken at the site was carried out. It should be noted that boulders/gravel > 20 mm were excluded from the test. A sedimentation test was also carried out at the 1.5 m sample depth. Soil/subsoil texture classification was carried out accordance with BSI (1999) through the aid of a flowchart produced by the Groundwater section of the GSI and included in Appendix C of EPA (2009a). The overall site characteristics are shown in Table 3.9.

Table 3.9 Site F - site characteristics

Site Details	
Site Location	Cork
PE	5
T-Value	8
K_{fs} (m/d)	0.56
Depth to bedrock (m)	3
Subsoil Classification	Silty SAND (0 threads, 0 ribbons)

Particle Size Analysis				
Depth (m)	*Clay/Silt*		*Sand*	*Gravel*
	Clay	*Silt*		
1.0	3%	23%	39%	35%

As well as the physical properties of each site, the overall system configuration and the daily wastewater production was an important aspect of the site selection criterion. Table 3.10 summaries the properties of the existing systems at each site. With the exception of Site D all the systems monitored treated a combination of black and gray water. At all of the sites rainwater was diverted away from the septic tank.

Table 3.10 Summary of existing system sizing and wastewater production

	Site A	Site B	Site C	Site D	Site E	Site F
No. of permanent residents	3	4	3	3	3	5
No. of regular visitors	1	0	1	2	1	0
Estimated flow rate (L d^{-1})	372	416	360	420	360	600
Septic tank capacity (L)	2600	2600	2450	2450	2600	2750[b]
Sources of wastewater[a]	Black & gray	Black & gray	Black & gray	Black	Black & gray	Black & gray

[a]Black water originates from toilet fixtures, dishwashers and food preparation sinks; Gray water originates from non-food preparation sinks, showers, baths and clothes washing. [b]Estimated based on householders recollection at time of construction.

An overall summary of the six selected OSWTS sites (consisting of a septic tank and soak-pit) is detailed in Table 3.11. From this it can be seen that the site selection criteria was achieved with two sites located in low permeability areas, two sites in moderate permeability areas and two sites in high permeability areas.

Table 3.11 Characteristics of soak-pit sites across a range of subsoil permeabilities

Site	K_{fs} ($m\ d^{-1}$)	Permeability Classification	Subsoil Depth (m)	Subsoil Classification[a]	Groundwater Vulnerability[b]
A	0.059	Low	5	Sandy SILT/CLAY	Moderate
B	0.061	Low	10	SILT/CLAY	Moderate
C	0.21	Moderate	3 - 10 (varies across site)	Gravelly SAND and SILT/CLAY	High
D	0.37	Moderate	5	Gravelly SAND	High
E	1.39	High	4	Gravelly SAND	High
F	0.56	High	3	Silty SAND	Extreme/High

[a] carried out in accordance with BSI (1999); [b] DELG, EPA, GSI (2004)

Chapter 4 Site Construction, Instrumentation and Analysis Methodology

4.1 Introduction

Careful instrumentation of the existing sites as well as construction and instrumentation of the alternative infiltration systems (LPP and DD systems) was paramount to the successful completion of the project. In particular, the design and construction of the LPP and DD systems was critical. As there are currently no Irish guidelines for the installation of these systems, both were design in collaboration with the expertise of Joe Walsh (Ash Environmental) and Jerry Tyler (University of Wisconsin). Site assessments were carried out by TCD, the results of which were then used to establish specific design criteria. The installation of both systems at both sites was supervised by Joe Walsh to ensure best practice methods were employed.

As the project centred on the collection and analysis of on-site effluent percolation, suction lysimeters were installed at strategic positions at each site to obtain soil moisture samples for analysis of some of domestic wastewaters' key constituents of concern. Tensiometers were also installed across the newly installed alternative infiltration systems to monitor the soil moisture tension below the distribution area in conjunction with soil moisture probes. Installation of the lysimeters, tensiometers and soil moisture probes was carried out using a combination of hand augers and a compact hammer drill rig. Effluent loadings to both alternative infiltration systems were monitored by a combination of a tipping bucket and energy meter, and an Orpheus Mini level sensor and energy meter. Finally, in order to measure the meteorological effects (evapotranspiration and precipitation levels) on the newly installed systems a weather station and rain gauge were positioned at both upgraded sites.

4.2 Monitoring of the Soak-pit Systems

Following the selection of six suitable soak-pit systems across a range of subsoil permeabilities, the chosen sites were instrumented in order to determine their treatment performance. At each site this consisted of suction lysimeters, with the installation of upstream and downstream groundwater monitoring points if an existing on-site well was not already present.

4.2.1 Suction Lysimeter Installation and Sampling

One of the most challenging aspects of the project was the successful installation of sampling instrumentation in the subsoil beneath the existing and upgraded systems. A suction lysimeter study was proposed to establish and analyse both the pollutant effect of the wastewater and attenuation capacity of the subsoil at different depths beneath the infiltrative surface. By placing the instrumentation at strategic positions a detailed three-dimensional profile of the wastewater's chemical and bacteriological constituents, coupled with its hydraulic behaviour, could be determined.

Soilmoisture Equipment Corporation Model 1900 suction lysimeters (which will be referred to from this point onwards as lysimeters) of different lengths were installed to different depths below ground level and left in the soil for the duration of the field trials to allow periodic sampling to occur with minimal disturbance of the subsoil. These lysimeters consist of a sample collection PVC tube (48 mm OD) and porous ceramic cup (48 mm OD). The effective pore size of the cup is 1.3 μm. The lid of the tube consists of a Santroprene stopper with neoprene tubing attached as an access tube for air evacuation and sample extraction. A vacuum is created within the lysimeter using a vacuum pump which draws pore water from the soil matrix.

Alternatively, stainless steel lysimeters could have been considered, however ceramic lysimeters had been successfully used by three previous on-site research projects carried out by Trinity College Dublin and so were readily available. Additionally, ceramic lysimeters are considerably less expensive allowing a greater number of sampling points at each site. In order to ensure the accuracy of the soil moisture samples collected via the ceramic lysimeters, a controlled laboratory study was carried out using domestic effluent. The aim of the test was to establish the potential interference of ceramic sorption of orthophosphate and filtration of bacteria as soil moisture passed through the ceramic cup. Results of the laboratory test are detailed in the test report in Appendix B. A summary of the results is presented in Table 4.1.

Table 4.1 Reduction in orthophosphate and bacteria concentrations within ceramic suction lysimeters

Parameter	**Reduction in concentration within soil moisture sampler**
Orthophosphate	19.7 %
Total Coliform	35.3 %
E. coli	37.0 %

These results reflect similar studies carried out on ceramic lysimeters (Weihermüller et al., 2007, Bell, 1974, Peters and Healy, 1988) which showed a greater reduction in bacterial concentrations than that of nutrients (chemical concentrations). Overall, the representativeness of the collected samples is within an acceptable range. As observed by Weihermüller et al. (2007) it is difficult if not impossible to obtain pore water samples which are not altered or biased by the sampling process with cost considerations dictating the point at which increased sample representativeness is not practical.

At the existing sites the positioning of the lysimeters was determined following consultation with the homeowner and with the aid of a GPS Survey. One of the most problematic aspects of these existing sites was the lack of knowledge in relation to the location and positioning of the effluent pipes and soak-pit pits. The aim was to install the lysimeters in nests of 3 different depths around the soak-pit area but within the effluent plume. This was to prevent disturbance or intrusion of the soak-pit which might alter its performance by creating preferential flow paths. As soak-pits consist of large stone backfill trial and error using hand augers was used to indicate the location of the soak-pit at each site. GPS surveys were also carried out using a Trimble Land Survey RTK Total Station and Data Capture System. The software programme Surfer10 was then used to create map projections of each site in order to determine the probable direction of groundwater flow and effluent percolation. Together this allowed the determination of the approximate location and extent of the soak-pit at each site.

The first sites instrumented where Site A and Site B, two low permeability sites. Following determination of the soak-pit location lysimeter clusters of three different lengths were installed, 1.3 m (red), 1.6 m (blue) and 1.9 m (black), below ground level downstream of the expected soak-pit plume. At these sites a 45 mm diameter hand auger was used to bore an initial hole to the desired lysimeter depth. The use of an auger with a diameter slightly smaller than the external diameter of the lysimeter was intended to result in good contact between the porous cup and the subsoil matrix. This was an extremely difficult and time consuming process at both Site A and Site B due to the presence of boulders and changing soil properties within the subsoil matrix at both sites. The porous cup of a lysimeter is extremely fragile and will shatter very easily if cobbles or gravel are present at the sides of the bored holes, this meant a number of lysimeters were broken during the installation phase. This also impacted the positioning of the lysimeters as it was not always possible to install the nests in the areas indentified prior to instrumentation. If a hole could be bored the relevant lysimeter (each marked with red, blue and black tape to signify 1.3, 1.6 and 1.9 m lengths respectively) was inserted and pushed down to the base of the hole to insure it fitted. To maximise contact between the porous cup and the soil matrix, the holes were partially backfilled with a soil slurry produced by mixing the excavated soil, from which any gravel had been removed, with water. The lysimeter was then inserted and pushed into the slurry until the base of the hole was reached. Once the lysimeter was in place slurry was poured down the sides of the lysimeter in order to fill any voids between the lysimeter and subsoil. Finally, a bentonite slurry, consisting of bentonite powder and water, was mixed and used to ensure a good seal for the top 0.5 m between the lysimeter and the subsoil, preventing preferential flow paths for rainfall or surface run-off.

Following the difficulties encountered with lysimeter installation at the low permeability sites (with a relatively low percentage of cobbles/gravel) it was decided that a different method of lysimeter installation was required for the high/moderate permeability sites which consisted of much higher proportions of gravel, pebbles and cobbles. As a remedy to this problem, a hammer rig, of diameter 50 mm was used to install lysimeters at the remaining sites (Site C, D, E and F). A hand auger was then used to for the last 100 mm to ensure the correct sizing for the lysimeter ceramic cup. As the diameter of the drill rig was greater than diameter of the lysimeters, particular care was taken when backfilling the base of each lysimeter hole and void space surrounding the lysimeter. Again a combination of soil slurry and bentonite slurry was used to ensure a good seal around each lysimeter.

The utilisation of the hammer rig also enabled greater installation depths to be achieved despite the difficult subsoil conditions. This was of added benefit as it was assumed effluent found travel more rapidly and to greater depths in high permeability conditions. It was therefore decided to extend the existing lysimeter lengths using remaining lengths of broken lysimeters from the installation process at sites A and B. This was done by means of a nylon collar (50 mm OD and 48 mm ID) made specifically for this purpose by the Trinity College Civil Engineering Department. The collars were glued to both lengths of PVC pipe using Loctite 435 adhesive and a trial run was carried out in the lab to ensure a strong vacuum was achieved within the lysimeter. Following successful testing in the lab lysimeters of varying depths of up to 3 m were installed at the remaining sites.

4.2.2 SAMPLING OF GROUNDWATER AND SATURATED ZONE

As the protection of groundwater was critical for the existing soak-pit systems in high to moderate permeability areas the four sites selected in these subsoil ranges also had pre-existing wells (all of which supplied drinking water). This allowed groundwater samples to be extracted and analysed for the presence of effluent contamination.

Unfortunately, due to the difficulties in locating existing soak-pits in low permeability areas, the two sites selected did not have pre-existing wells and so there was no means of sampling the groundwater. To compensate for this, upstream and downstream boreholes were installed at both Site A and Site B using a hammer drill rig. The installed boreholes were 50 mm in diameter and as with the lysimeters a combination of soil slurry and bentonite slurry was used to ensure a good seal around installed PVC pipe. Borehole sampling was carried out using ClearView disposable single valve PVC bailers (Wattera-In-Situ).

At Site D, the presence of two distinct subsoil layers (a freely draining layer to a depth of 1.4 m, followed by a saturated layer) both piezometers and lysimeters were used to monitor the changing subsoil conditions. Unlike lysimeters, piezometers do not operate under vacuum, they are located in the phreatic saturated zone and simply allow water to move into the sampling tube through a highly porous screen. As with the boreholes, samples could then be collected by means of a PVC bailer.

4.3 Layout and Instrumentation of Low Permeability Sites

The overall layout, direction of groundwater flow and installed instrumentation for both low permeability sites are detailed below.

4.3.1 Site A - Layout and Instrumentation

At Site A a GPS survey of the site shows gradient of the site, and the assumed direction of groundwater flow, moves away from the septic tank with a drainage ditch located adjacent to the soak-pit area (Figure 4.1). The location of a downstream surface water body is also shown, however this was not monitored over the course of the study due to the distance from it to the soak-pit as well the presence of multiple other potential sources of contamination due to neighbouring agricultural activity.

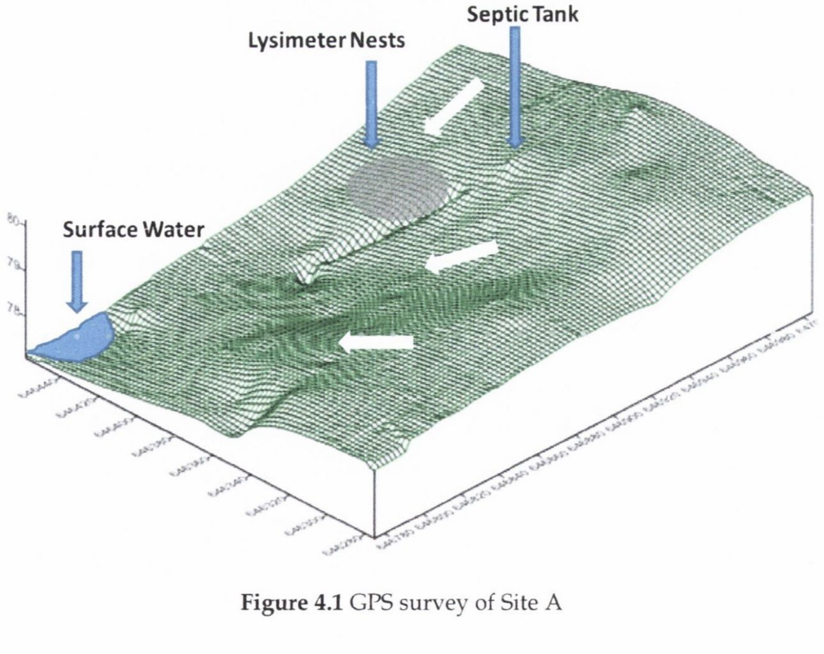


Figure 4.1 GPS survey of Site A

Figure 4.2 details the location of the installed lysimeters in relation to the soak-pit at Site A. From this it can be seen that two of the lysimeter nests (3.1 and 3.2) were installed within the adjacent drainage ditch. Lysimeters were installed in nests of 3 at nominal lengths of 1.3 m, 1.6 m and 1.9 m. A total of 17 lysimeters were installed at the site during the first phase of the project.

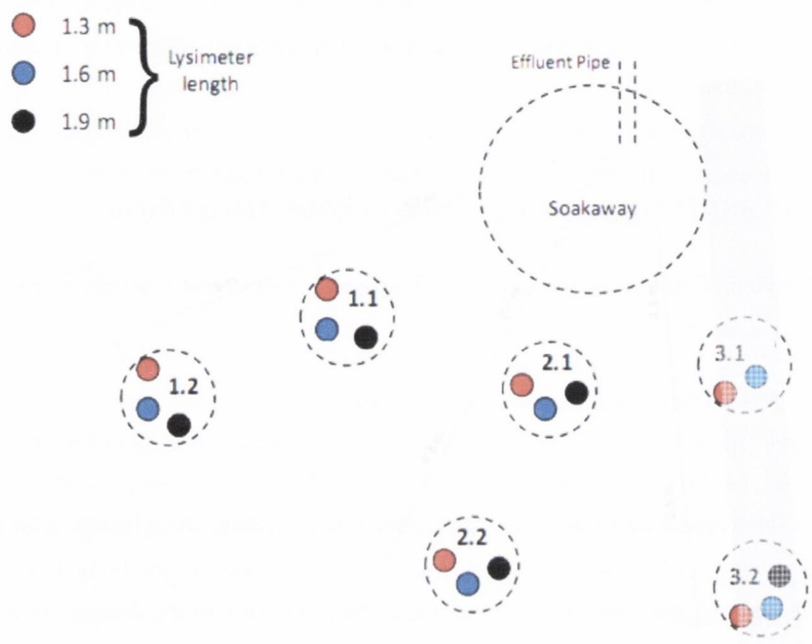


Figure 4.2 Instrumentation layout at Site A

At Site A, seven boreholes were installed with fractured bedrock being reached at 4.5 m to 5 m. At the time of drilling, groundwater was present at this depth however the groundwater level fluctuated greatly at the site and groundwater samples were not always obtained during the sampling period. The location of the installed boreholes with respect to the soak-pit area is shown in Figure 4.3. Critically, as shown, the site provided sufficient space for the upgrading of the site to a new alternative infiltration system during phase two of the project.

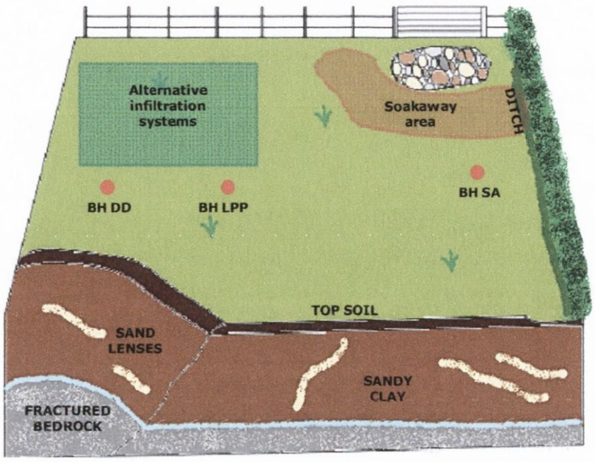


Figure 4.3 Locations of downstream boreholes installed at Site A

4.3.2 SITE B - LAYOUT AND INSTRUMENTATION

As with Site A, a GPS survey of Site B was carried out. Figure 4.4 shows gradient of the site with respect to the existing soak-pit. As with the previous site, the gradient of Site B falls away from the soak-pit area.

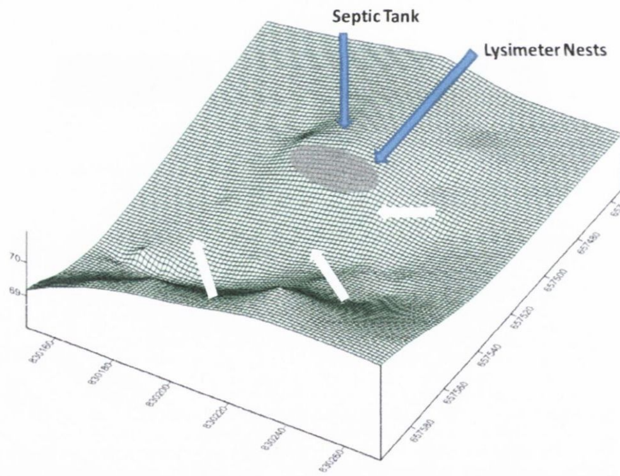


Figure 4.4 GPS Survey of Site B

Figure 4.5 shows the location of the installed lysimeter nests at Site B. These were located at varying distances from the soak-pit area in an attempt to indentify the extent of the effluent plume. Again the nest consisted of 3 lysimeters 1.3 m, 1.6 m and 1.9 m in length. A total of 21 lysimeters were installed at the site during the first phase of the project.

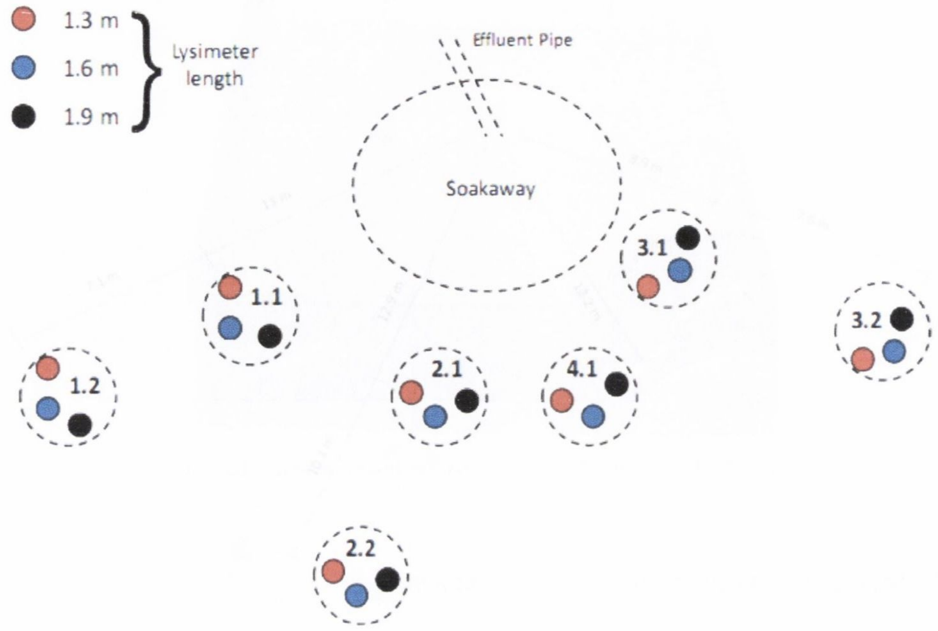


Figure 4.5 Instrumentation layout at Site B

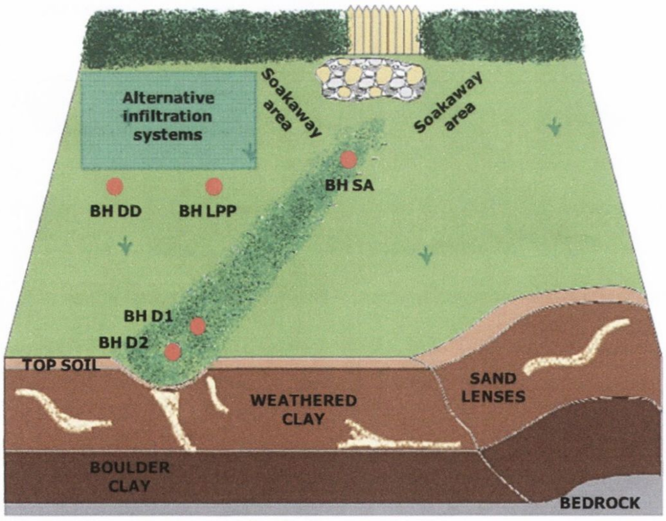


Figure 4.6 Locations of downstream boreholes installed at Site B

At Site B, the subsoil was estimated to be approximately 10 m in depth. Heavy boulder clay was reached at approximately 2.5 m to 3 m through which the hammer drill rig could not penetrate. As such, boreholes at Site B were used to take samples from the saturated zone upstream and downstream of the soak-pit area. The locations of the installed downstream boreholes with respect to the soak-pit areas are shown in Figure 4.6. Again the site provided sufficient space for the upgrading of the site to a new alternative infiltration system during phase two of the project.

4.4 Layout and Instrumentation of Moderate/High Permeability Sites

Following the instrumentation of the two low permeability sites, a further four moderate/high permeability sites were identified and instrumented. At each of these sites pre-existing on-site well allowed easy access to groundwater samples and so installed instrumentation consisted of either lysimeters or a combination of lysimeters and piezometers.

4.4.1 Site C - Layout and Instrumentation

Results of a GPS survey carried out at Site C are shown in Figure 4.7 from which the sites soak-pit can be seen to be located on a steep slope. The shallow water table at the in relation to the soak-pit is indicated by the water level of the adjacent river. The location of the on-site well (10 m in depth) is also indicated.

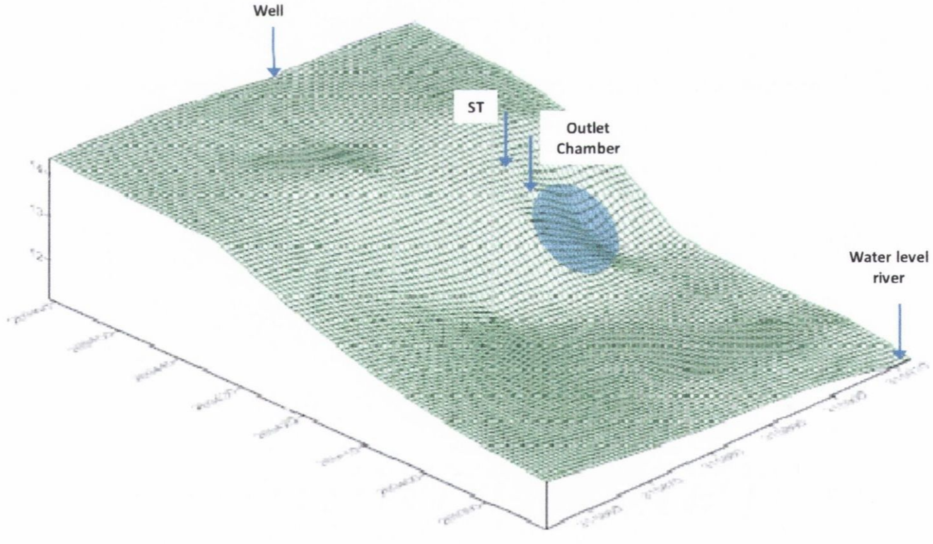
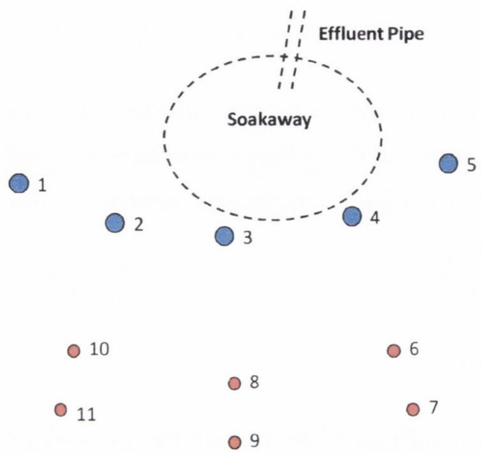


Figure 4.7 GPS Survey of Site C

At Site C, the presence of two distinct subsoil layers (a freely draining layer to a depth of 1.4 m, followed by a saturated layer) both piezometers and lysimeters were used to monitor the changing subsoil conditions. Figure 4.8 indicates the location of both in relation to the soak-pit as well as their depth from the septic tank discharge point and respective ground levels. Groundwater samples were also taken from the on-site well.



Sample ID	Depth below GL (m)	Distance from Outlet Pipe (m)
Lys 1	1.15	7.7
Lys 2	1.5	5.3
Lys 3	1.2	3.9
Lys 4	1.05	3
Lys 5	1.2	2.6
Piez 6	1.1	6.6
Piez 7	2.1	7.5
Piez 8	1.7	4.8
Piez 9	2.75	5.7
Piez 10	1.1	7.6
Piez 11	2.0	8.3

Figure 4.8 Instrumentation layout of Site C

4.4.2 SITE D - LAYOUT AND INSTRUMENTATION

A GPS survey of Site D shows a steep gradient falling away from both the septic tank soak-pit (blue) and grey water soak-pit (red) which were in operation at the site (Figure 4.9). The location of the on-site well downstream of both is also indicated.

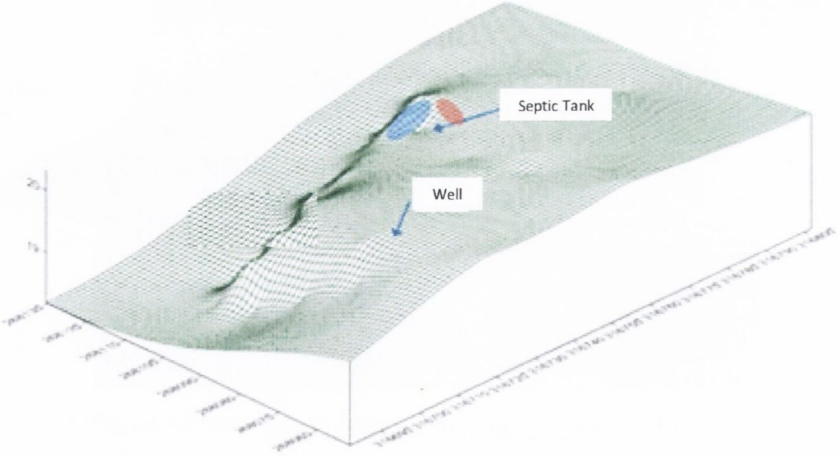
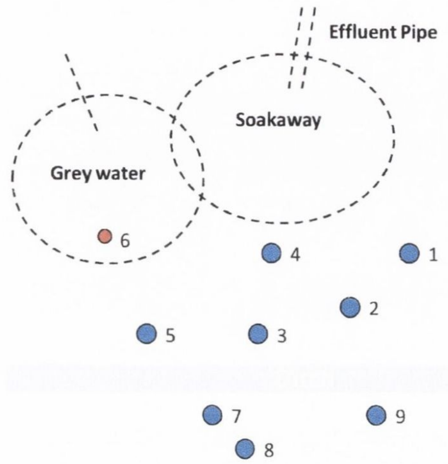


Figure 4.9 GPS Survey of Site D

The instrumentation of Site D consisted primarily of lysimeters with only a single piezometer located within the saturated zone of the grey water soak-pit area. The location and depths of all instrumentation are detailed in Figure 4.10. Groundwater quality was also monitored by means of samples taken from the on-site well.



Sample ID	Depth below GL (m)	Distance from Outlet Pipe (m)
Lys 1	1.95	4.0
Lys 2	1.95	4.8
Lys 3	2.5	5.4
Lys 4	2.1	3.0
Lys 5	1.75	4.7
Piez 6	1.6	3.4
Lys 7	1.85	7.5
Lys 8	2.6	7.9
Lys 9	1.1	7.8

Figure 4.10 Instrumentation layout Site D

4.4.3 SITE E - LAYOUT AND INSTRUMENTATION

One of the interesting features of Site E was the location of the household's on-site well downstream of the soak-pit discharge point as shown in Figure 4.11. The free-draining nature of the soil indicates a potential risk of groundwater contamination as a result of effluent discharge.

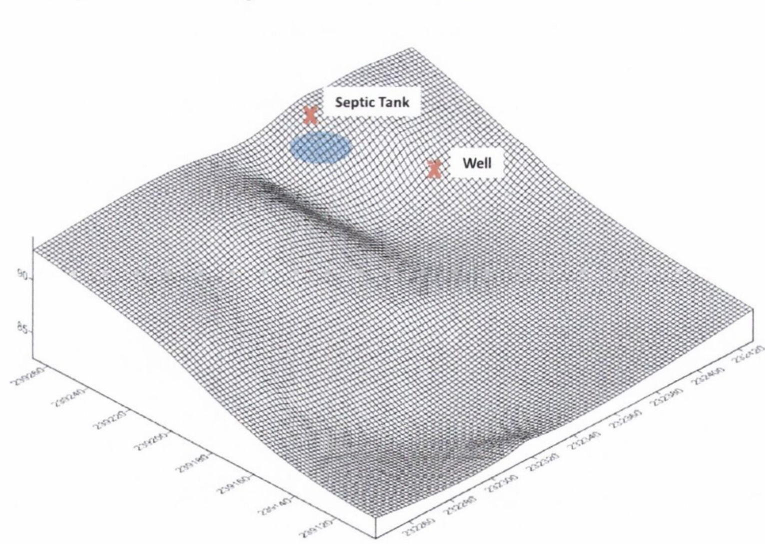
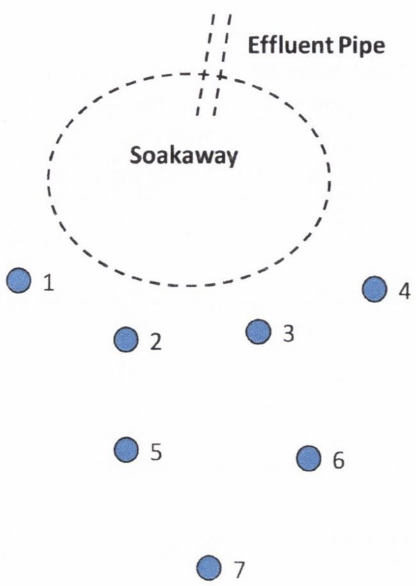


Figure 4.11 GPS Survey at Site E

To determine the extent of the effluent plume in the unsaturated subsoil lysimeters were installed as per Figure 4.12 and groundwater quality was monitored by sampling the on-site well.



Sample ID	Depth below GL (m)	Distance from Outlet Pipe (m)
Lys 1	1.6	1.8
Lys 2	1.6	2.1
Lys 3	1.7	2.0
Lys 4	1.2	1.7
Lys 5	3.0	3.2
Lys 6	1.9	4.2
Lys 7	1.3	5.8

Figure 4.12 Instrumentation layout at Site E

4.4.4 SITE F - LAYOUT AND INSTRUMENTATION

At Site F a similar scenario to that observed at Site E is also shown (Figure 4.13) with the domestic water supply located downstream of the effluent discharge point. The overall steep gradient of the site in combination with shallow, free draining subsoil again indicates a potential risk of contaminant migration to the underlying groundwater.

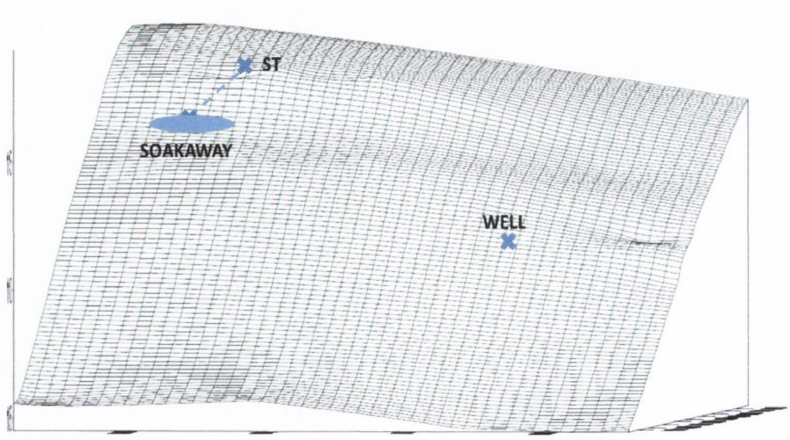
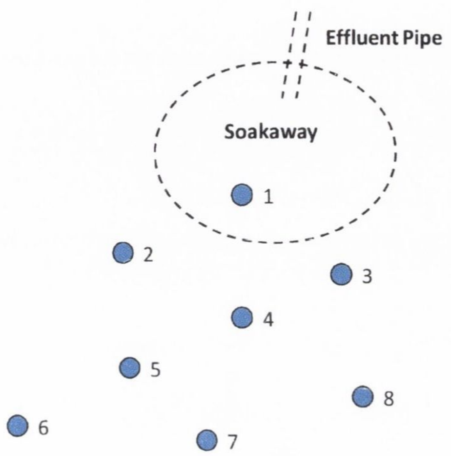


Figure 4.13 GPS Survey at Site F

Instrumentation at Site F consisted of lysimeters in the unsaturated zone (Figure 4.14) with groundwater quality assessed through the collection of samples from the on-site well.



Sample ID	Depth below GL (m)	Distance from Outlet Pipe (m)
Lys 1	1.4	0.5
Lys 2	2.0	1.8
Lys 3	3.0	2.6
Lys 4	1.9	2.2
Lys 5	1.8	3.8
Lys 6	2.2	6.1
Lys 7	1.9	6.0
Lys 8	2.0	5.5

Figure 4.14 Instrumentation layout at Site F

4.5 Construction of Alternative Infiltration Systems

Following the completion of the monitoring phase of the existing soak-pit systems at Site A and Site B, the instrumentation at both sites was removed to allow the construct of alternative infiltration systems. These systems consisted of a secondary treatment unit from which effluent was distributed via a DD and LPPS operated in parallel at each site.

4.5.1 Site Layouts

Site A, serving 3 people, originally operated on STE. As part of the site upgrade an ASP (Activated Sludge Plant) detailed in Section 4.5.2 was installed to ultimately replace the existing septic tank. However, it was initially intended to feed the new pressurised distribution systems with STE to monitor performance with such less treated effluent before switching it to SE. As such, pipe work was laid to allow the system to be fed with either STE or SE (Figure 4.16). Effluent from either the existing septic tank of ASP was fed by gravity to tipping bucket which split the effluent evenly between the LPP sump and DD sump. Effluent in the LPP sump was pumped to the LPP distribution laterals on a volume-dosed pump cycle. The pump, controlled by a float switch, began pumping once a certain level of effluent was reached in the sump.

The DD pump operated on a timer run by a control panel in conjunction with four float switches as shown in Figure 4.15.

- Float A - Low-level (or on/off) float - determines if enough effluent present in sump for pump to operate
- Float B - First timer float - if effluent levels are above Float B pump will operate for set time interval
- Float C - Secondary timer float - if 2 hours after the first pumping cycle sump levels remain/are above Float C pump will operate a second time for set time interval
- Float D - High level alarm float - if effluent levels are above Float D high level alarm sounds on panel

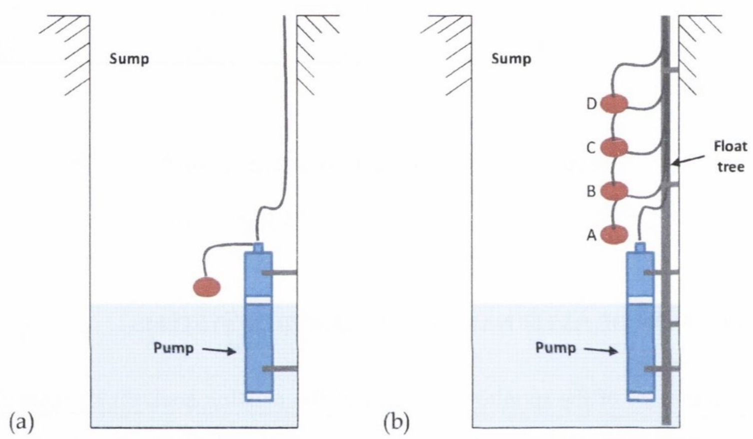


Figure 4.15 Float configuration for (a) LPP pump sump and (b) DD pump sump

Site B (4 PE) originally operated on STE. As part of the site upgrade a coconut husk media filter (Clereflo ECO) detailed in Section 4.5.2 was installed to replace the existing septic tank. Effluent from filter was piped by gravity to the first sump (the LPP sump). When in operation the LPP pump pumped effluent to a Hydrotek 4000 indexing valve (K-Rain) which was cammed to split the effluent two ways (Figure 4.17). This valve allowed effluent to be dosed to the LPP distribution laterals during the first pumping cycle of the LPP pump. During the second pumping cycle the valve cam would rotate and effluent would pump to the DD pump sump. This alternating cycle allowed the even distribution of effluent between the two distribution systems during the course of the project. At Site B both the LPP and DD pumps operated in the same manner as described for Site A.

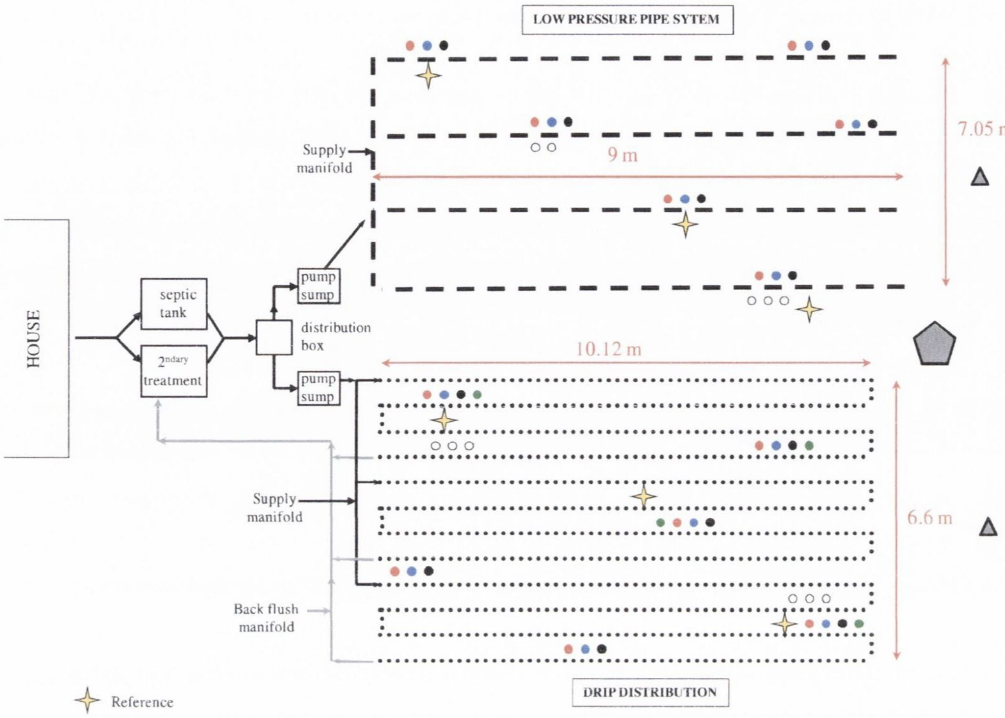


Figure 4.16 Overall setup at Site A

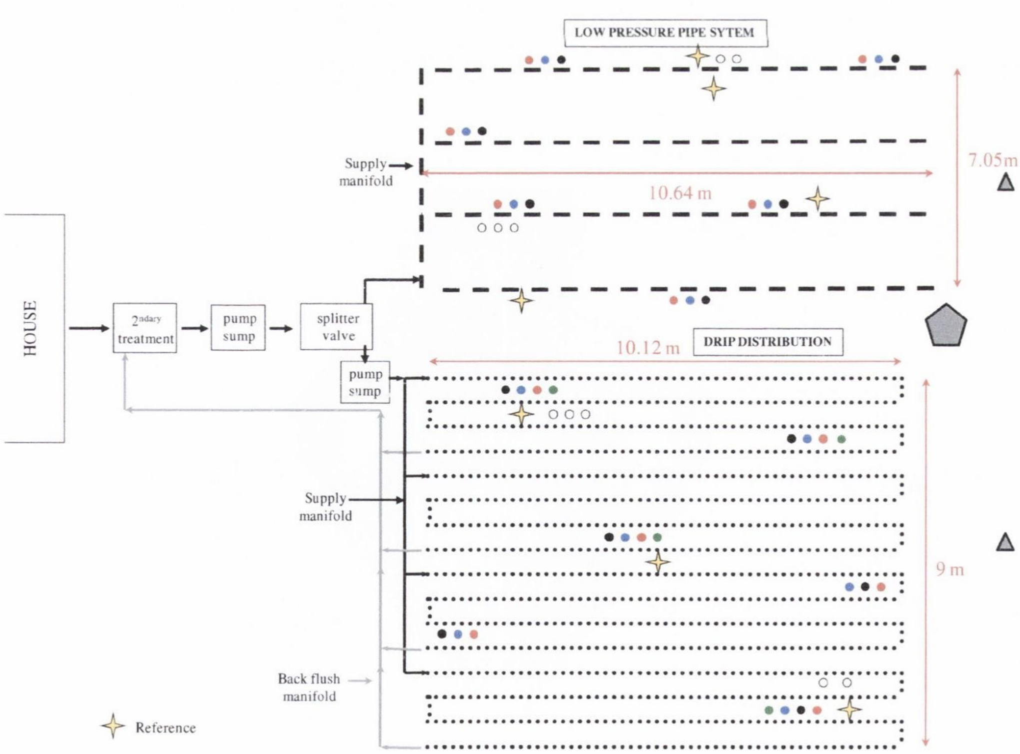


Figure 4.17 Overall setup at Site B

4.5.2 SECONDARY TREATMENT UNITS

The secondary treatment units chosen for the project were selected based on their potential as remediation options for existing OSWTS as well as future developments requiring a higher standard of effluent treatment. Both systems are designed for the domestic market however they employ different treatment processes. Through their installation and monitoring it was hoped to determine their treatment performance, economic sustainability and so compare their potential future usage in Ireland.

At Site A, a Bison ASP (Activated Sludge Plant) was installed to replace the existing septic tank in order to provide secondary treated effluent following the installation of the alternative infiltration systems. The unit is made out of glass reinforced plastic. It treats domestic wastewater using the extended aeration principle. It has an inner central chamber and an outer settlement tank (Figure 4.18); it does not have a primary settlement chamber. A coarse bubble diffuser, housed in a draft tube, introduces the air that provides the oxygen to the bacteria, which treat the sewage. The bio-zone retains the mixture of sewage and bacteria until the level of treatment has been achieved. In the conical clarifier tank final settlement takes place. While the final effluent is discharged over a weir that extends around the circumference of the tank at the outlet level the settled solids are returned through the draft tube into the bio-zone. The water movement through the system is by gravity displacement. At Site A, effluent from the ASP was gravity fed to two pump sumps via a tipping bucket. The ASP has a typical desludging period of 2-3 years.

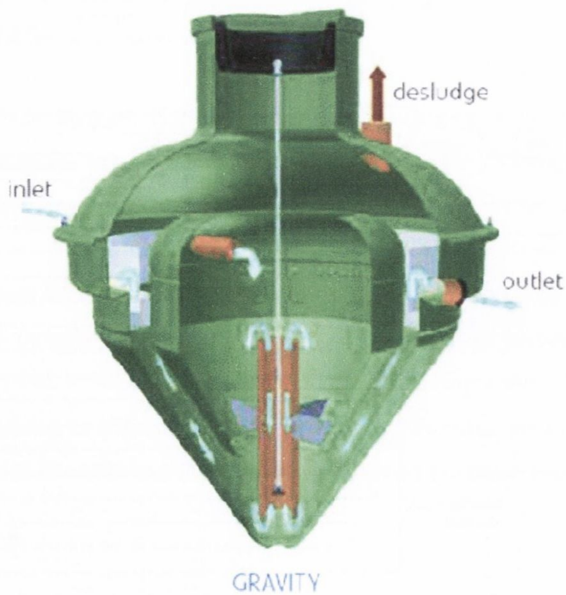


Figure 4.18 ASP (Activated Sludge Plant) installed at Site A

A coco media filter (Bison Clereflo ECO) was installed at Site B in order to provide secondary effluent treatment. The tank is made of glass reinforced plastic and is divided into two sections: a primary settlement section and a biological treatment section (Figure 4.19). As the flow through the plant is by gravity it requires no energy supply. The filter media is made of transformed coco husk residues and provides a high surface area and open structure that promotes the growth of bacteria and microorganisms to treat the wastewater. The primary settled effluent is distributed evenly over the surface of the media by a tipping plate mechanism and trickles downwards through the substrate. Thus the pollutants are retained or degraded within the media. Air required for the biological treatment process is introduced to the plant through a natural ventilation system. However, when installed, the effluent discharge point of the tank is at a depth of 2 m below ground level. Consequently, most conventional STU would require effluent be pumped up to a more suitable infiltration depth, leading to an energy requirement. Depending on the plant loading desludging of the primary settlement tank should be carried out every 1 to 3 years. At Site B, effluent from the filter discharges by gravity directly to the LPP sump from which it is pumped to either the LPP system or the DD sump (Figure 4.17).

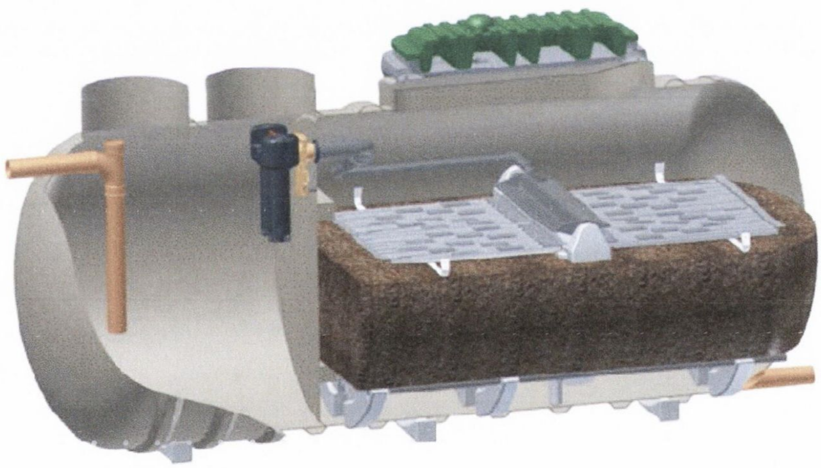


Figure 4.19 Clereflo filter installed at Site B

4.5.3 Construction of Low Pressure Pipe System

At Site A and Site B LPP systems were installed to meet a design load of 240 L per day (i.e. 120 L per capita). It should be noted however, that both secondary treatment units were sized greater than the household PE on both sites to ensure effluent quality was not compromised.

The first stage of the construction process of the distribution network was the excavation the supply manifold trench and lateral trenches. At both sites the trenches were 400 mm deep and 400 mm wide approximately. The overall dimensions of the LPP systems at both sites are detailed in Table 4.2. Unlike conventional gravity fed percolation systems the slope of the percolation trenches was not critical as the pumped system ensures even effluent distribution throughout the network. A thin layer of gravel (~100 mm) was placed in the base of each trench.

Table 4.2 Design flow and overall dimension of LPP systems installed at Site A and Site B

Location	Design Flow L	Trench Width m	Trench Length m	No. of Trenches	Total LPP Footprint m^2
Site A	240	0.4	9	4	63.5
Site B	240	0.4	10.64	4	75

The supply manifold consists of 40 mm diameter 10 bar PVC pipe distributing to four 25 mm diameter 10 bar PVC pipe laterals, (see Figure 4.20b). At Site A, four laterals 9 m in length were installed 2.35 m apart. These laterals had predrilled 4 mm holes located at 950 mm intervals along their length totalling 36 holes across the distribution network. At Site B, four laterals 10.64 m in length were installed 2.35 m apart also with predrilled 4 mm holes located at 950mm intervals along their length totalling 40 holes across the distribution network.

Shut-off ball valves were located at both ends of each lateral to allow sections of the system to be blocked off. They also facilitate the flushing out of the system to prevent any potential sediment build-up. Once the piping and valves had been installed another thin layer of gravel was added to protect and cover the pipe. Finally a geotextile (Terram® 1 000) was placed over the laterals in each trench before backfilling to prevent fines from washing down and clogging up the gravel layer (Figure 4.20c). The trenches were carefully backfilled with the excavated soil (Figure 4.20d).

(a) (b) (c) (d)

Figure 4.20 (a) Installation of ASP unit at Site A (August 2012), (b) construction of LPP gravel trench, (c) geotextile in LPP trench and (d) complete LPP trenches 4 weeks after installation (September 2012)

4.5.4 Construction of Drip Distribution System

As with the LPP systems, the DD systems at Site A and Site B were installed to meet a design load of 120 L per capita. The drip distribution network is comprised of 40 mm PVC supply and return manifolds combined with a network of drip laterals as shown in Figure 4.21a. This Geoflow drip tubing is pre-treated to prevent bacterial deposits building up on the tubing walls and also to prevent root intrusion from trees and shrubs. The dripline was laid at 600 mm spacing with 0.03 litre per minute discharge emitters spaced at 600 mm intervals in the tubing.

The first stage of the construction of the DD system was the excavation of a trench along which the supply and return manifolds were placed. Air valves were installed at the end of both the supply and return manifolds to allow air release at the end of each dosing event. At both sites a filter was installed just downstream of the DD pump to prevent clogging of the dripline and drip emitters. At both sites a manual FLD Rotofilter (S/S Mesh 120 -Micron 130) was installed as shown in Figure 4.22d. This allowed manual flushing of the system during each sampling trip by opening the two backwash valves while the pump was operational.

The dripline itself was installed by hand, without aggregate (Figure 4.21b). The location of each lateral was carefully measured and marked out, then, spades were used to create channels approximately 150 mm deep in the subsoil into which the dripline pressed. The overlying subsoil was then carefully pressed back over the dripline by foot. One end of each dripline was attached to the supply line; it was then looped back at the end of each lateral where it was connected to the return line which fed back to the secondary treatment unit. At Site A, a total of 6 looped laterals were installed (i.e. 12 drip laterals in total) resulting in a total length of 120 m of dripline with 200 emitters. At Site B, a total of 8 looped laterals were installed (i.e. 16 drip laterals in total) resulting in a total length of 160 m of dripline with 266 emitters. Once all driplines had been successfully installed and connected to the manifolds the trench was carefully backfilled with the excavated material.

(a)

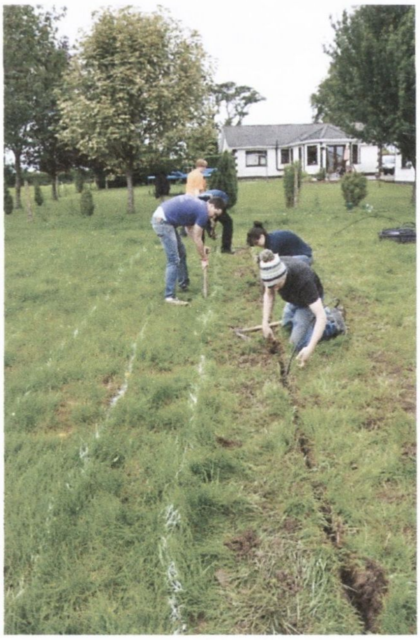
(b)


Figure 4.21 (a) Installation of Clereflo filter unit at Site B and (b) installation of driplines by hand

(a)

(b)

(c)

(d)

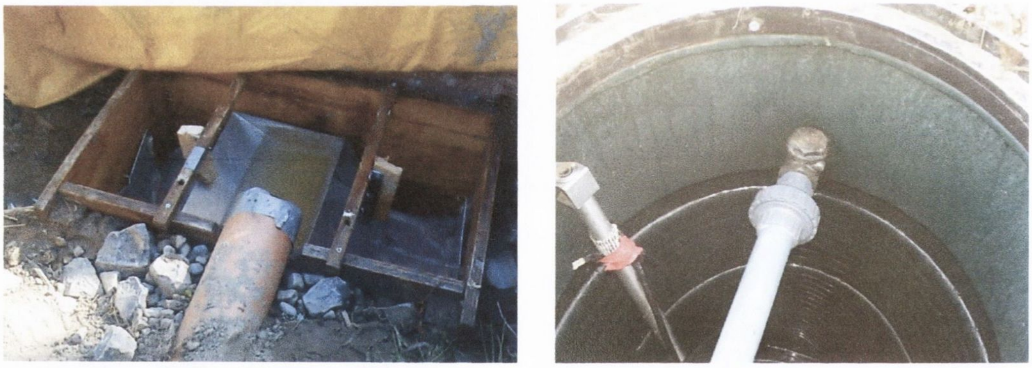
Figure 4.22 (a) Installed driplines and supply/return manifolds, (b) completed DD system 4 weeks after installation, (c) DD control panel with installed Elink meter and (d) filter for DD system

4.5.5 MONITORING OF HOUSEHOLD EFFLUENT

The overall wastewater production and comparison of different flow rates split between the two alternative systems at Site A and Site B was measured. At Site A this was achieved by means of a tipping bucket and reed switch in combination with a CR800 data logger. The tipping bucket divided the effluent between each pump sump whilst the reed switch recorded the number of tips from which the volume of effluent to each sump was calculated (Figure 4.23a).

At Site B the effluent level in the LPP sump (Figure 4.23b) was monitored for the first 6 months by an Orpheus mini (± 0.05 % full span). This recorded the change in effluent levels within the sump at 30 min intervals. From this the volume of effluent leaving the sump (i.e. being pumped to the LPP network or to the DD sump) could be calculated.

In conjunction with this, an Elink energy meter (Efergy) was installed at both sites to record the power usage of each system. This recorded the number of pumping cycles of both the LPP and DD pumps as well the energy usage of the ASP unit (Site A only). The installed Elink at Site A can be seen in Figure 4.22c.



(a) (b)

Figure 4.23 (a) Tipping bucket at Site A and (b) Orpheus mini level sensor at Site B

4.6 Monitoring of the Alternative Infiltration Systems

4.6.1 Suction Lysimeter Installation and Sampling

The installation of the lysimeters across the newly installed LPP and DD systems at Site A and Site B was a more straightforward process as the exact depths and locations of effluent discharge was known. Six of the lysimeters at Site A were installed with the hammer rig, there remaining 34 were installed by hand auger. All 40 lysimeters at Site B were installed using a hand auger. The installation procedure was identical to that carried out at the existing soak-pit sites.

Again lysimeters were installed in clusters of three different lengths, 1.3 m (red), 1.6 m (blue) and 1.9 m (black) at strategic positions across both the LPP and DD systems. Both systems are designed to provide even distribution of effluent to the subsoil; lysimeters were installed at varying distances along the distribution area in order to ascertain if this was indeed the case. In total, 6 clusters were installed within each system at each site, an overview of their locations are detailed in Figures 4.25 - 4.28. Due to the very shallow infiltration depth of the DD system (150 mm) shallow 1 foot (300 mm) lysimeters were installed at four of the sampling positions within these systems at both sites following 3 months of operation.

At both the existing soak-pit sites and upgraded sites the sampling of the soil moisture samples was the same and involved two days of site work:

- Day 1 - placing the lysimeters under suction
- Day 2 - extraction of samples

On the morning of Day 1, all lysimeters were put under a suction of 0.5 bar (50 kPa) using a vacuum-pressure hand pump. This value is well below the air-entry value of the lysimeter (2 bar) which helped ensure the soil moisture solution was pulled horizontally from the vadose zone and preventing the local soil from drying out and causing discontinuity in the sample. While a potential gradient is needed to draw soil moisture from the soil matrix into the lysimeter, too great a suction would result in moisture, that would otherwise be unavailable to recharge due to the adhesive force between the moisture and the soil matrix, being extracted. Once the vacuum was created by the application of the requisite pressure through the lysimeters neoprene tubing, the latter was clamped with a plastic ring to maintain suction. On the morning of Day 2, after approximately 24 hours under suction, the lysimeter clamp was released and the samples were ready for extraction.

Figure 4.24 Soil moisture sampling apparatus

The extraction kit for sampling consisted of the vacuum-pressure hand pump and a 1 L conical flask and rubber bung with an extraction tube attached (Figure 4.24). To recover a sample from the base of the lysimeter the vacuum hand pump was connected to the side arm of the conical flask, the stopper on the lysimeter was removed and the extraction tube inserted down the lysimeter. The total volume of sample collected was recorded before the samples were transferred to sample bottles. After each extraction the conical flask and tubing were rinsed with distilled water to minimise sample contamination. Sampling was also sequenced to extract samples from the black labelled lysimeters firs, followed by their blue and red counterparts. This was done to reflect the improving quality of effluent with subsoil depth and so reduce any impact from potential cross contamination of samples.

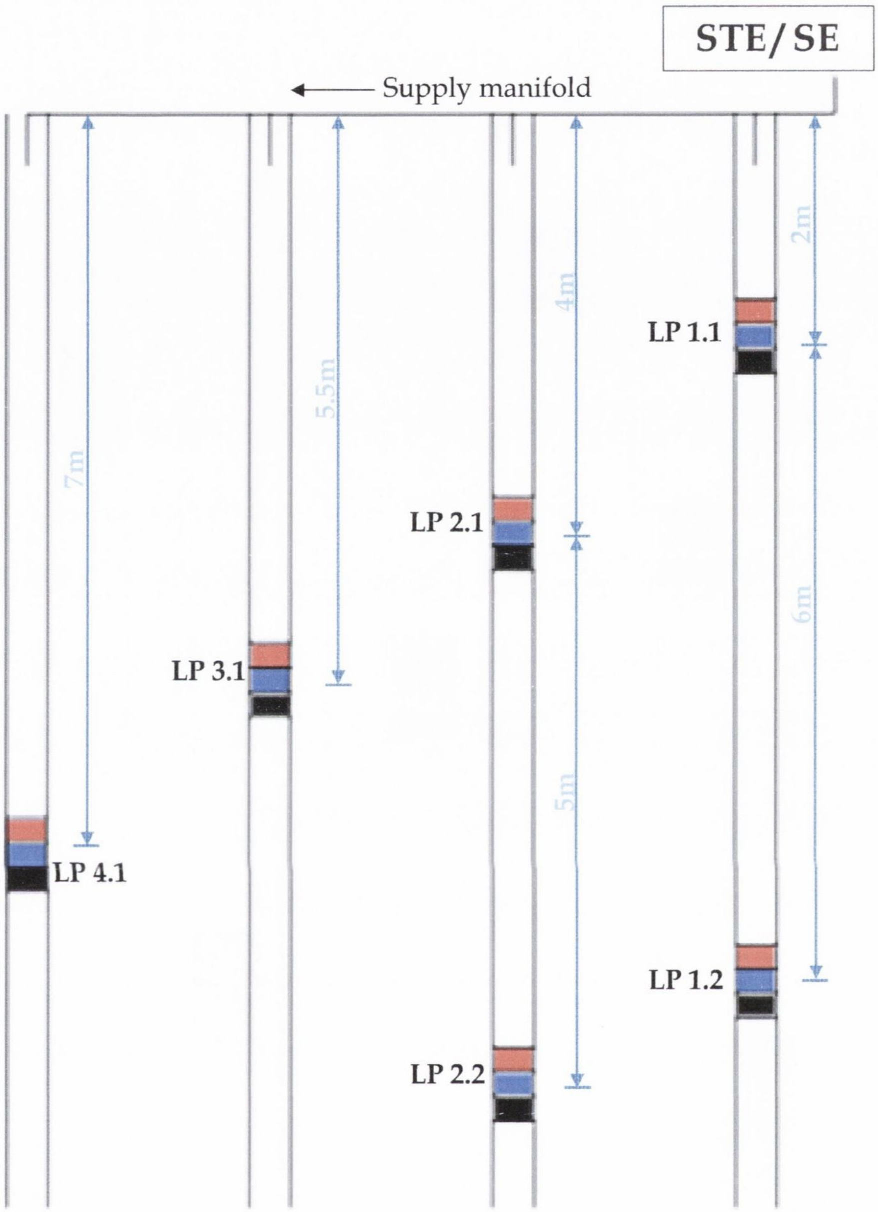
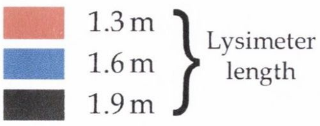


Figure 4.25 Labelling sequence for LPP soil moisture samples at Site A



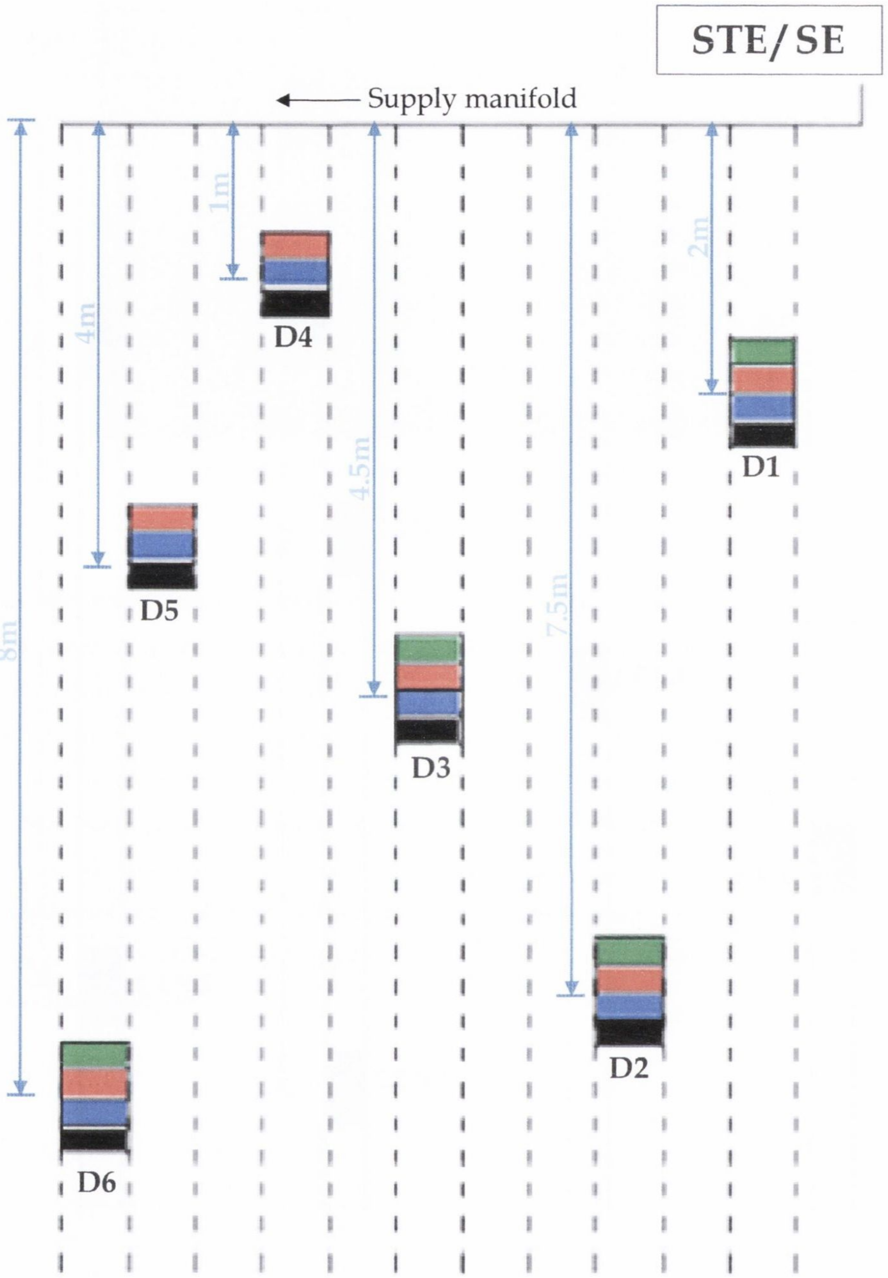
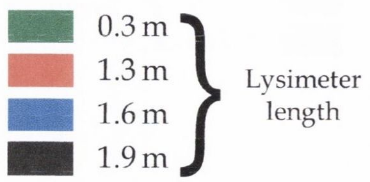


Figure 4.26 Labelling sequence for DD soil moisture samples at Site A



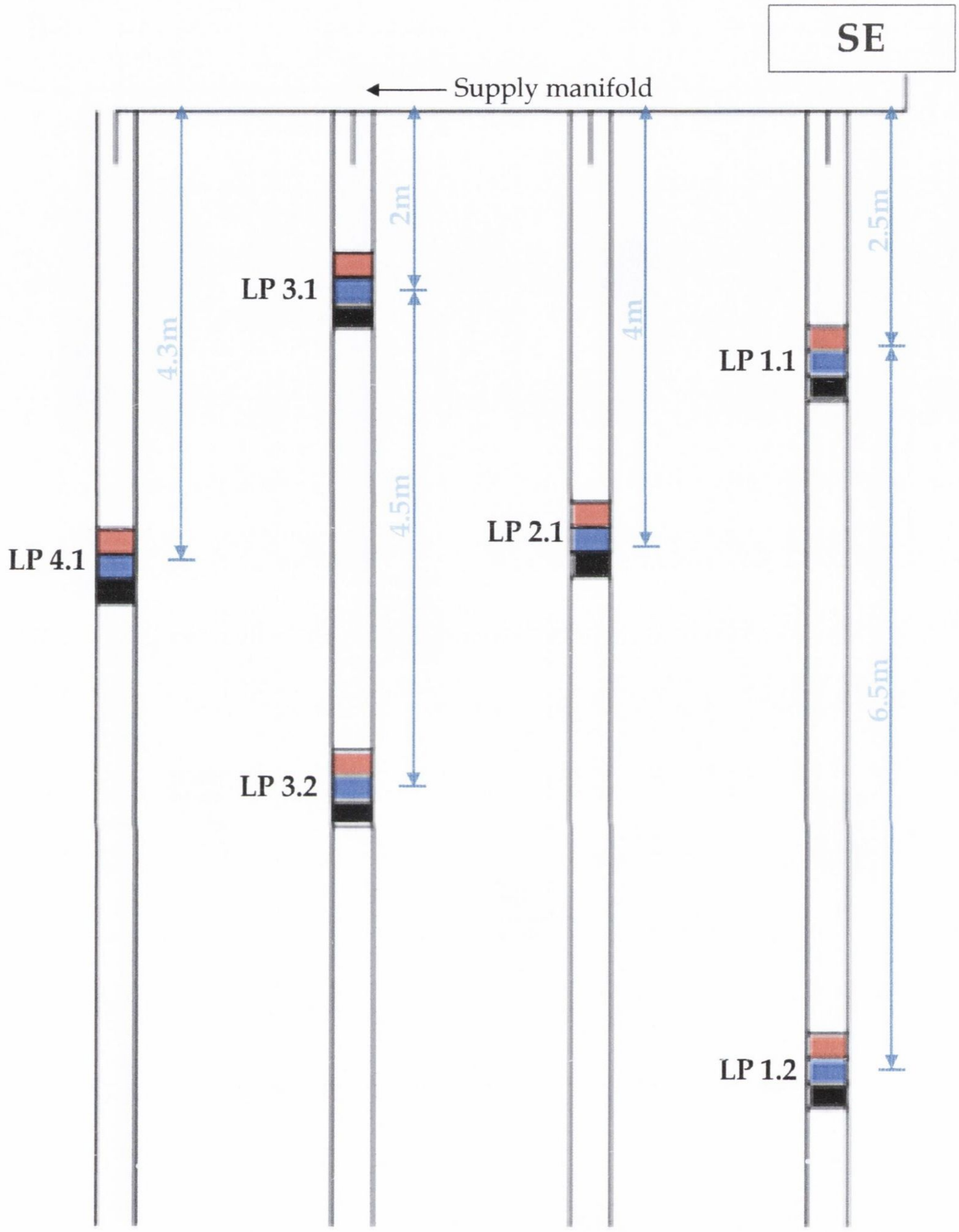
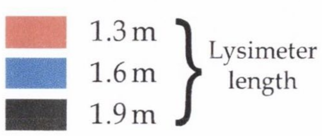


Figure 4.27 Labelling sequence for LPP soil moisture samples at Site B



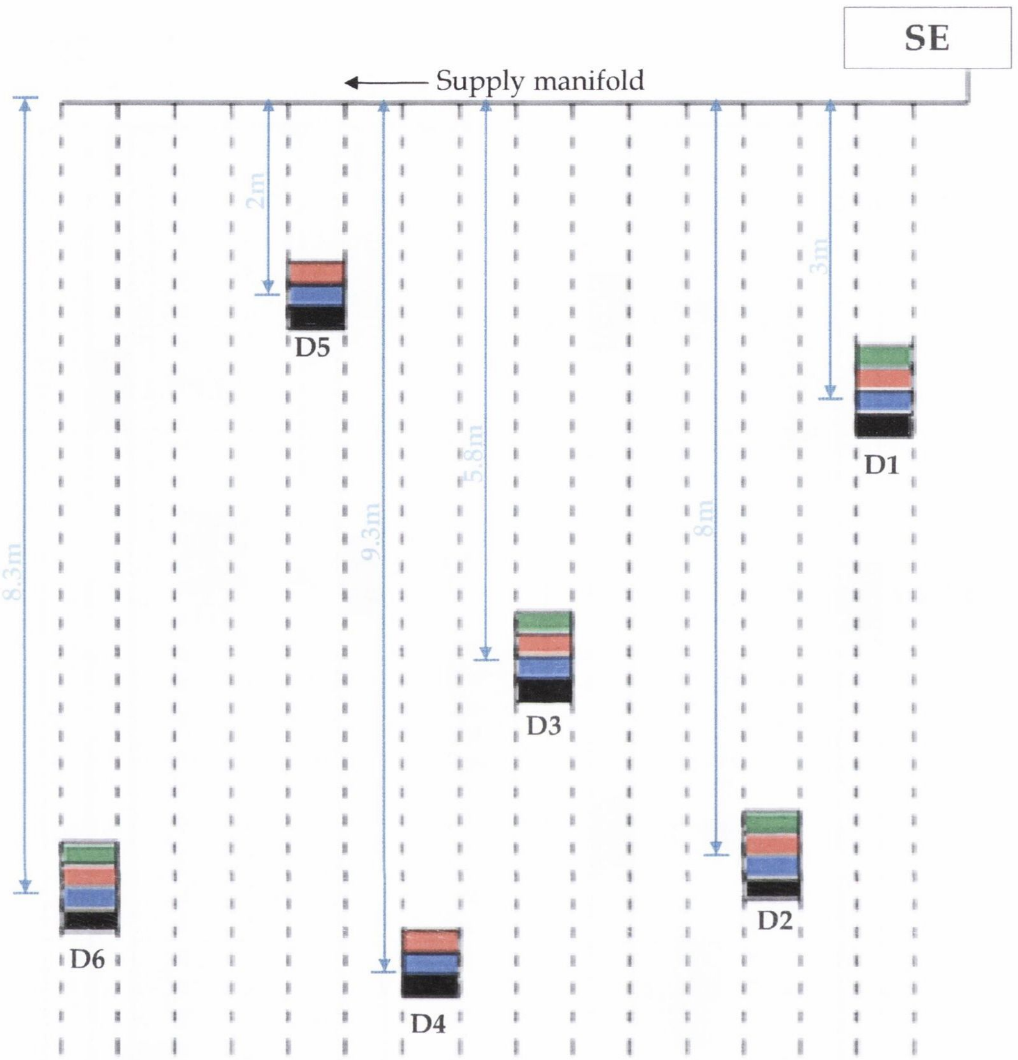
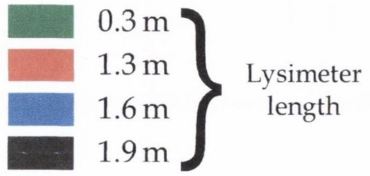


Figure 4.28 Labelling sequence for DD soil moisture samples at Site B



4.6.2 TENSIOMETER INSTALLATION AND MONITORING

A tensiometer is a device used to determine the matric potential, Ψ_m, of the soil, i.e. the force with which water is held in the soil. A matric potential exists in the soil when it is unsaturated and the water in the soil is under tension. As such, this measurement is more commonly referred to as the soil moisture tension. For this project Jet Fill Tensiometers (Soilmoisture Equipment Corporation) were used which consist of a water-filled tube closed at the bottom with a porous ceramic cup and with a jet-fill reservoir and sealed readout gauge at the top (Figure 4.29a).

(a)

(b)

Figure 4.29 (a) Jet Fill Tensiometer and (b) data logging tensiometer

Under saturated conditions, as water is pulled out of the soil by plant roots and evaporation, the water in the tensiometer is drawn through the porous cup until the moisture potential in the tensiometer is the same as the soil moisture potential. The vacuum inside the tensiometer tube increases in this case. In contrast, as the soil moisture content increases, the vacuum inside the tensiometer tube pulls moisture from the soil. The vacuum decreases accordingly.

When tensiometers are placed at different depths, as is the approach adopted for this project, the moisture status and pressure gradient within the soil profile can be characterised. As such, two clusters of tensiometers of different depths were installed beneath each of the systems at both Site A and Site B. As with the lysimeters the tensiometer nest were positions strategically to determine if the water potential in the soil was equal across the distribution systems. Under the LPP and DD system at each site tensiometers of 1.0 m (red), 1.5 m (blue) and 2.0 m (black) length were placed. Under the DD systems a 0.5 m (purple) tensiometer was also positioned at a single sampling location. Installation involved the uses of a gouge hand auger of 30 mm diameter after which the tensiometers were installed in the same fashion as the lysimeters. Prior to placing them in the tensiometers were filled to the top with de-aerated de-ionised water until the ceramic cup was saturate. A hand vacuum pump was used to ensure no air remained in the tensiometer or the attached dial gauge. The jet filled reservoir, also filled with de-aerated de-ionised water, was attached and pumped quickly 50 to 60 times for each tensiometer to ensure no further air bubbles were present.

The vacuum created in the tensiometer was read from the dial gauge in mbar during each sampling trip. During sustained dry periods with continuous unsaturated conditions, water levels in the tensiometers may drop and need to be topped up with de-aerated de-ionised water by pumping the jet filled reservoir as outlined above.

As well as the point readings taken during each sampling trip, one cluster of tensiometers at each site was connected to a CR800 data logger to allow continuous soil tension levels to be record between sampling trips (Figure 4.29b). At both sites the position of the data logging tensiometers was varied in order to access the performance of both systems during varying conditions.

4.6.3 Soil Moisture Probe Installation and Monitoring

PR2 Profile Probes (Delta-T Devices Ltd) were used to record the soil moisture levels beneath the LPP and DD systems at both sites. The profile probes consist of a 1 m sealed polycarbonate rod, 25 mm in diameter, with electronic sensors arranged at fixed intervals along its length.

Access tubes for the PR2 were installed within each system close to the tensiometer locations in order allow the comparison of results. A specially design augering kit, also from Delta-T Devices Ltd) was used to ensure the access tubes were installed correctly in good contact with the soil. This augering kit included a stabilisation plate and stakes, a 24 mm pilot auger, a finishing auger and a mallet. Using the stabilisation plate (Figure 4.30a) and pilot auger an initial 1 m hole was bored in the desired location (Figure 4.30b). Once the required depth was reached the finishing auger was used to carefully widen the bored hole until it is 28 mm in diameter (although the heterogeneity of soil makes this difficult to achieve). The access tube is then gently hammered into the bored hole with the sides flush to the surrounding subsoil. Once in place the stabilisation plate is removed and a rubber collar is placed around the top of the access tube and ground level to prevent any potential preferential flow of water down the sides of the access tube. A bung is fitted to the top of each access tube to prevent any water or soil entering.

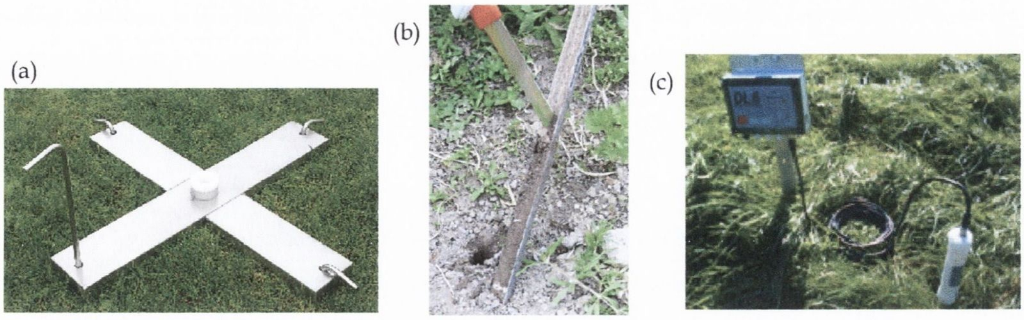


Figure 4.30 (a) soil moisture stabilisation plate, (b) soil moisture auger and (c) installed soil moisture probe and data logger

In total six access tubes were installed at Site A beneath the LPP and DD systems, whilst six were installed at Site B. Reference access tubes were also installed at both sites outside the distribution areas in order to record the natural variation in soil moisture levels of each location. During each sampling trip soil moisture readings were taken at location by inserting the profile probe into the access tube. These point readings were taken using a portable HH2 meter reader and soil moisture levels at 100 mm, 200 mm, 300 mm, 400 mm, 600 mm and 1 m depths where recorded. At each sampling point and average of three readings was taken with the tube rotated 120° each time to ensure accuracy.

Between sampling events a profile probe was left in place in a chosen access tube and connected to a DL6 Soil Moisture Logger (Delta-T Devices Ltd). This allowed the continuous logging of hourly soil moisture levels at the depths listed above at each site (Figure 4.30c). As there was only one profile probe per site the position of the logger and probe was moved a number of times on both sites over the course of the monitoring period in order to assess the performance of both systems and their performance under varying climatic conditions and effluent loadings.

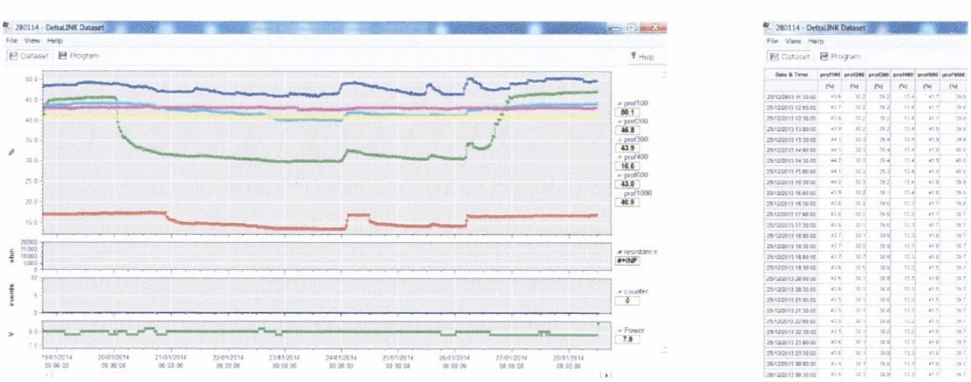


Figure 4.31 Output from DL6 logger in (a) chart format and (b) table format

Figure 4.31 shows the output from the DL6 datalogger. As well as producing a graphical output (Figure 4.30a) of the soil moisture readings at each depth (100, 200, 300, 400, 600 and 1000 mm) the soil moisture value (at intervals of 30 mins) for each depth is presented in tabular format which is easily exported to excel to allow analysis (Figure 4.31b).

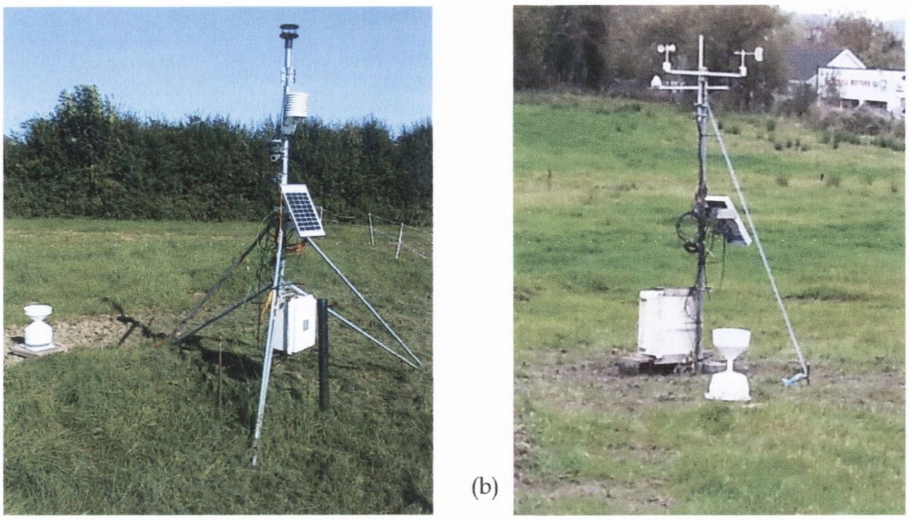
Although the profile probes worked well most of the time, although one drawback was they could not be used during rain. Water landing on the profile probe when moving it between access points could alter the results. Also, water entering the access tubes when the bungs were removed or following the insertion of a moist profile probe had the potential to compromise the accuracy of the readings. This was a difficulty as during wet weather readings could only be taken during breaks between showers.

4.7 METEOROLOGY

An important influence on both the existing soak-pit sites and the newly installed alternative infiltration systems was the effect of rainfall recharge on dilution and hydraulic conductivity of the subsoil. The rate of evapotranspiration was also a significant feature for the LPP and DD systems. In order to assess these meteorological effects on the percolation areas, appropriate data from weather stations and rain gauges was required. Due to the projects financial restrictions it was not possible to erect full weather stations at all six test sites. As such, weather stations were installed at Site A and Site B as the monitoring of the alternative infiltration systems was deemed most critical (Figure 4.31). For the remaining sites weather data from the nearest weather station to each site was attained from Met Éireann.

The weather stations complete with CR800 data loggers, installed at Site A and B, recorded temperature, wind speed, wind direction and solar radiation whilst a rain gauge recorded precipitation levels. In order to determine the potential evapotranspiration levels atmospheric pressure and relatively humidity data was also obtained from Met Éireann from the closest weather station available for each site.

At both sites the weather stations were located away from any obstacles or shading so as not to impede its operation. The rain gauges were secured and levelled on concrete slabs to ensure they remained steady throughout the monitoring phase. Data was collected from the weather stations during each sampling visit and a visual inspection the rain gauge was carried out to ensure it had not become clogged with leaves or insects. All meteorological data for each of the sites can be viewed in Appendix D.



(a) (b)

Figure 4.32 Weather stations installed at (a) Site A - Kilkenny and (b) Site B - Monaghan

4.8 ANALYSIS METHODOLOGY

4.8.1 SOIL MOISTURE SAMPLE COLLECTION

During each sampling trip soil moisture samples were collected using the vacuum pump, tubing and 1 L conical flask described previously. Each sample was collected, its total volume recorded, and transferred directly to 250 ml plastic sample bottles for chemical and bacteriological analysis. All 300 ml bottles were sterilised prior to each sampling event. Sample for phage analysis were collected in 30 ml Sterilin polystyrene containers. The samples were then transported directly to the Environmental Engineering Laboratory in TCD for analysis.

At both the pre-existing soak-pit sites and newly installed alternative infiltration systems lysimeters were installed at both multiple locations and depths. The number of sample points, variation in depth and sampling regime were implemented to address the potential for spatial variability of the field results. This allowed the comparison of results across each depth plane thus making it possible to identify the effect of any preferential flow paths within the subsoil.

4.8.2 CHEMICAL ANALYSIS

Monthly septic tank/secondary treated effluent, soil moisture and borehole samples were taken at each site and analysed for chemical oxygen demand (COD), ammonium (NH_4-N), nitrite (NO_2-N), nitrate (NO_3-N), orthophosphate (PO_4-P) and chloride (Cl) using a Merck Spectroquant Nova 60® spectrophotometer and associated US EPA approved reagent kits. The methods used for each test are detailed in Table 4.3.

Table 4.3 Chemical parameters monitored and methods used

Parameter	Range mg L^{-1}	Reference No.	Method
Total Nitrogen	10 - 150	1.14763	Oxidation, 2.6-Dimethylphenol
	5 - 15	1.00613	
Ammonia	5 - 150	1.00683	Indophenol blue
	0.01 - 3.0	1.14752	
Nitrate	0.1 - 25	1.09713	2.6-Dimethylphenol
Phosphate	0.01 - 25	1.14848	PMB
Chloride	10 - 250	1.14897	Iron (III)-thiocyanate
	2.5 - 25	1.14897	
COD	10 - 150	1.14682	Chromosulfuric acid oxidation

Analysis of total nitrogen (TN) was carried out in conjunction with a Hach Lange spectrophotometer DR2800. Concentrations of organic nitrogen (org-N) and total kjeldahl nitrogen (TKN) of the samples could then be deduced using TN, NH_4-N, NO_2-N and NO_3-N concentration results derived from laboratory analysis. Eqn. 4.1 was used to determine the inorganic-N concentrations while Eqn. 4.2 was used to determine the org-N concentrations. TKN concentrations were then calculated using Eqn. 4.3.

$$\text{Inorganic-N} = NH_4\text{-N} + NO_2\text{-N} + NO_3\text{-N} \quad \text{(Eqn. 4.1)}$$

$$\text{Organic-N} = TN - (NH_4\text{-N} + NO_2\text{-N} + NO_3\text{-N}) \quad \text{(Eqn. 4.2)}$$

$$TKN = \text{Organic-N} + NH_4\text{-N} \quad \text{(Eqn. 4.3)}$$

During the course of the sampling period, acquiring a sufficient sample volume of soil moisture and borehole samples at certain sites was problematic due to dry weather conditions. Where there was an insufficient volume to carry out zero dilution analysis of a sample dilutions were carried out with a known volume of distilled water. This was also the case if parameter concentrations were outside the detectable range for a specific reagent.

4.8.3 Quality Assurance and Control of Chemical Analysis

Throughout the course of the sampling period quality control measures were implemented to ensure the reliability of the results. Where a sample was diluted, an error in the analysis would be multiplied by the size of the dilution step in the reported concentration. To ensure accuracy, these dilutions were carried out in duplicate. During each sample run Merck Spectroquant® CombiCheck solutions were used for quality assurance for associated photometric methods (Table 4.4). These standard solutions were run alongside the collected samples allowing confirmation of the accuracy of the results for each chemical parameter. During the analysis samples with recorded values below the parameter's lowest detection limit were deemed negligible and assigned zero-values in calculations.

Table 4.4 List of parameters analysed, range of testing and degree of accuracy of quality control

Parameter	Range mg L^{-1}	Reference No.	CombiCheck No.	Accuracy mg L^{-1}
Total Nitrogen	10 - 150	1.14763	70	50 ± 7
	5 - 15	1.00613	50	5 ± 0.11
Ammonia	5 - 150	1.00683	70	50 ± 0.53
	0.01 - 3.0	1.14752	50	1 ± 0.023
Nitrate	0.1 - 25	1.09713	20	9 ± 0.11
Phosphate	0.01 - 25	1.14848	10	0.8 ± 0.08
Chloride	10 - 250	1.14897	60	125 ± 13
	2.5 - 25	1.14897	10	25 ± 6
COD	10 - 150	1.14682	10	30 ± 8

4.8.4 Bacteriological Analysis

All samples tested for chemical analysis were also tested for the presence of indicator athogenic bacteria. The presence of two common faecal indicators Total Coliforms (TC) and *E. coli* was determined using IDEXX Colilert–18 test kits. Colilert-18/Quanti-Tray is the International Organization for Standardization (ISO) worldwide standard for detecting TC and *E. coli* in water. This method uses Defined Substrate Technology® (DST®) nutrient indicators ONPG and MUG to detect coliforms and *E. coli*. Coliforms use their β-galactosidase enzyme to metabolize ONPG and change it from colourless to yellow whilst *E.coli* use β-glucuronidase to metabolize MUG and create fluorescence.

Colilert-18 was used in conjunction with 120 ml vessels (IDEXX) containing sodium thiosulfate which neutralises chlorine. 100 ml of sample was added to the 120 ml vessels along with a Colilert-18 sachet and mixed completely. This was then transferred to a 97-well Quanti-Tray®/2000 (IDEXX) and sealed and incubated for 18 hours. The Quanti-Tray quantification method is based on the Standard Methods Most Probable Number (MPN) model. Following the 18 hour incubation time the TC concentration was established by counting the number of yellow wells visible under natural light (Figure 4.33a). The *E. coli* concentration was established by counting the number of fluorescent wells under a UV light (Figure 4.33b). The MPN for each is then determined from the IDEXX Quanti-Tray®/2000 MPN Table. The maximum count (97 wells) of each tray only equates to 2 419 MPN 100 ml^{-1}, serial dilutions using sterilised water were prepared in the laboratory for both septic tank and secondary treated effluent samples. Dilutions of soil moisture samples were also necessary on occasion when sufficient volumes of samples were not obtained. In such cases, minimum counts for TC and *E. coli* increased relative to the dilution factor. This is displayed in the results (Appendix E) where the lowest detection limit varies depending on the extent of dilution.

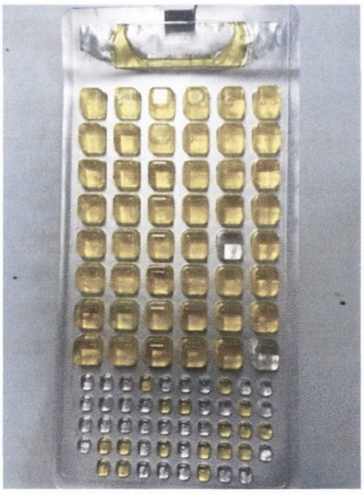
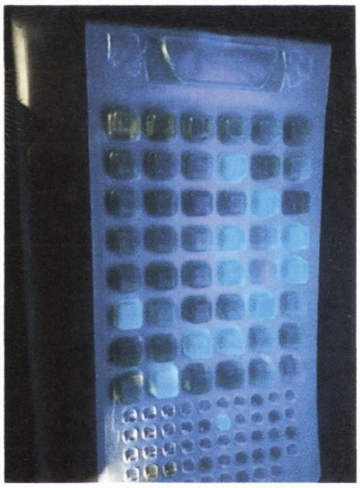
(a)  (b) 

Figure 4.33 Positive readings for (a) Total coliforms and (b) *E. coli*

4.8.5 Quality Assurance and Control of Bacteriological Analysis

Colilert®-18 / Quanti-Tray® is the International Organization for Standardization (ISO) standard 9308-2:2012. Colilert-18 is also US EPA-approved and included in Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF, 2012). However, to ensure the accuracy duplicates of random samples were carried out during each testing run to ensure accuracy.

4.8.6 Bacteriophage Analysis

Three bacteriophages, MS2, ΦX174 and PR772, were used in two tracer studies carried out following the installation of alternative infiltration systems at Site A and Site B. These bacteriophages were employed as surrogates for human enteric viruses to determine the viral treatment capacity of both systems at both sites.

MS2 is a F-RNA coliphage while ΦX174 and PR772 are DNA somatic coliphages. A profile of each of the three phages was previously presented in Section 2.7.4. While MS2 and ΦX174 have commonly been used in many environmental studies under both saturated and unsaturated subsoil conditions, PR772 is a relatively untried and untested phage in the field with its structure and DNA sequence only given attention in the more recent past.

All three bacteriophages were grown on their host *Escherichia coli* lawns by the agar-overlay method while enumeration of the phages was performed by the plaque forming unit (PFU) method described by Adams (1959). Single colonies of each *Escherichia coli* host were isolated by streaking them on to an agar plate (Figure 4.33) ensuring each host was uncontaminated prior to commencement. Assaying of the phage samples briefly involved the following techniques. Agar plates were prepared and allowed to dry for 2-3 days, with the bottom agar for the phage assays consisting of Trypticase soy broth (TSB) containing 15g of agar per litre. The host bacteria was mid-log phase (OD_{600mm} = 0.5). Top agar consisting of Trypticase soy broth containing (per litre) 7g of agar and 1 mL of 1M $CaCl^2$ was melted in a steamer after which 3.5 ml were aliquoted into a series of sterile culture tubes (one for every dilution plus one blank). The sterile tubes were then placed in a water bath and maintained at a temperature of 45°C. Serial dilutions of the phage sample were then prepared in TSB. The surface of the pre-warmed agar plates were overlaid with the 45°C melted top agar from each of the sterile tubes, of which 100µl of mid-log phase *Escherichia coli* host had been added. The plates were then incubated at room temperature for 1 - 5 minutes to allow the top agar to solidify. One drop of each phage dilution (25µl) was spotted on the surface of the prepared plates and allowed to cool for approximately 5 minutes. The plates were then inverted and incubated at 37°C for 24 hours to allow bacterial growth and semiconfluent lysis of the bacterial lawn by the phage. Phage enumeration was carried out using the Miles and Misera technique (Miles et al., 1938) with each plate split into four quarters for MS2 and PR772 and halves for ΦX174 (Figure 4.34).

Duplicates were carried out for each phage per quarter and were counted. Calculation of the quantity of phage present in the sample was then deduced using Eqn. 4.4:

$$\text{Phage Quantity (PFU ml}^{-1}\text{)} = \text{(No. of plaques on plate)} \times \text{(dilution factor)} \times 40 \qquad \text{(Eqn. 4.4)}$$

Bacteriophage stocks were propagated by preparing plates with the soft agar/host overlay just described, and covering the surface with approximately 0.5ml of the concentrated phage. After the plates were confluent with plaques (i.e. post 24-hr incubation), the soft agar was gently scraped off the surface and centrifuged at 1000 rpm for 25 minutes to sediment the cellular debris and agar. The supernatant was conserved and passed through a 0.22 µm Millipre filter and the filtrate stored at 4°C.

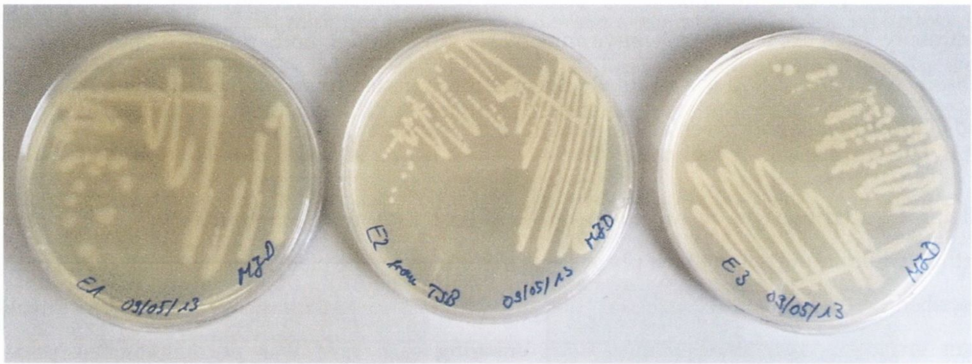


Figure 4.34 Preparation of *Escherichia coli* hosts

4.8.7 Quality Assurance and Control of Bacteriophage Analysis

Bacteriophage analysis was carried out in a carefully controlled sterile environment. The quantification of stock solutions was determined using triplicates of each dilution whilst the phage enumeration of soil moisture samples was carried out in duplicates (Figure 4.35). This ensured the reliability of the results of the viral studies.

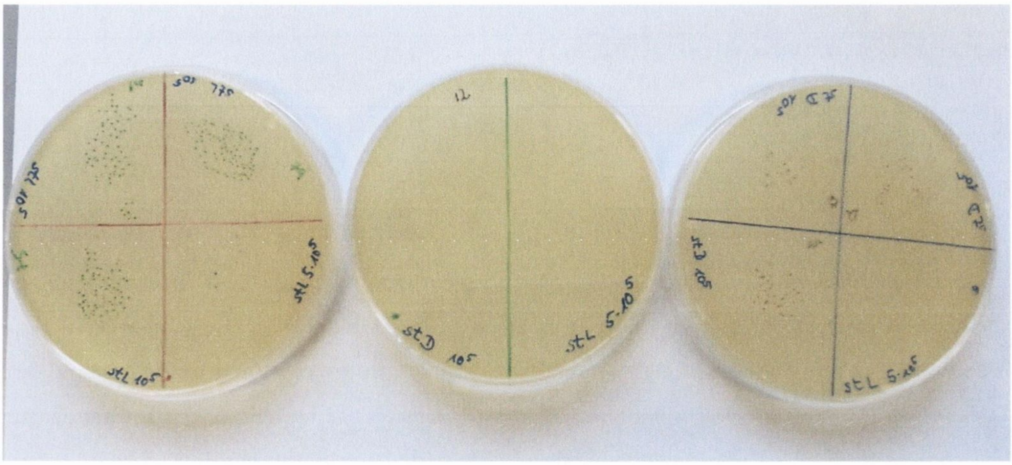


Figure 4.35 Quantification of phage presence

Chapter 5 On-Site Loadings

5.1 INTRODUCTION

Pollutant loadings for the existing septic tank soak-pit systems were assessed through sampling of the effluent prior to discharge via gravity to the soak-pit. Effluent quality was monitored for all sites excluding Site F where aforementioned difficulties with the condition of the existing septic tank prevented the retrieval of samples. In the absence of site specific data for these existing gravity systems the EPA recommended hydraulic loading of 150 l per capita was assumed for each of the four moderate to high permeability existing soak-pit systems. However, it should be noted that previous on-site studies in Ireland have found 101.3 l per capita to be a more realistic figure of effluent production (Dubber and Gill, 2014).

For each of the two upgraded sites, A and B, the hydraulic and pollutant loadings for the both the septic tank and secondary treatment units were measured and assessed during the second phase of the project. The flow data collected during this time was used to determine the average hydraulic loadings at both sites. Given the household populations at both sites remained the same over the entire project duration, the hydraulic loadings measured during the second phase of the project were deemed to be representative of the effluent production during the first phase also.

With the exception of Site B, each effluent treatment system was analysed based purely on its effluent quality over time as a means of determining the source chemical and bacteriological concentrations and loadings to subsoil percolation areas. At Site B primary treated wastewater from the household was sampled over a 6 month period to determine the treatment performance of the secondary treatment unit installed at the site. Results of chemical and bacterial effluent quality at all six sites are presented below.

As with the soil moisture and groundwater samples, effluent quality at each site was sampled and analysed on a monthly basis. Grab samples were taken from each septic tank during sampling runs to determine the pollutant concentrations being applied to the receiving subsoil at each site. Following the upgrade of Site A and B grab samples of secondary treated effluent were taken from both pumping chambers at each site to determine the pollutant loading to each dispersal network.

5.2 Site A (Co. Kilkenny)

5.2.1 Effluent Characteristics

At Site A, monitoring of the existing septic tank and soak-pit area took place from the 7th of December 2011 to the 17th of July 2012 inclusive (Appendix E). Following the upgrade of Site A to the alternative infiltration systems, the existing septic tank remained in operation and was monitored for a further period from the 9th November 2012 to 1st of October 2013. Table 5.1 summaries the chemical results of relating to the STE whilst Table 5.2 presents the bacteriological results across the entire monitoring period. On the 1st of October 2013 the sites effluent supply was switched from STE to SE effluent provided by means of an ASP (activated sludge plant) which had been installed at the site during the upgrade process. Following this switchover, effluent quality from the ASP unit was then monitored from the 1st of October to the 29th of January 2014 (Table 5.3 and 5.4). For each parameter the coefficient of variation (CV), also known as the relative standard deviation (RSD) is detailed. This is a normalised measure of dispersion of a probability distribution and is useful for comparing datasets with hugely different mean values (Brown and Mac Berthouex, 2002). CV values less than 1 are indicative of low variation in the sample values.

Table 5.1 Summary of chemical analysis of STE on Site A

Pollutant	n	Range ($mg\ L^{-1}$)	Mean Concentration (±sd)	CV	Mean Load[a] ($g\ d^{-1}$)
COD	19	226 - 720	**414** (±94.8)	0.2	153.9
BOD_5	1	n/a	**128.8**	n/a	47.9
TN	20	69.9 - 324	**129.6** (±57.9)	0.4	48.2
NH_4-N	14	17.7 - 146	**64.0** (±15.0)	0.2	23.8
NO_3-N	15	0.25 - 4	**1.4** (±1.2)	0.9	0.5
NO_2-N	11	0.0 - 0.31	**0.15** (±0.11)	0.7	0.1
Org-N	20	0.85 – 178.4	**82.4** (±60.8)	0.7	30.6
PO_4	20	5.98 - 39.8	**20.2** (±10.1)	0.5	7.5
Cl	21	68 - 230	**132.7** (±46.4)	0.3	49.3

[a] Based on an effluent flow of 371.84 l/d (as measured post remediation)

Table 5.2 Summary of bacteriological analysis of STE on Site A

Parameter	n	Range (MPN $100mL^{-1}$)	Geom.Mean (MPN $100mL^{-1}$)	CV[a]
Total Coliforms	21	7.94E+5 - 1.38E+9	9.08E+06	0.11
E. coli	21	1.35E+5 - 3.45E+8	2.23E+06	0.12

[a] calculated through conversion of coliform data to logarithmic scale

Table 5.3 Summary of chemical analysis of SE on Site A

Pollutant	n	Range (mg L^{-1})	Mean Concentration (±sd)	CV	Mean Load[a] (g d^{-1})
COD	3	49 - 68	**61** (±10.4)	0.2	22.7
TN	3	87.8 - 130	**109.9** (±21.2)	0.2	40.9
NH_4-N	3	0.25 - 3.5	**1.78** (±1.63)	0.9	0.7
NO_3-N	3	84.1 - 125	**106.3** (±20.61)	0.2	39.4
NO_2-N	3	0.02 - 0.09	**0.05** (±0.04)	0.7	0.02
Org-N	3	1.38 - 3.36	**2.07** (±1.12)	0.5	0.8
PO_4	3	9.5 - 17.7	**14.8** (±4.65)	0.3	5.5
Cl	3	82 - 103	**91** (±10.82)	0.1	33.8

[a] Based on effluent flow of 371.84 l/d

Table 5.4 Summary of bacteriological analysis of SE on Site A

Parameter	n	Range (MPN 100mL^{-1})	GeoMean (MPN 100mL^{-1})	CV
Total Coliforms	3	3.87E+5 - 6.49E+7	3.93E+06	0.17
E. coli	3	1.71E+4 - 2.46E+6	1.25E+05	0.22

The changeover from STE to SE resulted in a reduction in the concentration of effluent applied to the distribution systems at Site A. An average 85% reduction in the organics concentration was observed reducing the mean load to 22.7 g d^{-1}. As well as producing highly nitrified effluent in comparison with the STE, the secondary treatment unit resulted in a modest reduction (15%) in the overall total nitrogen loading. A decrease in PO_4-P in the SE is also noteworthy and is most likely as a result of bacteriological uptake in the aerated reactor. Finally, the ASP unit produced a 1.3 log reduction in *E. coli* concentrations. As the system was only receiving household effluent from the 1st of October 2013 onwards, the above concentrations represent the initial system start-up. This was particularly evident in the recorded *E. coli* concentrations which showed a reduction over the 3 month monitoring period (2.46 x 10^6, 4.64 x 10^4, and 1.71 x 10^4 in November, December and January respectively). As such the long term SE *E. coli* concentration may be lower than reported.

5.2.2 Effluent Hydraulic Loadings

The upgraded system at Site A was installed in August 2012. Upstream and downstream groundwater samples were taken in October 2012 however the first full sampling trip did not take place until the 9th of November 2012 when site instrumentation was complete. As outlined in Section 4.2.5, the measurement of flow levels to the pump sumps at Site A was achieved by means of a tipping bucket and reed switch in combination with a CR800 data logger. An energy meter was also used to determine the frequency of pumping to both distribution systems as well as the energy costs of both systems (Table 5.5). Both the reed switch and energy meter were installed on the 16th of January 2013 and operated from this time onwards. Apart from a few brief periods where data was not collected as a result of the system overloading trials or damage to cabling due to cattle, a continuous record of flow to each distribution system was recorded. During two overloading trials carried out at Site A during summer 2013 and winter 2013/2014 the tipping bucket was wedged so that the total effluent load was diverted to either the LPP system or the DD system for a period of 4 weeks each. During this time effluent discharge to the relevant system was determined from pumping frequency recorded by the energy meter.

Table 5.5 Energy consumption at Site A (from 16/01/2013 to 16/01/2014)

	kWh/yr	EUR/kWh[a]	EUR/yr
ASP Unit	254.04	0.1729	43.9
LPP Pump	29.32	0.1729	5.1
DD Pump	31.88	0.1729	5.5
		Total Cost	54.5
		Cost per person	18.2

[a] ESB Ireland

The mean flow measured on Site A was 371.8 L d^{-1} calculated by cumulating the number of tips (each representing a volume of 1.6 L) over a 24-hour period and averaging the resultant daily flow rates over the trial period. This figure equates to a mean effluent production per person of 123.9 litres per capita per day (L c^{-1} d^{-1}). Again, as found on other single houses monitored in the past, this is somewhat lower than the assumed value of 150 L c^{-1} d^{-1} outlined in the EPA Code of Practice (EPA, 2009a).

However, as effluent application to both the LPP and DD systems was via two separate pumping chambers the pumping frequency of both pumps needed to be accessed. This was done through the installation of an Elink energy meter which recorded how often the pumps operated. Details of both systems are outlined in Table 5.6.

Table 5.6 Site A - Operating Parameters

System	LPP	DD
Mean effluent loading[a]	185.9 l/day	185.9 l/day
Total footprint area	63.5m^2	66.8 m^2
Infiltration rate	2.9 l/m^2/day	2.8 l/m^2/day
Emitter discharge rate	-	0.03 l/minute
Dispersal events per day	2.05	4
Dispersal duration	1.06 min[b]	10 min
Dispersal volume	93 litres	60 litres

[a] Mean effluent loading to sumps based on tipping bucket data; [b] Based on pump design capacity of 88 l/minute

5.3 Site B (Co. Monaghan)

5.3.1 Effluent Characteristics

Monitoring of the existing septic tank and soak-pit area at Site B took place from the 29th of November 2011 to the 9th of August 2012 inclusive (Appendix E). Table 5.7 summaries the chemical results relating to the STE whilst Table 5.8 presents the bacteriological results. Again the CV is shown to be less than 1 for all STE constituents indicating low variance throughout.

Table 5.7 Summary of chemical analysis of STE on Site B

Pollutant	n	Range ($mg\ L^{-1}$)	Mean Concentration (±sd)	CV	Mean Load[a] ($g\ d^{-1}$)
COD	8	524 - 740	**639** (±88.8)	0.1	266
BOD_5	1	n/a	**234.1**	n/a	97.4
TN	9	40 - 160	**92.3** (±34.2)	0.4	38
NH_4-N	9	8.2 - 98.4	**44** (±30.2)	0.7	18
NO_3-N	9	1.3 - 23.7	**10** (±9.3)	0.9	4.2
NO_2-N	9	0.27 - 1.11	**1.0** (±0.3)	0.5	0.2
Org-N	9	13.7 - 74.5	**42.4** (±21.8)	0.5	18
PO_4	9	10.2 - 45.7	**26** (±11.1)	0.4	10.7
Cl	9	1200 - 2710	**2006** (±50.2)	0.3	835.1

[a] Based on effluent flow of 416 l/d(as measured post remediation)

Table 5.8 Summary of bacteriological analysis of STE on Site B

Parameter	n	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)	CV
Total Coliforms	9	1.53E+5 - 2.22E+6	5.78E+05	0.11
E. coli	9	7.5E+3 - 3.36E+5	5.59E+04	0.07

Results from the bacteriological analysis at Site B showed TC and *E. coli* concentrations were 1.2 and 1.6 log-unit lower than Site A respectively. Interestingly, results of bacteriological analysis of primary effluent (Table 5.12) shows higher concentrations of TC and *E. coli* in comparison with the pre-existing septic tank. As the householder was unable to provide details of the size or design of the septic tank, one conclusion is that the tank at Site B may have been substantially bigger than Site A thus increasing the effluent retention time and therefore facilitating higher natural die-off within the tank.

The upgraded system at Site B was installed in September 2012. Upstream and downstream groundwater samples were taken in October 2012 however the first full sampling trip did not take place until the 13th of November 2012 when site instrumentation was complete.

Following the upgrade of Site A to the alternative infiltration systems, the existing septic tank was decommissioned and secondary effluent treatment was provided by a Clereflo filter. Table 5.9 summarises the chemical results relating to the SE whilst Table 5.10 presents the bacteriological results across the entire monitoring period. For each parameter the coefficient of variation (CV) is detailed.

Table 5.9 Summary of chemical analysis of SE on Site B

Pollutant	n	Range (mg L^{-1})	Mean Concentration (±sd)	CV	Mean Load[a] (g d^{-1})
COD	15	27 - 351	**106.1** (±87.7)	0.8	44.2
TN	16	12.5 - 70.8	**30.6** (±16.5)	0.5	12.7
NH_4-N	16	0.9 – 14.4	**4.3** (±4.0)	0.9	1.8
NO_3-N	17	2.3 - 27.6	**17.2** (±7.8)	0.5	7.1
NO_2-N	17	0.05 - 1.4	**0.43** (±0.43)	0.98	0.18
Org-N	16	0.04 – 42.2	**9.3** (±11.8)	1.2	3.9
PO_4	17	1.9 - 19.2	**5.8** (±4.0)	0.7	2.4
Cl	17	299 - 1460	**516.1** (±302.9)	0.59	214.9

[a] Based on an effluent flow of 416 l/d

Table 5.10 Summary of analysis of bacteriological analysis of SE on Site B

Parameter	n	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)	CV
Total Coliforms	17	2.78E+4 - 1.20E+6	2.31E+05	0.08
E. coli	17	8.60E+1 - 1.61E+5	5.23E+03	0.26

Results show a significant improvement in effluent quality between the pre-existing septic tank and that of the newly installed secondary treatment unit. In particular a significant loss in total-N was consistently recorded between the primary settlement tank (STE) and filter effluent (SE). The sampled SE was not fully nitrified upon discharge from the filter, perhaps indicating the presence of saturated zones within the filter media. The presence of partially saturated conditions could also be responsible for the over reduction in total-N by facilitating the occurrence of both nitrification and denitrification within the filter media. A greater reduction in PO_4-P was also recorded in the SE at Site B in comparison with Site A; however, the capacity of the filter for PO_4-P adsorption will most likely decrease overtime. Again, as outlined above, the ASP unit at Site A had only been in operation for three months and so may not represent the future mean PO_4-P effluent concentrations. This must also be taken into account when comparing the improved pathogen removal at Site B.

Samples taken from the 4th of October 2013 to the 24th of January 2014 of the influent (primary treated) to the Clereflo filter is summarised in Tables 5.11 and 5.12. Overall an average COD removal rate of 82% was observed, whilst NH_4-N and PO_4-P where reduced by 98% and 67% respectively.

Table 5.11 Summary of chemical analysis of primary treated effluent on Site B

Pollutant	n	Range (mg L^{-1})	Mean Concentration (±sd)	CV	Mean Load[a] (g d^{-1})
COD	6	429 - 582	**496** (±59.9)	0.1	206.6
TN	6	74.6 - 103.0	**90.7** (±10.2)	0.1	37.8
NH_4-N	6	50 - 91	**71.2** (±17.7)	0.2	29.6
NO_3-N	6	0.6 - 1.6	**1.3** (±0.4)	0.3	0.5
NO_2-N	6	0.0 - 0.01	**0.01** (±0.01)	0.8	0.0
Org-N	6	5.8 - 33.4	**18.2** (±11.6)	0.6	7.6
PO_4	6	10.8 - 30.8	**16.4** (±7.3)	0.4	6.8
Cl	6	1005 - 1425	**1245.8** (±153.7)	0.1	518.8

[a] Based on effluent flow of 416 l/d

Table 5.12 Summary of bacteriological analysis of primary treated effluent at Site B

Parameter	n	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)	CV
Total Coliforms	6	1.82E+7 - 5.79E+7	2.48E+07	0.03
E. coli	6	9.30E+5 - 4.76E+6	2.56E+06	0.05

5.3.2 Effluent Hydraulic Loadings

As outlined in Chapter 4, measurement of levels within the LPP pumping chamber was monitored by means of a level sensor. As the total effluent loading from the secondary treatment unit discharged to the LPP sump, this allowed the total volume of each LPP pumping cycle to be determined. This level sensor was in operation from the 1st of November 2012 to 22nd of April 2013. At Site B, effluent was then divided between the LPP distribution area and the DD pump sump by means of a splitter valve. An energy meter was used to determine the frequency of pumping by the LPP pump and DD pump as well as the energy costs from the 14th February 2013 to the end of the monitoring period (Table 5.13).

Results of the energy usage at both upgraded sites show that despite the increased pumping costs associated with the biofilter at Site B (which achieves aeration by gravity and so effluent is discharged from the unit 2 m below ground level) the overall electricity consumption per capita is only a forth of the cost of the aeration unit installed at Site A. This suggests that the installation of a gravity filter is more economically sustainable overall than the installation of aerated flooded reactor.

Table 5.13 Energy consumption at Site B (from 14/02/2013 to 14/02/2014)

	kWh/yr	EUR/kWh	EUR/yr
LPP Pump Total	65.4	0.1729	11.3
LPP Pump (to LPP only)	28.79	0.1729	5.0
DD Pump	39.32	0.1729	6.8
		Total Cost	18.1
		Cost per person	4.5

[a] ESB Ireland

Apart from a few brief periods where data was not collected as a result of the system overloading trials or pumps stopped operating due to float faults, a continuous record of flow to each distribution system was recorded. At Site B a single overloading trial was carried out during winter 2013/2014 with the splitter valve jammed so that it could not alternate between outlets resulting in the total effluent load being diverted to either the LPP system or the DD sump for a period of 4 weeks each. The mean flow measured on Site A was 416.4 L d^{-1} calculated by cumulating the number of LPP pumping cycles over a 24-hour period and averaging the resultant daily flow rates over the trial period. This figure equates to a mean effluent production per person of 104.1 litres per capita per day (L c^{-1} d^{-1}). As with Site A, this is again lower than the assumed value of 150 L c^{-1} d^{-1} outlined in the EPA Code of Practice (EPA, 2009a). As the splitter valve did not split the effluent load evenly, the overall effluent loading to the DD was greater than that to the LPP system (Table 5.14).

Table 5.14 Site B - Operating Parameters

System	LPP	DD
Mean effluent loading[a]	171.2 l/day	253.9 l/day
Total footprint area	75.01 m^2	91.08 m^2
Infiltration rate	2.3 l/m^2/day	2.8 l/m^2/day
Emitter discharge rate	-	0.03 l/minute
Dispersal events per day	5[b]	4
Dispersal duration	1 min[c]	12 min
Dispersal volume	87.4 litres	72 litres

[a]Mean effluent loading to sumps based on Orpheus data; [b]Split between LPP trenches and DD sump; [c]Based on pump design capacity of 88 l/minute

5.4 SITE C (BRIARLEAS) – EFFLUENT CHARACTERISTICS

On Site C, monitoring of the existing septic tank and soak-pit area took place from the 9th of May 2013 to the 16th of January 2014 inclusive (Appendix E). Table 5.15 summarises the chemical results of relating to the STE whilst Table 5.16 presents the bacteriological results.

Table 5.15 Summary of chemical analysis of STE on Site C

Pollutant	n	Range (mg/l)	Mean Concentration (±sd)	CV	Mean Load[a] (g/d)
COD	7	145 - 750	**551.3** (±224.6)	0.4	248.1
TN	7	55 -89.8	**75.1** (±13.3)	0.2	33.8
NH_4-N	7	44.4 -90	**69.6** (±16.9)	0.2	31.3
NO_3-N	7	0.9 - 1.7	**1.27** (±0.31)	0.3	0.57
NO_2-N	7	0 - 0.19	**0.09** (±0.08)	0.9	0.04
Org-N	4	3.2 - 22.5	**12.5** (±10.3)	0.8	5.62
PO_4	7	9 - 13.15	**10.3** (±1.52)	0.2	4.6
Cl	7	37 - 296	**115.6** (±84.1)	0.7	52.0

[a] based on assumed effluent flow of 450 l/d

Table 5.16 Summary of bacteriological analysis of STE on Site C

Parameter	n	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)	CV
Total Coliforms	7	6.51E+5 - 5.24E+7	8.25E+06	0.11
E. coli	7	3.76E+5 - 2.62E+7	3.11E+06	0.10

Effluent samples from the septic tank system at Site C were taken from a designated effluent inspection chamber installed downstream of the tank outlet. The STE was found to contain a high organic fraction throughout the duration of the monitoring period. The nitrogen concentration was predominantly in the form of NH_4-N. The site recorded the lowest mean PO_4-P concentration in comparison with the other septic tanks monitored during the project.

5.5 SITE D (IRISHTOWN) – EFFLUENT CHARACTERISTICS

Monitoring of the existing septic tank and soak-pit area at Site D took place from the 9th of May 2013 to the 16th of January 2014 inclusive (Appendix E). Table 5.17 summarises the chemical results of relating to the STE whilst Table 5.18 presents the bacteriological results.

Table 5.17 Summary of chemical analysis of STE on Site D

Pollutant	n	Range (mg/l)	Mean Concentration (±sd)	CV	Mean Load[a] (g/d)
COD	7	220 - 495	**312.1** (±91.9)	0.3	140.5
TN	7	165 - 300	**232.3** (±45.4)	0.2	104.5
NH_4-N	7	129.5 - 294	**216** (±65.2)	0.3	97.2
NO_3-N	7	1.0 - 2.9	**1.8** (±0.7)	0.4	0.95
NO_2-N	7	0.1 - 0.3	**0.2** (±0.1)	0.7	0.09
Org-N	3	7.4 - 78.7	**39.2** (±35.7)	0.9	17.6
PO_4	7	18.4 - 54.2	**28.9** (±12.7)	0.4	13.0
Cl	7	120 - 243	**187.4** (±48.3)	0.3	84.3

[a] based on assumed effluent flow of 450 l/d

Table 5.18 Summary of bacteriological analysis of STE on Site D

Parameter	n	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)	CV
Total Coliforms	7	1.0E+5 - 5.04E+6	1.33E+06	0.11
E.coli	7	1.0E+5 - 3.18E+6	6.34E+05	0.09

The high nitrogen concentration of the STE at Site D was found to be predominantly in the form of NH_4-N and was significantly higher than the concentrations recorded for the other septic tank systems. Ortho-P concentrations at Site C were also elevated in comparison with the STE from the other sites which may have been as a result of the grey water diversion in operation.

5.6 Site E (Westmeath) – Effluent Characteristics

On Site E, monitoring of the existing septic tank and soak-pit area took place from the 7[th] of March 2013 to the 14[th] of January 2014 inclusive (Appendix E). Table 5.19 summarises the chemical results of relating to the STE whilst Table 5.20 presents the bacteriological results.

Table 5.19 Summary of chemical analysis of STE on Site E

Pollutant	n	Range (mg L^{-1})	Mean Concentration (±sd)	CV	Mean Load[a] (g d^{-1})
COD	8	106.4 - 777	**445.3** (±235.2)	0.5	167
TN	8	80.4 - 173.4	**125.7** (±33.0)	0.3	47.1
NH_4-N	7	33.3 - 143	**106.5** (±42.6)	0.4	40
NO_3-N	5	2 - 4.9	**2.8** (±1.2)	0.4	1.04
NO_2-N	6	0.02 - 0.36	**0.2** (±0.1)	0.8	0.07
Org-N	5	3.4 – 62.1	**32.4** (±22.4)	0.7	12.2
PO_4	8	10.7 - 20.3	**15.9** (±3.3)	0.2	6.0
Cl	8	118 - 162	**133.8** (±16.0)	0.1	50.2

[a] based on assumed effluent flow of 375 l/d

Table 5.20 Summary of bacteriological analysis of STE on Site E

Parameter	n	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)	CV
Total Coliforms	7	3.53E+6 - 1.79E+7	9.86E+06	0.03
E.coli	7	6.20E+5 - 5.80E+6	3.12E+06	0.05

Concentrations of chemical and bacteriological constituents within the STE at Site E were within the expected ranges. Again NH_4-N was the predominant form of nitrogen present and high levels of *E. coli* were recorded throughout the sampling phase.

5.7 Site F (Co. Cork) – Effluent Characteristics

Monitoring at Site F took place between the 15th of January and the 10th of December 2013. As outlined previously, STE samples for Site F were unable to be retrieved over the course of the sampling period. As such, the overall mean effluent results recorded at Sites A to E (Tables 5.21 and 5.22) are assumed to be representative of the pollutant loadings at Site F.

Table 5.21 Mean values of chemical analysis of STE quality at Sites A - E

Parameter	Range (mg L^{-1})	Mean Concentration (±SD)
COD	312 – 639	**472** (± 126)
TN	75 – 232	**131** (± 61)
NH_4	44 – 216	**100** (± 69)
NO_2	0.1 – 1.0	**0.3** (± 0.4)
NO_3	1.3 - 10	**3.5** (± 3.7)
Org-N	13 – 82	**42** (± 26)
PO_4	10 – 29	**20** (± 8.0)
Cl	116 - 2006	**515** (± 834)

Table 5.22 Mean values of bacteriological analysis of STE quality at Sites A - E

Parameter	Range (MPN $100mL^{-1}$)	GeoMean (MPN $100mL^{-1}$)
Total Coliforms	5.78E+05 - 9.86E+06	5.05E+06
E. Coli	5.59E+04 - 3.12E+06	1.66E+06

A comparison of the mean septic tank effluent concentrations for each of the five sites monitored is shown in Tables 5.23 and 5.24. Overall the recorded STE concentrations are comparable with previous field studies carried out in Ireland (Table 5.25). As with the previous research mean COD, TN and Ortho-P values were found to be higher than those outlined by EPA (2000). Mean Cl concentrations were found to be greatly elevated in comparison with previous research, however this was due to the high concentrations recorded at Site B. With the exclusion of Site B, the mean concentration of the remaining sites is 142 mg L^{-1} and is line with Table 5.25. Overall slightly lower TC and *E. coli* concentrations were recorded at the sites in comparison with Table 5.25.

Table 5.23 Mean STE concentrations of chemical constituents recorded during sampling

Pollutant	Mean Load (g d^{-1})				
	Site A	Site B	Site C	Site D	Site E
COD	153.9	266	248.1	140.5	167
BOD_5	47.9	97.4	-	-	-
TN	48.2	38	33.8	104.5	47.1
NH_4-N	23.8	18	31.3	97.2	40
NO_3-N	0.5	4.2	0.57	0.95	1.04
NO_2-N	0.1	0.2	0.04	0.09	0.07
Org-N	30.6	18	5.62	17.6	12.2
PO_4	7.5	10.7	4.6	13	6
Cl	49.3	835.1	52	84.3	50.2

Table 5.24 Geometric mean STE concentrations of bacteria recorded during sampling

Pollutant	Geom. Mean (MPN $100mL^{-1}$)				
	Site A	Site B	Site C	Site D	Site E
Total Coliforms	9.08E+06	5.78E+05	8.25E+06	1.33E+06	9.86E+06
E. coli	2.23E+06	5.59E+04	3.11E+06	6.34E+05	3.12E+06

Table 5.25 Characteristics of domestic wastewater from a single house (EPA, 2000) and previous field studies carried out in Ireland shown in brackets

Parameter	Mean Concentration (mg L^{-1})
COD (mg L^{-1})	400 (580)
Total N (mg L^{-1})	50 (121)
Total P (mg L^{-1})	10 (18.1)
Cl (mg L^{-1})	n/a (134)
Total Coliforms (MPN 100mL^{-1})	10^7 - 10^8 (1.8x 10^7)
E. coli **(MPN 100mL^{-1})**	n/a ((1.8x 10^6)

Chapter 6 Existing Septic Tank Soak-pit Systems

6.1 INTRODUCTION

As outlined in Chapter 4, the initial phase of the project involved the assessment of the treatment performance of traditional pre-existing on-site systems in the form of septic tank soak-pits. Soak-pit systems comprising of a septic tank discharging by a single gravity pipe to a backfilled stone pit were identified at six sites across Ireland within subsoils of varying permeability. A recap of the characteristics of each of the six selected sites is provided in Table 6.1.

Table 6.1 Characteristics of soak-pit sites across a range of subsoil permeabilities

Site	PE	K_{fs} (m d^{-1})	Permeability Classification	Subsoil Classification[a]	Groundwater Vulnerability[b]
A	3	0.059	Low	Sandy SILT/CLAY	Moderate
B	4	0.061	Low	SILT/CLAY	Moderate
C	3	0.21	Moderate	Gravelly SAND and SILT/CLAY	High
D	3	0.37	Moderate	Gravelly SAND	High
E	2/3	1.39	High	Gravelly SAND	High
F	5	0.56	High	Silty SAND	Extreme/High

[a] carried out in accordance with BSI (1999); [b] DELG, EPA, GSI (2004)

6.2 LOW PERMEABILITY SOAK-PIT PERFORMANCE

6.2.1 SITE A (CO. KILKENNY)

The existing system at Site A consisted of a traditional septic tank discharging by gravity to soak-pit. As appears to be the case with many on-site systems across Ireland, the effluent discharge point at the site was located adjacent to a drainage ditch (Figure 4.11). In order to determine the extent of the effluent plume arising from the soak-pit system suction lysimeters were installed within the surrounding subsoil as well as within the aforementioned ditch as outlined in Section 4.3.1 and presented in Figure 6.1.

Following the successful instrumentation of the site, soil moisture samples were collected on a monthly basis from the 7th of December 2011 to the 17th of July 2012. Samples were then transported directly to the TCD laboratory for analysis for a range of parameters with the aim of determining the treatment performance of the system.

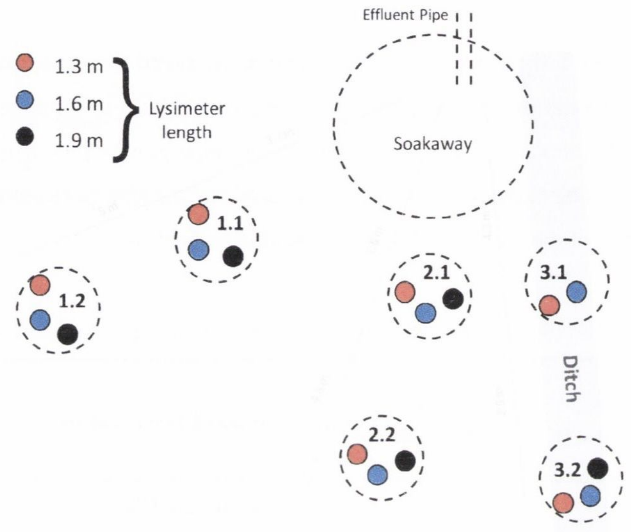


Figure 6.1 Plan of instrumentation at Site A (pre-remediation)

As Cl is regarded as a non-reactive chemical the initial assessment of the location of effluent migration beneath the surface was done by analysing the Cl concentrations recorded at the site throughout the sampling period. Figure 6.2 depicts the mean Cl concentrations recorded at each sampling location.

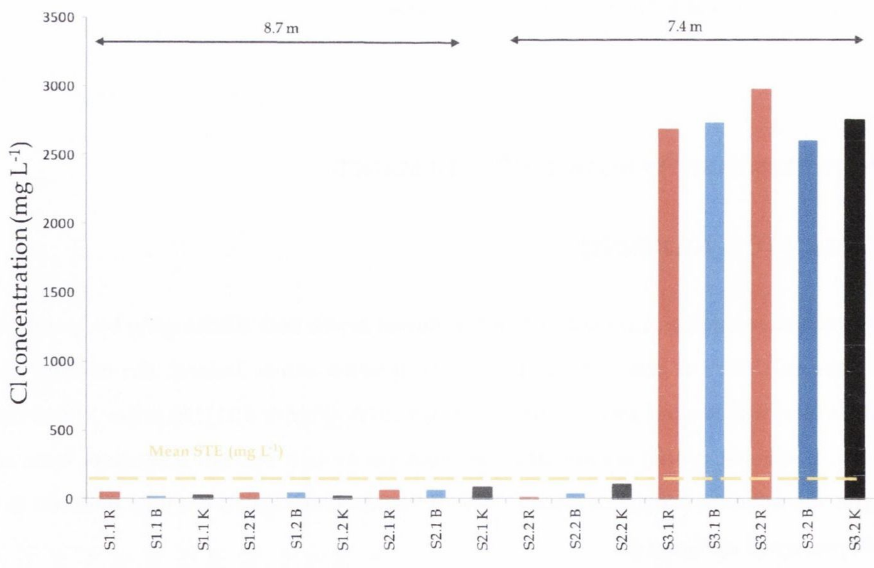


Figure 6.2 Mean Cl concentrations across all sample locations

From this it is immediately apparent that Cl concentrations recorded at both lysimeter nests S3.1 and S3.2 located within the ditch were well in excess of the remaining soil moisture samples as well as the applied mean STE concentration (132.7 mg L^{-1}). The reason for such high levels is unclear given that Cl does not form complexes readily and shows little affinity or specificity in its adsorption to soil components and as such its movement is largely determined by water flow (White and Broadley, 2001). The source of continually high concentrations over the monitoring period is therefore unknown, however, given that the site's existing (and historical) use is cattle grazing one possibility is that the remains of a mineral supplement for cattle (salt lick) had been discarded within the ditch at some point in the past. Typical compositions of such mineral supplements include 95.73% NaCl (sodium chloride) and 1.24% KCl (potassium chloride) and would account for the elevated levels observed at the site.

Analysis of the mean Cl concentrations recorded at the remaining sampling positions within the subsoil is detailed in Figure 6.3. From this, elevated mean Cl concentrations can be seen have to occurred at the "black" depth planes of S2.1 and S2.2 however it is unclear if this is the influence of effluent presence or as a result of a combination of effluent discharge and their proximity to the drainage ditch.

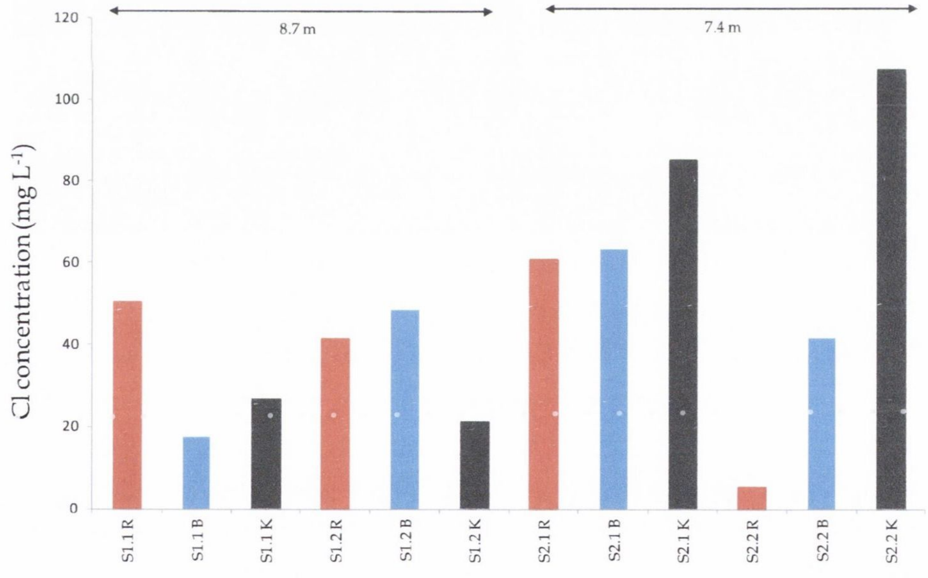


Figure 6.3 Mean Cl concentrations of soil moisture sample from subsoil lysimeters only

Due to the difficulties in interpreting the Cl results a visual assessment of the site proved beneficial in determining the fate of the discharging effluent. During site instrumentation in October 2011 effluent ponding at the surface of the drainage ditch was observed (Figure 6.4) indicating this was likely to be the primary route of effluent movement particularly during/following periods of rainfall recharge. The low permeability of the surrounding subsoil and intense loading into the small soak-pit prevented adequate drainage and so effluent was pushed to the surface and moved laterally along the surface of the ditch. A GPS study of the site (Figure 4.10) confirmed this was in fact the direction of the overall gradient of the site and its surrounding area. Effluent ponding was not observed directly above the soak-pit system throughout the monitoring period, however, during the upgrade of the site in August 2012 it was discovered that a plastic lining had been placed over the soak-pit beneath the soil surface to prevent such an occurrence.

Figure 6.4 Effluent ponding at surface of drainage ditch

Since analysis of the Cl concentrations proved inconclusive as to the location of the effluent plume, the other measured contaminants were analysed across all lysimeters in order to see whether evidence of the plume could be picked up at the different depth profiles. Table 6.2 details the reduction in organics recorded across each of the sample depth planes over the course of the monitoring period. Overall high removal rates were achieved at all depth planes as illustrated in Figure 6.5. The plot shows only a minor increase in COD concentrations at sample positions 3.1 blue and 3.2 red located within the ditch. As the existing soak-pit system had been in operation for over 20 years it is reasonable to assume significant biomat formation within the soak-pit. This is assumed to be responsible for the reduction in COD recorded at the site. The marginal increase in COD levels in samples retrieved from the drainage ditch is most likely due an increase in saturated conditions within the soil matrix at this point.

Table 6.2 Reduction in COD concentration with respect to STE at each sample depth plane

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	414	-
1.3 m	37.0	91%
1.6 m	35.0	92%
1.9 m	26.0	94%

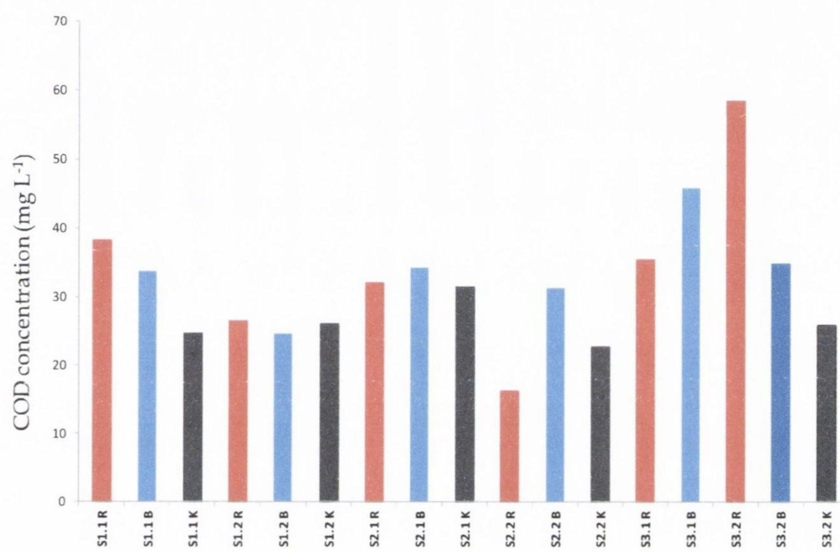


Figure 6.5 Mean COD concentrations at each sample location at Site A

The overall uniformity of COD concentrations did not provide any further insight into the extent of the effluent plume at Site A. Analysis of NH_4-N and NO_3-N results however gave a much greater indication of the fate of the effluent within the subsoil. Figure 6.6 shows significantly higher levels of mean NH_4-N concentrations at all three depth planes at the S2.1 sample position indicating the presence of percolating effluent. Figure 6.7 also shows an increase in mean NO_3-N concentrations at this location. No such increase in NH_4-N or NO_3-N was observed at sample point S2.2 black indicating that the high Cl concentrations recorded at this location were not due to the presence of percolating effluent and more likely as a result of its proximity to the drainage ditch.

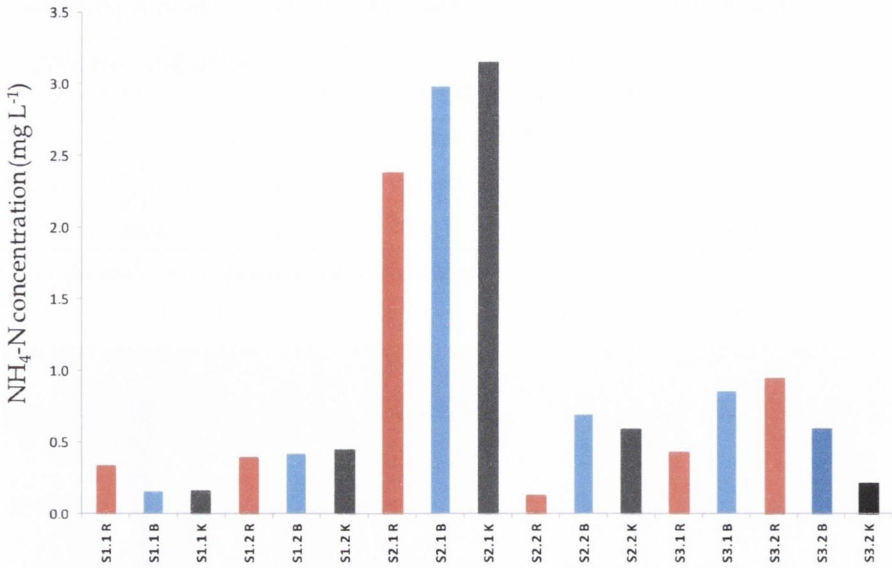


Figure 6.6 Mean NH_4-N concentration at each sample location at Site A

An elevation in NH_4-N concentrations was also apparent at the S3.1 and S3.2 sample positions; however NO_3-N concentrations remained low which was attributed to the saturated conditions present below the ditch. These observed NH_4-N concentrations confirm a percentage of the effluent is indeed travelling along this drainage route however it is not the sole effluent pathway as initially assumed.

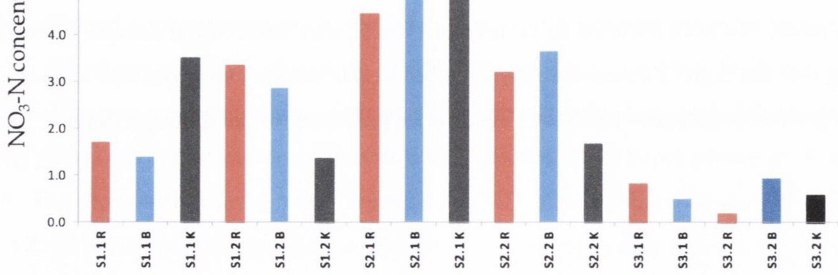


Figure 6.7 Mean NO_3-N concentrations at each sample location at Site A

A closer examination of the temporal fluctuation in concentrations against effective rainfall occurring at S2.1 reveals the concentrations of NH_4-N and NO_3-N were influenced by degree of saturation of the subsoil as detailed in Figure 6.8.

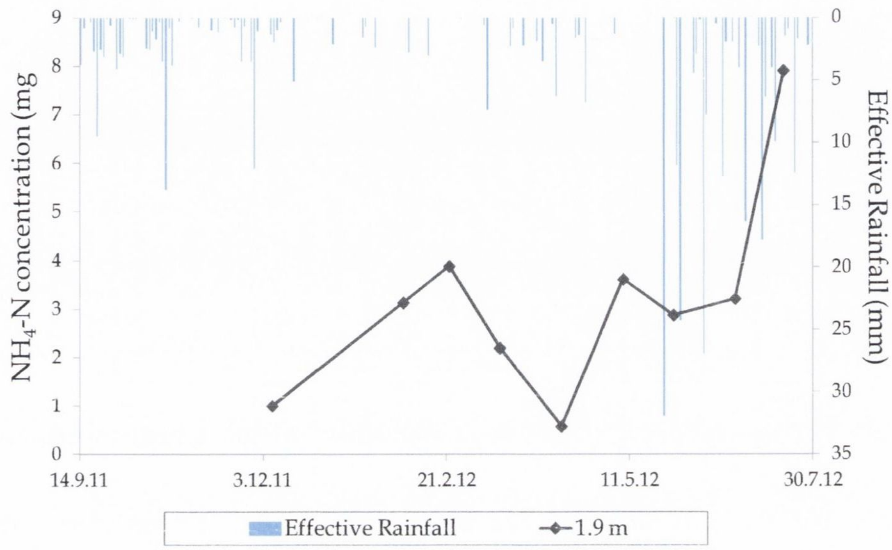


Figure 6.8 Time series plot of NH_4-N concentrations at S2.1 Black in response to effective rainfall

From this plot a significant rise in NH_4-N concentrations is apparent following an increase in effective rainfall levels between May and July 2012 as a result of reduced nitrification as the level of saturation in the subsoil increases. In contrast to this a decrease in NH_4-N concentrations in Figure 6.8 corresponds to a significant increase in NO_3-N levels at the same sample position (Figure 6.9) following a period of reduced effective rainfall.

Given the low permeability nature of the subsoil, changes in soil moisture contents occur gradually as water drains slowly from the small pore spaces between the clay particles. As such, changes in the subsurface water content would also be expected to change gradually. Although Figure 6.8 and 6.9 appear to shown sudden increases in NH_4-N and NO_3-N respectively, these are based on single monthly samples at each depth plane. In reality, the increase in NH_4-N and NO_3-N is more likely to occur at a more gradual rate owing to the lag-time between rainfall events and the consequential impact on subsurface water concentrations and reactions.

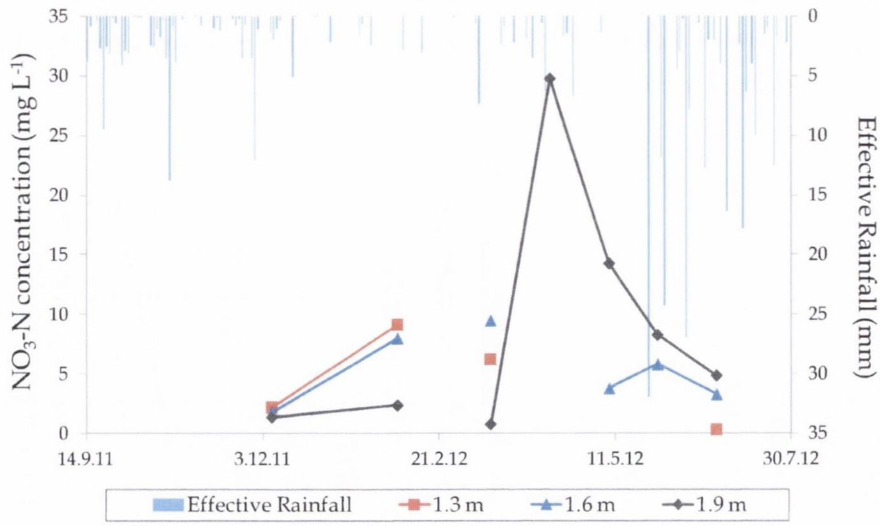


Figure 6.9 Time series plot of NO_3-N concentrations at S2.1 in response to effective rainfall

Overall analysis of the NH_4-N and NO_3-N results indicated that S2.1, 3.1 and 3.2 are primarily influenced by percolate from the soak-pit. As such, the breakdown of inorganic-N within the subsoil (S2.1) and within in the drainage ditch (S3.1 and S3.2) are presented below. Tables 6.3 and 6.4 show that the percolate is not fully nitrified by the black depth plane at S2.1 however an overall reduction of 84% was achieved.

Table 6.3 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes at S2.1

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})
STE	64	0.15	1.4	65.6
1.3 m	1.4	0.10	2.2	3.7
1.6 m	1.9	0.20	2.6	4.7
1.9 m	3.2	0.20	6.9	10.3

Table 6.4 Average breakdown of total inorganic-N in STE and across the three depth planes at S2.1

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	97.6%	0.2%	2.1%
1.3 m	37.8%	2.7%	59.5%
1.6 m	40.4%	4.3%	55.3%
1.9 m	31.1%	1.9%	67.0%

Tables 6.5 and 6.6 show that lower inorganic-N concentrations were recorded within the drainage ditch (S3.1 and S3.2) where a reduction of 99% in inorganic-N with respect to the applied STE was observed. Again complete nitrification of the effluent was not shown to have taken place. The improved reduction in comparison with S2.1 may be as a result of increased dilution and/or increased denitrification as a result of the saturated conditions in the drainage ditch.

Table 6.5 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes at S3.1 and S3.2

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})
STE	64	0.15	1.4	65.6
1.3 m	0.7	0.06	0.5	1.3
1.6 m	0.7	0.05	0.7	1.5
1.9 m	0.2	0.06	0.6	0.9

Table 6.6 Average breakdown of total inorganic-N in STE and across the three depth planes at S3.1 and S3.2

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	98%	0.2%	2.1%
1.3 m	56%	4.8%	40%
1.6 m	48%	3.4%	48%
1.9 m	23%	7.0%	70%

Removal of phosphorus from the percolate in the subsoil is typically due to soil adsorption and mineral precipitation processes. The P-fixation capacity of a soil is dependent on a number of factors, particularly its percentage clay fraction, the presence of Al, Fe or Mn in acidic soils, either as dissolved ions, as oxides or as hydrous oxides, and the presence of Ca in alkaline soils. Analysis of the PO_4-P concentrations in the STE and at the three depth planes at S2.1 reveals a minimum reduction rate of 86% at the blue depth plane (Table 6.7).

Table 6.8 shows the reduction in PO_4-P recorded in the drainage ditch. Again the reduced concentrations in comparison with those recorded within the subsoil indicate an increased degree of dilution at this location. Although a systemic decrease in mean PO_4-P concentrations is not apparent across the sample positions (Figure 6.10) the presence of a 20% clay fraction in the subsoil is thought to be responsible for the reduction in concentrations by providing a high P-sorption capacity. X-ray diffraction (XRD) analysis of soil samples from the site showed the mineral composition was predominately quartz, dolomite and muscovite with a small proportion of calcite and clinochlore ferroan. This suggests the presence of Ca, Fe and Al may also play a role in the soils capacity to fix phosphate with moderate pH levels recorded over the monitoring period, with Arias et al. (2001) reporting that at pH levels greater than 6 the reactions are a combination of physical adsorption to Fe and Al oxides and precipitation as sparingly soluble calcium phosphates.

Table 6.7 Reduction in PO_4-P concentration wrt STE at each depth plane at S2.1

	Mean Conc. ($mg\ L^{-1}$)	Reduction (wrt STE) (%)
STE	20.2	-
1.3 m	0.94	95%
1.6 m	2.77	86%
1.9 m	1.48	93%

Table 6.8 Reduction in PO_4-P concentration wrt STE at each depth plane at S3.1 and S3.2

	Mean Conc. ($mg\ L^{-1}$)	Reduction (wrt STE) (%)
STE	20.2	-
1.3 m	0.45	97.8%
1.6 m	0.71	96.5%
1.9 m	0.09	99.6%

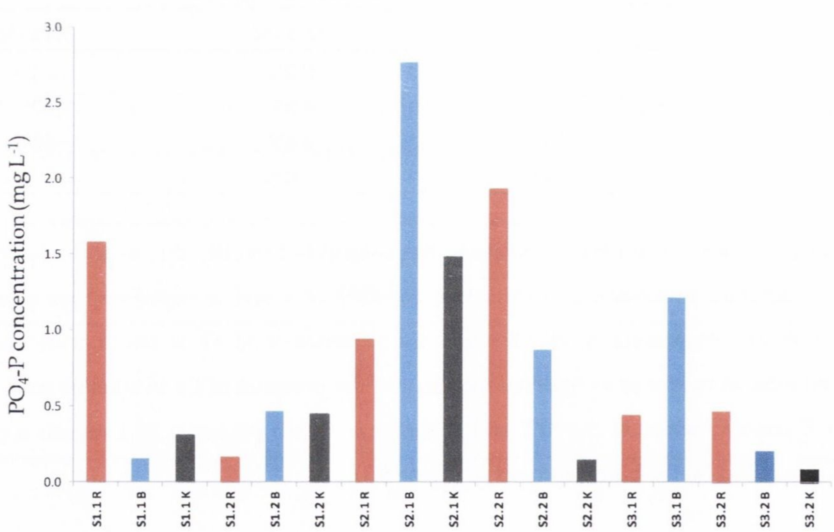


Figure 6.10 Mean PO_4-P concentrations at each sample location at Site A

As with the reduction in organics, the reduction in TC presented in Table 6.9 is believed to be primarily as a result of physical straining, by the assumed biomat layer within the soak-pit, and natural die-off. Additional removal may also have occurred in the subsoil due to the high percentage of fines (clay and silt) present in the subsoil as detailed in Table 6.1. As with the PO_4-P removal, the large surface area provided by clay particles make them conducive to bacteria adsorption. Figure 6.11 shows the geometric mean concentration of total coliforms recorded at each sample point. With the exception of locations S2.1 ad S3.2, the remaining lysimeter nests show a systematic reduction in TC concentrations with depth. S2.1 and S3.2 show slightly elevated TC concentrations at the black depth planes. This may be as a result of increased soil moisture conditions due to percolating effluent at S2.1 (as indicated by the NH_4-N analysis) and at S3.2 due to the high soil moisture conditions within the drainage ditch. More saturated conditions in the underlying subsoil would lead to faster effluent movement and therefore increased bacterial migration with depth.

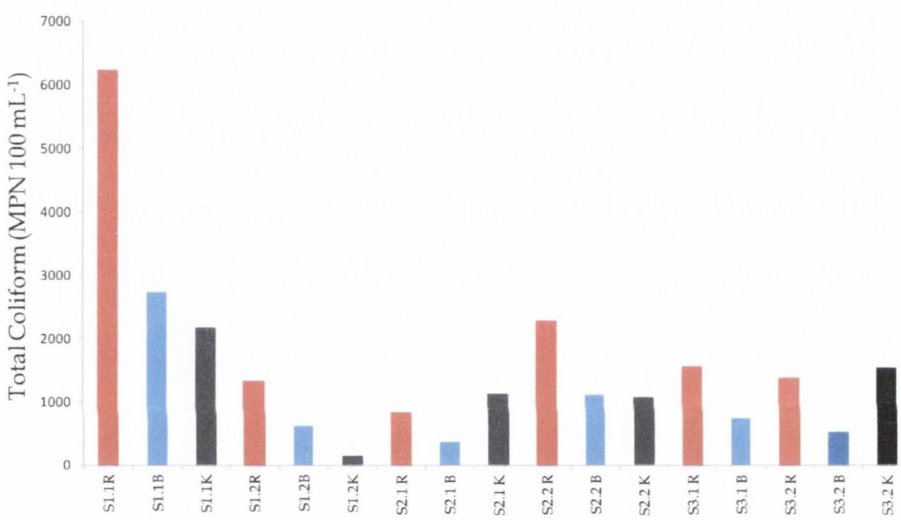


Figure 6.11 Geometric mean values of TC concentrations recorded at each sample point

Table 6.9 Reduction in total coliform concentrations with respect to STE at the three depth planes across influenced sampling positions

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	21	$7.94 \times 10^5 - 1.38 \times 10^9$	5.78E+05	-
1.3 m	25	$8.4 \times 10^2 - 6.2 \times 10^3$	2.09E+03	2.4
1.6 m	30	$3.7 \times 10^2 - 2.7 \times 10^3$	1.08E+03	2.7
1.9 m	29	$1.3 \times 10^2 - 2.2 \times 10^3$	7.68E+02	2.9

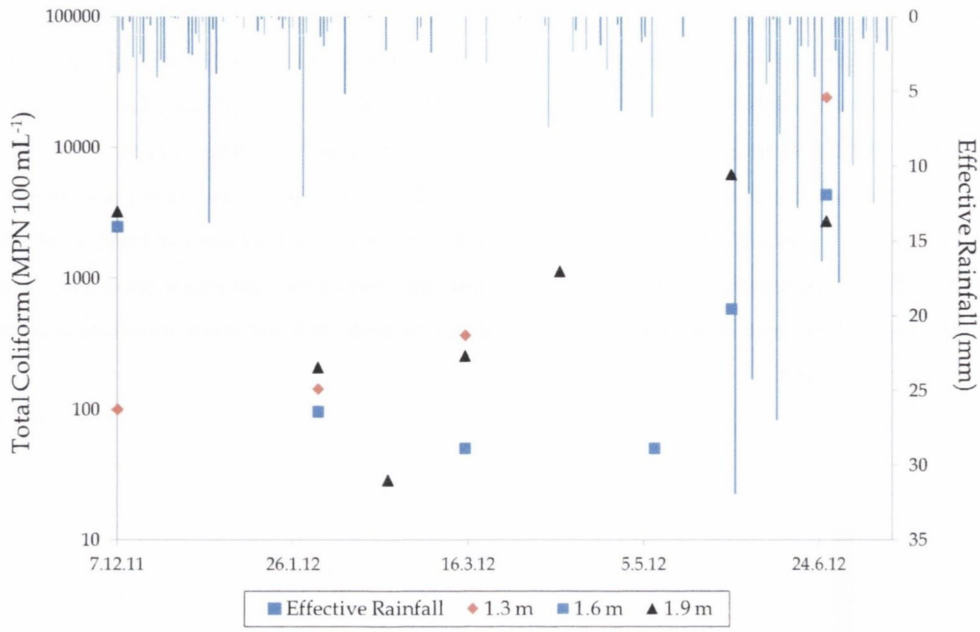


Figure 6.12 Record concentrations of TC at S2.1 in response to effective rainfall

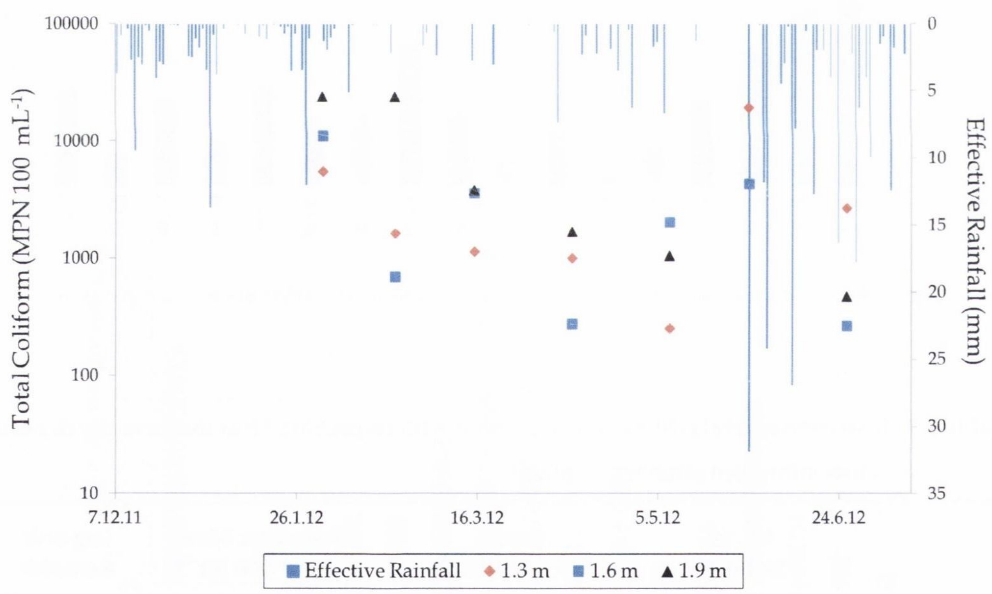


Figure 6.13 Geometric mean concentrations of TC at S3.1 and S3.2 in response to effective rainfall

Figure 6.12 and 6.13 show the temporal fluctuations of TC concentrations at S2.1 and S3.1/S3.2 respectively. Both locations show a drop in the recorded concentrations of TC coinciding with a drop in effective rainfall.

Table 6.10 presents the results of sample analysis for *E.coli* which shows that in only a small number of samples the presence of enteric bacteria was detected. Figure 6.14 shows the geometric mean concentration of *E. coli* across the sampling locations with elevations at the S1.1B and S2.2K locations. The detection of *E. coli* at the black depth plane (S2.2) at a concentration of 1.44 x 10^3 MPN 100 mL^{-1} on the 15/03/12 indicates that even under low permeability conditions the migration of pathogens is still of concern. The elevated *E. coli* concentration reported for S1.1B is as a result of a single sampling event (i.e. *E. coli* was only detected at this sampling location once during the soak-pit study). Both of these breakthroughs coincided with increasing *E. coli* concentrations within the STE.

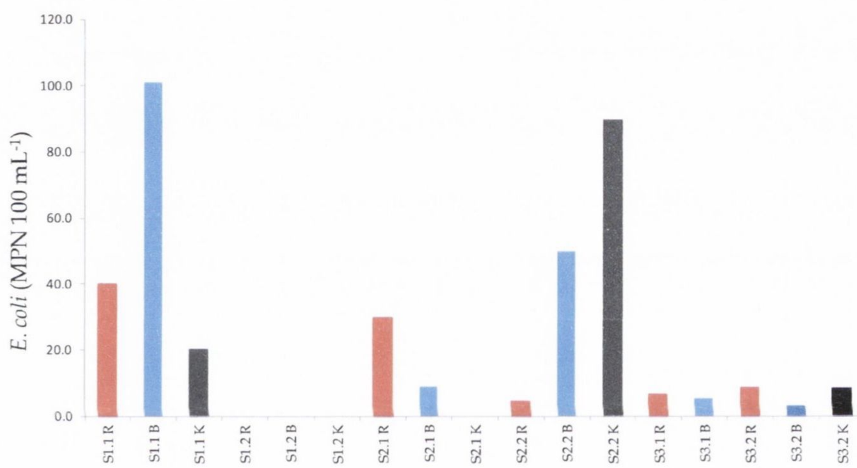


Figure 6.14 Geometric mean concentrations of *E. coli* recorded at Site A

Table 6.10 Concentrations of *E.coli* detected across the three depth planes planes across influenced sampling positions

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1}) < 10	10 - 100	100 - 1000	> 1000
1.3 m	25	20	5	0	0
1.6 m	30	26	3	1	0
1.9 m	29	23	5	0	1

Figure 6.15 and 6.16 show the temporal fluctuations of *E. coli* concentrations within the subsoil and within the drainage ditch respectively. As with the TC concentrations, the drainage ditch shows a drop in the recorded concentrations of *E. coli* coinciding with a drop in effective rainfall. Figure 6.15 shows less response to rainfall; however this may be a result of the dilution of samples when testing (due to insufficient soil moisture sample volumes) which in turn increases the minimum detection limit (Section 4.8.3).

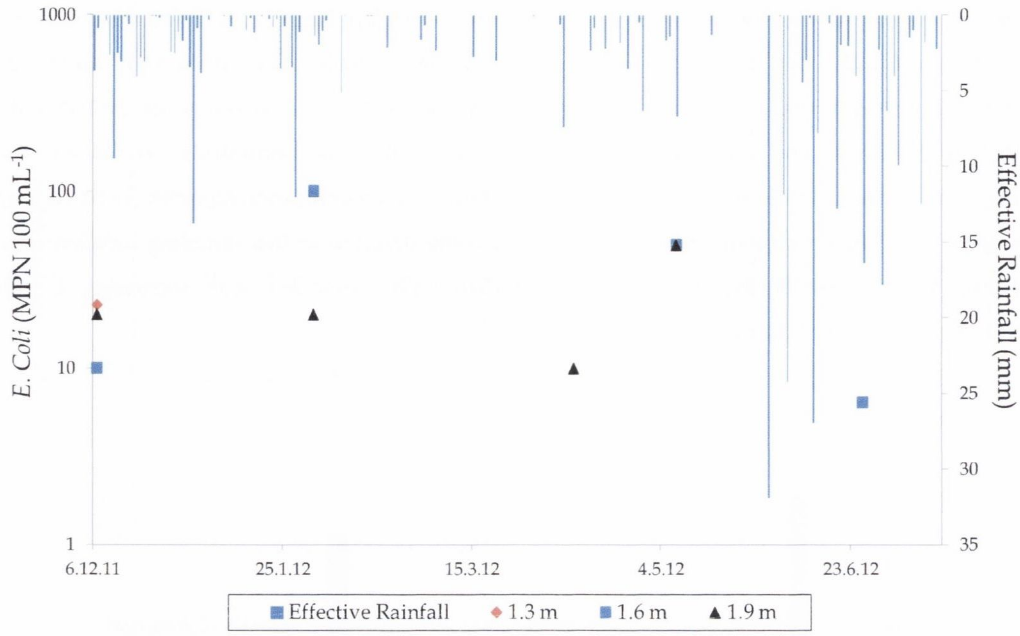


Figure 6.15 Geometric concentrations of *E. coli* concentrations recorded in subsoil soil moisture samples

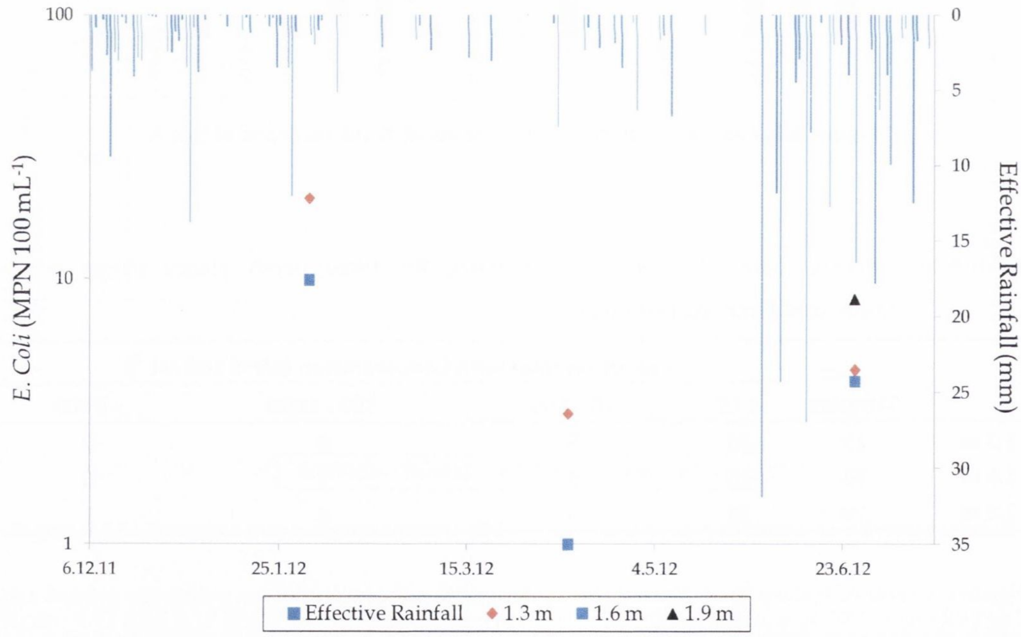


Figure 6.16 Geometric concentrations of *E. coli* concentrations recorded in drainage ditch

Following the completion of the soak-pit monitoring phase at Site A the site was upgraded to an alternative treatment system as described in Chapter 4. In order to make room for the new secondary treatment unit the existing soak-pit was dug out. Figure 6.17a shows the ponded effluent following the removal of the soil cover from above the soak-pit. In Figure 6.17b the plastic lining covering the soak-pit and preventing surface ponding is apparent. The extent of effluent ponding within the soak-pit is apparent in Figure 6.17c whilst biomat formation is visible in Figure 6.17d. Overall the extent of the soak-pit was much greater than expected. As the deepest lysimeter depth monitored at the site was only 1.7 m below ground level the extent of the plume beneath the soak-pit is unknown.

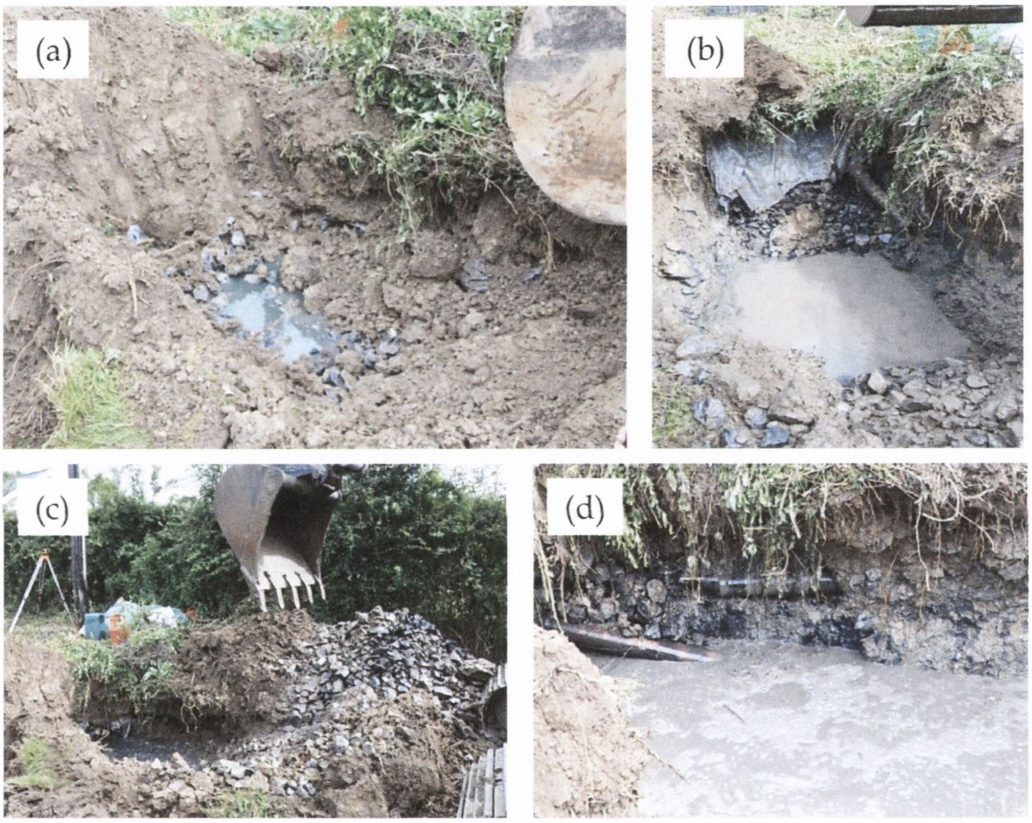


Figure 6.17 Removal of existing soak-pit at Site A

6.2.2 Site B (Co. Monaghan)

Soil suction lysimeters, were installed at Site B as per Figure 6.18 in order to assess the extent of the effluent plume. As with Site A, the initial assessment of effluent migration beneath the surface was done by analysing the Cl concentrations recorded at the site throughout the sampling period.

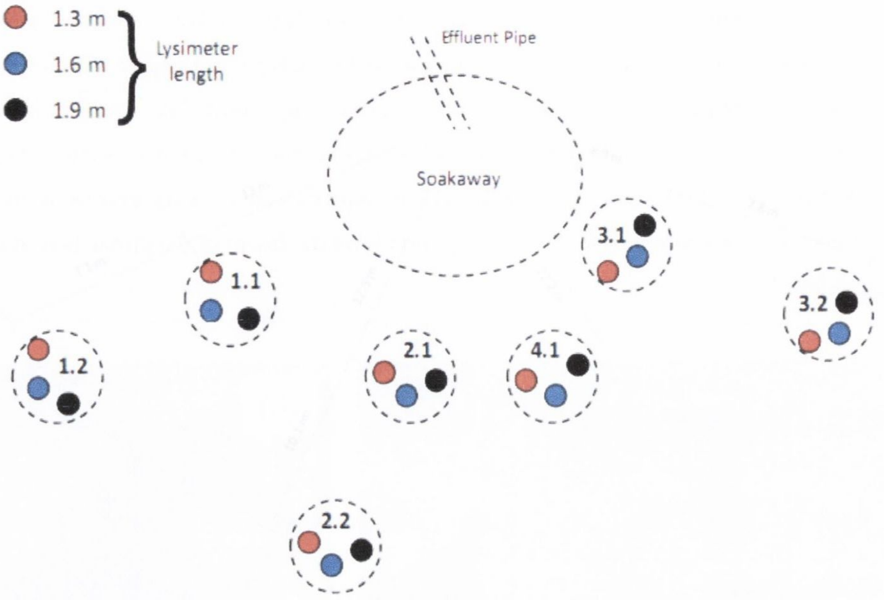
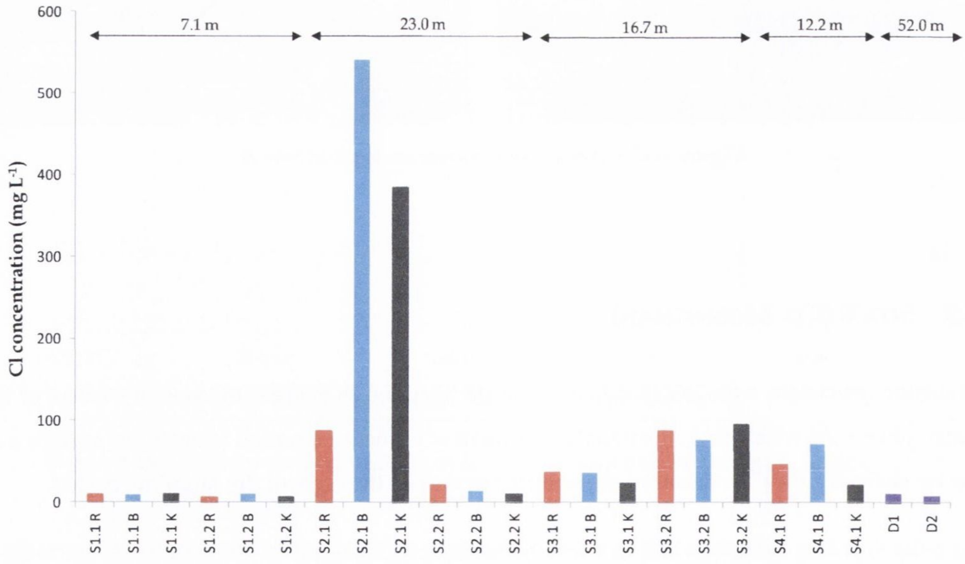


Figure 6.18 Instrumentation layout at Site B

Figure 6.19 depicts the mean Cl concentrations recorded at each sampling location. From this it is immediately apparent that sample nests S1.1 and S1.2 were not located within the effluent plume and the low levels of Cl recorded are assumed to reflect background Cl levels at the site. As such these were omitted from further analysis. The extent of effluent migration to the remaining lysimeter nests can be seen to vary greatly. Of particular interest was lysimeter nest S2.1 which recorded elevated Cl concentrations throughout the study suggesting it was located directly in the soak-pit plume.



6.19 Mean Cl concentrations across each sampling location at Site B

The results of the Cl analysis served to confirm the initial assumptions of effluent transport based on a visual assessment of the site. Figure 6.20 (taken from the soak-pit area) shows the locations of S2.1, S2.2 and S4.1 in relation to a shallow valley which indicated the lowest point of the site. From the image the presence of standing water both above the soak-pit and at the end of the valley is apparent. A variation in grass growth is also evident from the soak-pit area along the length of the valley. This was assumed to be indicative of effluent migration laterally along the valley which served as the drainage point for the entire site. Although a reduction in Cl concentrations is recorded by the S2.2 sample position, further analysis outlined in the following sections suggests this is due to the majority of effluent making its way from this point and moving laterally along the upper soil horizons of the valley.

An elevation in Cl levels was also recorded at the S3.1 and S3.2 sample positions despite being located 8.9 m and 16.7 m respectively from the soak-pit, approximately 90 degrees from the aforementioned valley. Figure 6.21 indicates the location of both nests from the soak-pit and again the presence of standing water was apparent. Lower Cl levels at all three depth planes at S3.1 as well as the presence of surface water indicates that effluent was unable to percolate vertically at this point and was most likely forced to move laterally in the upper subsoil horizons (above the red depth plane). By the S3.2 lysimeter nest (7.8 m from S3.1) elevated Cl concentrations at the red, blue and black planes indicate that effluent was gradually starting to percolate vertically, however primary effluent movement is in the lateral direction.

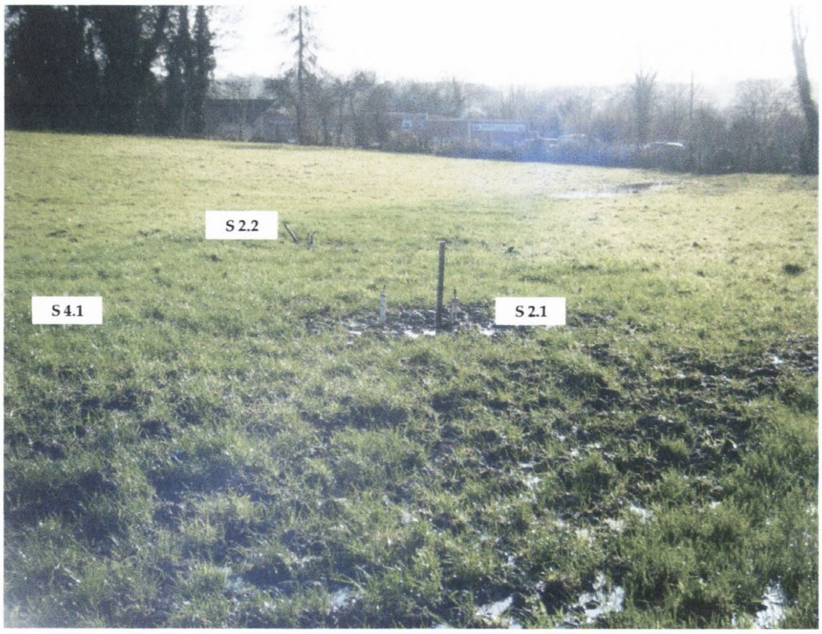


Figure 6.20 Sample locations S2.1, S2.2 and S4.1 at Site B

Figure 6.21 Sample locations S3.1 and S3.2 at Site B

Although the presence of elevated Cl (in comparison with background levels recorded at S1.1 and S1.2) was observed at five of the sampling locations, only concentrations at S2.1 were indicative of high effluent concentrations considering a mean Cl concentration of 2006 mg L^{-1} was recorded in the STE effluent over the course of the study (Table 5.7).

As Cl is regarded as a non-reactive chemical it is probable that, given the low permeability characteristics of the site as well as the distances from the soak-pit to each of the lysimeter nests, the high reduction in Cl concentrations was primarily due to high levels of dilution as a result of rainfall recharge. Given the obvious extent of the effluent plume as well as the lack of information regarding the infiltrative depth of effluent to the soak-pit (or indeed the overall depth of the soak-pit itself) it was not possible to make a reasonable assumption of the effect of dilution on pollution reduction. Mean Cl concentrations from two downstream boreholes, D1 and D2 (located approximately 50 m from the soak-pit) were 11 mg L^{-1} and 8 mg L^{-1} respectively (Figure 6.19). Again this was presumed to be as a result of extensive dilution due to rainfall recharge.

Analysis of the organic levels observed at each of the sample points where elevated Cl concentrations were recorded is presented in Figure 6.22. From this plot it can be seen that the highest COD concentrations recorded during the sampling period were at the sampling locations closest to the soak-pit (S2.1 Red and S3.1 Black) and above which periodic effluent ponding was observed. As unsaturated flow in an STU is critical to the effective straining of wastewater and the removal of organic chemicals, the increase in recorded COD levels at these locations may be as a result of their proximity to the highly saturated soak-pit area. Aside from these two lysimeters, overall COD removal was relatively uniform across the remaining sample positions. Table 6.11 presents the mean COD removal at each depth plane at the sample positions closest to the soak-pit where elevated Cl concentrations were recorded. From this it can be seen that the greatest decrease in organic loading occurred before the *red* depth plane. Table 6.12 shows the reduction in COD concentrations recorded at the sampling positions where the lateral movement of percolate was expected showing little further decrease in COD concentrations compared to Table 6.11.

Table 6.11 Reduction in COD concentration with respect to STE at each sample depth plane at S2.1/S3.1/S4.1

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	639	-
1.3 m	44	93%
1.6 m	39	94%
1.9 m	45	93%

Table 6.12 Reduction in COD concentration with respect to STE at each sample depth plane at S2.2/S3.2

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	639	-
1.3 m	20	97%
1.6 m	26	96%
1.9 m	17	97%

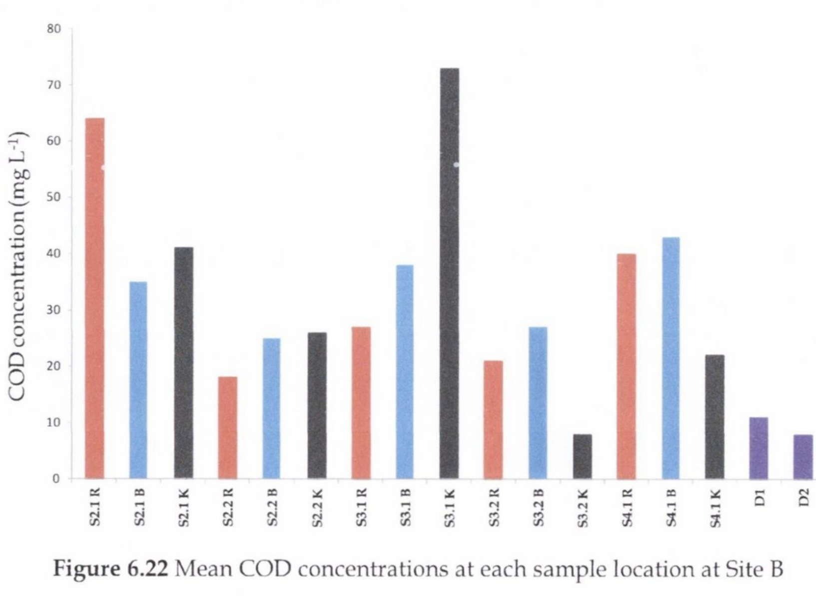


Figure 6.22 Mean COD concentrations at each sample location at Site B

Nitrogen analysis of the STE and soil moisture samples from the lysimeters, believed to be influenced by percolate, is presented in Tables 6.13 to 6.16. At the sample locations closest to the soak-pit this shows a decrease in the recorded total inorganic-N concentration of 98% at the black depth plane. The same decrease was found at the sample locations further from the soak-pit (Table 6.15). The breakdown of the remaining fraction of inorganic-N at depth shows complete nitrification had not occurred at either of the sampling locations. Figure 6.23 and 6.24 show the overall decrease in total inorganic-N at all three depth planes with respect to STE and in response to effective rainfall. A greater reduction in inorganic-N is observed during periods of high effective rainfall. From Table 6.13, a significant reduction in total inorganic-N is observed as the effluent percolates downwards, especially in the first 300 mm, which could be due to denitrification and/or the Anammox process.

Table 6.13 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes at S2.1/S3.1/S4.1

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	**Mean Conc. (mg L^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Conc. (mg L^{-1})**
STE	44	1	10	55
1.3 m	0.53	0.07	2.02	2.62
1.6 m	0.62	0.04	0.83	1.49
1.9 m	0.5	0.08	0.69	1.27

Table 6.14 Average breakdown of total inorganic-N in STE and across the three depth planes at S2.1/S3.1/S4.1

	% of total inorganic-N		
	NH_4-N	**NO_2-N**	**NO_3-N**
STE	80.0%	1.8%	18.2%
1.3 m	20.2%	2.7%	77.1%
1.6 m	41.6%	2.7%	55.7%
1.9 m	39.4%	6.3%	54.3%

Table 6.15 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes at S2.2/S3.2

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	**Mean Conc. (mg L^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Conc. (mg L^{-1})**
STE	44	1	10	55
1.3 m	0.76	0.05	0.71	1.52
1.6 m	0.54	0.05	2.48	3.07
1.9 m	0.43	0.04	0.89	1.36

Table 6.16 Average breakdown of Total Inorg-N in STE and across 3 depth planes at S2.2/S3.2

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	80.0%	1.8%	18.2%
1.3 m	50.0%	3.3%	46.7%
1.6 m	17.6%	1.6%	80.8%
1.9 m	31.6%	2.9%	65.4%

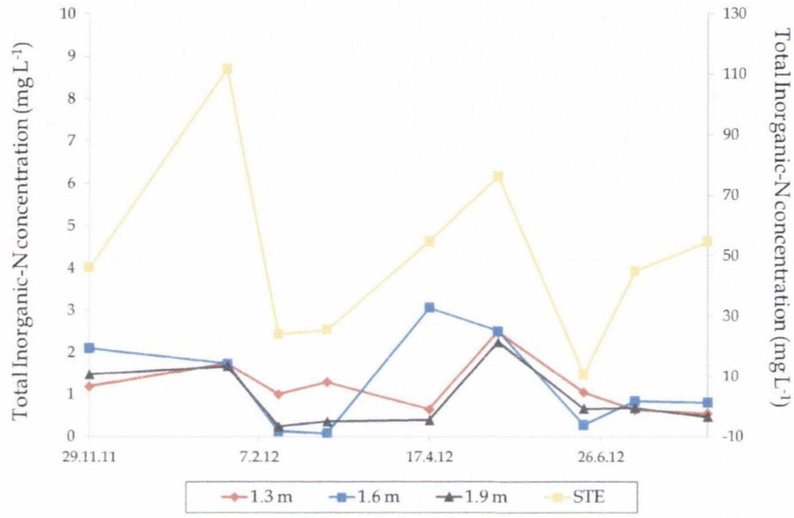


Figure 6.23 Reduction in Total Inorganic-N with respect to STE for lysimeters within the effluent plume

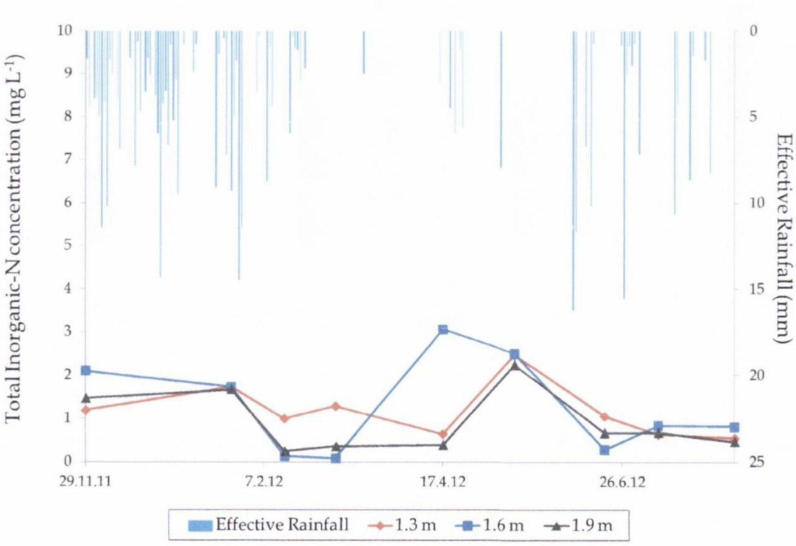


Figure 6.24 Reduction in Total Inorganic-N with respect to effective rainfall for lysimeters within the effluent plume

Table 6.17 details the PO_4-P removal at Site B. A total PO_4-P reduction of 90.5% is apparent at the *black* depth plane. Figure 6.25 shows high PO_4-P concentrations at across the majority of sample positions, including S1.1 and S1.2 deemed to be outside of the effluent plume. Closer inspection of these results revealed the high PO_4-P concentrations were confined to two sample dates, the 29/11/11 and the 25/01/12. The grazing of cattle at the test site up until the beginning of December 2011 is thought to be responsible for the spike in PO_4-P concentrations recorded on the 29/11/11 and with a residual effect remaining during the subsequent sampling run.

Table 6.17 Reduction in PO_4-P concentration wrt STE at each depth plane

	Mean Conc. (mg L^{-1})	**Reduction (wrt STE) (%)**
STE	26	-
1.3 m	2.66	89.8%
1.6 m	2.02	92.2%
1.9 m	2.48	90.5%

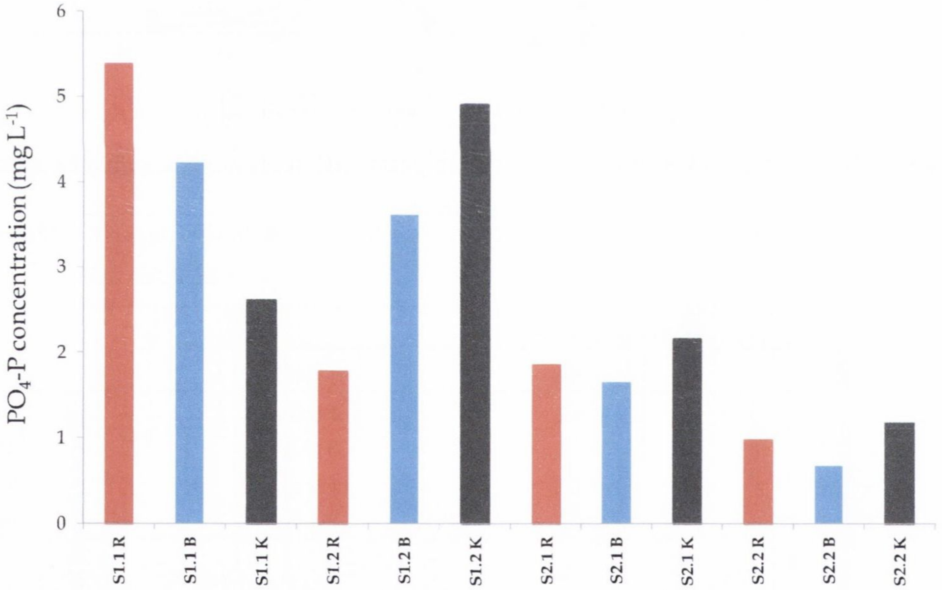


Figure 6.25 Mean PO_4-P concentrations at each sample location at Site B

Table 6.18 and Figure 6.26 appear to confirm this assumption. The results presented exclude the above sampling results and an improved PO_4-P reduction at all depth planes is observed. As the downstream boreholes were not present during the winter of 2011/2012 no groundwater sample results were available for the two months of high soil moisture PO_4-P concentrations. However, subsequent sampling of the boreholes showed low mean PO_4-P concentrations, indicating a significant reduction overall (Figure 6.26) during the latter monitoring stage. As with Site A, the high clay fraction present at Site B (24% - 32%) is thought to be the predominant reason for the reduction in PO_4-P concentrations between the STE and soil moisture samples. XRD analysis showed the soil minerals at Site B to be predominately dolomite and quartz with small proportions of albite, calcite, muscovite ferrian and clinochlore ferron. As with Site A, the presence of of Ca, Fe and Al may also play a role in the soils capacity to fix phosphate with moderate pH levels recorded during the monitoring period.

Table 6.18 Reduction in PO_4-P load from the STE at each depth plane within the effluent plume excluding samples taken on the 29/11/11 and the 25/01/12

	Mean Conc. (mg L^{-1})	Net Load Removal (%)
STE	26	-
1.3 m	0.60	97.7%
1.6 m	0.41	98.4%
1.9 m	0.50	98.1%

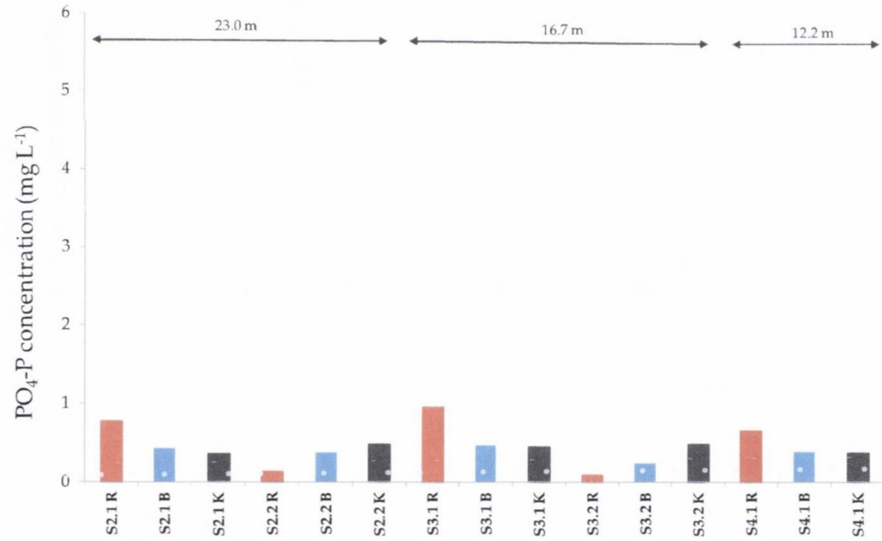


Figure 6.26 Mean PO4-P concentrations at each sample location at Site B excluding samples taken on the 29/11/11 and the 25/01/12

Bacteriological results at Site B (Table 6.19) show a minimum of 3 log-unit removal recorded TC at the *blue* depth plane. The reduction in TC across all influenced sampling locations within the effluent plume is believed to be as a result of the formation of a biomat layer within the soak-pit as well as the high clay fraction present at the site (Table 3.2) providing a high capacity for the adsorption of pathogens.

Table 6.19 Reduction in total coliform concentrations with respect to STE at the three depth planes at influenced lysimeters

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	9	1.53 x 10^5 - 2.2 x 10^6	5.78E+05	-
1.3 m	38	4.8 x 10^1 – 7.42 x 10^2	2.60E+02	3.3
1.6 m	44	1.2 x 10^2 – 6.8 x 10^3	5.48E+02	3.0
1.9 m	44	1.6 x 10^2 – 8.6 x 10^2	4.40E+02	3.1

However, elevated mean TC concentrations at S3.2 blue as well as in downstream borehole samples indicates the suspected lateral movement of effluent along preferential flow paths of increased permeability within the low permeability subsoil (Figure 6.27).

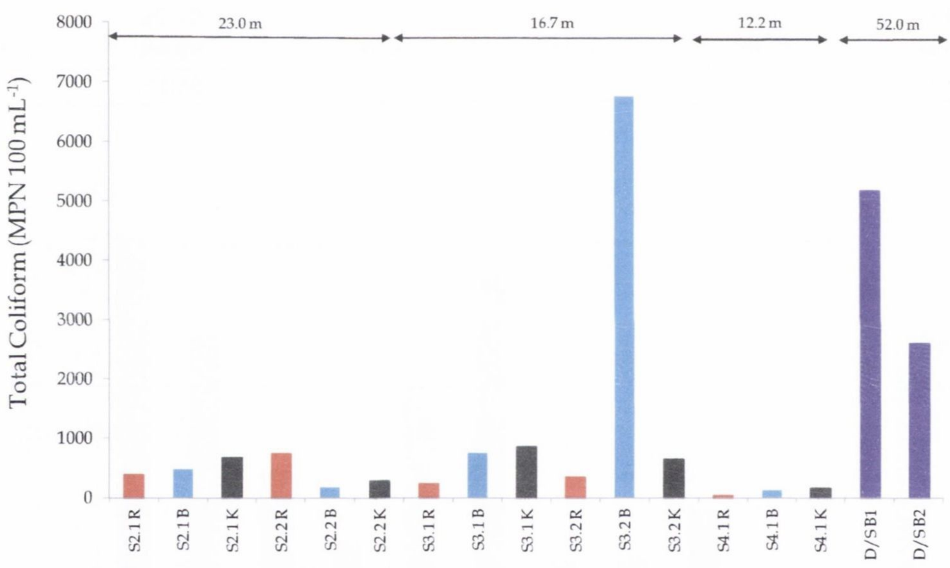


Figure 6.27 Elevated mean TC concentrations at S3.2 Blue and downstream boreholes

Figure 6.8 illustrates the geometric mean TC concentrations recorded at Site B across all sample positions believed to be influenced by percolate. The results show a decrease in TC concentrations were recorded at all depth planes during periods of reduced effective rainfall.

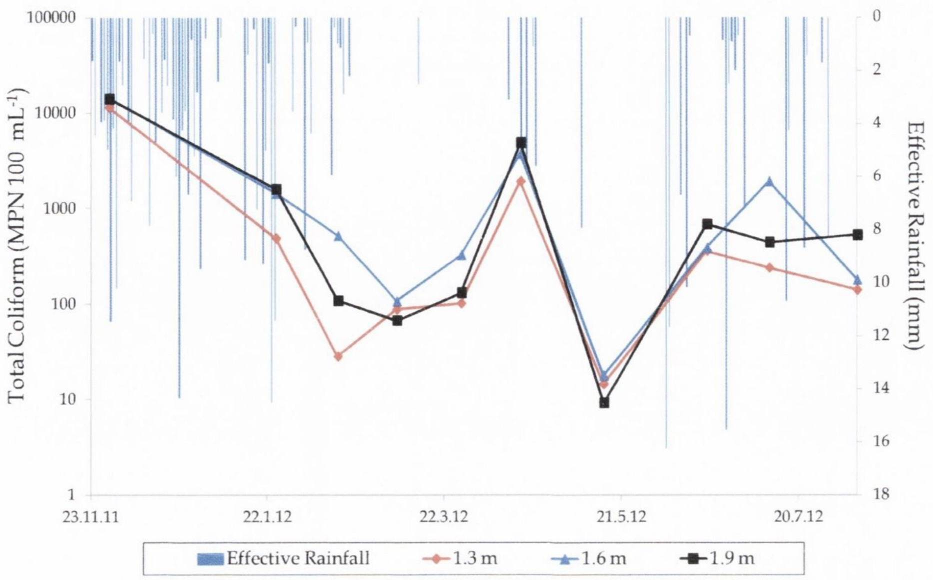


Figure 6.28 Geometric mean concentrations of TC of influenced lysimeters in response to effective rainfall

Similar results were also evident in the analysis of *E.coli* concentrations at the site (Table 6.20 and Figure 6.29). Again high concentrations were detected at S3.2 blue as well as in the downstream boreholes. This highlights the risk to both surface water and groundwater bodies due to insufficient subsoil permeability resulting in the run-off of ponded effluent. Although concentrations in the subsoil soil and downstream boreholes were significantly reduced compared with the STE, Figure 6.30 illustrates the distance of migration of faecal contamination recorded at Site B.

Over the course of the study, STE, soil moisture and borehole samples were taken by NUI Galway Microbial Department in parallel to the work carried out by TCD. Microbial source tracking (MST) was carried out by NUIG using *Bacteroidales* sp. as described in Keegan et al. (2014) and confirmed the presence of human faecal bacteria in the downstream borehole samples at Site B confirming the migration of effluent laterally along the site. Faecal contamination from an agricultural source (bovine) was also detected within the borehole samples demonstrating the potential of MST in identifying the source of bacterial pollution (i.e. domestic or agricultural) in contaminated water sources. MST analysis by NUIG was also carried out for Site A as well as the upgraded systems installed at both low permeability sites. Results from this analysis are currently being compiled with the TCD monitoring results and are hoped to give further insight into the migration of effluent within the low permeability setting.

Table 6.20 Concentrations of *E.coli* detected across the three depth planes

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
1.3 m	38	33	5	0	0
1.6 m	44	37	4	2	1
1.9 m	44	37	7	0	0

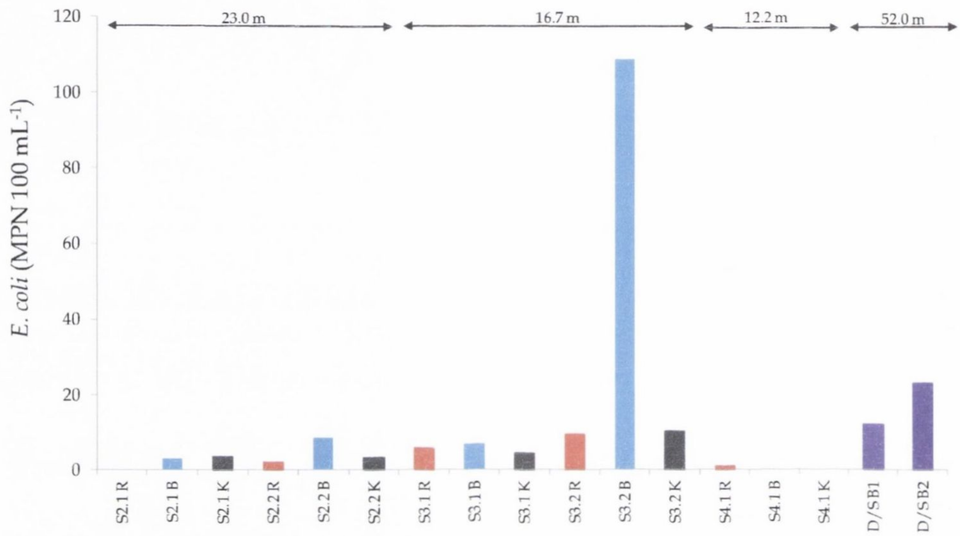


Figure 6.29 Elevated geometric mean *E.coli* concentrations at S3.2 Blue and downstream boreholes

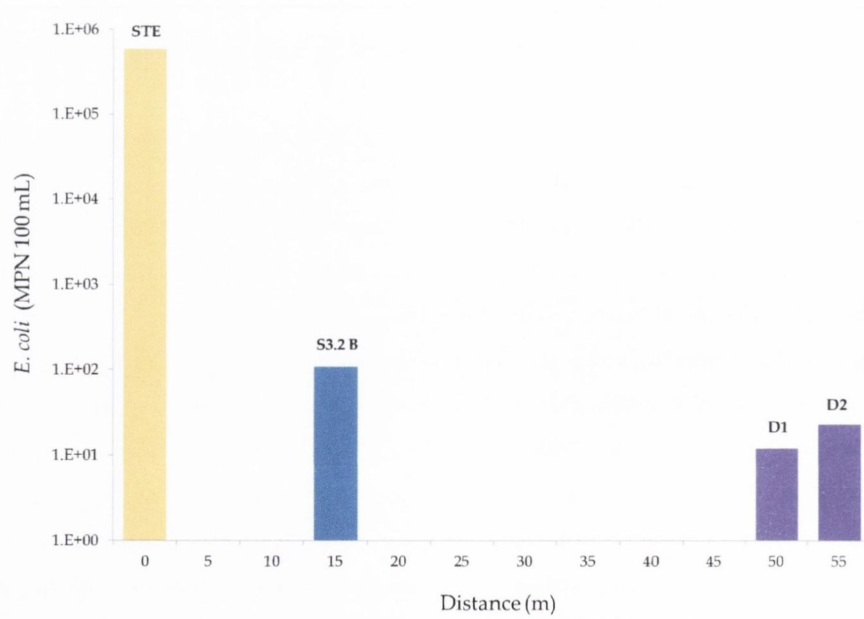


Figure 6.30 Distance of migration of *E. coli* at Site B

Finally, the response of *E. coli* concentrations to effective rainfall is illustrated in Figure 6.31. A decrease in the concentrations recorded was found during periods of lower effective rainfall.

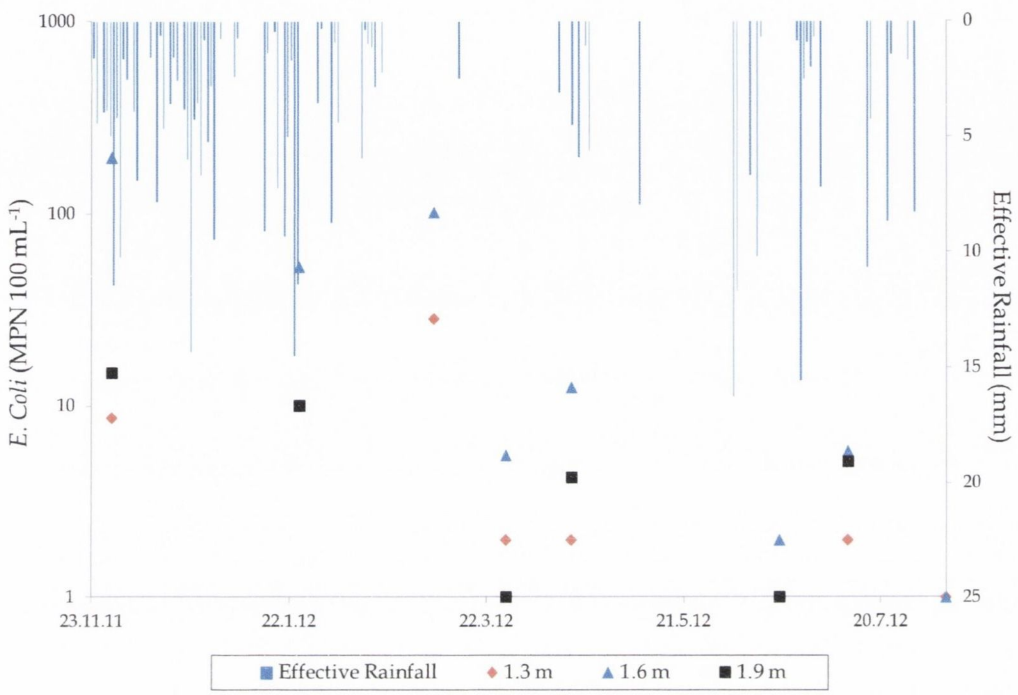


Figure 6.31 Geometric mean concentrations of *E. coli* recorded at influenced lysimeters in response to effective rainfall

6.3 Moderate to High Permeability Soak-pit Performance

The assessment of soak-pit performance in subsoils of higher permeabilities was also examined. As described in Chapter 3, two sites in areas of moderate permeability and two sites in areas of high permeability subsoil conditions were identified and instrumented. As with the low permeability sites the extent of development of the effluent plume as well as the effectiveness in the attenuation of key pollutants was examined.

6.3.1 Site C (Briarleas, Co. Meath)

Effluent and soil moisture samples (from both the vadose and saturated zones) as well as groundwater samples were monitored from the 9th of May 2013 to the 16th of January 2014 at Site C. As outlined in Section 3.41 the site has three distinct soil horizons, a well drained gravelly SAND layer (0 m to 1.4 m), a SILT/CLAY layer (1.4 m to 1.8 m) and a further gravelly SAND layer

(>1.8 m). Lysimeters and piezometers were installed at the site in order to sample the unsaturated and saturated zones respectively. Figure 6.32a shows a view of the installed instrumentation while Figure 6.25b shows a cross-section of each of the lysimeters and piezometers in relation to the aforementioned SILT/CLAY layer and unsaturated zone.

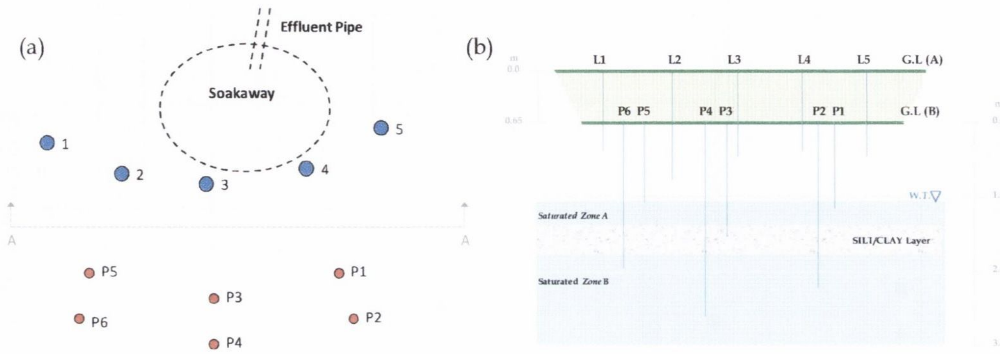


Figure 6.32 (a) Plan view and (b) A-A cross-section of installed instrumentation at Site C

Over the course of the study the water table at Site C remained approximately 1.0 m - 1.2 m below ground level B (Figure 6.32b) which was in keeping with the surface water level of a downstream river approximately 25 m from the soak-pit (Figure 4.14). Pairs of piezometers where installed above and below the low permeability SILT/CLAY layer in order to ascertain any impact it may have on water quality within saturated zones A and B (Figure 6.32). Due to the variation in ground levels at Site C mean Cl concentrations at each sampling location were assessed to assist in the determination of effluent migration beneath the surface.

Figure 6.33 Mean Cl concentrations across all sample locations

Figure 6.33 shows the variation in Cl concentrations between both the lysimeter and piezometer samples in relation to the mean effluent concentration of 103 mg L^{-1}. From this plot elevated Cl concentrations are apparent at all five lysimeter locations, particularly Lys 4. The downstream piezometers also show significant Cl concentrations however a drop can be seen the three piezometers located beneath the low permeability layer (P2, P4 and P6) and those located in the upper horizons. The reduction in Cl concentrations in the saturated zones is believed to be as a result of significant dilution by groundwater as Cl is non-reactive. As illustrated in Figure 6.34, the reduction in Cl concentration with depth remained relatively uniform throughout the sampling period. As such the mean Cl reduction for each subsoil zone is presented in Table 6.21 and is assumed to give an estimate of the mean dilution applied to the subsequent chemical and bacteriological analysis.

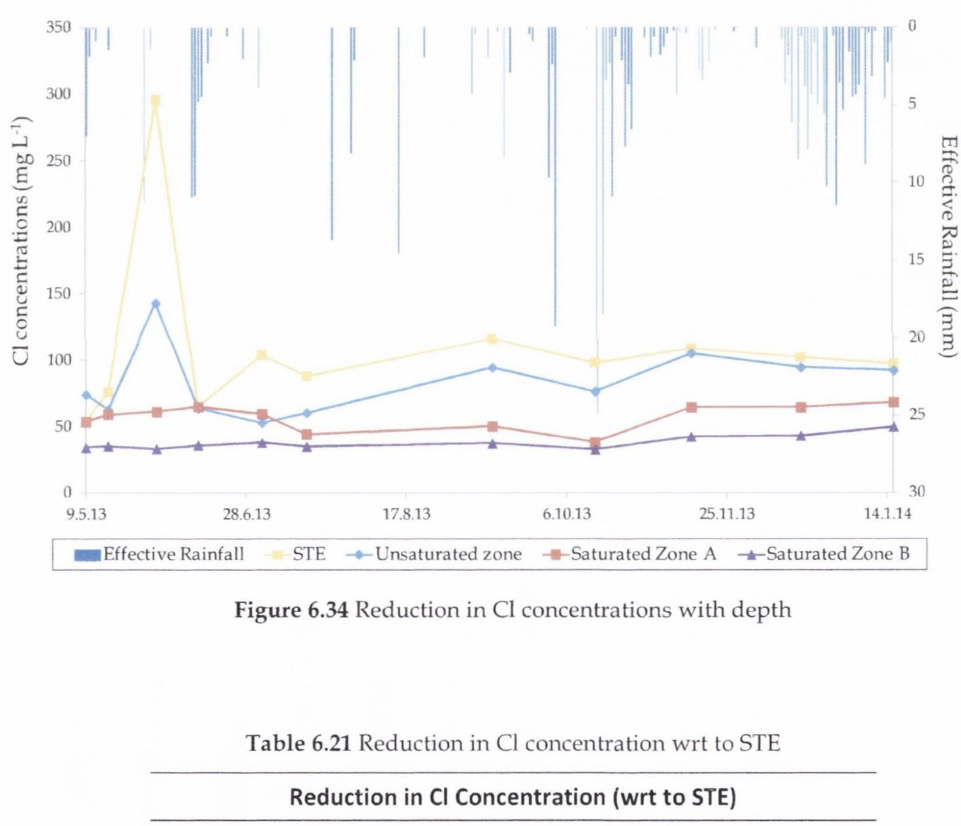


Figure 6.34 Reduction in Cl concentrations with depth

Table 6.21 Reduction in Cl concentration wrt to STE

Reduction in Cl Concentration (wrt to STE)	
Unsaturated Zone	24%
Saturated (Zone A)	48%
Saturated (Zone B)	65%

Table 6.22 details the mean COD removal recorded at Site C at each respective subsoil layer. This shows that the majority of organic removal occurred in the unsaturated zone were aerobic

conditions prevail. Taking into account the 24 % reduction due to dilution, the biologically active zone within the soak-pit at the point of effluent discharge was presumed to be responsible for the remaining 71% decrease in COD concentrations by allowing both physical straining and biodegradation to occur. Further reductions in COD levels in the saturated zones were limited and are thought to be primarily due to increasing dilution effects with depth.

Figure 6.35 illustrates the uniformity of mean COD levels recorded across both the unsaturated and saturated zones. As with the Cl concentrations, a marginal drop-off in levels between the saturated zones above and below the low permeability SILT/CLAY layer was observed (Figure 6.36). The most significant drop-off between the two zones occurred during June and July. Figure 6.37, which shows the degree of Cl reduction between the two saturated zones, appears to confirm that the difference in dilution at this time was high.

Table 6.22 Reduction in COD load with respect to STE

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	551.0	-
Unsaturated Zone	31.2	95%
Saturated (Zone A)	23.8	96%
Saturated (Zone B)	19.9	97%

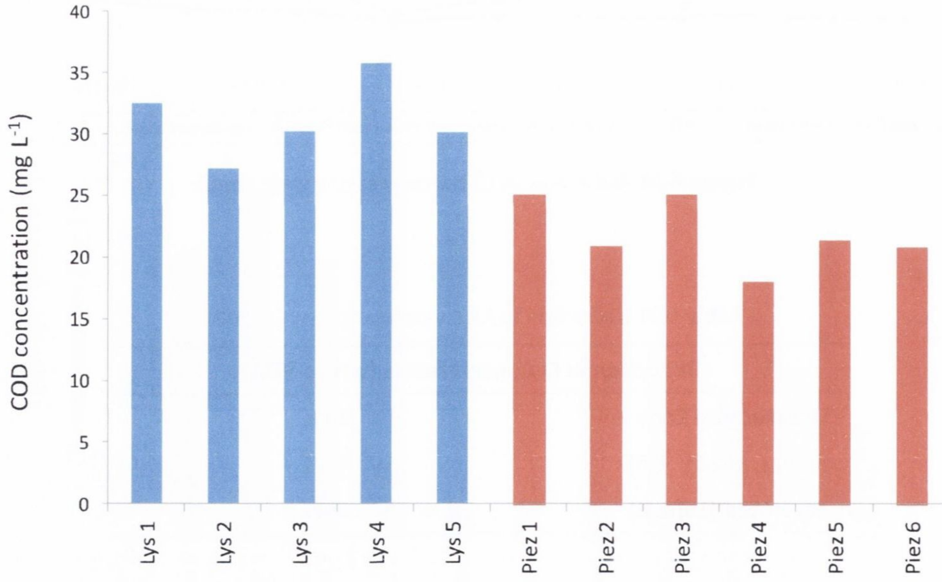


Figure 6.35 Mean COD concentrations at each sample location at Site C

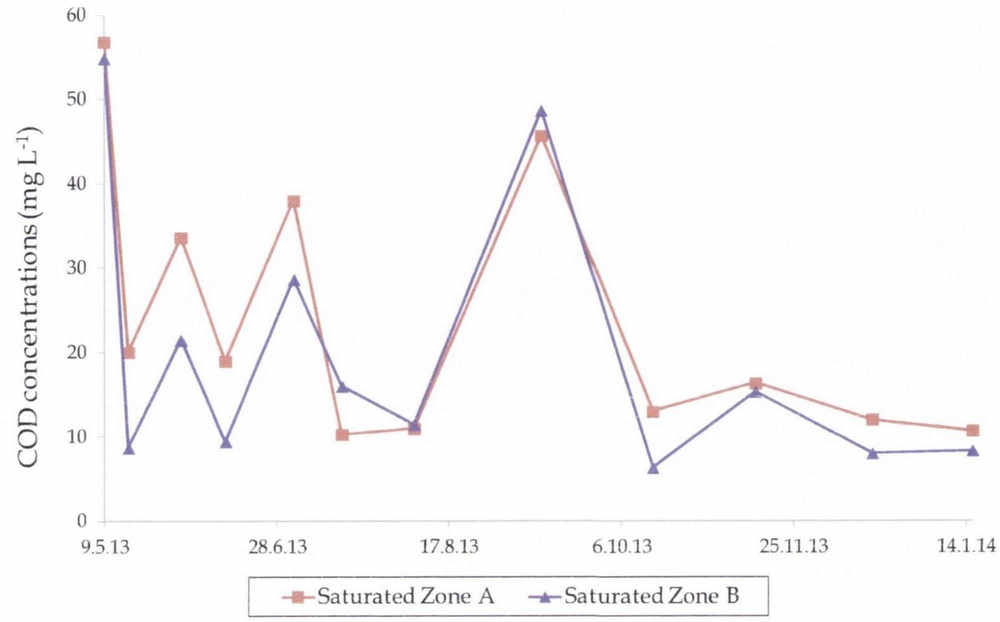


Figure 6.36 Time series plot of reduction in COD concentration between saturated zone A and saturated zone B

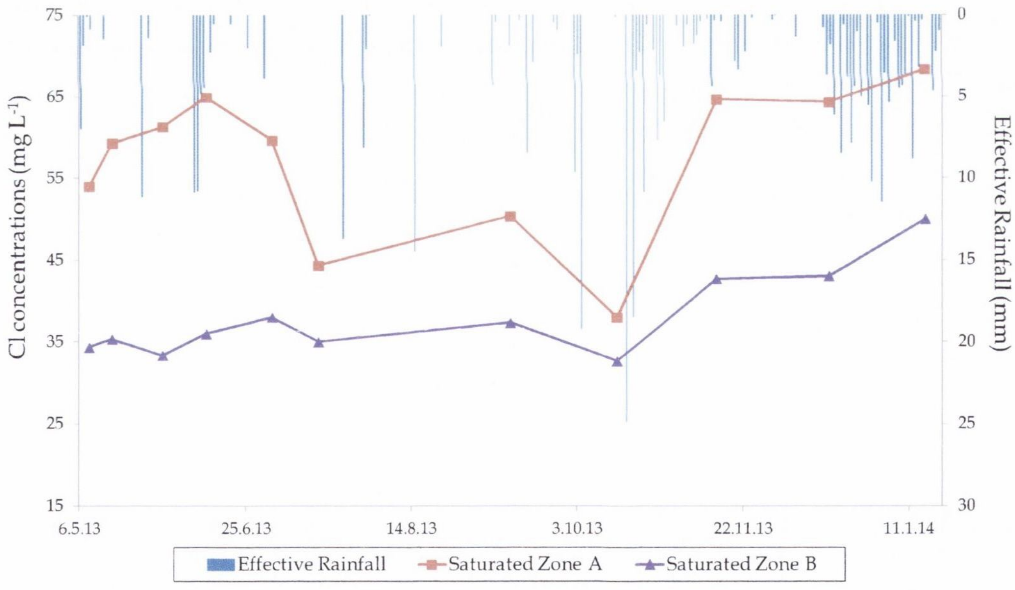


Figure 6.37 Concentrations of Cl recorded within the saturated zones in response to effective rainfall.

A distinct increase in NO_3-N concentrations within the unsaturated zone (Figure 6.38) was apparent as nitrification due to aerated subsoil conditions prevailed. In comparison, the nitrate levels recorded within both saturated zones are limited. The 10% decrease in NO_3-N between the unsaturated zone and saturated zone A is attributed to dilution which was estimated at 24%.

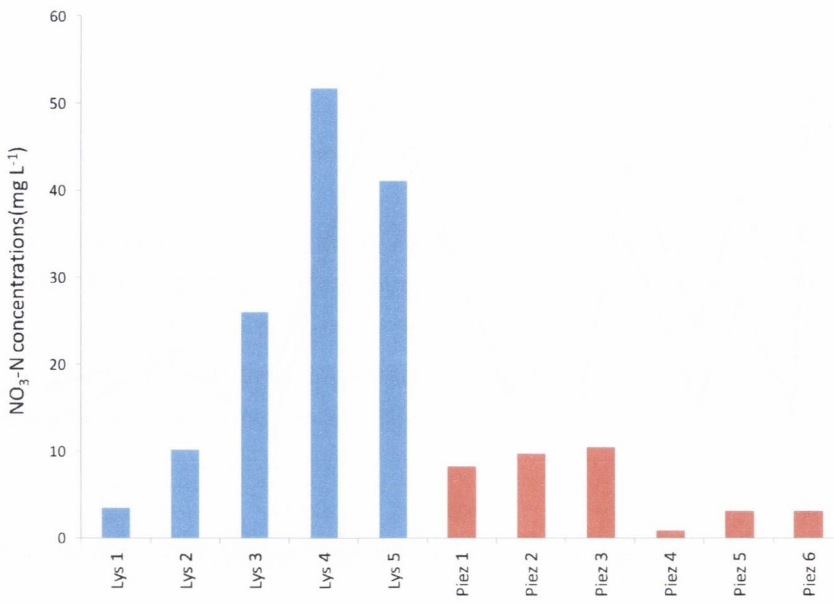


Figure 6.38 Mean NO_3-N concentrations at each sample location at Site C

Figure 6.39 shows the increase in NO_3-N levels with a corresponding drop-off in NH_4-N concentrations in the summer of 2013 in relation to the overall NH_4-N concentrations applied to the subsoil as a result of effluent discharge. Prior to this point a reduction in both NO_3-N and NH_4-N was observed through the unsaturated zone presumably due to residual localised micro-sites where saturated conditions existed within the effluent infiltrative zone allowing both nitrification followed by rapid denitrification to occur.

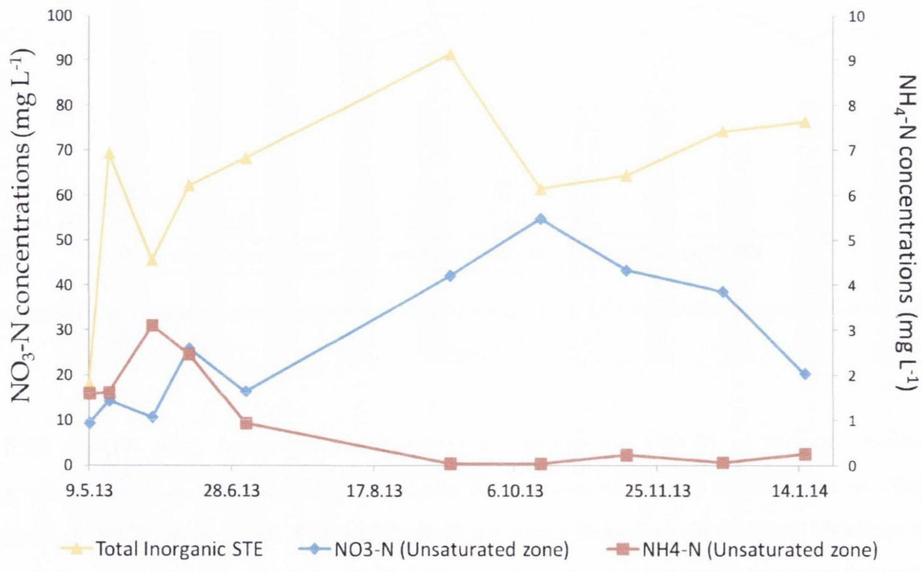


Figure 6.39 Time series plot of variation in NH_4-N and NO_3-N within the unsaturated zone with respect to STE Total inorganic-N

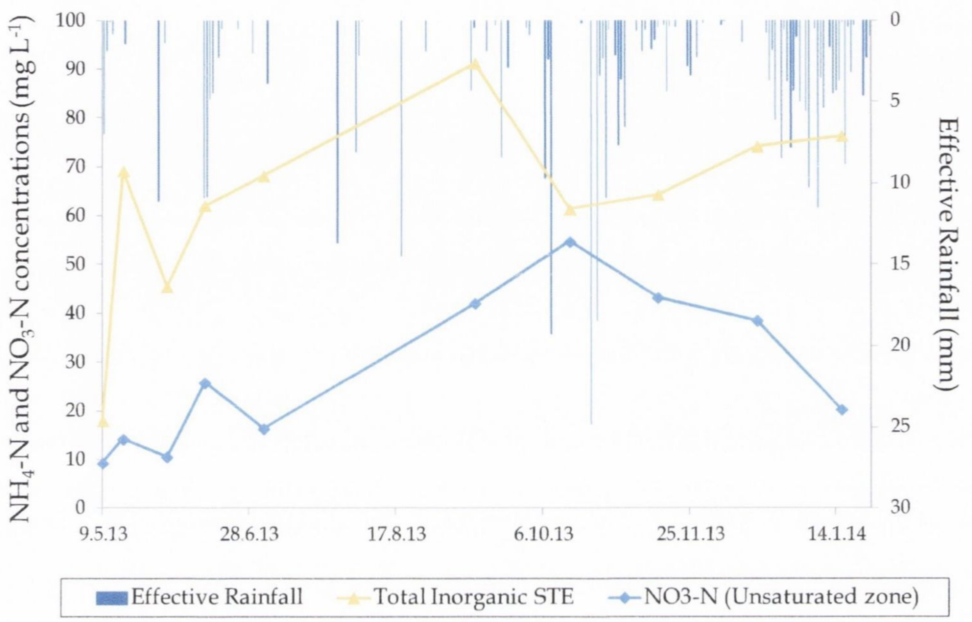


Figure 6.40 Time series plot of NO_3-N within the unsaturated zone with respect to STE NH_4-N concentrations in response to rainfall recharge.

Figure 6.40 shows a decrease in rainfall recharge over the summer months would have promoted increased aeration within the subsoil and a consequential decrease in denitrification levels. As a result, the remaining inorganic-N in the unsaturated zone was primarily in the form of NO_3-N (Table 6.23 and 6.24).

Table 6.23 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})
STE	69.6	0.10	1.2	70.9
Unsaturated Zone	0.93	0.08	26.5	27.5
Saturated (Zone A)	2.41	0.09	7.2	9.7
Saturated (Zone B)	0.25	0.05	4.5	4.8

Table 6.24 Average breakdown of total inorganic-N

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	98%	0.1%	2.1%
Unsaturated Zone	3%	0.1%	96.3%
Saturated (Zone A)	25%	0.3%	74.2%
Saturated (Zone B)	5%	0.4%	93.8%

In contrast, elevated NH_4-N concentrations were observed in saturated zone A in comparison with the overlying unsaturated zone (Figure 6.41) during the first two months of sampling at Site C. As outlined in Table 6.24 a high percentage (25%) of total inorganic-N in the form of NH_4-N was recorded in saturated zone A. This suggests effluent resident times in the freely draining unsaturated zone were insufficient and a proportion of effluent discharge reaches the saturated zone without undergoing nitrification. One possible explanation for this could be the presence of preferential flow paths within the soak-pit providing a direct route for effluent to the shallow groundwater. As with the unsaturated zone outlined above, a reduction in NH_4-N occurred during the summer months and a corresponding increase between NO_3-N concentrations in both the unsaturated and saturated zones was seen to occur (Figure 6.42). A significant reduction in NO_3-N levels in the both saturated zone is believed to be as a result of the combined effect of denitrification and dilution in the saturated conditions of the phreatic zone.

Overall this suggests a predominantly vertical plume in the free draining upper horizon at Site C. A limited extension of the plume in a lateral direction along the gradient of the site is apparent however the fluctuating water table results in a reduced attenuation capacity during periods of increased rainfall recharge with associated more direct effluent transport to the saturated zone.

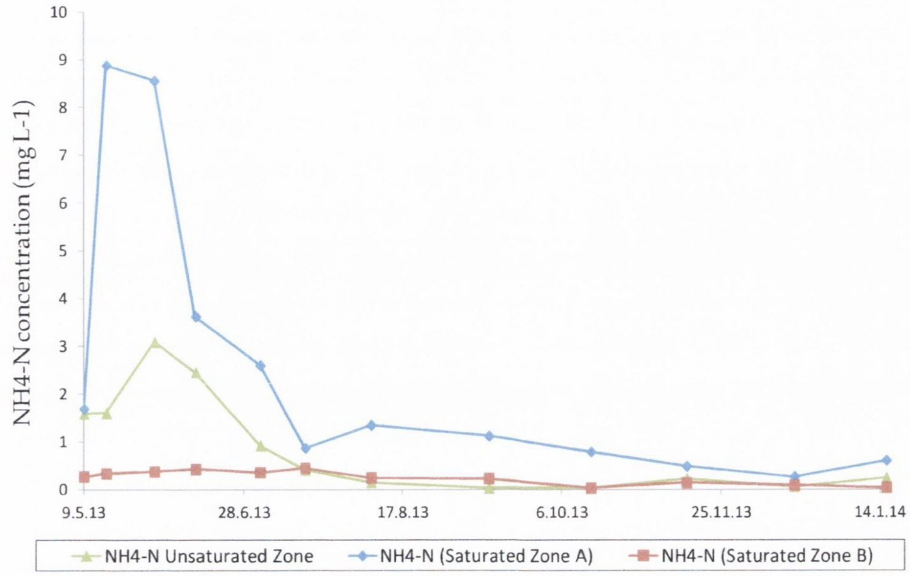


Figure 6.41 Time series plot of NH_4-N concentrations within the unsaturated zone and saturated zones at Site C

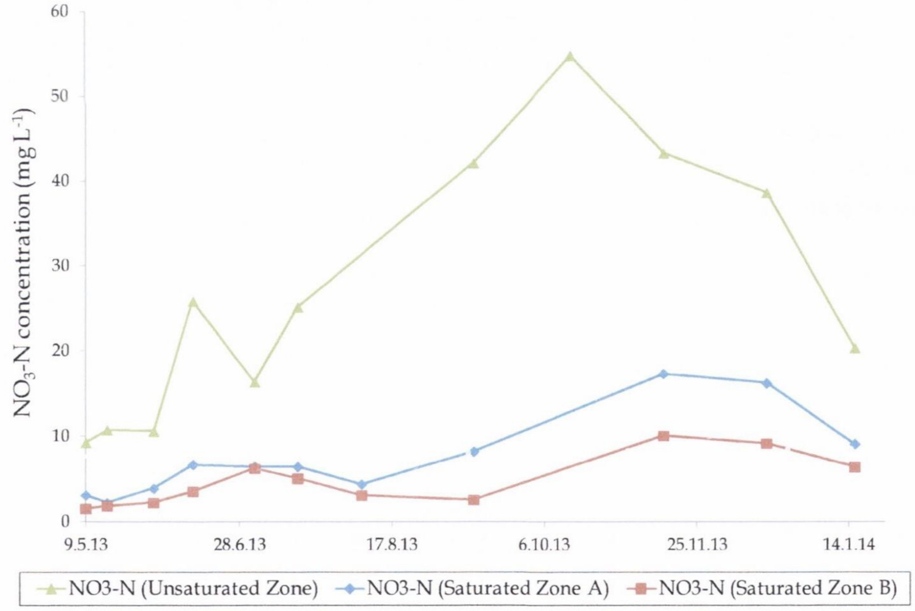


Figure 6.42 Time series plot of NO_3-N concentrations within the unsaturated zone and saturated zones at Site C

Examination of PO_4-P concentrations recorded at Site C confirms this assumption. Table 6.25 shows a significant reduction in PO_4-P levels in the unsaturated zone. However, as evident in Figure 6.43 PO_4-P concentrations in saturated zone A are much greater in magnitude indicating a significant proportion of effluent is passing through the unsaturated zone via preferential flow paths without undergoing sufficient attenuation. As outlined in Table 3.3, the upper unsaturated subsoil horizon contains a 16% fraction of fines (silt and clay). Although the net load removal of 97% within this zone was observed, the results suggest only a proportion of the effluent is percolating past the sampling locations in this region. As the depth and extent of the soak-pit at Site C is unknown, it is possible that an increase in saturation within the soak-pit provides direct passage of the effluent to the underlying water table. This may account for the elevated concentrations in saturated zone A. Also of interest is the significant decrease in PO_4-P levels between the upper and lower saturated zones defined above. A further 5% decrease in concentrations may be attributed to increased dispersion with depth but also as a result of the presence of the low permeability layer SILT/CLAY layer consisting of a 28% clay fraction which may serve to reduce the PO_4-P concentrations between the two depths. XRD analysis showed the soil to consist predominately of quartz, calcite, albite and muscovite with small fractions of dolomite and chinochlore meaning the presence of Al, Ca and Fe may also contribute PO_4-P removal through mineral precipitation.

Table 6.25 Reduction in PO_4-P concentrations with depth at Site C

	Mean Conc. ($mg\ L^{-1}$)	**Reduction (wrt STE) (%)**
STE	10.3	-
Unsaturated Zone	0.31	97%
Saturated (Zone A)	0.79	93%
Saturated (Zone B)	0.21	98%

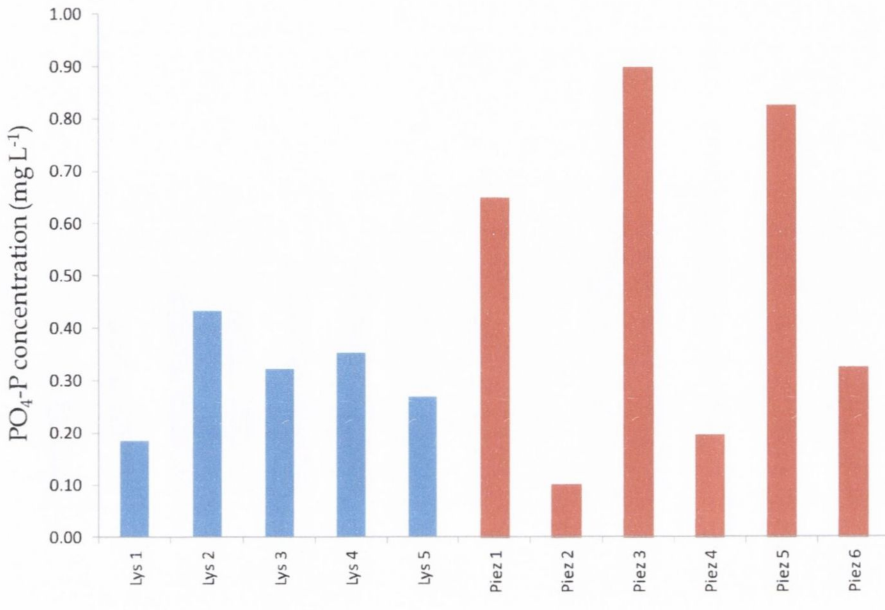


Figure 6.43 Mean PO4-P concentrations at each sample location at Site C

As detailed in Table 6.26, a high level of indicator bacteria removal was recorded within the unsaturated zone at Site C. A 3.7 log-unit reduction was recorded within the vadose zone which increased slightly to a 4.2 log-unit removal by the upper saturated zone. As the estimated degree of dilution between the unsaturated and saturated zone (24%) greatly exceeds the 6% reduction in TC recorded between the same depth planes the further removal in the saturated zone is attributed primarily to dilution. The biologically active zone within the soak-pit at the infiltrative surface is thought to prevent significant transport of bacteria through physical straining. As such overall TC migration both in a vertical and lateral direction is reduced with a further reduction as a result of dilution observed in both saturated zones A and B. The uniformity of mean TC removal is illustrated in Figure 6.44.

Table 6.26 Reduction in total coliform concentrations with respect to STE at Site C

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	11	6.5×10^5 - 5.24 107	8.25E+06	-
Unsaturated Zone	41	$1.1 \times 10^1 - 4.8 \times 10^4$	1.64E+03	3.7
Saturated (Zone A)	28	$1.0 \times 10^1 - 2.4 \times 10^4$	5.48E+02	4.2
Saturated (Zone B)	30	$4.1 \times 10^0 - 1.2 \times 10^4$	4.40E+02	4.3

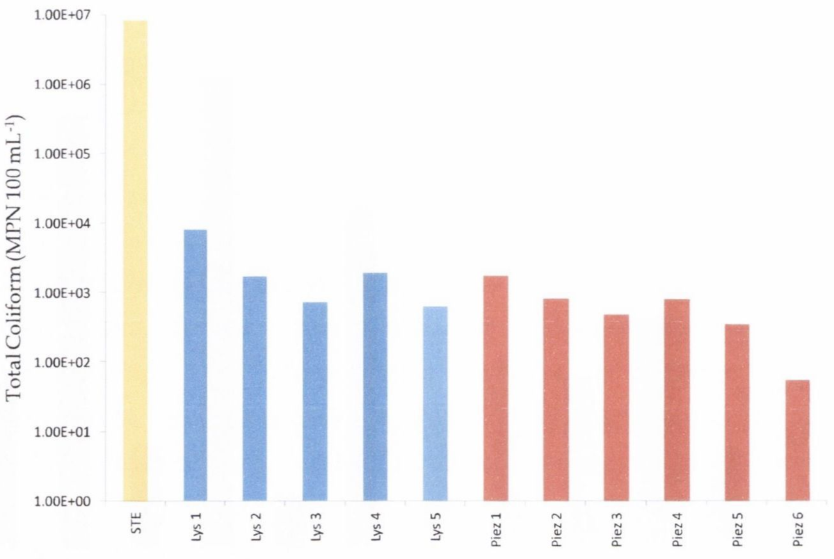


Figure 6.44 Geometric mean TC concentrations at each sample location at Site C

Significant breakthroughs of *E.coli* were recorded at all sample depths and locations over the course of the monitoring period. Table 6.27 shows that overall the magnitude of the breakthroughs decrease with depth with concentrations in excess of 1000 MPN 100 mL^{-1} only recorded in the upper subsoil horizon. However, the increase in *E.coli* presence recorded downstream of the soak-pit in comparison with those recorded upstream can be directly attributed to effluent discharge.

Table 6.27 Concentrations of *E.coli* detected across Site C

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
Unsaturated Zone	41	10	10	14	7
Saturated (Zone A)	28	7	13	8	0
Saturated (Zone B)	30	15	11	4	0
Groundwater	7	6	1	0	0

Figure 6.45 shows the geometric mean concentrations of *E. coli* recorded within the unsaturated and saturated subsoil zones. Figure 6.46 shows the recorded concentrations in response to effective rainfall. High levels of *E. coli* were recorded within the unsaturated zone until the winter of 2013 at which point an increase in concentrations in the saturated zones is observed. This suggests an increase in effective rainfall has resulted in an increase in the migration of *E. coli* to the underlying water table.

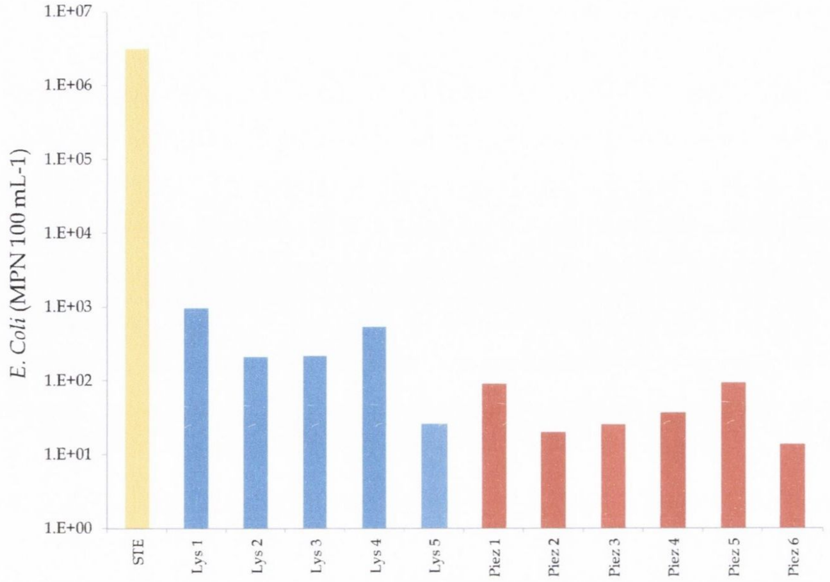


Figure 6.45 Geometric mean ***E. coli*** concentrations at each sample location at Site C

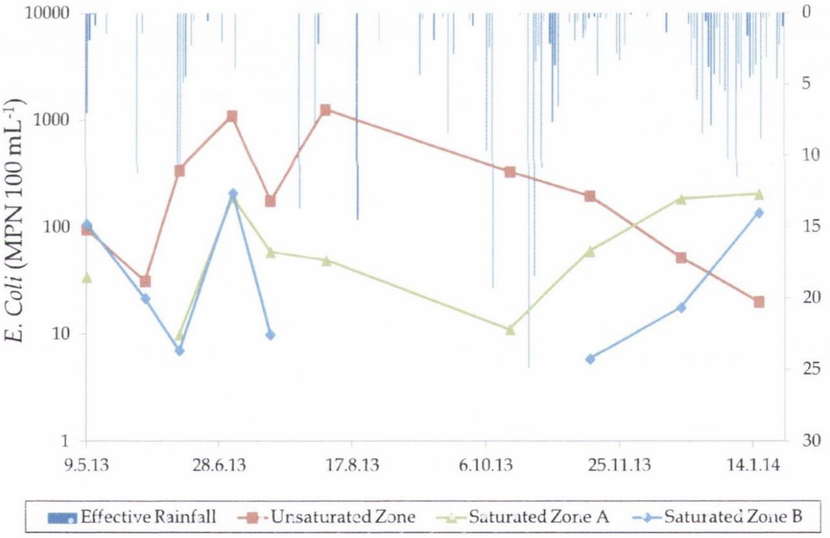


Figure 6.46 Geometric mean ***E. coli*** concentrations in response to effective rainfall

Overall this indicates the soak-pit system is inadequate and does not provide sufficient protection to the underlying groundwater. The continuous migration of enteric bacteria indicates an alternative on-site treatment system should be considered.

6.3.2 SITE D (IRISHTOWN, CO. MEATH)

Site D (approximately 2 km from Site C) was monitored from the 9th of May 2013 to the 16th of January 2014. Sampling instrumentation at the site consisted of lysimeters as well as a single piezometer installed within the grey water soak-pit area (Figure 6.35). Despite its proximity to Site C, the subsoil characteristics at Site D were found to be considerably different (Table 3.4). Overall the site consisted of a well drained subsoil with a high sand and gravel proportion. The soak-pit was located adjacent to a large ditch between the site boundary and an adjoining field. A drop in ground level of approximately 0.6 m was recorded between the site and the ditch (Figure 4.16) with the overall topography of the area then sloping away from this point. According to the householder two separate soak-pits had been installed adjacent to each other at the site with grey water discharge to one and STE to the other. Figure 6.47a shows a plan view of Site D whilst Figure 6.47b details a cross-section of the installed instrumentation relative to the change in ground levels between the site boundary and adjoining field.

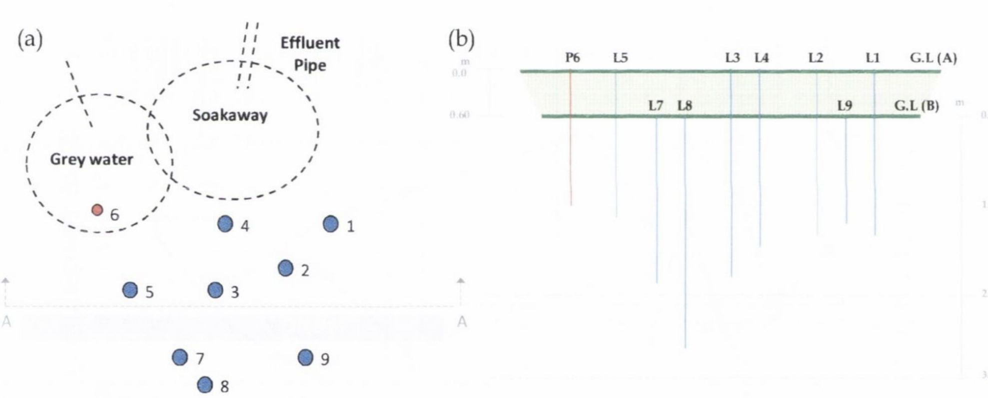


Figure 6.47 (a) Plan view and (b) A-A cross-section of installed instrumentation at Site D

Despite the free-draining conditions observed at the site (K_{fs} = 0.37 m d^{-1}) an initial hand auger test in the area of the grey water soak-pit found that water levels in the area of this soak-pit to be approximately 0.8 m below ground level A. A piezometer was installed at this location to monitor the saturated conditions, however, interestingly the further installation of lysimeters in the surrounding locations revealed unsaturated conditions to a depth > 2.6 m relative to ground level B (Figure 6.47b). This suggests over the lifetime of the system (> 20 years) the continuous accumulation of solids and biological clogging of the infiltrative surface within the soak-pit had caused a significant reduction in permeability and thus increased the hydraulic retention time of the otherwise free-draining subsoil to the point where continuous saturated conditions were found to exist. In contrast to this no samples were obtained from Lys 1 over the course of the sampling period whilst volumes from all of the other lysimeters were low with no samples retrieved on many occasions attributed to the free-draining nature of the subsoil (Appendix E).

Analysis of the mean Cl concentrations recorded at the site immediately indicate elevated concentrations in the all three lysimeters located in the adjacent field downstream of the soak-pit in comparison with mean STE results (Figure 6.48). This may be as a result of the additional loading from the grey water discharge point, however, mean concentrations from samples retrieved from Piez 6 were low (81 mg L^{-1}). As there was no means of monitoring the influent concentrations of the grey water to the soak-pit the source of these elevated Cl concentrations is unclear.

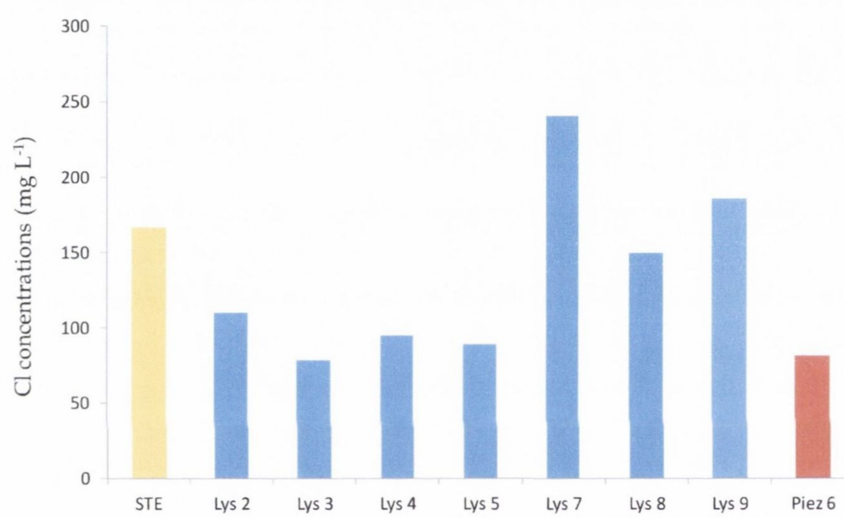


Figure 6.48 Mean Cl concentration of STE and across all sample locations

Table 6.28 shows the mean COD reduction within the subsoil was 73%. However, as Figure 6.49 shows, the highest mean concentrations were observed at Lys 2 whilst increased levels were also found at Piez 6, presumably due to the COD concentrations as a result of grey water discharge. The combined STE and grey water loading appears significantly reduced by downstream sample locations L7, L8 and L9 however as stated previously the pollutant loading of the grey water was undetermined and so the total organic removal may have been higher overall.

Table 6.28 Reduction in COD concentration with respect to STE at Site D

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	312	-
Piezometer	186.8	36%
Lysimeters	79.1	73%

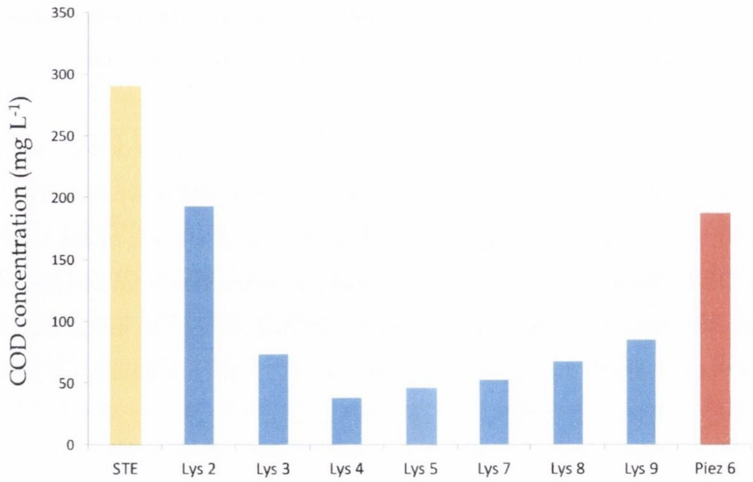


Figure 6.49 Mean COD concentration of STE and across each sample location at Site D

Examination of nitrogen levels at Site D showed NH_4-N concentrations in the STE were also well in excess of the EPA (2009) average influent concentration of 22 - 80 mg L^{-1} (Table 6.29). Despite this, high levels of nitrification were deemed to be taking place with 98.2% of the remaining inorganic-N of soil moisture samples in the form of NO_3-N (Table 6.30). Overall an average 78% reduction in total inorganic-N was found to have occurred within the unsaturated zone with denitrification limited in the well-drained subsoil conditions. With a mean load of 15.9 g d^{-1} of NO_3-N available for groundwater recharge, the risk of nitrate leaching to groundwater appears high (Figure 6.50). Limited nitrification in the saturated grey water soak-pit was apparent with 77% of the inorganic-N remaining in NH_4-N form. This is in sharp contrast to the NH_4-N concentrations recorded in the unsaturated zone (Figure 6.51). Overall the elevated NO_3-N concentrations downstream of both the STE and grey water soak-pits indicated a degree of lateral movement of the plume along the site's gradient. However, the limited volume of soil moisture samples collected within the unsaturated subsoil suggests a large percentage of the discharged effluent is moving rapidly in a vertical direction.

Table 6.29 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})
STE	216	0.09	1.3	71.0
Piezometer	10.37	0.10	3.0	13.5
Lysimeters	0.69	0.13	44.1	44.9
Groundwater	0.04	0.02	9.1	9.1

Table 6.30 Average breakdown of total inorganic-N

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	98.1%	0.1%	1.8%
Piezometer	77.0%	0.7%	22.3%
Lysimeters	1.5%	0.3%	98.2%
Groundwater	0.4%	0.2%	99.4%

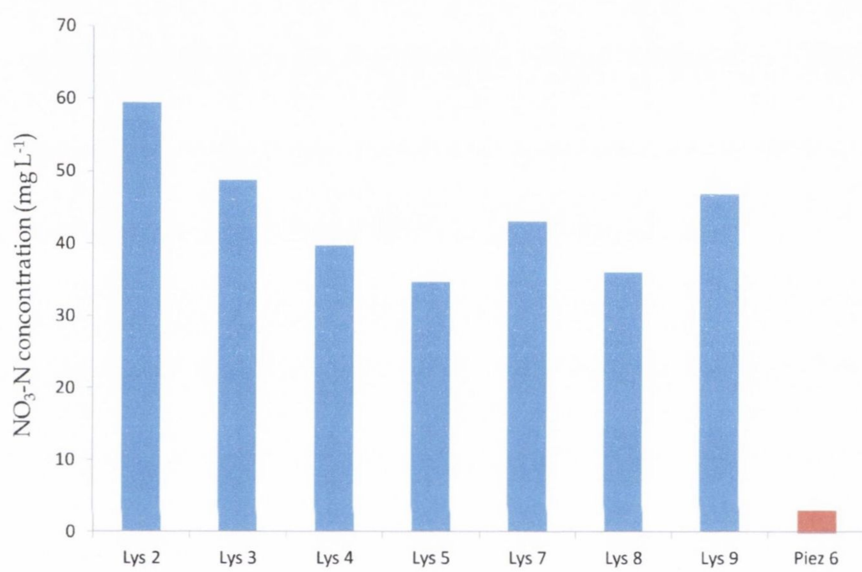


Figure 6.50 Mean NO_3-N concentrations at each sample location at Site D

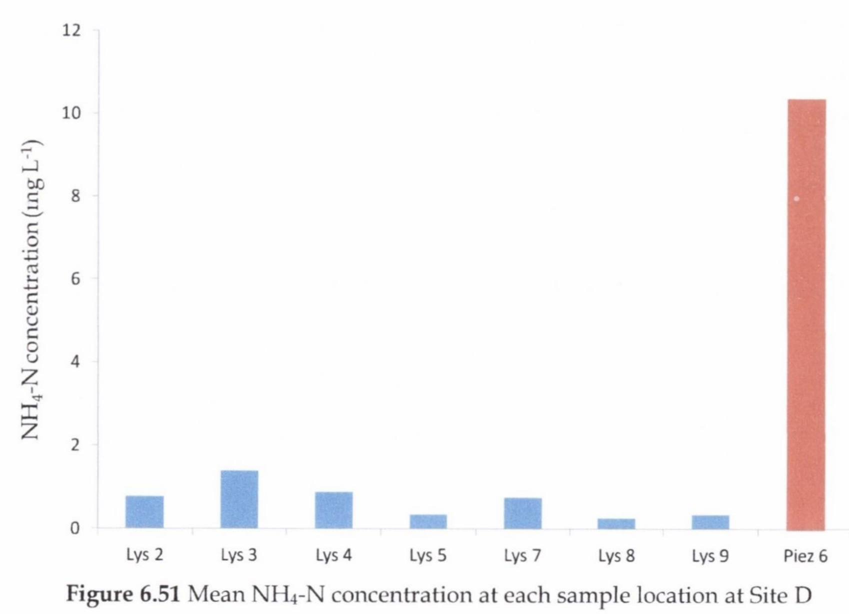


Figure 6.51 Mean NH_4-N concentration at each sample location at Site D

From Table 6.31 the mean PO_4-P STE concentration is shown to be above average at 28.9 mg L^{-1}. (compared to the wastewater influent characteristics outlined by EPA (2009a)). This is interesting given that black water is estimated to contribute only 17% of the TP load found in STE (Canter and Knox, 1985). As black water can have a high concentration but low daily volume thus resulting in low daily load this suggests the STE at Site D is highly concentrated. In addition to this mean PO_4-P concentrations observed at Piez 6 were lower than those recorded in the soil moisture sample downstream of the septic tank discharge point which might indicate that not all of the grey water was being diverted to the separate soak-pit at Site D (Figure 6.52).

Despite these uncertainties it is apparent from Table 6.31 that a considerable proportion of PO_4-P removal was provided by the unsaturated subsoil. Highest PO_4-P concentrations were recorded at L2 and L3 located within the boundary of the site. A drop-off in concentration was then observed by L7, L8 and L9 located within the field and also within the lower subsoil horizon which was found to contain a greater proportion of fines (Table 3.4). These results suggest PO_4-P removal could be attributed to phosphorus adsorption at the effluent moves through the unsaturated subsoil. As expected, due to their proximity, XRD analysis of the soil at Site D was very similar to that at Site C. Again, quartz and albite were the dominant components. Interestingly there was a much smaller fraction of calcite present (only 2.9% compared to 12.3% at Site C). With the mineral composition consisting mainly of quartz (57.4%) which is not associated with precipitation of phosphate ions, suggests the very small fraction of Ca plays a limited role in the removal of PO_4-P.

Table 6.31 Reduction in PO_4-P concentrations with respect to STE at Site D

	Mean Conc. (mg L^{-1})	**Reduction (wrt STE) (%)**
STE	28.9	
Piezometer	0.26	99%
Lysimeters	0.94	97%

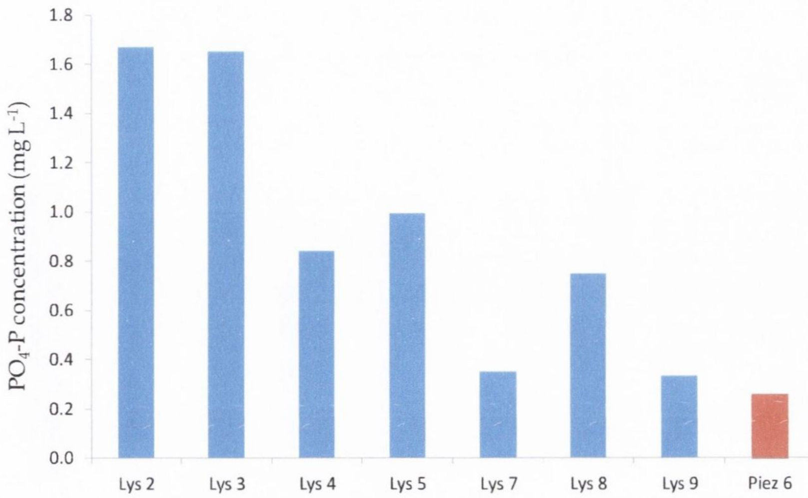


Figure 6.52 Mean PO_4-P concentrations at each sample location at Site D

Results of bacteriological analysis at Site D are presented in Table 6.32. A 2.4 log-unit decrease with respect to STE was observed at Piez 6. The extent to which the two soak-pits interact was uncertain as is their overall depth and extent. As such the bacterial concentrations within the grey water may be influenced by discharging STE and the reduction in concentration may be as a result of dilution by the grey water within the saturated soak-pit conditions. However, as previous studies have shown, grey water can also contain total coliforms in the range of 6.6×10^5 - 2.1×10^8 CFU 100 mL^{-1} (Casanova et al., 2001) and so TC concentrations at Piez 6 may be solely as a result of grey water discharge.

The uniformity of TC levels recorded across all lysimeter sampling points is illustrated in Figure 6.53. A slight increase in concentrations at L5 may be as a result of the combined influence of both the STE and grey water discharges or simply due to its shallow positioning downstream of the soak-pits. Overall a 3.6 log-unit removal of TC was found to occur at Site D over the sampling period, believed to be primarily as a result of physical straining within the soil clogging layer assumed to occur within the STE soak-pit. The saturated conditions found to exist within the grey water soak-pit also suggest the formation of a mature soil clogging layer which may aid in the overall reduction in TC concentrations at Site D.

Table 6.32 Reduction in total coliform concentrations with respect to STE at Site D

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	9	$1.0 \times 10^5 - 5.04\ 10^6$	1.33E+06	-
Piezometer	6	$2.0 \times 10^3 - 9.7 \times 10^4$	3.08E+04	2.4
Lysimeters	30	$1.9 \times 10^1 - 9.7 \times 10^4$	1.92E+03	3.6

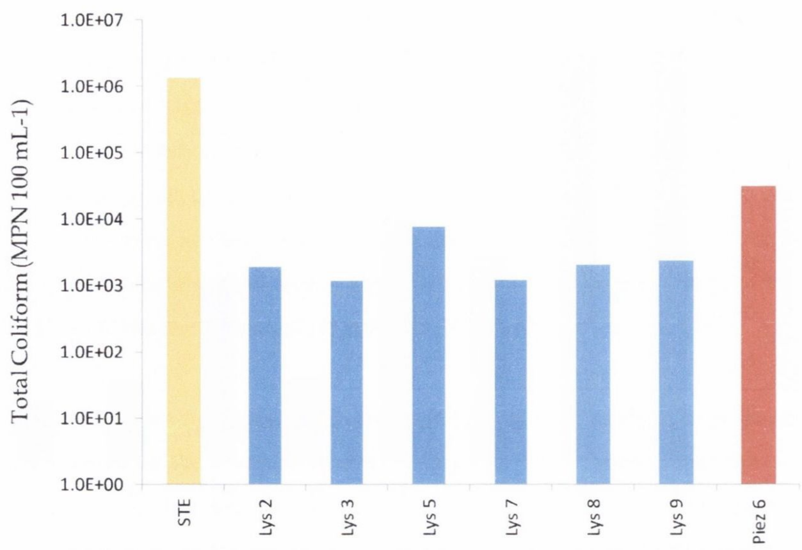


Figure 6.53 Mean TC concentrations at each sample location at Site D

However, as shown in Table 6.33, the reduction in concentration of enteric bacteria at Site D was limited and thus poses a risk to groundwater quality. During the course of the sampling period *E.coli* concentrations in excess of 1000 MPN 100 mL^{-1} were recorded in downstream soil moisture samples on six occasions. Of these six recorded breakthroughs two were recorded at sample position L2, two at sample position L7 and two at sample position L8. Breakthroughs of this magnitude are of particular concern as both sample positions L7 and L8 are located at the deepest sampling points installed at the site, 1.85 m and 2.6 m below ground level B respectively. Figure 6.54 shows *E. coli* concentrations in relation to effective rainfall, however, due to the lack of sample volumes retrieved and the dilution of the samples during testing a clear trend is difficult to distinguish.

Given the estimated subsoil depths recorded in the area surrounding Site D are only 3 - 10 m (Nolan, 2013) the risk to groundwater supplies appears significant. Despite this concern groundwater samples taken from an on-site well (Figure 4.16) showed no presence of *E.coli* throughout the sampling period. One explanation for this is that subsoil the increase in the depth of unsaturated subsoil beneath Site D in comparison with the nearby Site C, or the absence of bacterial concentrations may be due to the degree of dilution provided by the underlying groundwater. However, in general, results from the study suggest the soak-pit system in operation at the site does not provide sufficient protection to underlying groundwater supplies and as with Site C alternatives should be considered.

Table 6.33 Concentrations of *E.coli* detected across Site D

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
Piezometer	6	0	0	2	4
Lysimeters	30	3	13	8	6
Groundwater (on-site well)	7	7	0	0	0

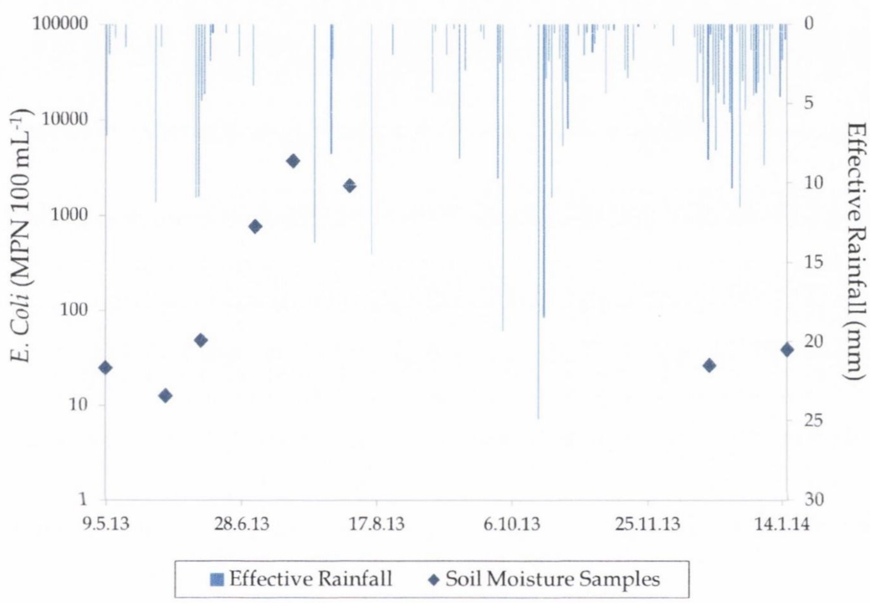


Figure 6.54 Geometric mean concentrations of *E. coli* in response to effective rainfall

6.3.3 SITE E (CO. WESTMEATH)

Effluent and soil moisture samples as well as groundwater samples were monitored from the 7th of March 2013 the 14th of January 2014. Interestingly, the well used for water supply to the house at Site E is located downstream of the septic tank discharge point (Figure 4.18). Soil moisture lysimeters where installed at a variety of depths within the soak-pit area ranging from 1.2 m to 3.0 m down gradient of the septic tank outlet pipe. Due to the highly permeable nature of the subsoil (Table 3.5) at Site E, effluent was expected to percolate rapidly in a vertical direction. A plan view of the setup at Site E is shown in Figure 6.55a whilst a cross-section of the relevant depths at which samples were retrieved is detailed in Figure 6.55b.

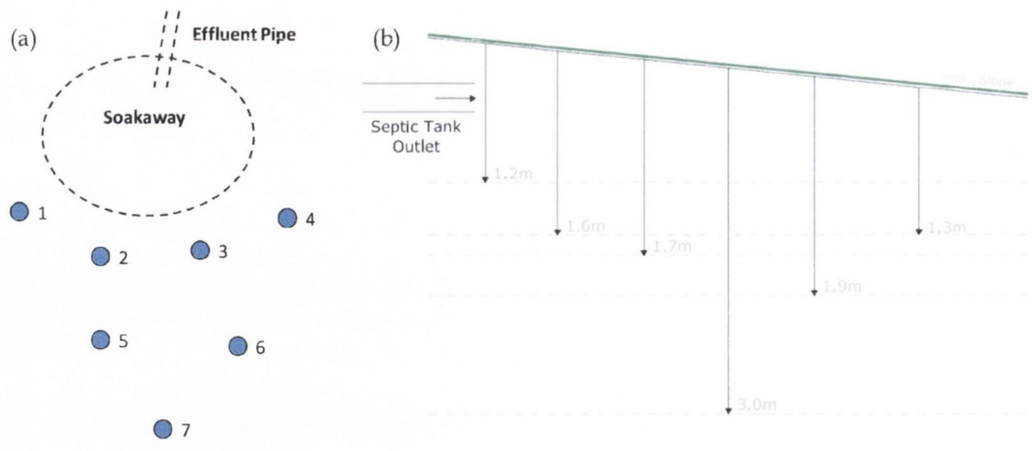


Figure 6.55 (a) Plan view and (b) cross-section of installed instrumentation at Site E

As with the previous sites, analysis of the mean Cl concentrations recorded at each sample point was used to give an initial estimation of the movement of the percolate within the soak-pit area. Figure 6.56 shows that concentrations in samples retrieved from Lys 1 were well in excess of the mean effluent concentration of 125 mg L^{-1}. Throughout the sampling period at Site E samples extracted from Lys 1 were seen to contain sediment. Although the lysimeter had been extensively flushed out with distilled water on both the 07/03/13 and the 11/04/13 the presence of sediment persisted suggesting a fracture in the ceramic cap. This may have been responsible for the elevated Cl concentrations present in the soil moisture samples at this location. As such the results from Lys 1 appear anomalous and so are omitted from the overall analysis presented below.

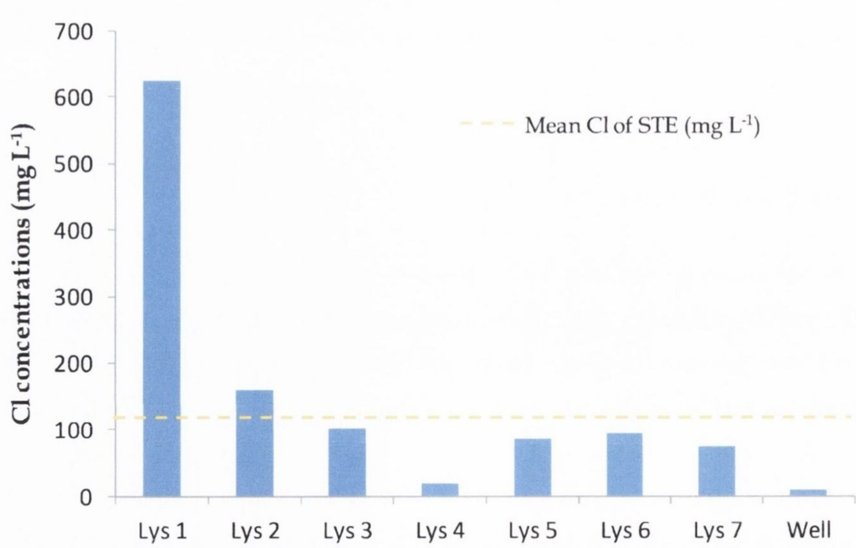


Figure 6.56 Mean Cl concentrations across all sample locations

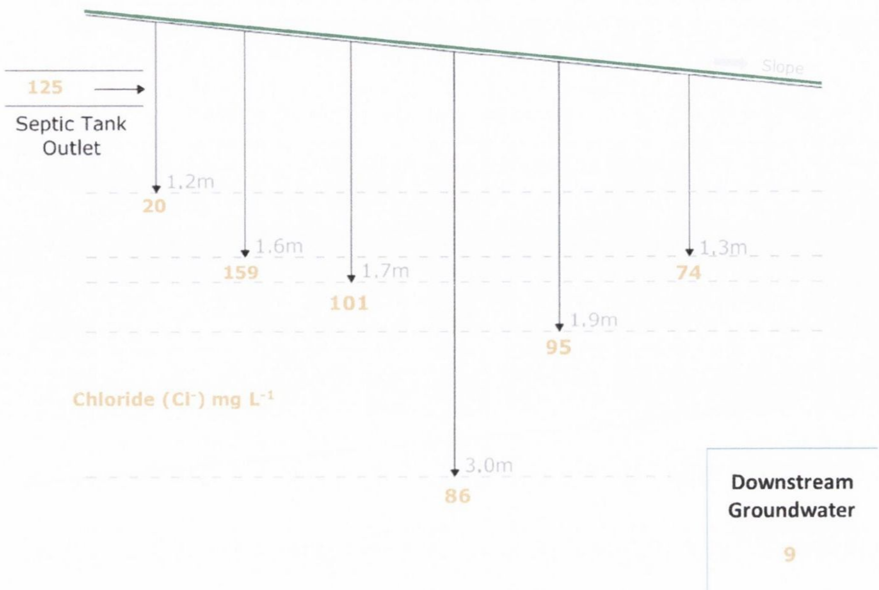


Figure 6.57 Cross-section of mean Cl concentrations in relation to subsoil depth

It is apparent from the Cl concentrations presented in Figure 6.57 that the effluent being discharged to the subsoil moved rapidly in a predominantly vertical direction in the direction of the overall gradient of the site. This is concluded from the consistently low concentrations of Cl recorded at the Lys 4 position (1.2 m depth) which is slightly upstream of the effluent discharge point. At the 1.2 m depth little or no presence of effluent percolation indicates that the effluent plume did not extend laterally in the direction of Lys 4 at this depth. This assumption is corroborated by the fact that only three samples of <15 mL were retrieved from Lys 4 for the duration of the sampling at Site E indicating it was not located within the extent of the STE plume. Overall the Cl results show a predominantly vertical plume with some extension in the lateral direction determined as a result of the overall gradient of the site.

Table 6.34 presents the results from the COD analysis at Site E which shows that, despite the high hydraulic conductivity of the site the vast majority of the organic concentration was reduced within the soak-pit system. This is believed to occur in the biologically active zone within the soak-pit which develops at the infiltrative surface of the STE discharge by a combination of physical straining and biodegradation processes. The development of such a soil clogging layer within the receiving subsoil is critical in such high permeable subsoils as it increases the effluent retention time in the vadose zone and thus the potential for pollutant attenuation is also increased. Figure 6.58 illustrates the mean COD concentrations recorded at each sample depth within the soak-pit area at Site E from which the movement of effluent through the subsoil appears to correspond to that illustrated in Figure 6.57 with a decrease in COD concentrations in both the vertical and lateral directions. Despite the highly permeable characteristics of the overlying subsoil no adverse affects were detected in the groundwater quality during the course of the monitoring period.

Table 6.34 Reduction in COD concentrations with respect to STE at Site E

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	473	-
Lysimeters	61	87%
Groundwater	10	98%

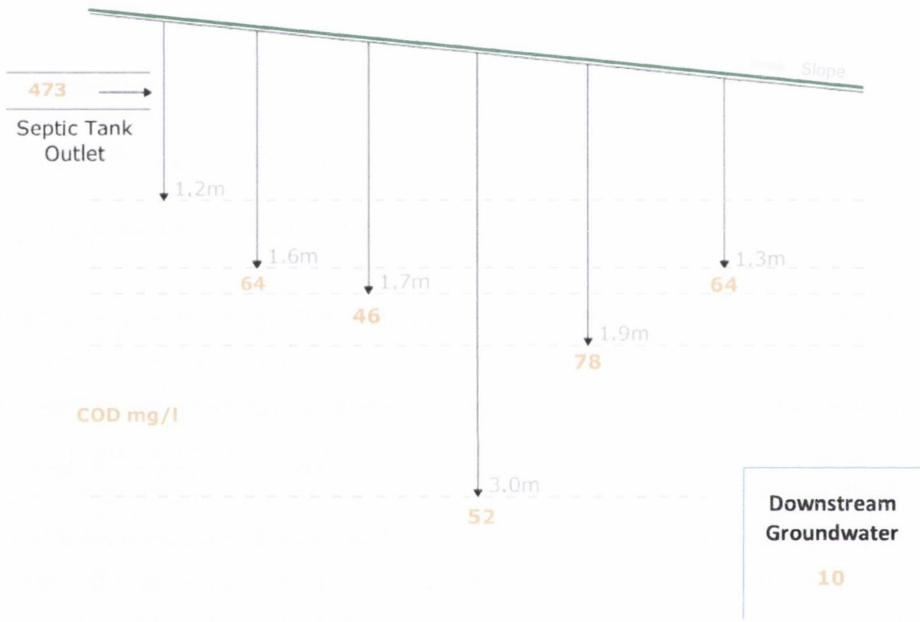


Figure 6.58 Cross-section of mean COD concentrations in relation to subsoil depth

As with the previously described moderate permeability sites (Sites C and D), the unsaturated conditions at Site E gave rise to high levels of nitrification which occurred rapidly within the receiving subsoil with 98% of the inorganic-N present in the soil moisture samples in the form of NO_3-N (Table 6.36). However, as detailed in Table 6.35 only 35% of the overall total inorganic-N was removed within the upper subsoil horizons monitored during the study. This is most likely as a result of a limited availability of saturated micro-sites in this free-draining soil matrix and thus limited denitrification potential. As such, inorganic-N remained as NO_3-N as it percolates through the subsoil with eventual recharge to groundwater most likely.

Table 6.35 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N

	NH_4-N	**NO_2-N**	**NO_3-N**	**Tot. Inorganic-N**
	Mean Conc. (mg L^{-1})	**Mean Conc. (mg L^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Conc. (mg L^{-1})**
STE	77.9	0.29	3.3	81.5
Lysimeters	0.86	0.09	52.1	53.1
Groundwater	0.08	0.01	2.5	2.6

Figure 6.59 shows this rapid nitrification to have occurred by the 1.6 m sample depth, a slight decrease in NO_3-N values is observed by the 3.0 m depth by which time the STE plume is expected to have extended further in a lateral as well as vertical direction resulting in more dispersal of the overall concentration. This gradual dispersion with depth may contribute to the reduction in impact on groundwater quality, the average concentration of which was found to be 3 mg L^{-1} over the course of the study. The dilution capacity of the groundwater would also serve to mitigate the potential impact to the water supply to the house.

Table 6.36 Average breakdown of total inorganic-N

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	96%	0.4%	4%
Lysimeters	2%	0.2%	98%
Groundwater	3%	0.3%	97%

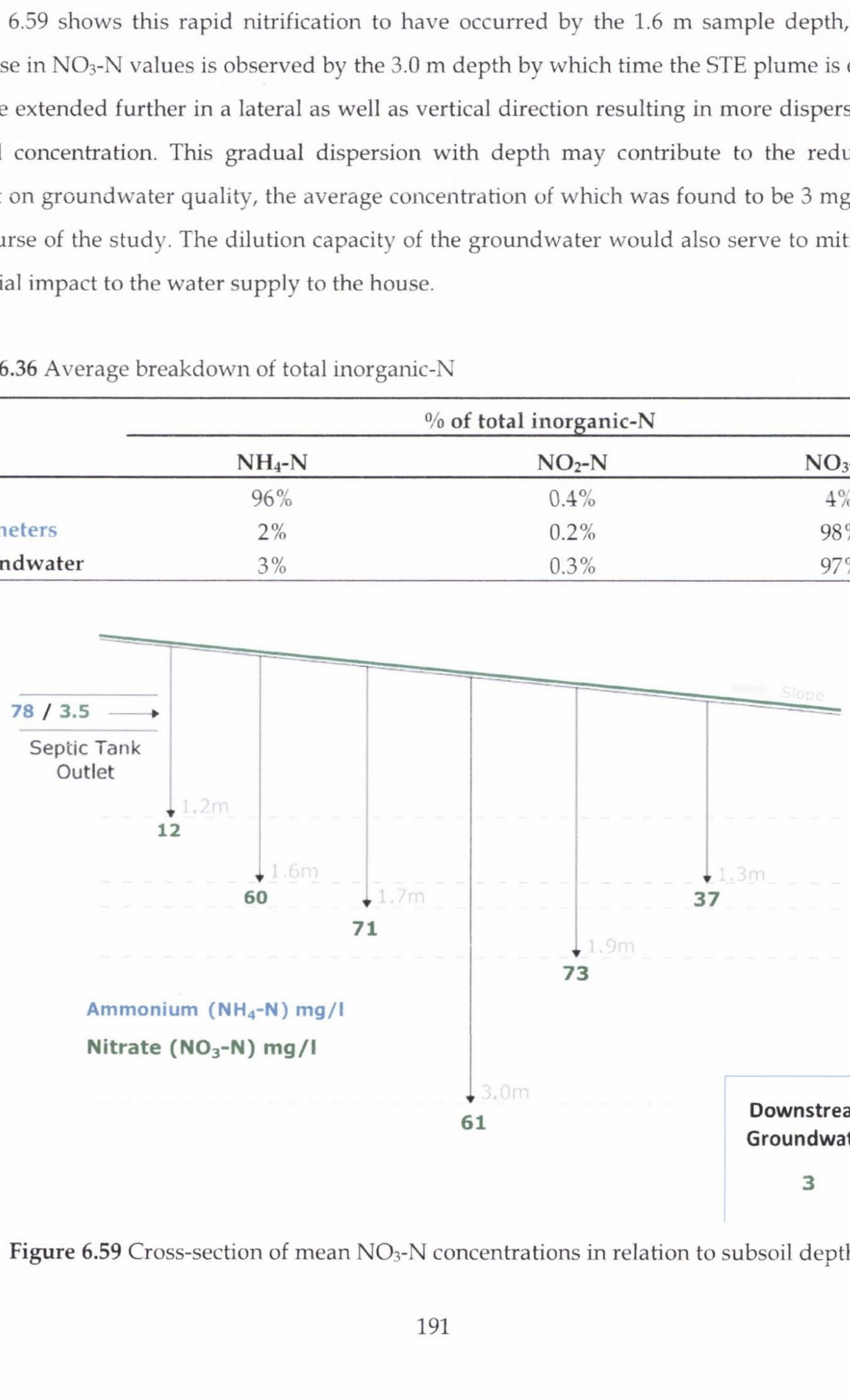


Figure 6.59 Cross-section of mean NO_3-N concentrations in relation to subsoil depth

As with the organic and nitrogen analysis, the examination of PO_4-P concentrations within the subsoil as a result of STE discharge showed considerable attenuation despite soil analysis showing predominantly gravelly sand with a clay fraction of just 1%. Consequently, the reduction in PO_4-P at Site E is believed to be a result of organic matter providing P-sorption sites in the absence of a significant clay fraction in combination with the presence of Ca with XRD analysis showing the mineral composition to be predominantly calcite. Overall, PO_4-P removal at Site E was limited with mean soil moisture concentrations of 1 - 2.6 mg L^{-1} indicating the high point hydraulic loading results in the fast vertical movement of effluent and reduces the potential for P removal. This is illustrated by Table 6.37 which shows that, on the whole, PO_4-P removal slightly less than that recorded at the other sites. Despite this PO_4-P concentrations in groundwater sample remained low with a mean concentration of 0.5 mg L^{-1}.

Table 6.37 Reduction in PO_4-P load at Site E

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE	16.8	
Lysimeters	1.8	89%
Groundwater	0.5	97%

Figure 6.60 shows the mean PO_4-P concentrations recorded at each sampling depth below the effluent discharge point. Again a vertical plume with limited lateral extension is observed.

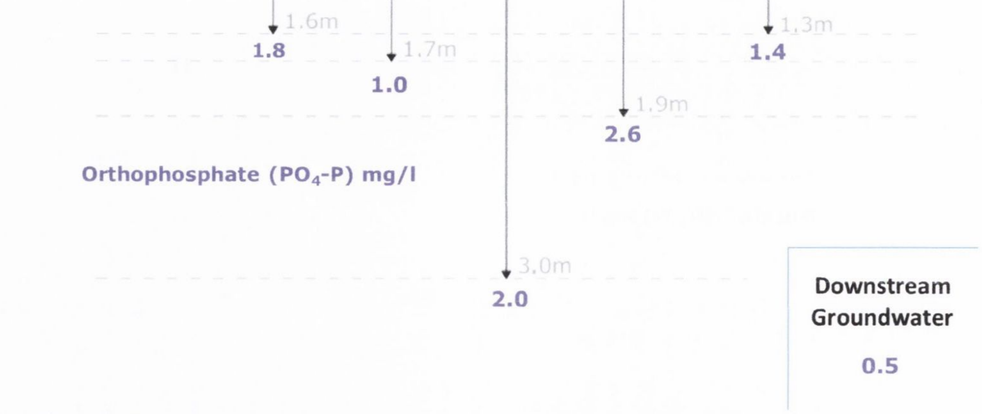


Figure 6.60 Cross-section of mean PO_4-P concentrations in relation to subsoil depth

Analysis of the bacteriological results from Site E, show a mean reduction of 3.3 log-units of total coliform within soil moisture samples beneath the infiltrative surface (Table 6.38). This was attributed to the clogged interstitial pore spaces within the developed biomat layer preventing significant transport of bacteria through physical straining. The formation of this clogging layer is crucial in free-draining subsoil such as those present at Site E.

Table 6.38 Reduction in total coliform concentrations with respect to STE

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	11	$3.5 \times 10^6 - 2.2 \times 10^7$	9.13E+06	-
Lysimeters	48	$1.0 \times 10^1 - 1.2 \times 10^5$	4.49E+03	3.3
Groundwater	11	$1.5 \times 10^1 - 9.8 \times 10^2$	2.47E+02	4.6

Table 6.39 Concentrations of *E.coli* detected at Site E

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
Lysimeters	48	27	9	6	6
Groundwater	11	11	0	0	0

Despite this, significant concentrations of *E.coli* were observed during the study. Figure 6.61 shows the geometric mean concentration of *E. coli* across each sample position at Site E. From this plot, it can be seen that consistently high concentrations were recorded at the Lys 3 (1.7 m) sample location. This may be indicative of the focal point of the effluent hydraulic loading to the subsoil. Detection of enteric bacteria in concentrations exceeding 1000 MPN 100 mL^{-1} at the 3.0 m sample depth on two occasions is of concern given the depth to bedrock at Site E is approximately 4.0 m. As with the previous moderate permeability sites, no adverse affect on groundwater quality was detected, however the results highlight the vulnerability and substantial threat to groundwater quality which could pose a serious health risk to drinking water quality.

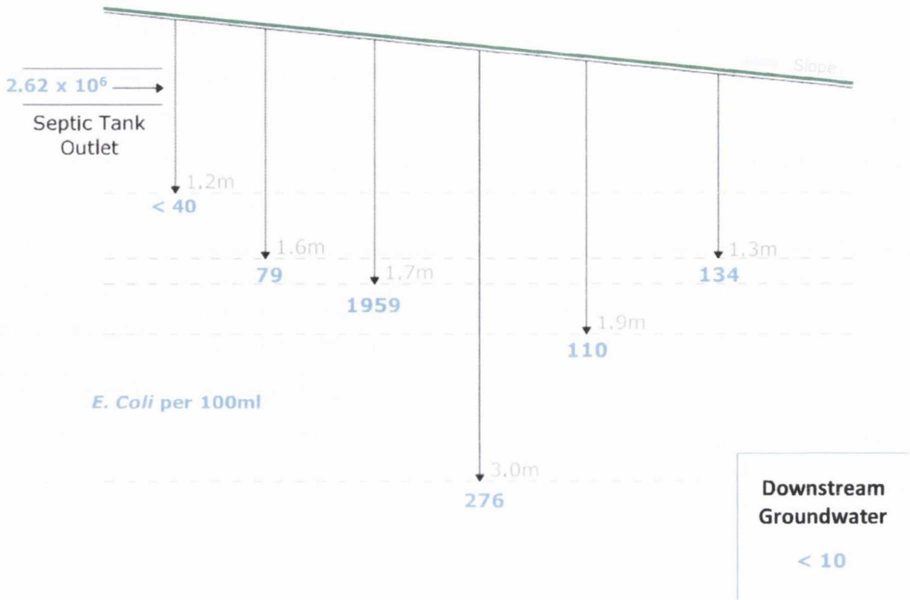


Figure 6.61 Cross-section of mean *E. coli* concentrations in relation to subsoil depth

6.3.4 SITE F (CO. CORK)

A second high permeability site located outside Fermoy in Co. Cork was monitored from the 15th of January 2013 to the 10th of December 2013. As with the previous sites, the monitoring instrumentation consisted of suction lysimeters as well as groundwater samples taken from existing on-site well downstream of the soak-pit area. Due to the poor condition of the existing septic tank sampling of the effluent quality was not possible at Site F. Hence, STE concentrations are assumed to be in line with average concentrations recorded by previous studies carried out in Ireland (Section 5.9).

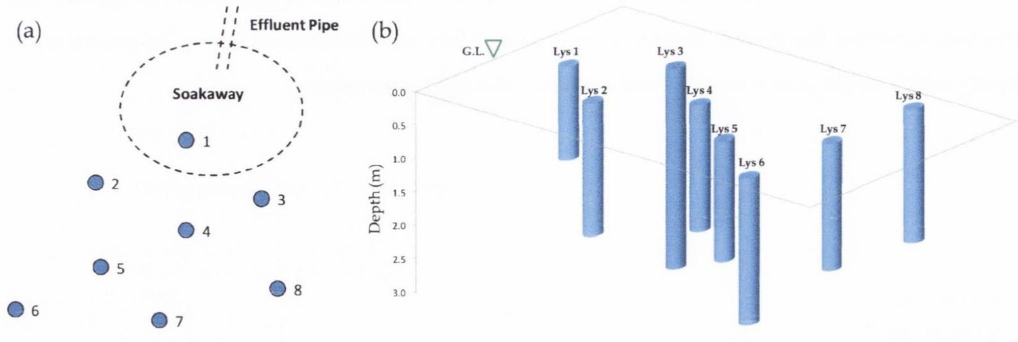


Figure 6.62 (a) Plan view and (b) 3D view of installed instrumentation at Site F

Figure 6.62 shows the location of the installed lysimeters relative to the soak-pit area at Site F. From the Cl concentrations presented in Figure 6.63 it is assumed that Lys 1 is directly in the effluent plume close to the discharge point of the septic tank. The mean Cl concentration of Lys 7 is also elevated relative to the remaining soil moisture sampling points. As Lys 7 is located at a 1.9 m depth approximately 6.0 m downstream of the estimated septic tank discharge point (according to the homeowner) this presents the conceptualisation of the effluent plume extending in both the vertical and lateral direction along the gradient of the overall site (Figure 4.20).

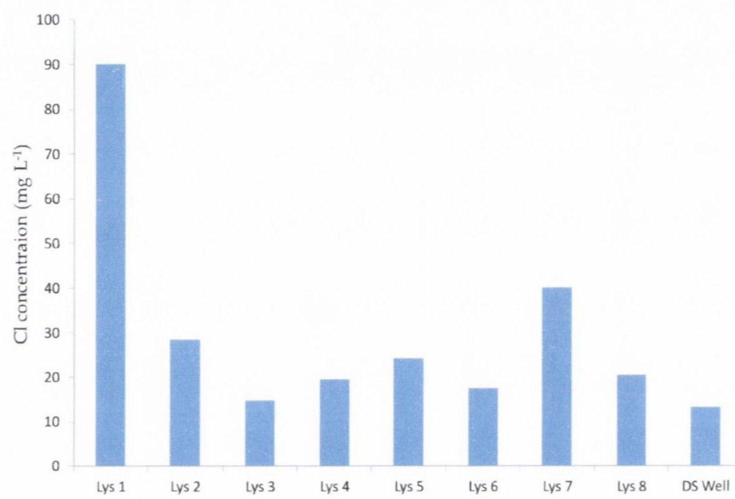


Figure 6.63 Mean Cl concentrations across all sample locations

Assuming an average COD effluent concentration of 580 mg L^{-1} (Table 5.19) gives an estimated reduction in organic concentrations of 90% in the soil moisture samples downstream of STE discharge point (Table 6.40). As with the previous sites of higher permeability subsoils the formation of a biomat or clogging layer is assumed to have developed at the effluent infiltrative zone which is responsible for the reduction in organic concentrations. The subsoil depth to bedrock at Site F was found to be approximately 3.0 m. The further reduction in COD concentrations between the subsoil and the groundwater obtained from the downstream well (30 m in depth) is attributed to percolate dilution as it passes through the underlying bedrock as well as substantial dilution within the groundwater itself.

Table 6.40 Reduction in COD load with respect to estimated STE load at Site F

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load Removal (%)
STE*	580	348	-	-
Lysimeters	58	34.8	313.1	90%
Groundwater	4	2.5	345.4	99%

*presumed value

As with the Cl concentrations presented in Figure 6.63, the highest concentrations of COD were recorded at the Lys 1 and Lys 7 locations (Figure 6.64). The extension of the effluent plume laterally to Lys 7 indicates the formation of a considerable soil clogging formation along the gradient of the site. Overtime, the development of such a layer in high permeability soils such as those present at Site F, increase the effluent retention time in the upper subsoil horizon as well as spreading the effluent loading over a greater area, thus reducing the intensity of the hydraulic loading and enhancing the treatment quality of the system.

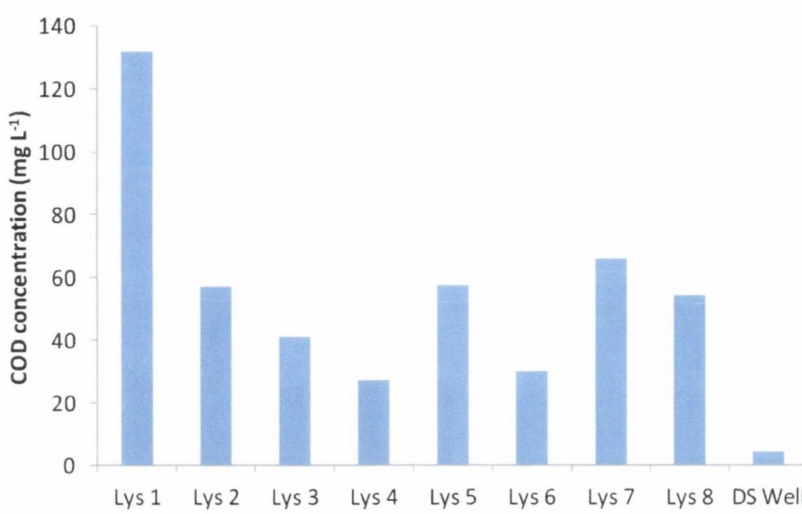


Figure 6.64 Mean COD concentrations at each sample location at Site A

As with the previous higher permeability sites, rapid nitrification of the STE was seen to occur within the subsoil at Site F. Figure 6.65 again indicates a high effluent presence at Lys 1, with the NO_3-N concentrations across the remain in sampling positions relatively uniform. With estimated NH_4-N concentrations of 22 - 80 mg L^{-1} (the dominant from of inorganic-N) in STE as measured at other sites this suggests a limited fraction of inorganic-N within the unsaturated subsoil. As with the previous sites, the free-draining conditions at Site F reduces the potential for denitrification and thus NO_3-N remains in the subsoil until eventual recharge to groundwater.

Table 6.41 Mean concentration of NH_4-N, NO_2-N, NO_3-N and total inorganic-N

	NH_4-N	NO_2-N	NO_3-N	Tot. Inorganic-N
	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})	Mean Conc. (mg L^{-1})
Lysimeters	0.32	0.10	15.0	15.4
Groundwater	0.02	0.01	3.5	3.5

Consequently, the remaining inorganic-N fraction in both the soil moisture and groundwater samples is 97% and 99% NO_3-N respectively (Table 6.41 and Table 6.42).

Table 6.42 Average breakdown of total inorganic-N at Site F

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
Lysimeters	2%	0.7%	97%
Groundwater	1%	0.2%	99%

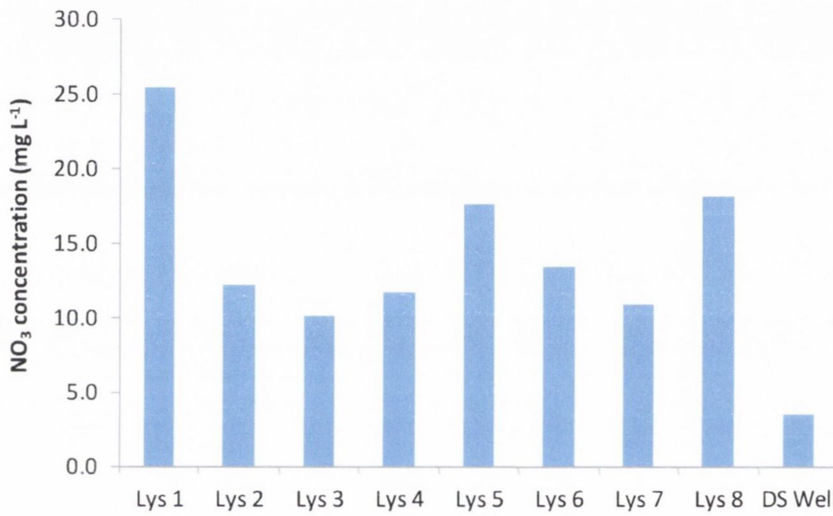


Figure 6.65 Mean NO_3-N concentrations at each sample location at Site F

Assuming an estimated value (based on previous research carried out by Trinity College Dublin (Table 5.19)), of 18.8 mg L^{-1} of PO_4-P being applied to the soak-pit by the STE discharge, a significant reduction in PO_4-P concentrations were observed at Site F. As with Site E, it is assumed the P-sorption to organic matter plays an important role in the reduction in PO_4-P concentrations. A slightly higher clay fraction of 3% present in the subsoil at Site F may also contribute to the increase in PO_4-P reduction in comparison with Site E. XRD analysis at Site F showed the 75% of the mineral composition consisted of quartz and muscovite with the remaining fraction made up by clinochlore, albite and hernatite again suggesting the role of PO_4-P removal through mineral precipitation is limited.

Table 6.43 Reduction in PO_4-P concentration in relation to estimated STE concentration at Site F

	Mean Conc. (mg L^{-1})	Reduction (wrt STE) (%)
STE*	18.8	
Lysimeters	0.5	97.1%
Groundwater	0.0	99.8%

*presumed value

As with Site E, total coliform removal at Site F seemed to be predominantly across the assumed biomat depth and so was attributed to physical straining in conjunction with adsorption to the small fraction of clay particles present. Assuming a mean value of 1.18 x 10^7 MPN 100 mL^{-1}, this equates to a TC removal of 3.8 log-units in the soil moisture samples obtained at Site F (Table 6.44). Despite the shallow, high permeability subsoil overlying the site, the groundwater quality sampled from the downstream well location showed no adverse response to effluent discharge upstream with a mean 6.1 log-unit removal recorded over the sampling period.

Table 6.44 Reduction in total coliform concentrations with respect to estimated STE loading

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE*	-	-	1.18E+07	-
Lysimeters	58	4.1 x 10^0 – 4.8 x 10^4	1.70E+03	3.8
Groundwater	10	2.0 x 10^0 – 2.0 x 10^1	9.86E+00	6.1

*presumed value

As detailed in Table 6.45, high *E.coli* concentrations were also recorded within the soil moisture samples at Site F. Figure 6.66 shows the geometric mean concentration of *E. coli* at the site. Lysimeters locations 2, 3, 5 and 7 showed elevated concentrations of enteric bacteria and suggest the development of an effluent plume as shown in Figure 6.67. As with Site E, the plume was thought to be predominantly vertical, with lateral dispersion aided as a result of biomat formation in the direction of the slope of the site. The shallow free-draining subsoil gives rise to concern particularly in relation to enteric bacteria. However, as with the prior results outlined for sites C, D and E, the groundwater samples remained clear of any *E.coli* presence.

Table 6.45 Mean concentrations of *E.coli* across all sample locations at Site F

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
Lysimeters	58	31	11	13	3
Groundwater	10	10	0	0	0

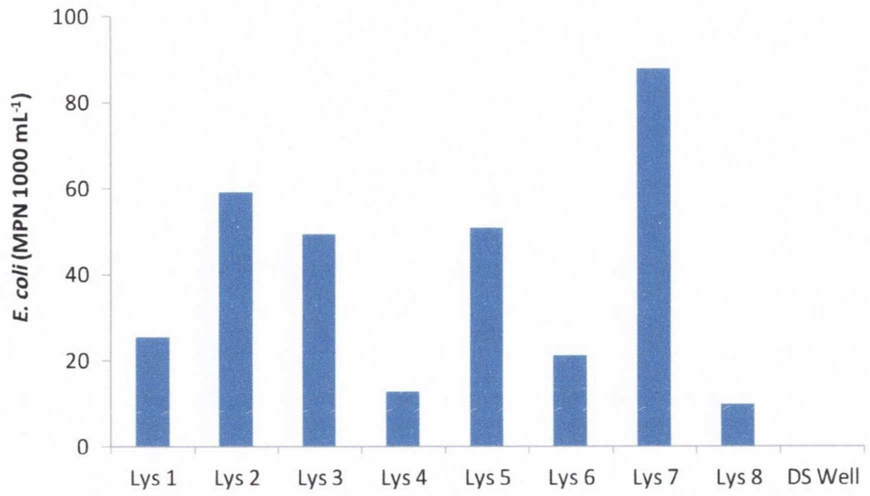


Figure 6.66 Geometric mean concentrations of *E. coli* at Site E

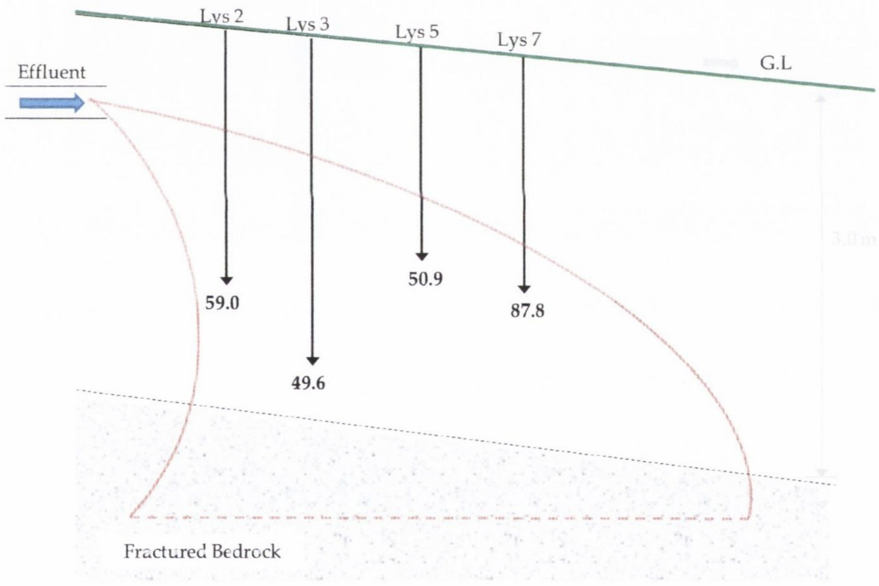


Figure 6.67 Cross-section of geometric mean concentrations of *E. coli* at selected locations at Site E

Chapter 7 Alternative Infiltration Systems

7.1 METHOD OF ANALYSIS

As previously described in Chapter 4, the two sites of low permeability subsoil were upgraded to parallel alternative distribution systems consisting of LPP and DD networks. The effluent at both sites was split equally between the two distribution networks and monitoring instrumentation was installed to determine the performance of each system. Figure 7.1 shows a cross-section of the instrumentation installed at both sites beneath the LPP and DD infiltration surfaces.

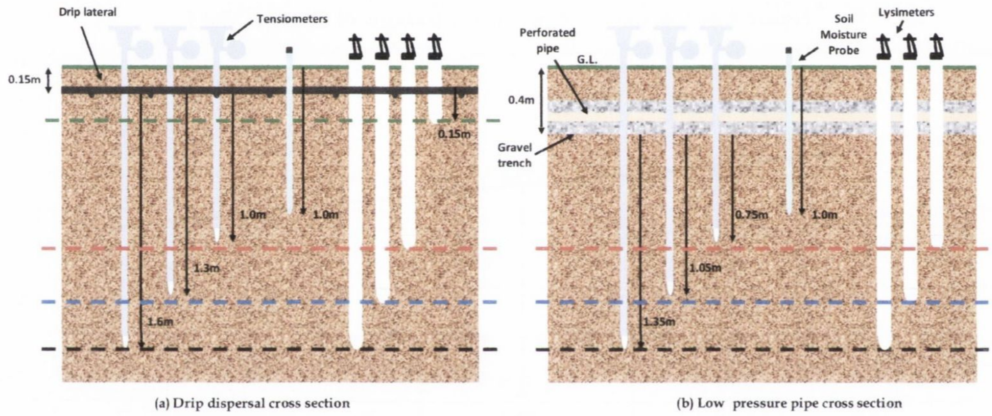


Figure 7.1 Cross-section of instrumentation installed beneath (a) DD system and (b) LPP system at Sites A and B

As chloride (Cl) does not play a significant role in geochemical reactions (Marshall et al, 1999) it was employed as a crude tracer throughout the duration of the field study to identify those areas across the distribution networks which were receiving wastewater effluent. Such analyses would help in determining the most representative method of reporting the attenuation of the percolate as well as confirming if uniform distribution was in fact achieved.

The distribution systems installed at both sites were monitored for approximately 14 months each. Results for Cl at the different sample locations beneath each system were averaged at the same depth plane at which they were recorded. This enabled the identification of differences in loading rates between sampling locations at the same depths, thus highlighting any anomalies within each plane which may be indicative of the presence of preferential flow paths (PFP's).

Given the uniform pressurised effluent distribution of both the LPP and DD systems the analysis of the attenuation of the percolate was carried out based on the planar average (the averaging of the concentrations of each parameter across all sampling positions at each depth plane beneath each system). This then allowed the difference between the mean loading rates to be compared for each of the depth planes.

In general the presentation of the results of chemical, bacteriological and viral analysis of soil moisture samples will assume homogeneous and isotropic subsoil properties and so only takes account of matrix flow (i.e. no heterogeneous PFP's). However, as illustrated in Chapter 6, the monitoring of both sites pre-remediation indicated the presence of PFP's within the low permeability subsoils, which are highlighted for specific incidences.

7.1.1 LOW PRESSURE PIPE SYSTEM (SITE A)

The attenuation of the percolate from the LPP system at Site A was carried out by analysing soil moisture samples from the suction lysimeters installed the four trenches. Initial analysis involved the plotting of the mean Cl concentrations at each depth plane lysimeter across all sample positions beneath the LPP over the course of the monitoring period (Figure 7.2).

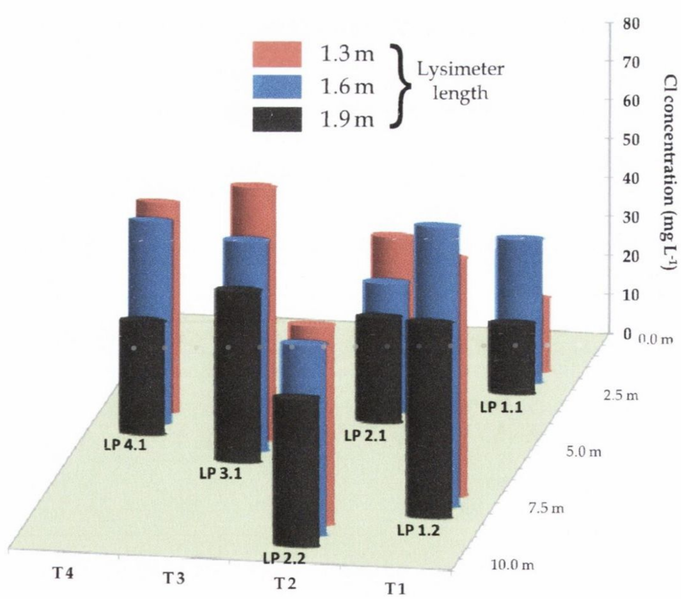


Figure 7.2 Mean Cl Concentrations beneath LPP system at Site A at each depth plane

The results from the monitoring of the pre-remediation soak-pit system at Site A indicated that sample location S1.2 was outside of the effluent plume (Chapter 6), consequently the mean Cl concentrations recorded at this location where deemed indicative of background Cl concentrations in the subsoil (5.5 mg L^{-1}).

In examining Figure 7.2, it can be seen that lower Cl concentrations were recorded at lysimeter nests 1.1 and 2.1, which were located towards the top of T1 and T2 respectively, despite these being located closest to the supply manifold. Marginally higher mean Cl concentrations were recorded in the remaining lysimeter nests across each of the four trenches. This indicates that although pressurised effluent application has been utilised to provide uniform distribution across the percolation area, the natural gradient of the site did influence the direction of the percolate in the subsoil to some extent in such low permeability conditions. Following the third month of sampling (February 2013) initial sampling results indicated sufficiently uniform effluent treatment was being achieved at each sampling location and as such, sample numbers were reduced from this point onwards to three sample positions deemed to be most representative; LP 1.2, LP 2.2 and LP 4.1. A planar average method was then used to determine the mean attenuation of pollutants at each depth plane. As evident from Figure 7.2 the three sample locations chosen were representative of a "worse-case scenario" beneath the LPP network as these were the locations where the highest mean Cl concentrations, indicating the presence of percolating effluent, were recorded. A secondary motivation for this approach was the lack of soil moisture sample being retrieved beneath the LPP system at Site A despite the low permeability conditions. This was particularly problematic during periods of sustained zero effective rainfall. As a result, LP 1.2 at the blue depth plane was the only sample location from which a soil moisture sample was retrieved during every sampling trip (Table 7.1).

Table 7.1 No. of soil moisture samples retrieved from each sampling location beneath LPP system at Site A

Location	LP 1.1	LP 1.2	LP 2.1	LP 2.2	LP3.1	LP 4.1
0.75	5	15	9	13	9	12
1.05	7	16	9	13	11	13
1.35	12	15	10	14	10	14

Table 7.2 details the mean sample volumes retrieved over the course of the sampling period. It can be seen that at a number of locations, when sample volume was retrieved, the average volume was below 100 mL, (the minimum volume required to perform zero dilution TC and *E.coli* analysis).

Table 7.2 Mean (±sd) of volumes (mL) recorded beneath LPP system at Site A

Location	LP 1.1	LP 1.2	LP 2.1	LP 2.2	LP3.1	LP 4.1
0.75	**63** (± 71)	**138** (± 170)	**119** (± 196)	**236** (± 306)	**108** (± 227)	**207** (± 283)
1.05	**153** (± 373)	**394** (± 371)	**298** (± 336)	**319** (± 442)	**315** (± 412)	**363** (± 386)
1.35	**133** (± 93)	**155** (± 220)	**164** (± 183)	**168** (± 157)	**168** (± 262)	**68** (± 63)

The result of the disparity in the number of samples retrieved, as well as the variation in available sample volume, meant applying the method of depth averaging was unsuccessful given the considerable gaps in the data set across the monitoring period. Consequently, as expected from the pressurised distribution of effluent, planar averaging was indeed deemed a suitable approach in analysing the treatment performance of the system.

Although full analysis of all parameters was reduced to three sample locations from February 2013 onwards, all soil moisture samples retrieved continued to be analysed for Cl concentrations across the entire sampling period. A time-series plot of the combined Cl concentrations measured at all six sampling locations for the three depth planes is illustrated in Figure 7.3. From the plot a general trend can be seen between all three depth planes. Any noticeable reductions would have been due to both the effects of physical straining of the percolating effluent and that of dilution, to be discussed in Section 7.2.1.

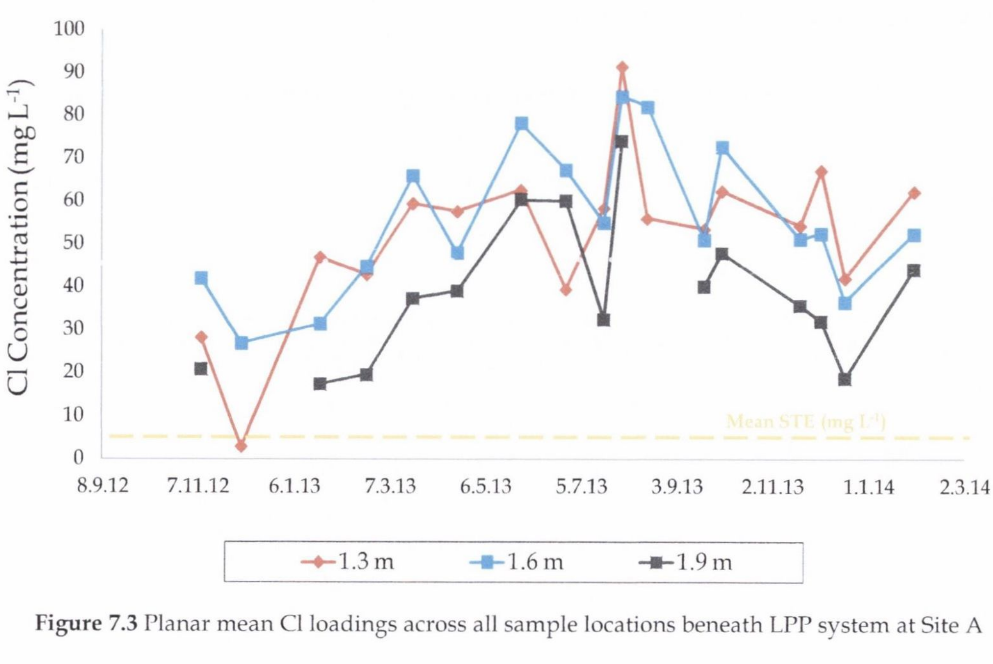


Figure 7.3 Planar mean Cl loadings across all sample locations beneath LPP system at Site A

A further time-series plot of the mean planar loadings at the three selected sample positions (LP 1.2, LP 2.2 and LP 4.1) is illustrated in Figure 7.4. This plot depicts a similar trend as that shown in Figure 7.3, indicating that results from the selected locations give a good indication of treatment performance across the entire distribution area.

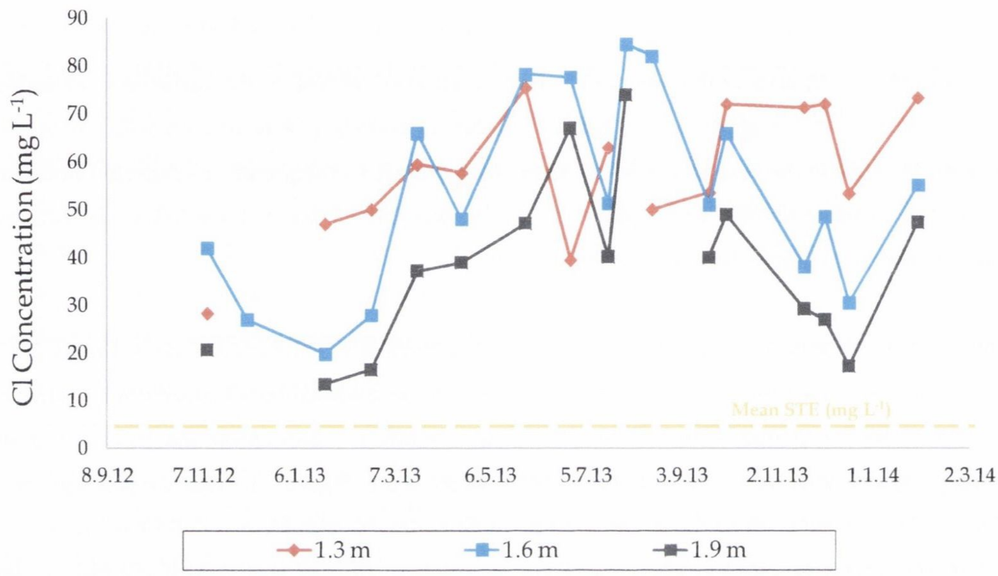


Figure 7.4 Planar mean Cl loadings recorded at three selected sample locations (LP 1.2, 2.2 and 4.1)

7.1.2 DRIP DISTRIBUTION SYSTEM (SITE A)

The results of soil moisture analysis for Cl were again used to determine which of the two methods (depth average or planar average) outlined earlier was the optimum choice in representing the distribution of effluent across the DD system at Site A. A plot of the mean Cl concentrations at each depth plane lysimeter across all sample positions beneath the DD over the course of the monitoring period is depicted in Figure 7.5. Based on this plot, the uniform application of effluent to the subsoil is apparent with very little variation in mean Cl concentrations across the distribution network. As with the LPP system at Site A the number of lysimeter nests for which full chemical and bacteriological analysis was carried out was reduced to three representative positions from February 2013 onwards.

In the case of the DD system, sample locations D1, D2 and D6 were selected. Again, the planar average method was then used to determine the mean attenuation of pollutants at each depth plane across the entire distribution network.

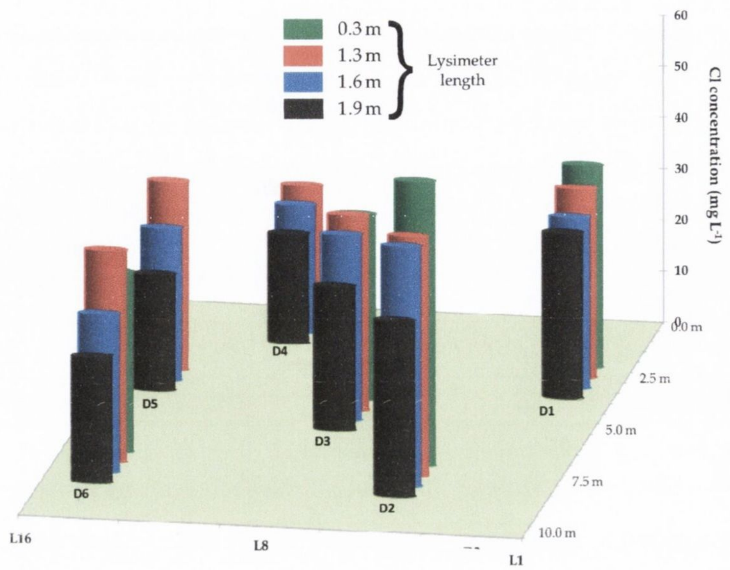


Figure 7.5 Mean Cl Concentrations beneath DD system at Site A at each depth plane

As with the adjacent LPP system, the poor soil moisture volumes retrieved beneath the DD system at Site A was again problematic, particularly during periods of sustained zero effective rainfall. As a result at no sample location below the DD was a full set of soil moisture samples retrieved during the 16 sampling trips (Table 7.3).

Table 7.3 No. of soil moisture samples retrieved from each sampling location beneath DD system at Site A

Location	D1	D2	D3	D4	D5	D6
0.15	11	11	10	-	-	7
1.00	10	12	7	13	9	9
1.30	10	11	13	12	14	10
1.60	10	10	11	8	13	11

Table 7.4 details the mean sample volumes retrieved over the course of the sampling period. It can be seen that at a number of locations, when sample volume was retrieved, the average volume was below 100 mL. Interestingly, the mean sample volumes at each of the depth planes (*red, blue* and *black*) differed significantly beneath the LPP and DD systems at Site A. Beneath the LPP the mean samples for the *red, blue* and *black* plane where 145 mL, 307 mL and 143 mL respectively. In contrast to this mean values beneath the DD at the *green, red, blue* and *black* planes where 30 mL, 216 mL, 217 mL and 244 mL respectively. The low volumes, consistently recorded at the *green* plane (0.3 m), are thought to be as a result of evapotranspiration of effluent located in the shallow subsoil. The variation in sample volume with depth beneath the LPP (compared with the DD) may be as a

result of the installation of the lysimeters adjacent to the trenches rather than directly below them. As outlined in Section 7.2.1, the plume of effluent from the infiltration trench expands gradually with depth, therefore one potential explanation is that, of the three depth planes, the *blue* depth is most consistently within the zone of contribution as the extent of the plume fluctuates in response to rainfall recharge. Sample volumes from the DD system were more uniform across the depth planes owing to the uniform effluent distribution via a greater number of effluent discharge locations.

Table 7.4 Mean (±sd) of volumes (mL) recorded beneath DD system at Site A

Location	D1	D2	D3	D4	D5	D6
0.15	**22** (± 22)	**25** (± 20)	**39** (± 29)	-	-	**34** (± 27)
1.00	**150** (± 71)	**224** (± 170)	**123** (± 196)	**132** (±306)	**368** (± 227)	**296** (± 283)
1.30	**276** (± 389)	**139** (± 151)	**239** (± 349)	**167** (± 247)	**233** (± 356)	**245** (± 324)
1.60	**215** (± 306)	**235** (± 196)	**91** (± 102)	**277** (± 383)	**303** (± 421)	**345** (± 436)

Again all soil moisture samples retrieved beneath the DD system at Site A continued to be analysed for Cl concentrations from February 2013 onwards. A time-series plot of the combined Cl concentrations measured at all six sampling locations for the three depth planes is illustrated in Figure 7.6. Again, a general trend can be seen between all three depth planes with any noticeable reductions due to both the effects of physical straining of the percolating effluent and that of dilution.

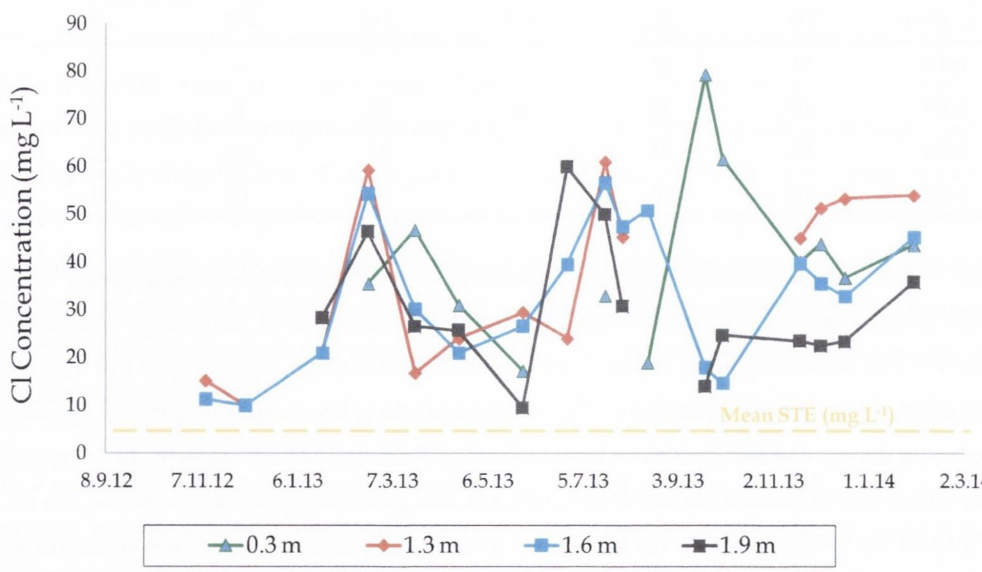


Figure 7.6 Planar mean Cl loadings across all sample locations beneath DD system at Site A

A further time-series plot of the mean planar loadings at the three selected sample positions (D1, D2 and D6) is illustrated in Figure 7.4. This plot depicts a similar trend as that shown in Figure 7.3, indicating that results from the selected locations give a good indication of treatment performance across the entire distribution area.

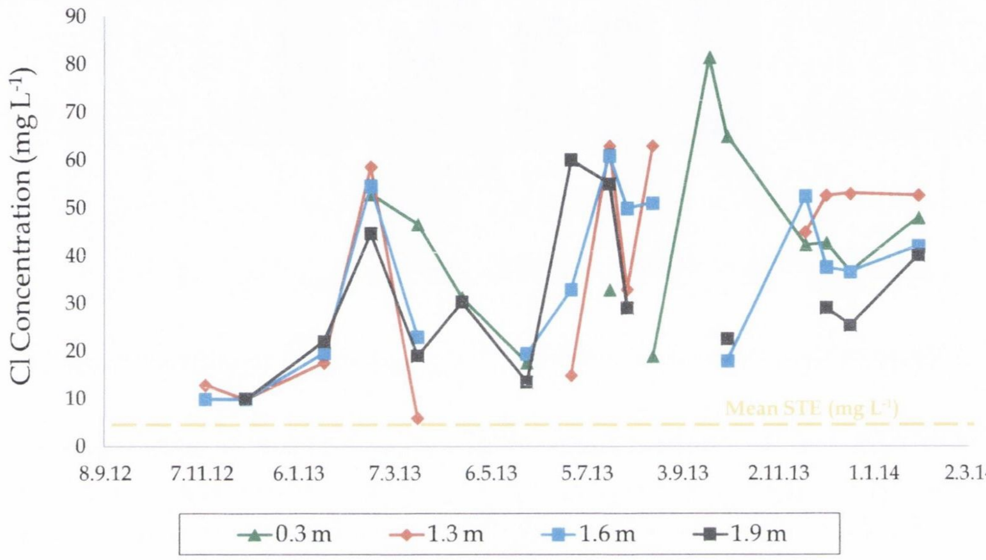


Figure 7.7 Planar mean Cl loadings recorded at three selected sample locations (D1, D2 and D6)

7.1.3 Low Pressure Pipe System (Site B)

Initial analysis of the LPP system at Site B was carried out in the same way as for Site A. This involved the plotting of the mean Cl concentrations at each depth plane lysimeter across all sample positions beneath the LPP over the course of the sampling period (Figure 7.8). From the monitoring of the soak-pit system in operation during the initial pre-remediation monitoring phase (Chapter 6) it was apparent that S1.2 was located outside of the effluent plume. As with Site A, the mean Cl concentration recorded at this location was taken to be the background concentration of the soil, in this case 7 mg L^{-1}.

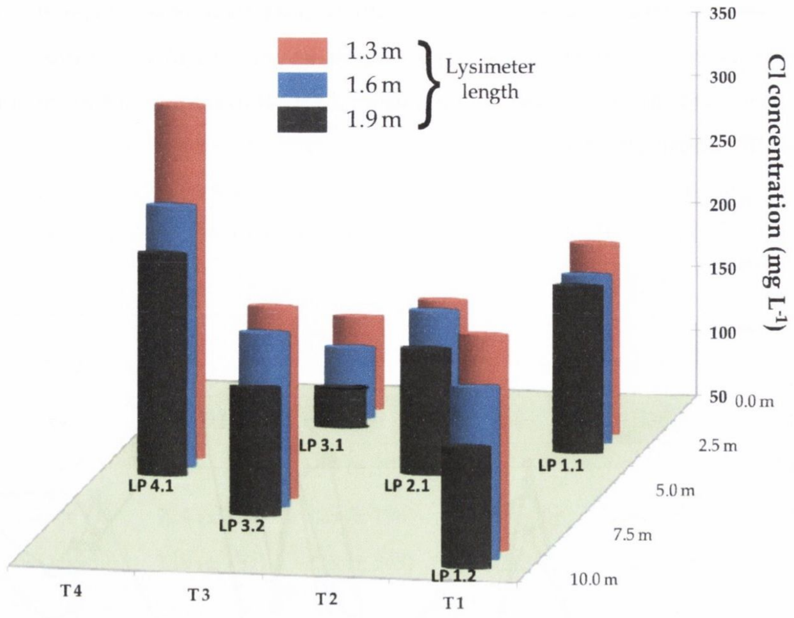


Figure 7.8 Mean Cl Concentrations beneath LPP system at Site B at each depth plane

In examining Figure 7.8, it can be seen that relatively uniform mean Cl concentrations were recorded at all lysimeter nests with the exception of LP 4.1. This is most likely due to the fact that all three lysimeters at this location were installed directly beneath the LPP trench, unlike the remaining lysimeter nests which were installed adjacent to the trenches. As a result, LP 4.1 was located within the concentrated effluent plume below the LPP trench and consequently the mean Cl concentrations at this location are higher.

As with Site A, sampling numbers at Site B were reduced from February 2013 onwards. The sample positions deemed to be most representative of overall system treatment were LP 1.2, LP 2.1 and LP 4.1. A planar average method was then used to determine the mean attenuation of pollutants at each depth plane. As evident from Figure 7.2 the three sample locations chosen were representative of a "worse-case scenario" beneath the LPP network as these were the locations where the highest Cl concentrations, indicating the presence of percolating effluent, were recorded. Unlike Site A, there was no indication of enhanced loading at the bottom of the LPP trenches at Site B, due to the comparatively lesser site gradient.

Soil moisture sample volume at Site B was not an issue (Table 7.6), with failure to retrieve a soil moisture sample from all lysimeters occurring only twice during the entire sampling period (Table 7.5).

Table 7.5 No. of soil moisture samples retrieved from each sampling location beneath LPP system at Site B

Location	LP 1.1	LP 1.2	LP 2.1	LP 3.1	LP3.2	LP 4.1
0.75	17	17	17	17	17	17
1.05	17	17	17	17	17	17
1.35	17	16	17	16	17	17

Table 7.6 Mean (±sd) of volumes (mL) recorded beneath LPP system at Site B

Location	LP 1.1	LP 1.2	LP 2.1	LP 3.1	LP3.2	LP 4.1
0.75	**246** (± 56)	**325** (± 149)	**279** (± 73)	**371** (±244)	**345** (± 431)	**413** (± 256)
1.05	**196** (± 84)	**219** (± 76)	**482** (± 286)	**279** (± 73)	**565** (± 259)	**408** (± 239)
1.35	**303** (± 184)	**178** (± 154)	**243** (± 124)	**118** (± 70)	**428** (± 324)	**566** (± 309)

All soil moisture samples retrieved beneath the LPP system at Site B continued to be analysed for Cl concentrations from February 2013 onwards, with Figure 7.8 indicating sufficiently uniform effluent distribution across the lysimeter nests located adjacent to the percolation trenches.

A time-series plot of the combined Cl concentrations measured at all six sampling locations for the three depth planes is illustrated in Figure 7.9 and shows relatively little difference with depth. A second time-series plot of the selected lysimeters (Figure 7.10) indicates how closely representatives the chosen lysimeter nests are of the overall Cl concentrations, confirming the planar average method is the most representative way of analysing the attenuation of percolate.

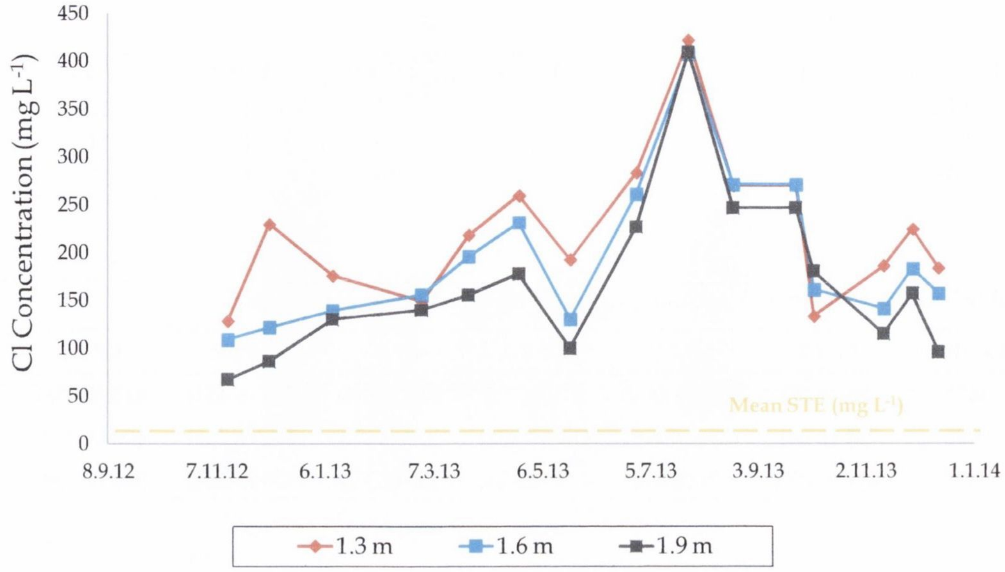


Figure 7.9 Planar mean Cl loadings across all sample locations beneath LPP system at Site B

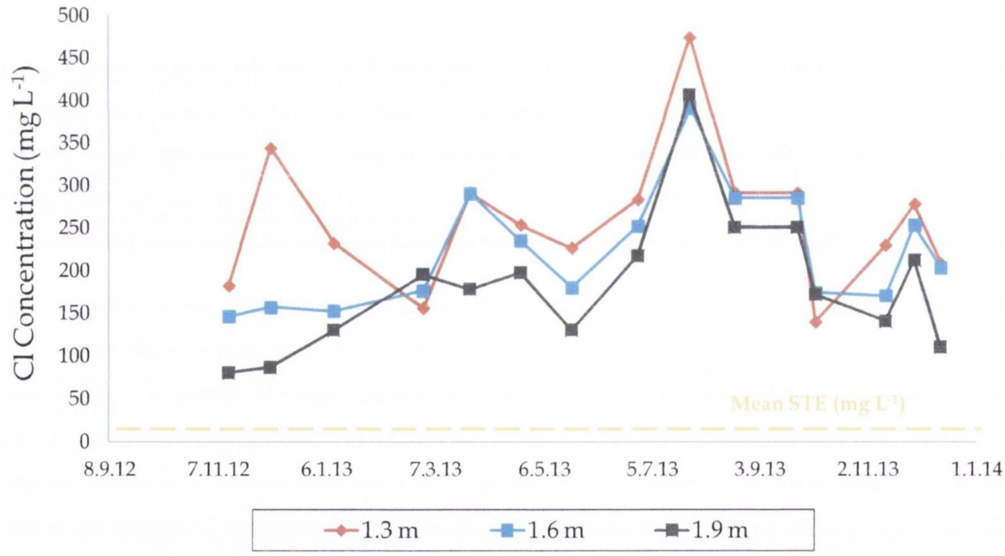


Figure 7.10 Planar mean Cl loadings recorded at three selected sample locations (LP 1.2, LP 2.1 and LP 4.1)

7.1.4 DRIP DISTRIBUTION SYSTEM (SITE B)

The mean Cl concentrations beneath the DD system at Site B over the course of the sampling period are shown on Figure 7.11. From this plot it can be seen that Cl concentrations at each of the sampling positions are relatively uniform with the exception of D5.

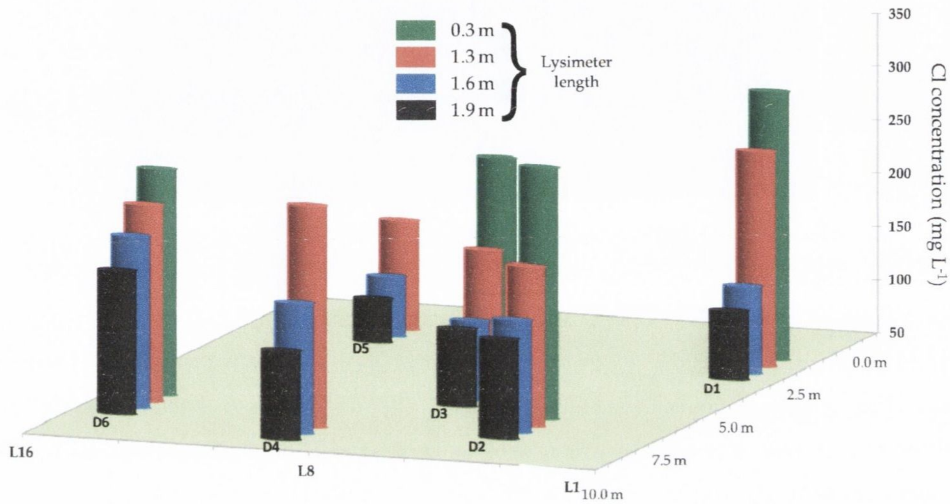


Figure 7.11 Mean Cl Concentrations beneath DD system at Site B at each depth plane

Examination of the GPS survey carried out at the site revealed D5 is located at the highest point of the distribution network with a slight gradient in the direction of both D2 and D6. This is also apparent from Figure 7.12 which was taken at Site B in January 2013. The end of each dripline is indicated by a white post; however, the migration of effluent along the gradient of the site, beyond these markers is evident by the contrast in grass colour, indicative of the overall direction of effluent percolation beneath the system at Site B. It should be noted that following an increase in temperature and growth rates in February 2013 grass growth above the DD system increased rapidly and this increased grass growth beyond the driplines was no longer apparent.

Figure 7.12 Grass growth beyond DD system at Site B (January 2013)

Table 7.7 shows that over the course of the sampling period a total of 10 samples failed to be obtained from across the lysimeter nests beneath the DD system as Site B. Overall, as with the LPP system at the site, the soil moisture volumes recorded were well in excess of 100 mL (Table 7.8). As with the LPP system at the site, a planar average method was adopted to assess the treatment performance of the DD system.

Overall, soil moisture sample volumes recorded at Site B were more uniform than those at Site A. Again, lysimeters where installed adjacent to the LPP trenches, however, a greater zone of contribution beneath the trenches (Section 7.2.3) in comparison with the previous site, has led to higher and more consistent mean volume retrieval of 330 mL, 358 mL and 306 mL at the *red*, *blue* and *black* depths respectively. As with Site A, reduced volumes were recorded for the *green* depth beneath the DD systems, again thought to be as a result of evapotranspiration at this shallow depth. At the lower depths a gradual increase in volume with depth was recorded believed to be as a result of the overlapping of effluent discharges as it percolates vertically (Section 7.2.4).

Table 7.7 No. of soil moisture samples retrieved from each sampling location beneath DD system at Site B

Location	D1	D2	D3	D4	D5	D6
0.15	12	12	12	-	-	10
1.00	17	16	17	16	16	17
1.30	17	16	17	16	16	17
1.60	17	16	17	16	16	16

Table 7.8 Mean (±sd) of volumes (mL) recorded beneath DD system at Site B

Location	D1	D2	D3	D4	D5	D6
0.15	**101** (± 65)	**76** (± 60)	**68** (± 57)	-	-	**69** (± 64)
1.00	**268** (± 181)	**535** (± 304)	**157** (± 110)	**475** (±363)	**225** (± 172)	**277** (± 260)
1.30	**573** (± 326)	**303** (± 132)	**149** (± 133)	**622** (± 295)	**208** (± 98)	**473** (± 400)
1.60	**461** (± 306)	**770** (± 196)	**238** (± 102)	**562** (± 383)	**410** (± 421)	**467** (± 436)

As with the LPP system at the site, sampling numbers at beneath the DD system were also reduced from February 2013 onwards. The sample positions deemed to be most representative of overall system treatment were D1, D2 and D6. As with the previously outlined systems all soil moisture samples retrieved beneath the DD system at Site B were be analysed for Cl concentrations from February 2013 onwards as illustrated in Figure 7.13. A second time-series plot of the selected lysimeters (Figure 7.14) follows the same trend, thus confirming the planar average method is the most representative way of analysing the attenuation of percolate. Both graphs illustrate the same trend, showing an increase in Cl concentrations at the shallow depth planes (*green* and *red*) during the summer months whilst the *blue* and *black* plane concentrations remain low. One potential reason for this may be a reduction in soil moisture levels during periods of low or zero effective rainfall (Figure 7.23), resulting in a more concentrated effluent plume at shallow depths.

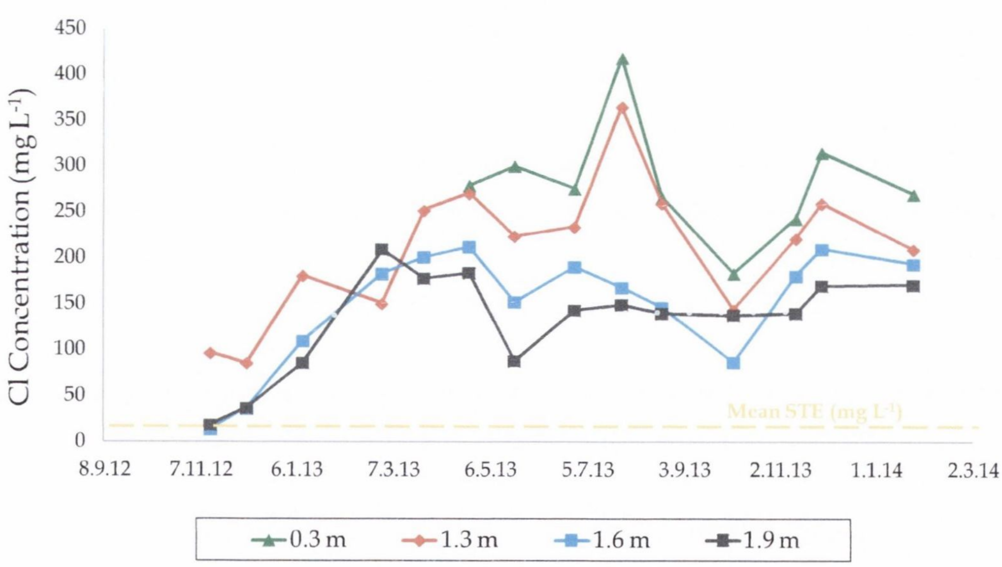


Figure 7.13 Planar mean Cl loadings across all sample locations beneath DD system at Site B

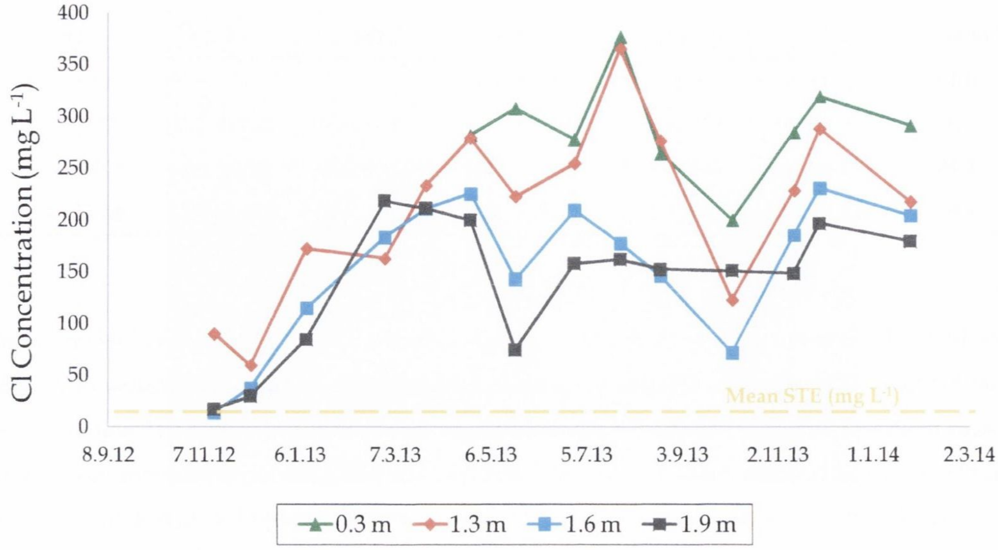


Figure 7.14 Planar mean Cl loadings recorded at three selected sample locations (D1, D2 and D6)

7.2 Effect of Dilution of Effluent Attenuation

In addition to the crucial role played by physical, chemical and biological processes in the attenuation of the percolate, consideration must also be given to the extent and effects of dilution by effective rainfall recharge.

Effective rainfall refers to the percentage of rainfall which becomes available to plants and crops. It considers losses due to runoff and evapotranspiration. During periods of heavy rainfall and low evapotranspiration higher levels of effective rainfall recharge result in the greater dilution of the effluent within a STU.

As outlined in Chapter 4 and included in Appendix D, rainfall figures available for dilution at the depth planes over the duration of the project on Sites A and B were collected for on-site rain gauges while daily Penman-Monteith reference evapotranspiration (ETo) figures (FAO, 1998) were calculated using data from the on-site meteorological stations in combination with data obtained from nearby Met Eireann weather stations.

The FAO Penman-Monteith method (FAO, 1998) of reference evapotranspiration (ETo) was used to calculate actual evapotranspiration (AET) (Eqn 7.1) (Appendix D).

When the soil moisture deficit (SMD) was greater than 10 mm, the AET was considered to occur at a slower rate than ETo and was therefore calculated using the Aslyng scale:

$$AET = ETo\,(110 - SMD\,*)/(110 - 10)\,mm \quad \text{(Eqn.7.1)}$$

where, SMD* is the accumulated soil moisture deficit at the beginning of each period and where SMD* > 10 it must be updated to SMD

SMD = SMD* + (AET – RF)

RF = total rainfall (mm) for the period

(Keane, 2001)

Daily effective rainfall (ERF) was then calculated by subtracting the daily AET and accumulated SMD figures from the daily rainfall measurement (mm).

$$ERF = Total\ RF\ mm - AET\ mm \quad \text{(Eqn.7.2)}$$

Meteorological data from Sites A and B were collected for the first time in 19th December 2012 and 2nd of November 2012 respectively at a time of year when a SMD would not generally exist in these low permeability conditions; however, it was necessary to confirm this for both sites at these start-up dates to enable the accurate calculation of effective rainfall over the following project duration. As SMD is a cumulative number and given the absence of earlier meteorological data from the on-site stations, it was necessary to use historical meteorological data from the nearby Met Éireann weather stations at Oak Park (Site A) and Ballyhaise (Site B) and to search back on the records to find a date when there was no SMD. As the subsoil at both sites was assumed to be "poorly drained" no SMD was indicated by a value of minus 10 mm. As expected the SMD at Sites A and B from the first day of data collection (19/12/12 and 02/11/12 respectively) was in fact minus 10 mm.

Using this method it was found that on Site A, for a recorded rainfall of 953.8 mm over the 14-month period 19/12/12 to 28/01/14, the total effective rainfall was 602.9 mm. Similarly on Site B, for a recorded rainfall of 1184.36 mm for the period 02/11/12 to 23/01/14, the calculated effective rainfall was 562.1 mm.

7.2.1 Low Pressure Pipe System (Site A)

In analysing the effect of dilution on the attenuation of the percolate and calculating the zone of contribution around the distribution network, the disparity in Cl concentrations between STE/SE and the soil moisture sampling depth planes was examined during both dry periods and periods of sustained effective rainfall. Figure 7.15 shows a time series plot of the concentrations at the three depth planes against the effective rainfall.

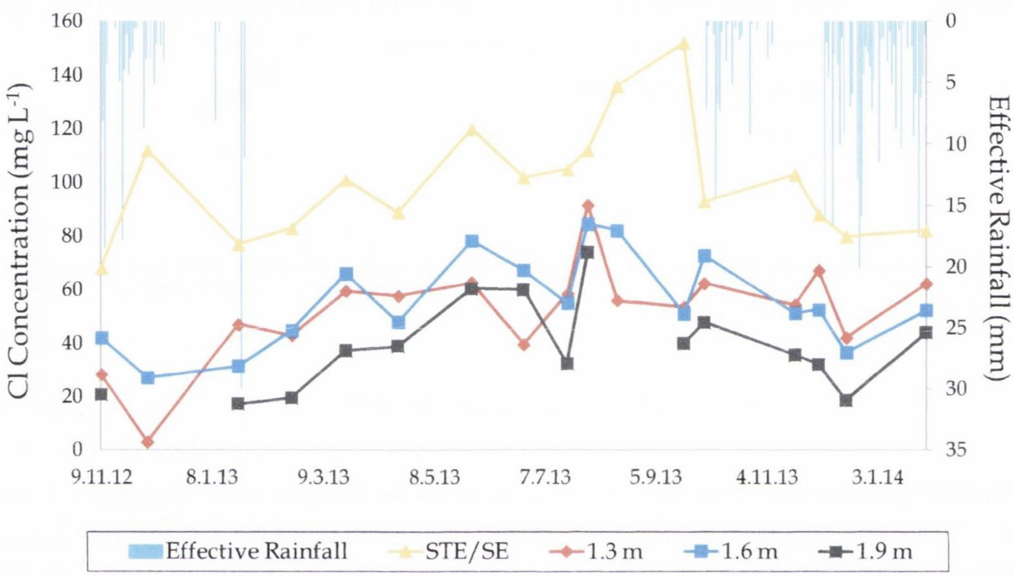


Figure 7.15 Effect of dilution by ERF on Cl concentrations beneath LPP system at Site A

Effluent Cl concentrations showed a gradual increase during the monitoring of the STE as the tank was not desludged during the monitoring period. A drop in Cl concentrations is then apparent from the end of September 2013 onwards as a result of the changeover to SE. As Cl is regarded as a non-reactive chemical it is probable that the noticeable reduction in Cl concentration between the STE/SE and each of the depth planes during periods of zero effective rainfall is due to the physical straining of colloidal matter in both the biomat and underlying subsoil. However, during periods of high recharge it is necessary to quantify the contribution of ERF to effluent dilution; the reduction in Cl concentration between the STE/SE and the monitored depth planes was initially calculated during periods of high effective rainfall (Table 7.9). Based on the initial assumption of a homogeneous subsoil a decrease in Cl concentrations with depth would be expected as found with previous studies in higher permeability subsoils (O'Luanaigh, 2009).

Table 7.9 Mean percentage reduction in Cl concentrations between the STE/SE and three depth planes during periods of sustained effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
21/03/2013	41	69	83
19/11/2013	50	40	65
Mean	**46**	**55**	**74**

However, due to the nature of the subsoil structure, this decrease with depth was only evident during a number of sampling runs beneath the systems at both sites. As illustrated by Figure 7.15, higher Cl concentrations were recorded at the lower depth planes for a number of sampling events during both periods of sustained effective rainfall and periods of zero effective rainfall. This may be as a result of PFPs within the subsoil matrix or due to the failure to obtain soil moisture samples from all sampling locations across each depth plane resulting in an incomplete data set. The latter was particularly problematic at Site A. However, as an estimate of the effect of dilution was required for each depth plane, the sample dates which did indicate a reduction with depth were chosen to approximate the effect of rainfall recharge, i.e. the 46%, 55% and 74% mean percentage reductions (shown in Table 7.9).

This reduction in Cl concentration, however, was a combination of both the effects of physical straining on the percolate and dilution due to recharge. The same aforementioned procedure was, therefore, carried out for periods of zero effective rainfall (Table 7.10) and the difference in mean percentages between both sets of data was calculated to yield the percentage reduction in Cl concentration due exclusively to dilution. It was found that, on average, the effect of dilution was equivalent to 21%, 25% and 28% reductions in Cl concentration at the red, blue and black planes, respectively beneath the LP system.

Table 7.10 Mean percentage reduction in Cl concentrations between the STE/SE and three depth planes during periods of zero effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
19/07/2013	45	48	69
30/07/2013	5	12	23
Mean	**25**	**30**	**46**

Having quantified the dilution factors at each depth plane a simple mass balance approach (Eqn 7.3) was adopted to estimate the zone of contribution (Ac) of effective rainfall at each depth plane as follows:

$$(Qin)(df)(Cin) + (ERF)(Ac) = (QT)(Cout) \qquad \text{(Eqn. 7.3)}$$

where, Qin = mean flow received to the distribution network on each sampling date (m^3 d^{-1})

df = dilution factor

ERF = effective rainfall (m)

Ac = zone of contribution of effective rainfall (m^2)

QT = total flow at depth plane (m^3 d^{-1})

Cin = STE Cl concentration on each sampling date (g m^{-3})

Cout = depth plane Cl concentration on each sampling date (g m^{-3})

With a mean background concentration of Cl estimated as 5.5 mg L^{-1} (based on Cl concentrations recorded outside of the soak-pit plume during pre-remediation monitoring) and with the mean flows and concentrations recorded on each date of sampling, it was possible to estimate that the areal zone of contribution of effective rainfall for the red depth plane was 12.3 m^2. Multiplying by the total effective rainfall over the sampling period of 461 mm equates to a total volume of effective rainfall at the red depth plane of 5.6 m^3. As the LPP is a pressurised distribution system it was assumed that effluent distribution was equal along each percolation trench. As such, the effective length of each trench was taken as 10 m and trench width was taken as 0.4 m. This equates to a zone of contribution of 0.04 m on all sides of each of the trenches by the *red* depth plane. Similarly, calculations carried out for the *blue* and *black* planes estimated areal zones of contribution due to effective rainfall of 12.5 m^2 (equivalent to 5.7 m^3 of effective rainfall) and 12.9 m^2 (equivalent to 5.9 m^3 of effective rainfall), respectively. The increasing surface area with depth is due to the dispersion of the effluent plume below each percolation trench which had thus extended to an estimated 0.043 m on all sides of each of the trenches at the *blue* plane and 0.05 m on all sides at the *black* plane (Table 7.11 and Figure 7.16).

Table 7.11 Estimated zone of contribution of effective rainfall

Site A (LPP)	**Length of wetted infiltrative surface (m)**	**Width of plume (m) from edge of trench at depth plane**		
		0.75 m	1.05 m	1.35 m
Trenches 1 - 4	10	0.04	0.043	0.05

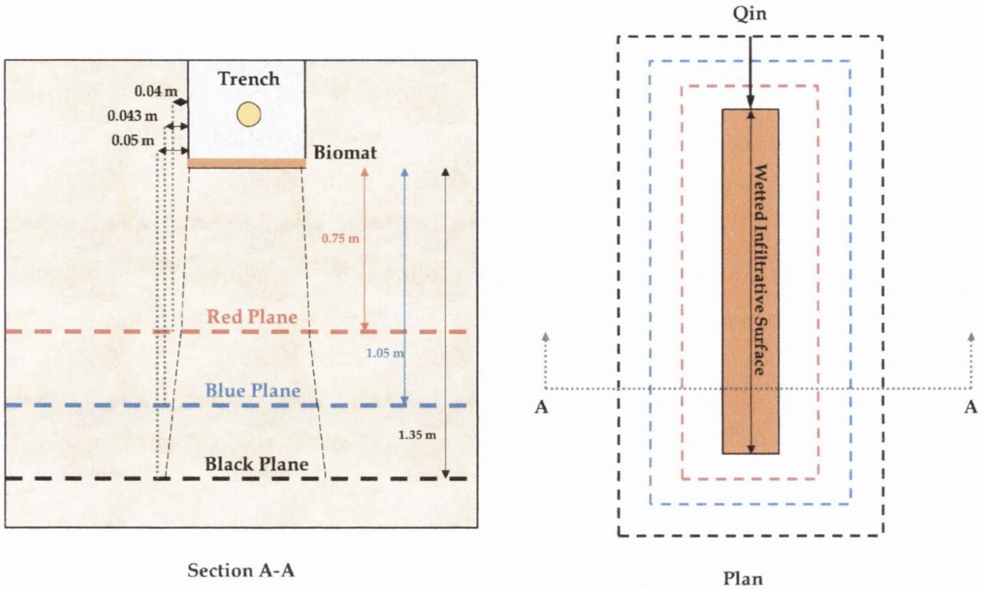


Figure 7.16 Plan and section-view of trench receiving SE, showing the estimated zone of contribution of effective rainfall at each depth plane

The results indicate an extremely narrow area of contribution of effective rainfall considering the low permeability of the subsoil. In order to corroborate the (i) findings on dilution effects and (ii) dispersion of the effluent, the soil moisture levels at strategic sample positions across the distribution area were examined. This was achieved through soil moisture readings and soil moisture tension readings from instrumentation installed as per Figure 4.2.

Soil moisture access tubes were installed at three locations (adjacent to the distribution trenches) beneath the LPP system at Site A. At each of these locations, monthly spot soil moisture readings were recorded to give an insight into the degree of saturation of the STU as well as the uniformity of effluent dispersal via the LPP system (i.e. was there any evidence of enhanced loading at the bottom of the LPP trenches). In conjunction with these spot readings, continuous soil moisture readings at a single location were recorded through the installation of a data logger. As there was a single soil moisture probe for the site, the logger was switched between the parallel LPP and DD systems at the site intermittently.

The recorded soil moisture readings were supported by soil moisture tension readings through tensiometers installed at nominal depths beneath the LPP system (Figure 4.2). As with the soil moisture access tubes, jet-filled tensiometers were installed to allow monthly spot readings to be recorded beneath the LPP system. A single nest of continuously logging tensiometers was also installed at the site, and as with the soil moisture probe, these logging tensiometers were switched intermittently between the LPP and DD system. A soil moisture access tube was also installed outside of the percolation areas at the site to determine background (reference) soil moisture levels. In analysing the soil moisture and soil moisture response of each of the alternative infiltration systems the initial step was to compare mean soil moisture values recorded within the percolation area to those recorded outside (i.e. the background soil moisture). In the case of the LPP at Site A, it was found that above the infiltration surface (located at 400 mm depth) the soil moisture levels were lower than measured background levels. This is most likely due to the effect of the coarse gravel in the percolation trench providing drainage for the adjacent subsoil (Figure 7.17).

Below the infiltrative surface however, an increase was seen beneath the LPP system compared to the background (reference) levels, as a result of the increased hydraulic loading to the subsoil from the applied effluent.

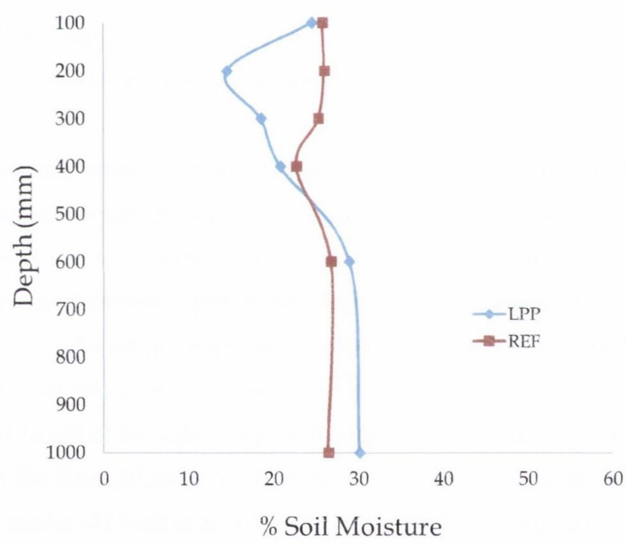


Figure 7.17 Mean soil moisture variation with depth beneath LPP system

One of the key objectives of the study was to investigate the impact of effluent application on soil moisture levels within the STU. To assess this, the rate of effluent application and rainfall recharge were recorded throughout the monitoring phase. Figures 7.18 and 7.19 show the increase in continuously recorded soil moisture levels beneath the LPP system between the 19th of November 2012 and the 17th of February 2013. From these figures it is apparent that soil moisture levels are greatly impacted by high intensity rainfall events (Figure 7.18). On the other hand, soil moisture levels show little reaction to the uniformly applied effluent during periods of zero effective rainfall (Figure 7.19). As a result of the shallow placement of effluent distribution system the degree of rainfall infiltration is high. This is particularly applicable during the initial months of operation due to the potential for rainfall to be preferentially infiltrated along the newly installed distribution trenches. Compaction of the subsoil and regrowth of overlying vegetation reduces the impact of rainfall infiltration overtime.

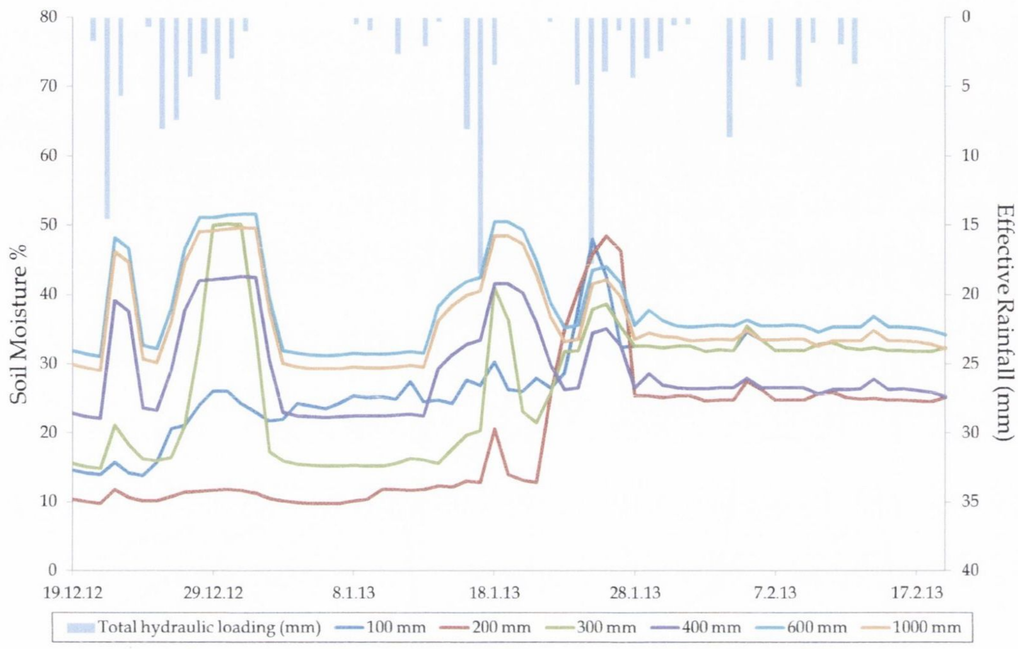


Figure 7.18 Soil moisture response to effective rainfall beneath LPP at Site A

Figure 7.19 Soil moisture response to total hydraulic loading beneath LPP at Site A

Examination of soil moisture tension recorded beneath the LPP over the same time period supports this analysis. Under more saturated subsoil conditions the soil tension readings are low whilst in drier subsoil conditions they rise. Figure 7.20 presents the continuous soil moisture tension recorded and, as with the soil moisture, the greatest fluctuation is in response to high intensity rainfall. Interestingly, there is only a short lag between rainfall events and soil moisture tension response at the *red* (1100 mm), *blue* (1600 mm) and *black* (1800 mm) tensiometer depth planes suggesting relatively fast movement of the hydraulic load through the subsoil as soil moisture levels increase. This needs to be borne in mind with respect to the impact on the STUs performance during periods of heavy rainfall.

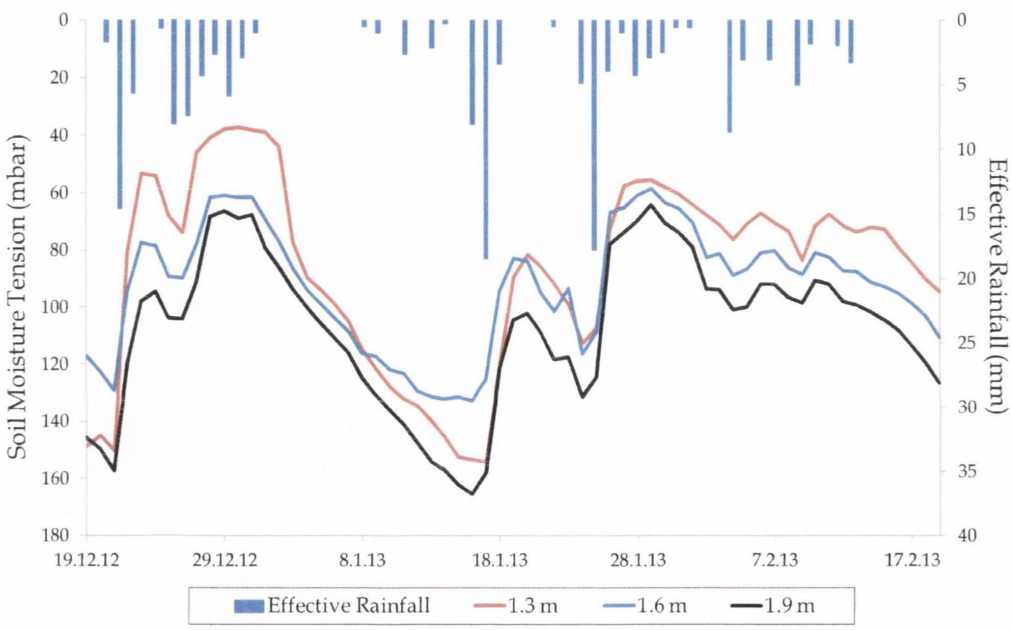


Figure 7.20 Soil moisture tension response to effective rainfall beneath LPP system at Site A

Figure 7.21 shows the recorded spot soil tension readings beneath the LPP system at Site A over the course of the monitoring period. As expected all three depth planes show a decrease in soil moisture tension during high rainfall events. During the extended periods of zero effective rainfall soil moisture tension increases significantly and remains high despite the continued application of effluent to the system. Soil moisture tension at the shallowest *red* depth plane did not increase as significantly during these periods, presumably due to its closer proximity to the effluent infiltrative surface. From this plot it can be seen that although effluent application at the applied rates has a muted impact on the degree of saturation of the subsoil, overall the soil moisture is affected to a greater extent by rainfall recharge, particularly during high intensity rainfall events. Although the system at Site A remained unsaturated for the majority of the sampling period, saturated conditions were recorded during the winter of 2013/2014 beneath both systems. The results suggest that due to the low permeability conditions at the site, subsoil saturation occurs as a result of rainfall infiltration alone which has an impact on the performance of the STU in the attenuation of contaminants.

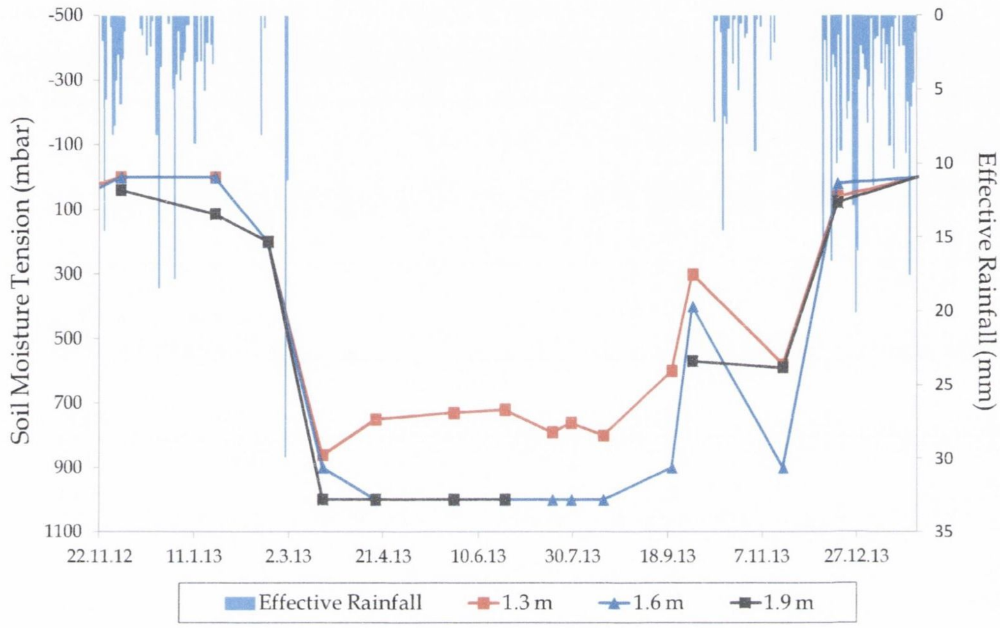


Figure 7.21 Soil moisture tension plotted against effective rainfall

A closer inspection of soil moisture variation beneath the LPP trenches during a period of sustained effective rainfall and zero effective rainfall is outlined in Table 7.12. Overall it can be seen that above the infiltrative surface soil moisture levels remain lower than background levels and below the infiltrative surface only a minor increase in soil moisture was recorded. The above results suggest that extremities in soil moisture levels could be attributed to increased effective rainfall and accounted for a significant increase in soil moisture during winter months. Table 7.12 presents the mean soil moisture results recorded across all sample locations beneath the LPP in comparison with background levels for a period of sustained effective rainfall (winter) and zero effective rainfall (summer). A decrease in background soil moisture levels was attributed to a decrease in rainfall recharge in combination with increased evapotranspiration at the upper depth planes. The greatest decrease in soil moisture levels beneath the LPP system was also evident at the upper depth planes (above the infiltrative surface). Soil moisture levels below the LPP trench are less than those recorded outside of the percolation area as a result of continuous application of effluent to the system.

Table 7.13 presents the breakdown of the hydraulic loading to the LPP during the period outlined in Table 7.12. Although overall the mean effluent loadings to the system greatly exceeded the effective rainfall during both the summer and winter periods presented, there is a limited increase on the soil moisture beneath the LPP system. This may be due to the controlled rate of effluent application, with a mean daily loading of 2.91 mm d^{-1} dosed over an average of 2-3 pumping cycles per day. By comparison, Figure 7.18 shows that the greatest fluctuations in soil moisture resulted in rainfall events > 5 mm d^{-1} applied in conjunction with the effluent load. The location of the soil moisture access tubes adjacent to the LPP trenches rather than directly beneath them may also contribute to degree of soil moisture fluctuation recorded.

Table 7.12 Seasonal soil moisture variation beneath LPP at Site A

Depth (mm)	Soil moisture (%)				Seasonal decrease from Winter to Summer	
	Winter		Summer			
	LPP %	REF %	LPP %	REF %	LPP %	REF %
100	33.4	35.8	8.8	18.1	74%	49%
200	15.8	28.0	6.8	19.3	57%	31%
300	20.3	31.9	12.4	21.5	39%	33%
400	26.9	27.4	19.6	21.0	27%	23%
600	35.8	31.3	31.8	24.9	11%	20%
1000	36.9	29.9	33.5	25.0	9%	16%
Reduction between 100 mm and 400 mm					49%	34%
Reduction between 600 mm and 1000 mm					10%	18%

Table 7.13 Hydraulic loadings during winter and summer months to LPP at Site A

	Rainfall (mm)	ET actual (mm)	Effective Rainfall (mm)	Effluent Load (mm)	Total Hydraulic load (mm)
Winter[a]	109.5	31.7	77.8	174.3	250.1
Summer[b]	42.9	62.4	0.0	139.6	139.6

[a] Winter based on data recorded between the 21/01/2013 and 20/03/2013

[b] Summer based on data recorded between the 28/05/2013 and 19/07/2013

7.2.2 Drip Distribution System (Site A)

Due to the shallow IS of the DD system a modified analysis methodology was applied to determine the hydraulic loading to the DD systems at both Sites A and B. Unlike the LPP, the shallow placement of the DD (150 mm below ground level) results in greater potential for evapotranspiration of the effluent. Hence, on a daily basis, any residual ET left after rainfall was subtracted from potential ET, was then applied to the effluent loading. The results showed the soil moisture deficit value remained above the minimum value (-10 mm for poorly draining soil) throughout the study, i.e. the rate of ET was equal to the maximum rate throughout the year. However, at Site A, the effect of ET only produced a limited reduction in the total applied effluent loading, equating to a decrease from 884 mm to 864 mm over the study period (excluding overloading trials). In reality, applied effluent and rainfall recharge would be mixed forming a combined hydraulic load; however, given the application of rainfall to the surface (whilst effluent is applied at depth of 150 mm) it is assumed that rainfall would have been preferentially evapotranspired.

The potential reduction in Cl concentrations resulting from plant uptake was also considered. Cl is an essential micronutrient for plants, however the minimal requirement for crop growth is generally supplied by rainfall and Cl-deficient plants are rarely observed in agriculture or nature (White and Broadley, 2001). Overall, a large reduction in Cl concentrations was recorded beneath the DD system throughout the sampling period (Figure 7.22). During periods of effective rainfall this reduction was attributed primarily to dilution. However, a large reduction in Cl was maintained during periods of zero effective rainfall potentially indicating removal may be as a result of evapotranspiration/plant uptake.

Figure 7.23 illustrates the response of Cl concentrations to the total net hydraulic loading (i.e. effluent and effective rainfall). This shows that as zero effective rainfall persisted during the summer of 2013, and assuming effluent was available for evapotranspiration, there was an extended period were the net hydraulic loading to the DD system was zero.

The plot of the Cl concentrations at the depth planes shows a number of occasions when higher concentrations were recorded at lower depth and the gradual decrease with depth expected for a homogenous subsoil was not evident.

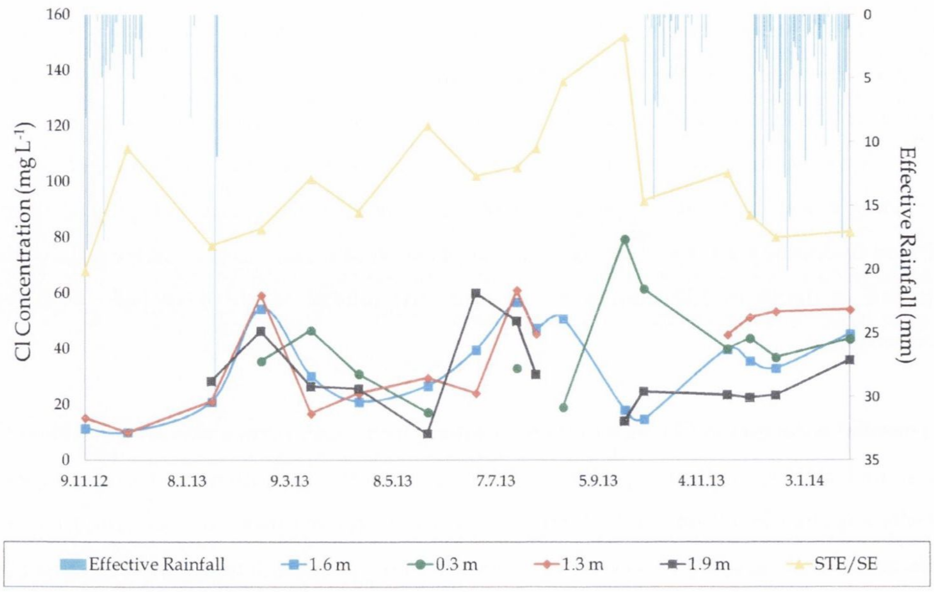


Figure 7.22 Effect of dilution by ERF on Cl concentrations beneath DD system at Site A

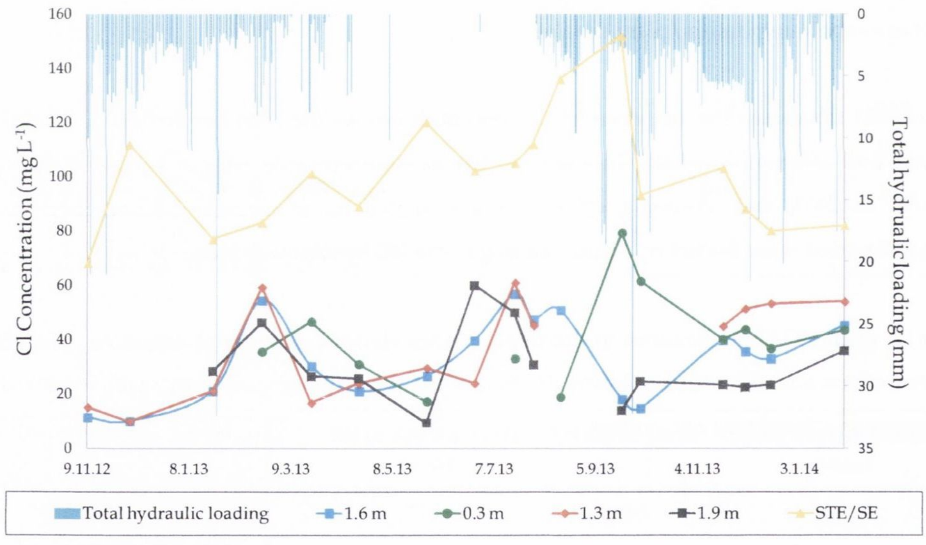


Figure 7.23 Cl concentrations beneath DD system at Site A in response to combined effective effluent and rainfall loading

An additional shallow 300 mm *green* depth plane was monitored beneath the DD systems from the 20th of March 2013 on account of their very shallow effluent infiltration depth (Figure 7.1). Although Cl concentrations at this shallow depth were elevated compared to the lower depth planes during sustained periods of zero effective rainfall this was not observed across the entire course of the monitoring period. During periods of effective rainfall the average Cl concentrations recorded across the *green* plane were lower than those recorded at the lower depth planes. This was possibly as a result of dilution due at the slow draining properties of the subsoil resulting in high soil moisture levels present for a considerable time following high rainfall events. Due to the considerable difference in depth below the infiltrative surface of the *green* depth plane (0.15 m) and the *red* depth plane (1.0 m) in combination with the low permeability of the subsoil it is not unreasonable to assume a reasonable lag time of the percolate between the *green* depth plane and lower sampling depths. As such, the effect of dilution beneath the DD system was only calculated for the *red, blue* and *black* depth planes (Table 7.14 and Table 7.15). The resultant percentage reduction in Cl concentration due exclusively to the dilution effects of recharge were found to be 13%, 17% and 18% at the *red, blue* and *black* planes, respectively.

Table 7.14 Mean percentage reduction in Cl concentrations between the STE and three depth planes during periods of zero effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
25/06/2013	41	44	51
19/07/2013	53	55	60
Mean	**47**	**49.5**	**56**

Table 7.15 Mean percentage reduction in Cl concentrations between the STE/SE and three depth planes during periods of sustained effective rainfall

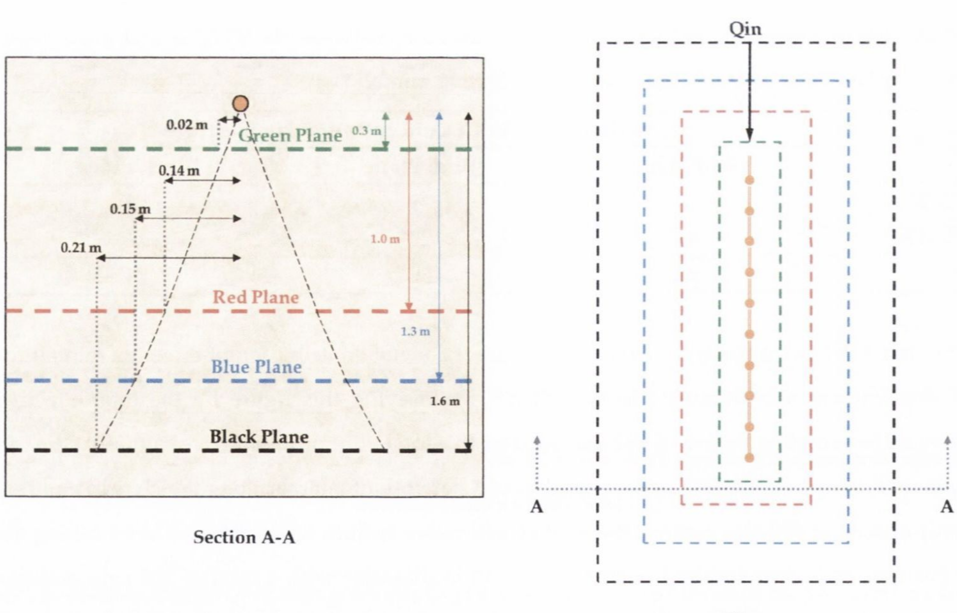
Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
21/03/2013	76	79	75
19/11/2013	44	53	74
Mean	**60**	**66**	**74**

Using the mass balance approach of Eqn 7.2, the areal zone of contribution of effective rainfall for the *red* depth plane was estimated to be 9.81 m^2. Multiplying this figure by the total effective rainfall over the sampling period of 652 mm equates to a total volume of effective rainfall at the red depth plane of 6.4 m^3. As the DD system consists of a network of laterals along which drip emitters are evenly spaced at 600 mm centres, the wetted infiltrative surface was estimated as by taking the infiltrative area of each individual emitter as 0.05 m in diameter with a total of 200 drip emitters located across the network. This allowed an effective radius around each emitter to be estimated. As with the LPP system, effluent distribution across the network was assumed to be uniform and the resulting calculations gave an estimated zone of contribution of effective rainfall of 0.14 m radially on all sides of each emitter at the *red* depth plane (Figure 7.19). Similarly, calculations carried out for the *blue* and *black* planes estimated areal zones of contribution due to recharge of

10.9 m^2 (equivalent to 7.1 m^3 of effective rainfall) and 13.8 m^2 (equivalent to 9.0 m^3 of effective rainfall), respectively. This equates to a 0.15 m width of plume on all sides of each emitter at the *blue* plane and 0.20 m on all sides at the *black* plane. The effluent plume was seen to increase with depth on these sampling occasions owing to the natural hydrodynamic dispersion of the effluent in the course of its travel (Table 7.16). However, as with the LPP system this was only an estimate as the systematic decrease in Cl with depth was not evident during the entirety of the monitoring period. As soil moisture samples across the *green* depth plane did record high Cl concentrations during the course of the monitoring period it was confirmed that effluent percolate was indeed present at this depth. As such an average zone of contribution of ERF of 0.02 m was estimated at this 300 mm plane (Table 7.16 and Figure 7.24).

Table 7.16 Estimated zone of contribution of effective rainfall

Site A (DD)		Width of plume (m) from edge of dripline at depth plane			
	Length of wetted infiltrative surface (m)	0.15 m	1.0 m	1.3 m	**1.6 m**
Dripline 1-12	10	0.02	0.14	0.15	0.20



Plan

Figure 7.24 Plan and section-view of trench receiving SE, showing the estimated zone of contribution of effective rainfall at each depth plane

As with the LPP system, analyses of soil moisture and soil moisture tension results were used to corroborate the results of the Cl analysis. Soil moisture access tubes and tensiometers were installed as per Figure 4.2. Again, monthly soil moisture readings were recorded beneath the DD system for comparison with background (reference) levels. The mean results are presented in Figure 7.24 and show only a marginal increase in soil moisture from 100 mm to 600 mm depth in comparison with background levels. A slightly greater increase at the 1000 mm depth appears to confirm the assumption of widening effluent plume at the lysimeter red depth plane (1150 m) below ground level. The smaller deviation shown across the 100 mm to 300 mm depth also suggests that the assumption of a narrower plume at the green depth plane is reasonable.

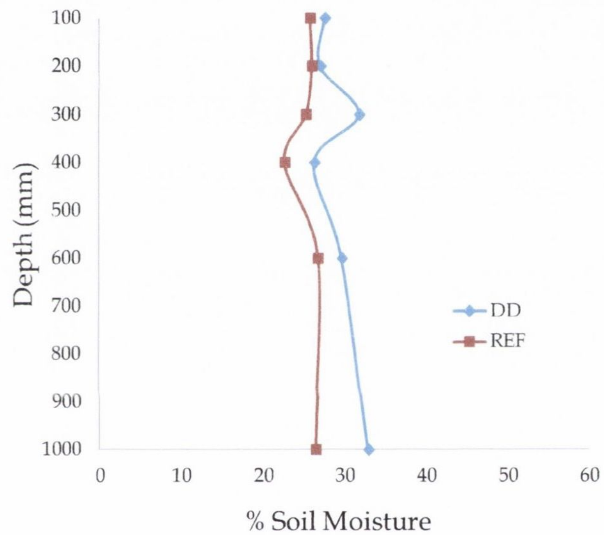


Figure 7.25 Mean soil moisture variation with depth beneath DD system

Continuous soil moisture readings below the DD were also assessed to examine the impact of rainfall recharge and effluent discharge. Figure 7.25 illustrates the soil moisture variation beneath the DD between the 20th of February 2013 and the 17th of April 2013 in response to effective rainfall whilst Figure 7.26 shows the response to the net total hydraulic loading (i.e. effluent and effective rainfall as outlined in section 7.2.2). As with the LPP system, the greatest fluctuation in soil moisture was recorded following heavy rainfall events. A uniform response to effluent application is apparent, however one notable observation is that, unlike the LPP, the increase in soil moisture is more persistent beneath the DD. While soil moisture readings beneath the LPP returned to their initial levels prior to rainfall recharge (Figure 7.18), levels beneath the DD seemed to take longer to recover. One potential explanation is that unlike the trenched LPP, the DD has a much smaller hydraulic storage capacity within the receiving subsoil and therefore does not have the same drainage afforded to the LPP.

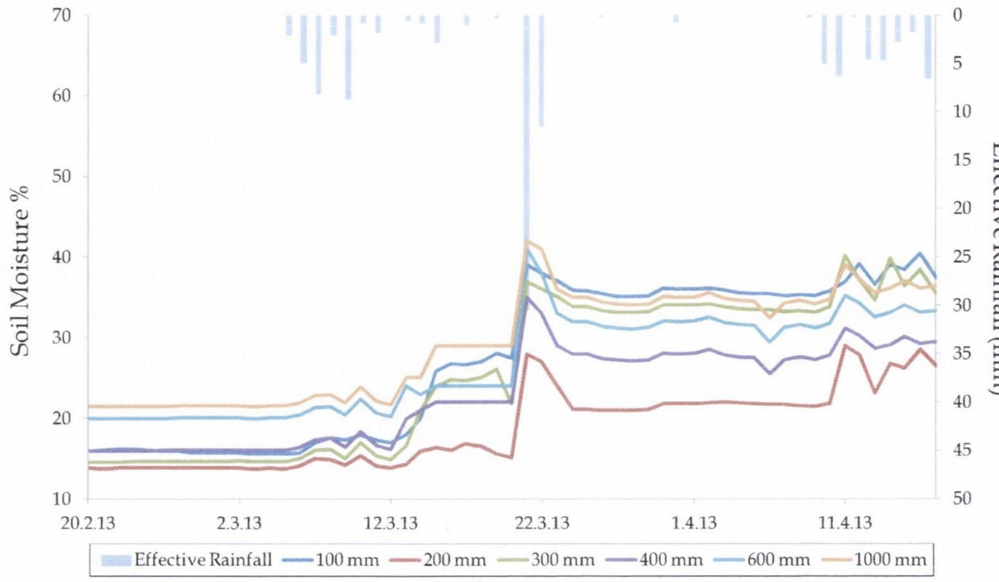


Figure 7.26 Soil moisture response to effective rainfall beneath DD at Site A

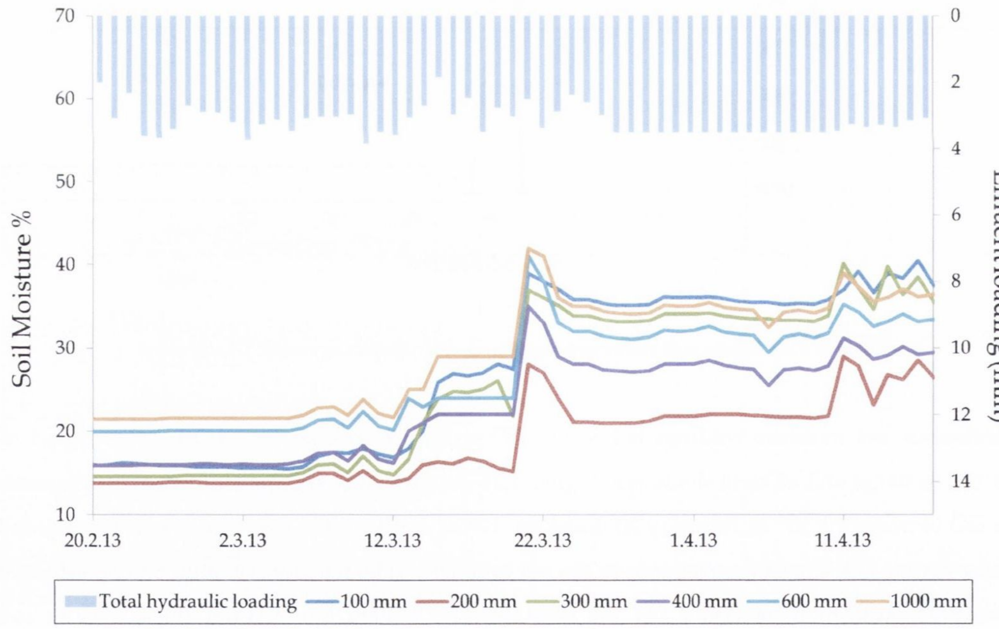


Figure 7.27 Soil moisture response to effluent loading beneath DD at Site A

A plot of the soil moisture tension during this period shows a similar response, with a drop in soil moisture tension following heavy rainfall and lag in recovery at the *red* (1100 mm), *blue* (1600 mm) and *black* (1800 mm) depth planes (Figure 7.27). Again a short lag was recorded between the rainfall events and the soil moisture tension response owing to the low permeability (slow draining) nature of the subsoil.

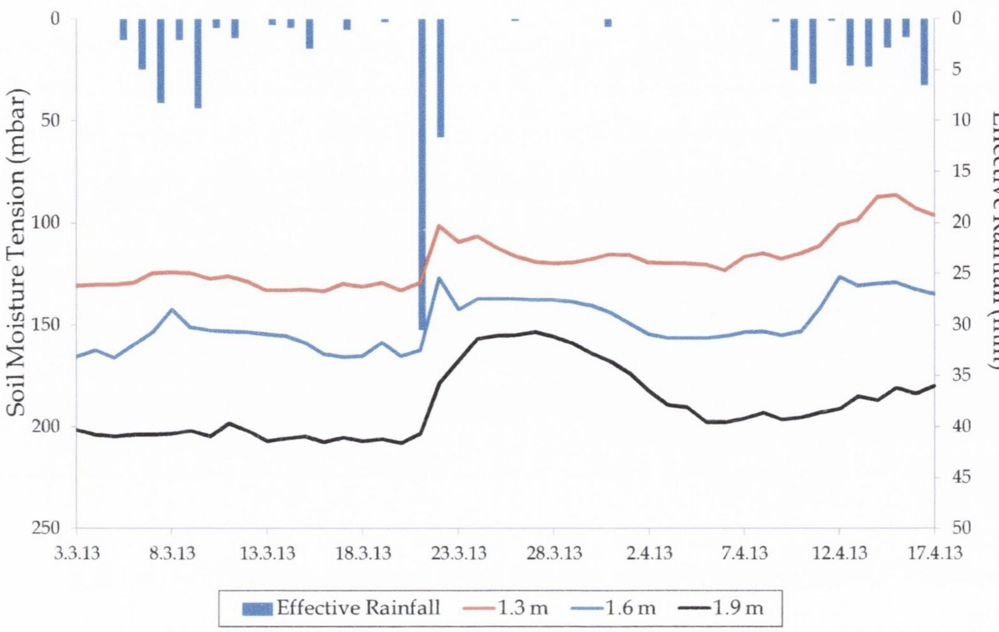


Figure 7.28 Soil moisture response to effective rainfall beneath DD at Site A

Results of the spot tensiometer readings beneath the DD at Site A show the greatest reduction in soil moisture tension is apparent at the lower depth planes which appear to be influenced less by effluent application. This corroborates the earlier conclusion of an increased zone of effective rainfall contribution with depth. As with the LPP system, the shallowest depth planes (green and red) show the most muted response to reduced effective rainfall loading, again indicating at these depth planes, effluent application is influential (Figure 7.29).

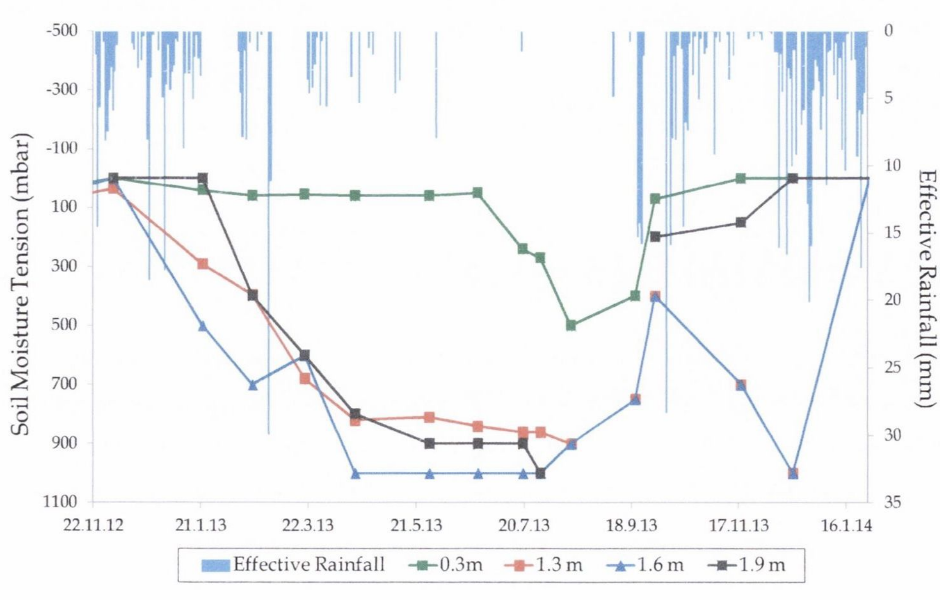


Figure 7.29 Soil moisture tension plotted against effective rainfall

Table 7.17 details the soil moisture variation beneath the DD network under summer and winter conditions whilst Table 7.18 describes the hydraulic loadings over the same periods. Overall, it can be seen that, above the infiltrative surface, soil moisture levels remain higher than background levels. Soil moisture levels decrease significantly during periods of zero effective rainfall but overall remain higher than background levels. The decrease in soil moisture recorded at the 100 mm depth during the summer months is attributed to the increased rate of evapotranspiration.

Table 7.17 Seasonal soil moisture variation beneath DD at Site A

Depth (mm)	Soil moisture (%)				Seasonal decrease from Winter to Summer	
	Winter		Summer			
	DD%	REF %	DD%	REF %	DD %	REF %
100	38.3	35.8	18.3	18.1	52%	40%
200	31.1	28.0	20.1	19.3	36%	25%
300	36.3	31.9	22.9	21.5	37%	26%
400	31.5	27.4	23.1	21.0	27%	20%
600	33.9	31.3	28.0	24.9	17%	16%
1000	33.4	29.9	28.9	25.0	14%	13%
Reduction between 100 mm and 400 mm					38%	28%
Reduction between 600 mm and 1000 mm					16%	15%

Table 7.18 Hydraulic loadings during winter and summer months to DD at Site A

	Rainfall (mm)	ET actual (mm)	Effective Rainfall (mm)	Effluent Load (mm)	Total Hydraulic load (mm)
Winter	109.5	31.7	92.6	167.5	245.3
Summer	42.9	179.7	11.6	130.8	16.6

[a] Winter based on data recorded between the 21/01/2013 and 20/03/2013
[b] Summer based on data recorded between the 28/05/2013 and 19/07/2013

7.2.3 Low Pressure Pipe System (Site B)

As with Site A, quantification of effluent dilution within the subsoil was carried out to give an estimation of the zone of contribution for the LPP system at Site B. Again, due to the nature of the underlying subsoil analysis of the average reduction in Cl concentrations with depth showed that although the concentrations decreased significantly, these reductions were not always systematic (Figure 7.30).

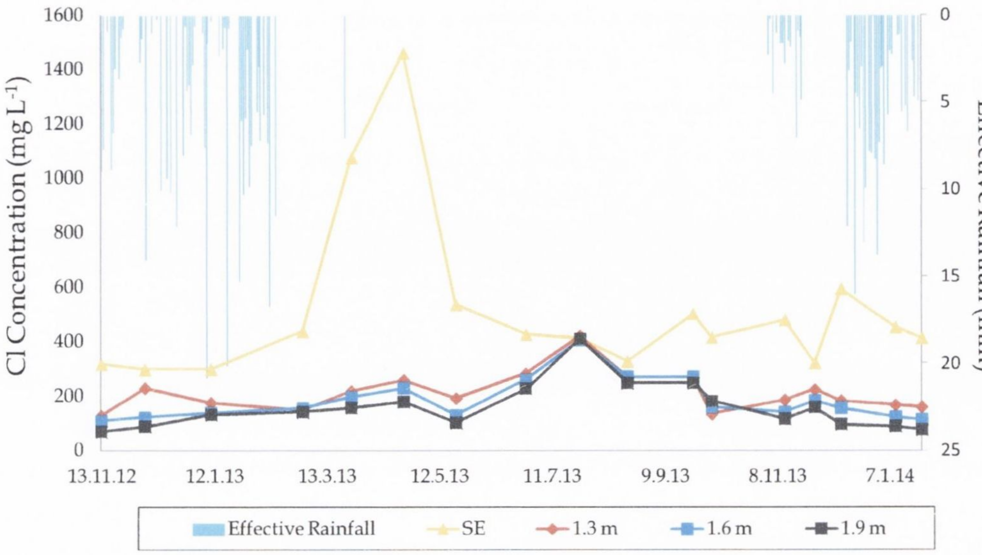


Figure 7.30 Effect of dilution by ERF on Cl concentrations beneath LPP system at Site B

As with Site A, sampling events which did show a systematic reduction during both periods of sustained effective rainfall and zero effective rainfall were used to estimate the influence of dilution of rainfall recharge across the monitoring period. The background Cl concentration at the site was estimated at 7 mg L^{-1} based on the average concentration recorded from soil moisture sample extracted from outside the soak-pit plume during the pre-remediation monitoring phase. It was found that, on average, 20%, 21% and 26% reductions were recorded at the red, blue and black planes respectively (Tables 7.19 and 7.20).

Table 7.19 Mean percentage reduction in Cl concentrations between the SE and three depth planes during periods of zero effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
23/04/2013	76	78	83
27/06/2013	32	39	47
20/08/2013	20	17	25
Mean	**43**	**45**	**52**

Table 7.20 Mean percentage reduction in Cl concentrations between the SE and three depth planes during periods of sustained effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
13/11/2012	72	66	79
10/01/2014	51	59	71
24/01/2014	66	72	82
Mean	**63**	**66**	**77**

With an average background Cl concentration of 7 mg L^{-1} and using the mean flows and concentrations recorded on each sampling date, the areal zone of contribution of effective rainfall for the red depth plane was estimated to be 33.9 m^2. Given the total effective rainfall over the sampling period was calculated as 547.7 mm, this equates to a total volume of effective rainfall at the red depth plane of 18.5 m^3. Similarly, calculations carried out for the blue and black planes estimated areal zones of contribution due to recharge of 36.7 m^2 (equivalent to 20.1 m^3 of effective rainfall) and 42.0 m^2 (equivalent to 23.0 m^3 of effective rainfall), respectively. The wetted infiltrative area of the pressurised system was assumed to be across the entire trench length (10 m) with a width of 0.4 m. This yields a zone of contribution of effective rainfall of 0.21 m, 0.25 m and 0.31 m on all sides of each trench at the red, blue and black planes respectively (Table 7.21).

Table 7.21 Estimated zone of contribution of effective rainfall

Site B (LPP)	Length of wetted infiltrative surface (m)	Width of plume (m) from edge of trench at depth plane		
		0.75 m	1.05 m	1.35 m
Trenches 1 - 4	8	0.21	0.25	0.31

At Site B, as with Site A, three soil moisture access probes were located across the LPP distribution area at strategic positions adjacent to the trenches. An additional access tube was also located within T1, allowing soil moisture readings above, within and directly below the infiltrative surface to be recorded (Figure 4.3). A comparison of soil moisture levels adjacent to and within the LPP trenches at Site B is shown in Figure 7.31. A high fluctuation in soil moisture levels within the LPP trench is evident at the 300 mm and 400 mm depth however no such fluctuation is evident adjacent to the trench. In contrast, the soil moisture levels adjacent to the trench are in line with background soil moisture levels indicating that despite the low permeability subsoil, effluent is being allowed to percolate vertically from the distribution trench. By the 1000 mm depth an average increase both within and next to the percolation trench is apparent, this is confirms the existence of a narrow effluent plume expanding with depth from the red depth plane (1150 mm) downwards.

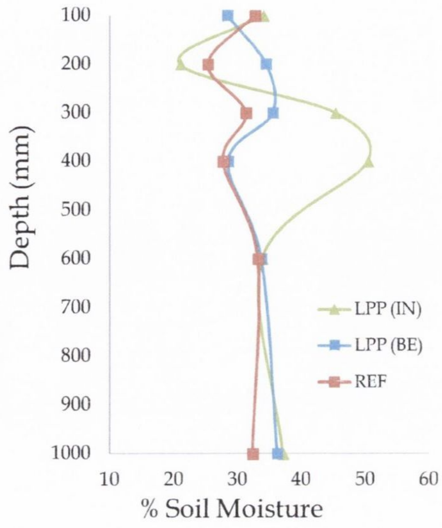


Figure 7.31 Mean soil moisture variation with depth beneath LPP system at Site B

Soil moisture recorded below the LPP system showed a similar response to that observed at Site A. Figure 7.32 shows the response of the STU to effective rainfall whilst Figure 7.33 illustrates the total hydraulic loading. Again the greatest variation in soil moisture readings occurs following heavy rainfall with the uniform discharge of effluent having little impact on the overall soil moisture. This is an indication that the sites subsoil (as with Site A) has the capacity to cope with the applied effluent loading, however, when combined with rainfall recharge the degree of saturation increases and the risk of contaminant migration rises.

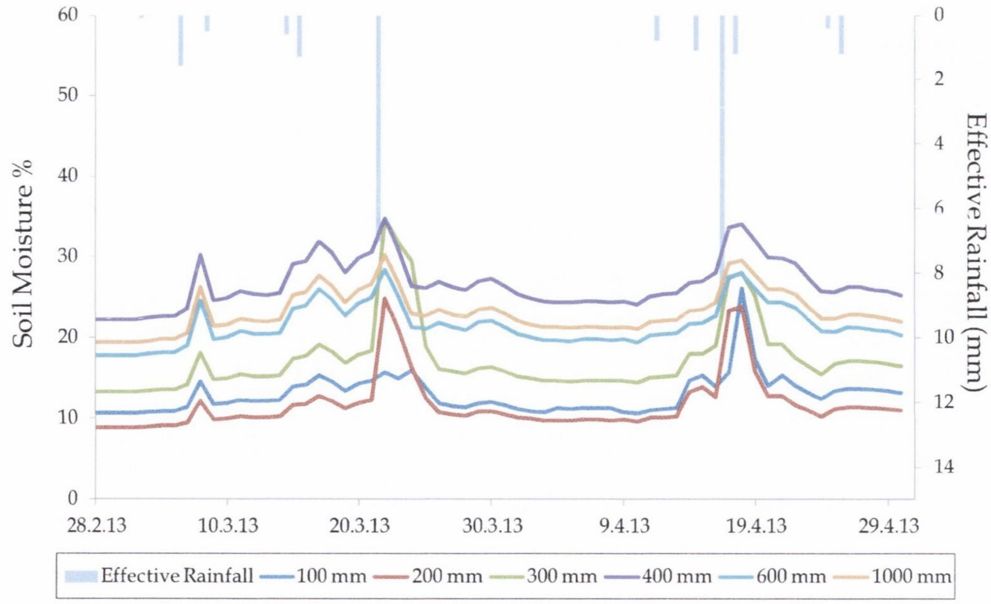


Figure 7.32 Soil moisture response to effective rainfall beneath LPP at Site B

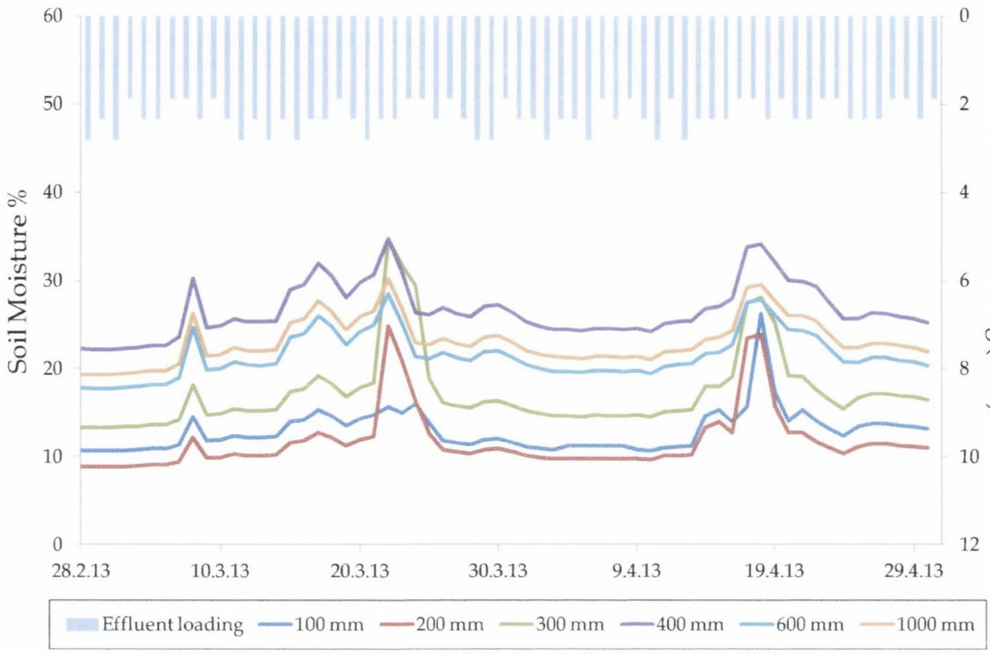


Figure 7.33 Soil moisture response to effective rainfall beneath LPP at Site B

Despite the fluctuation in soil moisture recorded during this period soil tension data shows that the subsoil remained unsaturated (Figure 7.34). As with the soil moisture, the soil moisture tension again varies greatly in response to intense rainfall at all three depth planes.

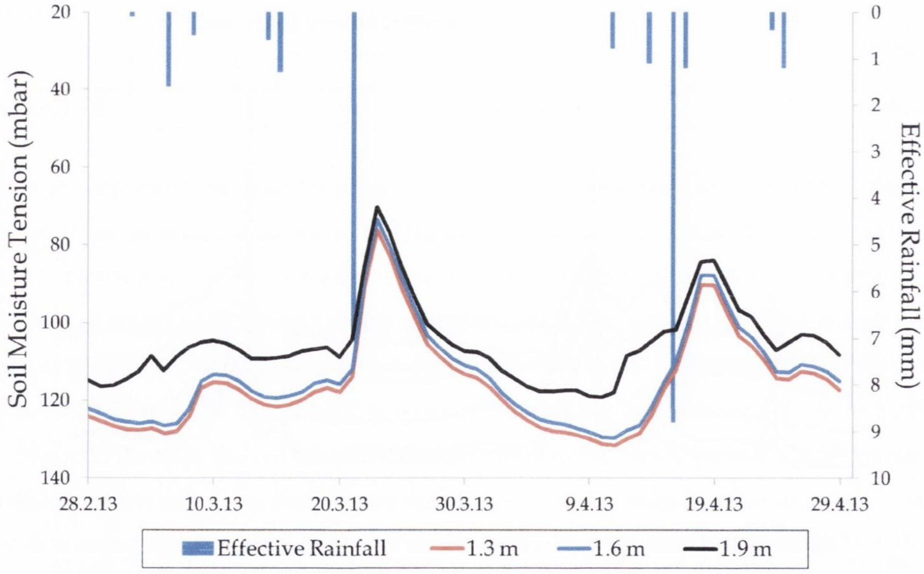


Figure 7.34 Soil moisture response to effective rainfall beneath LPP at Site B

Figure 7.35 shows a similar response in spot soil tension readings beneath the LPP system at Site B to that evident at Site A. As expected all three depth planes show a decrease in soil moisture tension during high rainfall events. During the extended periods of zero effective rainfall soil moisture tension increases significantly and remains high despite the continued application of effluent to the system. In contrast to Site A it is the lowest depth plane (*black* plane) which displays the least reduction in soil moisture potential during periods of zero effective rainfall. However, if should be noted that unsaturated conditions persist below the system throughout sampling period

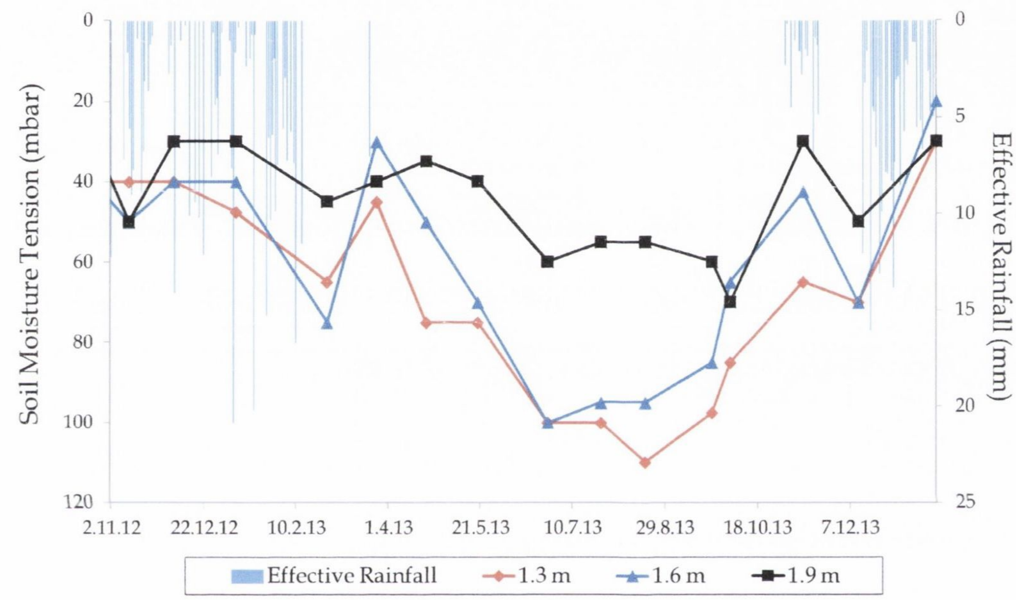


Figure 7.35 Soil moisture tension plotted against effective rainfall

Average soil moisture levels recorded during a period of sustained effective rainfall and zero effective rainfall are shown in Table 7.22. The corresponding hydraulic loadings are detailed in Table 7.23. In a similar fashion to Site A, soil moisture levels within the LPP distribution network are lower than background levels above the infiltrative surface but begin to increase from the 600 mm depth downwards. Again this is indicative of a vertical plume expanding gradually with depth.

Table 7.22 Seasonal soil moisture variation beneath LPP at Site B

Depth (mm)	Soil moisture (%)				Seasonal decrease from Winter to Summer	
	Winter		Summer			
	LP %	REF %	LP %	REF %	LP %	REF %
100	28.2	37.5	18.0	20.0	36%	47%
200	29.7	33.7	17.5	21.5	41%	36%
300	29.0	38.4	16.9	26.9	42%	30%
400	27.1	33.5	14.9	26.0	45%	22%
600	38.8	35.8	29.6	26.1	23%	25%
1000	39.7	34.1	27.4	25.7	24%	25%
Reduction between 100 mm and 400 mm					41%	34%
Reduction between 600 mm and 1000 mm					23%	25%

Table 7.23 Hydraulic loadings during winter and summer months to LPP at Site B

	Rainfall (mm)	ET_O (mm)	Effective Rainfall (mm)	Effluent load (mm)	Total Hydraulic load (mm)
Winter[a]	160.5	19.8	136.8	131.2	268.0
Summer[b]	111.6	74.9	0.0	119.7	119.7

[a] Winter based on data recorded between the 12/11/2012 and 04/01/2013

[b] Summer based on data recorded between the 27/06/2013 and 19/08/2013

7.2.4 Drip Distribution System (Site B)

Finally the same analysis procedure was carried out for the DD system at Site B. A plot of the Cl concentrations at the depth planes (Figure 7.36) reveals for the most part a systematic decrease in concentration with each depth plane. The net hydraulic loading to the system is illustrated in Figure 7.37.

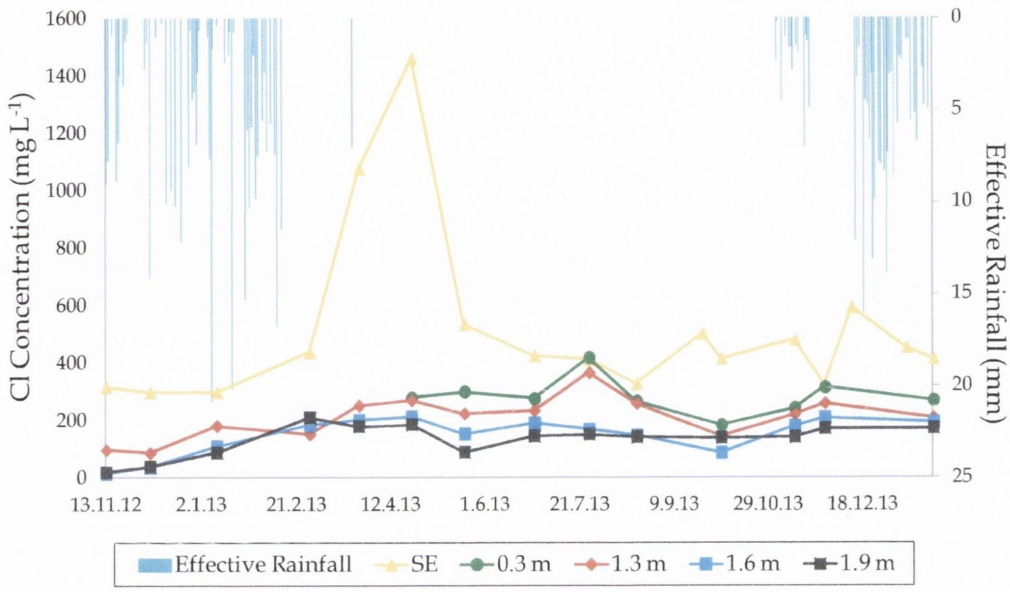


Figure 7.36 Effect of dilution by ERF on Cl concentrations beneath DD system at Site B

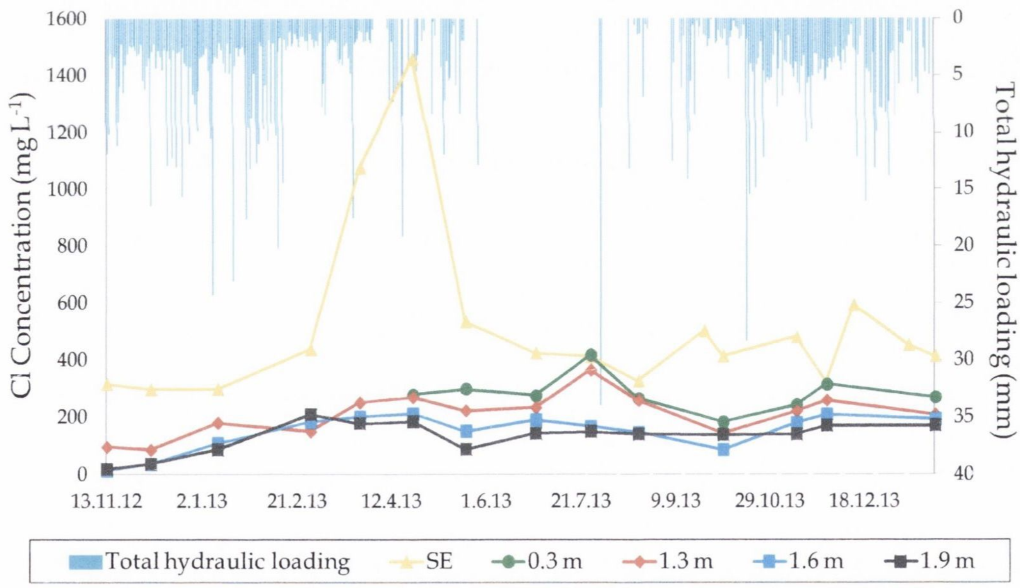


Figure 7.37 Cl concentrations against total hydraulic loading beneath DD system at Site B

As with Site A, an additional depth plane was monitored beneath the DD system (green plane at 300 mm below ground level) at four locations across the system (Figure 4.3) on the 23/04/2013 and monitored in conjunction with the existing lysimeters for the remainder of the study. As with Site A, Cl concentrations at this shallow depth were elevated in comparison with the lower depth planes during periods of zero effective rainfall. However, during periods of effective rainfall the average Cl concentrations recorded across the green plane were not significantly lower than those recorded during zero effective rainfall. This is assumed to be as a result of the proximity of the sampling locations at the green depth plane to the effluent infiltration surface resulting in a reduced dilution effect prior to soil moisture sample collection. Consequently, the effect of dilution beneath the DD system was calculated for the red, blue and black depth planes (Table 7.24 and Table 7.25). The resultant percentage reduction in Cl concentration due exclusively to the dilution effects of recharge were found to be 13%,17% and 8% at the red, blue and black planes, respectively.

Table 7.24 Mean percentage reduction in Cl concentrations between the SE and three depth planes during periods of zero effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
27/06/2013	46	66	67
26/07/2013	11	59	64
24/09/2013	18	13	13
Mean	**25**	**46**	**48**

Table 7.25 Mean percentage reduction in Cl concentrations between the SE and three depth planes during periods of sustained effective rainfall

Date	% Reduction in Cl Concentration from effluent		
	Red Plane	Blue Plane	Black Plane
06/12/2012	69	88	88
10/01/2013	54	63	71
Mean	**62**	**76**	**80**

The areal zone of contribution of effective rainfall for the red depth plane was estimated to be 25.2 m^2. Multiplying this figure by the total effective rainfall over the sampling period of 910.3 mm equates to a total volume of effective rainfall at the red depth plane of 17.2 m^3. As with Site A the infiltrative area of each individual emitter as estimated as 0.05 mm in diameter with a total of 240 drip emitters located across the network. Assuming uniform effluent distribution the resulting calculations gave an estimated zone of contribution of effective rainfall of 0.34 m on all sides of each emitter at the red depth plane (Table 7.26). Similarly, calculations carried out for the blue and black planes estimated areal zones of contribution due to recharge of 41 m^2 (equivalent to 33 m^3 of effective rainfall) and 42.8 m^2 (equivalent to 34.7 m^3 of effective rainfall), respectively. This equates to a 0.64 m width of plume on all sides of each emitter at the blue plane and 0.68 m on all sides at the black plane. As with Site A, an average zone of contribution of effective rainfall of 0.05 m was estimated for the green depth plane. This was estimated at a slightly higher value than at Site A owing to the overall increase in surface area of the DD system at Site B and so the effect of rainfall dilution would be expected to be greater as evident at the red, blue and black depth planes.

Table 7.26 Estimated zone of contribution of effective rainfall

Site B (DD)	Length of wetted infiltrative surface (m)	Width of plume (m) from edge of dripline at depth plane			
		0.15 m	1.0 m	1.3 m	1.6 m
Dripline 1-16	10	0.05	0.34	0.64	0.68

Mean soil moisture levels recorded beneath the DD at Site B show a similar trend to that at Site A. Again a gradual increase in soil moisture levels from the 600 mm depth downwards is indicative of a vertical plume gradually expanding in a lateral direction (Figure 7.38).

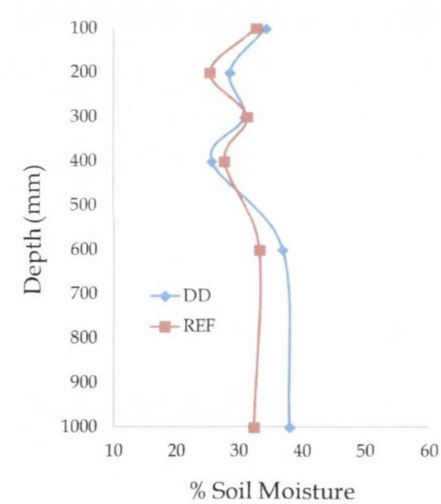


Figure 7.38 Soil moisture variation with depth beneath DD system at Site B

Soil moisture samples recorded beneath the DD from the 1st of August 2013 to the 31st of August 2013 again show a response to high intensity rainfall followed by a gradual recovery back to initial soil moisture levels with limited response to effluent dosing (Figures 7.39 and 7.40). As the logged tensiometers were not moved to the DD at Site B until the overloading trial in December 2013, soil moisture tension data for this period is not available.

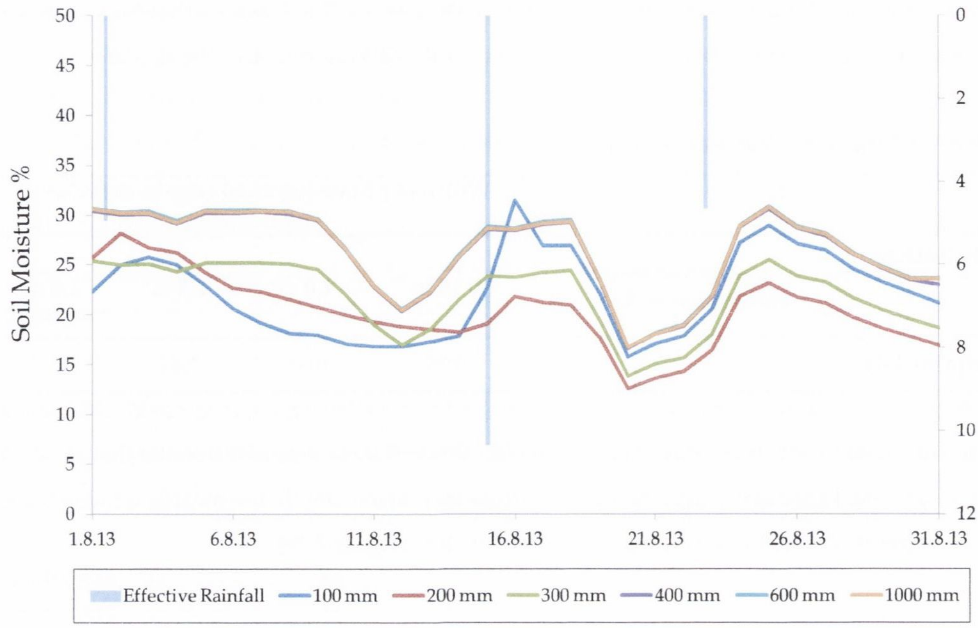


Figure 7.39 Soil moisture response to effective rainfall beneath DD at Site B

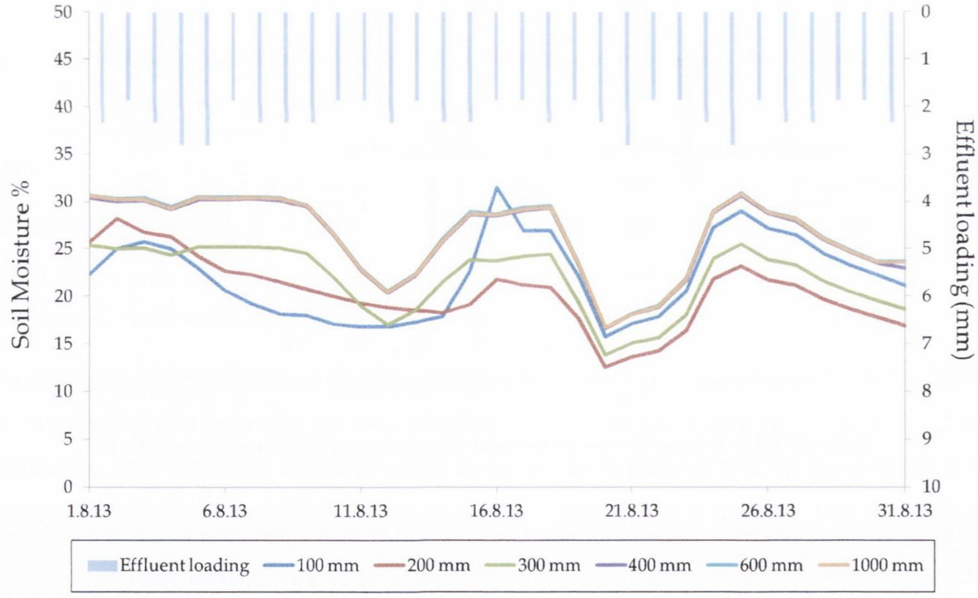


Figure 7.40 Soil moisture response to effective rainfall beneath DD at Site B

As with Site A, the shallowest depth plane (green plane) is shown to be influenced by a combination of effluent application and rainfall recharge. Again the greatest reduction in soil moisture tension is apparent at the lower depth planes. As no black depth plane tensiometers were installed beneath the DD system at Site B no comparison can be made. However, the red and blue depth planes show a similar response of increased soil moisture tension following a reduction in effective rainfall.

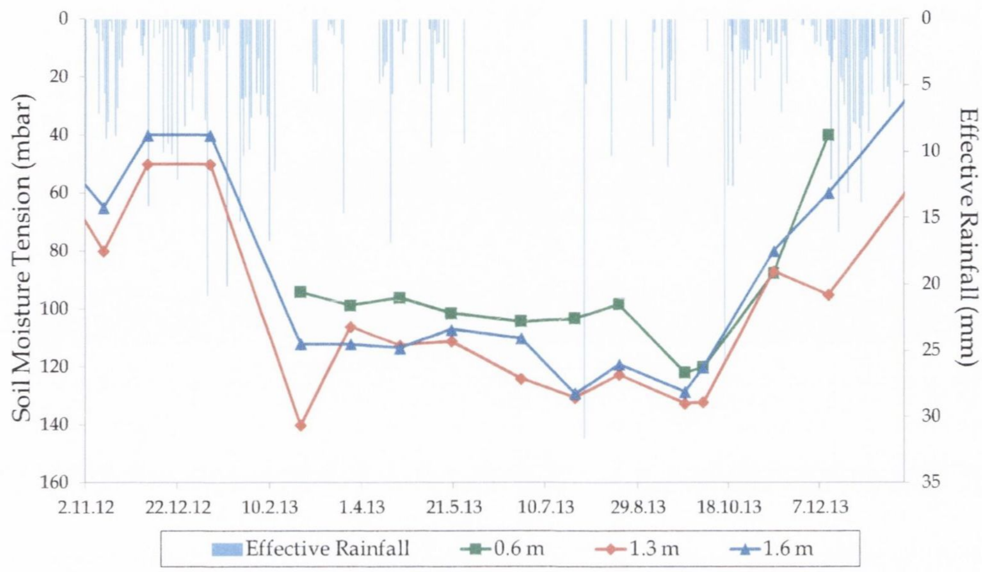


Figure 7.41 Soil moisture tension plotted against effective rainfall

As with the previously discussed systems the overall soil moisture levels during both periods of sustained effective rainfall and periods of zero effective rainfall are outlined below. They reveal only a marginal increase in comparison with background soil moisture levels recorded at the site (Tables 7.27 and 7.28). The greatest reduction in soil moisture levels during dry conditions is at the 100 mm depth. This is as a result of reduced rainfall recharge. However, the same reduction between seasons is not evident from the 200 mm depth downwards. The sustained soil moisture levels at these depths are thought to be as a result of the continuous application of effluent as a greater reduction was seen in background soil moisture levels.

Table 7.27 Seasonal soil moisture variation beneath DD at Site B

Depth (mm)	Soil moisture (%)				Seasonal decrease from Winter to Summer	
	Winter		Summer			
	DD %	REF %	DD %	REF %	DD %	REF %
100	39.3	37.5	21.5	20.0	45%	47%
200	33.8	33.7	22.6	21.5	33%	36%
300	35.7	38.4	23.1	26.9	35%	30%
400	32.9	33.5	21.9	26.0	33%	22%
600	37.4	35.8	27.7	26.1	26%	25%
1000	38.4	34.1	28.4	25.7	26%	25%
Reduction between 100 mm and 400 mm					37%	34%
Reduction between 600 mm and 1000 mm					26%	25%

Table 7.28 Hydraulic loadings during winter and summer months to DD at Site B

	Rainfall (mm)	ET_O (mm)	Effective Rainfall (mm)	Effluent Load (mm)	Total Hydraulic load (mm)
Winter	160.5	19.8	143.7	158.2	298.9
Summer	111.6	201.4	47.0	146.2	55.6

[a] Winter based on data recorded between the 12/11/2012 and 04/01/2013

[b] Summer based on data recorded between the 27/06/2013 and 19/08/2013

7.3 Results of Chemical Analysis

The results of all chemical analysis carried out on STE, SE, soil moisture and groundwater samples obtained from the post-remediation monitoring of Sites A and B are contained in Appendix E. In presenting the results of the chemical analysis, pollutant loading rates are reported in addition to parameter concentrations. The pollutant loads from the applied effluent at both sites to the distribution networks are calculated as the mean daily flow to each system multiplied by the concentration of each parameter. Subsoil pollutant loads are measured as the mean daily flow applied to each network plus any effective rainfall dilution over the zone of contribution multiplied by the mean parameter concentration across the specified depth plane beneath each system.

7.3.1 Low Pressure Pipe System (Site A)

Table 7.29 presents the results from the COD analysis, which shows that the vast majority of organic concentration and load is reduced above the *red* depth plane and/or within the distribution gravel directly under the percolation pipe. As the application of effluent is via a uniform distribution network, the formation of a significant biomat at the infiltrative surface appears to be limited. This was confirmed by the inspection of the LPP trenches in May 2014 following completion of the project. Figure 7.42 shows no evidence of a significant biomat layer at the base of T1. Therefore it is believed that the development of a biozone of activity at the IS was largely responsible for the 91% removal in organic load through both physical straining and biodegradation processes. Further reduction in COD levels was shown to be limited between the *red* and *black* depth planes owing to the reduced microbial populations. When figure 7.43 is further examined it is also clear that the attenuation performance of the subsoil remained high despite the varying organic load of the STE. A steady increase in COD concentrations within the STE resulted in muted increases in the soil moisture concentrations the end of August onwards. The increase in STE concentration over the course of the trial was presumably due to a build up in solids within the septic tank resulting in the production of increased soluble organics through anaerobic processes.

Figure 7.42 Excavated LPP trench at Site A

Table 7.29 Reduction in COD load with respect to the STE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load Removal (%)
STE	414.0	94.6	-	-
0.75	36.8	8.7	85.9	90.8%
1.05	36.0	8.5	86.1	91.0%
1.35	30.5	7.2	87.4	92.4%

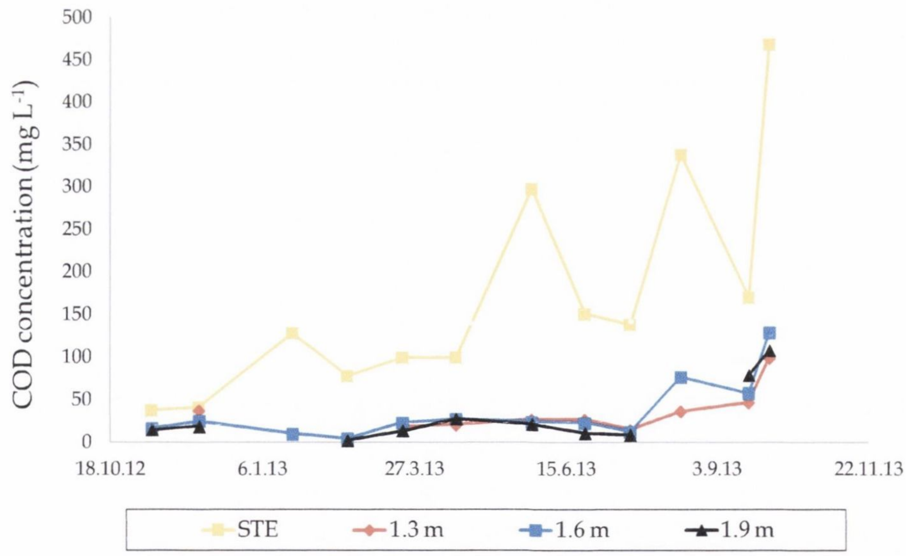


Figure 7.43 COD concentrations in STE and across the three depth planes

Similarly, nitrogen analysis of the STE and soil moisture samples (Table 7.30) shows the greatest reduction in total inorganic-N concentration (94%) occurred above the *red* depth plane (Figure 7.44). However, the decrease in NH_4-N concentration in the percolate with depth is not sufficiently accounted for by the corresponding increase in NO_3-N concentration. This suggests that a large percentage of the NH_4-N is being lost in the system - most likely by nitrification followed by rapid denitrification in localised micro-sites where saturated conditions are prevalent - or through direct annamox transformation to nitrogen gas. Nitrification of the remaining NH_4-N above the *red* depth plane resulted in a jump in NO_3-N from 0.6% to 94.9% of the total inorganic-N in the STE and the percolate at the *red* depth plane, respectively (Table 7.31). This indicates nearly complete nitrification occurred beneath the system with little further loss between the *blue* and *black* planes with a total reduction in inorganic-N of 98%.

Table 7.30 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
STE	64	14.6	0.15	0.0	1.4	0.3	65.6	15.0
0.75	0.58	0.14	0.055	0.01	11.8	2.78	12.44	2.93
1.05	0.63	0.15	0.144	0.03	12.8	3.02	13.58	3.21
1.35	0.12	0.03	0.021	0.00	5.4	1.27	5.52	1.30

Table 7.31 Average fractionation of total inorganic-N in STE and across the three depth planes

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	97.6%	0.23%	2.1%
0.75	4.7%	0.44%	94.9%
1.05	4.6%	1.06%	94.3%
1.35	2.2%	0.38%	97.4%

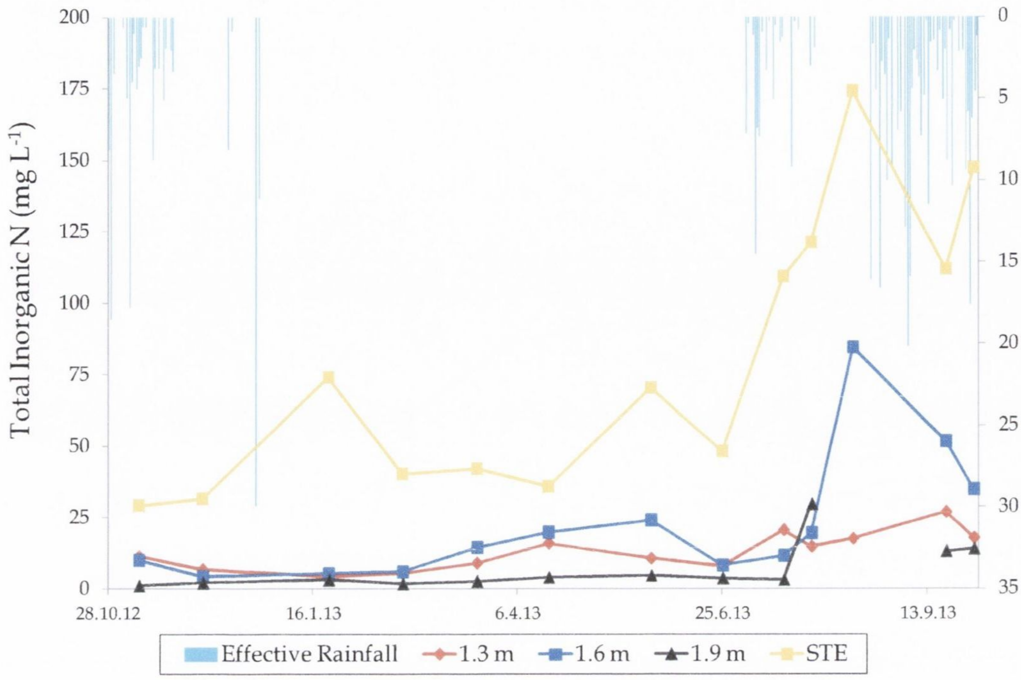


Figure 7.44 Total inorganic-N concentrations at each depth plane with respect to STE

As illustrated in Figure 7.45, NH_4-N levels at all three depth planes remained low despite variation in the STE concentrations indicating the continued nitrification of the percolating effluent under varying rainfall conditions. This suggests that even during periods of effective rainfall recharge the intermittent application of effluent allowed aerobic conditions to be maintained (at least periodically) and nearly complete nitrification to occur. Figure 7.46 shows an increase in NO_3-N at the end of July 2013. As Figure 7.45 shows no increase in NH_4-N concentrations at any depth plane at this point it is assumed that nearly complete nitrification is still occurring and the increase in NO_3-N is due to a reduction in denitrification as a result of increased aerated conditions in the subsoil following a long period of zero effective rainfall. This increase in NO_3-N may also have been contributed to by the increase in NH_4-N recorded in the STE.

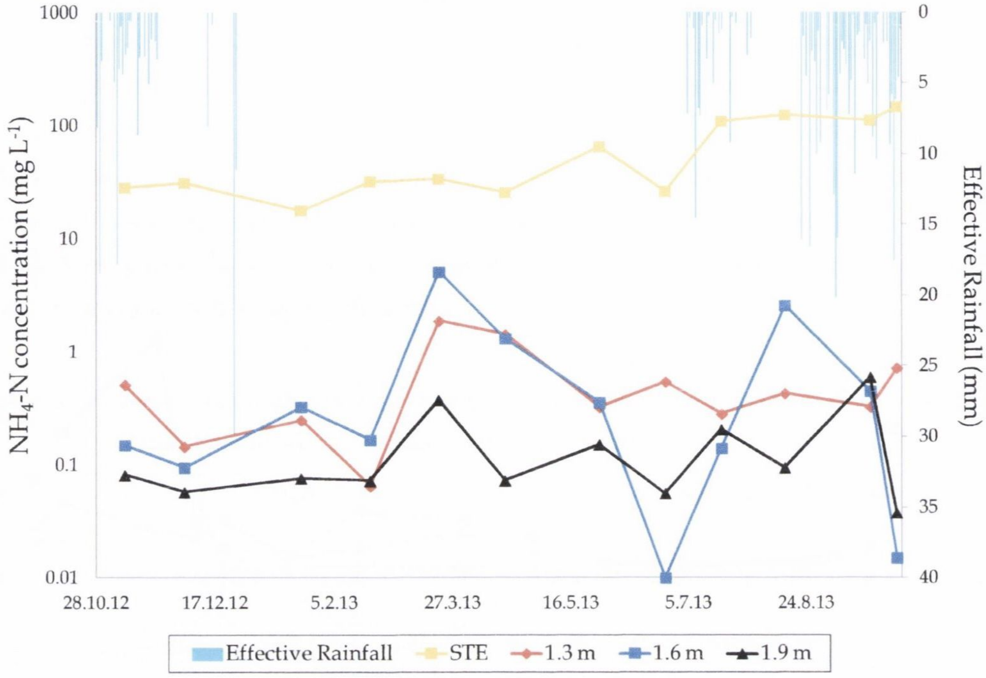


Figure 7.45 Reduction in NH_4-N in relation to effective rainfall

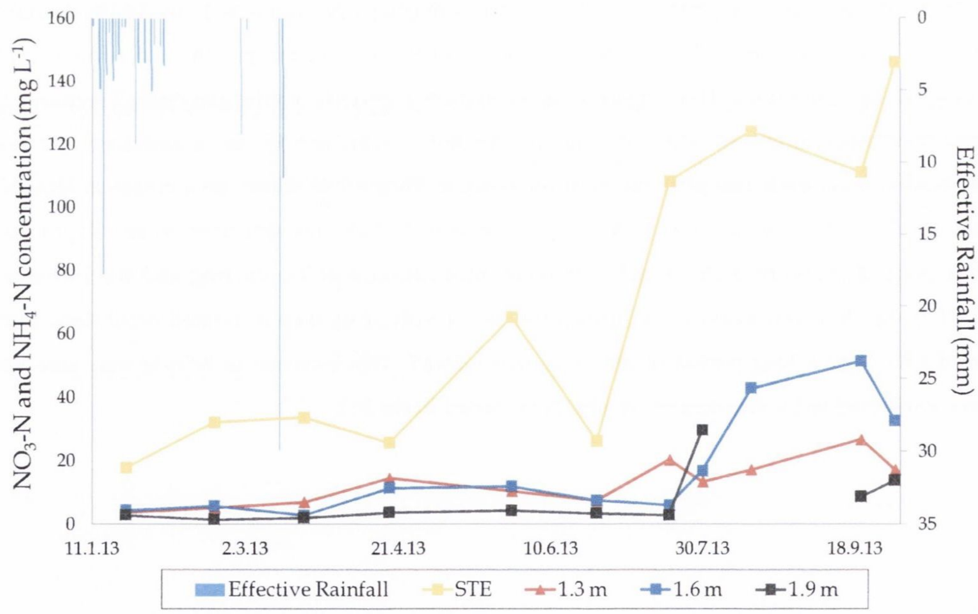


Figure 7.46 Reduction in NO_3-N in relation to effective rainfall and STE NH_4-N concentrations

Removal of phosphorus from the percolate in the subsoil is typically due to soil adsorption and mineral precipitation processes. The P-fixation capacity of a soil is dependent on a number of factors, particularly its clay content. Analysis of the PO_4-P concentrations and loads in the STE and at the three depth planes reveals that the majority of phosphorus fixation (97.2%) occurred above the *red* depth plane (Table 7.32 and Figure 7.47). The subsoil at Site A was characterised as a sandy SILT/CLAY (see Section 3.13) with further particle size analysis showing that it contained 20% clay. The presence of such a high percentage of fine particles provides a large specific surface conductive to phosphorus adsorption. The P-sorption capacity of fine-grained subsoils would be expected to hold for a period of 10 years at least (Jenssen, 2001). As outlined in Section 6.21, mineral precipitation and adsorption due to the presence of Ca, Fe and Al identified through XRD analysis may also contribution to the overall reduction in PO_4-P concentrations. Results from the monitoring of the soak-pit systems at Site A (prior to remediation) show high PO_4-P reduction despite the evidence of effluent transport along distinct lateral pathways. This indicates the continued high P-sorption capacity of the subsoil even under unfavourable conditions for a period of over 20 years. It is therefore unsurprising that the newly installed LPP system would also achieve excellent P removal. Figure shows that PO_4-P removal remains high despite the variation in the STE load.

Table 7.32 Reduction in PO_4-P with respect to STE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Load Removal (g d^{-1})	Net Load removal (wrt STE influent) (%)
STE	20.2	4.6	-	-
0.75	0.54	0.13	4.5	97.2%
1.05	0.39	0.09	4.5	98.0%
1.35	0.48	0.11	4.5	97.6%

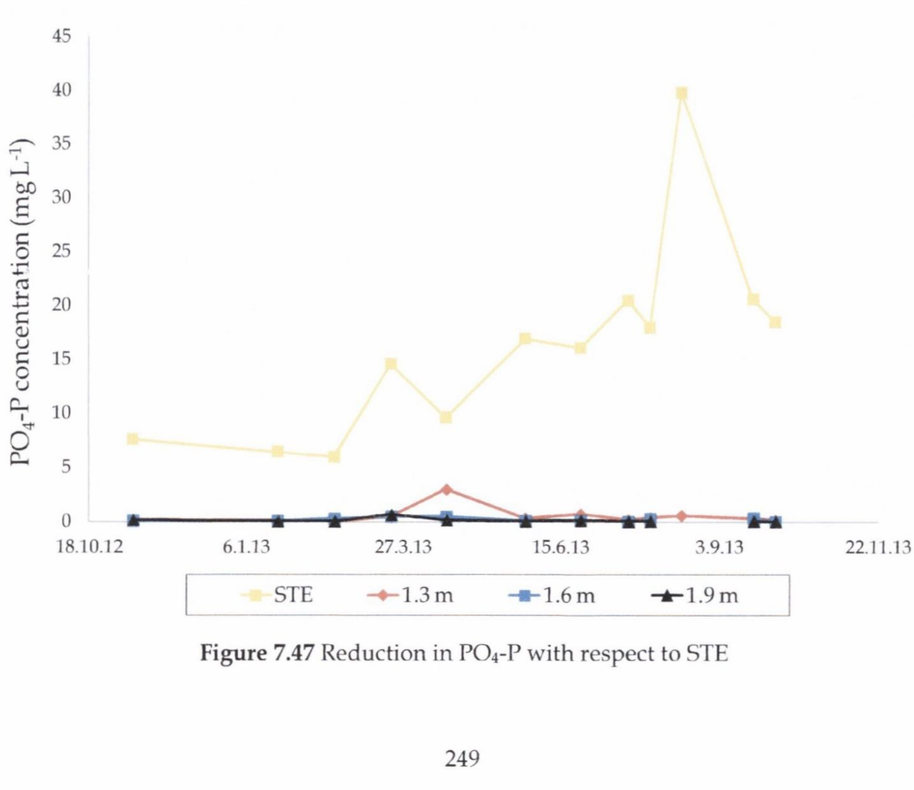


Figure 7.47 Reduction in PO_4-P with respect to STE

As detailed previously in Section 4.8.3, it was necessary to dilute some of the soil moisture samples collected during the course of the bacteriological analysis for TC and *E. coli* as volumes were too small (< 100 mL). In such cases the minimum detection level of the bacterial concentrations was affected and therefore expressed in the form of < x MPN 100 mL-1. For example, if a sample was analysed for *E. coli* and found to contain < 10 MPN 100 mL-1, this means that the original sample was diluted by a factor of 1 in 10 with distilled water. In other words, while the presence of *E. coli* was not detected the dilution step had to be accounted for. All bacteriological results from Sites A and B are tabulated in Appendix E.

Assuming that all samples analysed are representative of the sample position from which they were obtained, it can be seen that the high purification capacity of the intense biozone and 0.75 m thickness of underlying subsoil has provided 3.9 log-unit removal in TC (approximately 99.99% reduction) by the *red* depth plane (Table 7.33). As outlined previously, no significant biomat layer was found at the base of the LPP trenches owing to the uniform effluent dosing, therefore the reduction in TC with depth is thought to be largely as a result of physical straining, absorption and natural die-off as the percolate travels through the subsoil. Additional removal may have occurred in the subsoil underlying the percolation trench due to the high percentage of fines present in the subsoil as previously described. The large surface area provided by clay particles make them ideal as adsorption sites for bacteria along with other pathogenic organisms.

Table 7.33 Reduction in total coliform concentrations with respect to STE at the three depth planes

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	21	7.9×10^5 - 1.4×10^9	9.08E+06	-
0.75	41	2.0×10^0 - 1.2×10^5	1.13E+03	3.9
1.05	43	3.8×10^0 - 6.9×10^4	6.44E+02	4.1
1.35	47	4.6×10^0 - 3.9×10^4	3.02E+02	4.5

Similar to COD and PO_4-P, further reduction in TC concentrations was minimal over the 600 mm soil depth between the *red* and *black* planes. Overall a 4.5 log-unit removal was achieved beneath the system.

Table 7.34 presents the results of sample analysis for *E. coli* which shows that excellent removal of enteric bacteria was achieved within the system with the exception of a couple of samples. As previously described, sample dilutions were often required at Site A due to poor soil moisture sample volumes.

Table 7.34 Concentrations of *E. coli* across the three depth planes

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	41	39	3	0	0
1.05	43	40	2	1	0
1.35	47	41	4	2	0

While presence of enteric bacteria at the red depth plane does not pose an immediate threat to groundwater contamination and its associated health implications, the detection of pathogen migration to the black plane (1.35 m below the infiltrative surface) is a concern and emphasises the potential of pollutant migration despite the low permeability conditions.

The elevated *E. coli* concentrations detected at all three depth planes on the 09/11/12, 18/04/13 and 01/10/13 may have been a result of reversible adsorption (desorption) of the enteric bacteria from the aforementioned clay particles in the subsoil or due to higher infiltration rates as meteorology data showed high levels of rainfall occurring around these two sampling dates. Of more concern is the detection of elevated levels at LP 1.2 Blue (435 MPN 100 mL^{-1}) and LP 1.2 Black (135 MPN 100 mL^{-1}) on the 19/07/13. This breakthrough occurred during a period of sustained zero effective rainfall and as such the most likely cause of migration is as a result of the presence of preferential pathways within the subsoil. Results over the course of the sampling period indicated the presence of a preferential flow path to LP 1.2 Blue. This may have been due to the natural soil conditions or due to poor lysimeter installation. As this was the only lysimeter to indicate such results it is thought results from this sample depth are due to a degree of preferential flow it is believed the latter is the cause.

7.3.2 DRIP DISTRIBUTION SYSTEM (SITE A)

Table 7.35 presents the results from the COD analysis, which shows that the vast majority of organic concentration and load is reduced above the *green* depth plane (73.2%), i.e. within the first 0.15 m beneath the drip lines. It is assumed that the formation of an intense zone of biological activity at the infiltrative surface is largely responsible for the reduction in the organic load through both physical straining and biodegradation processes. Previous studies in Irish subsoils have reported a 75% to 89% reduction in organics between the septic tank and a depth of 0.3 m below the IS with the author suggesting that some of the organic attenuation occurred within the distribution gravel of the percolation trench as well as the first few 100 mm of subsoil (Gill et al., 2007). However, as the DD system is installed without aggregate it is assumed that the high reduction in COD is as a result of increased physical straining due to the high percentage of fines in the subsoil combined with the maintenance of aerobic conditions through the application of pressurised dosing of effluent. Further reduction in COD levels was limited between the *red* and *black* depth planes owing to the more recalcitrant nature of the organics left in the effluent by these depths. When Figure 7.48 is further examined it is also clear that the attenuation performance of the subsoil is remains high despite the varying organic load of the STE.

Table 7.35 Reduction in COD with respect to STE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load Removal (%)
STE	414	92.2	-	-
0.15	60.3	13.7	78.4	85.1%
1.00	27.1	6.2	86.0	93.3%
1.30	23.4	5.4	86.8	94.2%
1.60	17.5	4.0	88.1	95.6%

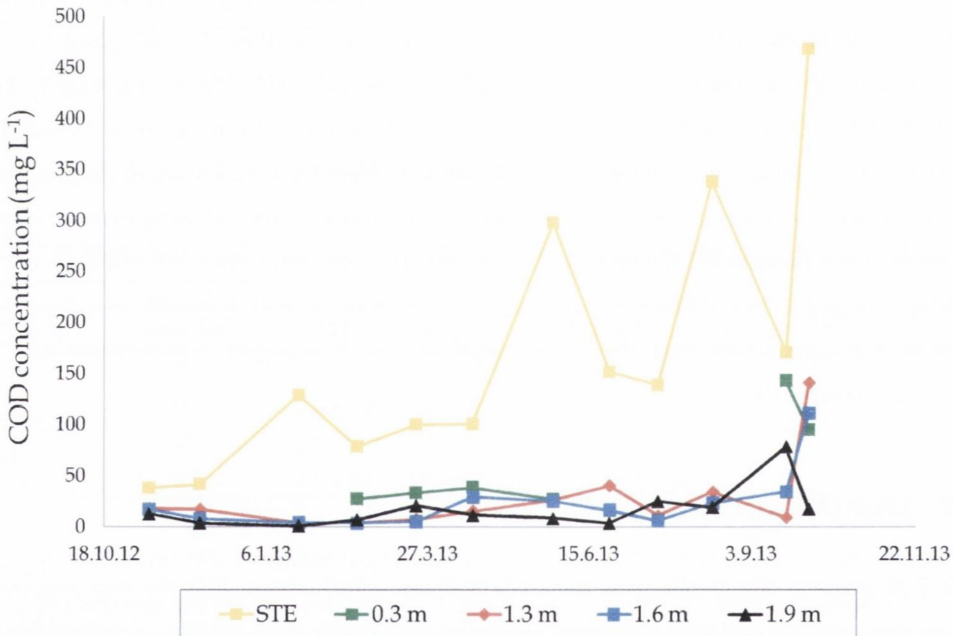


Figure 7.48 Reduction in COD concentrations across all depth planes in respect to STE

Analysis of the STE and soil moisture samples from the DD system (Table 7.36) shows the greatest reduction in total inorganic-N concentration occurred above the *green* depth plane (Figure 7.49). Again the observed decrease in NH_4-N concentrations in the percolate with depth could not be sufficiently accounted for by the corresponding increase in NO_3-N concentrations. As with the LPP this suggests that a large percentage of the NH_4-N is being lost in the system - most likely by nitrification followed by rapid denitrification in localised micro-sites where saturated conditions are prevalent - or through direct annamox transformation to nitrogen gas. As the infiltrative surface of the DD system was extremely shallow (0.15m) there would have been high potential for plant uptake which may also contribute to the high reduction in total inorganic-N by the *red* depth plane as most roots are found in the top 30 cm (300 mm) of soil (Mmolawa and Or, 2000). Nitrification of the remaining NH_4-N above the *green* depth plane resulted in a jump in NO_3-N from 0.6% to 93.7% of the total inorganic-N in the STE and the percolate at the green depth plane, respectively (Table 7.37). This indicates nearly complete nitrification occurred beneath the system with little further loss between the blue and black planes with a total reduction in inorganic-N of 98%.

Table 7.36 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**
STE	64	14.2	0.15	0.0	1.4	0.3	65.6	14.6
0.15	0.42	0.10	0.1	0.023	7.7	1.75	8.23	1.87
1.00	0.11	0.03	0.020	0.005	5.1	1.17	5.23	1.20
1.30	0.37	0.08	0.060	0.014	4.1	0.94	4.53	1.04
1.60	0.17	0.04	0.040	0.009	3.9	0.89	4.06	0.94

Table 7.37 Average fractionation of total inorganic-N in STE and across the three depth planes

	% of total inorganic-N		
	NH_4-N	**NO_2-N**	**NO_3-N**
STE	97.6%	0.23%	2.1%
0.15	5.1%	1.22%	93.7%
1.00	2.1%	0.38%	97.5%
1.30	8.2%	1.32%	90.5%
1.60	4.2%	0.99%	94.8%

As illustrated in Figure 7.50, NH_4-N levels at all three depth planes remained extremely low despite variation in the STE concentrations and varying rainfall conditions. This suggests that even during periods of effective rainfall recharge the intermittent application of effluent allows aerobic conditions to be maintained (at least periodically) and nearly complete nitrification to occur. Unlike that observed under the LPP system Figure 7.51 shows only a minor increase in NO_3-N at the end of July 2013 suggesting some of the increase load has been offset by plant uptake. With no corresponding increase in NH_4-N concentrations observed Figure 7.50 it is assumed that the nature of the DD effluent application is providing localised micro-sites where saturated conditions exist, even during periods of zero effective rainfall. As a result, nearly complete removal of inorganic-N occurred beneath the DD system.

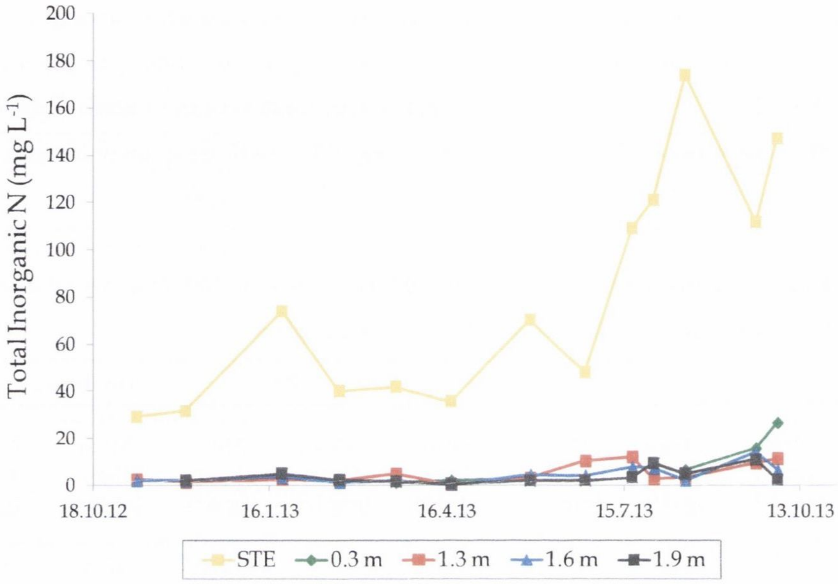


Figure 7.49 Reduction in total inorganic-N concentrations at all depth planes in relation to STE

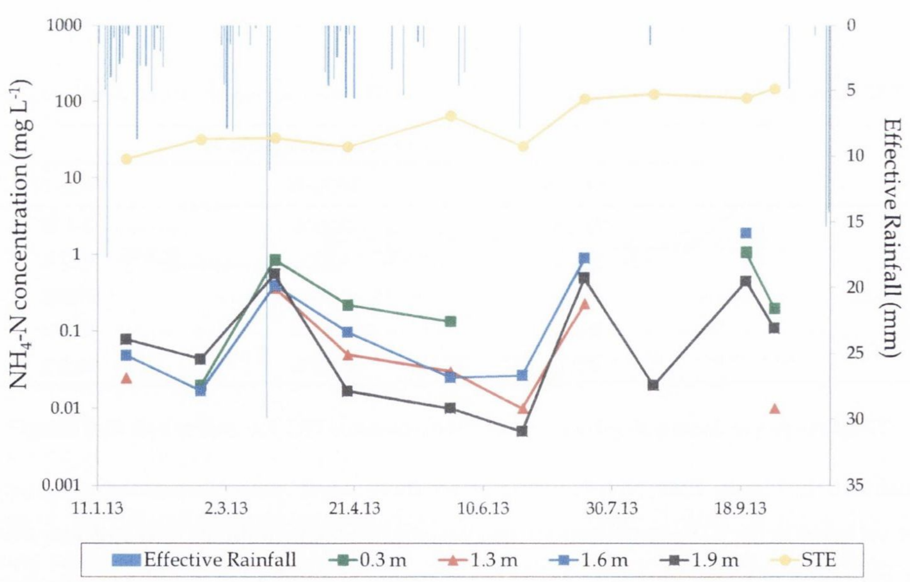


Figure 7.50 Reduction in NH_4-N concentrations at all depth planes in relation to STE and effective rainfall

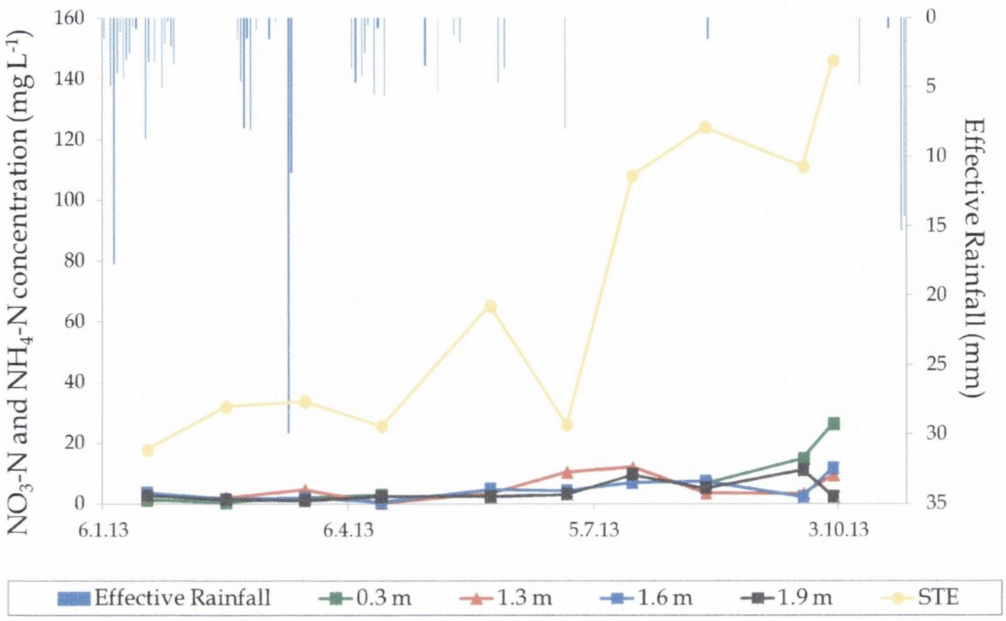


Figure 7.51 Reduction in NO_3-N concentrations at all depth planes in relation to STE NH_4-N concentrations and effective rainfall

Removal of phosphorus beneath the DD system at Site A was also extremely effective with 97.6% removal within 0.15 m of the infiltrative surface (*green* plane). As with the LPP system this removal was attributed to high percentage of fine particles providing a large specific surface for phosphorus adsorption. Further small removals were evident between lower depth planes with 99.1% removal achieved by the *black* plane. As with the LPP system, Figure 7.52 shows that PO_4-P removal remains high despite the variation in the STE load.

Table 7.38 Reduction in PO_4-P with respect to STE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Load Removal (g d^{-1})	Net Load removal (wrt STE influent) (%)
STE	20.2	4.5	-	-
0.15	0.48	0.11	4.4	97.6%
1.00	0.03	0.01	4.5	99.8%
1.30	0.48	0.11	4.4	97.6%
1.60	0.18	0.04	4.5	99.1%

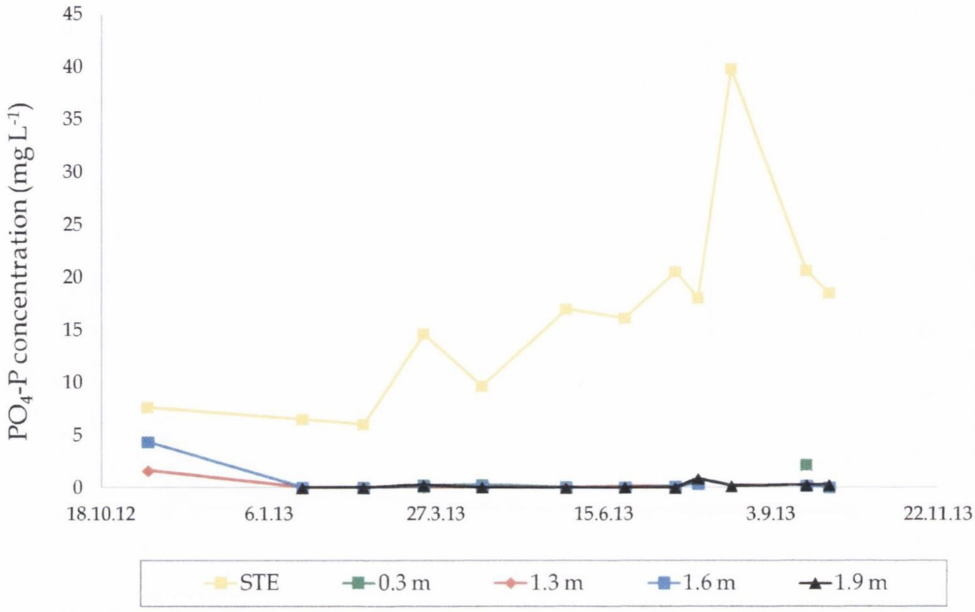


Figure 7.52 Reduction in PO_4-P with respect to STE at all depth planes

Table 7.39 presents the results of TC removal beneath the DD system at Site A. A 3.4 log-unit reduction was achieved within 0.15 m of the infiltrative surface (*green* depth plane). As with the LPP system at Site A, the high levels of TC removal are believed to be as a result of physical straining following intense biozone formation close to the IS in conjunction with adsorption to the clay particles present in the underlying subsoil. A further reduction in TC concentrations was minimal between the *red* and *black* planes with an overall log-unit removal of 4.3 achieved beneath the system.

Table 7.39 Reduction in total coliform concentrations with respect to STE at the four depth planes

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
SE	15	7.9×10^5 - 1.4×10^9	9.08E+06	-
0.15	30	3.1×10^1 - 7.7×10^4	3.48E+03	3.4
1.00	41	1.0×10^1 - 4.8×10^4	6.37E+02	4.2
1.30	48	5.5×10^0 - 8.9×10^4	6.07E+02	4.2
1.60	40	7.5×10^0 - 3.9×10^3	4.26E+02	4.3

Table 7.40 presents the results of sample analysis for *E. coli* which shows that almost complete removal of enteric bacteria was achieved beneath the DD system, with the exception of a couple of sample events.

Table 7.40 Concentrations of *E. coli* across the three depth planes

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.15	30	27	3	0	0
1.00	41	38	3	0	0
1.30	48	47	1	0	0
1.60	40	38	2	0	0

As with the LPP system the detection of pathogen migration to the *black* plane (1.6 m below the infiltrative surface) is a concern and emphasises the potential of pollutant migration despite the low permeability conditions.

The elevated *E. coli* concentrations were only detected at the *red* and *blue* depth planes during the occurrence of high effective rainfall. A low presence of *E. coli* at the *black* depth plane was detected on three sampling occasions during which high rainfall levels were recorded; 04/12/12 (7.5 MPN 100 mL^{-1}), 02/01/13 (1.0 MPN 100 mL^{-1}) and 17/12/14 (41 MPN 100 mL^{-1}). Again a single detection was recorded at the black depth (18.3 MPN 100 mL^{-1}) on the 19/07/13 during a period of no effective rainfall.

Groundwater quality at Site A was assessed by means of upstream and downstream boreholes as detailed in Chapter 4. Of particular interest was the analysis of NO_3-N, PO_4-P and *E. coli* concentrations. Concentrations of NO_3-N recorded in upstream and downstream borehole samples during both the pre-remediation and post-remediation monitoring are shown in Table 7.41. An increase in NO_3-N concentrations was recorded within samples retrieved from the LPP and DD boreholes following the remediation of the site however mean values remained only marginally higher than upstream groundwater samples. It should be noted that due to a drop in groundwater levels no borehole samples were retrieved from June to November 2013.

Table 7.41 Mean NO_3-N concentrations recorded at borehole locations

	NO_3-N	
Borehole	**Pre-remediation**	**Post-remediation**
Upstream	1.2	1.3
LPP	0.6	1.3
DD	0.8	1.5

Borehole samples at both site A recorded a marginal increase in PO_4-P concentrations downstream of the newly installed LPP and DD systems however levels remained low overall with no indication of significant of migration to groundwater (Table 7.42).

Table 7.42 Mean PO_4-P concentrations recorded at borehole locations

	Ortho-P	
Borehole	**Pre-remediation**	**Post-remediation**
Upstream	0.04	0.06
LPP	0.03	0.21
DD	0.04	0.08

Table 7.43 shows the detection of *E. coli* in the boreholes samples over the course of the monitoring period. An increase in *E. coli* was observed directly downstream of both the LPP and DD system. Elevated *E. coli* levels were detected in the upstream groundwater at Site A on a single occasion (19/10/12) however, MST analysis by NUI Galway Microbial Department showed that this was from a bovine source and not human faecal contamination. This highlights the potential of such techniques in identifying the source of faecal contamination in water sources. The magnitude of *E. coli* concentrations detected downstream of the LPP and DD at Site A are largely due to elevated concentrations also recorded on the 19/10/12. MST analysis showed the presence of both human and bovine faecal contamination.

Table 7.43 Geometric mean *E. coli* concentrations recorded at borehole

	E. coli	
Borehole	**Pre-remediation**	**Post-remediation**
Upstream	0	86
LPP	0	63.3
DD	0	4.7

7.3.3 Low Pressure Pipe System (Site B)

Table 7.44 presents the results from the COD analysis, which shows that the vast majority of the organic concentration and load was reduced above the *red* depth plane and/or within the distribution gravel directly under the percolation pipe. As with Site A, it is assumed that the formation a biological zone of activity at the infiltrative surface was largely responsible for the 76% removal in organic load through both physical straining and biodegradation processes. Further reductions in COD levels were limited between the *red* and *black* depth planes owing to the reduced microbial populations. Figure 7.53 also shows that the attenuation performance of the subsoil was not significantly affected by the varying organic load of the SE.

Table 7.44 Reduction in COD with respect to SE

	Mean Conc. (mg L-1)	Mean Load (g d-1)	Cumulative Load Removal (g d-1)	Net Load removal (wrt SE influent) (%)
SE	106.1	20.6	-	-
0.75	23.5	5.0	15.6	76%
1.05	20.6	4.4	16.2	79%
1.35	15.5	3.4	17.2	84%

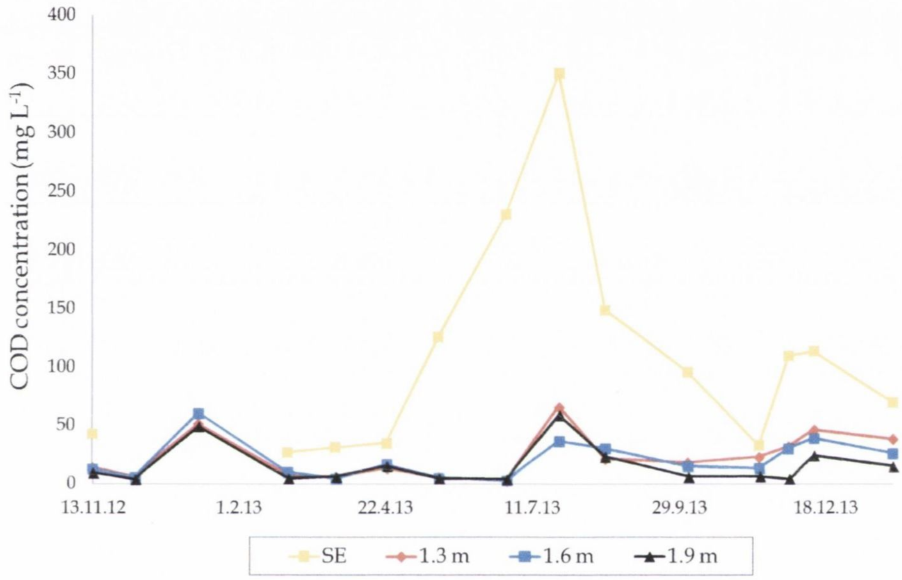


Figure 7.53 Reduction in COD with respect to SE at all depth planes

Similarly, nitrogen analysis of the SE and soil moisture samples (Table 7.45) shows the greatest reduction in total inorganic-N concentration (47%) occurred above the *red* depth plane (Figure 7.54). As the applied SE was highly nitrified upon discharge to the LPP trenches (74% NO_3-N) the reduction in inorganic-N concentrations was lower than that observed at Site A. The occurrence of nitrification above the red depth plane is apparent with a decrease in NH_4-N concentration and an increase in NO_3-N concentrations observed. Figure 7.54 shows the variation in total inorganic removal achieved beneath the LPP system. Facultative anaerobic heterotrophic bacteria responsible for denitrification require not only saturated conditions, but also a supply of organic matter from which to maintain their energy and carbon for metabolism. The reduced organic loading of the percolate by the *red* depth plane (Table 7.46) as well as a reduction in soil moisture levels during the summer of 2013, correspond to a gradual decrease in total inorganic removal during this period. It can also be seen that following an increase in effective rainfall recorded in December 2013 onwards a decrease in NO_3-N was again apparent presumably due to the return of saturated conditions. An overall reduction of 64% of total inorganic-N was observed by the black depth plane.

Table 7.45 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the SE and across the three depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
SE	5.6	1.1	0.43	0.1	17.2	3.3	23.2	4.5
0.75	0.48	0.10	0.031	0.007	9.5	2.02	9.98	2.13
1.05	0.35	0.08	0.020	0.004	8.7	1.87	9.05	1.94
1.35	0.27	0.06	0.019	0.004	6.8	1.49	7.13	1.55

Table 7.46 Average fractionation of total inorganic-N in SE and across the three depth planes

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
SE	24.1%	1.9%	74%
0.75	4.8%	0.3%	95%
1.05	3.9%	0.2%	96%
1.35	3.8%	0.3%	96%

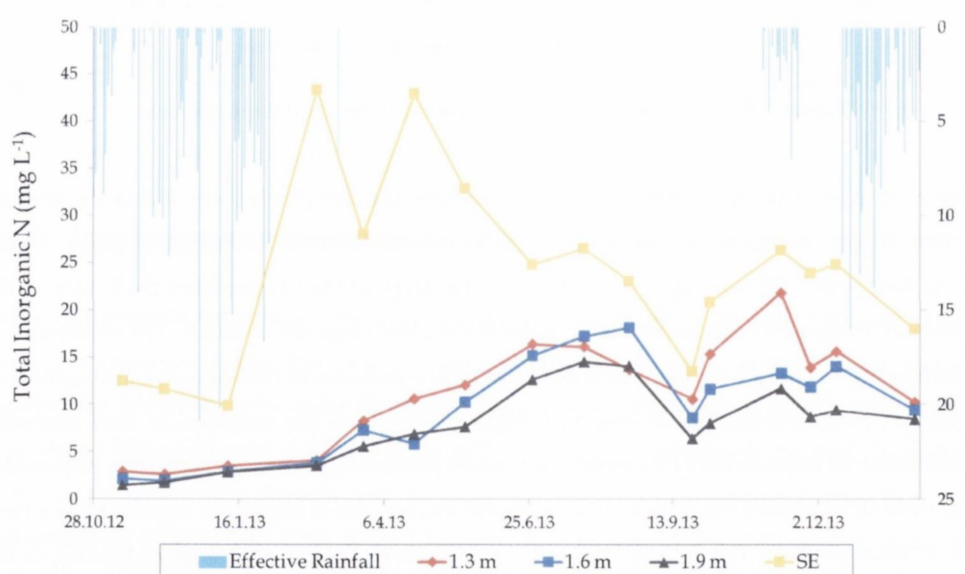


Figure 7.54 Reduction in total inorganic-N across the three depth planes in relation to SE and effective rainfall

As outlined previously removal of phosphorus from the percolate in the subsoil is typically due to soil adsorption and mineral precipitation processes is strongly influenced by the clay content. Analysis of the PO_4-P concentrations and loads in the SE and at the three depth planes reveals the majority of phosphorus fixation (97.6%) to have occurred above the *red* depth plane (Table 7.47 and Figure 7.55). The subsoil at Site B was characterised as a SILT/CLAY with further particle size analysis showing it contained 24% clay at a depth of 1.0 m. The presence of such a high percentage of clay particles would have provided a large specific surface conducive to phosphorus adsorption. XRD analysis (Section 6.2.2) showed the soil mineralogy contains Ca, Fe and Al which may also play a role in the reduction in PO_4-P recorded beneath the system. As with Site A, a high reduction of PO_4-P concentrations was recorded during the monitoring of the soak-pit prior to remediation despite the evidence of effluent transport along distinct lateral pathways. It is therefore unsurprising that the newly installed LPP system would also achieve excellent P removal (98.8% by the *black* plane). Figure shows that PO_4-P removal remains consistently high despite fluctuation in the SE load.

Table 7.47 Reduction in PO_4-P load with respect to the SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	5.8	1.1	-	-
0.75	0.13	0.03	1.10	97.6%
1.05	0.15	0.03	1.09	97.1%
1.35	0.06	0.01	1.11	98.8%

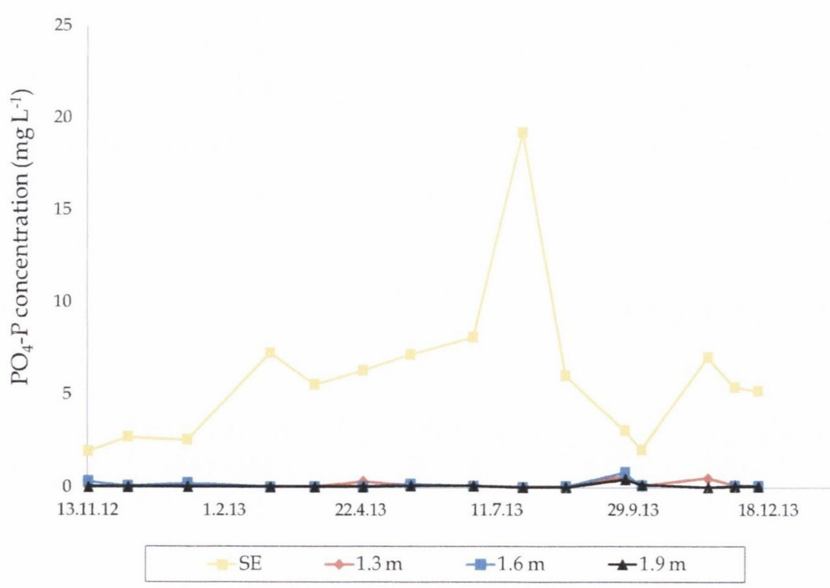


Figure 7.55 Reduction in PO_4-P load with respect to the SE at all depth planes

Table 7.48 details the TC concentrations recorded beneath the LPP system at Site B. Effluent applied to the systems was secondary treated and as such much lower concentrations compared to the STE at Site A. As a result, removal efficiency of 3.5 log-unit removal above the *red* depth plane is slightly lower than that observed at Site A. This indicates that the biomat/enhanced biozone activity as a result of the higher organic loading associated with STE was primarily responsible for the retention of the bacteriological constituents. With reduced soils and organic loading in the SE, in combination with effluent dosing cycles, biomat formation would have been muted and the potential for pathogen breakthrough much greater. However, due to the high clay presence the subsoil the impact of reduced biomat formation was mitigated to some extent although no further decrease in TC levels were recorded at the remaining sample planes. In contrast, higher TC levels were recorded at the *blue* depth. Further inspection of the results along with meteorological data shows that higher levels of TC where recorded at the *black* plane during three sampling occasions of high rainfall (13/11/2012, 06/12/12 and the 10/01/13). This suggests the occurrence of desorption bacteria from the particles in the subsoil (which is also indicative of significant TC retention due to adsorption to clay particles as opposed to physical straining within a biomat layer) and/or faster infiltration due to the higher soil moisture conditions.

Table 7.48 Reduction in total coliform concentrations with respect to STE at the three depth planes

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	15	2.7×10^4 - 1.2×10^6	2.77E+05	-
0.75	54	1.8×10^0 - 1.7×10^3	9.49E+01	3.5
1.05	55	2.0×10^0 - 4.1×10^3	7.55E+01	3.6
1.35	53	8.1×10^0 - 9.4×10^2	9.47E+01	3.5

Analysis of the *E coli* data measured at the three depth planes shows the majority of the samples were found to contain < 10 MPN 100 mL^{-1} despite the fact that (unlike at Site A) sample volumes allowed zero dilution analysis of the soil moisture samples to be carried out. Out of 159 samples, there were 22 however from which measurable levels of enteric bacteria were recovered (Table 7.49).

Table 7.49 Concentrations of *E. coli* across the three depth planes

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	53	47	6	0	0
1.05	54	47	7	0	0
1.35	52	44	8	1	0

Of the nine occurrences of *E coli* detection at the *black* depth plane, six were recorded during the high rainfall event on the 06/12/12. *E coli* was detected in the soil moisture samples retrieved from all six *black* depth lysimeters with the most significant breakthrough recorded at the LP 1.1 *black* sampling position (172.3 MPN 100 mL^{-1}).

7.3.4 Drip Distribution System (Site B)

In comparison with Site A, the reduction in COD by the *green* plane beneath the DD system at Site B was only 44% (Table 7.50). This may be attributed to the reduction in organic loadings to the system through the application of SE rather than the STE applied at Site A. A further reduction in COD concentrations by the *red* depth plane of 68% was observed (Figure 7.56). Despite being located 250 mm above the IS of the LPP, the DD removal was 8% lower than that recorded at the same depth beneath the LPP system at Site B, indicating that the presence of aggregate perhaps does play a role in the reduction of organics. Overall COD concentrations were reduced by 82% by the *black* plane depth.

Table 7.50 Reduction in COD load with respect to the SE

	Mean COD Conc. (mg L^{-1})	Mean COD Load (g d^{-1})	Cumulative COD Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	106.1	27.6	-	-
0.15	57.7	15.6	12.0	44%
1.00	31.7	8.7	18.9	68%
1.30	24.1	6.8	20.8	75%
1.60	17.3	4.9	22.7	82%

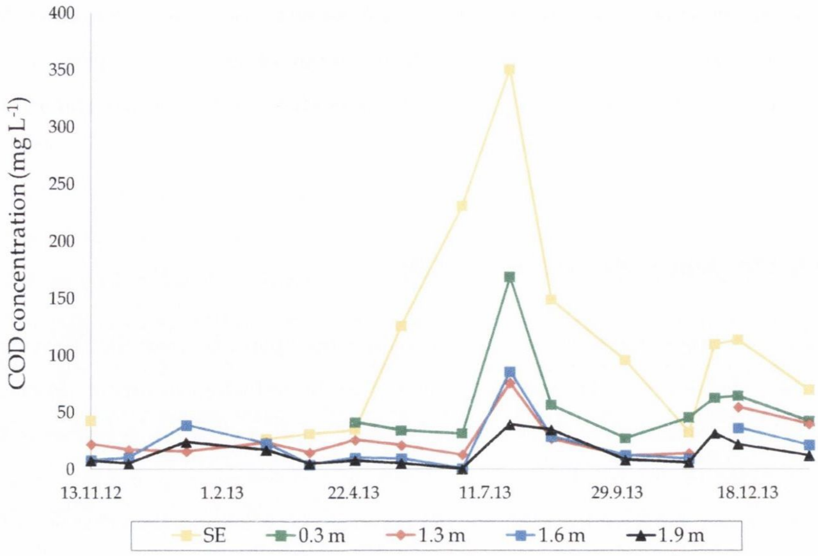


Figure 7.56 Reduction in COD load with respect to the SE at all depth planes

Analysis of the SE and soil moisture samples from the DD system (Table 7.51) shows the greatest reduction in total inorganic-N concentration of 61% occurred above the *green* depth plane (Figure 7.57). As described in previously, the SE applied to the distribution networks was highly nitrified accounting for 74% of the inorganic load. Unlike the LPP system, total inorganic removal remained consistent across the monitoring period with an 89% reduction in concentrations at the black depth plane. This is similar to the DD system at Site A suggesting that the DD network allows better alteration between aerobic and anaerobic conditions regardless of effective rainfall levels due to its shallow nature combined with effluent dosing. This in turn provides ideal conditions for both nitrification and denitrification to occur within the system. The presence of more organics at the DD shallow infiltration depth (due to plant decomposition) also improves the denitrification potential in comparison with the deeper LPP systems.

Table 7.51 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the SE and across the three depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**
SE	5.6	1.5	0.43	0.1	17.2	4.5	23.2	6.0
0.15	0.45	0.12	0.07	0.019	8.3	2.23	8.77	2.37
1.00	0.67	0.18	0.020	0.005	3.6	0.98	4.28	1.17
1.30	0.49	0.14	0.010	0.003	2.3	0.64	2.77	0.78
1.60	0.40	0.11	0.008	0.002	1.9	0.55	2.35	0.67

Table 7.52 Average fractionation of total inorganic-N in SE and across the three depth planes

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
SE	24.1%	1.85%	74.0%
0.15	5.2%	0.80%	94.1%
1.00	15.7%	0.47%	83.9%
1.30	17.7%	0.36%	81.9%
1.60	16.9%	0.34%	82.8%

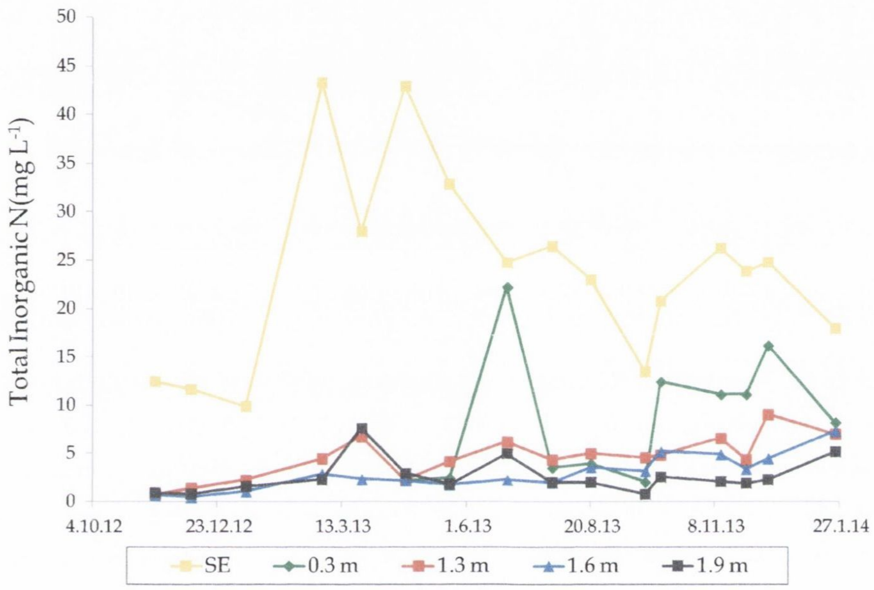


Figure 7.57 Reduction in total inorganic-N across all depth planes in relation to SE

Removal of phosphorus beneath the DD system at Site B was also extremely effective with 80.1% removal within 0.15 m of the infiltrative surface (*green* plane). As with the LPP system this removal was attributed to high percentage of fine particles providing a large specific surface for phosphorus adsorption. Further removal was evident between lower depth planes with 98.0% removal achieved by the *black* plane. As with the LPP system, Figure 7.58 shows that PO_4-P removal remains high despite the variations in the SE load.

Table 7.53 Reduction in PO_4-P load with respect to the SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	5.8	1.5	-	-
0.15	1.11	0.30	1.21	80.1%
1.00	0.190	0.052	1.46	96.5%
1.30	0.123	0.035	1.47	97.7%
1.60	0.117	0.033	1.48	97.8%

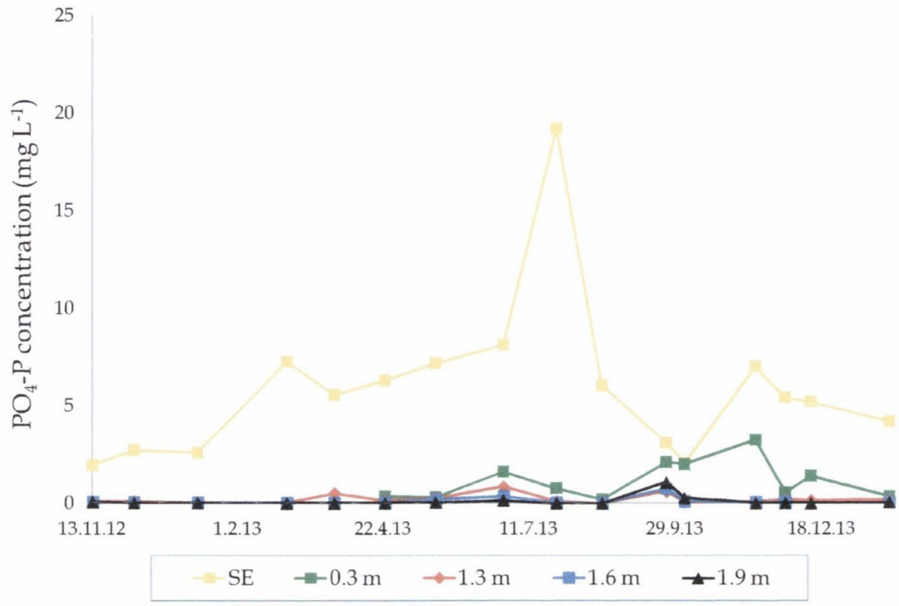


Figure 7.58 Reduction in PO_4-P load with respect to the SE at all depth planes

Unlike the TC concentrations recorded at Site A, results from Site B show a much more gradual decrease in TC levels with depth beneath the DD system (Table 7.54). This was most likely due to the reduction in biomat / biozone formation at the infiltrative surface due to reduced effluent organic loads. As with the LPP system, results of the DD system suggest adsorption of bacteria to clay particles as the percolate travels through the subsoil. Overall TC reduction was limited with only 3.3 log-unit removal achieved by the *black* depth plane (1.6 m below the infiltrative surface).

Table 7.54 Reduction in total coliform concentrations with respect to STE at the four depth planes

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
SE	15	$2.7 \times 10^4 - 1.2 \times 10^6$	2.77E+05	-
0.15	38	$6.1 \times 10^2 - 2.4 \times 10^4$	3.45E+03	1.9
1.00	58	$6.1 \times 10^0 - 4.7 \times 10^3$	3.56E+02	2.9
1.30	57	$8.5 \times 10^0 - 2.2 \times 10^3$	2.02E+02	3.1
1.60	57	$5.6 \times 10^0 - 1.5 \times 10^3$	1.30E+02	3.3

Despite this, the lowest *E. coli* levels were detected beneath the DD system at Site B (Table 7.55). This is thought to be due to the reduced effluent loading in combination with the increase in uniform distribution of effluent over a greater area. It is also worth noting that as previously described in Section 5.5, effluent distribution between the systems at Site B was not equal with an application rate of 2.8 l m^2 d^{-1} and 2.3 l m^2 d^{-1} to the LPP and DD systems respectively which may account for the improvement in the retention of enteric bacteria.

Table 7.55 Concentrations of *E. coli* across the three depth planes

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.15	38	38	0	0	0
1.00	58	58	0	0	0
1.30	57	56	0	1	0
1.60	57	56	1	0	0

As with Site A, concentrations of NO_3-N were recorded in upstream and downstream of the remediated Site B (Table 7.56). At Site B a slight increase in NO_3-N concentrations was recorded within samples retrieved from the LPP borehole following the remediation of the site. However, a decrease was observed at both downstream boreholes. Due to unforeseen circumstances the boreholes at Site B were removed at the end of March 2013 and no further samples were retrieved.

Table 7.56 Mean NO_3-N concentrations recorded at borehole locations

	NO_3-N	
Borehole	**Pre-remediation**	**Post-remediation**
Upstream	0.3	0.35
LPP	0.6	0.74
DD	0.6	0.6
Downstream 1	0.9	0.6
Downstream 2	0.7	0.6

As with Site A, borehole samples at Site B were also analysed for PO_4-P. Both the LPP and DD recorded an increase in concentration downstream of the newly installed systems. A decrease in PO_4-P was recorded at both downstream borehole samples following the decommissioning of the pre-remediation soak-pit (Table 7.57).

Table 7.57 Mean PO_4-P concentrations recorded at borehole locations

	Ortho-P	
Borehole	**Pre-remediation**	**Post-remediation**
Upstream	0.04	0.03
LPP	0.05	0.16
DD	0.04	0.08
Downstream 1	0.98	0.43
Downstream 2	0.76	0.47

At Site B the *E.coli* presence was only detected in each of the downstream LPP and DD on a single sampling occasion, both of which recorded substantial effective rainfall. Interestingly, a gradual decrease in *E. coli* concentrations with depth was recorded at the downstream boreholes at the site following remediation indicating an improvement in effluent treatment via the alternative infiltration systems. The results presented are until March 2013 (6 months after the decommissioning of the soak-pit), after which point the boreholes were removed. Had longer monitoring of the groundwater been possible it is presumed that a further decline in concentrations would have been observed (Table 7.58).

Table 7.58 Mean *E. coli* concentrations recorded at borehole locations

	E. coli	
Borehole	**Pre-remediation**	**Post-remediation**
Upstream	0	0
LPP	0	1
DD	0	4.1
Downstream 1	12	9.4
Downstream 2	23	9.7

7.4 Overloading Trials

"Overloading" trials were carried out in order to examine the response of the low permeability soils beneath the LPP and DD systems during periods of higher volumes of effluent application. The systems were installed at two sites with T-values of 75 and 73 however it is hoped that LPP and DD systems will also be appropriate forms of effluent discharge in soils with higher T-values (>90). By increasing the effluent loadings above the design loads for each system the hydraulic capacity (i.e. the point at which the subsoil is hydraulically "overloaded"/reaches saturation) for the LPP and DD at both sites could be determined. The data collected was used to determine the impact on soil moisture levels and recovery times under the higher hydraulic loading rates as well as to establish any potential increase in pollutant migration within the STU as a result of increased soil moisture levels. Modelling software could then be used to aid in the extrapolation of these results with the aim of establishing design criteria for these systems in subsoils of lower permeability.

Table 7.59 presents the details of the trials carried out at both sites. The first overloading trial was carried out at Site A. Under normal operating conditions the household effluent was split evenly between the LPP and DD systems which had been installed in parallel. In order to assess the impact of an increase in effluent application the total volume of household effluent was diverted to the LPP system only for a period of four weeks. During this period the applied load exceeded the design load and therefore the system was deemed to be hydraulically "overloaded". Following this four week period the total volume of household effluent was then diverted solely to the DD system at Site A in order to assess how it in turn coped with an increase in effluent application. As detailed in Table 7.59, the first overloading trial took place in the summer months when evapotranspiration rates were at their highest. Two further overloading trials (one at Site A and one at Site B) were then carried out during the winter months when evapotranspiration rates were at their lowest.

Despite the increase in effluent volumes applied neither the LPP nor DD systems became saturated during the summer trials at Site A. The degree of pollution attenuation beneath both systems remained comparable to that recorded during normal operation.

In contrast to this, intermittent saturation occurred beneath both systems during the winter trials carried out at Site A and B. Results showed saturation occurred primarily as a result of high intensity rainfall events and rising groundwater levels with the increase in effluent playing a minor role. Despite the consequential increase in hydraulic conductivity of the subsoil beneath the systems only minor increases in pollutant migration were recorded. Detailed results of the soil moisture and pollutant attenuation analysis of all four systems during these trials are included in Appendix F.

Table 7.59 Overloading trial carried out on LPP and DD systems at low permeability sites

Location	System	Time of Year	Effluent Quality	Design Hydraulic Load mm d^{-1}	Overloading Hydraulic Load mm d^{-1}
Site A	*LPP*	Summer	STE	3.0	4.9
	DD	Summer	STE		4.7
Site A	*LPP*	Winter	SE	3.0	5.9
	DD	Winter	SE		5.5
Site B	*LPP*	Winter	SE	3.0	5.3
	DD	Winter	SE		3.7

7.5 Results of Bacteriophage Study

To investigate the fate and transport of enteric viral pathogens in the subsurface environment of the percolation area, a multi-virus injection experiment was conducted using a selection of bacteriophages on both infiltration systems at Site A and Site B. Three bacteriophages (PR772, ΦX174, MS2) were chosen, all of which are members of families regarded as model indicators of anthropogenic viral pollution. A profile, including diametric size and isoelectric point, of each has been detailed in Section 2.7.4. The rationale for using more than one bacteriophage is that there is considerable variation in size, hydrophobicity, and isoelectric point among phages that, collectively, affect their transport through soils. In addition to the phages, bromide was also spiked into the effluent at the same time as a conservative tracer which would provide an indication of the potential breakthrough time of the phages. The purpose of the experiment was to ascertain if the presence of the phage was detected at each of the depth planes and, if so, at what concentrations and removal rates.

The systems at each site were spiked by adding 2 L of distilled water containing concentrated stocks of PR772, ΦX174, MS2, and potassium bromide (KBr) to each of the pump sumps. The initial volume of effluent in each sump prior the addition of the concentrated stock solutions was recorded to allow calculation of the additional dilution of the spiked solution along with effluent dosing volumes. During the first trial at Site A soil moisture samples were collected on 13 consecutive days following which time sampling trips were extended to every three days for a further two week period. Following sample collection, soil moisture samples were returned to the laboratory for immediate viral and bromide analysis.

7.5.1 Low Pressure Pipe System (Site A)

Phages PR772, ΦX174 and MS2 were added to the LPP pump sump at Site A and mixed well with the effluent volume present. A sample was then immediately retrieved from the sump in order to quantify the initial concentration of each phage prior to application to the percolation area. Initial concentrations of 3.4x 10^6 PFU mL^{-1}, 3.7 x 10^4 PFU mL^{-1} and 2.25 x 10^5 PFU mL^{-1} were recorded for each phage respectively.

Figure 7.59 illustrates the minimum planar log removal of each bacteriophage detected at all sample positions over the duration of the trial. The results are further summarised in terms of phage concentrations in Table 7.60. Phage values considered were only those seen to coincide with incidences of bromide evidence at that point. As with the TC analysis of results from the LPP system at Site A, results of the phage study beneath the system did not show a systematic reduction with depth. In contrast, higher concentrations of both PR772 and MS2 were recorded at the *black* depth plane over the course of the trial. This suggests effluent percolation is indeed influenced by the presence of preferential flow paths within the subsoil.

Table 7.60 Mean phage log-unit removal at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.75	4.93	2.97	3.60
1.05	4.54	2.49	2.53
1.35	5.23	3.27	3.14

Having said that, the log-unit removal of each of the phages with depth, detailed in Table 7.60, shows the effectiveness of the low permeability subsoil in retaining viral pathogens. As shown in Table 7.61, the maximum concentrations recorded at depth planes was only a fraction of the applied effluent concentration.

Table 7.61 Maximum concentration recorded at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.75	40	40	80
1.05	480	120	2180
1.35	20	20	260

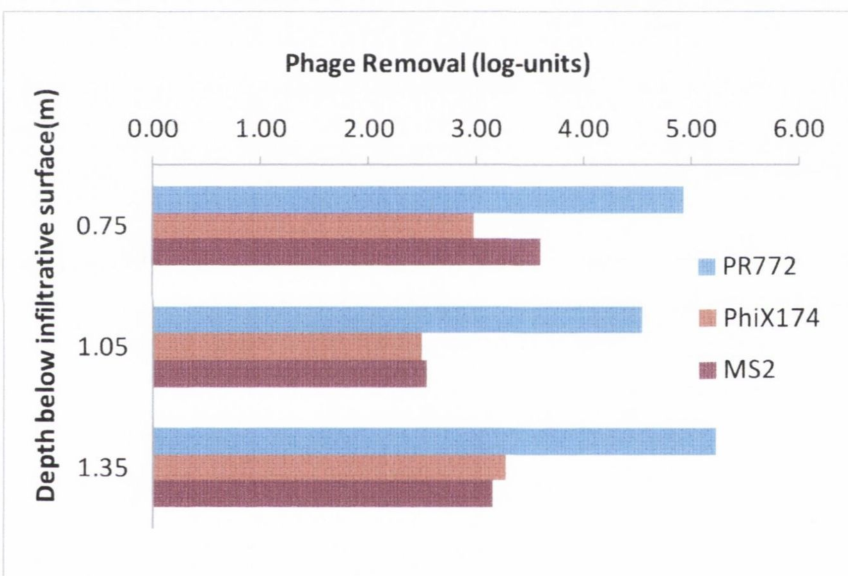


Figure 7.59 Phage log-unit removal with depth

The controlling factors and mechanisms surrounding the mobility of viral pathogens in the subsurface environment have been previously discussed in Section 2.7.4. From previous studies it is clear that there is high variability in virus retention and transport through different soils and aquifer material, depending on their properties (clay fraction, metal oxides, organic matter content, temperature, pH) and the degree of water saturation (saturated or unsaturated). The application of effluent through dosing cycles encourages the maintenance of aerobic conditions within the subsoil thus increasing the potential for virus adsorption and thereby decreasing virus migration to lower depth planes. Biomat purification capacity for viral attenuation is also thought to be high. However, the presence of a significant biomat layer is indicative of a high organic matter loading which has been shown to reduce virus attachment and thus facilitate virus transport by competing with viruses for attachment sites (Zhuang and Jin, 2003).

Although both the presence of unsaturated conditions as well as the formation of a biomat layer may play a role in viral attenuation beneath the LPP system on Site A, it is thought that the greatest retention capacity was due to viral adsorption to the high fraction of clay particles present in the subsoil matrix. . The reduced organic matter of the STE applied at the site means viral adsorption is maximised by a greater number of sorption sites for phage adhesion.

7.5.2 Drip Distribution System (Site A)

A simultaneous study of viral removal was carried out beneath the DD system at Site B. Phages PR772, ΦX174 and MS2 were added to the DD pump sump and mixed well with the effluent volume present. A sample was then immediately retrieved from the sump in order to quantify the initial concentration of each phage prior to application to the percolation area. Initial concentrations of 3.16 x 10^6 PFU mL^{-1}, 2.2 x 10^6 PFU mL^{-1} and 1.74 x 10^6 PFU mL^{-1} were recorded for each phage respectively.

Figure 7.60 illustrates the minimum planar log removal of each bacteriophage detected at all sample positions over the duration of the trial. The results are further summarised in terms of phage concentrations in Table 7.63. It can be seen from Figure 7.60 and Table 7.62 that only MS2 was detected at the *green* depth plane.

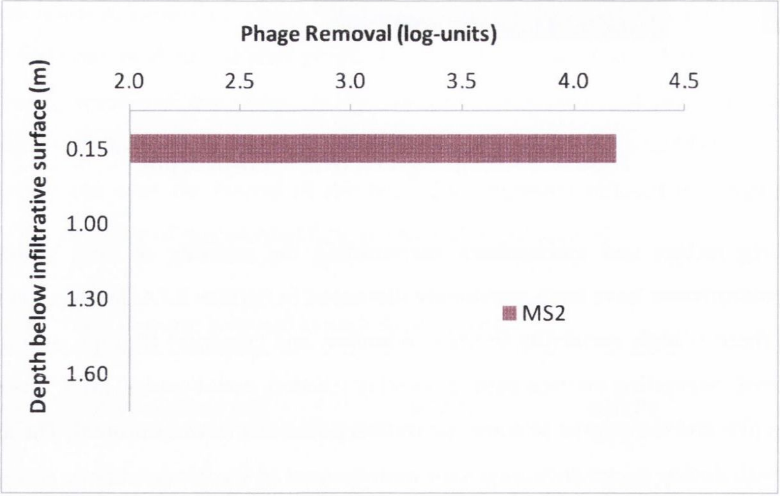


Figure 7.60 Phage log-unit removal with depth

Table 7.62 Mean phage log-unit removal at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.15	-	-	4.19
1.00	-	-	-
1.30	-	-	-
1.60	-	-	-

Table 7.63 Maximum concentration at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.15	0	0	80
1.00	0	0	0
1.30	0	0	0
1.60	0	0	0

As with the LPP system, it is thought that the greatest retention capacity of the DD system was due to the high fraction of clay particles present in the subsoil. The multi-log removal of all three phages between the infiltrative surface and *green* depth plane is again most likely due to viral adsorption to the soil matrix.

7.5.3 Low Pressure Pipe System (Site B)

Phages PR772, ΦX174 and MS2 were added to the LPP pump sump at Site B and mixed well with the effluent volume present. A sample was then immediately retrieved from the sump in order to quantify the initial concentration of each phage prior to application to the percolation area. Initial concentrations of 1.16×10^7 PFU mL^{-1}, 2.2×10^6 PFU mL^{-1} and 8.2×10^6 PFU mL^{-1} were recorded for each phage respectively.

Figure 7.61 illustrates the minimum planar log removal of each bacteriophage detected at all sample positions over the duration of the trial. The results are further summarised in terms of phage concentrations in Table 7.65. Phage values considered were only those seen to coincide with incidences of bromide evidence at that point. As with the TC analysis of results from the LPP system at Site A, results of the phage study beneath the system did not show a systematic reduction with depth. In contrast, higher maximum concentrations of both PR772 and MS2 were recorded at the *black* depth plane over the course of the trial. This suggests effluent percolation was indeed influenced by the presence of preferential flow paths within the subsoil.

Table 7.64 Mean phage log-unit removal at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.75	4.94	4.27	4.78
1.05	5.01	4.50	5.11
1.35	4.44	4.74	4.71

Having said that, the log-unit removal of each of the phages with depth, detailed in Table 7.64, shows the effectiveness of the low permeability subsoil in retaining viral pathogens.

Table 7.65 Maximum concentration at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.75	1100	200	160
1.05	660	140	340
1.35	420	20	160

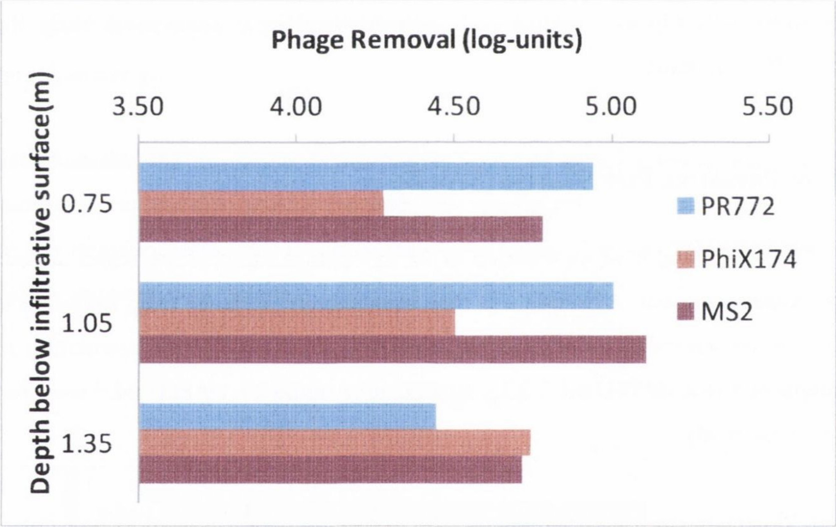


Figure 7.61 Phage log-unit removal recorded at each depth plane at all sample positions over the duration of the trial

7.5.4 Drip Distribution System (Site B)

A simultaneous study of viral removal was carried out beneath the DD system at Site B. Phages PR772, ΦX174 and MS2 were added to the DD pump sump with initial concentrations of 3.16 x 10^6 PFU mL^{-1}, 2.2 x 10^6 PFU mL^{-1} and 1.74 x 10^6 PFU mL^{-1} recorded for each phage respectively.

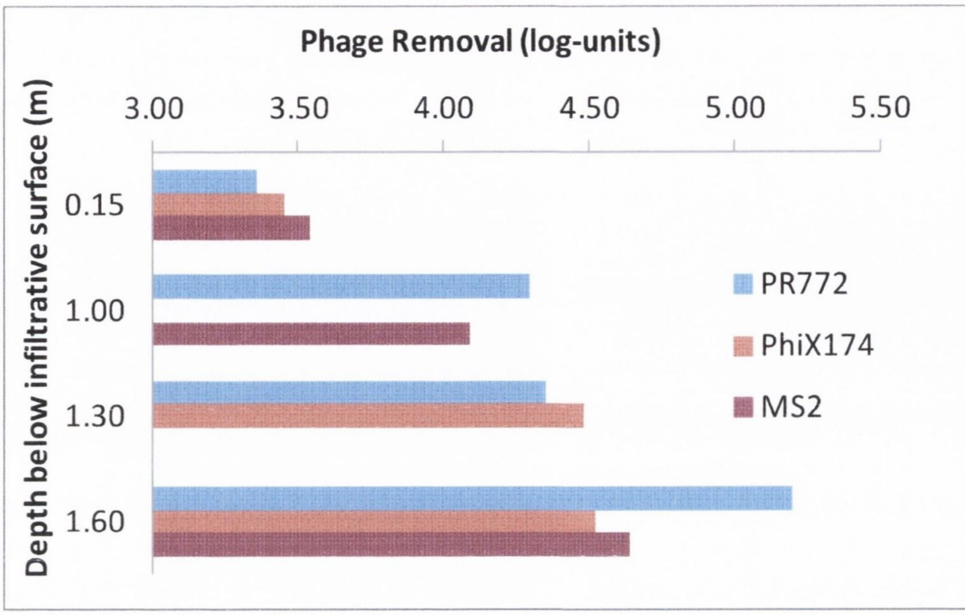


Figure 7.62 Phage log-unit removal recorded at each depth plane at all sample positions over the duration of the trial

Figure 7.62 illustrates the minimum planar log removal of each bacteriophage detected at all sample positions over the duration of the trial. The results are further summarised in terms of phage concentrations in Table 7.67. It can be seen from Figure 7.62 that each phage was not detected at all depth planes. This again suggests effluent percolation was indeed influenced by the presence of preferential flow paths within the subsoil. Table 7.66 shows that, despite this, a systematic reduction in log-unit removal was observed at the depth planes were phage presence was detected.

Table 7.66 Mean phage log-unit removal at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.15	3.36	3.45	3.54
1.00	4.30		4.09
1.30	4.35	4.49	
1.60	5.20	4.52	4.64

Table 7.67 Maximum concentration at each depth plane

Depth below infiltrative surface (m)	PR772	ΦX174	MS2
0.15	14200	4400	1080
1.00	160	0	140
1.30	140	140	0
1.60	20	180	40

As with the LPP system, it is thought that the greatest retention capacity of the DD system is due to the high fraction of clay particles present in the subsoil. The multi-log removal of all three phages between the infiltrative surface and sampling depths illustrates the effectiveness of the systems in removing pathogens in these conditions.

Although the fate of viruses in subsoil can be influenced by a number of factors, the results of this study suggest a key process was association with the soil matrix. There is a high degree of virus retention associated with a high clay fraction, which combined with low soil moisture levels at Site A during the summer months acted to reduce all three phages extensively beneath the LPP and almost completely beneath the DD.

A slightly greater fraction of the spiked phage concentrations were detected beneath the systems at Site B which received SE. As the trial was carried out later in the year, an increase in soil moisture may have contributed to the increase in phage concentrations beneath the LPP and DD. However, as with Site A, a high log-unit removal of the phages was recorded. Overall, the risk of the migration of viruses beneath the distribution systems in unsaturated low permeability subsoils was found to be low.

Chapter 8 Discussion of Results

8.1 INTRODUCTION

Groundwater in Ireland is a natural resource facing an ever-increasing risk of pollution from a number of anthropogenic activities, among which include the serious threat posed by inadequately designed, installed or maintained on-site wastewater treatment systems. However, the risk posed by such systems in not confined to groundwater, run-off from on-site systems operating in areas of inadequate permeability can promote deleterious effects on the quality of rivers, stream and lakes. As such the identification and remediation of dysfunctional or improperly sited on-site systems is imperative in the protection of human health and the environment. Of particular concern are existing on-site (legacy) systems which are operating across the country, often in conditions unsuitable for the safe discharge of septic tank effluent (STE). For the effective treatment of STE to take place effluent percolation through sufficiently permeable subsoil in the vadose zone is critical. The EPA Code of Practice in Ireland (EPA, 2009a) states that a minimum depth of 1.2 m of unsaturated subsoil must be present below the infiltrative surface of the system in ensure adequate pollutant attenuation prior to recharge to groundwater. However, in Ireland, many areas consist of shallow subsoils, high water tables, subsoils through which adequate percolation cannot occur or a combination of all of the above. In such areas remediation of existing systems is urgently required whilst effluent treatment options for future construction is also desired.

As such, one of the key issues this research aimed to address was the current performance of existing on-site systems whose configuration and construction called into question their applicability as a form of on-site effluent treatment. This aspect of the research focused on the pollution attenuation of soak-pit systems. These basic systems are no longer permitted under the current EPA Code of Practice, however previous research into their performance showed significant pollutant removal within certain subsoil setting. In order to quantify the treatment performance of these systems six existing soak-pits (in operation for over 20 years) were identified in a range of subsoil conditions and their treatment performance analysed.

In conjunction with this, a need for alternative solutions for effluent treatment and disposal in certain subsoil conditions was identified. At present EPA guidelines prevent the construction of on-site wastewater systems in regions were the subsoil percolation rate is too slow (T value < 75). Under the EPA's recently published "National Inspection Plan: Domestic Wastewater Treatment Systems", currently operating systems which fail to meet an acceptable standard will be identified and remediation options considered. However, in areas of inadequate percolation, remediation options are limited under the current guidelines. In order to provide alternative solutions, research was carried out into the performance of two alternative effluent disposal systems: Low pressure pipe (LPP) and Drip distribution (DD) systems. This was carried out by constructing two LPP and DD systems within low permeability settings at two locations in Ireland. These systems were then monitored for a period of 14 months during which time, the degree of soil saturation, shown to be a defining factor in the successful attenuation of effluent constituents, was monitored on an ongoing basis.

The field studies, as such, were divided into, and analysed as four separate on-site wastewater treatment systems in order to achieve the project objectives:

- Performance of soak-pit systems in low permeability subsoils (Site A and Site B)
- Performance of soak-pit systems in moderate/high permeability subsoils (Sites C - F)
- Performance of low pressure pipe systems in low permeability subsoils (Site A and Site B)
- Performance of drip distribution systems in low permeability subsoils (Site A and Site B)

8.2 On-Site Wastewater Production and Characteristics

8.2.1 Hydraulic Loading and Regime

The on-site wastewater production on both Sites A and B was continually measured over a 12 month and 14 month period, respectively. At Site A this was achieved by means of a tipping bucket and counter located downstream of the septic tank discharge pipe. Each tip represented a volume of 1600 mL of effluent and provided even distribution of effluent between two downstream pump sumps. The total number of tips per day was recorded by the counter, thus providing a very accurate and sensitive measure of the household flow rates. At Site B a sump level sensor was installed within the first pumping chamber. The change in volume with each pumping cycle was recorded allowing the quantification of total daily effluent use. In conjunction with these systems energy meters were installed on the power supplies to the submersible pumps in operation at both sites. This allowed an electrical cost comparison between the two system setups (Table 8.1).

Table 8.1 Electrical cost comparison of LPP and DD systems

System	Site A (Aerated Unit)[b]	Site B (Passive filter)[c]
LPP (€/yr)	5.1	5.0
DD (€/yr)	5.5	6.8
Secondary treatment unit (€/yr)	43.9	6.3
Total cost per person	18.2	4.5

[*]Cost of €/kWh based on ESB Ireland charges,
[b] Daily effluent production of 124 L per person per day
[c] Daily effluent production of 104 L per person per day

Results from the cost analysis show that despite the additional pumping costs associated with the passive filter (due to its effluent discharge depth of 2 m below G.L.) the overall operational costs at Site B are significantly lower than those associated with the aerated unit installed at Site A. The costs reported were found to be in line with those reported by the Water Environment Research Foundation (WERF, 2011a, WERF, 2011b).

As well as energy consumption the frequency of pumping to each pressurised distribution system was also recorded in conjunction with the volume being dosed. The total daily on-site flow rates at Site A remained relatively constant over the monitoring period measured as 371.8 L d^{-1}, on average, which equates to an effluent production per person of 123.9 L c^{-1} d^{-1}. The mean daily flow rates at Site B also remained relatively constant over the monitoring period at a mean of 416.4 L d^{-1} which equates to a mean effluent production per person of 104.1L c^{-1} d^{-1}.

Results from both sites reveal that the assumption of 150 L c^{-1} d^{-1} in the Irish EPA Code of Practice (EPA, 2009a) appears to over- predict the mean wastewater production in such one-off dwellings with typical family sized units. This matches data recorded in previous studies on 6 other sites continuously monitored for a minimum period of 12 months (O'Súilleabháin, 2004, O'Luanaigh, 2009). Based on results from the previous studies the EPA reduced the design flow rates from 180 L c^{-1} d^{-1} to the current figure of 150 L c^{-1} d^{-1}. However, results from this study again highlight the discrepancy between the estimated wastewater production and recorded wastewater production. The current design figure was originally based on a higher figure of 180 L c^{-1} d^{-1}. This design figure was based on wastewater production within an urban environment, which not only includes significant sewer infiltration (not applicable to on-site systems), but also assumes people live and works within the same drainage network. As such, an estimated design flow based on these figures assumes a full day's wastewater from each person is discharged into the same sewer network but at different locations. For on-wastewater, the same criteria do not apply. In general, some if not all of a household's residents will not spend the day at outside the septic tank "catchment" (i.e. the house) and as such during this time are not contributing to the household wastewater production. This explains why the mean wastewater figures recorded on these sites are considerably lower than the guideline value.

8.3 COMPARISON OF EXISTING SOAK-PIT SYSTEMS

Current EPA guidelines do not permit the construction of septic tank soak-pit system. However, the first legislation governing the installation of on-site wastewater systems did not come into effect until the introduction of SR6 document (NSAI, 1991) and so up until this time, the soak-pit was seen as an appropriate low cost solution to on-site wastewater disposal with little consideration given to the treatment quality of the discharging effluent. As a result, vast numbers of these sites are located across Ireland and are no longer in compliance with current guidelines. The identification, assessment and, where applicable, the remediation of these systems is paramount in the protection of Irish groundwater and surface water supplies.

One of the key issues highlighted by this research is the lack of information or design criteria available for these systems. Since the majority have been in operation for well over 20 years, knowledge of the location, extent or depth of effluent infiltration to the soak-pit is usually limited or in many cases completely unknown. With no recommended design criteria in place the sizing, depth and backfill material of these soak-pits varies greatly.

Results from this study show the treatment performance of these systems is directly linked to the subsoil characteristics within which it is located. As with current guidelines, results show the depth of unsaturated subsoil (either to bedrock or to water table) is of critical importance. The EPA currently recommends the presence of 0.9 m and 1.2 m of unsaturated subsoil below the invert of percolation trenches receiving SE and STE, respectively. The deconstruction of the existing soak-pit at Site B gave an indication of the extent of typical soak-pit constructions. When excavated the overall depth was found to be greater than 2 m. Consequently, the operational effluent infiltration depth to the subsoil was in reality much lower than the septic tank discharge pipe. The implications of this are particularly acute in subsoils of higher permeabilities and where the water table is shallow. The soak-pit provides a direct route to the underlying subsoil at a much greater depth than conventional systems thus aiding the migration of nutrient and pathogens.

The reverse was seen to occur within the soak-pits monitored in slow-draining low permeability subsoils. In these conditions the surrounding subsoil was of such low hydraulic conductivity that effluent percolation to the surrounding subsoil was limited.

Results showed the detection of a proportion of the percolate passing through the subsoil; however a proportion of the discharged effluent was also found to move laterally via preferential flowpaths. Results indicated effluent ponding resulted in effluent migration through the more permeable lenses present in the upper subsoil horizon or on occasion as surface water run-off.

Although the effluent passing through the subsoil showed good attenuation of contaminants, the health risk posed by standing effluent cannot be over emphasised. The risk to both groundwater and surface water quality was also evident with the presence of enteric bacteria in downstream boreholes at Site A, located approximately 50 m from the site soak-pit, as a result of the migration of effluent along surface level of the site whereby it then moved vertically to groundwater in an area of higher permeability.

The hydraulic behaviour of the systems as a result of surrounding subsoil properties also had a considerable impact of contaminant attenuation. The apparent formation of a low permeability biomat layer at the infiltrative surface was critical in the performance of soak-pits in higher permeability soils as it acted to increase the effluent retention time in the upper regions of the subsoil thus enhancing the treatment potential. The presence of this biomat layer was also of crucial importance in the reduction of the organic load in these conditions through a combination of physical straining and degradation. At Sites E and F the absence of any significant clay fraction in the subsoil was mitigated by the presence of the biomat and its role in the adsorption of PO_4-P through P-adsorption to organic matter. The development of a mature biomat at the lower permeability sites was thought to reduce the hydraulic conductively of the infiltrative surface further. It is this clogging of soil pores through the combined loading of organic matter and suspended solid with reduces the permeability of the soil infiltrative surface to the extent at which effluent is forced upwards.

The overall removal of inorganic-N was significantly higher within the soak-pits located in low permeability conditions than those in higher permeability soils. The presence of extensive saturated zones within the slow-draining subsoils allowed extensive denitrification and/or anammox to occur despite the unconventional effluent distribution. In contrast to this, denitrification within the higher permeability subsoils was limited and as a result high levels of NO_3-N were found to be present in the soil moisture samples which form the local groundwater recharge.

The migration of enteric bacteria was found to be much greater within the high permeability subsoil setting. Although migration via surface pathways was observed at the low permeability Site B, the maximum observed *E.coli* concentration was 22.9 MPN 100 mL^{-1}. In contrast to this, breakthroughs of magnitudes in excess of 1000 MPN 100 mL^{-1} were recorded at depths greater than

2.5 - 3 m beneath the high permeability systems. The prevention of even greater concentrations of bacteria migration appears to have been prevented through the formation of the biomat layer.

Overall, the effluent plume from the soak-pit systems in the low permeability conditions at sites A and B was found to extensive in a predominantly lateral direction, with the migration of contaminants detected at >50 m from soak-pit. In contrast, within higher permeability settings the effluent plume moves rapidly downwards, but overtime, the development of a soil clogging layer serves to spread the effluent laterally over a greater area in the direction of the site gradient. This biomat formation is crucial in the protection of the underlying groundwater quality, and interestingly none of the downstream boreholes at the sites appeared to exhibit any adverse affects as a result of the aforementioned effluent discharge. Overall, results show the likelihood of groundwater contamination, particularly in relation to enteric bacteria, as a result of domestic effluent discharges is highly probable within moderate to high permeability settings.

8.4 Comparison of Alternative Infiltration Systems

In order to access the performance of two alternative infiltration systems, the existing soak-pit systems at Site A and Site B were decommissioned and replaced by new pressurised distribution systems in the form of a low pressure pipe system (LPP) and drip distribution system (DD). Pre-remediation, the soak-pit systems in operation at both sites showed signs of hydraulic failure intermittently throughout the first phase of monitoring with effluent ponding visible particularly during and following high intensity rainfall. The installation of the alternative system was hoped to overcome the site limitations by employing the pressurised dosing of effluent uniformly over a greater surface area.

8.4.1 Hydraulic Loading and Regime

As outlined above, a key issue at both sites was the infiltrative capacity of the subsoil. Due to the low hydraulic conductivity of the subsoil at both sites, traditional gravity distribution methods had resulted in hydraulic failure. As such one of the key aspects of the study was the monitoring of the degree of saturation present beneath each system. This was carried out by a combination of soil moisture and soil moisture tension readings. In conjunction with this, the overall hydraulic loading to the systems was monitored, i.e. the applied effluent, rainfall recharge and the rate of evapotranspiration.

Results from the analysis showed that the subsoil beneath both systems remained unsaturated for approximately the first 11 months of operation, with the successful infiltration of effluent at the design loading rates for both systems. During the second winter of operation, an increase in intense rainfall (above average) resulted in saturated conditions at occurring at both sites. At Site A, this increase in rainfall coincided with an increase in groundwater levels to within 0.3 m of ground level. As a result, surface ponding was observed above each system. Analysis of historical data showed such a rise in groundwater levels had not occurred in since the winter of 2010, before the commencement of the project. Critically, sampling carried out during this saturated conditions at both sites did not indicate an increase in pollutant migration beneath the infiltrative surface.

8.4.2 COMPARISON OF TREATMENT PERFORMANCE OF ALTERNATIVE INFILTRATION SYSTEMS

Following the completion of the soak-pit monitoring phase, the existing systems at sites A and B were replaced with parallel alternative distribution systems consisting of LPP and DD networks. The effluent at both sites was split equally between the two distribution networks and monitoring instrumentation was installed to determine the performance of each system.

EFFLUENT DISTRIBUTION AND HYDRAULIC LOADING RATES

As highlighted by the pre-remediation results from Sites A and B a critical aspect of wastewater treatment and disposal in low permeability areas is the ability of the subsoil to cope with the applied hydraulic loading. Both LPP and DD systems are designed to maximise the hydraulic capacity of the subsoil through a combination of effluent dosing cycles and shallow uniform effluent infiltration. In order to assess the hydraulic performance of both systems effluent production, rainfall recharge and the rate of evapotranspiration was recorded at each site and the overall effective hydraulic loading being applied to each system was determined (Table 8.2). As discussed previously, the effluent production recorded for both households was in line with previous Irish field studies. The loading regime to the alternative infiltration systems was varied throughout the study in order to assess its impact on treatment performance with average infiltration rates presented in Table 8.2.

As outlined previously, the advantage of intermittent pressurised effluent dosing over conventional gravity fed systems (such as soak-pits) is the ability to control the effluent volume applied during each dosing cycle. As such, subsoil saturation as a result of effluent application can be prevented with periodic rest intervals allowing time for the percolate to infiltrate into the subsoil. In contrast to this, in septic tank soak-pit systems effluent is applied in shock loadings during periods of high wastewater production (usually morning and evening). In low permeability subsoils these high volumes of effluent cannot percolate into the receiving subsoil at a sufficient rate and as such the system becomes saturated and eventually fails as was evident at the pre-remediation low permeability sites. Following the introduction of alternating effluent dosing cycles and rest cycles at both low permeability sites, effluent ponding was eliminated and soil moisture profiles showed the vertical movement of percolate beneath the LPP and DD systems. This is deemed to be as a result of greater effluent distribution over a greater area, controlled volumes of effluent dosing and the implementation of rest cycles between effluent doses.

Table 8.2 Variation in effluent loading to the LPP and DD systems at Site A and B

Effluent loading regime	Site A		Site B	
	LPP (mm day^{-1})	DD (mm day^{-1})	LPP (mm day^{-1})	DD (mm day^{-1})
Normal operation	3.1	2.9	2.3	2.8
1st Overloading trial	4.9	4.7	5.3	3.7
2nd Overloading trial	5.9	5.5	-	-

Despite a lower mean daily effluent application rate at Site B, Table 8.3 shows that the rainfall recharge recorded at the site was considerably higher than at Site A.

Table 8.3 Record rainfall levels over the course of the study at Site A and B

Rainfall recharge	Site A		Site B	
	LPP (mm day^{-1})	DD (mm day^{-1})	LPP (mm day^{-1})	DD (mm day^{-1})
Total rainfall	883	883	1161	1161
Effective rainfall	461	652	545	865

In order to determine the subsoils response to the overall hydraulic loading soil moisture and soil moisture tension readings from beneath the LPP and DD were recorded at both sites. Results show the greatest increases in subsoil moisture levels were attributed to high intensity rainfall events. Increases in soil moisture conditions as a result of effluent application were more difficult to assess given its controlled uniform application of wastewater to the LPP and DD networks. Although daily mean effluent application ranged from between 2<6 mm, this was applied by multiple controlled doses over the course of a day. The muted response of soil moisture levels to effluent application appears to be as a result of the rest period between doses which prevents the spike in soil moisture observed when similar daily effective rainfall volumes were recorded.

As uniform effluent dispersal to the STU critical to the successful performance of both the LPP and DD, chloride was employed as a crude tracer to determine the fate of the effluent beneath the systems at both sites. Cl analysis of soil moisture samples from nominal depths beneath each of the systems revealed the successful uniform distribution of effluent via the pressurised distribution networks.

As well as providing an overall picture of effluent migration beneath each system, Cl analysis also allowed the determination of the effect of percolate dilution by effective rainfall. Results showed the average zone of contribution of effective rainfall was greater for both the LPP and DD systems installed at Site B in comparison with Site A. The mean soil moisture volumes retrieved from the sites are presented in Table 8.4 and appears to confirm this observation with higher mean volumes recorded beneath both systems at Site B. Overall the mean soil moisture levels recorded at Site B were greater than those at Site A (Table 8.5).

Table 8.4 Comparison of mean soil moisture sample volumes beneath LPP and DD systems at Sites A and B

System	*Site A*		*Site B*	
	LPP	DD	LPP	DD
0.3 m	-	30 mL	-	79 mL
1.3 m	120 mL	216 mL	330 mL	323 mL
1.6 m	302 mL	217 mL	358 mL	388 mL
1.9 m	116 mL	244 mL	306 mL	485 mL

Table 8.5 Comparison of mean soil moisture concentrations beneath the LPP and DD systems at Site A and B

System	Depth (mm)	*Site A*			*Site B*		
		LPP	DD	REF	LPP	DD	REF
Winter	100 - 400	24.1	34.3	**30.8**	28.5	35.4	**35.8**
	600 - 1000	34.6	33.7	**30.6**	37.2	37.9	**34.9**
Summer	**100 - 400**	11.9	21.1	**20.0**	16.8	22.3	**23.6**
	600 - 1000	32.6	28.5	**25.0**	34.0	30.1	**26.3**

Overall, both systems operated successfully over the course of the study. However, key differences in performance of both systems receiving STE at Site A were observed in comparison with the system receiving SE at Site B.

Attenuation of Chemical Constituents of STE and SE

The reduction in the organic loading of the LPP receiving STE (Site A) is presented in Table 8.6 and shows the majority of the removal occurred between the infiltrative surface and the *red* plane. Table 8.6 shows a comparison between COD removal under design and increased effluent loadings (see Table 8.2). Despite the increase in the hydraulic load, the LPP continued to remove the majority of the organic load within the first 0.9 m beneath the distribution trenches.

Table 8.7 presents the COD removal recorded beneath the LPP systems receiving SE at sites A and B during both normal effluent hydraulic loading as well as the overloading of the LPP systems at both sites. At Site B an increase in COD concentrations with depth was seen to occur beneath the LPP during the overloading trial with 57.3% of the applied effluent loading present at the *red* plane.

Table 8.6 COD loads with subsoil depth beneath LPP receiving STE at Site A

	COD			
	Site A			
Sample Depth	**LPP (STE)**		***Overloading* LPP (STE)**	
	%	$g\ d^{-1}$	%	$g\ d^{-1}$
Point of Infiltration	100	94.6	100	72.0
Red (1.3 m)	9.2	8.7	12.6	9.1
Blue (1.6)	9.0	8.5	18.1	13
Black (1.9 m)	7.6	7.2	5.3	3.8

Table 8.7 COD loads with subsoil depth beneath LPP receiving SE at Sites A and B

	COD					
	Site B		**Site A**		**Site B**	
Sample Depth	**LPP (SE)**		***Overloading* LPP (SE)**		***Overloading* LPP (SE)**	
	%	g d-1	%	g d-1	%	g d-1
Point of Infiltration	100	20.6	100	18.2	100	28.1
Red (1.3 m)	24.3%	5.0	22.5%	4.1	57.3%	16.1
Blue (1.6)	21.4%	4.4	15.4%	2.8	39.1%	11.0
Black (1.9 m)	16.5%	3.4	14.8%	2.7	22.1%	6.2

Due to the variation in the number of residences at each site a comparison of the treatment performance was carried out on a load per capita basis. Figure 8.1 shows the COD removal beneath the LPP at Site A whilst Figure 8.2 shows the removal beneath the LPP systems receiving SE. From both plots it can be seen that there is a significant reduction in the COD concentration in the SE. A much greater reduction in COD is observed beneath the STU receiving STE. Interestingly, concentrations recorded beneath both systems under varying effluent loadings are comparable with values ranging from 0.9 to 1.8 g COD c^{-1} d^{-1} at the 1.9 m depth

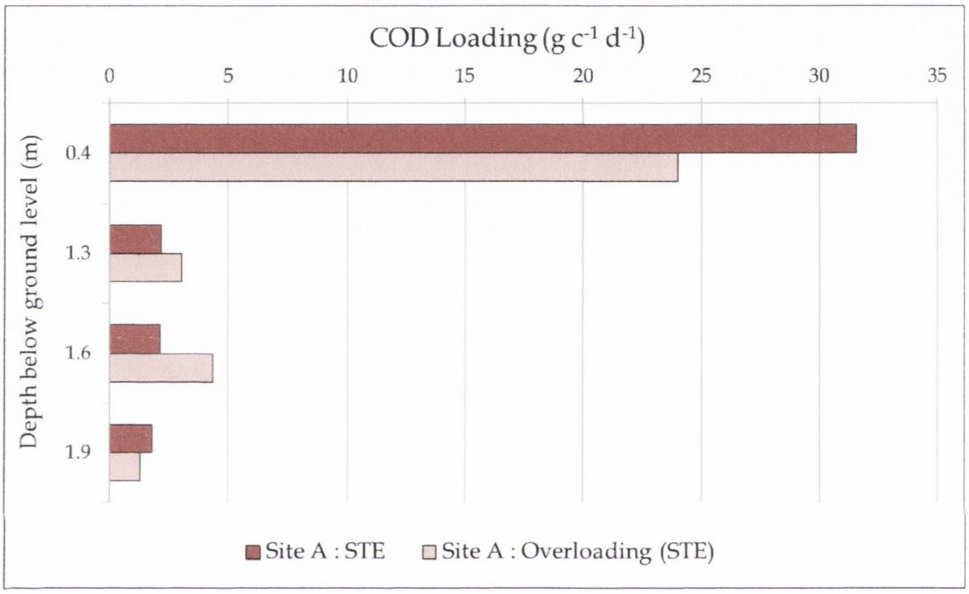


Figure 8.1 Mean COD load per capita at the designated depth planes beneath LPP (STE)

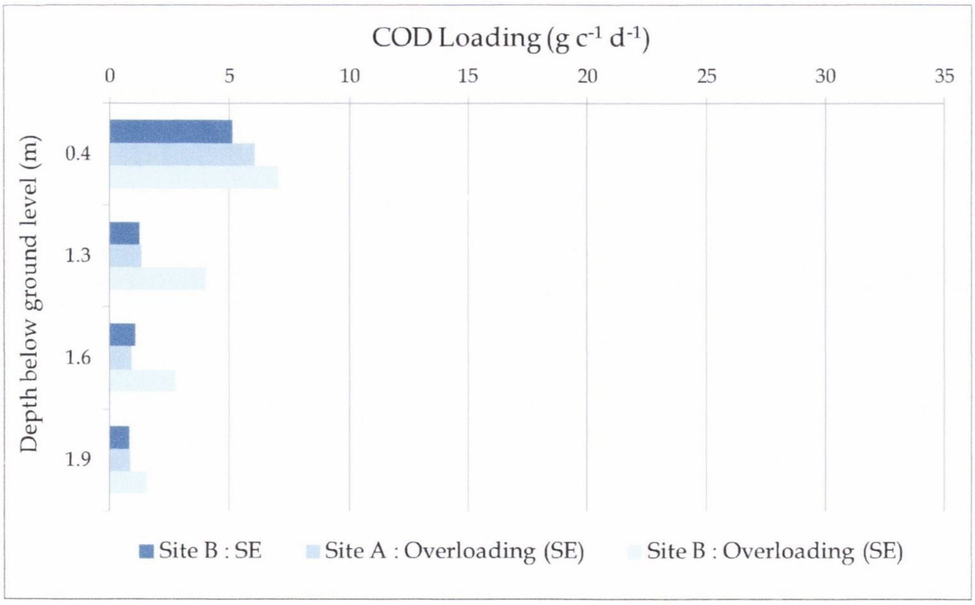


Figure 8.2 Mean COD load per capita at the designated depth planes beneath LPP (SE)

Drip Distribution System

Table 8.8 present the COD loadings applied to the LPP system at Site A over the course of the study. As with the LPP, removal of COD beneath the DD was found to be superior under the design effluent hydraulic loading rate. Despite a slight decrease in the applied effluent concentration during the overloading trial a greater mean COD load was recorded at the *black* plane. At Site B, an increase in effluent loading (SE) to the DD also resulted in an increase in COD concentrations with depth (Table 8.9).

Table 8.8 COD loads with subsoil depth beneath DD receiving STE at Site A

	COD			
	Site A			
Sample Depth	LPP (STE)		*Overloading* LPP (STE)	
	%	$g\ d^{-1}$	%	$g\ d^{-1}$
Point of Infiltration	100	92.2	100	53
Green (0.3 m)	14.9%	13.7	84.0%	44.5
Red (1.3 m)	6.7%	6.2	5.3%	2.8
Blue (1.6)	5.9%	5.4	20.0%	10.6
Black (1.9 m)	4.3%	4.0	11.1%	5.9

Table 8.9 COD loads with subsoil depth beneath DD receiving SE at Sites A and B

	COD					
	Site B		Site A		Site B	
Sample Depth	LPP (SE)		*Overloading* LPP (SE)		*Overloading* LPP (SE)	
	%	$g\ d^{-1}$	%	$g\ d^{-1}$	%	$g\ d^{-1}$
Point of Infiltration	100	21.5	100	27.6	100	37.3
Green (0.3 m)	93.5%	20.1	56.5%	15.6	58.4%	21.8
Red (1.3 m)	55.3%	11.9	31.5%	8.7	51.2%	19.1
Blue (1.6)	37.7%	8.1	24.6%	6.8	35.4%	13.2
Black (1.9 m)	20.0%	4.3	17.8%	4.9	26.0%	9.7

As with the LPP, a comparison of the DD receiving STE and SE was carried out on a load per capita basis (Figures 8.3 and 8.4). Results show that despite the significant decrease in COD concentration in SE in comparison with STE, the overall reduction with depth again remained comparable, ranging from 1.0 to 2.4 g COD $c^{-1}\ d^{-1}$ at the 1.9 m depth.

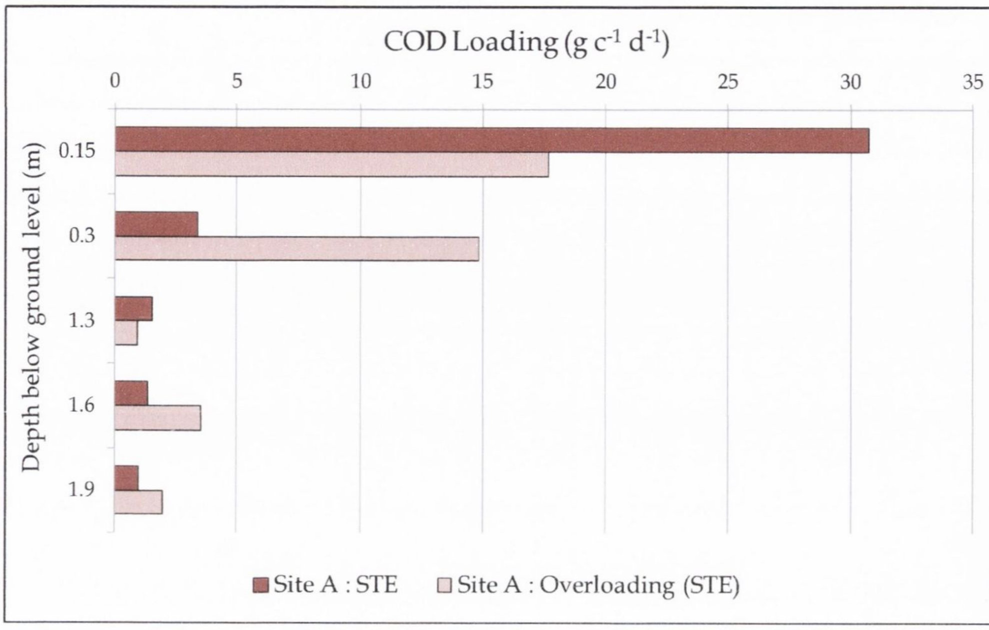


Figure 8.3 Mean COD load per capita at the designated depth planes beneath DD (STE)

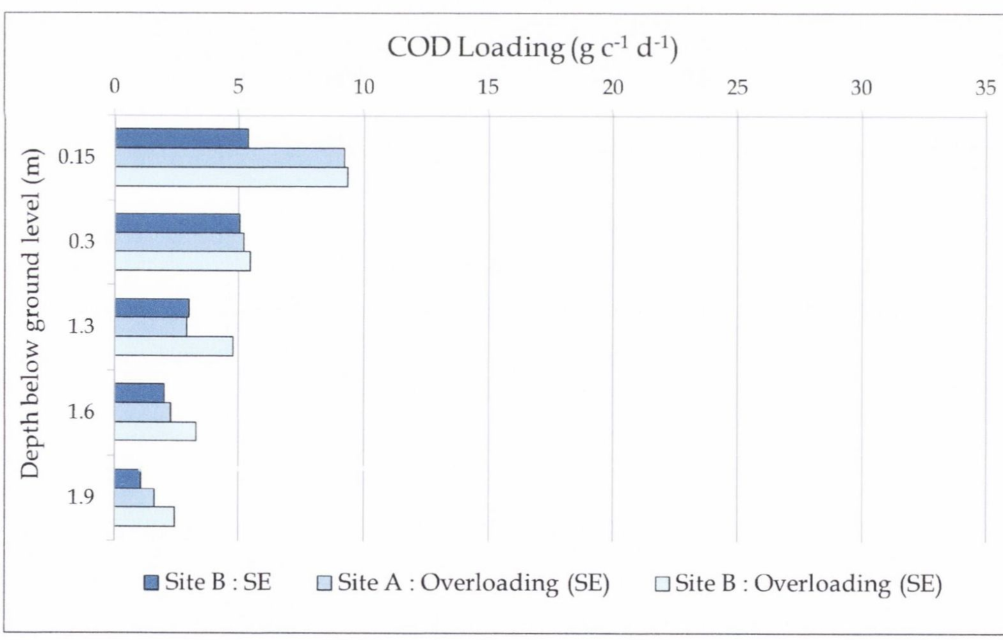


Figure 8.4 Mean COD load per capita at the designated depth planes beneath DD (SE)

Comparison of LPP and DD systems

As outlined above, comparison of the LPP and DD systems is most accurately demonstrated on a load per capita basis as detailed below. The variation in the depth of effluent infiltration between the LPP (0.4 m) and DD (0.15 m) must also be accounted for in order to achieve an accurate assessment of their treatment performance and so a direct comparison between the *red, blue,* and *black* planes is not applicable. As the EPA Code of Practice (EPA, 2009a) requires 0.9 m and 1.2 m of unsaturated subsoil below the invert of percolation trenches receiving SE and STE, respectively, the performance of each system was assessed with these regulatory depths in mind.

As the *red* and *blue* depth planes beneath the LPP IS were 0.9 m and 1.2 m respectively assessment of the LPP was straightforward. The depth planes beneath the DD IS were 0.15 m, 1.15 m 1.45 m and 1.75 m. In order to achieve the closest possible comparison corresponding depth planes for analysis of the two systems is shown in Table 8.10. As there was no depth plane at the 0.9 m depth beneath the DD the intermediate *green* (0.15 m) depth is shown instead.

Table 8.10 Comparable soil moisture sampling depth planes beneath the LPP and DD systems

Depth below infiltrative surface (m)	
LPP	*DD*
0.9	0.15
1.2	1.15
1.5	1.45

Figure 8.5 shows the reduction in COD of STE beneath the LPP and DD systems. The plot shows the similarity in the rates of removal beneath both systems. Of particular interest is the reduction in COD beneath the DD system by the *green* depth plane indicating that the majority of the organic load is removed within the first 0.15 m of subsoil.

Figure 8.6 indicates that under increased hydraulic loads the LPP achieves a greater mean reduction in COD. This trend is also apparent in Figure 8.7 and 8.8 which show the reduction in COD when SE is applied to both systems. This may be due to the more concentrated application of effluent to the LPP trenches resulting in a more intense zone of biological activity in comparison the DD. This in turn would result in a greater reduction in organic removal of the percolating effluent.

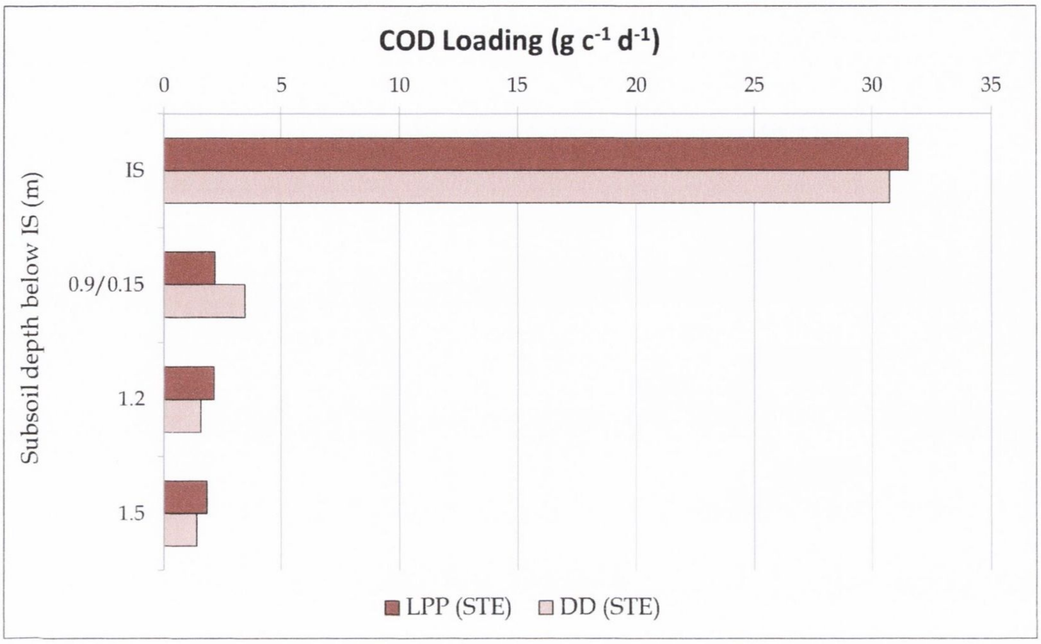


Figure 8.5 Mean COD load per capita at the designated depth planes beneath the LPP and DD

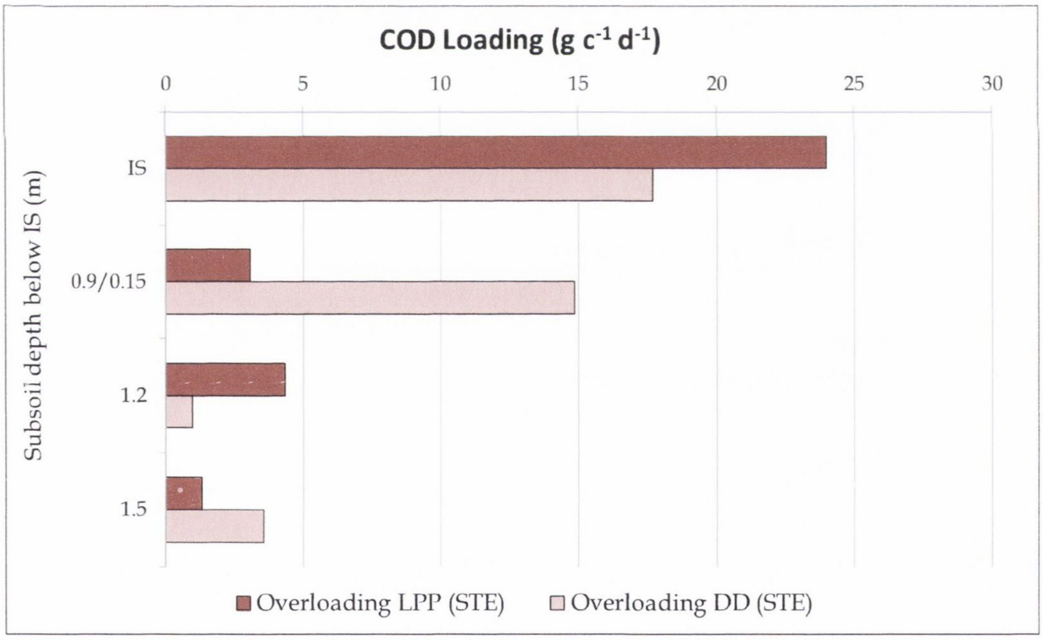


Figure 8.6 Mean COD load per capita at the designated depth planes beneath the LPP and DD

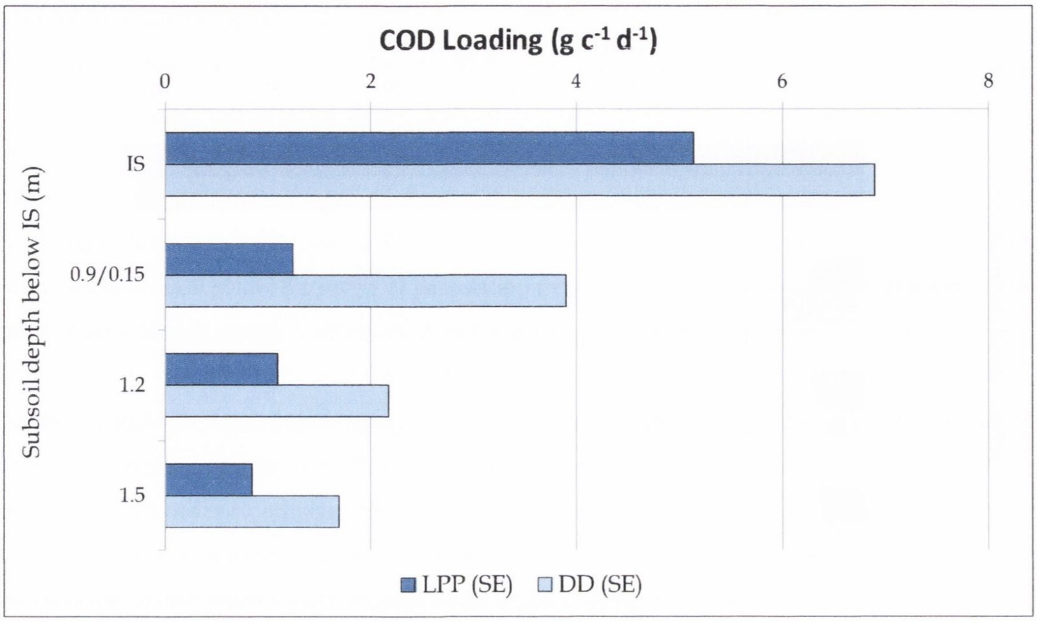


Figure 8.7 Mean COD load per capita at the designated depth planes beneath the LPP and DD

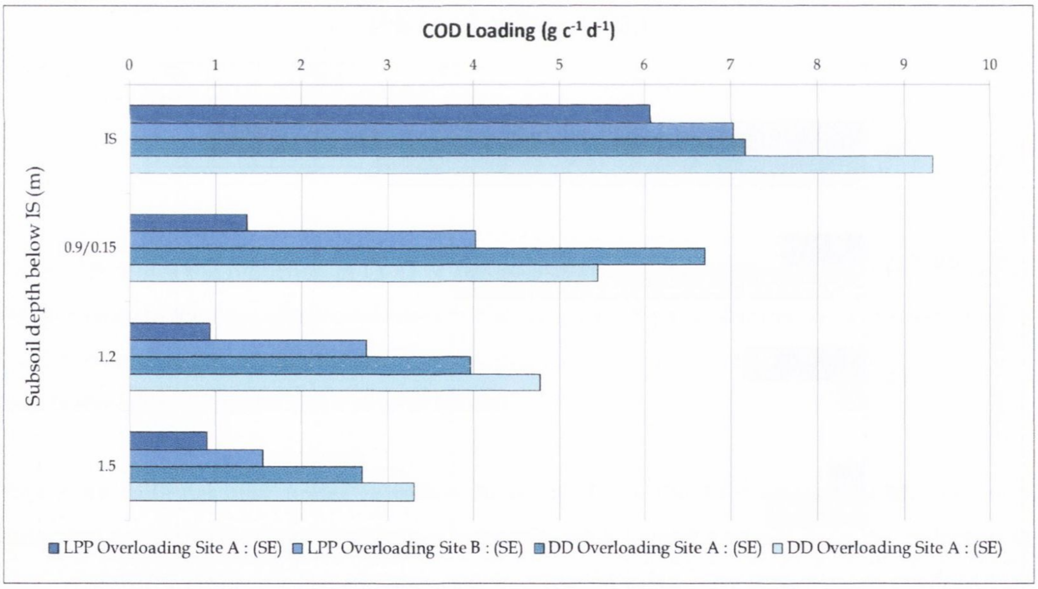


Figure 8.8 Mean COD load per capita at the designated depth planes beneath the LPP and DD

Low Pressure Pipe System

The reduction in total inorganic-N for both STE and SE was assessed beneath the LPP at both sites. At Site A, the remaining inorganic fraction at each of the depth planes was found to be primarily in nitrate form with nearly complete nitrification of the STE having occurred as a result of the aerobic conditions of the distribution gravel. However, the decrease in NH_4-N did not correspond to the increase in NO_3-N and so it is assumed that a overall reduction in inorganic-N is attributed to denitrification as a result of intermittent zones of saturation following effluent doses. At Site A , a significant increase in the STE load during the overloading trial at Site A resulted in an increase in inorganic-N concentrations with depth (in the form of 99.6% NO_3-N) as detailed in Table 8.11. A similar scenario was evident during the second overloading trial carried out at the site despite the changeover from STE to SE (Table 8.12). A Site B, the greatest reduction in total inorganic-N was observed between the IS and *red* depth plane under both operating conditions with little variation with further subsoil depth.

Table 8.11 Total inorganic-N loads with subsoil depth beneath LPP receiving STE at Site A

	Total inorganic-N			
	Site A			
Sample Depth	**LPP (STE)**		***Overloading* LPP (STE)**	
	%	**g d^{-1}**	%	**g d^{-1}**
Point of Infiltration	100	15	100	36.7
Red (1.3 m)	19.5%	2.93	14.4%	5.3
Blue (1.6)	21.4%	3.21	16.9%	6.2
Black (1.9 m)	8.7%	1.3	25.9%	9.5

Table 8.12 Total inorganic-N loads with subsoil depth beneath LPP receiving SE at sites A and B

	Total inorganic-N					
	Site B		**Site A**		**Site B**	
Sample Depth	**LPP (SE)**		***Overloading* LPP (SE)**		***Overloading* LPP (SE)**	
	%	**g d^{-1}**	%	**g d^{-1}**	%	**g d^{-1}**
Point of Infiltration	100	4.5	100	31.4	100	7.4
Red (1.3 m)	47.3%	2.13	29.9%	9.4	45.9%	3.4
Blue (1.6)	43.1%	1.94	31.2%	9.8	45.9%	3.4
Black (1.9 m)	34.4%	1.55	31.2%	9.8	48.6%	3.6

Figure 8.9 shows that an increase in the hydraulic load resulted in an increase in total inorganic-N (NO_3-N) beneath the LPP at Site A. From Figure 8.10 it can be seen that the biofilter at Site B

achieved much a much greater reduction in total inorganic-N than the activated sludge plant at Site A. However, as noted in Section 5.2.1, the ASP unit at Site A was only began receiving effluent towards the end of the monitoring phase and so long term removal rates may be higher. Overall, under SE, the LPP showed the greatest reduction between the IS and *red* plane following which concentrations remained uniform with depth.

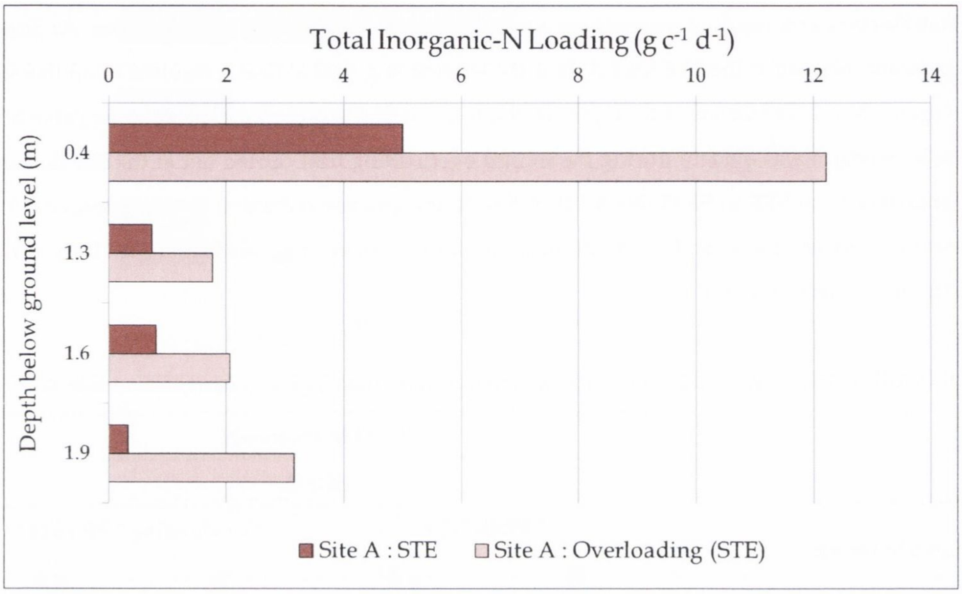


Figure 8.9 Mean Total Inorg-N load per capita at the designated depth planes beneath LPP (STE)

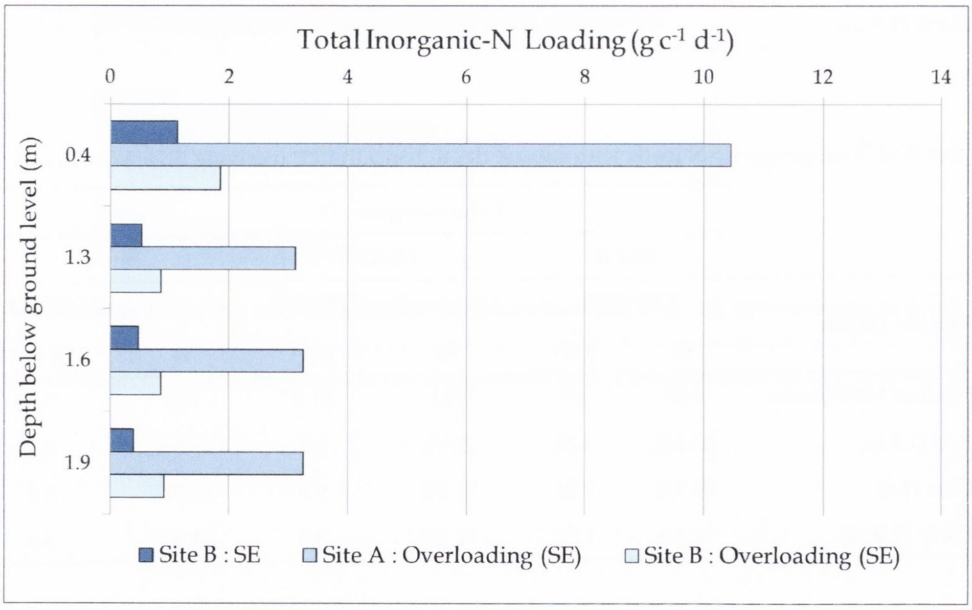


Figure 8.10 Mean Total Inorg-N load per capita at the designated depth planes beneath LPP (SE)

Drip Distribution System

A similar trend was again observed in term of inorganic-N removal beneath the DD system receiving STE. The greatest reduction in total inorganic-N was apparent between IS and the 0.3 m (*green*) depth with only a marginal decrease with continued subsoil depth (Table 8.13). Figures 8.11 and 8.12 show greater inorganic-N removal was achieved by the application of STE rather than SE at Site A. The loss of NH_4-N due to secondary treatment of the effluent reduces the denitrification and anammox potential thus increasing the proportion of NO_3-N remaining in the system (Table 8.14). As such, the increase NO_3-N load applied as SE at Site A corresponds to high NO_3-N concentrations within the subsoil as the reduction in inorganic-N is limited to the initial 0.15 m beneath the IS.

Table 8.13 Total inorganic-N loads with subsoil depth beneath DD receiving STE at Site A

	Total inorganic-N			
	Site A			
Sample Depth	LPP (STE)		*Overloading* LPP (STE)	
	%	g d^{-1}	%	g d^{-1}
Point of Infiltration	100	14.6	100	34.9
Green (0.3 m)	12.8%	1.87	14.0%	4.9
Red (1.3 m)	8.2%	1.2	8.6%	3
Blue (1.6)	7.1%	1.04	12.0%	4.2
Black (1.9 m)	6.4%	0.94	10.0%	3.5

Table 8.14 Total inorganic-N loads with subsoil depth beneath DD receiving SE at sites A and B

	Total inorganic-N					
	Site B		Site A		Site B	
Sample Depth	LPP (SE)		*Overloading* LPP (SE)		*Overloading* LPP (SE)	
	%	g d^{-1}	%	g d^{-1}	%	g d^{-1}
Point of Infiltration	100	6	100	35.1	100	8.2
Green (0.3 m)	39.5%	2.37	24.8%	8.7	57.3%	4.7
Red (1.3 m)	19.5%	1.17	28.8%	10.1	26.8%	2.2
Blue (1.6)	13.0%	0.78	20.8%	7.3	15.9%	1.3
Black (1.9 m)	11.2%	0.67	16.2%	5.7	8.5%	0.7

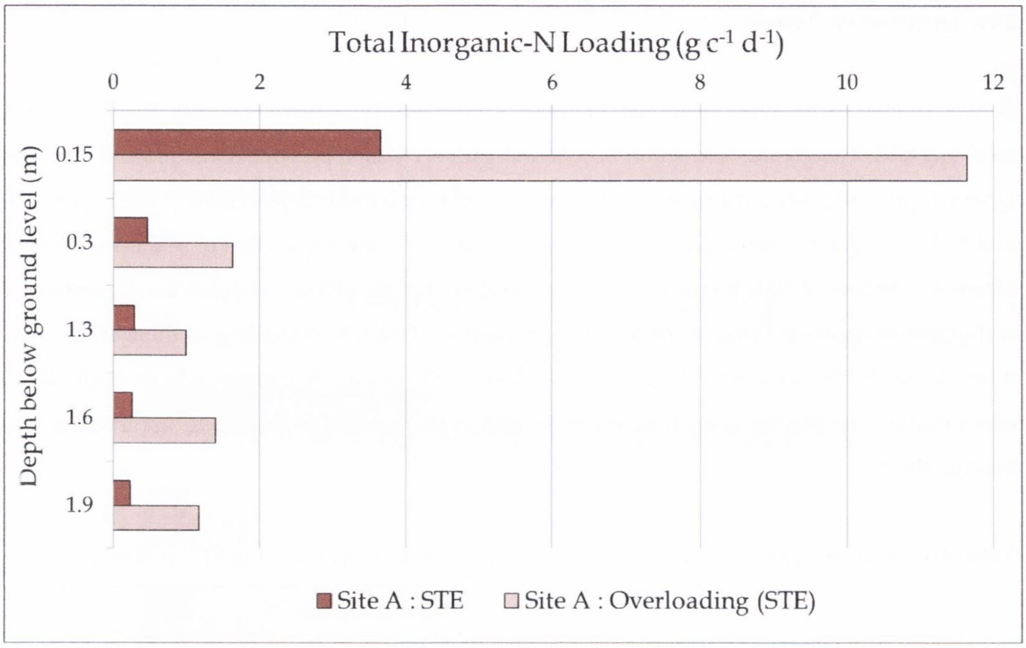


Figure 8.11 Mean Total Inorg-N load per capita at the designated depth planes beneath DD (STE)

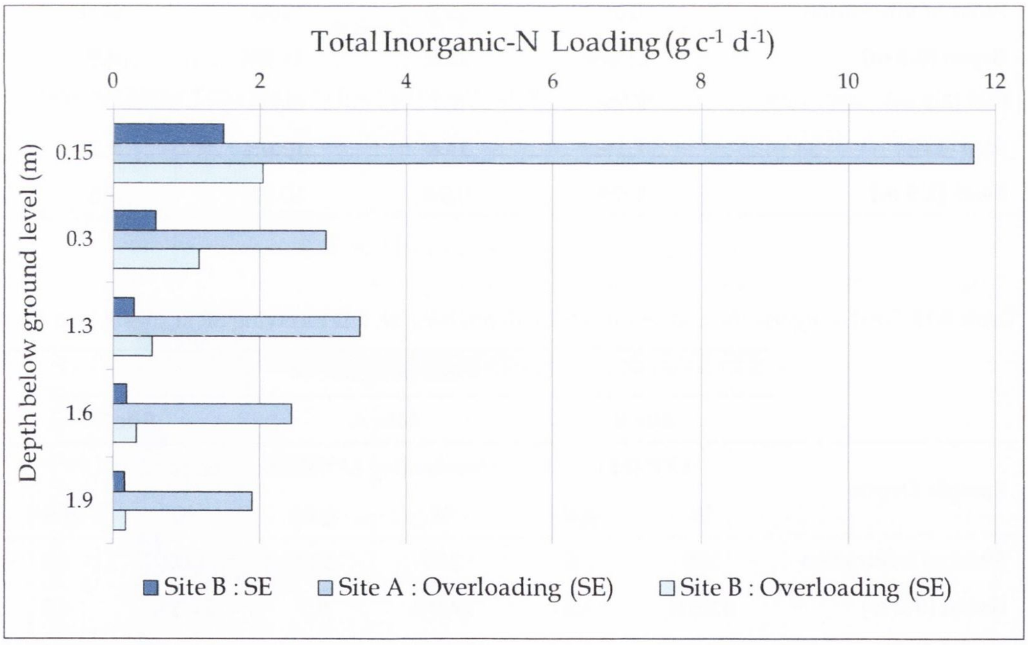


Figure 8.12 Mean Total Inorg-N load per capita at the designated depth planes beneath DD (SE)

Comparison of LPP and DD systems

Analysis of the reduction of total inorganic-N beneath both the LPP and DD shows that when receiving STE under normal conditions both systems performed to a similar standard. During the overloading trial in the summer of 2013, the DD recorded greater inorganic-N reduction with depth. Due to the shallow nature of the DD system and the high rates of evapotranspiration recorded at the time it is believed that a fraction of the NO_3-N was lost through plant uptake.

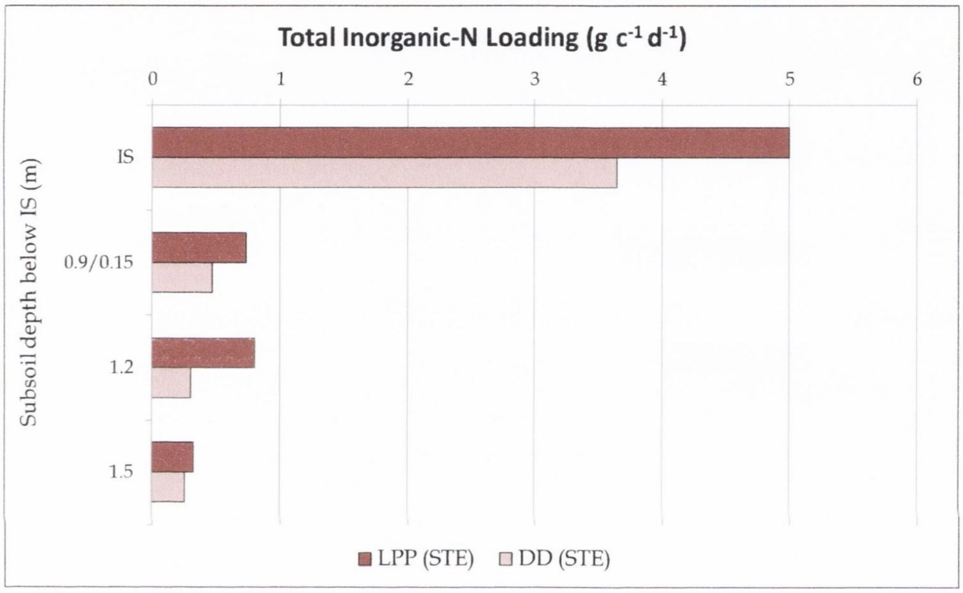


Figure 8.13 Mean Inorg-N load per capita at the designated depth planes beneath the LPP and DD

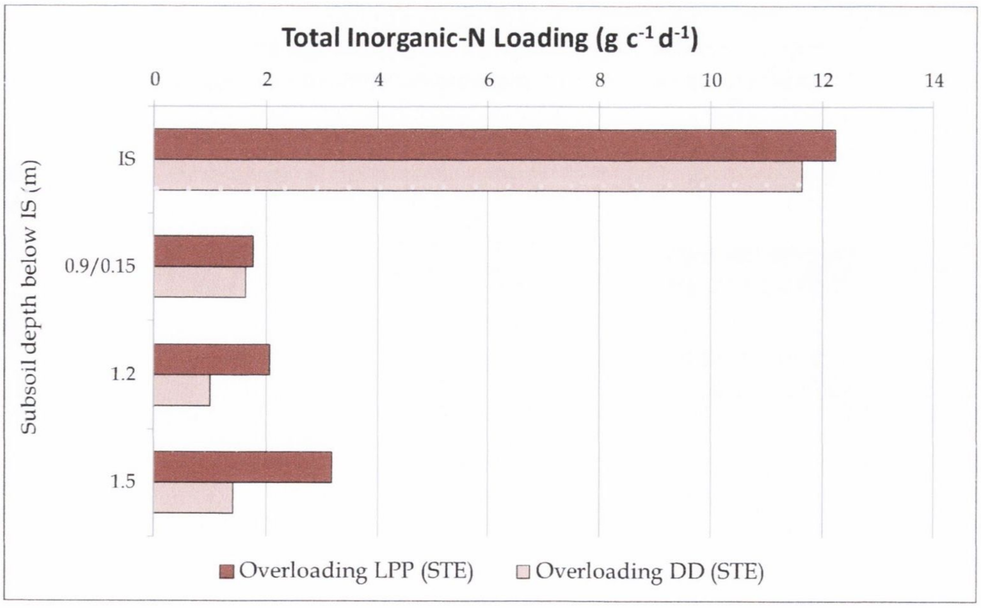


Figure 8.14 Mean Inorg-N load per capita at the designated depth planes beneath the LPP and DD

Similarly, the highly nitrified SE showed greater reduction under the DD than the LPP at Site B (Figure 8.15). Again the infiltration of effluent at the root zone by the DD is thought to have increased the evapotranspiration potential as well as maximising the possibility of plant uptake. Figure 8.16 again shows the greatest inorganic-N reduction occurred within the upper subsoil horizons.

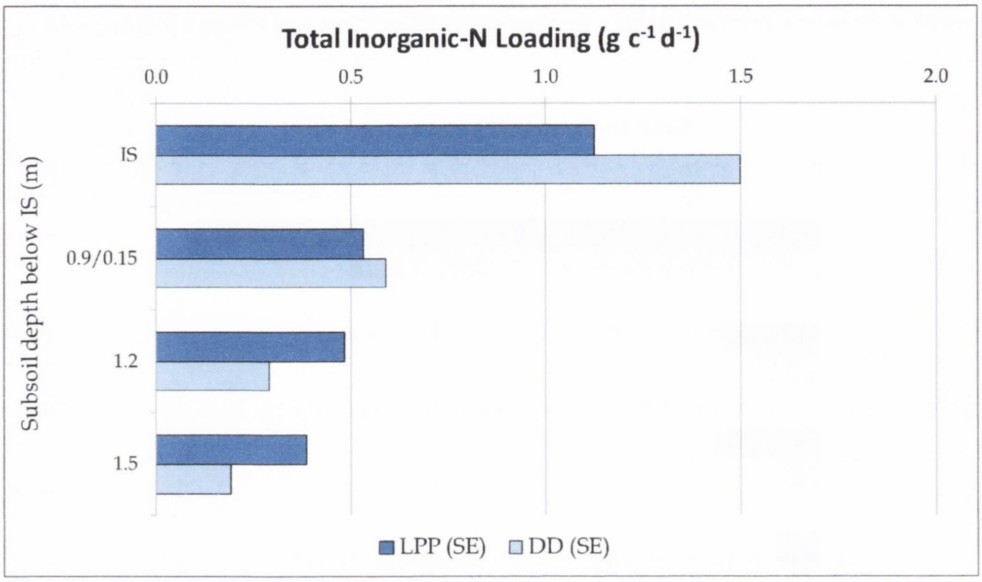


Figure 8.15 Mean Inorg-N load per capita at the designated depth planes beneath the LPP and DD

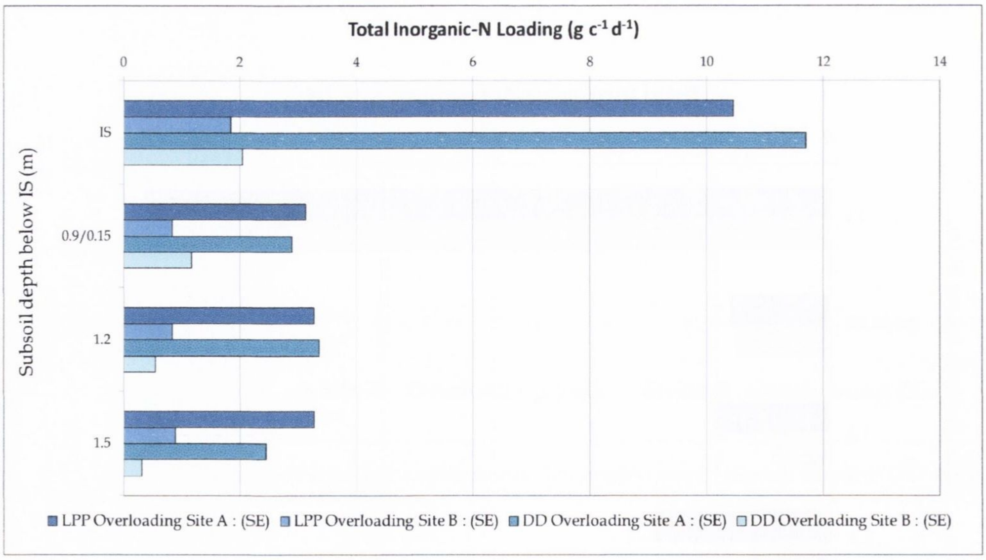


Figure 8.16 Mean Inorg-N load per capita at the designated depth planes beneath the LPP and DD

Concentrations of NO_3-N recorded in upstream and downstream borehole samples during both the pre-remediation and post-remediation monitoring at sites A and B are shown in Table 8.15. At Site A an increase in NO_3-N concentrations was recorded within samples retrieved from the LPP and DD boreholes following the remediation of the site. It should be noted that due to a drop in groundwater levels no borehole samples were retrieved from June to November 2013. At Site B an increase in NO_3-N concentrations was observed at the boreholes directly downstream of the newly installed LPP and DD systems; however a decrease was observed at both downstream boreholes. Due to unforeseen circumstances the boreholes at Site B were removed at the end of March 2013 and no further samples were retrieved.

Table 8.15 Mean NO_3-N concentrations recorded at borehole locations at sites A and B

	NO_3-N			
Borehole	**Pre-remediation**		**Post- remediation**	
	Site A	**Site B**	**Site A**	**Site B**
Upstream	1.2	0.3	1.3	0.4
LPP	0.9	0.09	1.3	0.7
DD	0.9	0.1	1.5	0.6
Downstream 1	n/a	0.9	n/a	0.6
Downstream 2	n/a	0.7	n/a	0.6

Phosphorous

Low Pressure Pipe System

There was little variation in the levels of PO_4-P achieved beneath the systems at either site. As P removal during the secondary treatment of effluent is limited (typically ~15%), the degree of PO_4-P removal in the subsoil is primarily due to a combination of soil adsorption and mineral precipitation processes. Analysis of the PO_4-P loads beneath the LPP systems at both sites revealed the majority of removal occurred above the *red* plane (1.3 m). The high clay fraction at both sites, potentially in combination with the precipitation of phosphate ions due to the mineral compositions, is thought to have played a dominant role in the adsorption of PO_4-P. Tables 8.16 and 8.17 show that despite the variation in effluent loading rates almost complete PO_4-P removal was achieved beneath the LPP at both sites. This is also reflected in Figures 8.17 and 8.18 which show PO_4-P removal on a load per capita basis.

Table 8.16 Ortho-P loads with subsoil depth beneath LPP receiving STE at Site A

	Ortho-P			
	Site A			
Sample Depth	LPP (STE)		*Overloading* LPP (STE)	
	%	g d^{-1}	%	g d^{-1}
Point of Infiltration	100	4.6	100	6.0
Red (1.3 m)	2.8%	0.13	3.3%	0.2
Blue (1.6)	2.0%	0.09	5.0%	0.3
Black (1.9 m)	2.4%	0.11	0.3%	0.02

Table 8.17 Ortho-P loads with subsoil depth beneath LPP receiving SE at sites A and B

	Ortho-P					
	Site B		Site A		Site B	
Sample Depth	LPP (SE)		*Overloading* LPP (SE)		*Overloading* LPP (SE)	
	%	g d^{-1}	%	g d^{-1}	%	g d^{-1}
Point of Infiltration	100	1.1	100	3.5	100	1.7
Red (1.3 m)	2.7%	0.03	11.4%	0.4	2.4%	0.04
Blue (1.6)	2.7%	0.03	2.9%	0.1	1.8%	0.03
Black (1.9 m)	0.9%	0.01	0.0%	0.0	1.8%	0.03

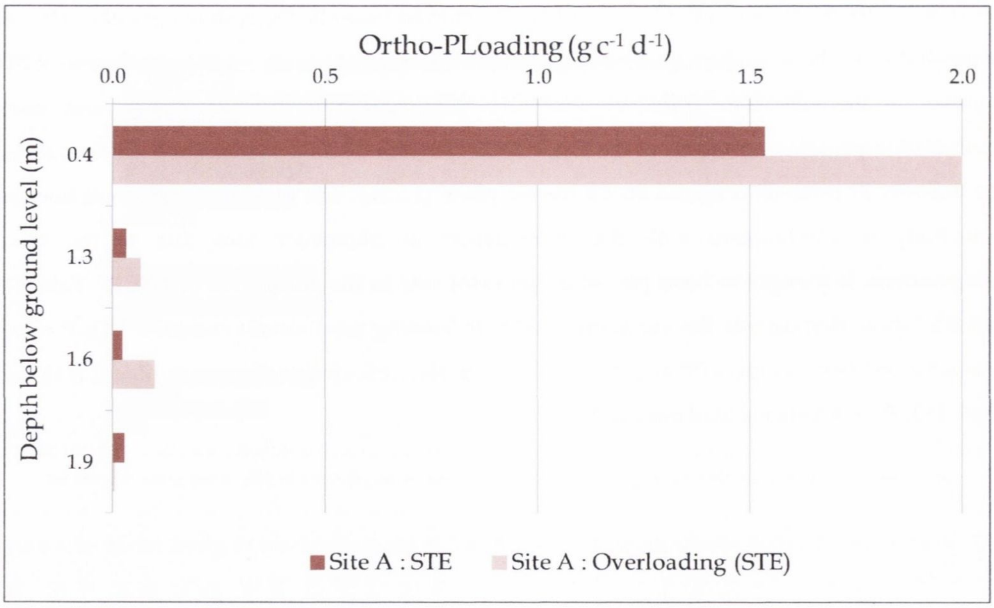


Figure 8.17 Mean Ortho-P load per capita at the designated depth planes beneath LPP (STE)

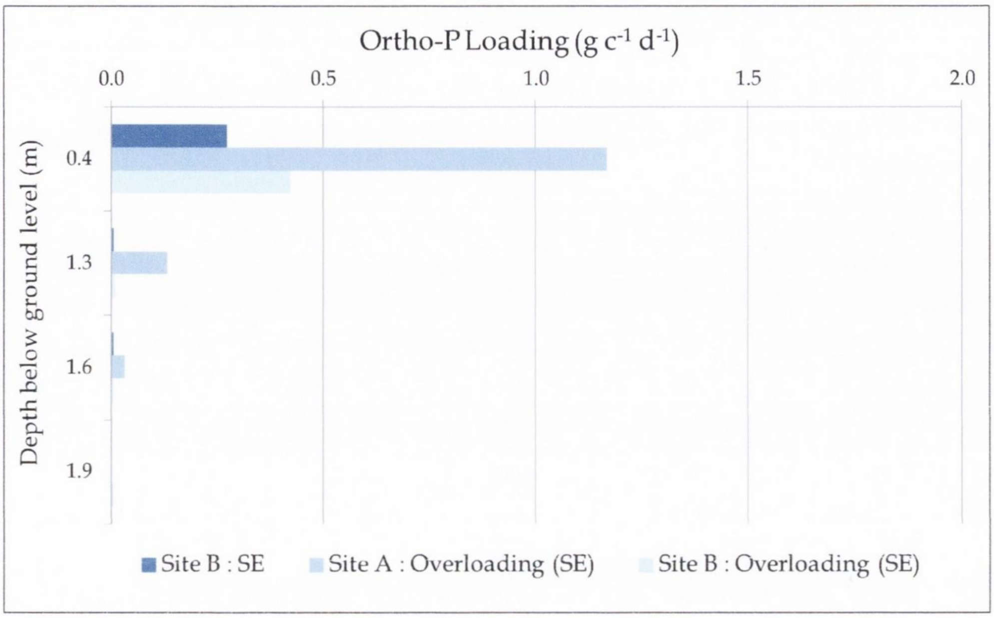


Figure 8.18 Mean Ortho-P load per capita at the designated depth planes beneath LPP (SE)

Drip Distribution System

As with the LPP, excellent PO_4-P removal beneath the DD system was recorded at both sites. Results showed the majority of the PO_4-P load was attenuated within the initial 0.15 m of subsoil with nearly complete removal achieved by the *red* (1.3 m) depth plane (Tables 8.18 and 8.19). Analysis of the load per capita for each site showed that slightly higher concentrations were detected at the *green* depth plane during the overloading trials, however, by the *red* plane concentrations were back in line with those observed under normal operation conditions (Figures 8.19 and 8.20).

Table 8.18 Ortho-P loads with subsoil depth beneath DD receiving STE at Site A

	Ortho-P			
	Site A			
Sample Depth	LPP (STE)		*Overloading* LPP (STE)	
	%	g d^{-1}	%	g d^{-1}
Point of Infiltration	100	4.5	100	6.4
Green (0.3 m)	2.4%	0.11	10.5%	0.67
Red (1.3 m)	0.2%	0.01	0.9%	0.06
Blue (1.6)	2.4%	0.11	0.9%	0.06
Black (1.9 m)	0.9%	0.04	1.4%	0.09

Table 8.19 Ortho-P loads with subsoil depth beneath DD receiving STE at Site A

	Ortho-P					
	Site B		Site A		Site B	
Sample Depth	LPP (SE)		*Overloading* LPP (SE)		*Overloading* LPP (SE)	
	%	g d^{-1}	%	g d^{-1}	%	g d^{-1}
Point of Infiltration	100	5	100	1.5	100	1.8
Green (0.3 m)	3.6%	0.18	20.0%	0.3	18.3%	0.33
Red (1.3 m)	2.8%	0.14	3.5%	0.052	3.3%	0.06
Blue (1.6)	1.8%	0.09	2.3%	0.035	1.1%	0.02
Black (1.9 m)	1.4%	0.07	2.2%	0.033	0.0%	0

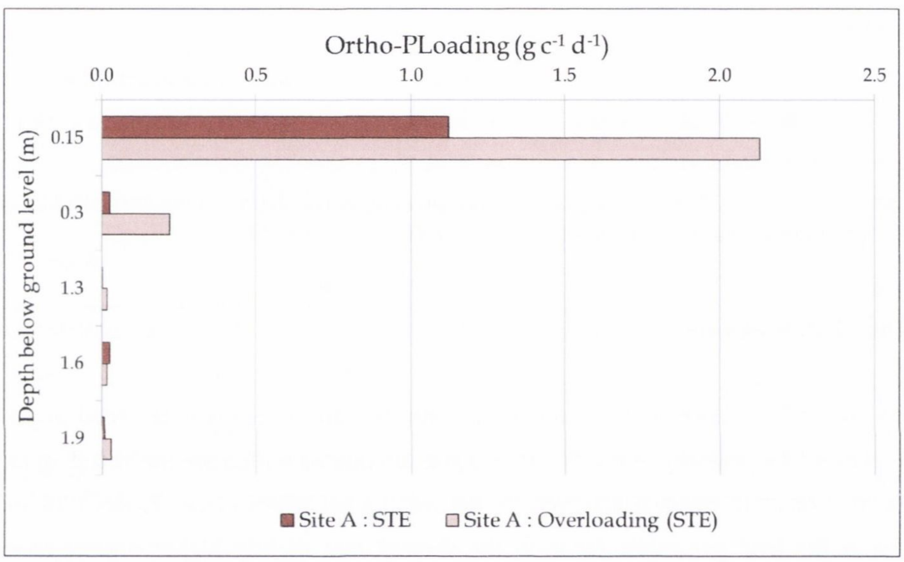


Figure 8.19 Mean Ortho-P load per capita at the designated depth planes beneath DD (STE)

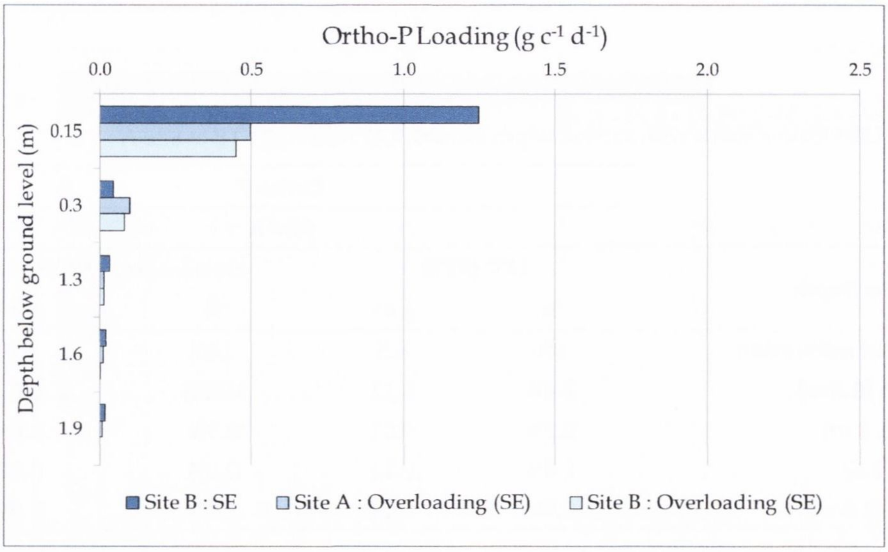


Figure 8.20 Mean Ortho-P load per capita at the designated depth planes beneath DD (SE)

Comparison of LPP and DD systems

Overall the removal of PO_4-P beneath both systems at both sites was comparatively high presumably due to the high fraction of clay within the subsoil. Figures 8.21 and 8.22 show the reduction in PO_4-P was largely unaffected by the increase in hydraulic loading rates. A similar scenario for SE is presented in Figures 8.23 and 8.24.

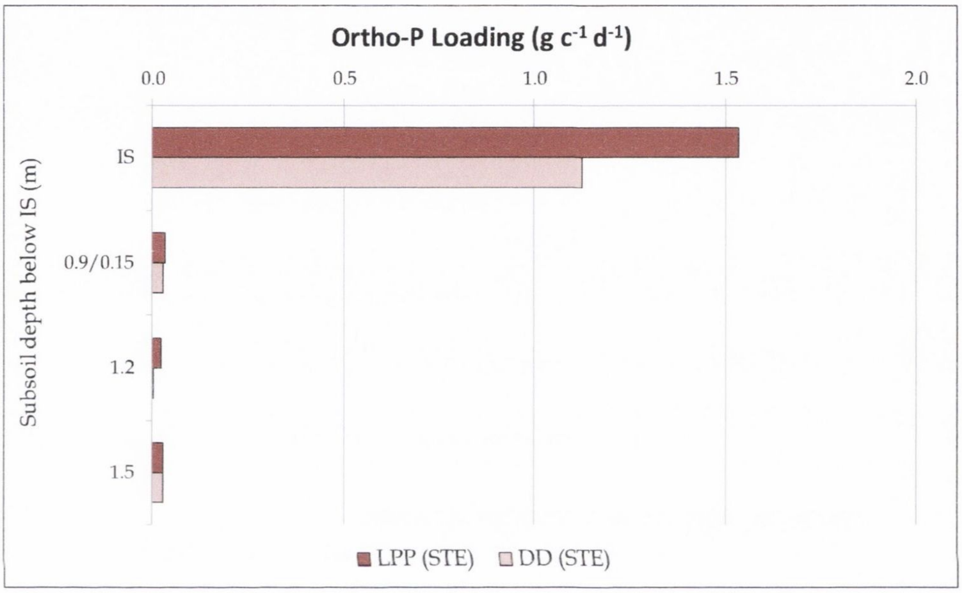


Figure 8.21 Mean Ortho-P load per capita at the designated depth planes beneath the LPP and DD

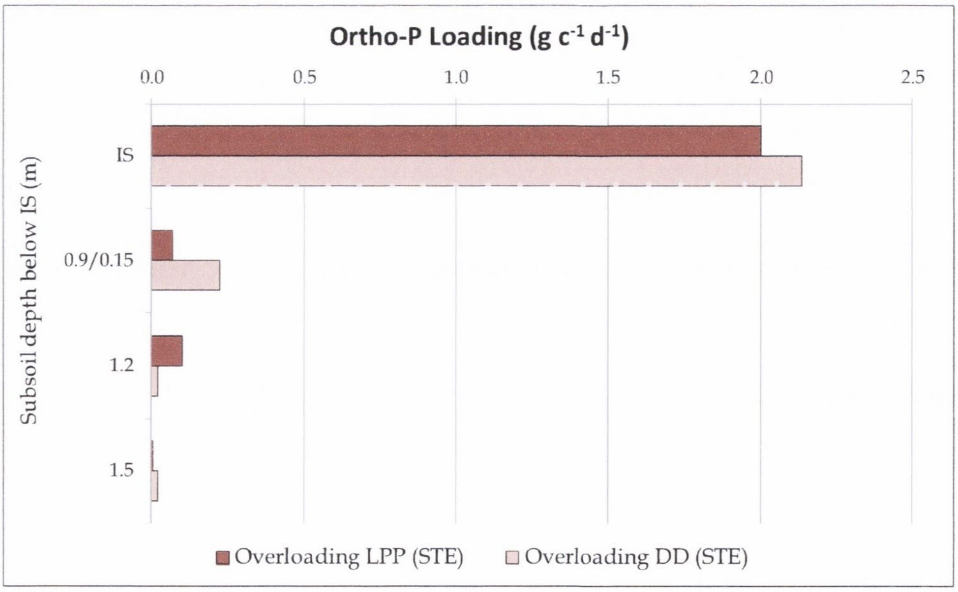


Figure 8.22 Mean Ortho-P load per capita at the designated depth planes beneath the LPP and DD

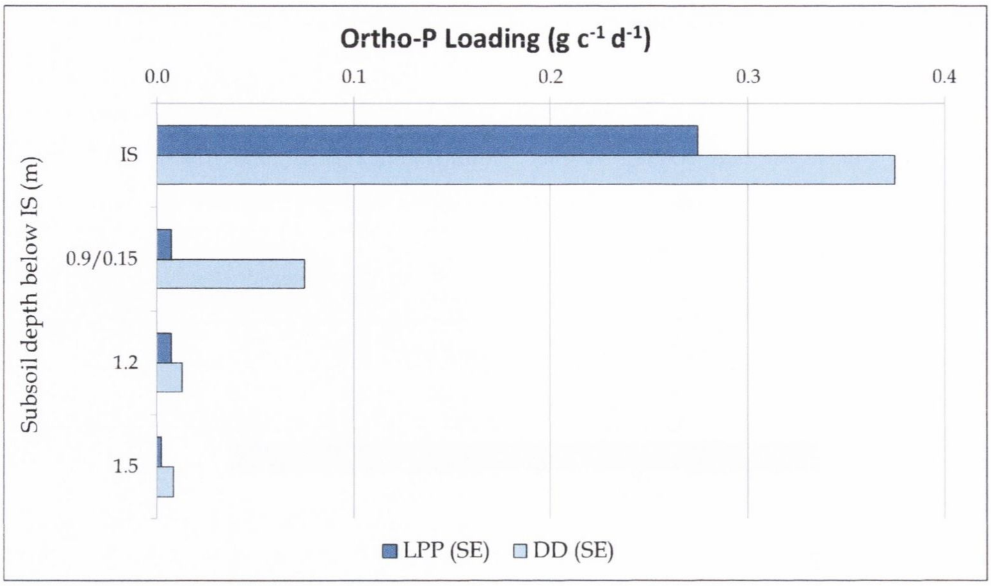


Figure 8.23 Mean Ortho-P load per capita at the designated depth planes beneath the LPP and DD

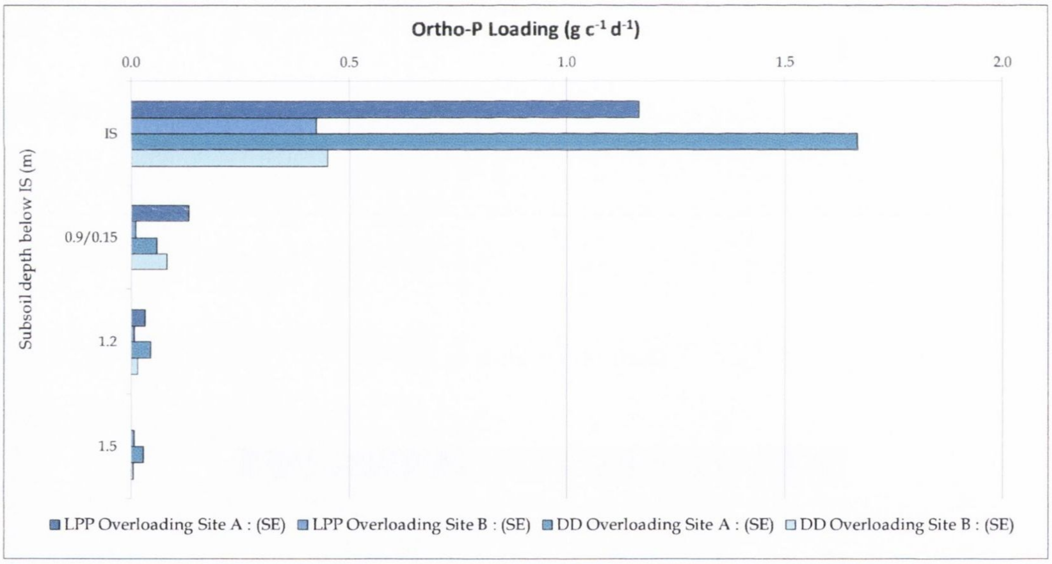


Figure 8.24 Mean Ortho-P load per capita at the designated depth planes beneath the LPP and DD

Borehole samples at both sites A and B both recorded a marginal increase in PO_4-P concentrations downstream of the newly installed LPP and DD systems. At Site B, a decrease in PO_4-P was recorded at both downstream borehole samples following the decommissioning of the pre-remediation soak-pit.

Table 8.20 Mean PO_4-P concentrations recorded at borehole locations at sites A and B

Borehole	Ortho-P			
	Pre-remediation		Post-remediation	
	Site A	Site B	Site A	Site B
Upstream	0.04	0.04	0.06	0.03
LPP	0.03	0.05	0.21	0.16
DD	0.04	0.04	0.08	0.08
Downstream 1	n/a	0.98	n/a	0.43
Downstream 2	n/a	0.76	n/a	0.47

Pathogens

Low Pressure Pipe System

Reduction in total coliform concentrations was found to be higher beneath the LPP system at Site A (STE) than that at Site B (SE) with a 3.9 log-unit and 3.5 log-unit removal achieved by the red depth plane respectively. The difference in treatment performance by the black depth plane was even greater, with the removal rates of 4.5 log-unit and 3.5 log-unit respectively.

A similar trend was observed for *E. coli* concentrations with a higher detection rate recorded beneath the LPP system receiving SE at Site B (Tables 8.21 and 8.23). An overloading trial of the LPP at Site A (receiving STE) showed no increase in the migration of enteric bacteria beneath the system (Table 8.22). Overloading trials for SE were carried out on the LPP systems at both sites during the winter of 2013/2014, however, despite an increase in soil moisture conditions, and consequently hydraulic conductivity, *E. coli* presence was not detected at any of the soil moisture sampling locations.

Table 8.21 Concentrations of *E. coli* recorded beneath LPP at Site A during normal operation (STE)

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	41	39	3	0	0
1.05	43	40	2	1	0
1.35	47	41	4	2	0

Table 8.22 Concentrations of *E. coli* recorded beneath LPP at Site A during overloading trial (STE)

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	5	5	0	0	0
1.05	3	2	1	0	0
1.35	2	2	0	0	0

Table 8.23 Concentrations of *E. coli* recorded beneath LPP at Site B during normal operation (SE)

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	53	47	6	0	0
1.05	54	47	7	0	0
1.35	52	44	8	1	0

Drip Distribution System

A similar scenario was seen to occur beneath the DD systems at both sites. Reduction in total coliform concentrations was found to be considerably higher beneath the DD system at Site A (STE) than that at Site B (SE) with a 4.2 log-unit and 2.9 log-unit removal achieved by the red depth plane respectively. As with the LPP the difference in treatment performance by the black depth plane was also significant, with the removal rates of 4.3 log-unit and 3.3 log-unit respectively.

A higher rate of *E. coli* detection was observed beneath the DD system receiving STE at Site A than that receiving SE at Site B. The effectiveness of the biofilter at Site B in reducing the pathogen loading (2.5 log-unit removal of primary treated effluent) has most likely contributed to the low detection rate at Site B with a geometric mean of just 5.2 x 10^3 MPN mL^{-1} recorded in the SE.

Table 8.24 Concentrations of *E. coli* recorded beneath DD at Site A during normal operation (STE)

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.15	30	27	3	0	0
1.00	41	38	3	0	0
1.30	48	47	1	0	0
1.60	40	38	2	0	0

Again, *E.coli* concentrations beneath the DD system receiving SE were found to be marginally lower than that receiving STE (Table 8.25). Only a single breakthrough of *E.coli* concentrations in excess of 10 MPN 100 mL^{-1} was recorded at the black depth at Site B, whilst two breakthroughs of this magnitude were recorded at Site A over the course of the sampling period.

Table 8.25 Concentrations of *E. coli* recorded beneath DD at Site A during normal operation (SE)

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.15	38	38	0	0	0
1.00	58	58	0	0	0
1.30	57	56	0	1	0
1.60	57	56	1	0	0

From the above results it can be seen that, taking into account the variation in the depth of effluent infiltration to both systems, the DD achieved greater attenuation of *E. coli* with subsoil depth throughout all operating conditions. This is mostly likely a result of the greater areal distribution of effluent across the DD in comparison with the more intense hydraulic loading regime of the LPP trenches.

Table 8.26 shows the detection of *E.coli* in the boreholes samples at both sites over the course of the monitoring period. An increase in *E. coli* was observed downstream of both the LPP and DD systems at both sites. Elevated *E. coli* levels were detected in the upstream groundwater at Site A on a single occasion (19/10/12) however, MST analysis by NUI Galway Microbial Department showed that this was from a bovine source and not human faecal contamination. This highlights the potential of such techniques in identifying the source of faecal contamination in water sources. The magnitude of *E. coli* concentrations detected downstream of the LPP and DD at Site A are largely due to elevated concentrations also recorded on the 19/10/12. MST analysis showed the presence of both human and bovine faecal contamination.

At Site B the *E.coli* presence was only detected in each of the downstream LPP and DD on a single sampling occasion, both of which recorded substantial effective rainfall. Interestingly a gradual decrease in *E. coli* concentrations with depth was recorded at the downstream boreholes at the site following remediation indicating an improvement in effluent treatment via the alternative infiltration systems.

Table 8.26 Geometric mean *E. coli* concentrations recorded at borehole locations at sites A and B

	E. coli **(MPN 100 mL)**			
Borehole	**Pre-remediation**		**Post-remediation**	
	Site A	**Site B**	**Site A**	**Site B**
Upstream	0	0	86	0
LPP	0	0	63.3	1
DD	0	0	4.7	4.1
Downstream 1	n/a	12	n/a	9.4
Downstream 2	n/a	23	n/a	9.7

Virus Study

The multi-phage injection trial revealed some interesting findings regarding the ability of the low permeability subsoils on both sites to remove viral pathogens.

At both sites the LPP and DD systems showed excellent removal of all three phages for both STE and SE application. At Site A, the timing of the injection trial meant sample volumes were a limiting factor in the determination of the phage attenuation beneath each system. As such, the concentrations reported at each depth plane beneath the LPP and DD systems are influenced by the presence of preferential flow paths within the low permeability subsoil. Simultaneous bromide spiking of the effluent indicated at what point the spiked effluent was detected at each sampling plane. Results of the bromide analysis found that the spiked effluent was not detected at each sample location indicating that the high rate of evapotranspiration at the time resulted in a low level of percolated reaching the sampling planes. Beneath the LPP at Site A PR772, ΦX174 and MS2 were reduced by a minimum of 99.9%, 99.7% and 99.03% at all depth planes. The degree of phage attenuation was most likely due to viral adsorption to the high clay fraction of the soil matrix during unsaturated conditions.

The degree of evapotranspiration from the DD system is believed to be greater than that of the LPP due to the shallow (0.15 m) effluent infiltration to the root zone. This may be responsible for the lack of phage retrieval beneath the DD system. Over the month long soil moisture sampling carried out at Site A, only two samples (at the *green* depth plane) showed the presence of phage MS2. Bromide analysis showed the presence of spiked effluent at the remaining depth planes however phage concentrations were not recorded. The lack of detection indicates nearly complete removal of all three phages by the within 0.15 m of subsoil, with limited percolate migration due to the high rate of evapotranspiration.

At Site B, carried out later in the year (September to October 2013), greater phage recovery was achieved. Beneath the LPP 99.9% removal of all 3 phages was recorded by the *red* depth plane with concentrations remaining relatively constant at the remaining sample depths. Greater phage migration occurred beneath the DD system at Site B as evapotranspiration levels were significantly lower. PR772, ΦX174 and MS2 were reduced by a minimum of 99.6%, 99.8% and 99.9% by the *green* depth plane indicating once again that the majority of attenuation occurred within the first 0.15 m of subsoil. Further log-unit reduction was recorded at the subsequent sample depths, presumably attributed to the high clay fraction providing an abundance of viral adsorption sites. Based on the results of the study both systems provided a high degree of pathogen attenuation with subsoil depth by the 0.9 m and 1.2 m planes for SE and STE respectively.

Chapter 9 Conclusions and Recommendations

9.1 CONCLUSIONS

9.1.1 EXISTING SEPTIC TANK SOAK-PIT SYSTEMS

i) Moderate/High Permeability Subsoils

- As with conventional systems, the depth of unsaturated subsoil available beneath existing soak-pit systems is crucial to the prevention of pollutant migration to groundwater, in particular, the main constituents of concern identified over the course of this study were nitrate (NO_3-N) and *E. coli*.

- It is presumed that the development of a mature biomat (soil clogging layer) at the infiltrative surface of the soak-pit has promoted the long-term pollutant attenuation of these systems, despite the permeable characteristics of the native subsoil. The development of this biomat layer reduces the conductivity of the subsoil at the infiltrative surface, thus increasing the residence time of percolate as well as regulating the percolation rate into the underlying subsoil and potentially maintaining aerobic conditions which consequently enhancing the treatment performance of the system.

- Where a gradient in the soak-pit region exists, biomat formation also plays a critical role in spreading the STE point-load over a greater infiltrative area and in doing so decreases the intensity of the hydraulic loading by extending the plume in a lateral as well as vertical direction.

ii) Low Permeability Subsoils

- Within a low permeability subsoil setting, hydraulic failure, either intermittently or permanently, results in effluent backing up to pond at the site's surface. Run-off of the resulting standing effluent has been shown to have detrimental effects on downstream groundwater quality through the lateral flow of effluent within the uppermost subsoil horizons and provides a risk to surface water. However, the natural attenuation of bacteria and P in such lateral flow pathways does seem to be significant.

- Within the low permeability subsoil, the presence of preferential flow paths was found to be a key transport route for pathogen migration to downstream groundwater monitoring locations.

- Overall the effluent plume observed from the soak-pits in low permeability subsoil was seen to extend in a predominantly lateral direction by means of distinct pathways.

9.1.2 ALTERNATIVE INFILTRATION SYSTEMS

- The degree of saturated beneath both systems appeared to be influence by the intensity/duration of rainfall recharge more than that of effluent application when controlled design loading were applied.

- The treatment performance of both the LPP and DD systems receiving STE was seen to be slightly superior to that of the systems receiving SE. This was attributed to a reduction in biological activity in the biozone directly beneath the infiltrative surface for the systems receiving SE due to the inherent reduction in organic loading following secondary treatment in the packaged plants.

- Overall the DD system achieved greater inorganic-N removal than the LPP system regardless of effluent application which was attributed to its shallower placement in the subsoil.

- The DD also achieved a greater removal rate in relation to enteric bacteria than the LPP regardless of effluent application. This may be as a result of its more even distribution over the infiltrative area, shallower placement in the subsoil compared to the LPP trenches or a combination of both.

- The field results have shown that both the LPP and DD systems could be a solution for sites with T-values <75. The exact permeability down to which each system might be suitable can be assessed using calibrated models with the soil moisture data collected in these studies.

- The fixed film packaged treatment plant produced a much cleaner effluent compared to the extended aeration process and was also considerably more efficient with respect to its ongoing energy requirements.

- The DD was found to require more maintenance over the course of the study particularly during the application of septic tank effluent which, over a time cause the pump to block in the absence of an upstream filter.

- The timed dosing system of the DD was also found to be more sensitive to high effluent loadings a peak water using times and a greater sump storage capacity was needed to accommodate effluent between dosing cycles in comparison with the LPP which pump "on-demand".

9.2 RECOMMENDATIONS

- A longer-term study on the hydraulic performance of both the LPP and DD systems should be carried out to access the potential reduction in infiltrative capacity over time as the soil clogging layer develops.

- A laboratory based study could be carried out on the variation in pollution migration (particularly with respect to pathogens) with subsoil depth depending on the proportion of clay particles present and effluent loading rates.

- The data from these DD and LPP system field results should be used to calibrate a transient saturated model of the respective STUs in order to assess the effect of reducing the soil's hydraulic conductivity. This information can then feed into national legislation with regard to providing on-site treatment solutions for soils with T-values <75.

- Quantification of the potential nutrient uptake of plants overlying DD systems should be attempted using nitrogen isotope experiments to determine any potential improvement in nutrient removal due to the introduction of specific vegetation.

- Further field research could be carried out in Irish soils in relation to controlled pilot-scale systems and replicate test cells of LPP and DD systems.

- Further studies of the plumes for septic tank soak-pits should be carried out but should also include soil moisture instrumentation to assess the degree of saturation within the plumes

- A study into the persistence of effluent plumes beneath decommissioned soak-pits following site remediation should be carried out to determine the long term impacts on groundwater and surface water quality.

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GSI

Site A: Kilkenny - Aerial View

0 750 1500 2250 m.

Map center: 246665, 146329

N

Legend

RBD Boundaries

Watermark

Scale: 1:28,176

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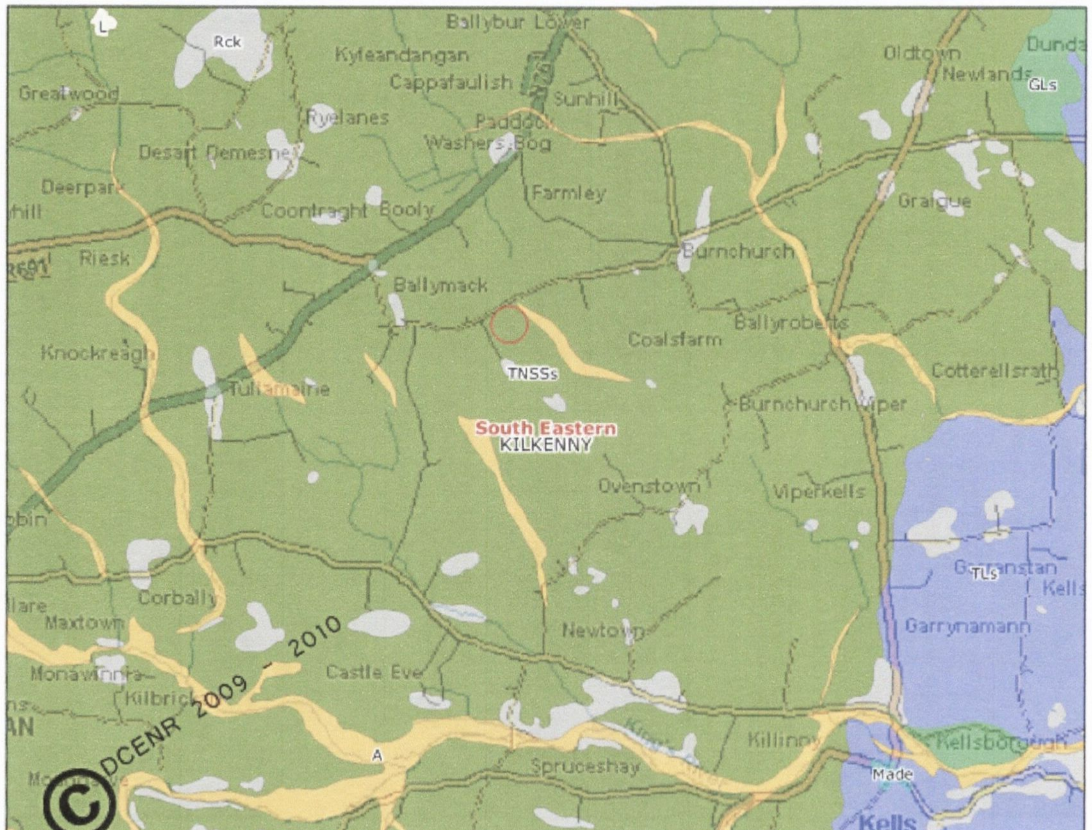
Snapshot Date: 07-Feb-2014

Site A: Kilkenny - Subsoil Map



0 1100 2200 3300 m.

Map center: 246739, 145998

Legend

RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
- Marsh
- Peat
- Scree
- Till derived chiefly from Devonian sandstones
- Till derived chiefly from Lower Palaeozoic rocks
- Till derived chiefly from Namurian rocks
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Till derived from metamorphic rocks
- Till derived from mixed Devonian and Carboniferous rocks
- Water
- Windblown sands
- RBD Boundaries
- County Boundaries

Scale: 1:42,676

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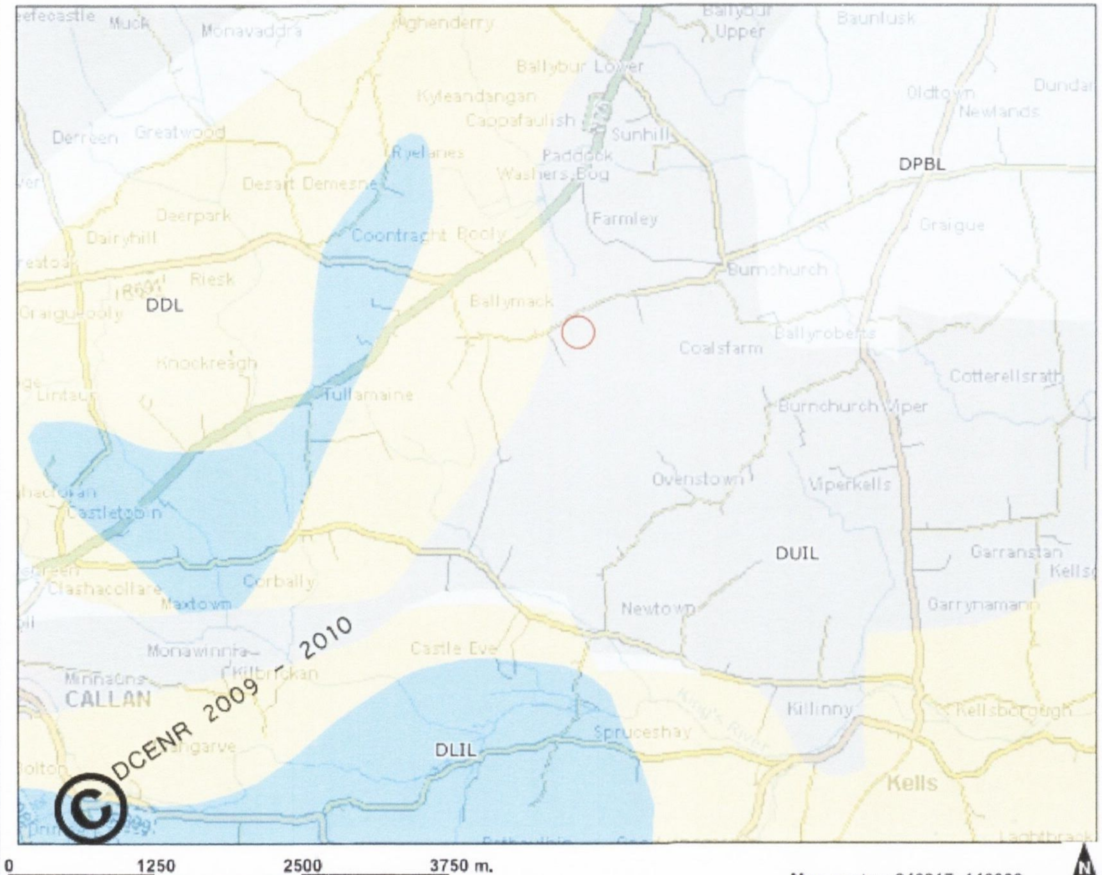
Snapshot Date: 07-Feb-2014

Site A: Kilkenny - Bedrock Map



Map center: 246317, 146003

Legend

National Draft Generalised Bedrock Map

- BV - Basalts and other Volcanic rocks
- CM - Cambrian Metasediments
- DDL - Dinantian Dolomitised Limestones
- DESSL - Dinantian early Sandstones, Shales and Limestones
- DKS - Devonian Kiltorcan type Sandstones
- DLIL - Dinantian Lower Impure Limestones
- DMSC - Dinantian Mudstones and Sandstones Cork Group
- MSSL - Dinantian Mixed Sandstones, Shales and Limestones
- DORS - Devonian Old Red Sandstones
- DPBL - Dinantian Pure Bedded Limestones
- DPUL - Dinantian Pure Unbedded Limestones
- DS - Dinantian Sandstones
- DSL - Dinantian Shales and Limestones
- DUIL - Dinantian Upper Impure Limestones
- GII - Granites and other Igneous Intrusive rocks
- NSA - Namurian Sandstones
- NSH - Namurian Shales
- NU - Namurian Undifferentiated
- OM - Ordovician Metasediments
- OV - Ordovician Volcanics
- PM - Precambrian Marbles
- PQGS - Precambrian Quartzites, Gneisses and Schists
- PTMG - Permo Triassic Mudstones and Gypsum
- PTS - Permo Triassic Sandstones
- SMV - Silurian Metasediments and Volcanics
- WSA - Westphalian Sandstones
- WSH - Westphalian Shales

Scale: 1:47,883

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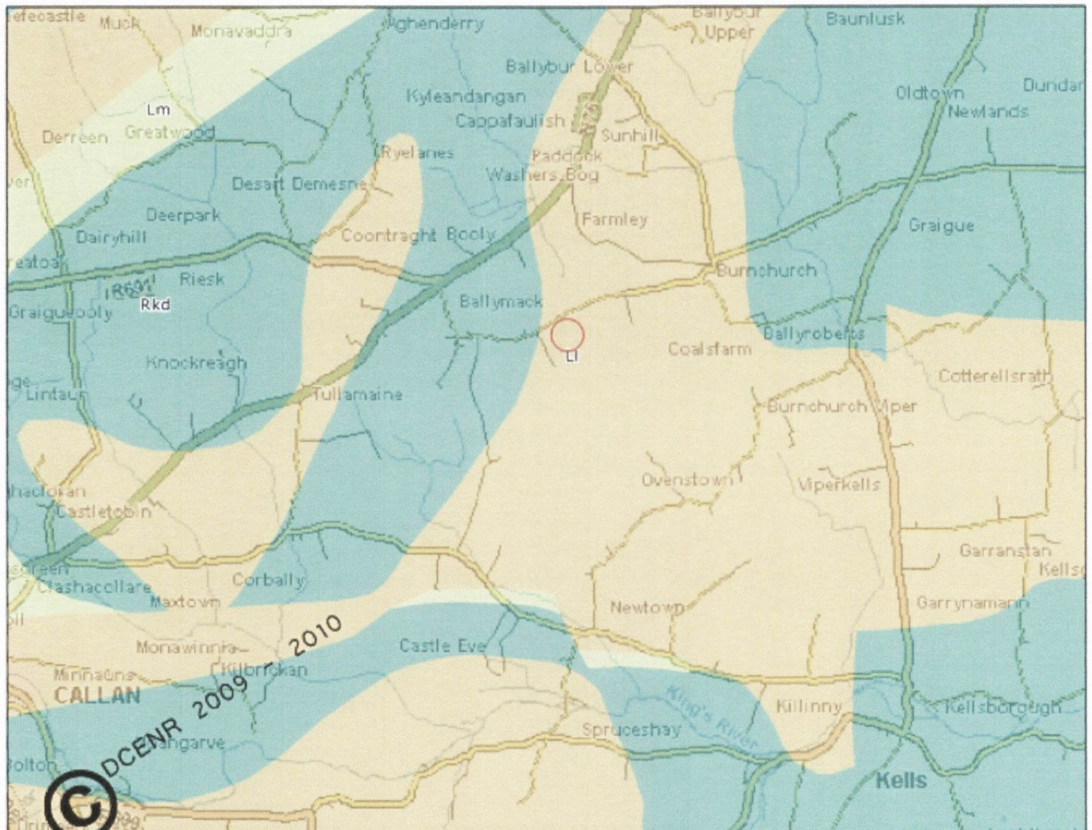
Snapshot Date: 07-Feb-2014

Site A: Kilkenny - Aquifer Map



0 1250 2500 3750 m.

Map center: 246317, 146003

Legend

National Draft Bedrock Aquifer Map

- Rf - Regionally Important Aquifer - Fissured bedrock
- Rk - Regionally Important Aquifer - Karstified
- Rkd - Regionally Important Aquifer - Karstified (diffuse)
- Rkc - Regionally Important Aquifer - Karstified (conduit)
- Lm - Locally Important Aquifer - Bedrock which is Generally Moderately Productive
- Lk - Locally Important Aquifer - Karstified
- Ll - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- Pl - Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones
- Pu - Poor Aquifer - Bedrock which is Generally Unproductive
- Unclassified

Scale: 1:47,883

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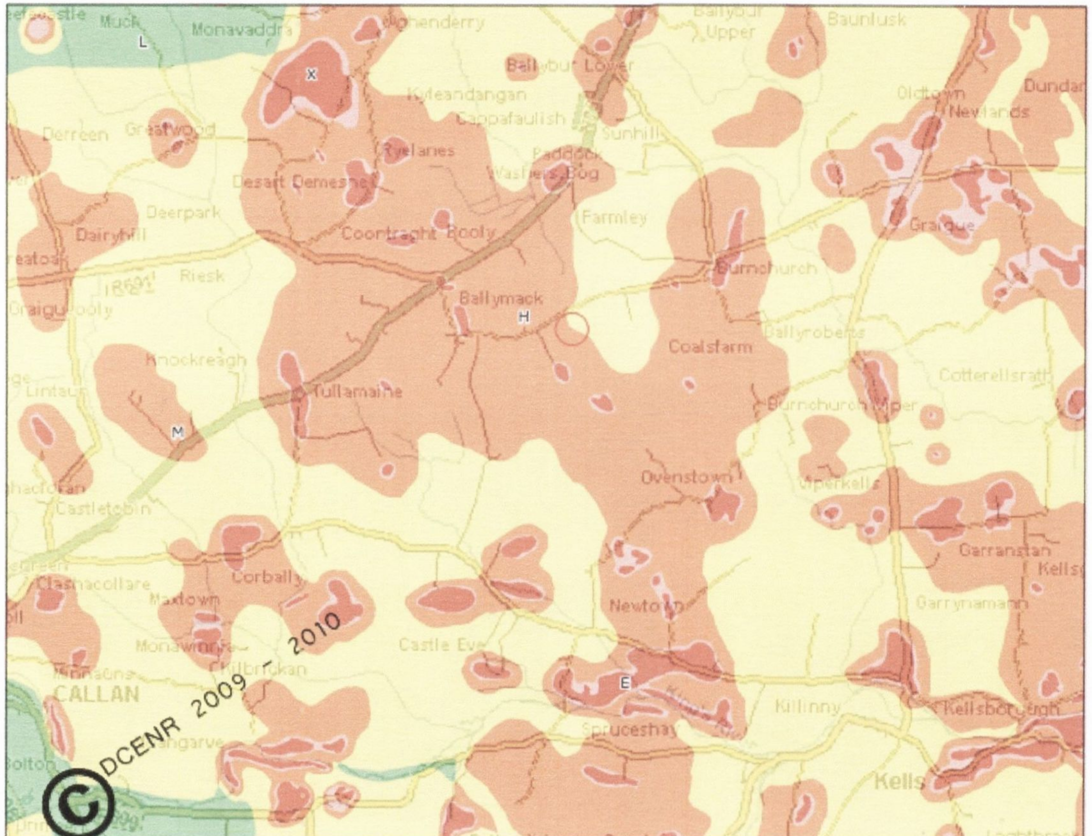
Snapshot Date: 07-Feb-2014

Site A: Kilkenny - National Vulnerability



0 1250 2500 3750 m.

Map center: 246317, 146003

Legend

Vulnerability

- X (Rock near Surface or Karst)
- E - Extreme
- H - High
- M - Moderate
- L - Low
- Water

Scale: 1:47,883

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Snapshot Date: 07-Feb-2014

Site B: Monaghan - Aerial View

Legend

RBD Boundaries

Watermark

0 750 1500 2250 m.

Map center: 258386, 329841

N

Scale: 1:28,123

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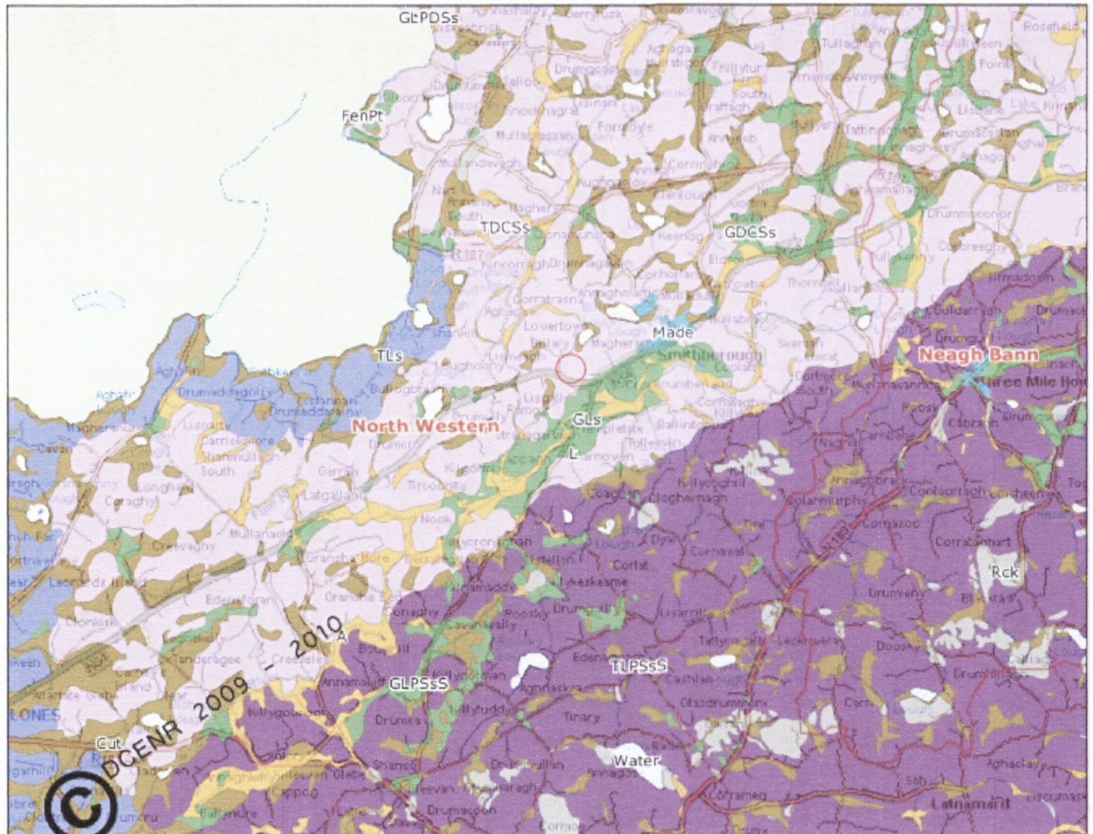
Snapshot Date: 07-Feb-2014

Site B: Monaghan - Subsoil Map



0 1.75 3.5 5.25 km.

Map center: 257361, 329612

Legend

RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
- Marsh
- Peat
- Scree
- Till derived chiefly from Devonian sandstones
- Till derived chiefly from Lower Palaeozoic rocks
- Till derived chiefly from Namurian rocks
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Till derived from metamorphic rocks
- Till derived from mixed Devonian and Carboniferous rocks
- Water
- Windblown sands
- RBD Boundaries

Scale: 1:67,435

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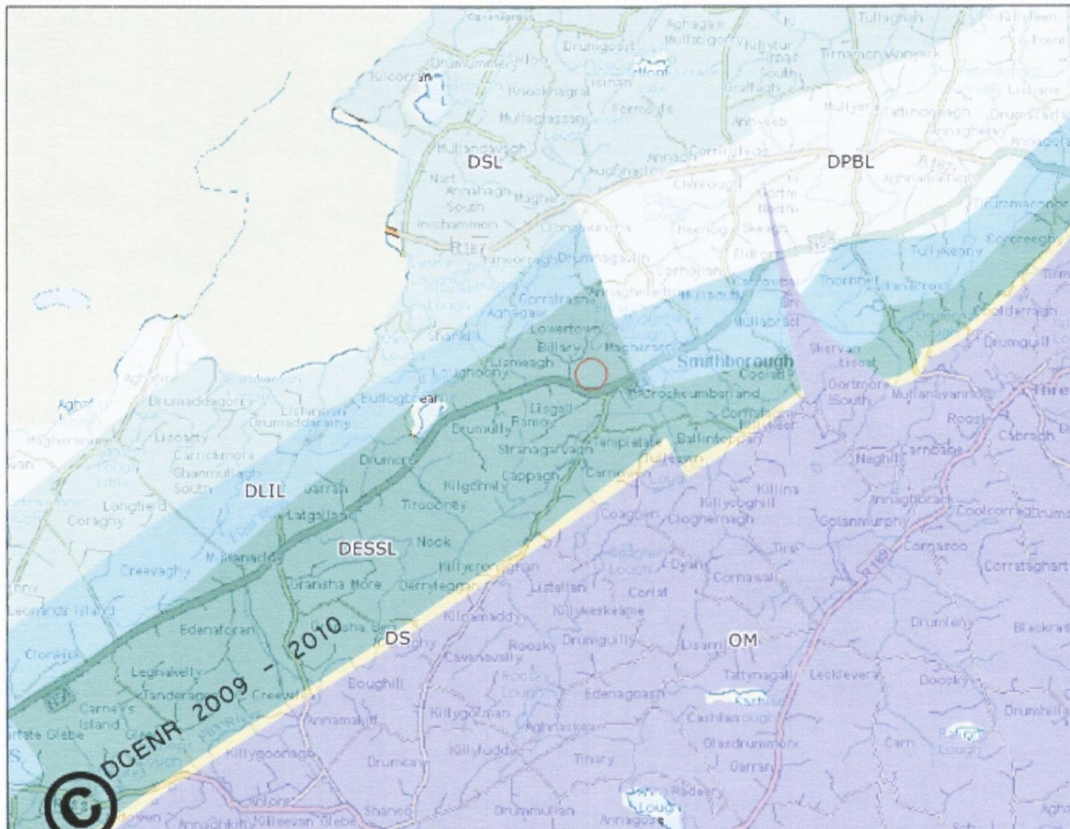
Snapshot Date: 07-Feb-2014

Site B: Monaghan - Bedrock Map



0 1.6 3.2 4.8 km.

Map center: 257249, 329734

Legend
National Draft Generalised Bedrock Map

- BV - Basalts and other Volcanic rocks
- CM - Cambrian Metasediments
- DDL - Dinantian Dolomitised Limestones
- DESSL - Dinantian early Sandstones, Shales and Limestones
- DKS - Devonian Kiltorcan type Sandstones
- DLIL - Dinantian Lower Impure Limestones
- DMSC - Dinantian Mudstones and Sandstones Cork Group
- MSSL - Dinantian Mixed Sandstones, Shales and Limestones
- DORS - Devonian Old Red Sandstones
- DPBL - Dinantian Pure Bedded Limestones
- DPUL - Dinantian Pure Unbedded Limestones
- DS - Dinantian Sandstones
- DSL - Dinantian Shales and Limestones
- DUIL - Dinantian Upper Impure Limestones
- GII - Granites and other Igneous Intrusive rocks
- NSA - Namurian Sandstones
- NSH - Namurian Shales
- NU - Namurian Undifferentiated
- OM - Ordovician Metasediments
- OV - Ordovician Volcanics
- PM - Precambrian Marbles
- PQGS - Precambrian Quartzites, Gneisses and Schists
- PTMG - Permo Triassic Mudstones and Gypsum
- PTS - Permo Triassic Sandstones
- SMV - Silurian Metasediments and Volcanics
- WSA - Westphalian Sandstones
- WSH - Westphalian Shales

Scale: 1:61,097

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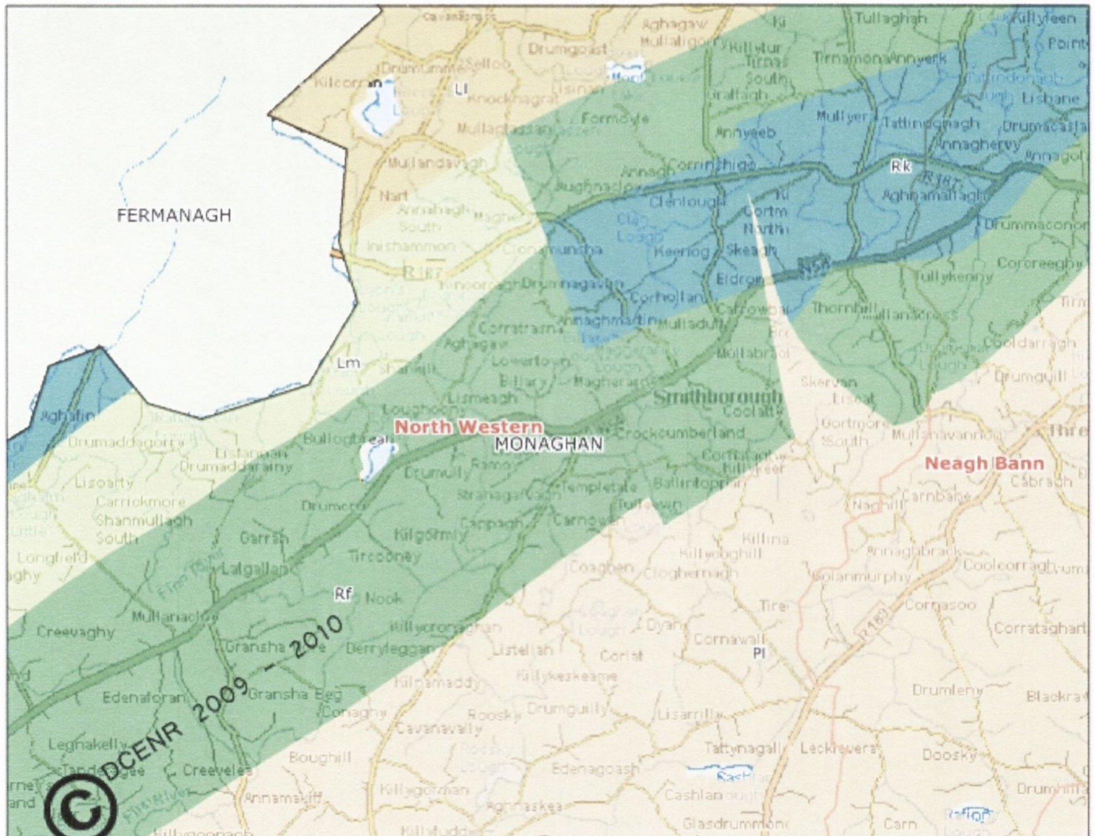
Snapshot Date: 07-Feb-2014

Site B: Monaghan - Aquifer Map



Legend

National Draft Bedrock Aquifer Map

- Rf - Regionally Important Aquifer - Fissured bedrock
- Rk - Regionally Important Aquifer - Karstified
- Rkd - Regionally Important Aquifer - Karstified (diffuse)
- Rkc - Regionally Important Aquifer - Karstified (conduit)
- Lm - Locally Important Aquifer - Bedrock which is Generally Moderately Productive
- Lk - Locally Important Aquifer - Karstified
- Ll - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- Pl - Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones
- Pu - Poor Aquifer - Bedrock which is Generally Unproductive
- Unclassified
- RBD Boundaries
- County Boundaries

0 1400 2800 4200 m.

Map center: 257637, 330174

Scale: 1:55,331

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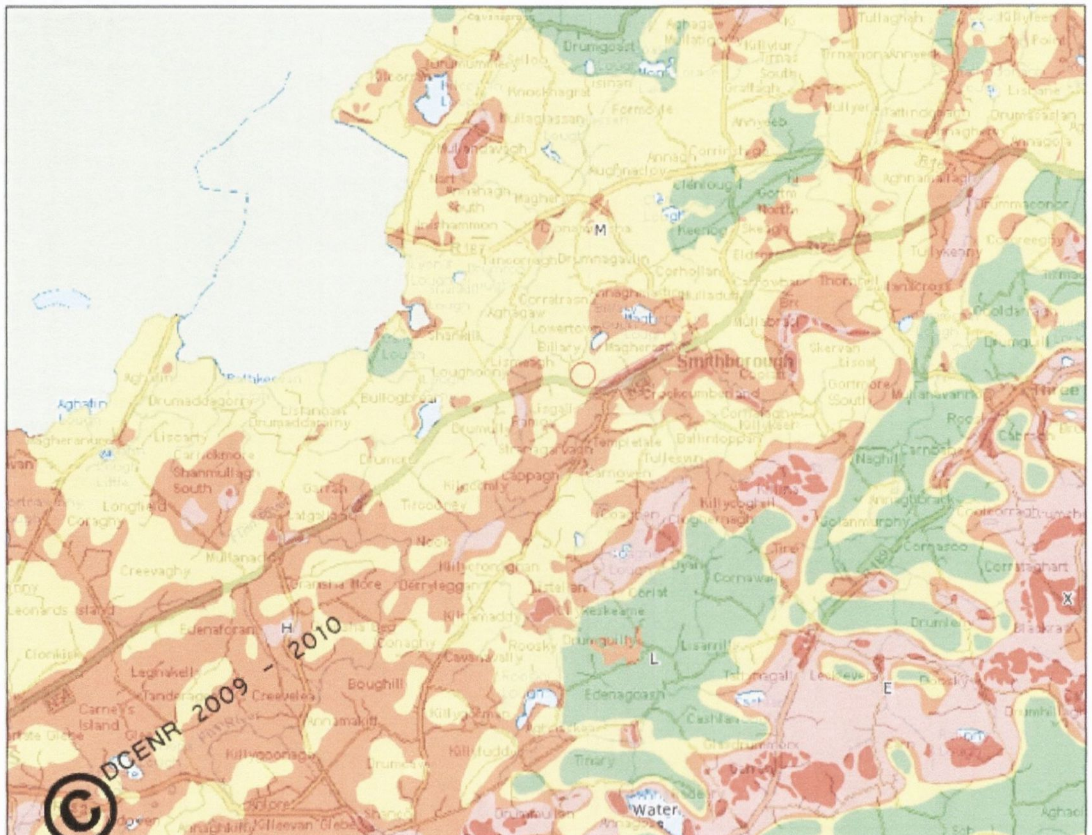
Snapshot Date: 04-Mar-2014

Site B: Monaghan - National Vulnerability



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0 1.6 3.2 4.8 km.

Map center: 257249, 329734

N

Legend

Vulnerability

- X (Rock near Surface or Karst)
- E - Extreme
- H - High
- M - Moderate
- L - Low
- Water

Scale: 1:61,097

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Snapshot Date: 07-Feb-2014

Site C and Site D: Meath - Aerial View

Legend

Watermark

Map center: 316219, 268667

Scale: 1:23,065

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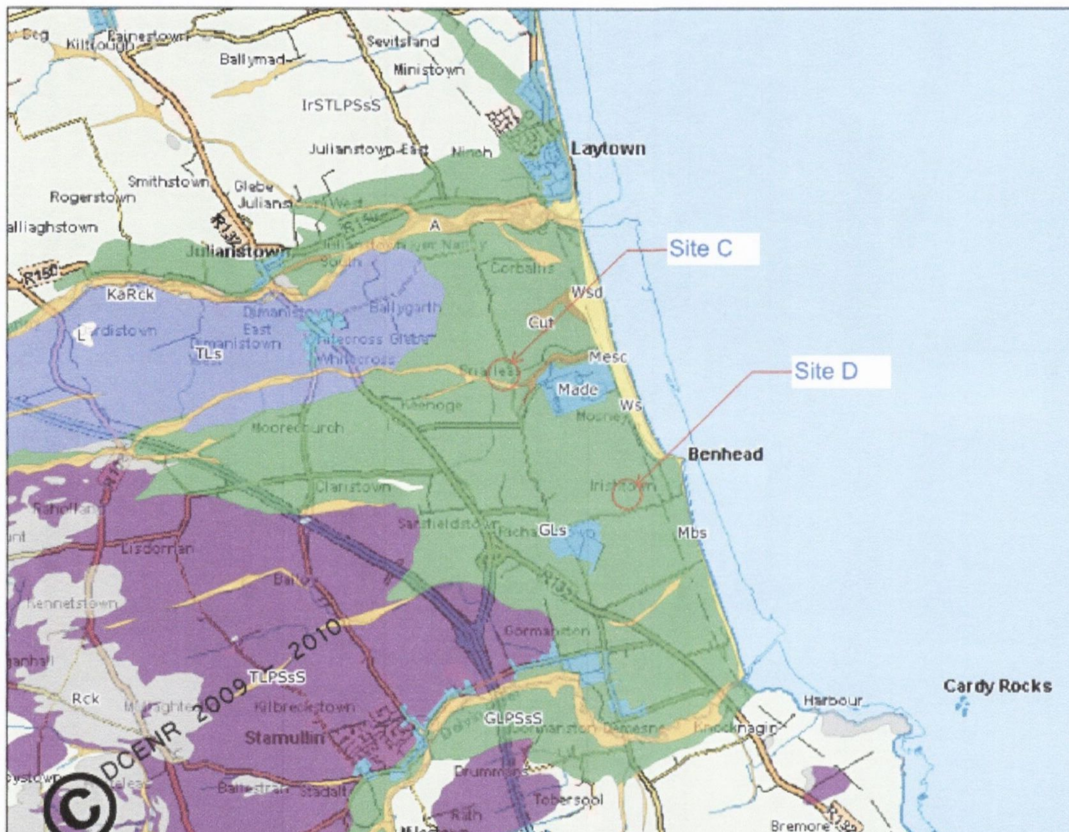
Snapshot Date: 07-Feb-2014

GSI

Site C and Site D: Meath - Subsoil Map



0 1500 3000 4500 m.

Map center: 316271, 268949

Legend

RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
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- Peat
- Scree
- Till derived chiefly from Devonian sandstones
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- Till derived chiefly from Namurian rocks
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Till derived from metamorphic rocks
- Till derived from mixed Devonian and Carboniferous rocks
- Water
- Windblown sands

Scale: 1:56,887

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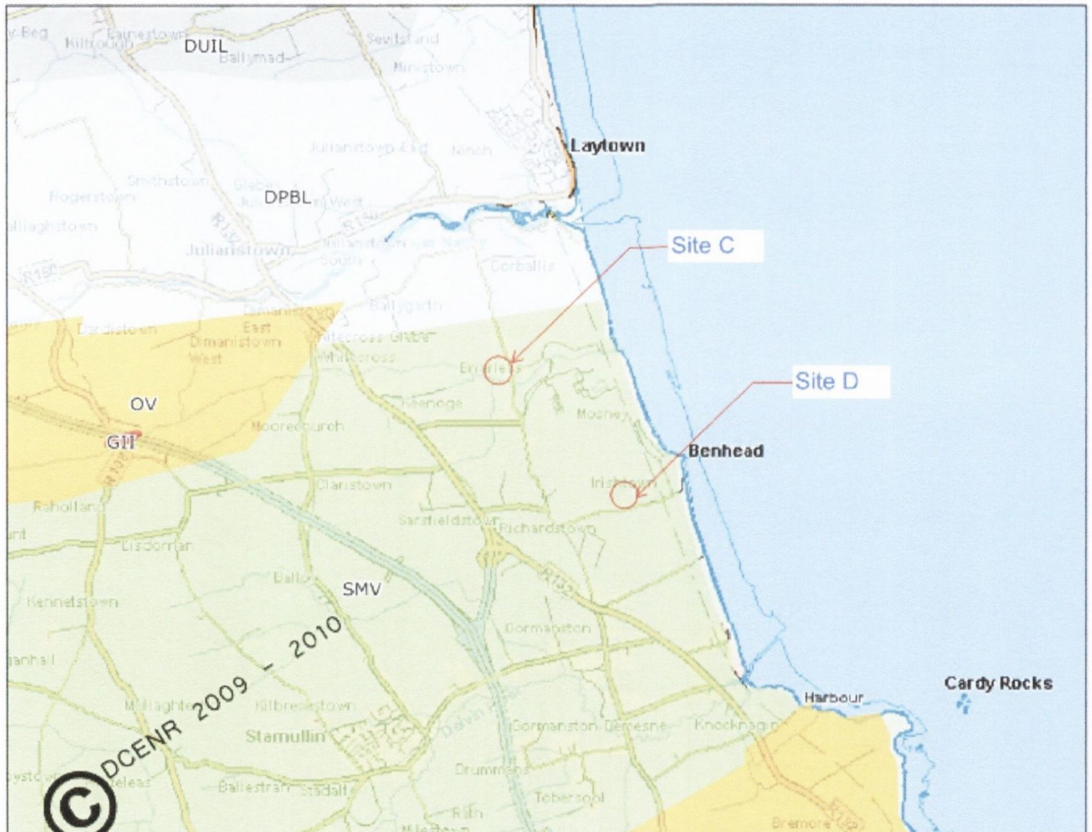
Snapshot Date: 07-Feb-2014

Site C and Site D: Meath - Bedrock Map



0 1500 3000 4500 m.

Map center: 316271, 268949

Legend
National Draft Generalised Bedrock Map

- BV - Basalts and other Volcanic rocks
- CM - Cambrian Metasediments
- DDL - Dinantian Dolomitised Limestones
- DESSL - Dinantian early Sandstones, Shales and Limestones
- DKS - Devonian Kiltorcan type Sandstones
- DLIL - Dinantian Lower Impure Limestones
- DMSC - Dinantian Mudstones and Sandstones Cork Group
- MSSL - Dinantian Mixed Sandstones, Shales and Limestones
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- DUIL - Dinantian Upper Impure Limestones
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- OV - Ordovician Volcanics
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- PQGS - Precambrian Quartzites, Gneisses and Schists
- PTMG - Permo Triassic Mudstones and Gypsum
- PTS - Permo Triassic Sandstones
- SMV - Silurian Metasediments and Volcanics
- WSA - Westphalian Sandstones
- WSH - Westphalian Shales

Scale: 1:56,887

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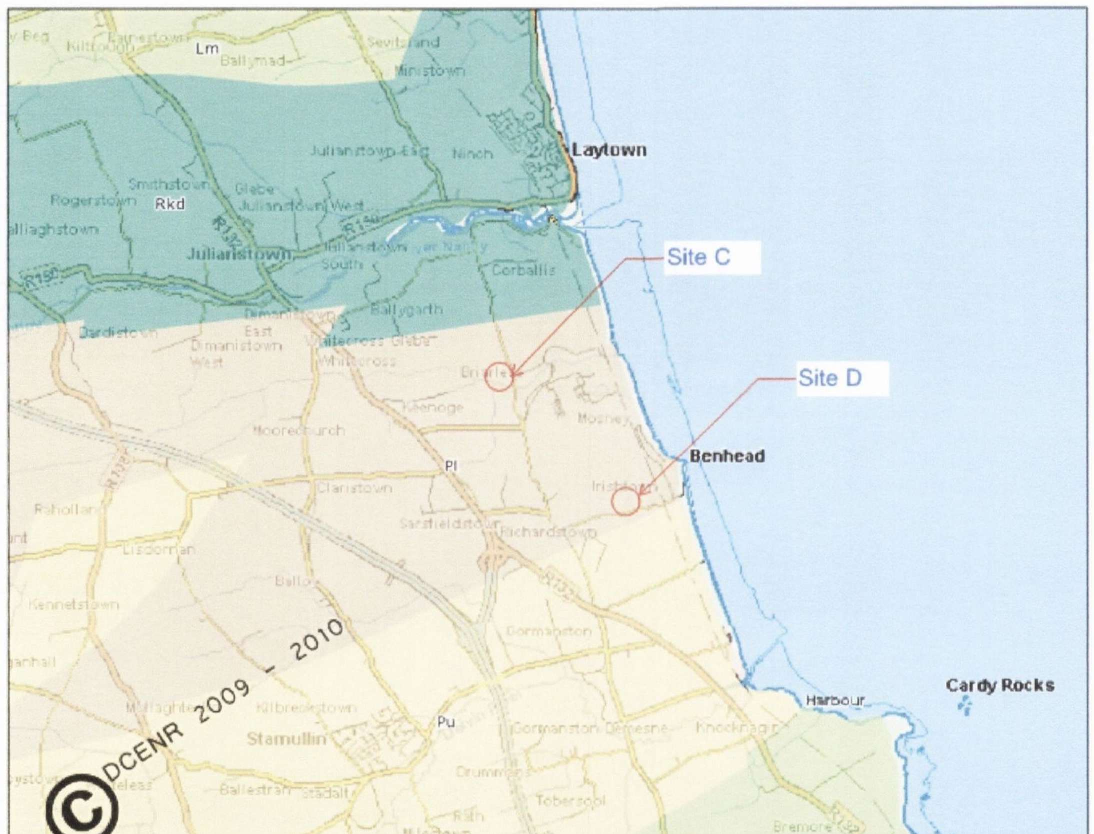
Snapshot Date: 07-Feb-2014

Site C and Site D: Meath - Aquifer Map



0 1500 3000 4500 m.

Map center: 316271, 268949

Legend

National Draft Bedrock Aquifer Map

- Rf - Regionally Important Aquifer - Fissured bedrock
- Rk - Regionally Important Aquifer - Karstified
- Rkd - Regionally Important Aquifer - Karstified (diffuse)
- Rkc - Regionally Important Aquifer - Karstified (conduit)
- Lm - Locally Important Aquifer - Bedrock which is Generally Moderately Productive
- Lk - Locally Important Aquifer - Karstified
- Ll - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
- Pl - Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones
- Pu - Poor Aquifer - Bedrock which is Generally Unproductive
- Unclassified

Scale: 1:56,887

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Snapshot Date: 07-Feb-2014

Site C and Site D: Meath - National Vulnerability

Legend

Vulnerability
- X (Rock near Surface or Karst)
- E - Extreme
- H - High
- M - Moderate
- L - Low
- Water

0 1500 3000 4500 m.

Map center: 316271, 268949

Scale: 1:56,887

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Snapshot Date: 07-Feb-2014

Site E: Westmeath - Aerial View

Legend

Watermark

Scale: 1:22,427

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Snapshot Date: 07-Feb-2014

Site E: Westmeath - Subsoil Map

Legend

RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
- Marsh
- Peat
- Scree
- Till derived chiefly from Devonian sandstones
- Till derived chiefly from Lower Palaeozoic rocks
- Till derived chiefly from Namurian rocks
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Till derived from metamorphic rocks
- Till derived from mixed Devonian and Carboniferous rocks
- Water
- Windblown sands

Watermark

0 600 1200 1800 m.

Map center: 232148, 238607

Scale: 1:22,427

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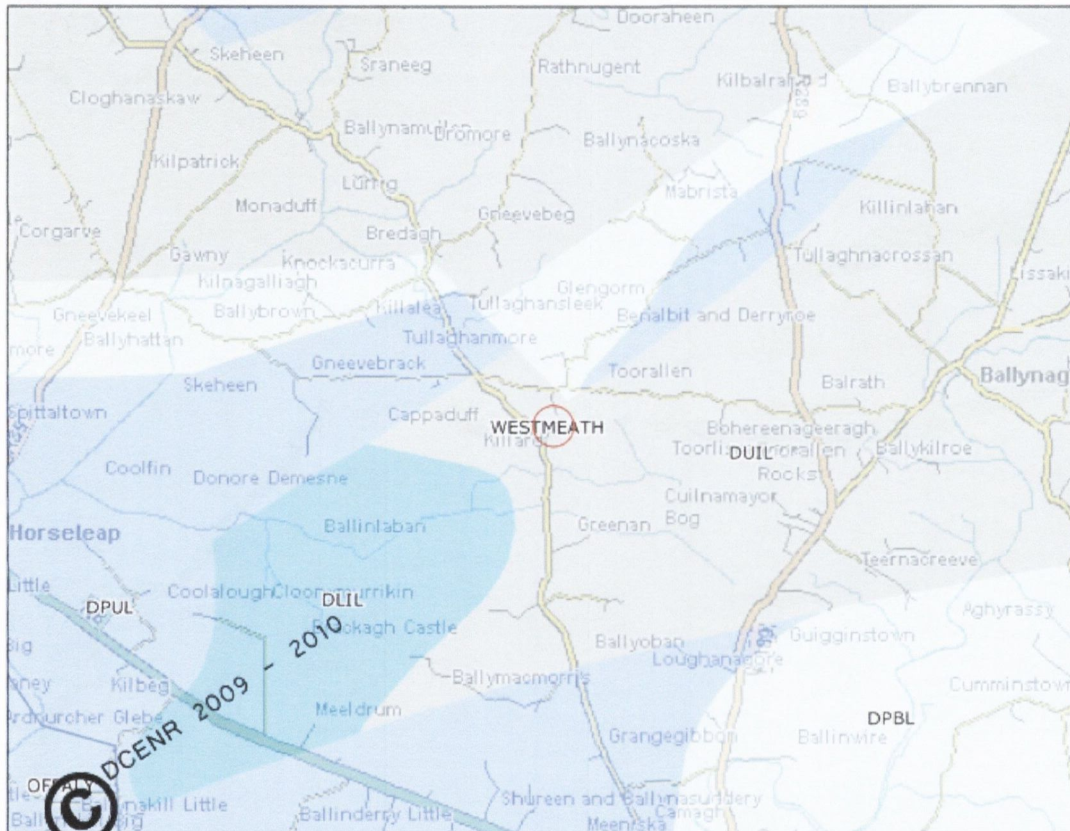
Snapshot Date: 07-Feb-2014

Site E: Westmeath - Bedrock Map



Legend

National Draft Generalised Bedrock Map

- BV - Basalts and other Volcanic rocks
- CM - Cambrian Metasediments
- DDL - Dinantian Dolomitised Limestones
- DESSL - Dinantian early Sandstones, Shales and Limestones
- DKS - Devonian Kiltorcan type Sandstones
- DLIL - Dinantian Lower Impure Limestones
- DMSC - Dinantian Mudstones and Sandstones Cork Group
- MSSL - Dinantian Mixed Sandstones, Shales and Limestones
- DORS - Devonian Old Red Sandstones
- DPBL - Dinantian Pure Bedded Limestones
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- DS - Dinantian Sandstones
- DSL - Dinantian Shales and Limestones
- DUIL - Dinantian Upper Impure Limestones
- GII - Granites and other Igneous intrusive rocks
- NSA - Namurian Sandstones
- NSH - Namurian Shales
- NU - Namurian Undifferentiated
- OM - Ordovician Metasediments
- OV - Ordovician Volcanics
- PM - Precambrian Marbles
- PQGS - Precambrian Quartzites, Gneisses and Schists
- PTMG - Permo Triassic Mudstones and Gypsum
- PTS - Permo Triassic Sandstones
- SMV - Silurian Metasediments and Volcanics
- WSA - Westphalian Sandstones
- WSH - Westphalian Shales

County Boundaries

0 1200 2400 3600 m.

Map center: 232368, 239212

Scale: 1:44,853

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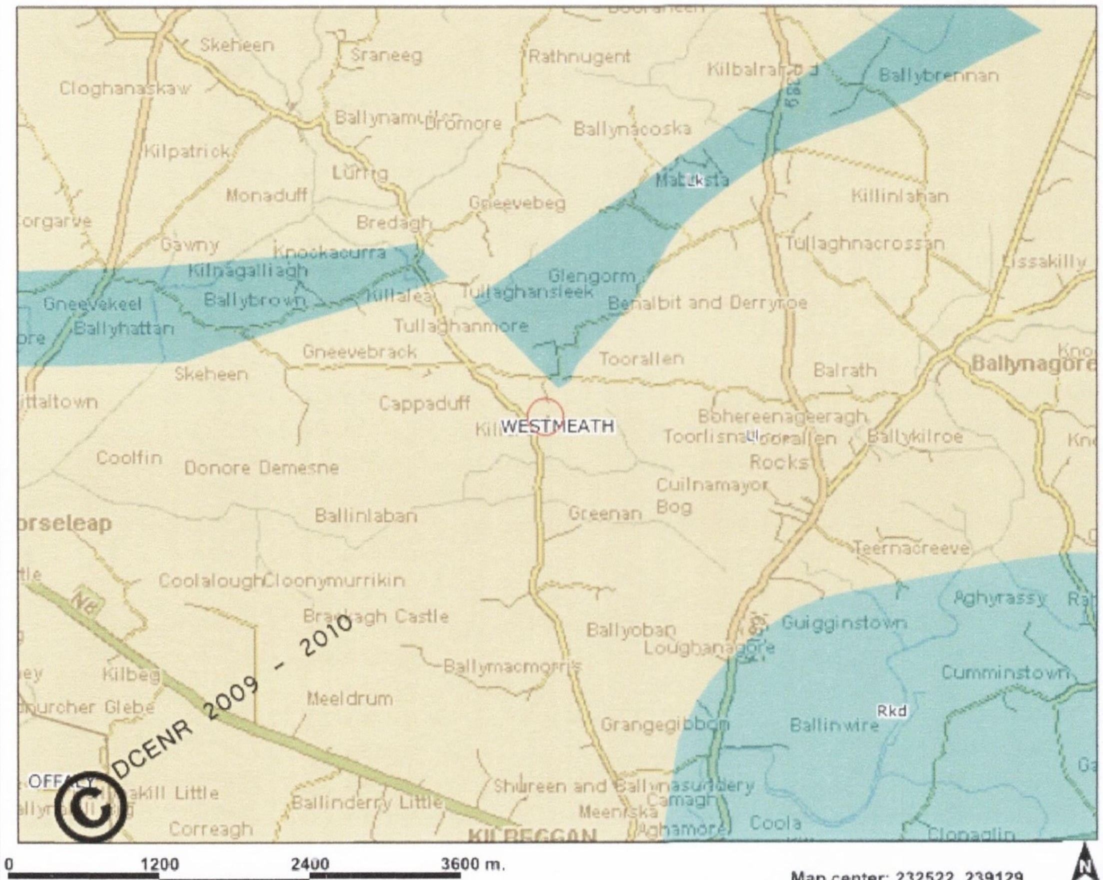
Snapshot Date: 07-Feb-2014

Site E: Westmeath - Aquifer Map



Map center: 232522, 239129

Legend

National Draft Bedrock Aquifer Map

- Rf - Regionally Important Aquifer - Fissured bedrock
- Rk - Regionally Important Aquifer - Karstified
- Rkd - Regionally Important Aquifer - Karstified (diffuse)
- Rkc - Regionally Important Aquifer - Karstified (conduit)
- Lm - Locally Important Aquifer - Bedrock which is Generally Moderately Productive
- Lk - Locally Important Aquifer - Karstified
- Ll - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
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- Pu - Poor Aquifer - Bedrock which is Generally Unproductive
- Unclassified
- County Boundaries

Scale: 1:44,853

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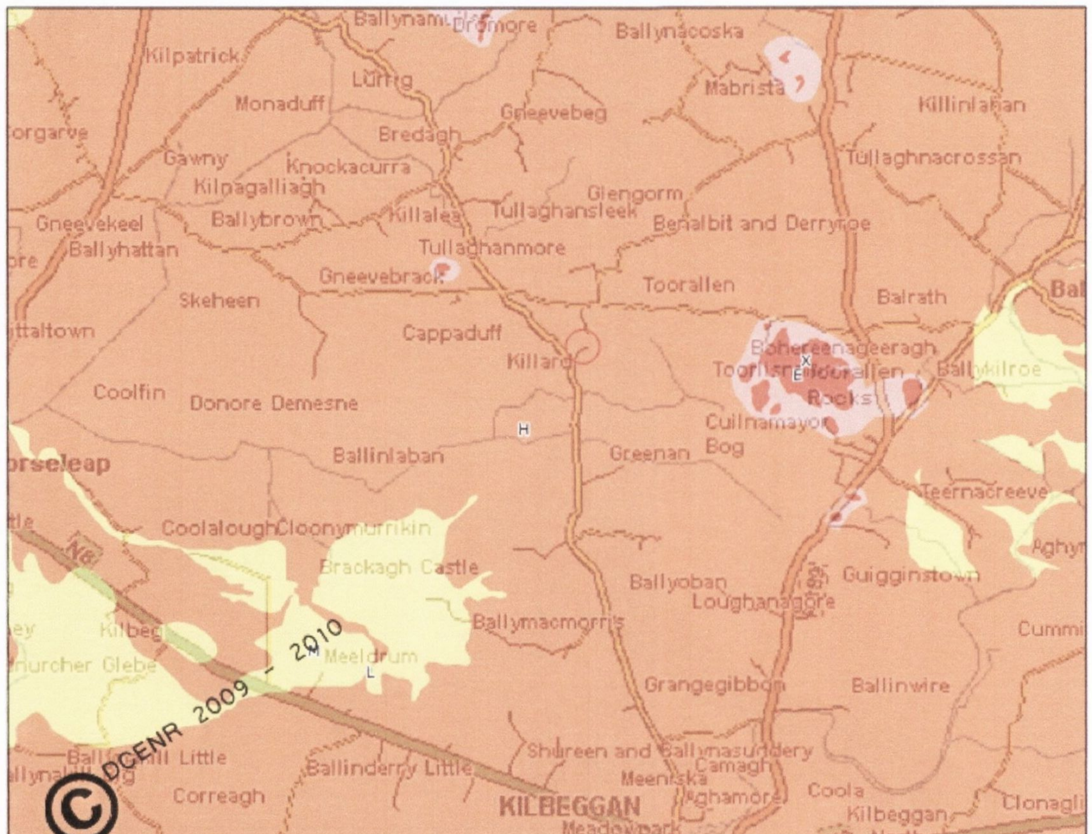
Snapshot Date: 07-Feb-2014

Site E: Westmeath - National Vulnerability



Legend

Vulnerability

- X (Rock near Surface or Karst)
- E - Extreme
- H - High
- M - Moderate
- L - Low
- Water

0 | 1100 | 2200 | 3300 m.

Map center: 232148, 238607

Scale: 1:40,972

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Snapshot Date: 07-Feb-2014

Site F: Cork - Aerial View

0 600 1200 1800 m.

Map center: 187973, 88868

N

Legend

Watermark

Scale: 1:23,855

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Snapshot Date: 08-Feb-2014

Site F: Cork - Subsoil Map

0 600 1200 1800 m.

Map center: 187916, 89486

Legend

RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Lake sediments
- Made ground
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- Peat
- Scree
- Till derived chiefly from Devonian sandstones
- Till derived chiefly from Lower Palaeozoic rocks
- Till derived chiefly from Namurian rocks
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Till derived from metamorphic rocks
- Till derived from mixed Devonian and Carboniferous rocks
- Water
- Windblown sands

Watermark

Scale: 1:23,855

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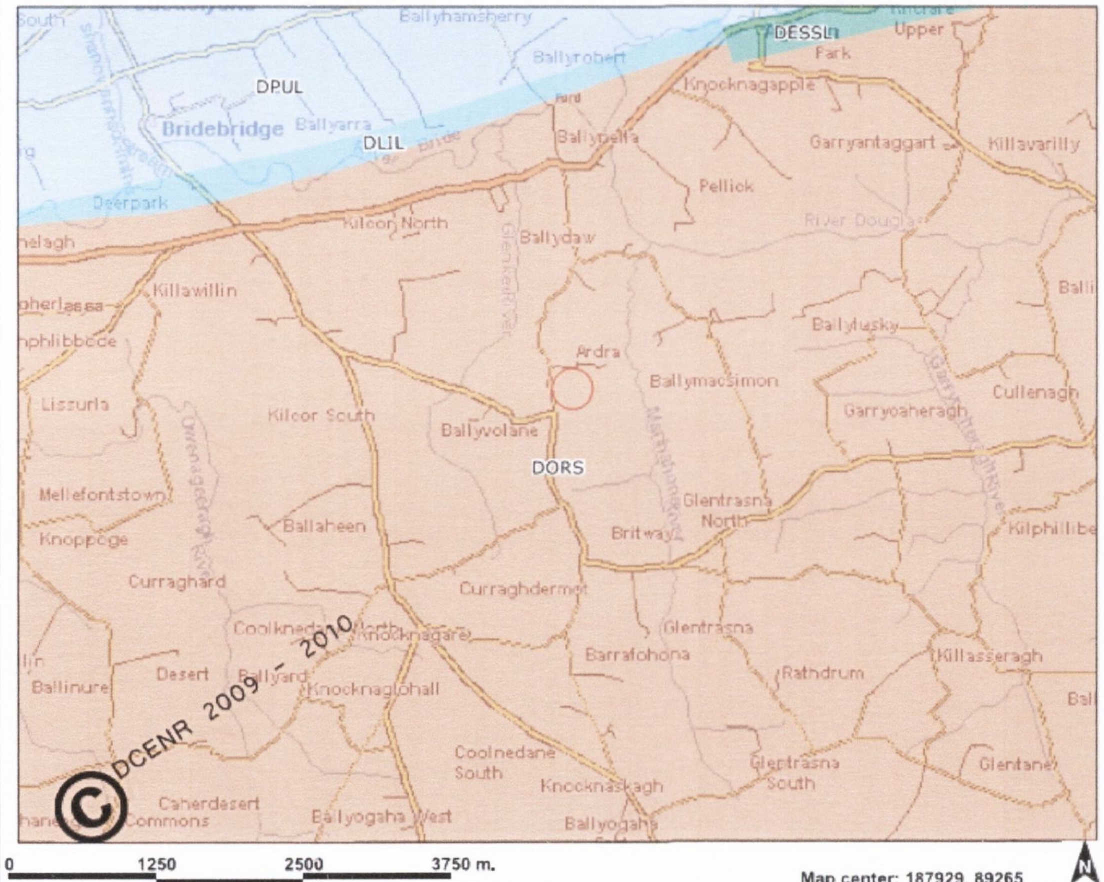
Snapshot Date: 08-Feb-2014

Site F: Cork - Bedrock Map



Map center: 187929, 89265

Legend

National Draft Generalised Bedrock Map

- BV - Basalts and other Volcanic rocks
- CM - Cambrian Metasediments
- DDL - Dinantian Dolomitised Limestones
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- PTMG - Permo Triassic Mudstones and Gypsum
- PTS - Permo Triassic Sandstones
- SMV - Silurian Metasediments and Volcanics
- WSA - Westphalian Sandstones
- WSH - Westphalian Shales

Scale: 1:47,710

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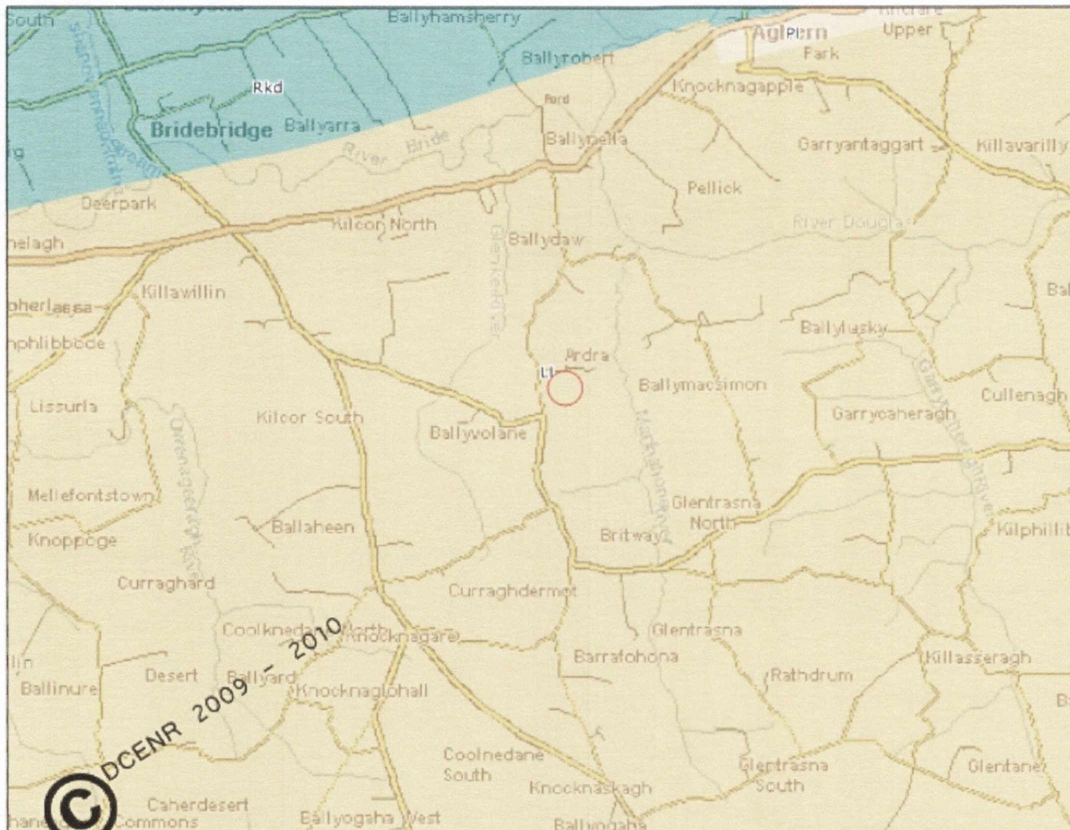
Snapshot Date: 08-Feb-2014

Site F: Cork - Aquifer Map



© DCENR 2009 - 2010

0 1250 2500 3750 m.

Map center: 187929, 89265

Legend

National Draft Bedrock Aquifer Map

- Rf - Regionally Important Aquifer - Fissured bedrock
- Rk - Regionally Important Aquifer - Karstified
- Rkd - Regionally Important Aquifer - Karstified (diffuse)
- Rkc - Regionally Important Aquifer - Karstified (conduit)
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- Ll - Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones
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- Pu - Poor Aquifer - Bedrock which is Generally Unproductive
- Unclassified

Scale: 1:47,710

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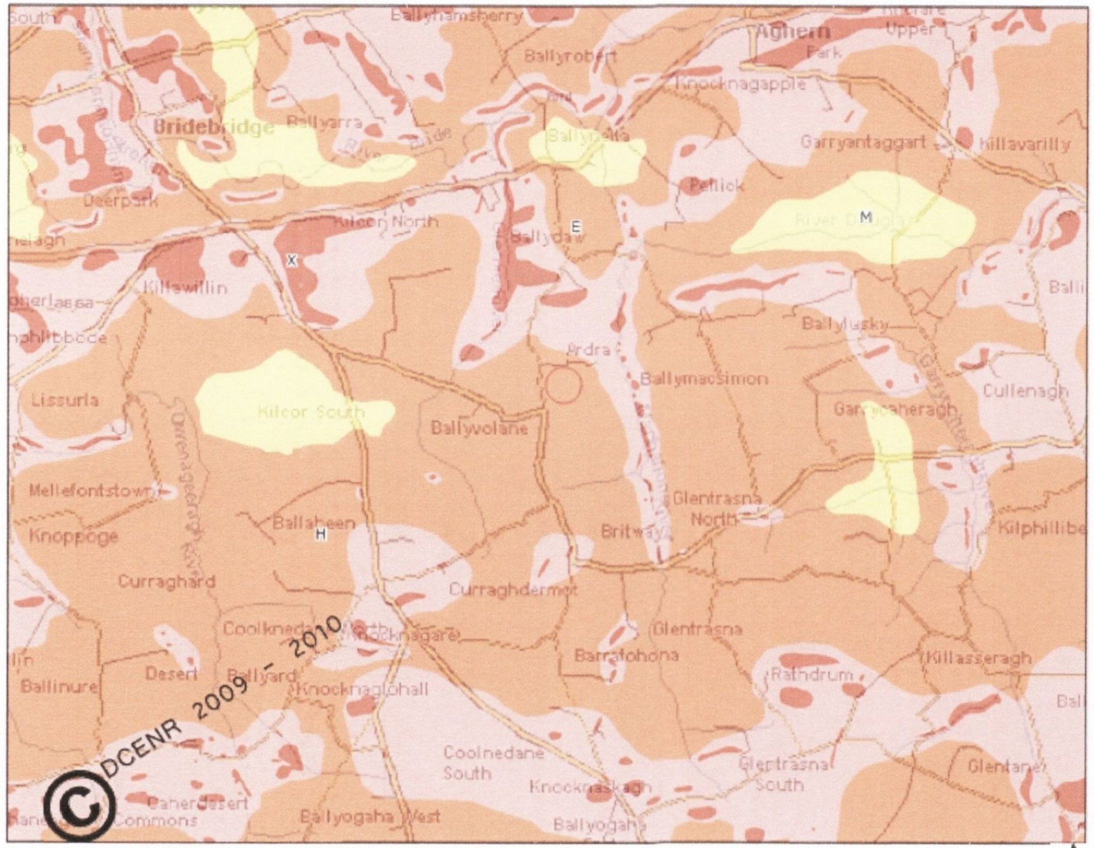
Snapshot Date: 08-Feb-2014

Site F: Cork - National Vulnerability



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Legend

Vulnerability

- X (Rock near Surface or Karst)
- E - Extreme
- H - High
- M - Moderate
- L - Low
- Water

0 1250 2500 3750 m.

Map center: 187929, 89265

Scale: 1:47,710

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Snapshot Date: 08-Feb-2014

tested, with result "not suitable"	tested, with result "suitable"	without testing found "probably unsuitable"	too far away	not interested anymore

Location	Subsoil (EPA Date)	Bedrock (GSI)	House type	Permanent occupants	Regular visitors	Est. permeability range	Comments	Date of assessment	T-test comments	standard or modified test	T-value	% silt (< 0.063 mm)	% sand (>0.063 mm, < 2 mm)	% gravel (>2 mm, < 60 mm)	auger test holes	reason for unsuitability
South Dublin	Sandstone and shales till, Lower Palaeozoic		farmers house	5	1	very low	soakaway pit	28/06/2011	level fell over night in 14 h from 300 to 200 mm	mod	≈210	49	32	19		T-value too high
Wicklow	Sandstone and shales till, Lower Palaeozoic or Cambrian, Precambrian		private house	3		moderate	soakaway in front garden, modified 12 years ago by laying gravel around the soakaway area	06/07/2011	Percolation Test Hole was not pre-soaked, soil sample taken at a depth of 550mm	std	32	29	38	34		to many stones in soil so that instrumentation wouldn't go in
Wexford	Shale till, Lower Palaeozoic		private house	2	3	very low		14/07/2011	test hole filled up to 400 mm mark with water level not changing over 3 hours	n/a	∞	69	19	11		T-value too high
Roscommon			private house	3	1		septic tank in extremely low soil permeability with 29+ years old soakaway	22/07/2011	test hole filled up to 300 mm mark with water level not changing over 2 hours	n/a	∞	49	33	18		T-value too high
Leitrim			private house	2	1		2 adults permanently living, 1 grandchild visiting almost every day, 30 year old system	10/08/2011	test hole filled up to 300 mm mark with water level not changing over 1.5 hours	n/a	∞	61	22	17		T-value too high
Cavan	Sandstone and shales till, Lower Palaeozoic or Peat		private house	7			septic tank and soakaway	12/08/2011	n/a	n/a	n/a	n/a	n/a	n/a		not enough space around the soakaway as land is owned by not coorperative farmer
Cavan	Shales and sandstones till, Namurian		private house	3		low	30-35 year old septic tank with soakaway	18/08/2011	2 test holes, 1.) in lawn 80 cm deep, 2.) in flower bed 60 cm deep with loads of boulders	std	1.) 5.08 2.) 2.44				none	not enough space around the soakaway to install instrumentation
Monaghan	Sandstone till (Devonian/Carboniferous) or peat		private house	7			dormer bungalow built in 1987	25/08/2011	test hole on top of a hill from which soakaway drains down into valley where the road is	std	<1				none	
Cavan	Shales and sandstones till (Namurian)		house with B&B	3	4 to 11	>90	soakaway going into field with plenty of space, river close by	29/08/2011	pipe comes out at top of hill into field, test hole located in valley at bottom of hill, 50 cm deep where it started to get very wet, filled up 300 mm with water	mod	80.21, 91.29, 130.68 = avg 100.79				2.3 m in valley at end of hill, further away hit stone at 0.6 m	pipe of soakaway comes out above ground level and water table with 1m during summertime is too high
Offaly	Limestone sands and gravels (Carboniferous)		private house	4			19 year old house, single 4" pipe waving from ST, 2 adults 2 children, 1 ft of topsoil followed by 1ft of coarse gravel (big stones mixed with gravel) followed by dense/compacted sandy gravel - test perforemed in this layer, first 5cm of hole drained faster possibly as it was closer to gravel layer, warm dry day (27/07/11) some rain overnight but soil still quite dry deep down, site area of 10m x 30m with possible room for expansion into veg garden & front lawn (front lawn dived by fence)	28/07/2011		mod	≈98	5	33	32		gravel layer with big stones but might be suitable
Kildare	Limestone till (Carboniferous)	Dinantian Upper Impure Limestones or maybe Namurian Undifferentiated		5		30-60	house that was built ca. 1985 with soakaway, 2 adults, 3 children, directions: Turn off M4 at Kilcock junction, head for Clane, Ballycahan is first turning right off the Clane road and we are 2km down that road.	27/09/2011		mod	>90					unsuitable T-value
Kildare	Limestone till (Carboniferous), or Alluvium undifferentiated		private house	4		30-60	2 adults 2 children, T test done 18 month ago (hole is still there), Value: unknown but low	27/09/2011		mod	>90					unsuitable T-value
Cork			private house													too far away
Galway			private house				parents house built in 1983									too far away
Cork	Sandstone till (Devonian)		private house				septic tank is 31 years old, causing no problems									
Sligo	Limestone till (Carboniferous)		private house													
Kerry	Shales and sandstones till (Namurian)		private house				house was built in 1982, its a 4 bed bungalow, 4 acre stand alone house									
Cork	Shales and sandstones till (Namurian) or peat		private house	3			house is 60 or 70 years old, septic tank about 35 years, almost certain soakaway									
Cork	Sandstone till (Devonian), or Sandstone and shales till (Devonian/Carboniferous)															
Cork			private house	3	2		built in 1977									
West Cork			private house				2 septic tank as house got extended over time, one built 1960's the other around 1985									
Louth/Meath	Sandstone and shales till, Lower Palaeozoic		farmers house	4	2	very low	actually no soakaway but a septic tank acting as cesspool, emptied twice a year (heavy rainfall noticeable)	11/07/2011	n/a	n/a	n/a	n/a	n/a	n/a		no soakaway present, septic tank used as cesspool
Galway	Limestone till Carboniferous		private house + appartment	2	1-2		only black water into septic tank, acidic river water is used for toilet flushing									probably bedrock too close to the surface, too far out, acidic water used for toilet flushing
Waterford	Sandstone till, Devonian		private house	5			**probably percolation system not soakaway** 2 adults, 3 children, system is 12-13 years old, 51.983658,-7.802718 in GPS									percolation area and not a soakaway
Kilkenny	Sandstone sand, shales and gravel		private house	3			old septic tank with soakpit, based on locally important gravel aquifer over limestone, perlorated pipe mentioned									modified soakaway with perforated pipe
Laois			private house	3			septic tank and a soakaway installed about 12 years ago, 3 or more occupants, in a limestone area, probably percolation area									probably percolation area and no soakaway
Clare				3			septic tank and soakaway, constructed approx. 15 yrs ago on a relatively low permeability soil, probably percolation area									probably percolation area and no soakaway

Clare	Karstified limestone bedrock at surface, or Limestone till (Carboniferous)				4				(Director of Water Scheme) problem of very little soil, 25 year old ST soakaway system									very little soil, bedrock might be too close to the surface
Clare	Karstified limestone bedrock at surface, or Limestone till (Carboniferous)			3 to 4														very little soil, bedrock might be too close to the surface
Westmeath	Limestone sands and gravels (Carboniferous)				3				built in 1994, 3 adults, percolation trenches									percolation trenches
Kildare	Limestone till (Carboniferous)				5				28 year old septic tank, many visitors, problem with rain water, have tank emptied at least three times a year, turned out to have percolation trenches									percolation trenches
Cavan	Sandstone and shale till (Lower Palaeozoic)		private house		3		2		percolation trenches, 2 adults, 1 child (19 years old)									percolation trenches
Cavan	Shales and sandstones till (Namurian) or Alluvium undifferentiated	Silurian Metasediments and Volcanics	private house	4					single out-flow pipe going into a large soakpit with three 4" stone drains running out from it (sounds like percolation trenches as he mentioned perforated pipes on phone), soil type is quite peaty, does rainwater harvesting and needs advice									probably percolation trenches
Kilkenny			private house	3					house from 1988 with soakaway in back garden, Postman at home in afternoons, unused old well near by	13/09/2011								not enough space in backgarden
Kilkenny			private house	4				>90	house built in 1999 with soakaway in lawn (trench filled with rubble, no pipe, leading away from soakaway), well near by, children are 21 and 23, one of them engaged the other one not likely to leave	13/09/2011								slight modification of existing soakaway
Kilkenny			private house	3					1995 with soakaway in backgarden	13/09/2011								not enough space in backgarden
Cavan	Sandstone and shale till (Lower Palaeozoic)		private house	4				20-40	4 adults with soakaway from 60th or 70th, plummer willing to help, trees in area of soakaway, river close to area	15/09/2011								septic tank on hill, area over grown by trees, wastewater collects in a pit at surface at end of hill, no space at all
Cavan									house on a hill with septic tank draining into a ditch ???? Maybe not suitable? Offered pictures, quite interested									septic tank discharges over ground into a ditch
Cork				5					North bank of the Owenbue River, house about 20m away from the high water mark 10m above sea level, there is very little space between the house and the river, with a steep gradient									far away and sounds like not enough space available
Galway				3		2			house build 1980, limestone + boggy area, follows a drain around our property and then along the roadside into the canal									probably not correct set up, far away
Kilkenny				3		2		30-60	32 years ST with soakhole at the back of the house	22/09/2011								
Kilkenny			private house	3		1		30-60	21 year old son with no sign of leaving, extended cottage on an 1/2 acre site, some space around septic tank, outlet pipe crashed so that it seeps away underneath the tank	19/09/2011								
Kilkenny			private house	6				20-40	4 children, 15 year old house with soakaway	22/09/2011								
Kilkenny			private house	2		1			house built 1989, only black water goes into ST with soakpit, 30-35 m deep well, not in use anymore									only 2 people in the house
Kilkenny				2		1-2				13/09/2011								not enough space in backgarden, only 2 people permanently
Kildare	Limestone till (Carboniferous)	Dinantian Upper Impure Limestones	private house/ farm	8				high		27/07/2011	test hole was pre soaked with water from 400 mm level down to 100 mm before starting 1st reading	std	3.5	21	53	26		bedrock close to surface, auger till 1.08 m uphill and 1.15 m downhill before hitting rock
Clare	Limestone till (Carboniferous)		private house	2	~4			high	septic tank and soakaway, wastewater backing up all the time	18/07/2011	Full T-test completed, 2 drops from 400 to 300 mm before starting reading	std	8	43	49	8		probably incorrect construction so that wastewater backs up to the house with septic tank being emptied regularly
Cavan	Shales and sandstones till, Namurian	Dinantian Lower Impure Limestones	private house	8				low	17 year old house with soakaway, 4-5 years ago dug up and put gravel in, all wastewater plus rainwater goes into the tank, area of soakaway is very muddy	18/08/2011	test hole of ca. 85cm depth filled to 300mm with test starting straight away	std	3.5				hitting stone at 1.27 or earlier at around 1m, soil very wet probably hitting water table	
Cavan	Sandstone and shale till (Lower Palaeozoic)			4 to 5		up to 10			30 year old soakaway	17/08/2011	test hole of ca. 80cm depth filled to 300mm with test starting straight away, soil sample from 70 cm depth	mod	54.2	28	52	20	1.) 1.27m, 2.)+3.) 0.6m, 4.) 1.6m with water table at 1.10m holes were situated from up to down hill on the lawn area	
Monaghan	**Sandstone till (Devonian/Carbonifero us)**	**Dinantian (early) Sandstones, Shales and Limestones**	**private house**	**4**				**30-60**	**2 adults 2 children (14, 17), soakaway in field next to house owned by father**	**25/08/2011**	**test hole in field, 80-85 cm deep, filled up to 300 mm with water, not pre soaked, test started straight away**	**mod**	55, 90, then slowed down 25 mm in 4h30min, avg 73	**31**	**30**	**39**	**1.33 m when caught in stone (maybe not bedrock yet), 1.3 m and 1.2 m further down the field**	**SUITABLE! INSTALLATION OF LYSIOMETERS MIDDLE OF SEPTEMBER**
Tipperary	Shales and sandstones till, Namurian		private house	3				30-60	33 year old system, some trees in back garden where septic tank is, soakaway probably going into next field, cattle and bulls in the field, possibility to fence a part off	08/09/2011	test hole in the back garden close to septic tank 75cm deep but soakaway goes into next field, couldn't be tested because bulls in the field that day, soil was very compact and dry, not pre-soaked, test started straight away at 300 mm	std	9.5, 11, 13, avg 12				none yet b/c bulls in field, maybe during winter time when field empty	

Kilkenny	Till derived from Namurian sandstones and shales, and generally dominated by CLAY (Robert)		private house	3		> 90 (in a lower backslope landscape position close to a floodplain. Gleyed soils generally.)	2 adults 1 teenager (13), 22 year old house with soakaway in seperate back garden with big area wild lawn, damp with some problems of backing up, next field owned by brother in law		13/09/2011	75.15	
Kilkenny			private house	2 (retired)	up to 4	60-90	20 year old house with sookpit in open field (geese in field), impermeable soil, dampness in wintertime, needs regular attention, retired civil servant anytime for visit except for Tuesday		19/09/2011	50.13	
Carlow	Granite till or Sandstone and shales till, Lower Palaeozoic		private house	2		20-40					
Cavan	Sandstone and shale till (Lower Palaeozoic)		private house	1 to 3		>90	soakaway from 1968, rainwater goes in ST as well				
Cavan	Sandstone and shale till (Lower Palaeozoic) or peat			7		20-40	27 year old soakaway in a lawn	not very nice on phone			
Cavan	North of N87: Shales and sandstones till (Namurian), South: Chert and Carboniferous sandstone till			6		>90	septic tank from 1964, few trees around, good soakage				
Cavan	Sandstone and shale till (Lower Palaeozoic)			5		20-40	soakaway from 1995, interested in outcome in general		03/07/2012		
Cavan	Sandstone and shale till (Lower Palaeozoic)		private house	5		>90	soakaway with loads of stones but still not working efficiently, poor drainage area with high % clay, 53.813537,-7.128376				
Cavan	Shales and sandstones till (Namurian)		private house	5		>90	30 year old soakaway				
Cavan	Sandstone and shale till (Lower Palaeozoic), or peat		private house	5		30-60	22 year old house with soakaway				
Cavan	Chert and Carboniferous sandstone till or peat		private house	5		>90	20 year old house with soakaway in garden, also interested in eco-friendly water saving devices - bring further info				
Cavan	Shales and sandstones till (Namurian), or peat, or Alluvium undifferentiated			4		30-50	4 adults, 28 year old soakaway				
Cavan				4			14-15 year old soakaway				
Cavan	Sandstone and shale till (Lower Palaeozoic)		farmers house	4		>90	2 adults, 2 children, 50 year old soakaway going into farmland				
Cavan	Sandstone and shale till (Lower Palaeozoic) or peat	Silurian Metasediments and Volcanics	private house	4		>90	visitors at weekends, house built 1995 with soakaway, greywater is going outside of septic tank to the soakaway, system never caused trouble				
Cavan	Limestone till (Carboniferous)	Dinantian Shales and Limestones or Dinantian Lower Impure Limestones	private house	4		>90	house from the 60s, soakaway at end of garden (not sure if enough space)				
Cavan	Sandstone and shale till (Lower Palaeozoic) or peat		private house	4		30-60	18 year old house with soakaway going into field owned by householder		03/07/2012		soakaway area covered with gravel, soakaway set up dubious
Cavan	Chert and Carboniferous sandstone till (like willow site in Leitrim)			3		>90	1 adult, 2 children, 30 year old soakaway				
Cavan	Sandstone and shale till (Lower Palaeozoic)	Silurian Metasediments and Volcanics	private house	3		20-40	50 year old soakaway in garden				
Cavan	Sandstone and shale till (Lower Palaeozoic)		old farm house	3		>90	100 year old soakaway, 1 acre of land	very nice			
Cavan	Sandstone and shale till (Lower Palaeozoic)			3			33 year old Bungalow on hill with soakaway, trees in the area of soakaway				
Cavan	Sandstone and shale till (Lower Palaeozoic)	Ordovician Metasediments	private house	3		30-60	about 100 year old house				ST under trees and exact location of soakaway not known - not obvious where it could go, driveways in the way
Cavan	Chert and Carboniferous sandstone till	Dinantian Lower Impure Limestones	private house	3		>90	45 year old soakaway				
Cavan	Sandstone and shale till (Lower Palaeozoic)	Ordovician Metasediments		3	1	>90	house over 100 years old, septic tank 30 years old with soakaway going into field owned by householder, needs emptying once in a while (last time 18 month ago)				
Cavan	Sandstone and shale till (Lower Palaeozoic)			3		30-60	2 adults, 3 year old child, house from 1977 with soakaway going into field at back of the house, haven't moved in yet but probably by mid or end September		03/07/2012		ST on border of field, soakaway location not exactly known, hedge and other field in the way when trying to monitor in all directions, WT hit within 1 m when auger testing
Cavan	Limestone till (Carboniferous) or Sandstone and shale till (Lower Palaeozoic)		private house	3		30-60	50 year old soakaway in wild garden, few trees				
Cavan				2							
Cavan	Shales and sandstones till (Namurian), or Chert and Carboniferous sandstone till (like Leitrim willow site)			2	2	>90	20+ year old house and soakaway in neighbours field (go ahead from neighbour), on holidays probably till mid september				

Cavan	Shales and sandstones till (Namurian)	Silurian Metasediments and Volcanics	private house	1	2	>90	almost most weekends up to 3 people, house is 42 years old, 4 bedrooms, 3 toilets							
Cavan														
Cavan				1	yes		5 family and 8 grandchildren in total who are visiting, 30 year old house possibly with soakaway in an 1 acre field							
Clare	Shales and sandstones till (Namurian), peat or rock at surface	Namurian Undifferentiated		3		>90	soakaway from 1974							
Clare	Sandstone till (Devonian), Sandstone sands and gravels (Devonian) or peat	Devonian Old Red Sandstones	private house			30-60, but in peat								
Clare/Limerick	Sandstone till (Devonian)	Dinantian Pure Unbedded Limestones	private house	4	2	>90	septic tank and soakaway from 1983, almost 1 acre site, call by any time we are around that area							
Cork	Sandstone till (Devonian)	Devonian Old Red Sandstones		at least 3		20-40		12/02/2012						
Cork	Sandstone till (Devonian)	Devonian Old Red Sandstones		5 to 6		10-30	soakaway going into a field	12/03/2012						messy system in the middle of his farm working area
Cork	Sandstone sands and gravels (Devonian), or Alluvium undifferentiated		private house	7		20-40	soakaway from 2000, PhD student in UCC working on constructed wetlands, pictures of site in email, good percolation							
Cork	Sandstone till (Devonian)	Dinantian Pure Unbedded Limestones	farmers house	5		20-40	house from the 1970s over limestone bedrock, free draining	maybe not anymore						
Cork	Sandstone till (Devonian)	Devonian Old Red Sandstones		5		20-40	house built in 1985, with soakaway going into a field with space around for monitoring, well downhill at the side of the field, many stones in field	visit on 12/03/2012 tested on 22/03/2012	many big stones, test hole as good as possible, 70 cm deep, water level drops from 400 to 300 mm: 1.) 17 min, 2.) 24 min, 3.) 30 min, 4.) 32 min, 5.) 38 min	std	mean out of 6, 7.5, 8, 9.5 = 7.75			too many rocks, not exact location of soakaway known
Cork	Rock at surface or Sandstone till (Devonian)	Devonian Old Red Sandstones		5		>90 (on floodplain)	2 adults, 3 children, house built in 1989							
Cork	Sandstone till (Devonian), rock at surface or Alluvium undifferentiated	Dinantian Pure Unbedded Limestones or Dinantian (early) Sandstones, Shales and Limestones	farmers house	5		20-40	house from 1988 with septic tank and a soakaway in a field owned by them, only black water goes into ST and is dug down to weathered shale bedrock, well about 500 m away	visit on 12/03/2012						soakaway straight into bedrock
Cork	Sandstone till (Devonian)	Devonian Old Red Sandstones	private house	5		20-40	37 year old house with soakaway, 2 adults + 3 children (aged 23, 20, 16)							
Cork	Sandstone till, Devonian	Devonian Old Red Sandstones	private house	4		10-30	house between 50 and 100 years old, location of soakaway pipe is not exactly known, drainage apparently excellent, 2 adults and 2 children with 3rd on the way							
Cork	Sandstone till, Devonian	Dinantian Pure Unbedded Limestones	private house	4		10-30	house built in 1990							
Cork	most likely Sandstone till, Devonian	Devonian Old Red Sandstones	private house	4		20-40	soakaway 30+ years old, into open lawn area							only 2 occupants, 3 hours away from Dublin
Cork	Sandstone and shale till, Cambrian/Precambrian	Devonian Old Red Sandstone or Dinantian Mudstones and Sandstones (Cork Group)	private house	4		10-30	40 year old soakaway							
Cork	most likely Sandstone till, Devonian	Devonian Old Red Sandstones	private house	4		20-40	20 year old system with soakaway in lawn							
Cork	Sandstone till (Devonian)	Dinantian Mudstones and Sandstones (Cork Group), or Dinantian Lower Impure Limestones	private house	4		10-30	4 bedroomed dormer bungalow built in 1995, first with percolation area not working and transformed to soakaway (see email)							
Cork	Sandstone and shales till (Devonian/Carboniferous)			4		20-40	septic tank system 20+ years old in a lawn area							
Cork	Sandstone till (Devonian)	probably Dinantian Pure Unbedded Limestones		4	2	10-30	soakaway in lawn area, washing maschine goes into own soakaway, 4 adults and grandchildren visiting regularly							
Cork				3	2		3 permanent and 2 in College back at weekends and during summer, house built in 1995 with soakaway	visit on 12/03/2012						no proper set up
Cork	Sandstone till (Devonian)	Dinantian Pure Unbedded Limestones, or Devonian Old Red Sandstones	private house	3		20-40	soakaway 30+ years old							
Cork	Sandstone till (Devonian)	Devonian Old Red Sandstones		3		20-40	septic tank from 1980							
Cork			private house	3		>90 (on floodplain)	10 year old house with soakaway							
Cork	probably Sandstone till (Devonian)	probably Devonian Old Red Sandstones		3			septic tank in operation for approximately 30 years, soakaway							
Cork	Sandstone and shales till (Devonian/Carboniferous), or Alluvium undifferentiated	Namurian Sandstones	private house	3	1	30-60	35 year old house on 1/2 acre site with soakaway going into field, part is owned, Green School coordinator, going to build a house on 20 acre in environmental friendly way							
Cork	Sandstone till (Devonian)		private house	3		30-60	house from 1977 with soakaway going into field outside hedge, owned by householders, damp around soakaway, rather poor drainage							
Cork	Sandstone till, Devonian or Sandstone and shales till, Lower Palaeozoic		private house	2	2	30-60	second soakaway dug in 1991, 2 visitors (children) coming home usually once a month							
Cork	Shales and sandstones till (Namurian)	Namurian Undifferentiated		2		30-60	system from 1988 but fed only since 2005							

Cork	Rock at surface or Shales and sandstones till (Namurian) or Alluvium undifferentiated					>90						
Cork	Sandstone till (Devonian)	Devonian Old Red Sandstones	private house			10-30	septic tank and soak-away were constructed in 1982 and service a four-bed bungalow		19/04/2012 82cm test hole, very few stones	9.25, 11, 13, avg = 11		bedrock too close to surface
Cork	most likely Sandstone till, Devonian	Devonian Old Red Sandstones										
Cork							built in 1972					
Kilkenny	Shale till (Lower Palaeozoic)			3			built in the mid 1970s with soakaway, never trouble with septic tank					
Laois	Limestone till (Carboniferous)			3	2	3-10	built in 1984, from tank it drains by way of 100mm wavin pipe with about 10 holes drilled in it at equal intervals, old postgraduate of Paul Johnston					
Limerick	esker sands and gravel		private house	4		15-35	soakaway around 40 years old, into a field					
Limerick			private house	3	1		1 college student back at weekends and during summer, 35-40 year old house with soakaway in big field, 61 year old divorsed women worries about finances					
Limerick	Limestone till (Carboniferous)			3		15-35	house was built in 1936, horse training yard behind the house on the same 2 acre site					
Limerick	Sandstone till (Devonian), or Sandstone sands and gravels (Lower Palaeozoic/Devonian)			3		3-15	3 adults, house built 1997/98, single pipe to culvert with a manhole where it looks like two drains spread out to the end of the garden					
Limerick	Sandstone till (Devonian)		private house	2	1	60-90	house was built in 1985 with septic tank and soak pit, soakaway are redone at some point, land does not have great soakage with risk of flooding, 2 adults full time plus daughter min 3 days a week sometimes more					
Longford							bought house 15 years ago and doesn't know what comes after septic tank					
Mayo	Basic esker sands and gravels, or Sandstone till (Devonian), or Limestone sands and gravels (Carboniferous)		farmers house	3		<1	35 year old system, never gave problems, soakaway at side of house in green area with possibly some trees	very nice				
Monaghan	Sandstone till (Devonian/Carboniferous)		private house	3 to 4	3 to 4	20-40	37 year old house with soakaway					
Offaly	Limestone till (Carboniferous)			5		20-40	soakaway					
Sligo	peat or sandstone and shales till, Lower Palaeozoic		private house	2	1	>90						
Tipperary	Limestone till (Carboniferous), or Shales and sandstones till (Namurian)		private house	3		20-40	house built in 1995, effluent is going down one pipe into a field and into a pit dug into the ground	visited				field owned by Nama and not exact location of soakaway known
Waterford	Sandstone till (Devonian)			7		10-25	20 year old house, always had problems with the soakage and just last year we dug in all up and attempted to rectify the problem but that still didn't work					
Waterford	Acid volcanic till or rock at surface		private house	4		>90	living there for 20 years, old septic tank and soakaway					
Waterford	Sandstone and shale till, Cambrian/Precambrian or Lower Palaeozoic		private house	3		10-25	35 year old septic tank with soakaway in garden with trees present, 2nd soakaway dug where water comes from 1st soakaway into 2nd one, soakage would be moderate and did cause runoff with more occupants					
Westmeath	chert till or sandstone and shales till Cambrian/ Precambrian		private house	3		30-60, but in peat						
Westmeath			private house	2	?		house is over 35 years old, regularly weekend visitors					
Wexford	Shale till (Lower Palaeozoic)		farmers house	5		60-90	Combined from 3 small houses (family) of old Farmhouse from 1972, 4 adults, 1 Baby					
Wexford	Shale till, Lower Palaeozoic or Sandstone and shales		private house	3			parents house with septic tank and soakaway, he did site assessor and will carry out percolation test					
Wexford	Shale till, Lower Palaeozoic or Sandstone and shales		private house	2	2	>90	old soakaway with a septic tank installed in 1983, 2 students away during term weeks					
Wicklow	Sandstone and shale till (Lower Palaeozoic) with patches of Limestone sands and gravels (Carboniferous)		farmers house	6		3-10	50 acre farm, 4 adults, 2 children, also parents (John and Jessica Harington) house uses septic tank, Jessie: +353 87 256 6129 John: +353 87 255 8944		03/07/2012			
Wicklow	igneous till or Sandstone and shales till, Lower Palaeozoic		private house	4		3-10						
Wicklow			private house	5			house was built in 1983					
Cavan			private house	4		>90	2 adults, 2 children (18, 15) cottage over 100 years old, been extended, own the land all round the septic tank plus subsequent fields after the tank as it goes down the hill for the soak away, private well 90 yards down the field, seem to be very ecological minded people					

Cavan		private house	4		>90	2 adults, 2 children, 35 year old house with soakaway, quite a lot of trees around, effluent going from end of garden into little forestry area				
Clare					1-5 (but in rock)					
Louth			6		3-15 (but high water table)	house built in 1975 with soakaway at end of garden going into field, trees behind it and to the side of it, near to beach				
Cork		private house	3	1	10-30	37 year old house with soakaway, 3 people but grown up child could leave, not visiting before 24th Sept				
Kilkenny		private house	3	1	30-60	14 year old septic tank with soakaway, position needs to be checked with builder, enough space in the back, some trees but still open enough	19/09/2011			
Kildare					3-10					
Cork			5		15-35	8 to 9 year old system with soakaway, percolation bed of 2" stone – not percolation trenches, with 1 outlet pipe from the tank to the middle of the bed				
Cork			6		30-60 (but on floodplain)	three acre site in a rural area, 20 year old house, not sure about system as bought second hand but probably soakaway in field next to house				
Cork			3	yes	10-30	house and septic tank from ca. 1978, very interested in general, pictures in email				
Cork			3			house built in1983 with soakaway in lawn area, on coast road about a mile and a half from Garryvoe, it is on the next turn down to the sea after Ballywilling Strand				probably too far away
Galway			3		3-10	34 year old house with soakaway in field next to house (sometimes used for cattle)				
Cavan			2	1	>90	early 70s, varies a lot can be up to 4, backgarden, 1/2 acre				
Wexford	Limestone till (Carboniferous) with matrix of irish Sea Basin origin, or Acid volcanic till with matrix of irish Sea Basin origin				>90 (but in rock)					
Limerick		farmers house	3	1		very annoying guy, has bungalow from 1992 with percolation area and two story house with soakaway but unoccupied, didn't want to understand that not of use				
Limerick			6 to 9			might be a percolation area but not sure, house built in 1980				
Cork			8 (not permanent)			26 year old system but unclear how set up, mention of second tank				
Cork	most likely Sandstone till, Devonian	farmers house	4		20-40	2 adults, 2 children, soakaway 15 to 20 years old, into a field				

APPENDIX B

Laboratory Test - Ceramic Lysimeters
11/07/2014

Introduction
Suction lysimeters with ceramic cups were tested to determine the potential interference of ceramic sorption of orthophosphate and filtration of bacteria (Total Coliform and *E. coli*).

Method
Secondary treated effluent (SE) from a domestic household was used for the laboratory test.

In order to determine the impact of the ceramic material 3 lysimeters were submerged in 3 different dilutions of the SE as shown in Figure 1. The age (i.e. how long the lysimeter had been used on-site prior to the test) was also varied to determine if this had any impact on the degree of sorption or filtration observed.

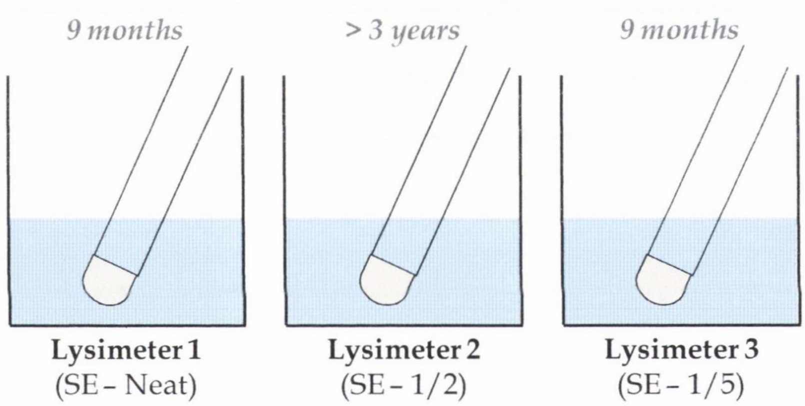


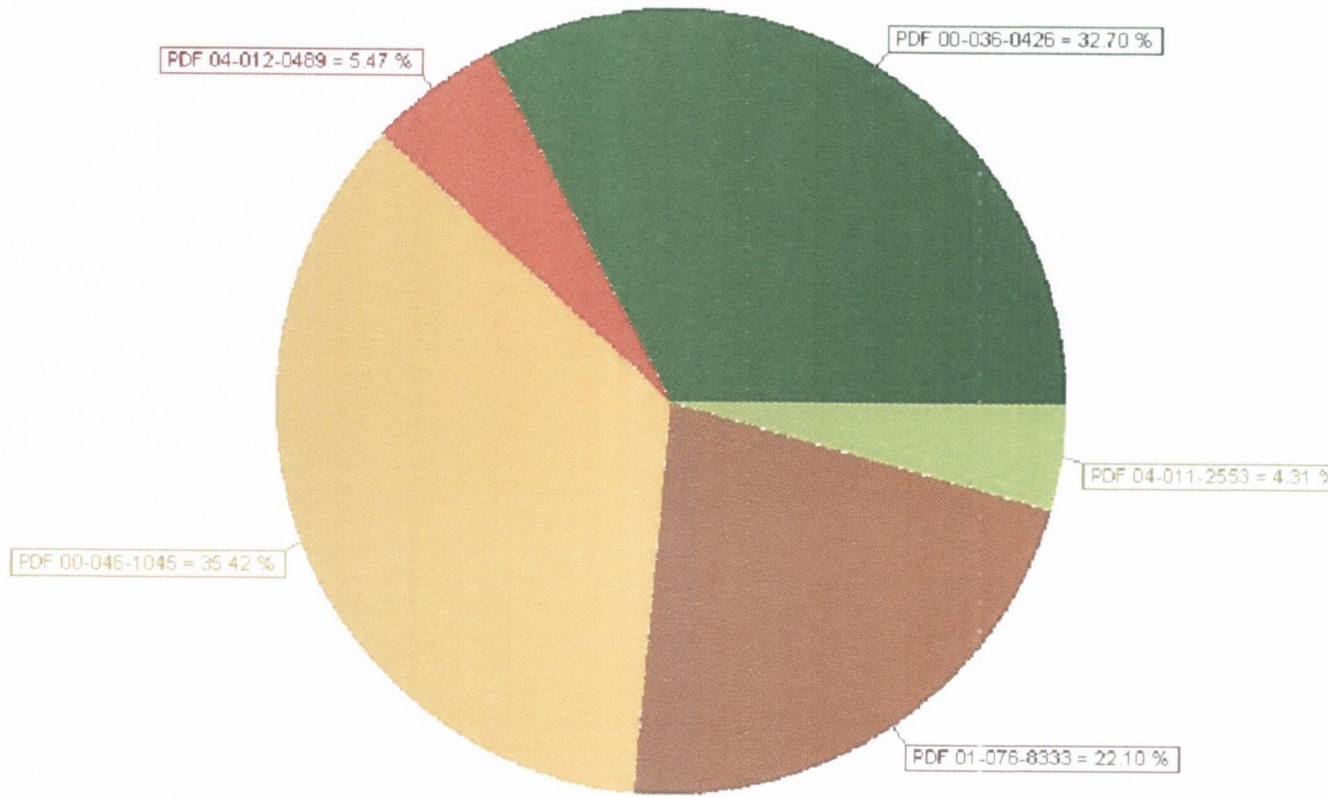
Figure 1 Testing apparatus showing dilution factors and age of lysimeters

All 3 lysimeters were put under a suction of 0.5 bar (50 kPa) using a vacuum-pressure hand pump for 24 hours during which time the ceramic cup remained submerged in the SE solutions.

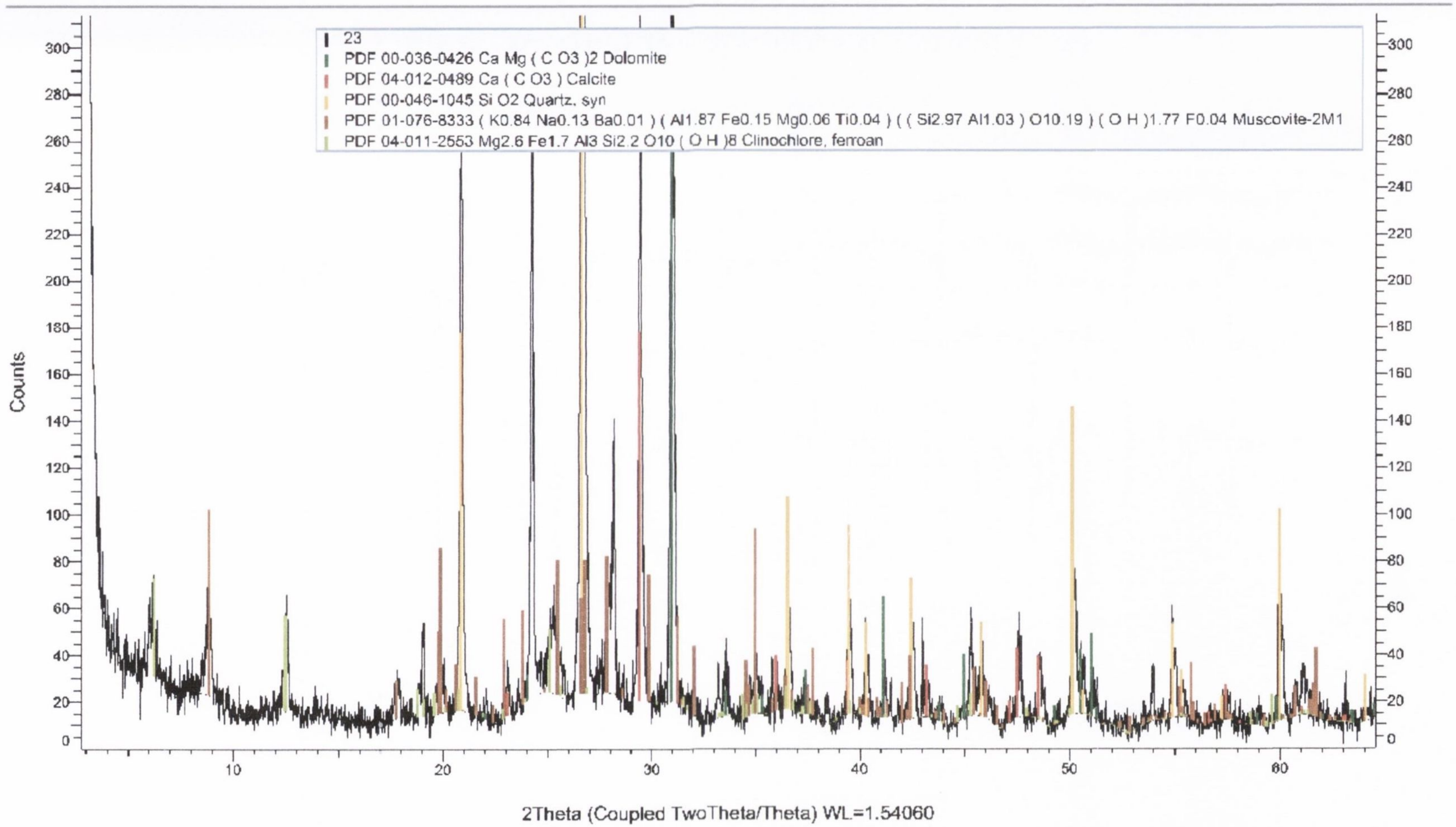
At the beginning of the test the initial SE concentration of orthophosphate and bacteria (Total Coliform and *E. coli*) were measured as follows:

Table 1 Initial concentrations of SE used for test

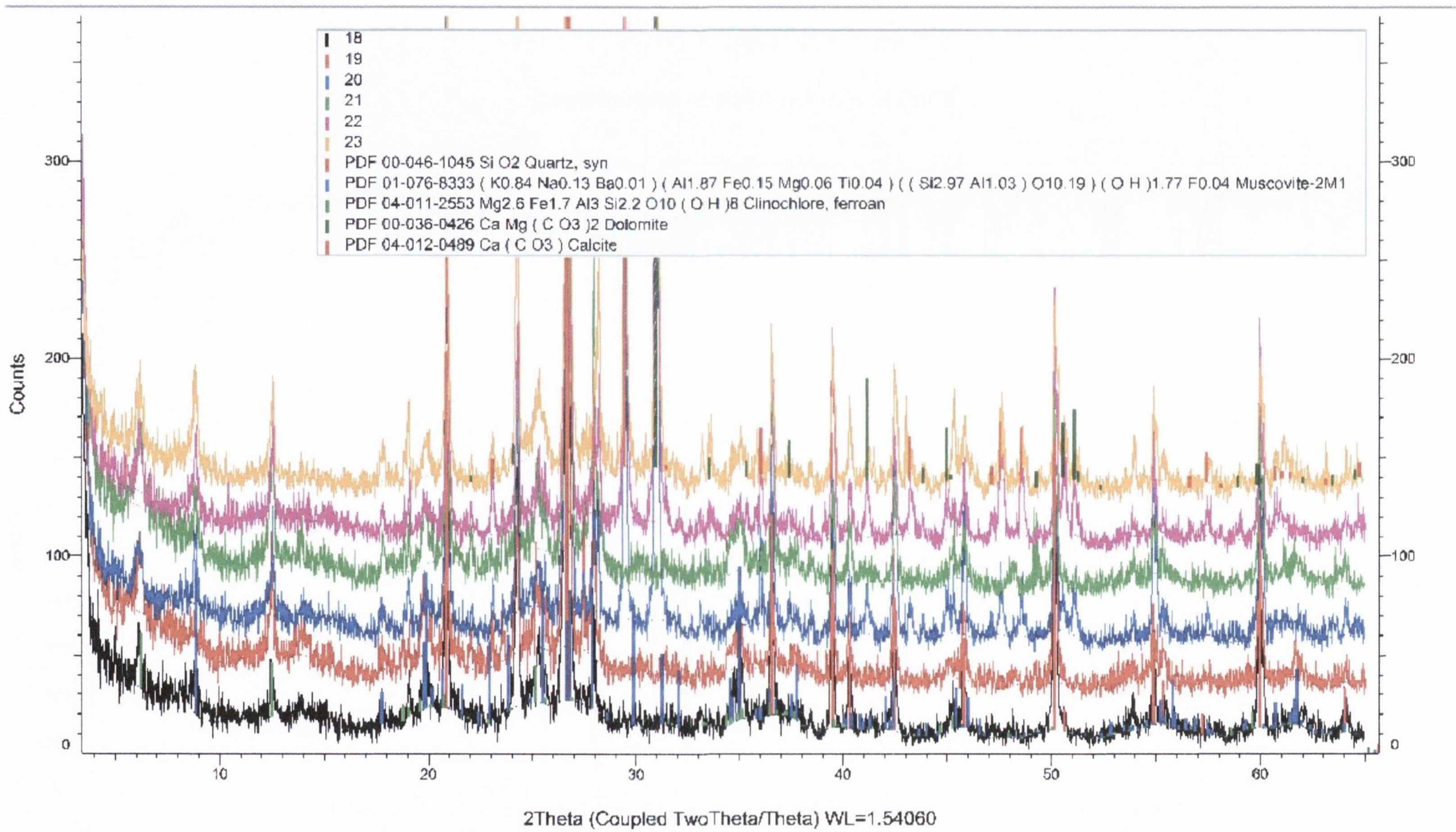
Initial Concentrations of STE		
Orthophosphate	9.5	*mg* L^{-1}
Total Coliform	3.6×10^6	*MPN per 100 ml*
E. Coli	3.2×10^6	*MPN per 100 ml*



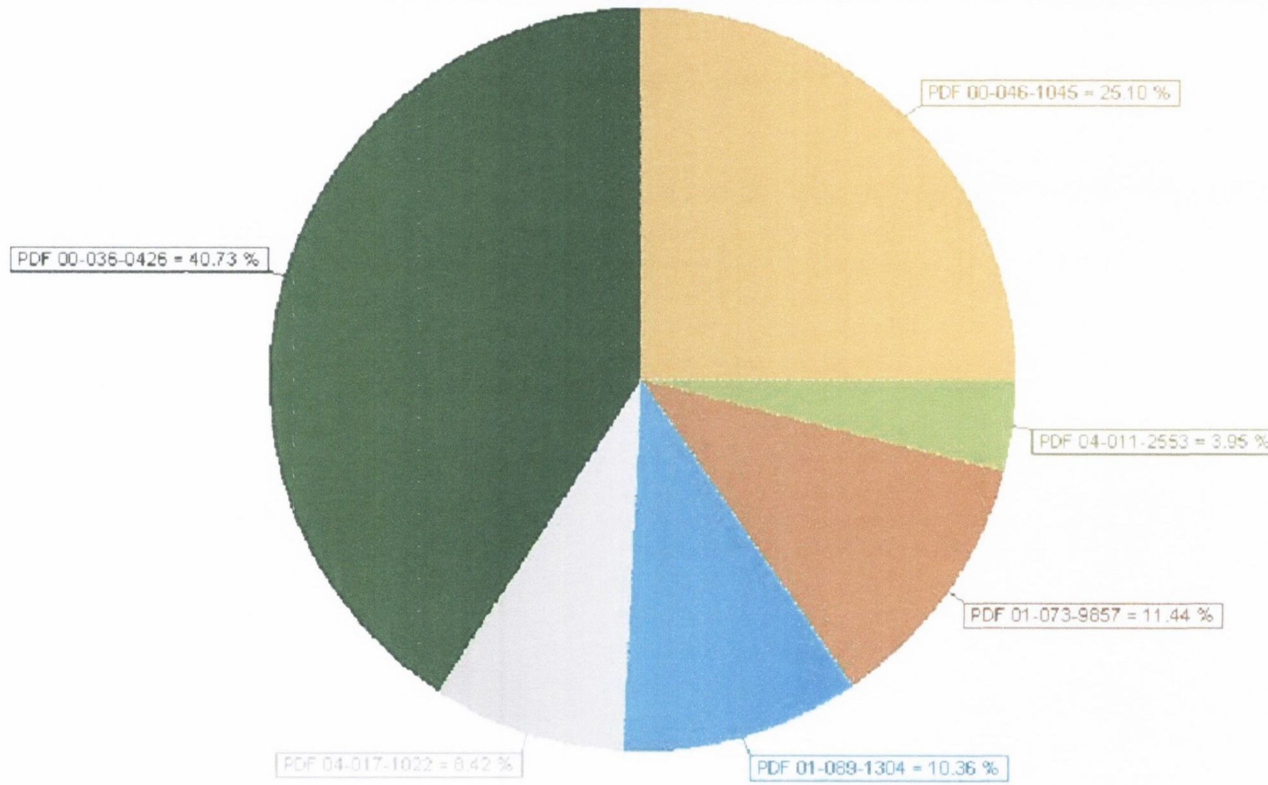
Site A - Kilkenny



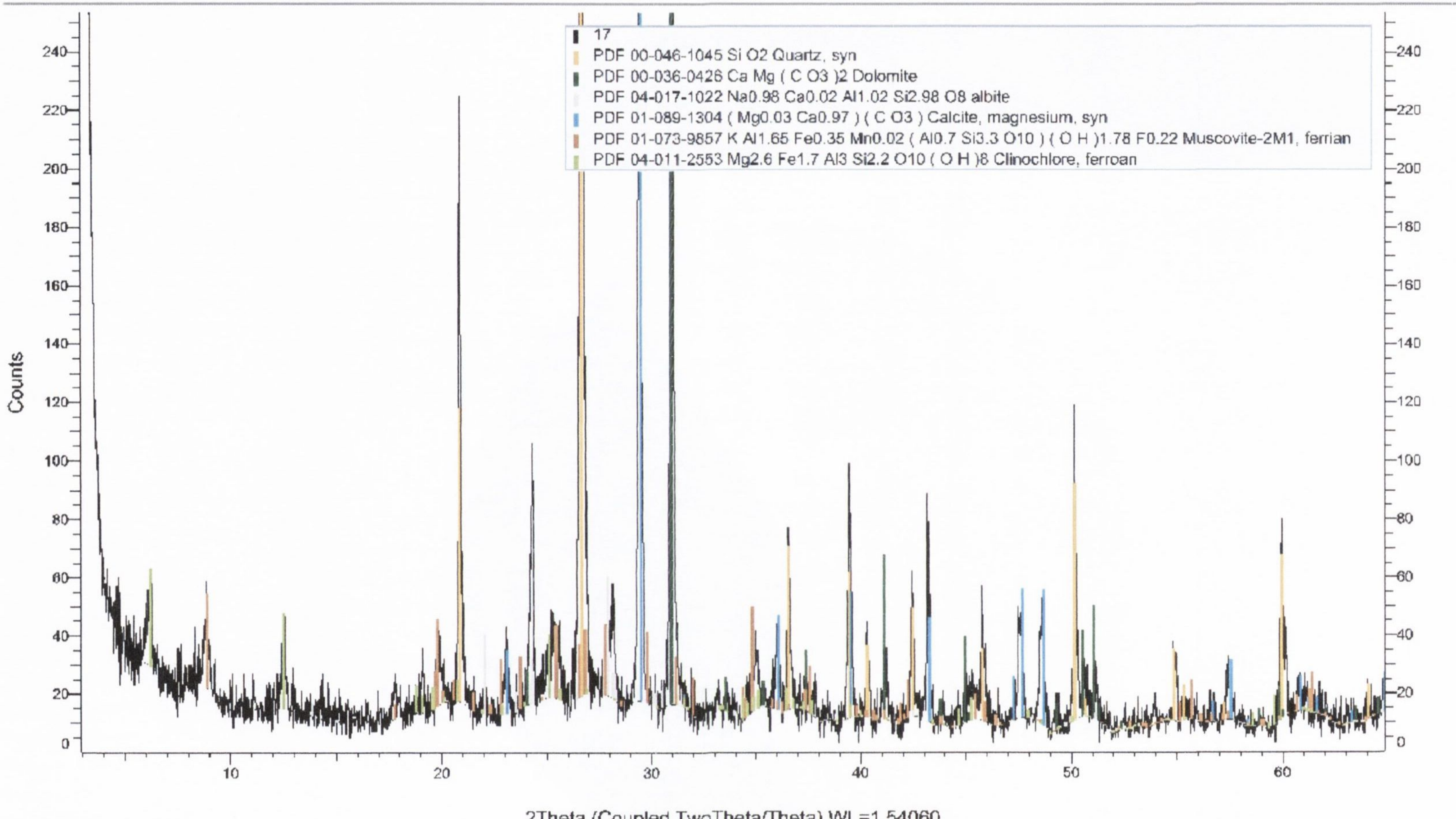
Site A - Kilkenny (2 m)



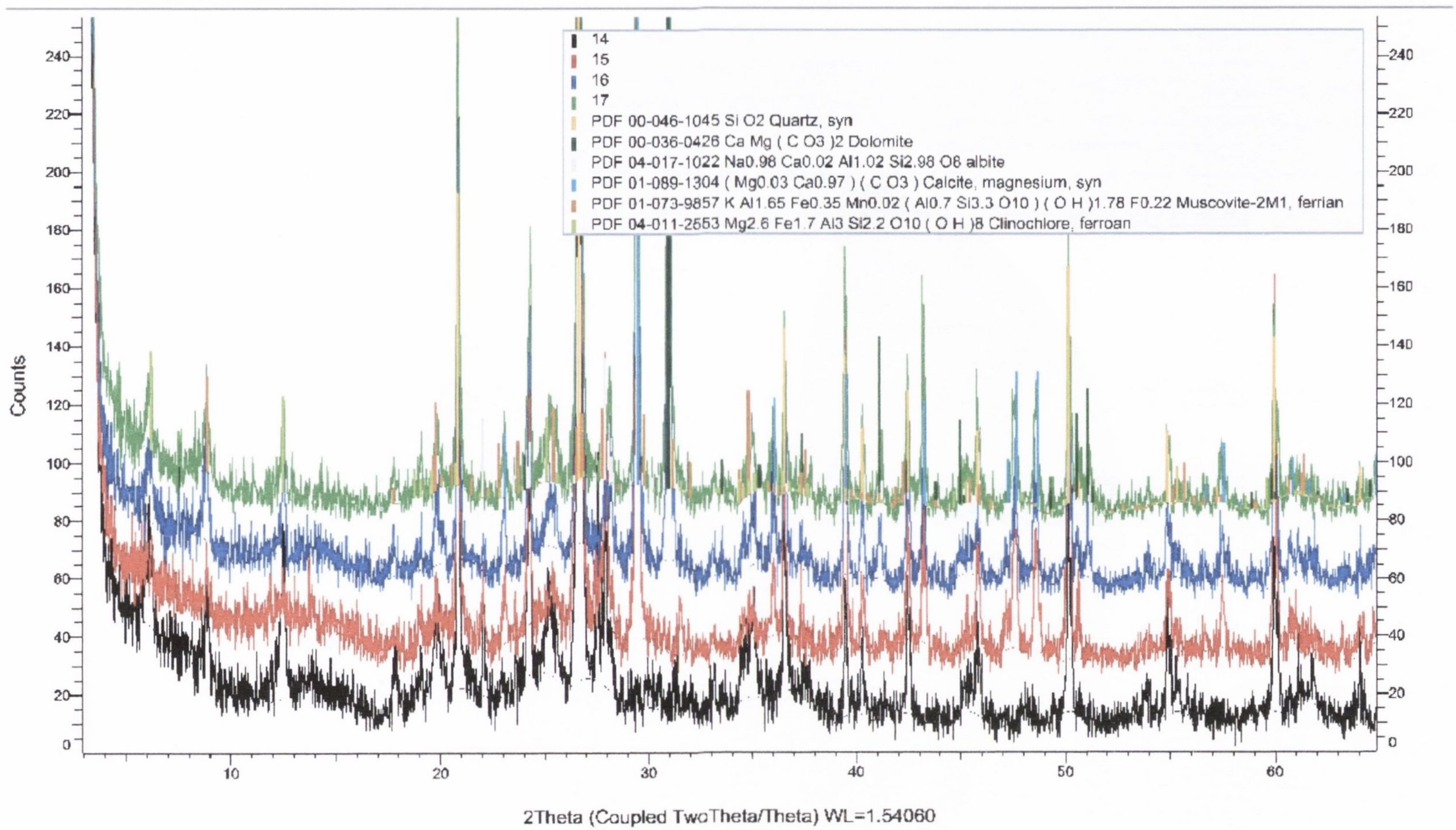
Site A - Kilkenny (0.5 m, 1 m, 1.5 m, 2 m and 2.5 m)



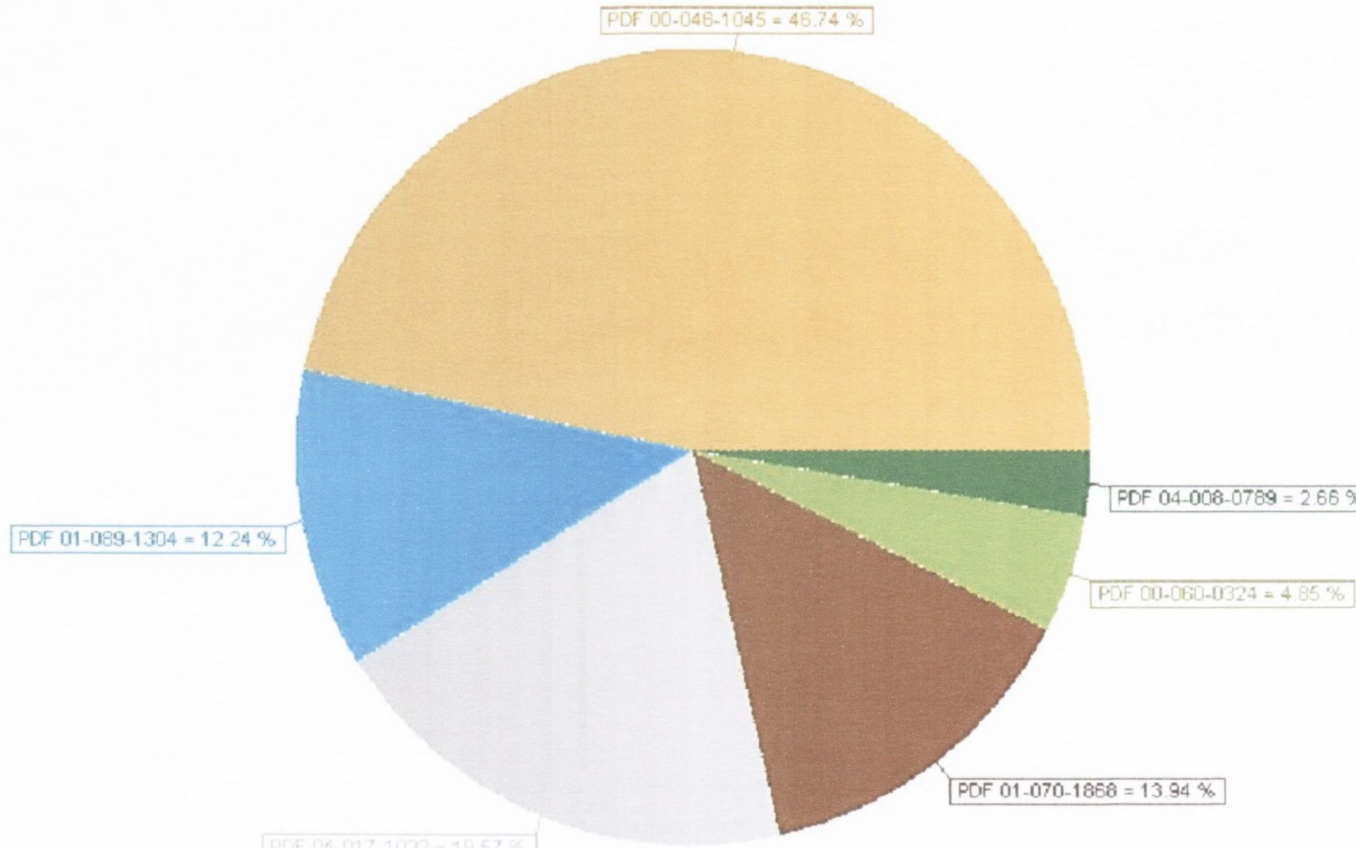
Site B – Monaghan



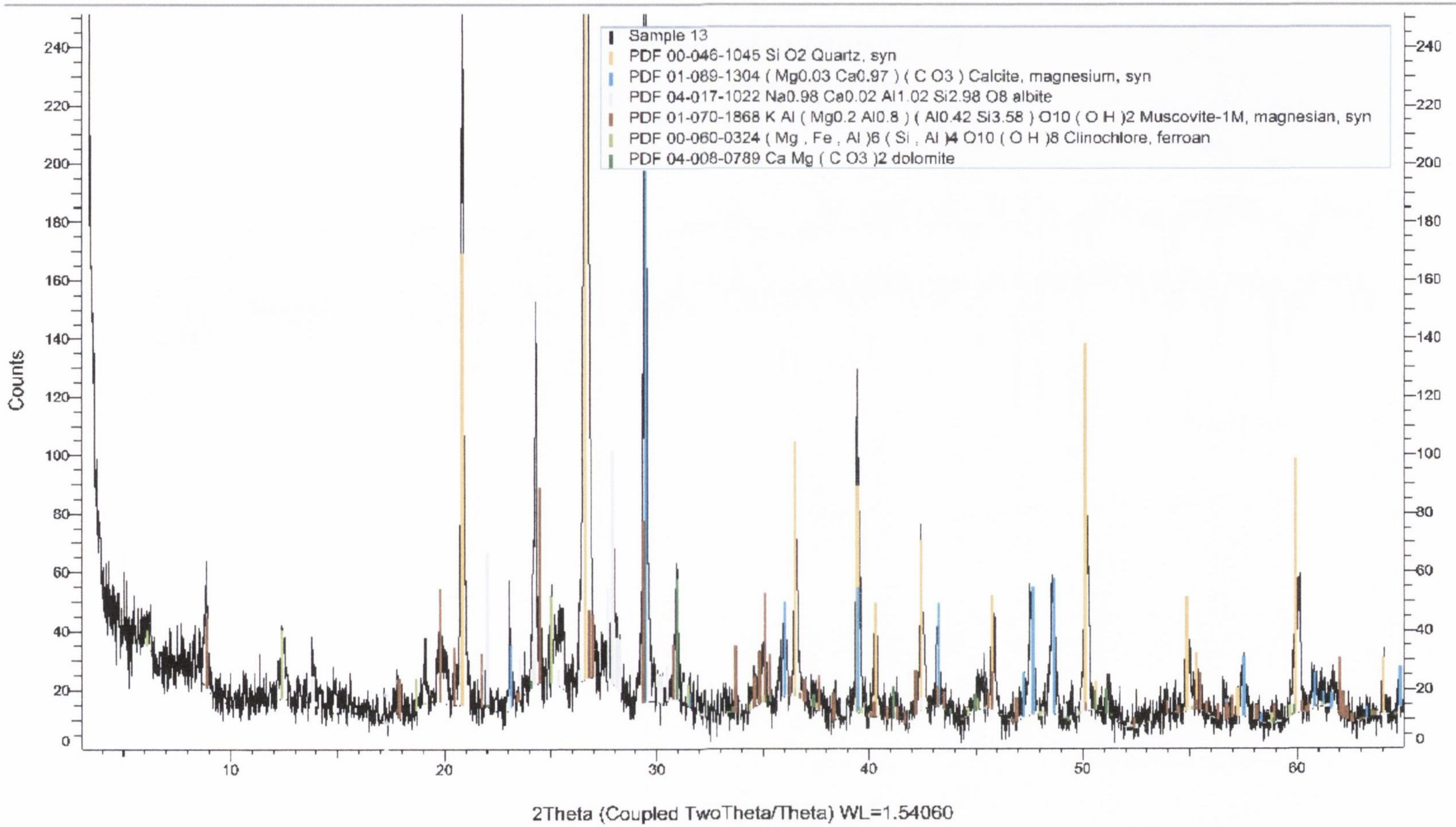
Site B - Monaghan (1.5 m)



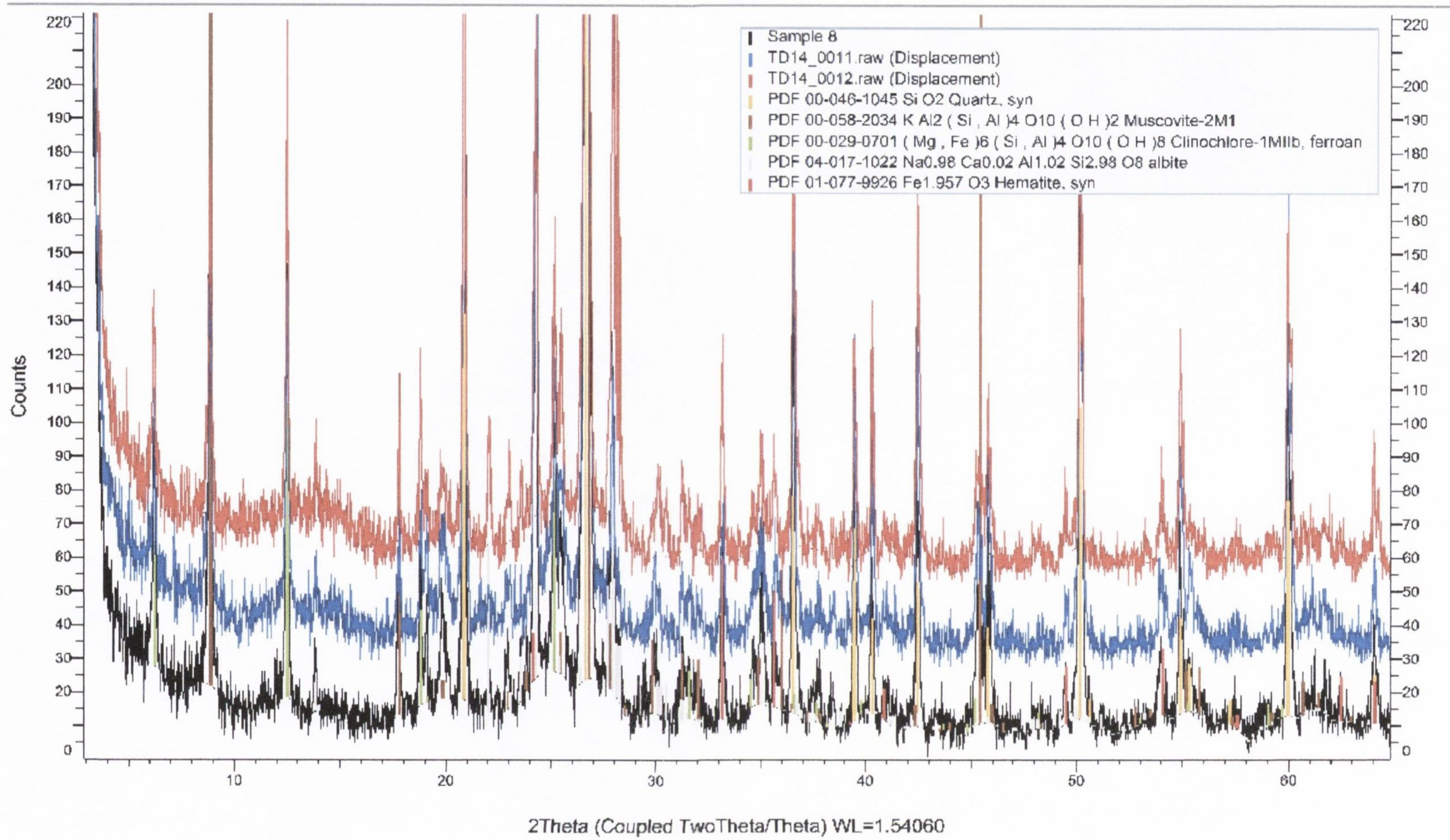
Site B – Monaghan (0.5 m, 1 m, 1.5 m and 2.2 m)


PDF 00-046-1045 = 46.74 %
PDF 04-008-0789 = 2.66 %
PDF 00-060-0324 = 4.85 %
PDF 01-070-1868 = 13.94 %
PDF 04-017-1022 = 19.57 %
PDF 01-089-1304 = 12.24 %

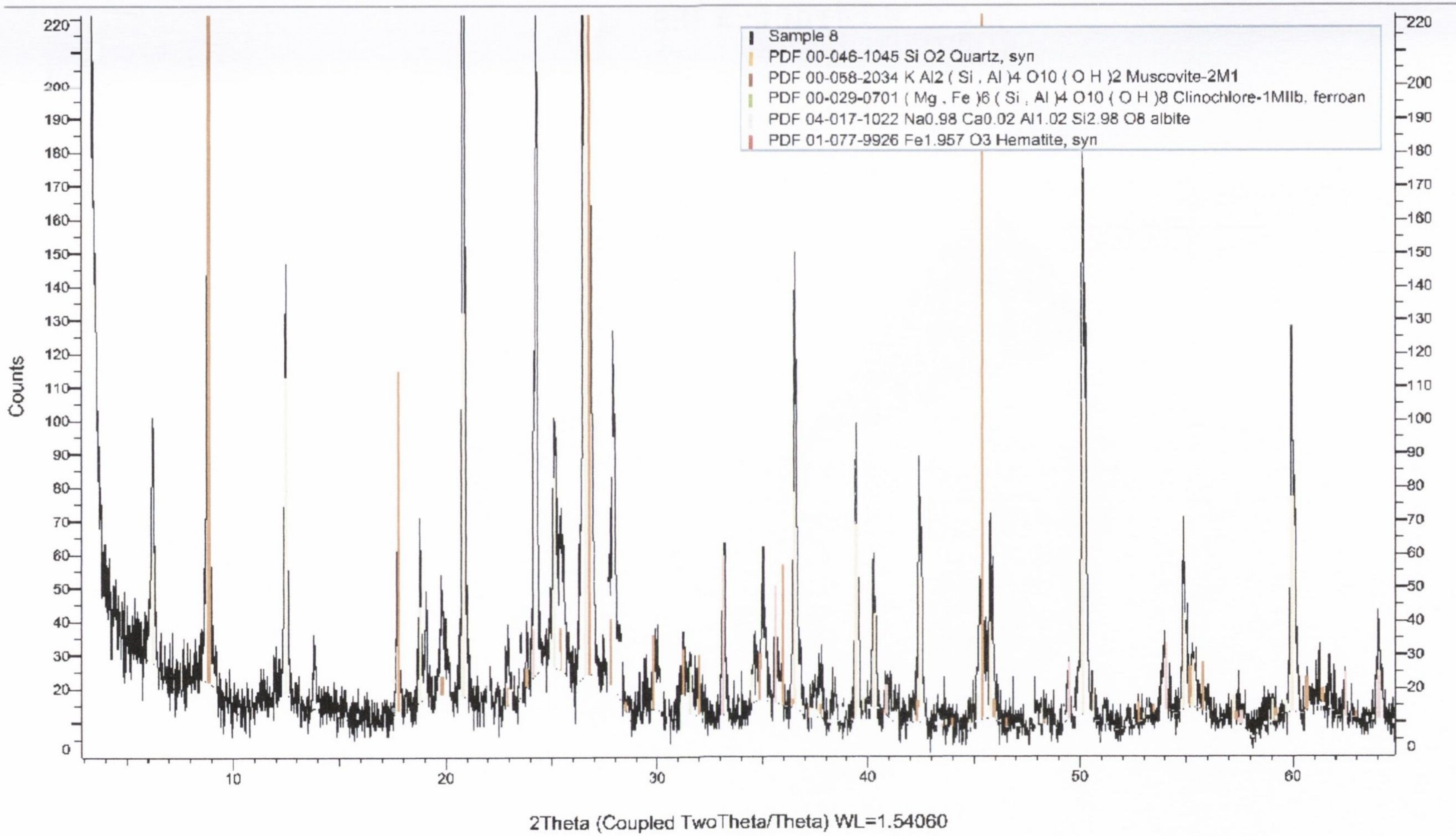
Site C – Meath



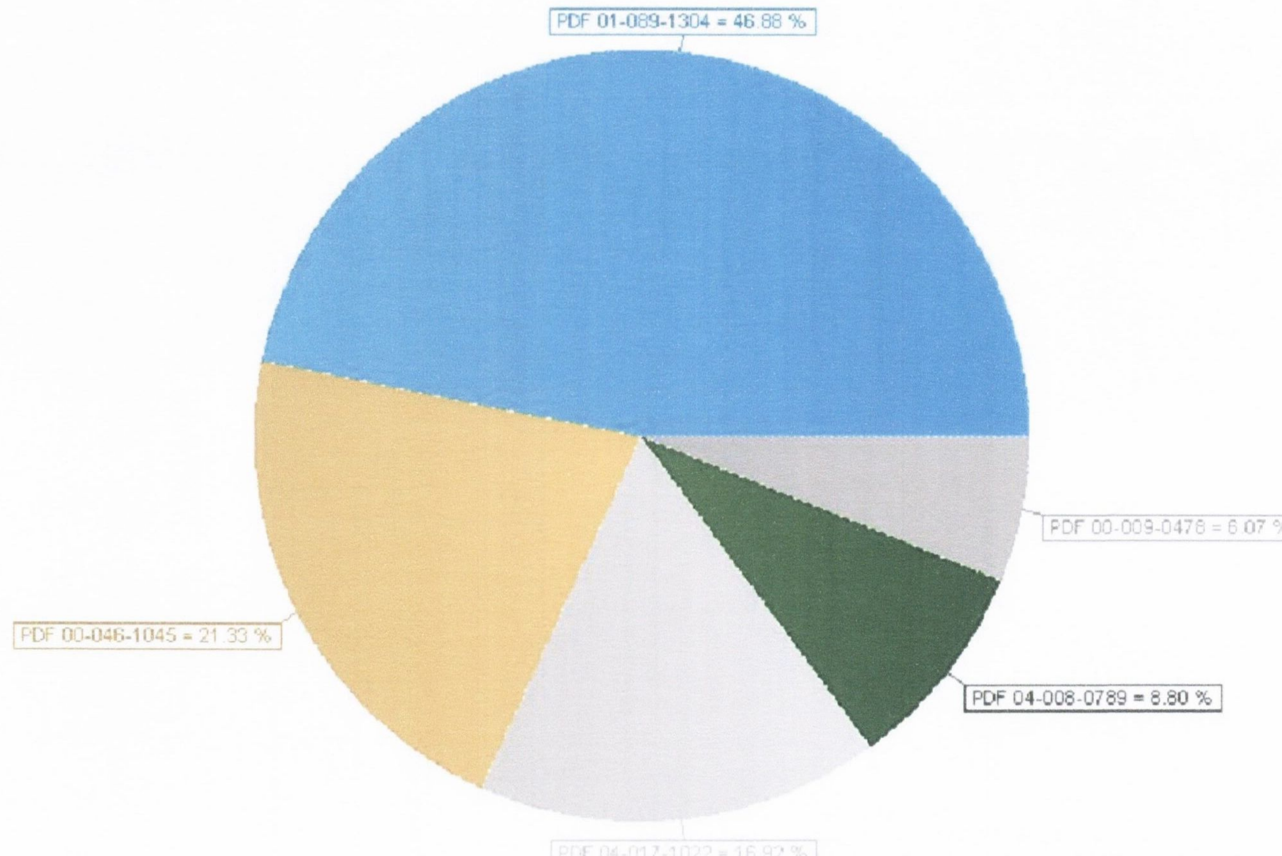
Site C - Meath (1.5 m)



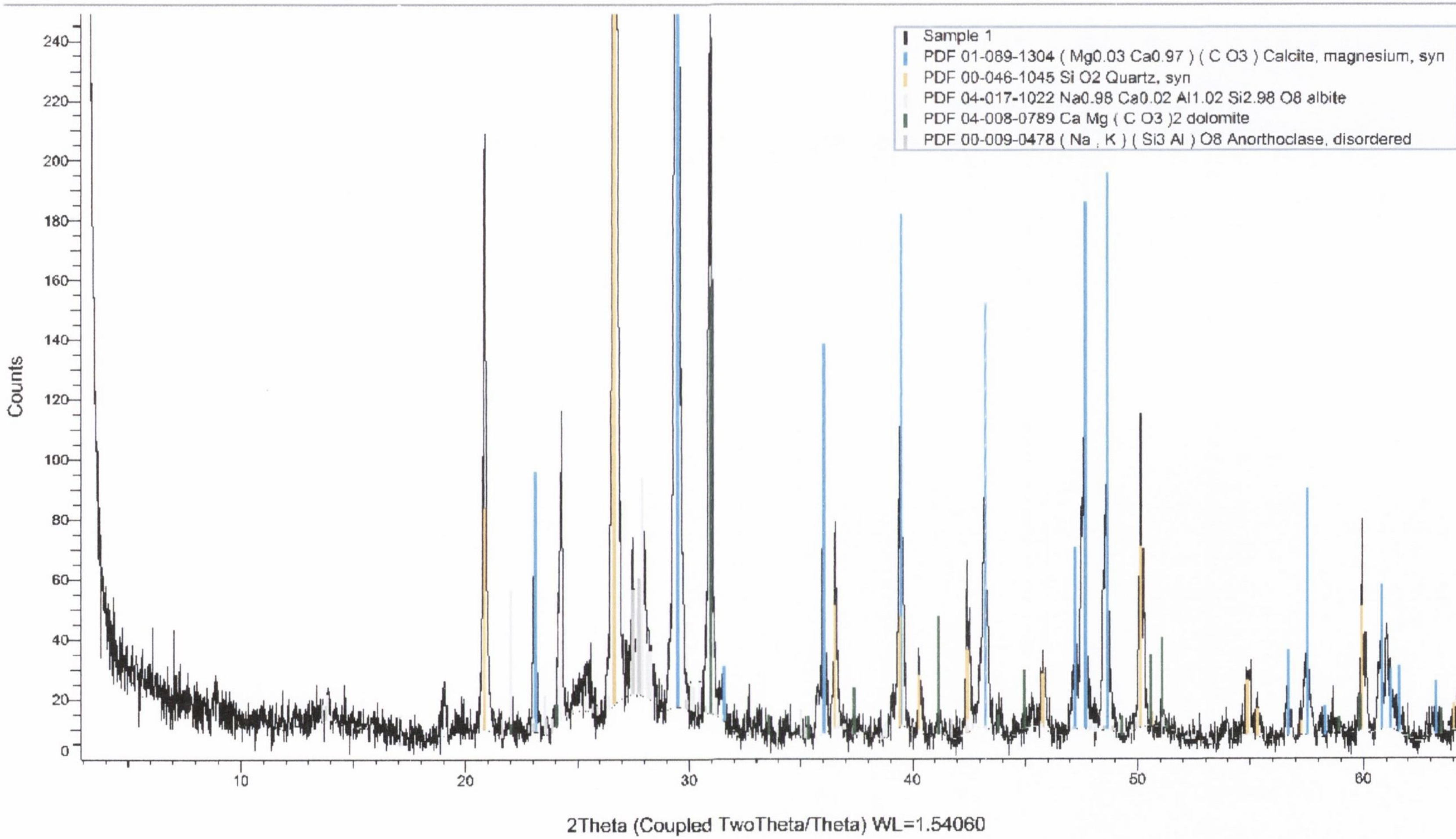
Site F - Cork (1 m, 1.5 m and 2 m)



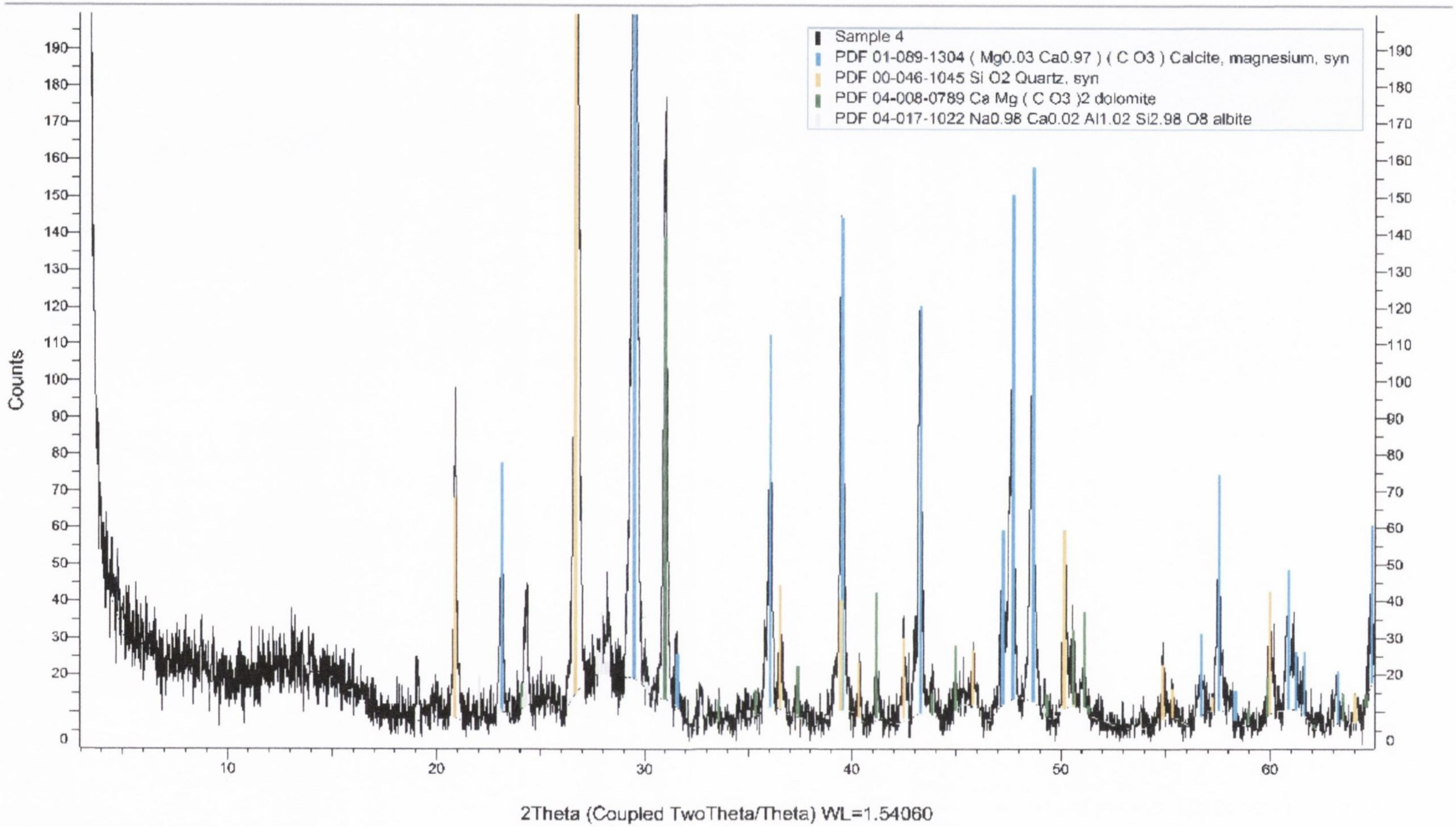
Site F - Cork (1.5 m)



Site E – Kilbeggan



Site E - Kilbeggan (3 m)



Site E – Kilbeggan (1.5 m)

APPENDIX D

Site A

(Co. Kilkenny)

Date	Measured Rainfall mm/day	Total Effluent load (l)	LP Effluent Loading (l)	LP Effluent Loading (mm)	DD Effluent Loading (l)	DD Effluent Loading (mm)	LP Total Hydraulic Loading mm/day	DD Total Hydraulic Loading mm/day	Calculated ETO mm/day	Calculated SMD (mm)	Available SMD (mm)	ET actual mm/day	Effective Rainfall	ET actual mm/day (LP)	ET actual mm/day (DD)	Effective Hydraulic Loading LP (mm)	Effective Hydraulic Loading DD (mm)
16/01/2013	8.2	259.2	129.6	2.0	129.6	2.0	10.2	10.2	0.1	-10.0	0.0	0.1	8.1	0.1	0.1	10.2	10.1
17/01/2013	18.7	331.2	165.6	2.6	165.6	2.5	21.3	21.2	0.2	-10.0	0.0	0.2	18.5	0.2	0.2	21.1	21.0
18/01/2013	3.8	393.6	196.8	3.1	196.8	3.0	6.9	6.8	0.3	-10.0	0.0	0.3	3.5	0.3	0.3	6.6	6.5
19/01/2013	0.4	486.4	243.2	3.8	243.2	3.7	4.2	4.1	0.1	-9.6	0.4	0.1	0.0	0.1	0.1	4.1	4.0
20/01/2013	0.0	412.8	206.4	3.3	206.4	3.1	3.3	3.1	0.2	-9.0	1.0	0.2	0.0	0.2	0.2	3.1	2.9
21/01/2013	0.0	345.6	172.8	2.7	172.8	2.6	2.7	2.6	0.1	-8.3	1.7	0.1	0.0	0.1	0.1	2.6	2.5
22/01/2013	1.5	454.4	227.2	3.6	227.2	3.4	5.1	4.9	0.1	-9.2	0.8	0.1	0.6	0.1	0.1	5.0	4.9
23/01/2013	0.0	392.0	196.0	3.1	196.0	3.0	3.1	3.0	0.1	-8.6	1.4	0.1	0.0	0.1	0.1	3.0	2.9
24/01/2013	5.1	387.2	193.6	3.1	193.6	2.9	8.2	8.0	0.2	-10.0	0.0	0.2	4.9	0.2	0.2	8.0	7.9
25/01/2013	18.3	425.6	212.8	3.4	212.8	3.2	21.7	21.5	0.5	-10.0	0.0	0.5	17.8	0.5	0.5	21.2	21.0
26/01/2013	4.5	336.0	168.0	2.6	168.0	2.5	7.1	7.0	0.5	-10.0	0.0	0.5	4.0	0.5	0.5	6.6	6.5
27/01/2013	2.0	507.2	253.6	4.0	253.6	3.8	6.0	5.8	1.0	-10.0	0.0	1.0	1.0	1.0	1.0	5.0	4.9
28/01/2013	5.4	360.0	180.0	2.8	180.0	2.7	8.2	8.1	1.0	-10.0	0.0	1.0	4.4	1.0	1.0	7.2	7.1
29/01/2013	3.6	443.2	221.6	3.5	221.6	3.4	7.1	7.0	0.6	-10.0	0.0	0.6	3.0	0.6	0.6	6.5	6.4
30/01/2013	3.7	542.4	271.2	4.3	271.2	4.1	8.0	7.8	1.2	-10.0	0.0	1.2	2.5	1.2	1.2	6.8	6.6
31/01/2013	1.8	409.6	204.8	3.2	204.8	3.1	5.0	4.9	1.2	-10.0	0.0	1.2	0.6	1.2	1.2	3.9	3.7
01/02/2013	1.5	387.2	193.6	3.1	193.6	2.9	4.6	4.4	0.7	-9.8	0.2	0.7	0.7	0.7	0.7	3.9	3.7
02/02/2013	0.0	424.0	212.0	3.3	212.0	3.2	3.3	3.2	0.5	-8.7	1.3	0.5	0.0	0.5	0.5	2.9	2.7
03/02/2013	0.0	427.2	213.6	3.4	213.6	3.2	3.4	3.2	0.5	-7.7	2.3	0.5	0.0	0.5	0.5	2.9	2.8
04/02/2013	9.8	313.6	156.8	2.5	156.8	2.4	12.3	12.2	1.1	-10.0	0.0	1.1	8.7	1.1	1.1	11.2	11.1
05/02/2013	3.8	377.6	188.8	3.0	188.8	2.9	6.8	6.7	0.6	-10.0	0.0	0.6	3.2	0.6	0.6	6.1	6.0
06/02/2013	0.0	369.6	184.8	2.9	184.8	2.8	2.9	2.8	0.7	-8.9	1.1	0.7	0.0	0.7	0.7	2.2	2.1
07/02/2013	3.5	449.6	224.8	3.5	224.8	3.4	7.0	6.9	0.4	-10.0	0.0	0.4	3.1	0.4	0.4	6.7	6.5
08/02/2013	0.2	318.4	159.2	2.5	159.2	2.4	2.7	2.6	0.4	-9.3	0.7	0.4	0.0	0.4	0.4	2.3	2.2
09/02/2013	5.3	347.2	173.6	2.7	173.6	2.6	8.0	7.9	0.2	-10.0	0.0	0.2	5.1	0.2	0.2	7.8	7.7
10/02/2013	2.2	684.8	342.4	5.4	342.4	5.2	7.6	7.4	0.3	-10.0	0.0	0.3	1.9	0.3	0.3	7.3	7.1
11/02/2013	0.4	305.6	152.8	2.4	152.8	2.3	2.8	2.7	0.1	-9.6	0.4	0.1	0.0	0.1	0.1	2.7	2.6
12/02/2013	2.1	380.8	190.4	3.0	190.4	2.9	5.1	5.0	0.1	-10.0	0.0	0.1	2.0	0.1	0.1	5.0	4.9
13/02/2013	3.8	382.4	191.2	3.0	191.2	2.9	6.8	6.7	0.5	-10.0	0.0	0.5	3.3	0.5	0.5	6.3	6.2
14/02/2013	0.4	436.8	218.4	3.4	218.4	3.3	3.8	3.7	0.7	-9.4	0.6	0.7	0.0	0.7	0.7	3.1	3.0
15/02/2013	0.1	364.8	182.4	2.9	182.4	2.8	3.0	2.9	0.5	-8.3	1.7	0.5	0.0	0.5	0.5	2.5	2.4
16/02/2013	0.0	459.2	229.6	3.6	229.6	3.5	3.6	3.5	0.6	-7.3	2.7	0.6	0.0	0.6	0.6	3.0	2.9
17/02/2013	0.0	483.2	241.6	3.8	241.6	3.7	3.8	3.7	1.0	-6.2	3.8	1.0	0.0	1.0	1.0	2.8	2.5
18/02/2013	0.0	416.0	208.0	3.3	208.0	3.2	3.3	3.2	0.9	-4.7	5.3	0.9	0.0	0.9	0.9	0.4	0.1
19/02/2013	0.0	612.8	306.4	4.8	306.4	4.6	4.8	4.6	0.6	-3.3	6.7	0.6	0.0	0.6	0.6	2.4	2.0
20/02/2013	0.0	268.8	134.4	2.1	134.4	2.0	2.1	2.0	0.6	-2.2	7.8	0.6	0.0	0.6	0.6	0.0	0.0
21/02/2013	0.0	409.6	204.8	3.2	204.8	3.1	3.2	3.1	0.9	-1.1	8.9	0.9	0.0	0.9	0.9	0.0	0.0
22/02/2013	0.0	308.8	154.4	2.4	154.4	2.3	2.4	2.3	0.8	0.3	10.3	0.8	0.0	0.8	0.8	0.0	0.0
23/02/2013	0.0	478.4	239.2	3.8	239.2	3.6	3.8	3.6	0.3	1.5	11.5	0.3	0.0	0.3	0.3	0.0	0.0
24/02/2013	0.0	484.8	242.4	3.8	242.4	3.7	3.8	3.7	0.7	2.3	12.3	0.7	0.0	0.7	0.7	0.0	0.0
25/02/2013	0.0	449.6	224.8	3.5	224.8	3.4	3.5	3.4	0.7	3.5	13.5	0.7	0.0	0.7	0.7	0.0	0.0
26/02/2013	0.0	360.0	180.0	2.8	180.0	2.7	2.8	2.7	0.3	4.7	14.7	0.3	0.0	0.3	0.3	0.0	0.0
27/02/2013	0.0	382.4	191.2	3.0	191.2	2.9	3.0	2.9	0.5	5.5	15.5	0.5	0.0	0.5	0.5	0.0	0.0
28/02/2013	0.0	385.6	192.8	3.0	192.8	2.9	3.0	2.9	0.4	6.5	16.5	0.4	0.0	0.4	0.4	0.0	0.0
01/03/2013	0.0	425.6	212.8	3.4	212.8	3.2	3.4	3.2	0.6	7.3	17.3	0.6	0.0	0.6	0.6	0.0	0.0
02/03/2013	0.0	494.4	247.2	3.9	247.2	3.7	3.9	3.7	0.6	8.4	18.4	0.6	0.0	0.6	0.6	0.0	0.0

03/03/2013	0.0	432.0	216.0	3.4	216.0	3.3	3.4	3.3	0.5	9.5	19.5	0.5	0.0	0.5	0.5	0.0	0.0
04/03/2013	0.0	414.4	207.2	3.3	207.2	3.1	3.3	3.1	0.5	10.5	20.5	0.5	0.0	0.5	0.5	0.0	0.0
05/03/2013	2.1	459.2	229.6	3.6	229.6	3.5	5.7	5.6	0.6	9.4	19.4	0.6	0.0	0.6	0.6	0.0	0.0
06/03/2013	5.0	409.6	204.8	3.2	204.8	3.1	8.2	8.1	0.4	5.4	15.4	0.4	0.0	0.4	0.4	0.0	0.0
07/03/2013	8.2	401.6	200.8	3.2	200.8	3.0	11.4	11.2	0.3	-1.8	8.2	0.3	0.0	0.3	0.3	6.1	5.8
08/03/2013	2.1	400.0	200.0	3.2	200.0	3.0	5.3	5.1	0.6	-3.1	6.9	0.6	0.0	0.6	0.6	0.9	0.7
09/03/2013	8.8	392.0	196.0	3.1	196.0	3.0	11.9	11.8	0.7	-10.0	0.0	0.7	8.1	0.7	0.7	11.2	11.1
10/03/2013	0.9	508.8	254.4	4.0	254.4	3.9	4.9	4.8	0.9	-9.7	0.3	0.9	0.0	0.9	0.9	4.0	3.8
11/03/2013	1.9	464.0	232.0	3.7	232.0	3.5	5.6	5.4	1.0	-10.0	0.0	1.0	0.9	1.0	1.0	4.5	4.4
12/03/2013	0.0	475.2	237.6	3.7	237.6	3.6	3.7	3.6	1.1	-8.5	1.5	1.1	0.0	1.1	1.1	2.7	2.5
13/03/2013	0.6	404.8	202.4	3.2	202.4	3.1	3.8	3.7	1.1	-7.5	2.5	1.1	0.0	1.1	1.1	2.7	2.6
14/03/2013	0.9	360.0	180.0	2.8	180.0	2.7	3.7	3.6	1.0	-6.8	3.2	1.0	0.0	1.0	1.0	2.4	2.2
15/03/2013	2.9	243.2	121.6	1.9	121.6	1.8	4.8	4.7	1.4	-8.2	1.8	1.4	0.0	1.4	1.4	3.4	3.3
16/03/2013	0.0	393.6	196.8	3.1	196.8	3.0	3.1	3.0	1.1	-6.3	3.7	1.1	0.0	1.1	1.1	1.4	1.2
17/03/2013	1.1	329.6	164.8	2.6	164.8	2.5	3.7	3.6	0.8	-5.8	4.2	0.8	0.0	0.8	0.8	1.3	1.1
18/03/2013	0.0	462.4	231.2	3.6	231.2	3.5	3.6	3.5	0.5	-4.5	5.5	0.5	0.0	0.5	0.5	1.2	1.0
19/03/2013	0.3	366.4	183.2	2.9	183.2	2.8	3.2	3.1	0.6	-3.8	6.2	0.6	0.0	0.6	0.6	0.0	0.0
20/03/2013	0.0	401.6	200.8	3.2	200.8	3.0	3.2	3.0	1.2	-2.6	7.4	1.2	0.0	1.2	1.2	0.0	0.0
21/03/2013	30.5	331.2	165.6	2.6	165.6	2.5	33.1	33.0	0.5	-10.0	0.0	0.5	30.0	0.5	0.5	32.6	32.5
22/03/2013	11.6	448.0	224.0	3.5	224.0	3.4	15.1	15.0	0.5	-10.0	0.0	0.5	11.1	0.5	0.5	14.7	14.5
23/03/2013	0.0	380.8	190.4	3.0	190.4	2.9	3.0	2.9	0.6	-9.0	1.0	0.6	0.0	0.6	0.6	2.4	2.3
24/03/2013	0.0	315.2	157.6	2.5	157.6	2.4	2.5	2.4	0.7	-8.0	2.0	0.7	0.0	0.7	0.7	1.8	1.7
25/03/2013	0.0	347.2	173.6	2.7	173.6	2.6	2.7	2.6	1.0	-6.8	3.2	1.0	0.0	1.0	1.0	1.2	1.0
26/03/2013	0.2	398.4	199.2	3.1	199.2	3.0	3.3	3.2	1.2	-5.5	4.5	1.2	0.0	1.2	1.2	0.7	0.5
27/03/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.3	-3.8	6.2	1.3	0.0	1.3	1.3	0.0	0.0
28/03/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.0	-1.9	8.1	1.0	0.0	1.0	1.0	0.0	0.0
29/03/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.6	-0.4	9.6	1.6	0.0	1.6	1.6	0.0	0.0
30/03/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.6	1.7	11.7	1.6	0.0	1.6	1.6	0.0	0.0
31/03/2013	0.8	465.6	232.8	3.7	232.8	3.5	4.5	4.3	1.5	3.0	13.0	1.5	0.0	1.5	1.5	0.0	0.0
01/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.5	5.0	15.0	1.5	0.0	1.5	1.5	0.0	0.0
02/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	2.4	7.0	17.0	2.4	0.0	2.4	2.4	0.0	0.0
03/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	2.3	9.9	19.9	2.3	0.0	2.3	2.3	0.0	0.0
04/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	2.1	12.7	22.7	2.0	0.0	2.1	2.1	0.0	0.0
05/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.8	15.2	25.2	1.7	0.0	1.7	1.7	0.0	0.0
06/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.8	17.4	27.4	1.7	0.0	1.7	1.7	0.0	0.0
07/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	1.1	19.5	29.5	1.0	0.0	1.1	1.1	0.0	0.0
08/04/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	2.7	21.1	31.1	2.4	0.0	2.5	2.5	0.0	0.0
09/04/2013	0.3	465.6	232.8	3.7	232.8	3.5	4.0	3.8	2.0	23.7	33.7	1.7	0.0	1.8	1.8	0.0	0.0
10/04/2013	5.1	465.6	232.8	3.7	232.8	3.5	8.8	8.6	1.5	20.8	30.8	1.3	0.0	1.4	1.4	0.0	0.0
11/04/2013	6.4	459.2	229.6	3.6	229.6	3.5	10.0	9.9	1.7	16.3	26.3	1.6	0.0	1.7	1.7	0.0	0.0
12/04/2013	0.2	430.4	215.2	3.4	215.2	3.3	3.6	3.5	1.6	18.2	28.2	1.5	0.0	1.5	1.5	0.0	0.0
13/04/2013	4.6	441.6	220.8	3.5	220.8	3.3	8.1	7.9	0.4	15.6	25.6	0.4	0.0	0.4	0.4	0.0	0.0
14/04/2013	4.7	435.2	217.6	3.4	217.6	3.3	8.1	8.0	2.2	11.8	21.8	2.2	0.0	2.2	2.2	0.0	0.0
15/04/2013	2.8	444.8	222.4	3.5	222.4	3.4	6.3	6.2	2.3	11.7	21.7	2.3	0.0	2.3	2.3	0.0	0.0
16/04/2013	1.8	416.0	208.0	3.3	208.0	3.2	5.1	5.0	3.6	12.7	22.7	3.5	0.0	3.6	3.6	0.0	0.0
17/04/2013	6.6	409.6	204.8	3.2	204.8	3.1	9.8	9.7	1.0	10.1	20.1	1.0	0.0	1.0	1.0	0.0	0.0
18/04/2013	3.1	430.4	215.2	3.4	215.2	3.3	6.5	6.4	2.4	8.5	18.5	2.4	0.0	2.4	2.4	0.0	0.0
19/04/2013	0.3	401.6	200.8	3.2	200.8	3.0	3.5	3.3	2.6	11.1	21.1	2.6	0.0	2.6	2.6	0.0	0.0
20/04/2013	8.0	388.8	194.4	3.1	194.4	2.9	11.1	10.9	2.4	6.2	16.2	2.4	0.0	2.4	2.4	0.0	0.0
21/04/2013	0.6	340.8	170.4	2.7	170.4	2.6	3.3	3.2	2.6	8.5	18.5	2.6	0.0	2.6	2.6	0.0	0.0

22/04/2013	0.2	352.0	176.0	2.8	176.0	2.7	3.0	2.9	1.9	11.4	21.4	1.9	0.0	1.9	1.9	0.0	0.0
23/04/2013	1.5	318.4	159.2	2.5	159.2	2.4	4.0	3.9	3.4	12.3	22.3	3.3	0.0	3.4	3.4	0.0	0.0
24/04/2013	1.7	339.2	169.6	2.7	169.6	2.6	4.4	4.3	2.4	14.4	24.4	2.3	0.0	2.3	2.3	0.0	0.0
25/04/2013	0.2	361.6	180.8	2.8	180.8	2.7	3.0	2.9	1.8	17.0	27.0	1.7	0.0	1.8	1.8	0.0	0.0
26/04/2013	1.4	364.8	182.4	2.9	182.4	2.8	4.3	4.2	2.5	17.8	27.8	2.3	0.0	2.4	2.4	0.0	0.0
27/04/2013	0.0	409.6	204.8	3.2	204.8	3.1	3.2	3.1	3.0	20.6	30.6	2.7	0.0	2.8	2.8	0.0	0.0
28/04/2013	0.4	350.4	175.2	2.8	175.2	2.7	3.2	3.1	2.3	23.3	33.3	2.0	0.0	2.1	2.1	0.0	0.0
29/04/2013	0.2	372.8	186.4	2.9	186.4	2.8	3.1	3.0	2.9	25.7	35.7	2.4	0.0	2.5	2.5	0.0	0.0
30/04/2013	0.0	320.0	160.0	2.5	160.0	2.4	2.5	2.4	2.7	28.6	38.6	2.2	0.0	2.3	2.3	0.0	0.0
01/05/2013	0.0	406.4	203.2	3.2	203.2	3.1	3.2	3.1	2.3	31.3	41.3	1.8	0.0	1.8	1.8	0.0	0.0
02/05/2013	0.0	387.2	193.6	3.1	193.6	2.9	3.1	2.9	3.5	33.6	43.6	2.7	0.0	2.8	2.8	0.0	0.0
03/05/2013	6.3	379.2	189.6	3.0	189.6	2.9	9.3	9.2	2.9	30.5	40.5	2.3	0.0	2.4	2.4	0.0	0.0
04/05/2013	0.2	350.4	175.2	2.8	175.2	2.7	3.0	2.9	3.9	33.1	43.1	3.0	0.0	3.1	3.1	0.0	0.0
05/05/2013	0.1	352.0	176.0	2.8	176.0	2.7	2.9	2.8	3.6	36.4	46.4	2.6	0.0	2.7	2.7	0.0	0.0
06/05/2013	0.0	360.0	180.0	2.8	180.0	2.7	2.8	2.7	2.5	39.6	49.6	1.8	0.0	1.9	1.9	0.0	0.0
07/05/2013	8.2	342.4	171.2	2.7	171.2	2.6	10.9	10.8	2.8	33.7	43.7	2.2	0.0	2.2	2.2	0.0	0.0
08/05/2013	1.5	340.8	170.4	2.7	170.4	2.6	4.2	4.1	3.3	34.8	44.8	2.5	0.0	2.5	2.5	0.0	0.0
09/05/2013	0.5	334.4	167.2	2.6	167.2	2.5	3.1	3.0	1.9	37.3	47.3	1.3	0.0	1.4	1.4	0.0	0.0
10/05/2013	2.7	387.2	193.6	3.1	193.6	2.9	5.8	5.6	3.3	36.4	46.4	2.4	0.0	2.5	2.5	0.0	0.0
11/05/2013	0.9	416.0	208.0	3.3	208.0	3.2	4.2	4.1	2.7	38.4	48.4	1.9	0.0	2.0	2.0	0.0	0.0
12/05/2013	2.6	363.2	181.6	2.9	181.6	2.8	5.5	5.4	1.4	38.2	48.2	1.0	0.0	1.0	1.0	0.0	0.0
13/05/2013	2.8	401.6	200.8	3.2	200.8	3.0	6.0	5.8	2.8	36.9	46.9	2.0	0.0	2.1	2.1	0.0	0.0
14/05/2013	3.4	366.4	183.2	2.9	183.2	2.8	6.3	6.2	1.6	36.0	46.0	1.2	0.0	1.3	1.3	0.0	0.0
15/05/2013	0.4	369.6	184.8	2.9	184.8	2.8	3.3	3.2	2.5	37.4	47.4	1.8	0.0	1.9	1.9	0.0	0.0
16/05/2013	0.3	377.6	188.8	3.0	188.8	2.9	3.3	3.2	3.1	39.4	49.4	2.2	0.0	2.3	2.3	0.0	0.0
17/05/2013	0.8	393.6	196.8	3.1	196.8	3.0	3.9	3.8	3.4	41.2	51.2	2.4	0.0	2.5	2.5	0.0	0.0
18/05/2013	0.4	374.4	187.2	3.0	187.2	2.8	3.4	3.2	3.0	43.7	53.7	2.0	0.0	2.1	2.1	0.0	0.0
19/05/2013	0.0	396.8	198.4	3.1	198.4	3.0	3.1	3.0	2.0	46.2	56.2	1.3	0.0	1.3	1.3	0.0	0.0
20/05/2013	0.0	372.8	186.4	2.9	186.4	2.8	2.9	2.8	1.9	48.0	58.0	1.2	0.0	1.2	1.2	0.0	0.0
21/05/2013	0.0	428.8	214.4	3.4	214.4	3.2	3.4	3.2	4.6	49.7	59.7	2.8	0.0	2.9	2.9	0.0	0.0
22/05/2013	0.0	425.6	212.8	3.4	212.8	3.2	3.4	3.2	3.5	52.9	62.9	2.0	0.0	2.1	2.1	0.0	0.0
23/05/2013	0.1	380.8	190.4	3.0	190.4	2.9	3.1	3.0	3.2	55.3	65.3	1.8	0.0	1.9	1.9	0.0	0.0
24/05/2013	0.0	384.0	192.0	3.0	192.0	2.9	3.0	2.9	3.0	57.6	67.6	1.6	0.0	1.7	1.7	0.0	0.0
25/05/2013	0.0	353.6	176.8	2.8	176.8	2.7	2.8	2.7	3.9	59.7	69.7	2.0	0.0	2.1	2.1	0.0	0.0
26/05/2013	8.5	252.8	126.4	2.0	126.4	1.9	10.5	10.4	3.9	53.6	63.6	2.2	0.0	2.3	2.2	0.0	0.0
27/05/2013	2.1	305.6	152.8	2.4	152.8	2.3	4.5	4.4	2.1	54.2	64.2	1.2	0.0	1.2	1.2	0.0	0.0
28/05/2013	6.1	356.8	178.4	2.8	178.4	2.7	8.9	8.8	2.5	49.8	59.8	1.5	0.0	1.6	1.5	0.0	0.0
29/05/2013	0.0	272.0	136.0	2.1	136.0	2.1	2.1	2.1	4.5	51.8	61.8	2.6	0.0	2.7	2.7	0.0	0.0
30/05/2013	0.0	460.8	230.4	3.6	230.4	3.5	3.6	3.5	4.9	54.9	64.9	2.7	0.0	2.9	2.8	0.0	0.0
31/05/2013	0.4	332.8	166.4	2.6	166.4	2.5	3.0	2.9	2.0	57.7	67.7	1.0	0.0	1.1	1.1	0.0	0.0
01/06/2013	0.0	411.2	205.6	3.2	205.6	3.1	3.2	3.1	2.6	59.2	69.2	1.3	0.0	1.4	1.4	0.0	0.0
02/06/2013	0.0	382.4	191.2	3.0	191.2	2.9	3.0	2.9	3.9	61.0	71.0	1.9	0.0	2.0	2.0	0.0	0.0
03/06/2013	0.0	411.2	205.6	3.2	205.6	3.1	3.2	3.1	4.1	63.5	73.5	1.9	0.0	2.1	2.1	0.0	0.0
04/06/2013	0.0	315.2	157.6	2.5	157.6	2.4	2.5	2.4	5.1	65.9	75.9	2.3	0.0	2.4	2.4	0.0	0.0
05/06/2013	0.0	268.8	134.4	2.1	134.4	2.0	2.1	2.0	5.0	68.6	78.6	2.1	0.0	2.2	2.2	0.0	0.0
06/06/2013	0.0	262.4	131.2	2.1	131.2	2.0	2.1	2.0	4.8	71.2	81.2	1.8	0.0	1.9	1.9	0.0	0.0
07/06/2013	0.0	241.6	120.8	1.9	120.8	1.8	1.9	1.8	5.3	73.5	83.5	1.9	0.0	2.0	2.0	0.0	0.0
08/06/2013	0.0	368.0	184.0	2.9	184.0	2.8	2.9	2.8	5.3	76.0	86.0	1.8	0.0	2.0	2.0	0.0	0.0
09/06/2013	0.0	201.6	100.8	1.6	100.8	1.5	1.6	1.5	5.1	78.3	88.3	1.6	0.0	1.7	1.7	0.0	0.0
10/06/2013	4.8	236.8	118.4	1.9	118.4	1.8	6.7	6.6	1.6	75.6	85.6	0.6	0.0	0.6	0.6	0.0	0.0

11/06/2013	1.7	352.0	176.0	2.8	176.0	2.7	4.5	4.4	2.4	75.0	85.0	0.8	0.0	0.9	0.9	0.0	0.0
12/06/2013	3.0	209.6	104.8	1.7	104.8	1.6	4.7	4.6	2.0	73.3	83.3	0.7	0.0	0.8	0.8	0.0	0.0
13/06/2013	2.8	225.6	112.8	1.8	112.8	1.7	4.6	4.5	3.2	71.7	81.7	1.2	0.0	1.3	1.3	0.0	0.0
14/06/2013	8.0	296.0	148.0	2.3	148.0	2.2	10.3	10.2	1.2	65.4	75.4	0.5	0.0	0.6	0.6	0.0	0.0
15/06/2013	0.6	243.2	121.6	1.9	121.6	1.8	2.5	2.4	2.9	65.9	75.9	1.3	0.0	1.3	1.3	0.0	0.0
16/06/2013	10.7	302.4	151.2	2.4	151.2	2.3	13.1	13.0	1.3	57.0	67.0	0.7	0.0	0.7	0.7	0.0	0.0
17/06/2013	0.3	371.2	185.6	2.9	185.6	2.8	3.2	3.1	4.5	57.9	67.9	2.3	0.0	2.5	2.5	0.0	0.0
18/06/2013	0.0	257.6	128.8	2.0	128.8	2.0	2.0	2.0	3.9	60.7	70.7	1.9	0.0	2.0	2.0	0.0	0.0
19/06/2013	0.0	372.8	186.4	2.9	186.4	2.8	2.9	2.8	4.8	63.1	73.1	2.3	0.0	2.4	2.4	0.0	0.0
20/06/2013	0.0	203.2	101.6	1.6	101.6	1.5	1.6	1.5	5.2	65.9	75.9	2.3	0.0	2.4	2.4	0.0	0.0
21/06/2013	0.2	459.2	229.6	3.6	229.6	3.5	3.8	3.7	3.8	68.5	78.5	1.6	0.0	1.7	1.7	0.0	0.0
22/06/2013	0.6	540.8	270.4	4.3	270.4	4.1	4.9	4.7	3.6	70.0	80.0	1.4	0.0	1.6	1.6	0.0	0.0
23/06/2013	0.4	345.6	172.8	2.7	172.8	2.6	3.1	3.0	3.6	71.5	81.5	1.4	0.0	1.5	1.5	0.0	0.0
24/06/2013	0.0	398.4	199.2	3.1	199.2	3.0	3.1	3.0	2.4	73.4	83.4	0.9	0.0	0.9	0.9	0.0	0.0
25/06/2013	0.0	244.8	122.4	1.9	122.4	1.9	1.9	1.9	3.1	74.8	84.8	1.1	0.0	1.1	1.1	0.0	0.0
26/06/2013	0.0	438.4	219.2	3.5	219.2	3.3	3.5	3.3	3.2	76.4	86.4	1.1	0.0	1.2	1.2	0.0	0.0
27/06/2013	0.0	339.2	169.6	2.7	169.6	2.6	2.7	2.6	3.0	77.9	87.9	1.0	0.0	1.0	1.0	0.0	0.0
28/06/2013	0.0	264.0	132.0	2.1	132.0	2.0	2.1	2.0	2.8	79.4	89.4	0.9	0.0	0.9	0.9	0.0	0.0
29/06/2013	0.0	344.0	172.0	2.7	172.0	2.6	2.7	2.6	2.9	80.7	90.7	0.9	0.0	0.9	0.9	0.0	0.0
30/06/2013	0.1	412.8	206.4	3.3	206.4	3.1	3.4	3.2	3.8	82.0	92.0	1.1	0.0	1.2	1.2	0.0	0.0
01/07/2013	0.6	368.0	184.0	2.9	184.0	2.8	3.5	3.4	3.6	83.0	93.0	1.0	0.0	1.1	1.1	0.0	0.0
02/07/2013	2.6	192.0	96.0	1.5	96.0	1.5	4.1	4.1	1.0	81.8	91.8	0.3	0.0	0.3	0.3	0.0	0.0
03/07/2013	0.0	339.2	169.6	2.7	169.6	2.6	2.7	2.6	3.9	82.6	92.6	1.1	0.0	1.2	1.2	0.0	0.0
04/07/2013	0.0	459.2	229.6	3.6	229.6	3.5	3.6	3.5	4.8	84.2	94.2	1.2	0.0	1.4	1.4	0.0	0.0
05/07/2013	0.0	190.4	95.2	1.5	95.2	1.4	1.5	1.4	4.7	85.9	95.9	1.1	0.0	1.2	1.2	0.0	0.0
06/07/2013	0.0	475.2	237.6	3.7	237.6	3.6	3.7	3.6	4.6	87.5	97.5	1.0	0.0	1.2	1.2	0.0	0.0
07/07/2013	0.0	224.0	112.0	1.8	112.0	1.7	1.8	1.7	5.4	89.1	99.1	1.1	0.0	1.2	1.2	0.0	0.0
08/07/2013	0.0	337.6	168.8	2.7	168.8	2.6	2.7	2.6	6.5	90.7	100.7	1.3	0.0	1.4	1.4	0.0	0.0
09/07/2013	0.0	558.4	279.2	4.4	279.2	4.2	4.4	4.2	2.3	92.5	102.5	0.4	0.0	0.5	0.5	0.0	0.0
10/07/2013	0.0	185.6	92.8	1.5	92.8	1.4	1.5	1.4	2.1	93.3	103.3	0.4	0.0	0.4	0.4	0.0	0.0
11/07/2013	0.0	299.2	149.6	2.4	149.6	2.3	2.4	2.3	3.1	94.2	104.2	0.5	0.0	0.6	0.6	0.0	0.0
12/07/2013	0.0	320.0	160.0	2.5	160.0	2.4	2.5	2.4	3.1	95.2	105.2	0.5	0.0	0.5	0.5	0.0	0.0
13/07/2013	0.0	347.2	173.6	2.7	173.6	2.6	2.7	2.6	1.4	96.2	106.2	0.2	0.0	0.2	0.2	0.0	0.0
14/07/2013	0.0	296.0	148.0	2.3	148.0	2.2	2.3	2.2	1.7	96.9	106.9	0.2	0.0	0.3	0.3	0.0	0.0
15/07/2013	0.0	270.4	135.2	2.1	135.2	2.0	2.1	2.0	3.1	97.6	107.6	0.4	0.0	0.4	0.4	0.0	0.0
16/07/2013	0.0	348.8	174.4	2.7	174.4	2.6	2.7	2.6	3.2	98.5	108.5	0.4	0.0	0.5	0.5	0.0	0.0
17/07/2013	0.0	320.0	160.0	2.5	160.0	2.4	2.5	2.4	3.6	99.3	109.3	0.4	0.0	0.5	0.5	0.0	0.0
18/07/2013	0.0	292.8	146.4	2.3	146.4	2.2	2.3	2.2	3.3	100.2	110.2	0.3	0.0	0.4	0.4	0.0	0.0
19/07/2013	0.0	518.4	372.0	5.9	146.4	2.2	5.9	2.2	4.3	101.0	111.0	0.4	0.0	0.6	0.5	0.0	0.0
20/07/2013	0.0	186.0	186.0	2.9		0.0	2.9	0.0	3.5	101.9	111.9	0.3	0.0	0.4	0.3	0.0	0.0
21/07/2013	0.0	279.0	279.0	4.4		0.0	4.4	0.0	3.7	102.7	112.7	0.3	0.0	0.4	0.3	0.0	0.0
22/07/2013	0.0	372.0	372.0	5.9		0.0	5.9	0.0	4.2	103.5	113.5	0.3	0.0	0.5	0.3	0.0	0.0
23/07/2013	3.3	372.0	372.0	5.9		0.0	9.2	3.3	1.7	100.9	110.9	0.2	0.0	0.2	0.2	0.0	0.0
24/07/2013	7.2	372.0	372.0	5.9		0.0	13.1	7.2	1.9	94.4	104.4	0.3	0.0	0.4	0.3	0.0	0.0
25/07/2013	3.3	372.0	372.0	5.9		0.0	9.2	3.3	2.1	91.9	101.9	0.4	0.0	0.5	0.4	0.0	0.0
26/07/2013	4.4	279.0	279.0	4.4		0.0	8.8	4.4	4.6	88.4	98.4	1.0	0.0	1.2	1.0	0.0	0.0
27/07/2013	3.2	372.0	372.0	5.9		0.0	9.1	3.2	4.9	86.7	96.7	1.2	0.0	1.4	1.2	0.0	0.0
28/07/2013	1.1	279.0	279.0	4.4		0.0	5.5	1.1	3.9	87.2	97.2	0.9	0.0	1.1	0.9	0.0	0.0
29/07/2013	9.4	279.0	279.0	4.4		0.0	13.8	9.4	2.9	79.2	89.2	0.9	0.0	1.0	0.9	0.0	0.0
30/07/2013	9.8	93.0	93.0	1.5		0.0	11.3	9.8	3.1	70.8	80.8	1.2	0.0	1.2	1.2	0.0	0.0

31/07/2013	18.9	372.0	372.0	5.9		0.0	24.8	18.9	2.5	53.6	63.6	1.4	0.0	1.6	1.4	0.0	0.0
01/08/2013	0.3	372.0	372.0	5.9		0.0	6.2	0.3	1.0	55.2	65.2	0.5	0.0	0.6	0.5	0.0	0.0
02/08/2013	5.6	465.0	465.0	7.3		0.0	12.9	5.6	2.7	50.6	60.6	1.6	0.0	1.8	1.6	0.0	0.0
03/08/2013	4.1	279.0	279.0	4.4		0.0	8.5	4.1	3.6	48.7	58.7	2.2	0.0	2.4	2.2	0.0	0.0
04/08/2013	2.5	372.0	372.0	5.9		0.0	8.4	2.5	2.1	48.9	58.9	1.3	0.0	1.4	1.3	0.0	0.0
05/08/2013	0.0	279.0	279.0	4.4		0.0	4.4	0.0	3.8	50.6	60.6	2.3	0.0	2.5	2.3	0.0	0.0
06/08/2013	0.0	279.0	279.0	4.4		0.0	4.4	0.0	2.0	53.4	63.4	1.1	0.0	1.2	1.1	0.0	0.0
07/08/2013	0.0	186.0	186.0	2.9		0.0	2.9	0.0	2.8	55.0	65.0	1.5	0.0	1.6	1.5	0.0	0.0
08/08/2013	0.6	372.0	372.0	5.9		0.0	6.5	0.6	1.8	56.5	66.5	1.0	0.0	1.1	1.0	0.0	0.0
09/08/2013	0.0	279.0	279.0	4.4		0.0	4.4	0.0	2.5	57.9	67.9	1.3	0.0	1.4	1.3	0.0	0.0
10/08/2013	0.0	186.0	186.0	2.9		0.0	2.9	0.0	4.6	59.7	69.7	2.3	0.0	2.4	2.3	0.0	0.0
11/08/2013	0.0	279.0	279.0	4.4		0.0	4.4	0.0	4.1	62.5	72.5	1.9	0.0	2.1	1.9	0.0	0.0
12/08/2013	0.0	372.0	372.0	5.9		0.0	5.9	0.0	3.6	65.0	75.0	1.6	0.0	1.8	1.6	0.0	0.0
13/08/2013	0.8	372.0	372.0	5.9		0.0	6.7	0.8	2.9	66.3	76.3	1.3	0.0	1.4	1.3	0.0	0.0
14/08/2013	0.7	279.0	279.0	4.4		0.0	5.1	0.7	2.7	67.4	77.4	1.2	0.0	1.3	1.2	0.0	0.0
15/08/2013	7.7	372.0	372.0	5.9		0.0	13.6	7.7	3.1	61.3	71.3	1.5	0.0	1.7	1.5	0.0	0.0
16/08/2013	1.2	312.2		0.0	312.2	4.7	1.2	5.9	1.9	62.1	72.1	0.9	0.0	0.9	1.0	0.0	0.0
17/08/2013	2.4	312.2		0.0	312.2	4.7	2.4	7.1	2.3	61.1	71.1	1.1	0.0	1.1	1.2	0.0	0.0
18/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	1.7	62.8	72.8	0.8	0.0	0.8	0.9	0.0	0.0
19/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	3.1	64.1	74.1	1.4	0.0	1.4	1.6	0.0	0.0
20/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	1.9	66.0	76.0	0.8	0.0	0.8	0.9	0.0	0.0
21/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	3.5	67.3	77.3	1.5	0.0	1.5	1.7	0.0	0.0
22/08/2013	1.2	312.2		0.0	312.2	4.7	1.2	5.9	2.9	68.1	78.1	1.2	0.0	1.2	1.4	0.0	0.0
23/08/2013	2.6	312.2		0.0	312.2	4.7	2.6	7.3	2.8	67.2	77.2	1.2	0.0	1.2	1.3	0.0	0.0
24/08/2013	1.0	312.2		0.0	312.2	4.7	1.0	5.7	1.6	67.9	77.9	0.7	0.0	0.7	0.7	0.0	0.0
25/08/2013	0.4	312.2		0.0	312.2	4.7	0.4	5.1	0.6	68.7	78.7	0.2	0.0	0.2	0.3	0.0	0.0
26/08/2013	0.2	312.2		0.0	312.2	4.7	0.2	4.9	2.1	69.2	79.2	0.9	0.0	0.9	1.0	0.0	0.0
27/08/2013	0.4	312.2		0.0	312.2	4.7	0.4	5.1	2.4	70.2	80.2	0.9	0.0	0.9	1.1	0.0	0.0
28/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	1.0	71.6	81.6	0.4	0.0	0.4	0.4	0.0	0.0
29/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	2.6	72.5	82.5	1.0	0.0	1.0	1.1	0.0	0.0
30/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	2.2	74.0	84.0	0.8	0.0	0.8	0.9	0.0	0.0
31/08/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	3.0	75.3	85.3	1.1	0.0	1.1	1.2	0.0	0.0
01/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	1.5	76.8	86.8	0.5	0.0	0.5	0.6	0.0	0.0
02/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	2.7	77.8	87.8	0.9	0.0	0.9	1.0	0.0	0.0
03/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	2.9	79.2	89.2	0.9	0.0	0.9	1.0	0.0	0.0
04/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	2.8	80.6	90.6	0.8	0.0	0.8	0.9	0.0	0.0
05/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	3.1	81.9	91.9	0.9	0.0	0.9	1.0	0.0	0.0
06/09/2013	0.9	312.2		0.0	312.2	4.7	0.9	5.6	2.5	82.4	92.4	0.7	0.0	0.7	0.8	0.0	0.0
07/09/2013	1.6	312.2		0.0	312.2	4.7	1.6	6.3	2.0	82.0	92.0	0.6	0.0	0.6	0.7	0.0	0.0
08/09/2013	0.2	312.2		0.0	312.2	4.7	0.2	4.9	2.6	82.8	92.8	0.7	0.0	0.7	0.8	0.0	0.0
09/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	2.5	84.1	94.1	0.7	0.0	0.7	0.8	0.0	0.0
10/09/2013	0.1	312.2		0.0	312.2	4.7	0.1	4.8	1.3	85.1	95.1	0.3	0.0	0.3	0.4	0.0	0.0
11/09/2013	0.2	312.2		0.0	312.2	4.7	0.2	4.9	1.1	85.7	95.7	0.3	0.0	0.3	0.3	0.0	0.0
12/09/2013	0.3	312.2		0.0	312.2	4.7	0.3	5.0	1.7	86.2	96.2	0.4	0.0	0.4	0.5	0.0	0.0
13/09/2013	0.0	312.2		0.0	312.2	4.7	0.0	4.7	1.6	87.1	97.1	0.4	0.0	0.4	0.4	0.0	0.0
14/09/2013	0.8	312.2		0.0	312.2	4.7	0.8	5.5	1.9	87.2	97.2	0.4	0.0	0.4	0.5	0.0	0.0
15/09/2013	2.2	312.2		0.0	312.2	4.7	2.2	6.9	2.5	85.9	95.9	0.6	0.0	0.6	0.7	0.0	0.0
16/09/2013	2.0	312.2		0.0	312.2	4.7	2.0	6.7	1.9	85.0	95.0	0.5	0.0	0.5	0.6	0.0	0.0
17/09/2013	5.6	312.2		0.0	312.2	4.7	5.6	10.3	0.7	80.4	90.4	0.2	0.0	0.2	0.2	0.0	0.0
18/09/2013	0.8	312.2		0.0	312.2	4.7	0.8	5.5	1.4	80.3	90.3	0.4	0.0	0.4	0.5	0.0	0.0

19/09/2013	1.1	312.2		0.0	312.2	4.7	1.1	5.8	2.0	80.1	90.1	0.6	0.0	0.6	0.7	0.0	0.0
20/09/2013	0.0	488.0	244.0	3.8	244.0	3.7	3.8	3.7	2.0	81.2	91.2	0.6	0.0	0.7	0.7	0.0	0.0
21/09/2013	0.0	348.8	174.4	2.7	174.4	2.6	2.7	2.6	1.5	82.3	92.3	0.4	0.0	0.5	0.5	0.0	0.0
22/09/2013	0.0	363.2	181.6	2.9	181.6	2.8	2.9	2.8	0.8	83.2	93.2	0.2	0.0	0.2	0.2	0.0	0.0
23/09/2013	0.0	348.8	174.4	2.7	174.4	2.6	2.7	2.6	1.3	83.9	93.9	0.3	0.0	0.4	0.4	0.0	0.0
24/09/2013	0.0	315.2	157.6	2.5	157.6	2.4	2.5	2.4	0.8	84.8	94.8	0.2	0.0	0.2	0.2	0.0	0.0
25/09/2013	0.3	348.8	174.4	2.7	174.4	2.6	3.0	2.9	1.3	85.2	95.2	0.3	0.0	0.4	0.4	0.0	0.0
26/09/2013	1.0	331.2	165.6	2.6	165.6	2.5	3.6	3.5	0.2	85.0	95.0	0.1	0.0	0.1	0.1	0.0	0.0
27/09/2013	0.0	337.6	168.8	2.7	168.8	2.6	2.7	2.6	0.9	85.6	95.6	0.2	0.0	0.2	0.2	0.0	0.0
28/09/2013	0.0	320.0	160.0	2.5	160.0	2.4	2.5	2.4	1.3	86.3	96.3	0.3	0.0	0.3	0.3	0.0	0.0
29/09/2013	0.0	364.8	182.4	2.9	182.4	2.8	2.9	2.8	1.6	87.1	97.1	0.4	0.0	0.4	0.4	0.0	0.0
30/09/2013	16.6	326.4	163.2	2.6	163.2	2.5	19.2	19.1	1.3	71.4	81.4	0.5	0.0	0.5	0.5	0.0	0.0
01/10/2013	14.6	360.0	180.0	2.8	180.0	2.7	17.4	17.3	0.3	57.7	67.7	0.2	0.0	0.2	0.2	0.0	0.0
02/10/2013	17.3	369.6	184.8	2.9	184.8	2.8	20.2	20.1	1.5	41.1	51.1	1.0	0.0	1.1	1.1	0.0	0.0
03/10/2013	2.1	363.2	181.6	2.9	181.6	2.8	5.0	4.9	0.2	40.5	50.5	0.2	0.0	0.2	0.2	0.0	0.0
04/10/2013	0.0	372.8	186.4	2.9	186.4	2.8	2.9	2.8	1.1	41.2	51.2	0.8	0.0	0.8	0.8	0.0	0.0
05/10/2013	0.1	465.6	232.8	3.7	232.8	3.5	3.8	3.6	1.1	42.4	52.4	0.8	0.0	0.8	0.8	0.0	0.0
06/10/2013	0.3	428.8	214.4	3.4	214.4	3.2	3.7	3.5	0.4	43.3	53.3	0.3	0.0	0.3	0.3	0.0	0.0
07/10/2013	0.4	452.8	226.4	3.6	226.4	3.4	4.0	3.8	1.4	43.7	53.7	0.9	0.0	1.0	1.0	0.0	0.0
08/10/2013	0.1	460.8	230.4	3.6	230.4	3.5	3.7	3.6	0.6	45.0	55.0	0.4	0.0	0.4	0.4	0.0	0.0
09/10/2013	0.0	475.2	237.6	3.7	237.6	3.6	3.7	3.6	1.0	45.9	55.9	0.6	0.0	0.6	0.6	0.0	0.0
10/10/2013	0.1	459.2	229.6	3.6	229.6	3.5	3.7	3.6	0.5	46.9	56.9	0.3	0.0	0.4	0.4	0.0	0.0
11/10/2013	0.0	433.6	216.8	3.4	216.8	3.3	3.4	3.3	0.4	47.8	57.8	0.3	0.0	0.3	0.3	0.0	0.0
12/10/2013	0.0	465.6	232.8	3.7	232.8	3.5	3.7	3.5	0.8	48.5	58.5	0.5	0.0	0.5	0.5	0.0	0.0
13/10/2013	0.2	476.8	238.4	3.8	238.4	3.6	4.0	3.8	0.5	49.3	59.3	0.3	0.0	0.3	0.3	0.0	0.0
14/10/2013	0.0	486.4	243.2	3.8	243.2	3.7	3.8	3.7	0.7	50.1	60.1	0.4	0.0	0.4	0.4	0.0	0.0
15/10/2013	28.6	505.6	252.8	4.0	252.8	3.8	32.6	32.4	0.2	22.4	32.4	0.2	0.0	0.2	0.2	4.0	3.7
16/10/2013	0.1	529.6	264.8	4.2	264.8	4.0	4.3	4.1	0.8	23.0	33.0	0.7	0.0	0.8	0.8	0.0	0.0
17/10/2013	16.5	478.4	239.2	3.8	239.2	3.6	20.3	20.1	0.6	7.7	17.7	0.6	0.0	0.6	0.6	5.7	5.4
18/10/2013	8.1	472.0	236.0	3.7	236.0	3.6	11.8	11.7	0.2	0.7	10.7	0.2	0.0	0.2	0.2	4.7	4.4
19/10/2013	2.5	449.6	224.8	3.5	224.8	3.4	6.0	5.9	0.7	-1.1	8.9	0.7	0.0	0.7	0.7	0.1	0.0
20/10/2013	9.1	441.6	220.8	3.5	220.8	3.3	12.6	12.4	1.0	-9.1	0.9	1.0	7.2	1.0	1.0	11.6	11.5
21/10/2013	1.8	510.4	255.2	4.0	255.2	3.9	5.8	5.7	0.8	-9.4	0.6	0.8	0.4	0.8	0.8	5.1	4.9
22/10/2013	0.4	451.2	225.6	3.6	225.6	3.4	4.0	3.8	0.6	-8.5	1.5	0.6	0.0	0.6	0.6	3.4	3.2
23/10/2013	2.4	409.6	204.8	3.2	204.8	3.1	5.6	5.5	1.1	-9.8	0.2	1.1	1.2	1.1	1.1	4.5	4.4
24/10/2013	14.8	406.4	203.2	3.2	203.2	3.1	18.0	17.9	0.3	-10.0	0.0	0.3	14.5	0.3	0.3	17.7	17.6
25/10/2013	7.4	385.6	192.8	3.0	192.8	2.9	10.4	10.3	0.6	-10.0	0.0	0.6	6.8	0.6	0.6	9.8	9.7
26/10/2013	8.3	377.6	188.8	3.0	188.8	2.9	11.3	11.2	0.9	-10.0	0.0	0.9	7.4	0.9	0.9	10.3	10.2
27/10/2013	2.1	371.2	185.6	2.9	185.6	2.8	5.0	4.9	1.2	-10.0	0.0	1.2	0.9	1.2	1.2	3.8	3.7
28/10/2013	0.0	361.6	180.8	2.8	180.8	2.7	2.8	2.7	0.7	-8.3	1.7	0.7	0.0	0.7	0.7	2.2	2.1
29/10/2013	3.7	414.4	207.2	3.3	207.2	3.1	7.0	6.8	0.4	-10.0	0.0	0.4	3.3	0.4	0.4	6.6	6.4
30/10/2013	0.8	401.6	200.8	3.2	200.8	3.0	4.0	3.8	0.4	-9.9	0.1	0.4	0.3	0.4	0.4	3.6	3.4
31/10/2013	0.1	424.0	212.0	3.3	212.0	3.2	3.4	3.3	0.5	-9.1	0.9	0.5	0.0	0.5	0.5	2.9	2.8
01/11/2013	5.1	396.8	198.4	3.1	198.4	3.0	8.2	8.1	0.0	-10.0	0.0	0.0	5.1	0.0	0.0	8.2	8.1
02/11/2013	1.1	406.4	203.2	3.2	203.2	3.1	4.3	4.2	0.5	-10.0	0.0	0.5	0.6	0.5	0.5	3.8	3.7
03/11/2013	0.0	382.4	191.2	3.0	191.2	2.9	3.0	2.9	0.3	-9.0	1.0	0.3	0.0	0.3	0.3	2.7	2.6
04/11/2013	1.7	419.2	209.6	3.3	209.6	3.2	5.0	4.9	0.0	-9.9	0.1	0.0	1.6	0.0	0.0	5.0	4.9
05/11/2013	1.5	406.4	203.2	3.2	203.2	3.1	4.7	4.6	0.3	-10.0	0.0	0.3	1.2	0.3	0.3	4.4	4.3
06/11/2013	0.1	380.8	190.4	3.0	190.4	2.9	3.1	3.0	0.1	-9.3	0.7	0.1	0.0	0.1	0.1	3.0	2.9
07/11/2013	0.2	409.6	204.8	3.2	204.8	3.1	3.4	3.3	0.4	-8.9	1.1	0.4	0.0	0.4	0.4	3.1	2.9

08/11/2013	0.5	392.0	196.0	3.1	196.0	3.0	3.6	3.5	0.4	-8.6	1.4	0.4	0.0	0.4	0.4	3.2	3.1
09/11/2013	9.4	393.6	196.8	3.1	196.8	3.0	12.5	12.4	0.2	-10.0	0.0	0.2	9.2	0.2	0.2	12.3	12.2
10/11/2013	0.5	403.2	201.6	3.2	201.6	3.1	3.7	3.6	0.0	-9.8	0.2	0.0	0.3	0.0	0.0	3.7	3.6
11/11/2013	0.1	366.4	183.2	2.9	183.2	2.8	3.0	2.9	0.0	-9.4	0.6	0.0	0.0	0.0	0.0	3.0	2.9
12/11/2013	1.2	412.8	206.4	3.3	206.4	3.1	4.5	4.3	0.4	-10.0	0.0	0.4	0.8	0.4	0.4	4.1	3.9
13/11/2013	0.0	376.0	188.0	3.0	188.0	2.8	3.0	2.8	0.6	-9.1	0.9	0.6	0.0	0.6	0.6	2.4	2.3
14/11/2013	0.0	393.6	196.8	3.1	196.8	3.0	3.1	3.0	0.7	-8.0	2.0	0.7	0.0	0.7	0.7	2.4	2.3
15/11/2013	0.0	364.8	182.4	2.9	182.4	2.8	2.9	2.8	0.3	-6.9	3.1	0.3	0.0	0.3	0.3	2.3	2.1
16/11/2013	0.4	379.2	189.6	3.0	189.6	2.9	3.4	3.3	0.1	-6.4	3.6	0.1	0.0	0.1	0.1	2.7	2.5
17/11/2013	3.6	369.6	184.8	2.9	184.8	2.8	6.5	6.4	0.0	-9.4	0.6	0.0	3.0	0.0	0.0	6.5	6.4
18/11/2013	0.0	353.6	176.8	2.8	176.8	2.7	2.8	2.7	0.0	-8.9	1.1	0.0	0.0	0.0	0.0	2.8	2.7
19/11/2013	2.0	365.4		0.0	365.4	5.5	2.0	7.5	0.1	-10.0	0.0	0.1	1.9	0.1	0.1	1.9	7.4
20/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.7	-9.4	0.6	0.7	0.0	0.7	0.7	0.0	4.8
21/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.3	-8.1	1.9	0.3	0.0	0.3	0.3	0.0	5.3
22/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-7.4	2.6	0.0	0.0	0.0	0.0	0.0	5.5
23/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-6.9	3.1	0.0	0.0	0.0	0.0	0.0	5.5
24/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-6.4	3.6	0.0	0.0	0.0	0.0	0.0	5.5
25/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-5.9	4.1	0.0	0.0	0.0	0.0	0.0	5.5
26/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-5.4	4.6	0.0	0.0	0.0	0.0	0.0	5.5
27/11/2013	0.6	365.4		0.0	365.4	5.5	0.6	6.1	0.0	-5.5	4.5	0.0	0.0	0.0	0.0	0.0	6.1
28/11/2013	0.1	365.4		0.0	365.4	5.5	0.1	5.6	0.0	-5.1	4.9	0.0	0.0	0.0	0.0	0.0	5.6
29/11/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-4.6	5.4	0.0	0.0	0.0	0.0	0.0	5.5
30/11/2013	0.4	365.4		0.0	365.4	5.5	0.4	5.9	0.0	-4.5	5.5	0.0	0.0	0.0	0.0	0.0	5.9
01/12/2013	0.1	365.4		0.0	365.4	5.5	0.1	5.6	0.0	-4.1	5.9	0.0	0.0	0.0	0.0	0.0	5.2
02/12/2013	0.1	365.4		0.0	365.4	5.5	0.1	5.6	0.0	-3.7	6.3	0.0	0.0	0.0	0.0	0.0	4.8
03/12/2013	0.4	365.4		0.0	365.4	5.5	0.4	5.9	0.2	-3.6	6.4	0.2	0.0	0.2	0.2	0.0	4.9
04/12/2013	0.7	365.4		0.0	365.4	5.5	0.7	6.2	0.0	-3.6	6.4	0.0	0.0	0.0	0.0	0.0	5.4
05/12/2013	0.1	365.4		0.0	365.4	5.5	0.1	5.6	0.3	-3.2	6.8	0.3	0.0	0.3	0.3	0.0	4.1
06/12/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-2.4	7.6	0.0	0.0	0.0	0.0	0.0	3.5
07/12/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-1.9	8.1	0.0	0.0	0.0	0.0	0.0	3.0
08/12/2013	0.1	365.4		0.0	365.4	5.5	0.1	5.6	0.0	-1.5	8.5	0.0	0.0	0.0	0.0	0.0	2.7
09/12/2013	0.2	365.4		0.0	365.4	5.5	0.2	5.7	0.0	-1.2	8.8	0.0	0.0	0.0	0.0	0.0	2.5
10/12/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.3	-0.7	9.3	0.3	0.0	0.3	0.3	0.0	1.4
11/12/2013	1.6	365.4		0.0	365.4	5.5	1.6	7.1	0.0	-1.5	8.5	0.0	0.0	0.0	0.0	0.0	4.1
12/12/2013	1.6	365.4		0.0	365.4	5.5	1.6	7.1	0.0	-2.6	7.4	0.0	0.0	0.0	0.0	0.0	5.2
13/12/2013	16.3	365.4		0.0	365.4	5.5	16.3	21.8	0.2	-10.0	0.0	0.2	16.1	0.2	0.2	16.1	21.6
14/12/2013	2.2	365.4		0.0	365.4	5.5	2.2	7.7	0.5	-10.0	0.0	0.5	1.7	0.5	0.5	1.7	7.3
15/12/2013	4.6	365.4		0.0	365.4	5.5	4.6	10.1	0.1	-10.0	0.0	0.1	4.5	0.1	0.1	4.5	10.1
16/12/2013	0.0	365.4		0.0	365.4	5.5	0.0	5.5	0.0	-9.4	0.6	0.0	0.0	0.0	0.0	0.0	5.5
17/12/2013	16.6	279.0	279.0	4.4		0.0	21.0	16.6	0.0	-10.0	0.0	0.0	16.6	0.0	0.0	21.0	16.6
18/12/2013	2.9	372.0	372.0	5.9		0.0	8.8	2.9	0.2	-10.0	0.0	0.2	2.7	0.2	0.2	8.6	2.7
19/12/2013	3.7	372.0	372.0	5.9		0.0	9.6	3.7	0.1	-10.0	0.0	0.1	3.6	0.1	0.1	9.4	3.6
20/12/2013	10.7	372.0	372.0	5.9		0.0	16.6	10.7	0.6	-10.0	0.0	0.6	10.1	0.6	0.6	15.9	10.1
21/12/2013	2.0	372.0	372.0	5.9		0.0	7.9	2.0	0.6	-10.0	0.0	0.6	1.4	0.6	0.6	7.2	1.4
22/12/2013	9.6	558.0	558.0	8.8		0.0	18.4	9.6	0.4	-10.0	0.0	0.4	9.2	0.4	0.4	18.0	9.2
23/12/2013	0.3	372.0	372.0	5.9		0.0	6.2	0.3	0.6	-9.4	0.6	0.6	0.0	0.6	0.6	5.6	0.0
24/12/2013	0.0	558.0	558.0	8.8		0.0	8.8	0.0	0.7	-8.3	1.7	0.7	0.0	0.7	0.7	8.1	0.0
25/12/2013	7.0	558.0	558.0	8.8		0.0	15.8	7.0	0.0	-10.0	0.0	0.0	7.0	0.0	0.0	15.8	7.0
26/12/2013	6.0	465.0	465.0	7.3		0.0	13.3	6.0	0.1	-10.0	0.0	0.1	5.9	0.1	0.1	13.2	5.9
27/12/2013	0.0	372.0	372.0	5.9		0.0	5.9	0.0	0.6	-9.4	0.6	0.6	0.0	0.6	0.6	5.2	0.0

28/12/2013	13.0	465.0	465.0	7.3	0.0	20.3	13.0	0.1	-10.0	0.0	0.1	12.9	0.1	0.1	20.2	12.9
29/12/2013	20.4	651.0	651.0	10.3	0.0	30.7	20.4	0.2	-10.0	0.0	0.2	20.2	0.2	0.2	30.4	20.2
30/12/2013	16.0	372.0	372.0	5.9	0.0	21.9	16.0	0.1	-10.0	0.0	0.1	15.9	0.1	0.1	21.8	15.9
31/12/2013	4.4	372.0	372.0	5.9	0.0	10.3	4.4	0.0	-10.0	0.0	0.0	4.4	0.0	0.0	10.3	4.4
01/01/2014	2.1	279.0	279.0	4.4	0.0	6.5	2.1	0.0	-10.0	0.0	0.0	2.1	0.0	0.0	6.5	2.1
02/01/2014	2.8	279.0	279.0	4.4	0.0	7.2	2.8	0.2	-10.0	0.0	0.2	2.6	0.2	0.2	7.0	2.6
03/01/2014	4.8	372.0	372.0	5.9	0.0	10.7	4.8	1.1	-10.0	0.0	1.1	3.7	1.1	1.1	9.6	3.7
04/01/2014	7.5	279.0	279.0	4.4	0.0	11.9	7.5	0.2	-10.0	0.0	0.2	7.3	0.2	0.2	11.7	7.3
05/01/2014	5.1	372.0	372.0	5.9	0.0	11.0	5.1	0.2	-10.0	0.0	0.2	4.9	0.2	0.2	10.7	4.9
06/01/2014	1.2	372.0	372.0	5.9	0.0	7.1	1.2	1.0	-10.0	0.0	1.0	0.2	1.0	1.0	6.1	0.2
07/01/2014	12.3	372.0	372.0	5.9	0.0	18.2	12.3	0.8	-10.0	0.0	0.8	11.5	0.8	0.8	17.4	11.5
08/01/2014	1.7	279.0	279.0	4.4	0.0	6.1	1.7	0.1	-10.0	0.0	0.1	1.6	0.1	0.1	6.0	1.6
09/01/2014	1.5	372.0	372.0	5.9	0.0	7.4	1.5	0.1	-10.0	0.0	0.1	1.4	0.1	0.1	7.3	1.4
10/01/2014	0.0	372.0	372.0	5.9	0.0	5.9	0.0	0.0	-9.4	0.6	0.0	0.0	0.0	0.0	5.9	0.0
11/01/2014	3.3	279.0	279.0	4.4	0.0	7.7	3.3	0.0	-10.0	0.0	0.0	3.3	0.0	0.0	7.7	3.3
12/01/2014	1.0	372.0	372.0	5.9	0.0	6.9	1.0	0.1	-10.0	0.0	0.1	0.9	0.1	0.1	6.7	0.9
13/01/2014	5.1	279.0	279.0	4.4	0.0	9.5	5.1	0.0	-10.0	0.0	0.0	5.1	0.0	0.0	9.5	5.1
14/01/2014	2.0	372.0	372.0	5.9	0.0	7.9	2.0	0.0	-10.0	0.0	0.0	2.0	0.0	0.0	7.9	2.0
15/01/2014	8.8	279.0	279.0	4.4	0.0	13.2	8.8	0.0	-10.0	0.0	0.0	8.8	0.0	0.0	13.2	8.8
16/01/2014	0.8	279.0	279.0	4.4	0.0	5.2	0.8	0.0	-10.0	0.0	0.0	0.8	0.0	0.0	5.2	0.8
17/01/2014	10.4	372.0	372.0	5.9	0.0	16.3	10.4	0.0	-10.0	0.0	0.0	10.4	0.0	0.0	16.3	10.4
18/01/2014	0.4	279.0	279.0	4.4	0.0	4.8	0.4	0.1	-9.9	0.1	0.1	0.2	0.1	0.1	4.7	0.3
19/01/2014	0.1	372.0	372.0	5.9	0.0	6.0	0.1	0.0	-9.4	0.6	0.0	0.0	0.0	0.0	5.9	0.0
20/01/2014	2.3	372.0	372.0	5.9	0.0	8.2	2.3	0.2	-10.0	0.0	0.2	2.1	0.2	0.2	8.0	2.1
21/01/2014	0.2	372.0	372.0	5.9	0.0	6.1	0.2	0.2	-9.5	0.5	0.2	0.0	0.2	0.2	5.9	0.0
22/01/2014	2.2	279.0	279.0	4.4	0.0	6.6	2.2	0.1	-10.0	0.0	0.1	2.1	0.1	0.1	6.5	2.1
23/01/2014	9.7	372.0	372.0	5.9	0.0	15.6	9.7	0.3	-10.0	0.0	0.3	9.4	0.3	0.3	15.2	9.4
24/01/2014	6.1	279.0	279.0	4.4	0.0	10.5	6.1	0.2	-10.0	0.0	0.2	5.9	0.2	0.2	10.3	5.9
25/01/2014	18.2	279.0	279.0	4.4	0.0	22.6	18.2	0.6	-10.0	0.0	0.6	17.6	0.6	0.6	22.0	17.6
26/01/2014	6.9	279.0	279.0	4.4	0.0	11.3	6.9	0.7	-10.0	0.0	0.7	6.2	0.7	0.7	10.6	6.2
27/01/2014	5.0	372.0	372.0	5.9	0.0	10.9	5.0	0.4	-10.0	0.0	0.4	4.6	0.4	0.4	10.5	4.6
28/01/2014	1.4	651.0	651.0	10.3	0.0	11.7	1.4	0.3	-10.0	0.0	0.3	1.2	0.3	0.3	11.4	1.2

measured values

Date	Temp	Humidity	Pressure	Net Rad.	Windspeec	Rainfall	J	Temp			Humidity		u_2	Δ	P	γ	A	B	C	D	e^0(Tmax)	e^0(Tmin)	e_s	e_a	e_s-e_a	Rn	ET_0	ET (no neg)
	C	%	mb	W/m2	m/s	mm		max	min	mean	max	min	m/s	kPa/C	kPa	kPa/C	(1+0.34*u	Δ/(Δ+γ*A)	γ/(Δ+γ*A)	900/(Tm+273)*	kPa	kPa	kPa	kPa	kPa	mm/day	mm/day	mm/day
daily	average	average	average	average	average	sum		max	min	mean	max	min																
19/12/2012 00:00	5.5	93	1006.11	0.23	0.27	0.40	354	5.71	5.27	5.49	98	83	0.27	0.063	100.611	0.067	1.090	0.462	0.493	0.858	0.916	0.889	0.903	0.816	0.087	0.008	**0.040**	**0.040**
20/12/2012 00:00	6.2	97	999.74	0.32	1.01	1.80	355	6.33	6.15	6.24	99	94	1.01	0.066	99.974	0.066	1.344	0.424	0.429	3.266	0.957	0.945	0.951	0.917	0.033	0.011	**0.052**	**0.052**
21/12/2012 00:00	3.5	94	1007.46	0.44	0.90	14.70	356	3.80	3.22	3.51	98	88	0.90	0.056	100.746	0.067	1.305	0.388	0.469	2.921	0.802	0.770	0.786	0.730	0.056	0.015	**0.082**	**0.082**
22/12/2012 00:00	11.6	94	994.92	0.17	2.76	6.00	357	11.77	11.48	11.63	97	86	2.76	0.091	99.492	0.066	1.940	0.414	0.302	8.739	1.382	1.355	1.369	1.251	0.117	0.006	**0.312**	**0.312**
23/12/2012 00:00	7.6	81	998.59	0.51	1.88	0.50	358	7.91	7.24	7.58	94	72	1.88	0.071	99.859	0.066	1.639	0.396	0.369	6.026	1.066	1.019	1.042	0.863	0.180	0.018	**0.407**	**0.407**
24/12/2012 00:00	7.4	90	993.53	0.54	0.92	1.10	359	7.62	7.09	7.36	95	80	0.92	0.070	99.353	0.066	1.312	0.448	0.421	2.947	1.046	1.008	1.027	0.897	0.130	0.019	**0.169**	**0.169**
25/12/2012 00:00	5.3	90	993.61	0.66	1.10	8.30	360	5.55	5.05	5.30	97	80	1.10	0.062	99.361	0.066	1.373	0.406	0.432	3.551	0.907	0.876	0.891	0.787	0.104	0.023	**0.169**	**0.169**
26/12/2012 00:00	6.3	85	999.08	0.39	1.60	7.80	361	6.56	6.03	6.30	96	74	1.60	0.066	99.908	0.066	1.544	0.391	0.394	5.152	0.972	0.937	0.955	0.809	0.145	0.014	**0.300**	**0.300**
27/12/2012 00:00	5.1	87	1005.82	0.67	1.13	4.60	362	5.40	4.89	5.15	96	76	1.13	0.061	100.582	0.067	1.383	0.399	0.435	3.641	0.897	0.866	0.881	0.756	0.125	0.024	**0.207**	**0.207**
28/12/2012 00:00	10.5	91	1003.16	0.21	2.39	3.00	363	10.73	10.27	10.50	97	83	2.39	0.085	100.316	0.067	1.814	0.412	0.324	7.599	1.289	1.251	1.270	1.142	0.128	0.007	**0.319**	**0.319**
29/12/2012 00:00	6.0	83	994.90	0.64	1.44	6.30	364	6.22	5.76	5.99	94	70	1.44	0.065	99.490	0.066	1.489	0.396	0.405	4.640	0.949	0.920	0.935	0.765	0.170	0.022	**0.329**	**0.329**
30/12/2012 00:00	6.6	83	1002.79	0.47	1.69	3.40	365	6.91	6.36	6.64	90	72	1.69	0.067	100.279	0.067	1.575	0.391	0.387	5.439	0.996	0.959	0.977	0.790	0.187	0.017	**0.401**	**0.401**
31/12/2012 00:00	7.5	85	996.09	0.59	1.70	1.40	366	7.73	7.23	7.48	93	78	1.70	0.071	99.609	0.066	1.577	0.404	0.378	5.448	1.053	1.017	1.035	0.884	0.151	0.021	**0.320**	**0.320**
01/01/2013 00:00	3.4	81	1010.41	0.81	1.10	0.10	1	3.67	3.19	3.43	86	73	1.10	0.055	101.041	0.067	1.373	0.375	0.456	3.570	0.794	0.768	0.781	0.620	0.161	0.029	**0.273**	**0.273**
02/01/2013 00:00	9.0	89	1021.97	0.29	0.86	0.00	2	9.25	8.82	9.03	94	83	0.86	0.078	102.197	0.068	1.293	0.469	0.410	2.752	1.167	1.134	1.151	1.017	0.133	0.010	**0.155**	**0.155**
03/01/2013 00:00	10.1	90	1031.11	0.62	0.73	0.00	3	10.36	9.89	10.12	93	84	0.73	0.083	103.111	0.069	1.247	0.492	0.407	2.312	1.258	1.219	1.238	1.095	0.143	0.022	**0.145**	**0.145**
04/01/2013 00:00	8.9	87	1034.45	0.35	0.94	0.00	4	9.08	8.74	8.91	92	80	0.94	0.077	103.445	0.069	1.321	0.459	0.409	3.017	1.154	1.128	1.141	0.980	0.161	0.012	**0.204**	**0.204**
05/01/2013 00:00	9.5	89	1030.58	0.42	0.91	0.10	5	9.82	9.26	9.54	97	83	0.91	0.080	103.058	0.069	1.309	0.472	0.404	2.895	1.213	1.168	1.191	1.070	0.121	0.015	**0.148**	**0.148**
06/01/2013 00:00	9.2	91	1027.20	0.27	0.83	1.10	6	9.36	9.06	9.21	98	85	0.83	0.079	102.720	0.068	1.283	0.472	0.411	2.658	1.176	1.153	1.164	1.065	0.100	0.009	**0.113**	**0.113**
07/01/2013 00:00	9.8	93	1019.38	0.14	1.16	1.70	7	9.90	9.78	9.84	95	91	1.16	0.081	101.938	0.068	1.396	0.463	0.385	3.704	1.220	1.210	1.215	1.130	0.085	0.005	**0.124**	**0.124**
08/01/2013 00:00	7.4	89	1021.26	0.79	0.88	1.80	8	7.76	7.08	7.42	97	74	0.88	0.071	102.126	0.068	1.298	0.445	0.428	2.814	1.055	1.007	1.031	0.879	0.152	0.028	**0.196**	**0.196**
09/01/2013 00:00	-1.7	97	1022.72	0.65	0.29	1.40	9	-1.47	-1.89	-1.68	99	88	0.29	0.040	102.272	0.068	1.097	0.348	0.594	0.947	0.548	0.532	0.540	0.504	0.036	0.023	**0.028**	**0.028**
10/01/2013 00:00	4.2	91	1015.55	0.77	0.81	0.00	10	4.51	3.82	4.16	98	76	0.81	0.058	101.555	0.068	1.276	0.402	0.469	2.631	0.843	0.803	0.823	0.714	0.109	0.027	**0.146**	**0.146**
11/01/2013 00:00	2.9	93	1014.30	0.78	0.57	2.80	11	3.33	2.47	2.90	97	86	0.57	0.053	101.430	0.067	1.193	0.399	0.504	1.856	0.776	0.730	0.753	0.687	0.065	0.027	**0.072**	**0.072**
12/01/2013 00:00	4.9	87	1010.76	0.47	1.04	0.00	12	5.14	4.64	4.89	94	79	1.04	0.060	101.076	0.067	1.355	0.399	0.444	3.378	0.881	0.851	0.866	0.748	0.118	0.016	**0.183**	**0.183**
13/01/2013 00:00	-0.3	95	1021.17	0.45	0.45	2.20	13	0.03	-0.59	-0.28	98	92	0.45	0.044	102.117	0.068	1.152	0.358	0.557	1.477	0.612	0.585	0.599	0.568	0.030	0.016	**0.031**	**0.031**
14/01/2013 00:00	3.9	85	1015.50	0.65	1.18	0.60	14	4.17	3.69	3.93	95	75	1.18	0.057	101.550	0.068	1.400	0.376	0.446	3.819	0.823	0.795	0.809	0.686	0.123	0.023	**0.217**	**0.217**
15/01/2013 00:00	1.5	88	1012.34	0.85	0.61	0.00	15	1.84	1.24	1.54	96	82	0.61	0.049	101.234	0.067	1.207	0.376	0.517	1.997	0.698	0.668	0.683	0.607	0.076	0.030	**0.090**	**0.090**
16/01/2013 00:00	4.2	93	1009.17	0.23	0.96	8.20	16	4.24	4.07	4.16	97	90	0.96	0.058	100.917	0.067	1.325	0.394	0.457	3.106	0.827	0.817	0.822	0.769	0.054	0.008	**0.079**	**0.079**
17/01/2013 00:00	6.4	94	1007.13	0.52	1.85	18.70	17	6.48	6.25	6.37	98	84	1.85	0.066	100.713	0.067	1.629	0.378	0.382	5.959	0.967	0.952	0.959	0.872	0.087	0.018	**0.205**	**0.205**
18/01/2013 00:00	4.6	89	992.41	0.60	2.75	3.80	18	4.81	4.29	4.55	95	81	2.75	0.059	99.241	0.066	1.936	0.317	0.353	8.930	0.861	0.830	0.846	0.743	0.103	0.021	**0.330**	**0.330**
19/01/2013 00:00	0.9	89	998.29	0.28	0.81	0.40	19	1.09	0.76	0.93	96	81	0.81	0.047	99.829	0.066	1.274	0.358	0.504	2.647	0.661	0.646	0.653	0.578	0.076	0.010	**0.105**	**0.105**
20/01/2013 00:00	0.4	81	997.91	0.44	1.17	0.00	20	0.49	0.26	0.38	92	74	1.17	0.046	99.791	0.066	1.396	0.329	0.480	3.838	0.633	0.622	0.628	0.521	0.107	0.016	**0.203**	**0.203**
21/01/2013 00:00	0.0	90	994.40	1.08	0.81	0.00	21	0.35	-0.30	0.02	97	84	0.81	0.045	99.440	0.066	1.275	0.346	0.513	2.664	0.626	0.598	0.612	0.553	0.059	0.038	**0.094**	**0.094**
22/01/2013 00:00	-2.2	92	1000.83	1.45	0.66	0.00	22	-1.82	-2.58	-2.20	97	84	0.66	0.039	100.083	0.067	1.225	0.321	0.554	2.196	0.534	0.505	0.520	0.469	0.050	0.051	**0.078**	**0.078**
23/01/2013 00:00	-1.3	89	1007.51	0.62	0.82	0.00	23	-1.03	-1.59	-1.31	97	76	0.82	0.041	100.751	0.067	1.278	0.323	0.530	2.708	0.567	0.544	0.555	0.479	0.076	0.022	**0.116**	**0.116**
24/01/2013 00:00	1.9	88	1014.47	0.71	0.94	5.10	24	2.16	1.73	1.94	95	77	0.94	0.050	101.447	0.067	1.320	0.361	0.484	3.079	0.714	0.692	0.703	0.603	0.099	0.025	**0.157**	**0.157**
25/01/2013 00:00	6.6	88	1003.17	0.15	2.47	18.30	25	6.71	6.44	6.57	96	69	2.47	0.067	100.317	0.067	1.841	0.353	0.351	7.959	0.982	0.964	0.973	0.801	0.171	0.005	**0.481**	**0.481**
26/01/2013 00:00	6.5	87	999.99	0.39	2.82	4.50	26	6.70	6.20	6.45	93	73	2.82	0.067	99.999	0.066	1.958	0.338	0.338	9.076	0.981	0.948	0.965	0.799	0.166	0.013	**0.513**	**0.513**
27/01/2013 00:00	4.4	78	990.25	1.11	5.43	2.00	27	4.73	4.00	4.36	86	65	5.43	0.059	99.025	0.066	2.845	0.238	0.268	17.608	0.856	0.813	0.835	0.628	0.207	0.039	**0.984**	**0.984**
28/01/2013 00:00	6.6	78	994.82	0.59	5.28	5.40	28	6.87	6.36	6.61	93	62	5.28	0.067	99.482	0.066	2.795	0.267	0.262	16.989	0.993	0.958	0.976	0.754	0.222	0.021	**0.996**	**0.996**
29/01/2013 00:00	8.8	84	994.33	0.34	3.44	3.60	29	9.07	8.52	8.80	96	73	3.44	0.077	99.433	0.066	2.171	0.348	0.300	10.997	1.154	1.112	1.133	0.955	0.178	0.012	**0.592**	**0.592**
30/01/2013 00:00	7.1	74	1003.17	1.26	5.30	3.70	30	7.39	6.75	7.07	87	62	5.30	0.069	100.317	0.067	2.801	0.270	0.261	17.021	1.029	0.985	1.007	0.747	0.259	0.044	**1.163**	**1.163**
31/01/2013 00:00	6.5	75	1006.41	1.09	5.22	1.80	31	6.83	6.23	6.53	85	62	5.22	0.067	100.641	0.067	2.776	0.265	0.265	16.820	0.990	0.950	0.970	0.711	0.259	0.038	**1.166**	**1.166**
01/02/2013 00:00	4.2	78	1004.43	1.14	3.17	1.50	32	4.52	3.97	4.24	91	63	3.17	0.058	100.443	0.067	2.078	0.295	0.339	10.294	0.844	0.811	0.827	0.635	0.193	0.040	**0.684**	**0.684**
02/02/2013 00:00	3.5	77	1022.27	1.30	1.41	0.00	33	3.84	3.09	3.47	91	52	1.41	0.055	102.227	0.068	1.478	0.355	0.436	4.576	0.804	0.763	0.783	0.556	0.227	0.045	**0.470**	**0.470**
03/02/2013 00:00	8.2	89	1017.70	0.70	4.15	0.00	34	8.37	8.07	8.22	95	83	4.15	0.074	101.770	0.068	2.413	0.312	0.285	13.297	1.100	1.078	1.089	0.969	0.120	0.024	**0.464**	**0.464**
04/02/2013 00:00	6.0	74	1013.14	1.08	5.70	9.80	35	6.30	5.68	5.99	92	60	5.70	0.065	101.314	0.067	2.939	0.246	0.256	18.400	0.954	0.914	0.934	0.707	0.227	0.038	**1.083**	**1.083**
05/02/2013 00:00	2.3	80	1003.68	1.49	4.72	3.80	36	2.49	2.08	2.28	92	70	4.72	0.051	100.368	0.067	2.605	0.228	0.296	15.431	0.731	0.709	0.720	0.582	0.138	0.052	**0.643**	**0.643**
06/02/2013 00:00	3.3	71	1019.90	1.61	2.62	0.00	37	3.50	3.02	3.26	84	58	2.62	0.055	101.990	0.068	1.892	0.299	0.371	8.551	0.785	0.759	0.772	0.547	0.226	0.056	**0.732**	**0.732**
07/02/2013 00:00	2.7	85	1021.96	0.66	2.63	3.50	38	2.94	2.51	2.73	95	75	2.63	0.053	102.196	0.068	1.894	0.291	0.374	8.587	0.755	0.732	0.743	0.631	0.113	0.023	**0.369**	**0.369**
08/02/2013 00:00	5.2	81	1025.21	1.36	2.43	0.20	39	5.51	4.97	5.24	93	74	2.43	0.062	102.521	0.068	1.826	0.332	0.366	7.859	0.904	0.871	0.887	0.739	0.148	0.047	**0.441**	**0.441**
09/02/2013 00:00	6.3	88	1017.44	0.82	1.39	5.30	40	6.46	6.15	6.31	96	81	1.39	0.066	101.744	0.068	1.473	0.398	0.408	4.485	0.966	0.945	0.955	0.845	0.111	0.029	**0.214**	**0.214**
10/02/2013 00:00	5.7	91	994.55	0.62	2.84	2.20	41	5.81	5.62	5.72	97	81	2.84	0.064	99.455	0.066	1.964	0.329	0.342	9.156	0.923	0.911	0.917	0.816	0.101	0.022	**0.324**	**0.324**
11/02/2013 00:00	3.5	92	1000.52	0.69	1.16	0.40	42	3.63	3.38	3.51	96	88	1.16	0.056	100.052	0.067	1.393	0.375	0.449	3.762	0.792	0.779	0.785	0.722	0.063	0.024	**0.116**	**0.116**
12/02/2013 00:00	3.8	94	1013.92	0.49	0.78	2.10	43	3.91	3.69	3.80	96	89	0.78	0.057	101.392	0.067	1.266	0.398	0.475	2.541	0.808	0.796	0.802	0.742	0.060	0.017	**0.080**	**0.080**
13/02/2013 00:00	8.4	92	1010.06	12.76	2.24	3.80	44	8.56	8.24	8.40	97	80	2.24	0.075	101.006	0.067	1.763	0.387	0.348	7.174	1.114	1.090	1.102	0.975	0.128	0.446	**0.492**	**0.492**
14/02/2013 00:00	6.1	82	1012.04	2.19	2.96	0.40	45	6.46	5.82	6.14	88	67	2.96	0.065	101.204	0.067	2.006	0.326	0.336	9.541	0.966	0.924	0.945	0.730	0.215	0.077	**0.713**	**0.713**
15/02/2013 00:00	4.7	85	1020.10	13.27	1.44	0.10	46	4.97	4.47	4.72	97	64	1.44	0.060	102.010	0.068	1.490	0.372	0.421	4.674	0.871	0.840	0.856	0.686	0.169	0.465	**0.506**	**0.506**
16/02/2013 00:00	8.1	87	1018.51	18.05	1.76	0.00	47	8.18	7.98	8.08	96	75	1.76	0.073	101.851	0.068	1.599	0.404	0.373	5.637	1.086	1.071	1.079	0.921	0.157	0.632	**0.586**	**0.586**
17/02/2013 00:00	7.0	78	1014.78	15.42	3.51	0.00	48	7.13	6.80	6.97	86	67	3.51	0.069	101.478	0.067	2.195	0.317	0.311	11.297	1.011	0.988	1.000	0.764	0.236	0.540	**1.001**	**1.001**
18/02/2013 00:00	5.7	76	1015.61	12.41	2.91	0.00	49	5.86	5.60	5.73	81	70	2.91	0.064	101.561	0.068	1.991	0.321	0.341	9.412	0.926	0.909	0.918	0.693	0.225	0.434	**0.863**	**0.863**
19/02/2013 00:00	5.2	81	1018.13	13.91	1.62	0.00	50	5.50	4.93	5.21	93	63	1.62	0.062	101.813	0.068	1.552	0.370	0.406	5.256	0.903	0.868	0.885	0.688	0.197	0.487	**0.601**	**0.601**
20/02/2013 00:00	3.5	83	1018.68	18.56	2.51	0.00	51	3.82	3.20	3.51	95	71	2.51	0.056	101.868	0.068	1.854	0.306	0.374	8.176	0.803	0.768	0.786	0.650	0.136	0.649	**0.614**	**0.614**
21/02/2013 00:00	2.0	69	1020.65	6.28	3.39	0.00	52	2.12	1.90	2.01	73	64	3.39	0.051	102.065	0.068	2.152	0.257	0.345	11.092	0.712	0.701	0.706	0.484	0.223	0.220	**0.909**	**0.909**
22/02/2013 00:00	0.3	64	1022.57	8.82	2.51	0.00	53	0.40	0.20	0.30	75	59	2.51	0.045	102.257	0.068	1.852	0.265	0.397	8.256	0.629	0.620	0.624	0.418	0.206	0.309	**0.758**	**0.758**
23/02/2013 00:00	0.7	78	1025.34	7.15	0.76	0.00	54	0.78	0.54	0.66	93	63	0.76	0.046	102.534	0.068	1.259	0.351	0.516	2.501	0.646	0.635	0.641	0.499	0.142	0.250	**0.271**	**0.271**
24/02/2013 00:00	0.8	79	1029.51	35.32	0.93	0.00	55	1.25	0.39	0.82	93	48	0.93	0.047	102.951	0.068	1.318	0.342	0.499	3.069	0.669	0.629	0.649	0.453	0.196	1.236	**0.723**	**0.723**

25/02/2013 00:00	0.8	78	1033.72	35.09	0.90	0.00	56	1.33	0.32	0.82	93	56	0.90	0.047	103.372	0.069	1.305	0.343	0.503	2.946	0.672	0.625	0.649	0.479	0.170	1.228	**0.673**	**0.673**
26/02/2013 00:00	1.6	85	1035.82	7.90	0.81	0.00	57	1.93	1.22	1.58	95	68	0.81	0.049	103.582	0.069	1.276	0.359	0.503	2.657	0.702	0.667	0.685	0.556	0.129	0.276	**0.272**	**0.272**
27/02/2013 00:00	4.2	83	1037.35	19.82	0.94	0.00	58	4.47	4.02	4.25	94	66	0.94	0.058	103.735	0.069	1.319	0.390	0.463	3.049	0.840	0.815	0.828	0.660	0.167	0.694	**0.506**	**0.506**
28/02/2013 00:00	2.5	88	1034.12	13.50	1.22	0.00	59	2.68	2.23	2.45	94	77	1.22	0.052	103.412	0.069	1.415	0.348	0.461	3.989	0.741	0.717	0.729	0.622	0.107	0.472	**0.361**	**0.361**
01/03/2013 00:00	3.6	79	1032.66	19.82	1.17	0.00	60	3.95	3.22	3.59	97	54	1.17	0.056	103.266	0.069	1.397	0.368	0.453	3.800	0.810	0.770	0.790	0.592	0.198	0.694	**0.595**	**0.595**
02/03/2013 00:00	3.7	77	1029.21	24.32	0.71	0.00	61	4.03	3.36	3.69	91	59	0.71	0.056	102.921	0.068	1.241	0.398	0.485	2.305	0.815	0.777	0.796	0.594	0.202	0.851	**0.565**	**0.565**
03/03/2013 00:00	1.6	84	1022.23	19.51	1.50	0.00	62	1.91	1.20	1.55	98	66	1.50	0.049	102.223	0.068	1.509	0.324	0.448	4.909	0.701	0.666	0.684	0.558	0.126	0.683	**0.498**	**0.498**
04/03/2013 00:00	3.9	79	1011.48	7.13	1.98	0.00	63	4.04	3.80	3.92	89	73	1.98	0.057	101.148	0.067	1.672	0.336	0.397	6.423	0.816	0.802	0.809	0.655	0.154	0.249	**0.477**	**0.477**
05/03/2013 00:00	3.4	79	1003.06	22.35	0.98	2.10	64	3.75	3.01	3.38	97	57	0.98	0.055	100.306	0.067	1.332	0.383	0.464	3.178	0.799	0.758	0.779	0.596	0.183	0.782	**0.569**	**0.569**
06/03/2013 00:00	7.1	88	997.95	6.76	1.71	5.00	65	7.18	7.00	7.09	95	74	1.71	0.069	99.795	0.066	1.581	0.397	0.381	5.492	1.014	1.002	1.008	0.851	0.157	0.236	**0.422**	**0.422**
07/03/2013 00:00	8.1	93	992.76	4.18	2.66	8.20	66	8.22	8.08	8.15	96	89	2.66	0.074	99.276	0.066	1.904	0.370	0.331	8.507	1.089	1.078	1.084	1.002	0.081	0.146	**0.284**	**0.284**
08/03/2013 00:00	8.9	93	992.96	26.38	2.15	2.10	67	9.05	8.77	8.91	97	83	2.15	0.077	99.296	0.066	1.731	0.403	0.345	6.860	1.152	1.130	1.141	1.026	0.115	0.923	**0.644**	**0.644**
09/03/2013 00:00	8.5	87	1000.33	23.83	2.74	8.80	68	8.68	8.27	8.48	93	82	2.74	0.075	100.033	0.067	1.931	0.369	0.327	8.758	1.124	1.093	1.108	0.969	0.139	0.834	**0.707**	**0.707**
10/03/2013 00:00	3.0	72	1007.11	-2.15	3.68	0.90	69	3.17	2.92	3.05	86	50	3.68	0.054	100.711	0.067	2.252	0.263	0.327	12.007	0.767	0.753	0.760	0.516	0.245	-0.075	**0.940**	**0.940**
11/03/2013 00:00	-1.0	73	1015.27	37.26	3.79	1.90	70	-0.61	-1.34	-0.98	94	45	3.79	0.042	101.527	0.068	2.288	0.213	0.344	12.534	0.584	0.554	0.569	0.392	0.177	1.304	**1.042**	**1.042**
12/03/2013 00:00	0.3	71	1017.96	60.14	1.79	0.00	71	0.58	0.02	0.30	85	57	1.79	0.045	101.796	0.068	1.607	0.294	0.439	5.881	0.637	0.612	0.624	0.442	0.183	2.105	**1.091**	**1.091**
13/03/2013 00:00	2.8	80	1016.56	55.97	1.60	0.60	72	3.18	2.38	2.78	92	58	1.60	0.053	101.656	0.068	1.545	0.337	0.429	5.231	0.767	0.725	0.746	0.556	0.190	1.959	**1.087**	**1.087**
14/03/2013 00:00	2.2	84	1016.21	51.65	2.23	0.90	73	2.66	1.74	2.20	95	64	2.23	0.051	101.621	0.068	1.757	0.301	0.398	7.277	0.740	0.692	0.716	0.566	0.150	1.808	**0.980**	**0.980**
15/03/2013 00:00	4.9	82	999.72	66.46	2.85	2.90	74	5.25	4.49	4.87	94	59	2.85	0.060	99.972	0.066	1.971	0.316	0.347	9.246	0.887	0.842	0.865	0.657	0.207	2.326	**1.399**	**1.399**
16/03/2013 00:00	1.7	83	992.53	66.42	0.91	0.00	75	2.16	1.21	1.68	99	52	0.91	0.049	99.253	0.066	1.310	0.364	0.485	2.989	0.714	0.667	0.690	0.515	0.175	2.325	**1.099**	**1.099**
17/03/2013 00:00	2.3	87	989.20	44.88	2.41	1.10	76	2.77	1.90	2.34	94	74	2.41	0.052	98.920	0.066	1.819	0.301	0.384	7.873	0.745	0.701	0.723	0.605	0.118	1.571	**0.830**	**0.830**
18/03/2013 00:00	3.1	87	991.88	22.12	1.22	0.00	77	3.41	2.86	3.14	94	72	1.22	0.054	99.188	0.066	1.414	0.368	0.447	3.969	0.780	0.750	0.765	0.634	0.132	0.774	**0.519**	**0.519**
19/03/2013 00:00	2.0	84	998.04	33.9	1.12	0.30	78	2.23	1.78	2.01	91	72	1.12	0.051	99.804	0.066	1.380	0.356	0.467	3.657	0.718	0.695	0.706	0.574	0.132	1.188	**0.647**	**0.647**
20/03/2013 00:00	2.0	84	1006.25	74.1	0.95	0.00	79	2.39	1.60	1.99	93	65	0.95	0.050	100.625	0.067	1.323	0.363	0.481	3.111	0.725	0.686	0.706	0.555	0.151	2.594	**1.168**	**1.168**
21/03/2013 00:00	4.2	86	1006.23	-2.0	4.70	30.50	80	4.31	4.04	4.18	91	78	4.70	0.058	100.623	0.067	2.597	0.250	0.289	15.254	0.831	0.815	0.823	0.695	0.128	-0.070	**0.547**	**0.547**
22/03/2013 00:00	6.9	92	998.13	11.9	4.66	11.60	81	7.06	6.82	6.94	95	89	4.66	0.069	99.813	0.066	2.584	0.286	0.276	14.978	1.006	0.990	0.998	0.918	0.080	0.416	**0.450**	**0.450**
23/03/2013 00:00	4.1	85	1007.84	15.4	3.13	0.00	82	4.23	4.05	4.14	92	79	3.13	0.058	100.784	0.067	2.065	0.294	0.342	10.174	0.827	0.816	0.821	0.702	0.119	0.538	**0.573**	**0.573**
24/03/2013 00:00	1.3	73	1014.14	6.3	2.98	0.00	83	1.35	1.20	1.27	80	68	2.98	0.048	101.414	0.067	2.014	0.262	0.366	9.786	0.673	0.666	0.670	0.495	0.174	0.221	**0.683**	**0.683**
25/03/2013 00:00	1.2	62	1017.74	18.7	2.94	0.00	84	1.39	1.02	1.21	75	52	2.94	0.048	101.774	0.068	2.001	0.262	0.369	9.664	0.676	0.658	0.667	0.422	0.244	0.655	**1.043**	**1.043**
26/03/2013 00:00	0.3	74	1017.64	75.5	2.09	0.20	85	0.69	-0.15	0.27	86	65	2.09	0.045	101.764	0.068	1.710	0.281	0.421	6.874	0.642	0.604	0.623	0.469	0.155	2.642	**1.190**	**1.190**
27/03/2013 00:00	0.3	77	1015.75	88.8	1.81	0.00	86	0.64	-0.07	0.28	90	60	1.81	0.045	101.575	0.068	1.616	0.293	0.437	5.965	0.640	0.607	0.624	0.465	0.158	3.108	**1.324**	**1.324**
28/03/2013 00:00	0.6	68	1014.67	43.0	2.13	0.00	87	1.00	0.23	0.62	89	48	2.13	0.046	101.467	0.067	1.723	0.285	0.415	6.992	0.657	0.621	0.639	0.434	0.205	1.504	**1.023**	**1.023**
29/03/2013 00:00	1.8	57	1010.72	57.2	3.02	0.00	88	1.95	1.57	1.76	64	52	3.02	0.050	101.072	0.067	2.026	0.268	0.362	9.885	0.703	0.684	0.694	0.402	0.292	2.002	**1.579**	**1.579**
30/03/2013 00:00	2.1	56	1013.00	72.2	2.17	0.00	89	2.43	1.74	2.09	69	47	2.17	0.051	101.300	0.067	1.739	0.302	0.401	7.112	0.728	0.693	0.710	0.410	0.300	2.525	**1.620**	**1.620**
31/03/2013 00:00	3.2	63	1010.72	44.8	3.39	0.80	90	3.39	3.06	3.23	71	55	3.39	0.055	101.072	0.067	2.154	0.274	0.337	11.060	0.779	0.761	0.770	0.484	0.286	1.566	**1.494**	**1.494**
01/04/2013 00:00	2.5	61	1010.74	44.1	3.68	0.00	91	2.68	2.39	2.53	68	57	3.68	0.052	101.074	0.067	2.253	0.256	0.330	12.035	0.741	0.725	0.733	0.458	0.275	1.543	**1.489**	**1.489**
02/04/2013 00:00	3.3	59	1017.03	133.0	2.83	0.00	92	3.65	2.99	3.32	77	42	2.83	0.055	101.703	0.068	1.964	0.292	0.360	9.233	0.793	0.757	0.775	0.458	0.317	4.655	**2.416**	**2.416**
03/04/2013 00:00	3.4	61	1021.84	126.2	2.11	0.00	93	3.79	3.07	3.43	92	28	2.11	0.055	102.184	0.068	1.717	0.321	0.395	6.865	0.802	0.761	0.781	0.462	0.319	4.419	**2.286**	**2.286**
04/04/2013 00:00	3.0	63	1022.31	119.2	2.02	0.00	94	3.48	2.51	3.00	87	39	2.02	0.054	102.231	0.068	1.687	0.319	0.403	6.594	0.784	0.732	0.758	0.471	0.287	4.171	**2.094**	**2.094**
05/04/2013 00:00	2.6	69	1023.59	102.0	1.52	0.00	95	3.04	2.08	2.56	85	47	1.52	0.052	102.359	0.068	1.515	0.337	0.438	4.948	0.760	0.710	0.735	0.480	0.255	3.571	**1.753**	**1.753**
06/04/2013 00:00	1.7	69	1025.64	113.3	1.05	0.00	96	2.30	1.19	1.74	89	41	1.05	0.050	102.564	0.068	1.358	0.349	0.479	3.453	0.721	0.666	0.693	0.444	0.249	3.966	**1.797**	**1.797**
07/04/2013 00:00	4.0	73	1015.64	41.6	2.94	0.00	97	4.20	3.78	3.99	88	61	2.94	0.057	101.564	0.068	2.000	0.298	0.351	9.556	0.825	0.801	0.813	0.604	0.209	1.455	**1.134**	**1.134**
08/04/2013 00:00	5.9	60	1002.11	122.2	3.82	0.00	98	6.17	5.70	5.93	70	47	3.82	0.064	100.211	0.067	2.299	0.296	0.306	12.328	0.946	0.916	0.931	0.543	0.388	4.278	**2.732**	**2.732**
09/04/2013 00:00	5.4	64	999.25	93.4	2.57	0.30	99	5.72	5.12	5.42	77	54	2.57	0.062	99.925	0.066	1.874	0.334	0.355	8.311	0.917	0.880	0.899	0.586	0.312	3.270	**2.014**	**2.014**
10/04/2013 00:00	6.1	82	1000.69	82.9	1.63	5.10	100	6.25	5.88	6.06	92	69	1.63	0.065	100.069	0.067	1.553	0.386	0.395	5.243	0.951	0.927	0.939	0.755	0.185	2.900	**1.502**	**1.502**
11/04/2013 00:00	6.9	89	993.13	106.3	1.58	6.40	101	7.27	6.55	6.91	95	80	1.58	0.068	99.313	0.066	1.539	0.402	0.388	5.093	1.021	0.972	0.996	0.870	0.126	3.721	**1.748**	**1.748**
12/04/2013 00:00	7.3	78	998.54	72.4	2.26	0.20	102	7.76	6.92	7.34	97	55	2.26	0.070	99.854	0.066	1.767	0.374	0.354	7.245	1.055	0.997	1.026	0.774	0.252	2.534	**1.596**	**1.596**
13/04/2013 00:00	6.2	91	1000.67	10.3	2.33	4.60	103	6.51	5.91	6.21	95	82	2.33	0.066	100.067	0.067	1.794	0.355	0.360	7.523	0.968	0.929	0.949	0.838	0.110	0.360	**0.427**	**0.427**
14/04/2013 00:00	10.3	86	998.36	139.0	4.92	4.70	104	10.46	10.06	10.26	95	78	4.92	0.084	99.836	0.066	2.673	0.320	0.254	15.632	1.267	1.233	1.250	1.080	0.170	4.864	**2.234**	**2.234**
15/04/2013 00:00	10.4	77	1005.97	94.2	4.36	2.80	105	10.77	10.13	10.45	90	59	4.36	0.084	100.597	0.067	2.484	0.337	0.267	13.858	1.292	1.239	1.266	0.939	0.327	3.297	**2.320**	**2.320**
16/04/2013 00:00	10.3	63	1008.01	156.8	4.36	1.80	106	10.69	9.98	10.33	85	39	4.36	0.084	100.801	0.067	2.483	0.335	0.268	13.854	1.286	1.226	1.256	0.772	0.484	5.488	**3.635**	**3.635**
17/04/2013 00:00	9.8	86	999.07	22.9	5.81	6.60	107	10.03	9.63	9.83	95	75	5.81	0.081	99.907	0.066	2.975	0.292	0.238	18.487	1.231	1.198	1.214	1.030	0.184	0.803	**1.043**	**1.043**
18/04/2013 00:00	7.8	77	1009.32	116.9	5.84	3.10	108	8.14	7.40	7.77	88	59	5.84	0.072	100.932	0.067	2.987	0.264	0.246	18.735	1.083	1.030	1.056	0.773	0.284	4.090	**2.391**	**2.391**
19/04/2013 00:00	7.6	73	1028.50	144.7	1.77	0.30	109	8.14	7.07	7.61	92	52	1.77	0.071	102.850	0.068	1.603	0.394	0.378	5.684	1.083	1.007	1.045	0.745	0.300	5.065	**2.642**	**2.642**
20/04/2013 00:00	6.7	78	1029.33	138.2	1.73	8.00	110	7.16	6.14	6.65	96	56	1.73	0.067	102.933	0.068	1.587	0.383	0.389	5.553	1.013	0.944	0.979	0.737	0.242	4.837	**2.374**	**2.374**
21/04/2013 00:00	8.5	76	1017.78	127.1	2.98	0.60	111	8.90	8.12	8.51	91	52	2.98	0.075	101.778	0.068	2.013	0.356	0.320	9.526	1.140	1.082	1.111	0.789	0.322	4.450	**2.567**	**2.567**
22/04/2013 00:00	9.8	82	1013.51	92.9	3.35	0.20	112	10.04	9.49	9.76	96	65	3.35	0.081	101.351	0.067	2.140	0.360	0.299	10.674	1.231	1.187	1.209	0.970	0.239	3.251	**1.934**	**1.934**
23/04/2013 00:00	12.2	74	1019.30	168.0	2.68	1.50	113	12.59	11.91	12.25	91	59	2.68	0.094	101.930	0.068	1.910	0.420	0.304	8.442	1.458	1.394	1.426	1.064	0.362	5.878	**3.397**	**3.397**
24/04/2013 00:00	11.9	85	1021.77	118.1	2.06	1.70	114	12.09	11.66	11.88	93	72	2.06	0.092	102.177	0.068	1.700	0.443	0.328	6.505	1.411	1.371	1.391	1.146	0.246	4.133	**2.354**	**2.354**
25/04/2013 00:00	8.8	77	1021.61	82.1	1.94	0.20	115	9.15	8.48	8.81	95	52	1.94	0.077	102.161	0.068	1.659	0.405	0.359	6.189	1.160	1.108	1.134	0.828	0.306	2.874	**1.843**	**1.843**
26/04/2013 00:00	5.0	73	1021.03	147.6	2.59	1.40	116	5.66	4.43	5.05	89	51	2.59	0.061	102.103	0.068	1.880	0.324	0.360	8.376	0.913	0.838	0.876	0.606	0.270	5.165	**2.485**	**2.485**
27/04/2013 00:00	6.8	63	1021.19	155.5	1.93	0.00	117	7.28	6.37	6.82	84	35	1.93	0.068	102.119	0.068	1.657	0.377	0.376	6.212	1.021	0.959	0.990	0.582	0.409	5.441	**3.006**	**3.006**
28/04/2013 00:00	7.9	71	1014.94	108.6	3.77	0.40	118	8.30	7.49	7.90	87	55	3.77	0.073	101.494	0.067	2.281	0.320	0.298	12.071	1.095	1.036	1.066	0.752	0.314	3.800	**2.346**	**2.346**
29/04/2013 00:00	7.3	70	1019.24	157.8	3.33	0.20	119	7.78	6.75	7.27	83	55	3.33	0.070	101.924	0.068	2.133	0.326	0.316	10.698	1.057	0.985	1.021	0.699	0.322	5.523	**2.888**	**2.888**
30/04/2013 00:00	7.0	69	1027.28	149.4	1.13	0.00	120	7.43	6.55	6.99	96	41	1.13	0.069	102.728	0.068	1.385	0.421	0.418	3.636	1.032	0.971	1.002	0.678	0.324	5.231	**2.694**	**2.694**
01/05/2013 00:00	8.8	70	1025.71	101.4	1.63	0.00	121	9.38	8.31	8.84	86	46	1.63	0.077	102.571	0.068	1.554	0.420	0.373	5.206	1.178	1.095	1.137	0.742	0.395	3.550	**2.258**	**2.258**
02/05/2013 00:00	9.1	72	1023.39	195.5	1.77	0.00	122	9.43	8.67	9.05	94	49	1.77	0.078	102.339	0.068	1.600	0.417	0.365	5.634	1.182	1.123	1.152	0.817	0.335	6.842	**3.539**	**3.539**
03/05/2013 00:00	11.1	73	1016.41	137.0	4.06	6.30	123	11.27	10.83	11.05	88	61	4.06	0.088	101.641	0.068	2.380	0.352	0.272	12.858	1.337	1.298	1.317	0.979	0.339	4.794	**2.874**	**2.874**
04/05/2013 00:00	10.7	72	1014.32	205.2	3.93	0.20	124	11.02	10.41	10.72	93	48	3.93	0.086	101.432	0.067	2.337	0.352	0.277	12.477	1.314	1.262	1.288	0.903	0.386	7.183	**3.866**	**3.866**
05/05/2013 00:00	12.0	73	1018.48	174.5	3.11	0.10	125	12.32	11.77	12.05	85	59	3.11	0.093	101.848	0.068	2.056	0.400	0.292	9.809	1.432	1.382	1.407	1.010	0.397	6.108	**3.579**	**3.579**
06/05/2013 00:00	11.2	77	1017.76	128.9	1.55	0.00	126	11.53	10.90	11.22	94	66	1.55	0.088	101.776	0.068	1.525	0.461	0.353	4.893	1.360	1.304	1.332	1.062	0.270	4.511	**2.547**	**2.547**
07/05/2013 00:00	11.8	74	1012.38	135.2	2.19	8.20	127	12.12	11.54	11.83	95	56	2.19	0.092	101.238	0.067	1.745	0.438	0.322	6.923	1.414	1.361	1.387	1.042	0.345	4.730	**2.842**	**2.842**

08/05/2013 00:00	10.6	82	997.25	189.2	4.74	1.50	128	11.01	10.19	10.60	96	61	4.74	0.085	99.725	0.066	2.612	0.330	0.257	15.050	1.313	1.243	1.278	0.997	0.281	6.621	**3.268**	**3.268**
09/05/2013 00:00	9.3	78	995.57	82.3	5.75	0.50	129	9.62	8.93	9.28	93	68	5.75	0.079	99.557	0.066	2.954	0.287	0.241	18.319	1.197	1.143	1.170	0.938	0.231	2.880	**1.851**	**1.851**
10/05/2013 00:00	9.3	76	1006.60	171.6	4.49	2.70	130	9.79	8.83	9.31	93	49	4.49	0.079	100.660	0.067	2.527	0.318	0.270	14.322	1.211	1.135	1.173	0.824	0.349	6.007	**3.258**	**3.258**
11/05/2013 00:00	8.2	78	1010.45	156.2	4.54	0.90	131	8.76	7.72	8.24	94	61	4.54	0.074	101.045	0.067	2.545	0.302	0.274	14.542	1.129	1.052	1.091	0.839	0.252	5.469	**2.657**	**2.657**
12/05/2013 00:00	9.6	83	1012.95	56.8	4.13	2.60	132	9.87	9.31	9.59	94	74	4.13	0.080	101.295	0.067	2.405	0.331	0.278	13.160	1.217	1.173	1.195	1.001	0.193	1.988	**1.366**	**1.366**
13/05/2013 00:00	6.7	74	1010.41	145.7	4.44	2.80	133	7.35	6.13	6.74	85	51	4.44	0.068	101.041	0.067	2.510	0.286	0.284	14.289	1.026	0.944	0.985	0.663	0.322	5.100	**2.770**	**2.770**
14/05/2013 00:00	6.9	76	1000.21	70.4	1.93	3.40	134	7.29	6.51	6.90	90	50	1.93	0.068	100.021	0.067	1.658	0.383	0.372	6.221	1.022	0.968	0.995	0.691	0.304	2.465	**1.647**	**1.647**
15/05/2013 00:00	7.3	72	999.59	133.6	2.30	0.40	135	7.84	6.79	7.32	89	56	2.30	0.070	99.959	0.066	1.782	0.372	0.352	7.385	1.061	0.987	1.024	0.737	0.288	4.675	**2.488**	**2.488**
16/05/2013 00:00	7.1	80	999.61	184.7	1.56	0.30	136	7.53	6.68	7.10	91	63	1.56	0.069	99.961	0.066	1.531	0.405	0.389	5.016	1.039	0.980	1.009	0.773	0.236	6.464	**3.078**	**3.078**
17/05/2013 00:00	8.3	74	1009.39	190.9	1.15	0.80	137	8.75	7.79	8.27	95	46	1.15	0.074	100.939	0.067	1.393	0.443	0.400	3.696	1.129	1.058	1.093	0.762	0.331	6.683	**3.449**	**3.449**
18/05/2013 00:00	8.2	80	1010.62	172.6	1.79	0.40	138	8.64	7.83	8.24	89	61	1.79	0.074	101.062	0.067	1.610	0.407	0.369	5.738	1.120	1.061	1.091	0.814	0.277	6.041	**3.042**	**3.042**
19/05/2013 00:00	10.6	79	1013.92	96.4	0.80	0.00	139	10.90	10.39	10.64	95	62	0.80	0.085	101.392	0.067	1.274	0.499	0.394	2.553	1.304	1.260	1.282	1.003	0.279	3.374	**1.963**	**1.963**
20/05/2013 00:00	11.6	84	1018.49	94.2	1.64	0.00	140	11.78	11.44	11.61	91	80	1.64	0.090	101.849	0.068	1.559	0.461	0.346	5.195	1.383	1.352	1.367	1.168	0.199	3.298	**1.879**	**1.879**
21/05/2013 00:00	12.2	72	1021.94	234.0	1.93	0.00	141	12.48	11.84	12.16	85	54	1.93	0.093	102.194	0.068	1.655	0.454	0.330	6.078	1.447	1.388	1.418	0.981	0.437	8.190	**4.592**	**4.592**
22/05/2013 00:00	10.6	66	1024.37	174.0	1.84	0.00	142	11.03	10.19	10.61	85	49	1.84	0.085	102.437	0.068	1.627	0.435	0.347	5.848	1.315	1.244	1.279	0.851	0.429	6.092	**3.520**	**3.520**
23/05/2013 00:00	8.3	67	1021.59	167.7	2.40	0.10	143	8.86	7.73	8.30	81	49	2.40	0.074	102.159	0.068	1.815	0.376	0.344	7.666	1.138	1.053	1.095	0.705	0.390	5.871	**3.237**	**3.237**
24/05/2013 00:00	8.5	66	1020.27	150.4	1.78	0.00	144	9.02	8.05	8.53	88	42	1.78	0.075	102.027	0.068	1.604	0.409	0.368	5.678	1.150	1.076	1.113	0.715	0.398	5.264	**2.987**	**2.987**
25/05/2013 00:00	10.0	70	1023.10	206.6	1.07	0.00	145	10.38	9.56	9.97	94	45	1.07	0.082	102.310	0.068	1.364	0.470	0.389	3.404	1.260	1.192	1.226	0.844	0.382	7.230	**3.901**	**3.901**
26/05/2013 00:00	10.3	76	1017.57	211.0	1.70	8.50	146	10.73	9.82	10.27	92	58	1.70	0.084	101.757	0.068	1.576	0.439	0.356	5.386	1.289	1.213	1.251	0.932	0.319	7.386	**3.857**	**3.857**
27/05/2013 00:00	9.7	80	1000.08	92.6	2.84	2.10	147	10.10	9.25	9.68	96	53	2.84	0.081	100.008	0.067	1.967	0.382	0.314	9.056	1.237	1.168	1.202	0.888	0.314	3.239	**2.130**	**2.130**
28/05/2013 00:00	8.7	79	1002.22	128.3	1.46	6.10	148	9.40	8.09	8.75	95	55	1.46	0.076	100.222	0.067	1.496	0.434	0.378	4.659	1.180	1.080	1.130	0.837	0.292	4.489	**2.463**	**2.463**
29/05/2013 00:00	13.5	69	1010.88	217.9	1.56	0.00	149	13.90	13.17	13.54	93	49	1.56	0.101	101.088	0.067	1.531	0.495	0.330	4.910	1.589	1.515	1.552	1.093	0.458	7.625	**4.518**	**4.518**
30/05/2013 00:00	13.5	67	1018.55	240.1	1.89	0.00	150	13.92	13.13	13.53	89	53	1.89	0.101	101.855	0.068	1.642	0.476	0.319	5.930	1.590	1.511	1.551	1.094	0.457	8.403	**4.864**	**4.864**
31/05/2013 00:00	11.5	79	1023.69	92.6	1.19	0.40	151	11.87	11.07	11.47	95	60	1.19	0.090	102.369	0.068	1.404	0.484	0.367	3.763	1.391	1.319	1.355	1.044	0.311	3.242	**1.999**	**1.999**
01/06/2013 00:00	10.4	73	1027.98	119.4	2.09	0.00	152	10.86	10.04	10.45	88	56	2.09	0.084	102.798	0.068	1.712	0.419	0.339	6.647	1.300	1.231	1.266	0.906	0.360	4.180	**2.564**	**2.564**
02/06/2013 00:00	11.9	74	1031.07	199.9	0.92	0.00	153	12.29	11.47	11.88	96	52	0.92	0.092	103.107	0.069	1.312	0.505	0.377	2.899	1.429	1.354	1.392	1.022	0.370	6.997	**3.939**	**3.939**
03/06/2013 00:00	14.4	78	1032.17	197.8	0.62	0.00	154	14.76	14.04	14.40	94	62	0.62	0.106	103.217	0.069	1.210	0.561	0.363	1.934	1.679	1.603	1.641	1.274	0.367	6.925	**4.142**	**4.142**
04/06/2013 00:00	13.5	65	1028.21	245.4	1.02	0.00	155	14.03	13.01	13.52	97	35	1.02	0.101	102.821	0.068	1.348	0.523	0.354	3.217	1.601	1.499	1.550	1.007	0.543	8.588	**5.107**	**5.107**
05/06/2013 00:00	13.3	70	1021.81	243.7	1.06	0.00	156	13.91	12.70	13.30	94	48	1.06	0.100	102.181	0.068	1.359	0.519	0.354	3.320	1.589	1.469	1.529	1.072	0.457	8.531	**4.966**	**4.966**
06/06/2013 00:00	13.7	71	1021.93	228.1	0.91	0.00	157	14.14	13.20	13.67	97	42	0.91	0.102	102.193	0.068	1.309	0.534	0.356	2.852	1.613	1.517	1.565	1.075	0.491	7.982	**4.758**	**4.758**
07/06/2013 00:00	14.8	66	1024.54	244.0	1.35	0.00	158	15.35	14.30	14.82	97	35	1.35	0.109	102.454	0.068	1.459	0.522	0.327	4.223	1.744	1.630	1.687	1.096	0.591	8.538	**5.277**	**5.277**
08/06/2013 00:00	15.7	66	1022.36	240.2	0.72	0.00	159	16.40	15.03	15.71	91	39	0.72	0.114	102.236	0.068	1.246	0.574	0.342	2.253	1.865	1.709	1.787	1.141	0.646	8.407	**5.326**	**5.326**
09/06/2013 00:00	13.9	64	1016.32	241.6	0.89	0.00	160	14.41	13.38	13.90	95	39	0.89	0.103	101.632	0.068	1.303	0.539	0.353	2.800	1.642	1.535	1.589	1.049	0.539	8.457	**5.094**	**5.094**
10/06/2013 00:00	10.9	82	1012.06	74.5	1.38	4.80	161	11.19	10.60	10.89	96	63	1.38	0.087	101.206	0.067	1.470	0.467	0.362	4.386	1.329	1.278	1.304	1.032	0.271	2.607	**1.649**	**1.649**
11/06/2013 00:00	13.2	91	1005.39	116.6	1.71	1.70	162	13.42	12.96	13.19	96	75	1.71	0.099	100.539	0.067	1.580	0.484	0.327	5.368	1.539	1.493	1.516	1.294	0.222	4.083	**2.365**	**2.365**
12/06/2013 00:00	13.0	88	1003.49	91.1	0.99	3.00	163	13.25	12.70	12.97	98	66	0.99	0.098	100.349	0.067	1.337	0.523	0.357	3.117	1.522	1.468	1.495	1.222	0.273	3.188	**1.972**	**1.972**
13/06/2013 00:00	12.7	79	1008.48	146.8	3.05	2.80	164	13.09	12.25	12.67	97	50	3.05	0.096	100.848	0.067	2.036	0.413	0.288	9.603	1.507	1.426	1.466	1.068	0.398	5.139	**3.225**	**3.225**
14/06/2013 00:00	10.9	86	1006.14	49.8	2.03	8.00	165	11.24	10.60	10.92	96	72	2.03	0.087	100.614	0.067	1.689	0.434	0.335	6.423	1.333	1.278	1.306	1.093	0.212	1.744	**1.214**	**1.214**
15/06/2013 00:00	10.3	83	1003.73	144.6	3.80	0.60	166	10.75	9.93	10.34	93	58	3.80	0.084	100.373	0.067	2.292	0.354	0.282	12.068	1.291	1.223	1.257	0.943	0.314	5.062	**2.861**	**2.861**
16/06/2013 00:00	10.8	83	1010.22	52.2	1.51	10.70	167	11.12	10.56	10.84	95	61	1.51	0.086	101.022	0.067	1.513	0.460	0.357	4.787	1.323	1.275	1.299	1.009	0.290	1.826	**1.335**	**1.335**
17/06/2013 00:00	13.4	86	1015.38	229.0	1.18	0.30	168	13.66	13.12	13.39	96	67	1.18	0.100	101.538	0.068	1.403	0.514	0.346	3.724	1.563	1.510	1.537	1.249	0.288	8.014	**4.491**	**4.491**
18/06/2013 00:00	14.6	80	1015.63	181.7	1.04	0.00	169	15.19	14.03	14.61	98	55	1.04	0.107	101.563	0.068	1.355	0.540	0.340	3.268	1.726	1.602	1.664	1.259	0.404	6.361	**3.883**	**3.883**
19/06/2013 00:00	14.2	70	1018.06	230.9	1.47	0.00	170	14.76	13.69	14.23	89	52	1.47	0.105	101.806	0.068	1.499	0.509	0.328	4.602	1.679	1.567	1.623	1.134	0.489	8.081	**4.848**	**4.848**
20/06/2013 00:00	14.3	75	1012.23	252.7	1.34	0.00	171	14.62	13.89	14.26	94	53	1.34	0.105	101.223	0.067	1.455	0.518	0.331	4.190	1.664	1.588	1.626	1.187	0.439	8.844	**5.191**	**5.191**
21/06/2013 00:00	13.9	78	1009.39	181.1	2.23	0.20	172	14.31	13.55	13.93	96	53	2.23	0.103	100.939	0.067	1.757	0.467	0.303	6.983	1.631	1.553	1.592	1.177	0.414	6.338	**3.837**	**3.837**
22/06/2013 00:00	13.0	80	999.94	190.1	4.30	0.60	173	13.31	12.63	12.97	95	63	4.30	0.098	99.994	0.066	2.462	0.374	0.254	13.536	1.528	1.461	1.495	1.176	0.319	6.653	**3.586**	**3.586**
23/06/2013 00:00	12.2	74	1014.68	176.6	3.96	0.40	174	12.65	11.77	12.21	84	60	3.96	0.094	101.468	0.067	2.348	0.371	0.268	12.510	1.464	1.381	1.423	1.019	0.403	6.182	**3.647**	**3.647**
24/06/2013 00:00	11.5	76	1025.16	110.4	1.53	0.00	175	11.82	11.10	11.46	93	57	1.53	0.090	102.516	0.068	1.519	0.464	0.353	4.833	1.386	1.321	1.354	1.010	0.344	3.865	**2.380**	**2.380**
25/06/2013 00:00	13.3	81	1029.10	149.9	0.93	0.00	176	13.62	12.95	13.28	97	67	0.93	0.100	102.910	0.068	1.316	0.525	0.361	2.926	1.560	1.492	1.526	1.246	0.280	5.248	**3.051**	**3.051**
26/06/2013 00:00	13.5	71	1032.96	143.8	1.05	0.00	177	14.08	12.97	13.52	92	47	1.05	0.101	103.296	0.069	1.357	0.520	0.354	3.297	1.607	1.495	1.551	1.065	0.486	5.032	**3.183**	**3.183**
27/06/2013 00:00	14.2	81	1029.17	135.0	2.49	0.00	178	14.53	13.77	14.15	93	63	2.49	0.105	102.917	0.068	1.846	0.453	0.296	7.797	1.655	1.575	1.615	1.254	0.361	4.724	**2.975**	**2.975**
28/06/2013 00:00	14.7	85	1023.16	141.0	3.64	0.00	179	14.97	14.48	14.72	94	77	3.64	0.108	102.316	0.068	2.237	0.415	0.261	11.378	1.702	1.649	1.675	1.430	0.245	4.934	**2.778**	**2.778**
29/06/2013 00:00	14.9	81	1024.62	130.4	2.77	0.00	180	15.15	14.56	14.86	96	63	2.77	0.109	102.462	0.068	1.943	0.451	0.282	8.676	1.722	1.657	1.690	1.338	0.352	4.562	**2.921**	**2.921**
30/06/2013 00:00	14.6	72	1020.02	159.5	3.84	0.10	181	14.86	14.32	14.59	83	56	3.84	0.107	102.002	0.068	2.306	0.407	0.257	12.021	1.690	1.632	1.661	1.151	0.510	5.583	**3.849**	**3.849**
01/07/2013 00:00	13.2	71	1016.30	157.3	2.57	0.60	182	13.57	12.78	13.17	90	47	2.57	0.099	101.630	0.068	1.875	0.438	0.299	8.096	1.554	1.476	1.515	1.029	0.486	5.504	**3.591**	**3.591**
02/07/2013 00:00	13.4	89	1003.99	37.9	2.29	2.60	183	13.67	13.22	13.45	95	83	2.29	0.101	100.399	0.067	1.780	0.458	0.304	7.207	1.565	1.520	1.542	1.371	0.171	1.328	**0.984**	**0.984**
03/07/2013 00:00	14.7	80	1008.76	185.9	2.42	0.00	184	15.01	14.44	14.72	92	65	2.42	0.108	100.876	0.067	1.824	0.469	0.291	7.579	1.707	1.645	1.676	1.311	0.364	6.507	**3.856**	**3.856**
04/07/2013 00:00	15.2	75	1017.74	240.2	3.57	0.00	185	15.59	14.85	15.22	95	58	3.57	0.111	101.774	0.068	2.215	0.426	0.259	11.158	1.771	1.689	1.730	1.316	0.414	8.407	**4.777**	**4.777**
05/07/2013 00:00	13.3	74	1028.18	228.2	0.84	0.00	186	13.89	12.79	13.34	93	53	0.84	0.100	102.818	0.068	1.285	0.532	0.364	2.636	1.587	1.477	1.532	1.107	0.425	7.987	**4.657**	**4.657**
06/07/2013 00:00	15.8	70	1029.31	205.4	1.30	0.00	187	16.27	15.27	15.77	91	46	1.30	0.115	102.931	0.068	1.444	0.537	0.321	4.067	1.850	1.735	1.793	1.215	0.578	7.188	**4.614**	**4.614**
07/07/2013 00:00	20.5	79	1034.20	229.2	0.77	0.00	188	20.97	19.96	20.46	92	64	0.77	0.148	103.420	0.069	1.263	0.631	0.292	2.369	2.482	2.332	2.407	1.867	0.540	8.023	**5.436**	**5.436**
08/07/2013 00:00	20.6	70	1034.03	269.9	0.69	0.00	189	21.18	20.05	20.62	97	43	0.69	0.150	103.403	0.069	1.234	0.638	0.293	2.109	2.515	2.346	2.431	1.679	0.752	9.446	**6.493**	**6.493**
09/07/2013 00:00	20.6	68	1029.89	79.7	0.66	0.00	190	21.17	20.13	20.65	96	41	0.66	0.150	102.989	0.068	1.223	0.641	0.293	2.012	2.513	2.357	2.435	1.646	0.789	2.790	**2.255**	**2.255**
10/07/2013 00:00	20.8	84	1028.06	81.1	0.69	0.00	191	21.38	20.31	20.84	93	68	0.69	0.151	102.806	0.068	1.236	0.642	0.290	2.126	2.545	2.383	2.464	1.973	0.491	2.839	**2.124**	**2.124**
11/07/2013 00:00	19.5	75	1025.42	121.2	0.76	0.00	192	20.00	18.95	19.47	98	48	0.76	0.141	102.542	0.068	1.260	0.621	0.301	2.349	2.338	2.190	2.264	1.634	0.630	4.243	**3.080**	**3.080**
12/07/2013 00:00	19.3	61	1025.28	117.1	0.75	0.00	193	19.84	18.70	19.27	96	30	0.75	0.139	102.528	0.068	1.255	0.619	0.304	2.307	2.315	2.156	2.236	1.382	0.853	4.097	**3.134**	**3.134**
13/07/2013 00:00	20.7	71	1026.38	34.9	1.00	0.00	194	21.26	20.19	20.73	94	45	1.00	0.151	102.638	0.068	1.338	0.622	0.282	3.050	2.527	2.366	2.447	1.681	0.766	1.223	**1.420**	**1.420**
14/07/2013 00:00	19.2	71	1025.51	34.7	1.45	0.00	195	19.67	18.74	19.20	94	40	1.45	0.139	102.551	0.068	1.492	0.577	0.284	4.458	2.291	2.162	2.226	1.474	0.752	1.213	**1.651**	**1.651**
15/07/2013 00:00	16.8	73	1025.43	124.7	1.26	0.00	196	17.18	16.44	16.81	92	52	1.26	0.121	102.543	0.068	1.429	0.555	0.311	3.917	1.960	1.870	1.915	1.370	0.545	4.365	**3.088**	**3.088**
16/07/2013 00:00	18.2	68	1024.93	124.7	1.09	0.00	197	18.65	17.83	18.24	91	52	1.09	0.131	102.493	0.068	1.370	0.585	0.303	3.366	2.150	2.042	2.096	1.488	0.608	4.366	**3.173**	**3.173**
17/07/2013 00:00	19.9	62	1026.53	136.9	0.81	0.00	198	20.31	19.42	19.86	85	38	0.81	0.144	102.653	0.068	1.274	0.623	0.296	2.477	2.383	2.256	2.319	1.411	0.908	4.791	**3.650**	**3.650**
18/07/2013 00:00	19.4	67	1027.86	126.8	0.66	0.00	199	20.02	18.83	19.43	94	40	0.66	0.140	102.786	0.068	1.225	0.626	0.305	2.039	2.342	2.174	2.258	1.490	0.768	4.437	**3.256**	**3.256**

19/07/2013 00:00	20.1	66	1025.78	167.4	0.90	0.00	200	20.73	19.48	20.11	98	33	0.90	0.146	102.578	0.068	1.308	0.620	0.291	2.779	2.446	2.265	2.355	1.513	0.842	5.860	**4.313**	**4.313**
20/07/2013 00:00	20.6	67	1023.00	132.7	0.95	0.00	201	21.16	20.02	20.59	94	44	0.95	0.149	102.300	0.068	1.323	0.624	0.284	2.916	2.511	2.341	2.426	1.653	0.773	4.646	**3.540**	**3.540**
21/07/2013 00:00	18.7	73	1019.03	151.5	0.95	0.00	202	19.03	18.30	18.66	95	53	0.95	0.135	101.903	0.068	1.322	0.600	0.302	2.922	2.201	2.103	2.152	1.582	0.570	5.304	**3.688**	**3.688**
22/07/2013 00:00	17.0	80	1014.22	190.1	0.73	0.00	203	17.26	16.70	16.98	91	68	0.73	0.123	101.422	0.067	1.250	0.593	0.326	2.280	1.970	1.901	1.936	1.535	0.401	6.652	**4.241**	**4.241**
23/07/2013 00:00	17.4	84	1011.03	62.5	1.11	3.30	204	17.77	17.08	17.43	96	66	1.11	0.126	101.103	0.067	1.377	0.576	0.308	3.433	2.035	1.948	1.991	1.606	0.385	2.189	**1.668**	**1.668**
24/07/2013 00:00	17.2	81	1009.85	70.1	1.15	7.20	205	17.42	16.92	17.17	95	60	1.15	0.124	100.985	0.067	1.389	0.571	0.309	3.552	1.990	1.928	1.959	1.513	0.446	2.452	**1.889**	**1.889**
25/07/2013 00:00	17.3	83	1009.00	65.7	1.80	3.30	206	17.65	16.89	17.27	97	52	1.80	0.125	100.900	0.067	1.612	0.535	0.288	5.584	2.019	1.924	1.972	1.458	0.513	2.299	**2.057**	**2.057**
26/07/2013 00:00	16.1	77	1010.41	204.2	1.22	4.40	207	16.72	15.54	16.13	97	49	1.22	0.117	101.041	0.067	1.413	0.552	0.317	3.783	1.904	1.765	1.835	1.323	0.512	7.147	**4.559**	**4.559**
27/07/2013 00:00	15.2	80	1006.65	229.7	0.83	3.20	208	15.81	14.69	15.25	98	52	0.83	0.111	100.665	0.067	1.283	0.564	0.339	2.603	1.796	1.672	1.734	1.286	0.448	8.041	**4.934**	**4.934**
28/07/2013 00:00	15.5	83	1001.84	174.4	1.01	1.10	209	16.05	15.03	15.54	98	48	1.01	0.113	100.184	0.067	1.344	0.558	0.329	3.155	1.824	1.709	1.766	1.275	0.491	6.104	**3.917**	**3.917**
29/07/2013 00:00	15.6	79	1006.50	119.8	2.17	9.40	210	16.19	15.03	15.61	96	58	2.17	0.114	100.650	0.067	1.738	0.494	0.291	6.772	1.841	1.709	1.775	1.354	0.421	4.194	**2.901**	**2.901**
30/07/2013 00:00	14.9	69	1010.68	114.2	2.13	9.80	211	15.31	14.39	14.85	94	41	2.13	0.109	101.068	0.067	1.725	0.484	0.299	6.667	1.740	1.640	1.690	1.127	0.562	3.998	**3.057**	**3.057**
31/07/2013 00:00	15.6	91	1009.29	117.2	1.27	18.90	212	15.77	15.38	15.57	96	80	1.27	0.113	100.929	0.067	1.432	0.541	0.320	3.965	1.791	1.747	1.769	1.555	0.214	4.104	**2.493**	**2.493**
01/08/2013 00:00	17.7	90	1002.92	30.6	1.77	0.30	213	17.85	17.61	17.73	97	77	1.77	0.128	100.292	0.067	1.601	0.545	0.284	5.469	2.045	2.014	2.030	1.764	0.265	1.070	**0.996**	**0.996**
02/08/2013 00:00	16.7	78	1001.95	93.8	2.81	5.60	214	17.11	16.29	16.70	91	58	2.81	0.121	100.195	0.067	1.957	0.481	0.265	8.744	1.952	1.852	1.902	1.409	0.493	3.284	**2.723**	**2.723**
03/08/2013 00:00	14.0	83	1010.81	166.8	2.33	4.10	215	14.45	13.57	14.01	94	56	2.33	0.104	101.081	0.067	1.791	0.463	0.300	7.296	1.646	1.554	1.600	1.191	0.409	5.838	**3.597**	**3.597**
04/08/2013 00:00	15.6	89	1012.00	89.3	0.74	2.50	216	16.09	15.13	15.61	97	67	0.74	0.114	101.200	0.067	1.251	0.574	0.340	2.305	1.829	1.720	1.775	1.447	0.328	3.125	**2.052**	**2.052**
05/08/2013 00:00	15.4	77	1011.59	172.1	1.48	0.00	217	15.81	15.03	15.42	97	51	1.48	0.112	101.159	0.067	1.503	0.526	0.315	4.619	1.796	1.709	1.752	1.287	0.466	6.024	**3.849**	**3.849**
06/08/2013 00:00	14.6	74	1014.84	71.6	1.36	0.00	218	14.90	14.21	14.56	90	54	1.36	0.107	101.484	0.067	1.463	0.520	0.328	4.260	1.694	1.621	1.658	1.187	0.471	2.505	**1.961**	**1.961**
07/08/2013 00:00	15.4	72	1015.90	116.0	0.88	0.00	219	15.88	14.85	15.36	98	39	0.88	0.112	101.590	0.068	1.299	0.561	0.338	2.743	1.804	1.689	1.746	1.179	0.567	4.060	**2.803**	**2.803**
08/08/2013 00:00	15.5	78	1016.40	53.3	1.75	0.60	220	15.83	15.16	15.50	91	50	1.75	0.113	101.640	0.068	1.594	0.512	0.306	5.451	1.799	1.723	1.761	1.234	0.527	1.865	**1.835**	**1.835**
09/08/2013 00:00	14.3	74	1020.79	100.1	2.05	0.00	221	14.60	14.00	14.30	92	58	2.05	0.106	102.079	0.068	1.698	0.478	0.307	6.429	1.661	1.599	1.630	1.217	0.413	3.504	**2.491**	**2.491**
10/08/2013 00:00	14.9	75	1021.50	211.2	1.81	0.00	222	15.30	14.57	14.93	86	55	1.81	0.109	102.150	0.068	1.616	0.499	0.310	5.659	1.739	1.658	1.699	1.191	0.507	7.393	**4.581**	**4.581**
11/08/2013 00:00	13.7	74	1018.71	189.4	2.53	0.00	223	14.08	13.41	13.75	92	48	2.53	0.102	101.871	0.068	1.859	0.448	0.297	7.932	1.607	1.539	1.573	1.094	0.479	6.628	**4.099**	**4.099**
12/08/2013 00:00	13.8	71	1019.65	152.1	2.36	0.00	224	14.20	13.41	13.81	87	50	2.36	0.103	101.965	0.068	1.801	0.456	0.302	7.397	1.620	1.538	1.579	1.074	0.505	5.322	**3.556**	**3.556**
13/08/2013 00:00	14.3	78	1022.29	130.3	1.94	0.80	225	14.54	13.97	14.26	90	65	1.94	0.105	102.229	0.068	1.660	0.483	0.312	6.078	1.656	1.596	1.626	1.256	0.370	4.561	**2.902**	**2.902**
14/08/2013 00:00	17.5	83	1018.18	111.7	1.68	0.70	226	17.72	17.26	17.49	95	64	1.68	0.126	101.818	0.068	1.571	0.543	0.291	5.206	2.028	1.970	1.999	1.585	0.414	3.911	**2.750**	**2.750**
15/08/2013 00:00	17.6	91	1012.86	144.0	2.32	7.70	227	17.79	17.34	17.56	97	76	2.32	0.127	101.286	0.067	1.790	0.512	0.272	7.198	2.036	1.980	2.008	1.734	0.274	5.039	**3.119**	**3.119**
16/08/2013 00:00	16.1	78	1013.76	58.1	2.35	1.20	228	16.45	15.68	16.06	94	60	2.35	0.117	101.376	0.067	1.798	0.490	0.284	7.308	1.871	1.781	1.826	1.398	0.428	2.033	**1.883**	**1.883**
17/08/2013 00:00	16.9	84	1004.64	83.6	3.57	2.40	229	17.20	16.56	16.88	95	68	3.57	0.122	100.464	0.067	2.214	0.452	0.248	11.083	1.962	1.885	1.924	1.563	0.361	2.925	**2.313**	**2.313**
18/08/2013 00:00	13.8	75	1009.11	44.0	2.67	0.00	230	14.19	13.32	13.76	92	54	2.67	0.102	100.911	0.067	1.908	0.444	0.291	8.380	1.618	1.530	1.574	1.141	0.433	1.539	**1.742**	**1.742**
19/08/2013 00:00	14.1	75	1020.63	127.0	2.38	0.00	231	14.47	13.68	14.07	88	55	2.38	0.104	102.063	0.068	1.809	0.459	0.299	7.455	1.648	1.566	1.607	1.142	0.465	4.444	**3.077**	**3.077**
20/08/2013 00:00	15.7	76	1024.86	57.5	1.99	0.00	232	15.97	15.36	15.66	91	57	1.99	0.114	102.486	0.068	1.677	0.499	0.299	6.207	1.814	1.746	1.780	1.311	0.469	2.014	**1.874**	**1.874**
21/08/2013 00:00	18.1	78	1020.23	133.5	2.61	0.00	233	18.45	17.82	18.13	91	58	2.61	0.131	102.023	0.068	1.886	0.505	0.262	8.053	2.123	2.040	2.082	1.544	0.538	4.673	**3.497**	**3.497**
22/08/2013 00:00	15.5	82	1017.65	127.7	0.99	1.20	234	15.79	15.14	15.46	95	57	0.99	0.113	101.765	0.068	1.336	0.555	0.333	3.081	1.794	1.721	1.757	1.329	0.429	4.471	**2.921**	**2.921**
23/08/2013 00:00	15.1	90	1012.95	135.7	1.20	2.60	235	15.28	14.82	15.05	95	82	1.20	0.110	101.295	0.067	1.407	0.537	0.329	3.738	1.736	1.686	1.711	1.513	0.198	4.750	**2.797**	**2.797**
24/08/2013 00:00	13.0	80	1016.07	58.4	1.52	1.00	236	13.33	12.64	12.98	97	57	1.52	0.098	101.607	0.068	1.515	0.489	0.337	4.769	1.530	1.463	1.497	1.146	0.351	2.043	**1.563**	**1.563**
25/08/2013 00:00	14.9	89	1019.52	13.2	1.20	0.40	237	15.20	14.63	14.92	97	73	1.20	0.109	101.952	0.068	1.409	0.533	0.331	3.763	1.728	1.665	1.696	1.438	0.258	0.463	**0.569**	**0.569**
26/08/2013 00:00	13.2	86	1022.12	99.9	0.78	0.20	238	13.68	12.72	13.20	98	69	0.78	0.099	102.212	0.068	1.264	0.536	0.367	2.438	1.565	1.471	1.518	1.261	0.257	3.498	**2.104**	**2.104**
27/08/2013 00:00	16.2	86	1021.79	107.2	0.79	0.40	239	16.54	15.93	16.24	97	75	0.79	0.118	102.179	0.068	1.270	0.577	0.333	2.472	1.882	1.811	1.846	1.584	0.262	3.752	**2.381**	**2.381**
28/08/2013 00:00	15.1	82	1023.79	25.5	1.14	0.00	240	15.42	14.74	15.08	93	57	1.14	0.110	102.379	0.068	1.387	0.539	0.333	3.554	1.752	1.677	1.714	1.279	0.435	0.893	**0.996**	**0.996**
29/08/2013 00:00	16.8	79	1020.37	97.2	1.98	0.00	241	17.12	16.39	16.76	93	59	1.98	0.121	102.037	0.068	1.673	0.516	0.289	6.144	1.953	1.865	1.909	1.443	0.466	3.402	**2.584**	**2.584**
30/08/2013 00:00	14.8	81	1019.39	85.9	2.30	0.00	242	15.29	14.26	14.77	96	63	2.30	0.108	101.939	0.068	1.783	0.473	0.296	7.203	1.738	1.626	1.682	1.328	0.354	3.006	**2.175**	**2.175**
31/08/2013 00:00	11.9	71	1029.39	136.1	1.79	0.00	243	12.44	11.43	11.93	91	45	1.79	0.092	102.939	0.068	1.608	0.456	0.339	5.644	1.444	1.350	1.397	0.939	0.458	4.763	**3.045**	**3.045**
01/09/2013 00:00	12.5	77	1031.06	44.9	2.35	0.00	244	12.87	12.15	12.51	94	59	2.35	0.095	103.106	0.069	1.800	0.436	0.314	7.417	1.485	1.417	1.451	1.104	0.347	1.572	**1.492**	**1.492**
02/09/2013 00:00	16.3	84	1028.41	126.3	2.24	0.00	245	16.50	16.02	16.26	96	75	2.24	0.118	102.841	0.068	1.763	0.494	0.287	6.978	1.877	1.821	1.849	1.578	0.271	4.421	**2.728**	**2.728**
03/09/2013 00:00	14.8	80	1025.90	125.5	1.09	0.00	246	15.29	14.25	14.77	98	45	1.09	0.108	102.590	0.068	1.369	0.537	0.338	3.395	1.738	1.625	1.681	1.187	0.494	4.391	**2.926**	**2.926**
04/09/2013 00:00	13.4	80	1018.20	121.7	1.04	0.00	247	13.93	12.91	13.42	97	44	1.04	0.100	101.820	0.068	1.355	0.522	0.352	3.283	1.592	1.489	1.540	1.072	0.468	4.259	**2.766**	**2.766**
05/09/2013 00:00	12.4	72	1014.77	142.0	1.41	0.00	248	12.86	11.99	12.43	93	46	1.41	0.095	101.477	0.067	1.480	0.487	0.347	4.451	1.484	1.402	1.443	0.993	0.450	4.971	**3.115**	**3.115**
06/09/2013 00:00	9.3	76	1012.83	121.1	1.01	0.90	249	9.90	8.69	9.30	95	42	1.01	0.079	101.283	0.067	1.342	0.466	0.398	3.204	1.220	1.124	1.172	0.790	0.382	4.239	**2.463**	**2.463**
07/09/2013 00:00	8.7	85	1013.05	117.6	2.58	1.60	250	8.97	8.51	8.74	92	77	2.58	0.076	101.305	0.067	1.876	0.377	0.332	8.226	1.146	1.111	1.128	0.952	0.176	4.116	**2.032**	**2.032**
08/09/2013 00:00	10.8	78	1014.64	124.4	2.07	0.20	251	10.98	10.55	10.77	94	54	2.07	0.086	101.464	0.067	1.703	0.428	0.336	6.555	1.311	1.274	1.293	0.953	0.340	4.352	**2.612**	**2.612**
09/09/2013 00:00	11.8	81	1019.59	122.1	1.07	0.00	252	12.20	11.30	11.75	97	57	1.07	0.091	101.959	0.068	1.365	0.496	0.369	3.389	1.421	1.339	1.380	1.055	0.326	4.275	**2.529**	**2.529**
10/09/2013 00:00	12.2	82	1027.49	48.0	1.58	0.10	253	12.48	11.96	12.22	94	61	1.58	0.094	102.749	0.068	1.537	0.471	0.344	4.980	1.448	1.399	1.423	1.099	0.324	1.680	**1.348**	**1.348**
11/09/2013 00:00	14.5	90	1024.60	46.9	2.50	0.20	254	14.71	14.29	14.50	97	83	2.50	0.107	102.460	0.068	1.848	0.459	0.293	7.811	1.674	1.629	1.651	1.485	0.167	1.642	**1.135**	**1.135**
12/09/2013 00:00	16.4	93	1019.16	77.8	2.52	0.30	255	16.52	16.21	16.37	97	83	2.52	0.119	101.916	0.068	1.858	0.485	0.277	7.851	1.880	1.843	1.861	1.674	0.187	2.725	**1.729**	**1.729**
13/09/2013 00:00	11.1	83	1020.26	74.9	0.71	0.00	256	11.45	10.78	11.11	97	63	0.71	0.088	102.026	0.068	1.240	0.511	0.394	2.240	1.352	1.293	1.323	1.053	0.270	2.621	**1.577**	**1.577**
14/09/2013 00:00	10.2	76	1020.07	90.3	0.83	0.80	257	10.69	9.68	10.19	98	47	0.83	0.083	102.007	0.068	1.281	0.489	0.399	2.624	1.286	1.202	1.244	0.891	0.353	3.160	**1.915**	**1.915**
15/09/2013 00:00	12.4	79	1006.10	83.6	4.39	2.20	258	12.75	12.04	12.39	94	51	4.39	0.095	100.610	0.067	2.492	0.362	0.256	13.836	1.473	1.406	1.440	1.036	0.403	2.926	**2.488**	**2.488**
16/09/2013 00:00	9.2	71	1004.95	56.4	3.86	2.00	259	9.61	8.77	9.19	83	56	3.86	0.078	100.495	0.067	2.314	0.336	0.287	12.326	1.196	1.130	1.163	0.804	0.359	1.973	**1.933**	**1.933**
17/09/2013 00:00	11.6	86	999.40	9.1	3.12	5.60	260	11.82	11.34	11.58	97	74	3.12	0.090	99.940	0.066	2.062	0.397	0.292	9.879	1.386	1.342	1.364	1.164	0.200	0.317	**0.705**	**0.705**
18/09/2013 00:00	11.1	80	1007.92	45.2	2.37	0.80	261	11.47	10.76	11.12	97	60	2.37	0.088	100.792	0.067	1.806	0.421	0.321	7.510	1.354	1.292	1.323	1.033	0.290	1.583	**1.365**	**1.365**
19/09/2013 00:00	12.4	78	1009.29	80.3	3.39	1.10	262	12.74	12.01	12.38	97	63	3.39	0.095	100.929	0.067	2.154	0.395	0.281	10.704	1.473	1.404	1.438	1.145	0.293	2.812	**1.993**	**1.993**
20/09/2013 00:00	12.7	78	1018.03	83.0	1.39	0.00	263	12.89	12.46	12.67	90	57	1.39	0.096	101.803	0.068	1.471	0.491	0.346	4.368	1.487	1.445	1.466	1.074	0.392	2.906	**2.019**	**2.019**
21/09/2013 00:00	17.3	83	1020.61	46.2	1.82	0.00	264	17.62	16.99	17.30	97	64	1.82	0.125	102.061	0.068	1.620	0.532	0.289	5.654	2.015	1.936	1.976	1.584	0.392	1.616	**1.499**	**1.499**
22/09/2013 00:00	15.2	84	1025.96	22.4	1.06	0.00	265	15.73	14.77	15.25	95	63	1.06	0.111	102.596	0.068	1.361	0.545	0.334	3.311	1.787	1.680	1.734	1.361	0.373	0.783	**0.839**	**0.839**
23/09/2013 00:00	15.3	92	1021.87	61.1	1.31	0.00	266	15.46	15.24	15.35	97	87	1.31	0.112	102.187	0.068	1.446	0.533	0.323	4.092	1.756	1.732	1.744	1.604	0.140	2.140	**1.325**	**1.325**
24/09/2013 00:00	14.9	92	1014.84	34.0	0.95	0.00	267	15.07	14.82	14.95	97	89	0.95	0.109	101.484	0.067	1.322	0.551	0.340	2.960	1.714	1.686	1.700	1.580	0.120	1.191	**0.776**	**0.776**
25/09/2013 00:00	14.8	93	1011.74	60.9	0.63	0.30	268	15.00	14.69	14.85	98	84	0.63	0.109	101.174	0.067	1.213	0.572	0.353	1.957	1.705	1.672	1.689	1.535	0.153	2.131	**1.324**	**1.324**
26/09/2013 00:00	14.7	93	1013.82	3.3	0.73	1.00	269	14.92	14.54	14.73	98	81	0.73	0.108	101.382	0.067	1.248	0.562	0.351	2.279	1.697	1.655	1.676	1.498	0.178	0.116	**0.207**	**0.207**

27/09/2013 00:00	14.5	87	1013.15	33.4	0.84	0.00	270	14.71	14.20	14.45	98	75	0.84	0.106	101.315	0.067	1.285	0.551	0.349	2.626	1.673	1.620	1.646	1.421	0.225	1.168	**0.851**	**0.851**
28/09/2013 00:00	14.5	79	1007.59	44.1	1.02	0.00	271	14.84	14.08	14.46	98	48	1.02	0.106	100.759	0.067	1.347	0.541	0.341	3.198	1.687	1.607	1.647	1.192	0.455	1.543	**1.330**	**1.330**
29/09/2013 00:00	14.8	69	1006.03	53.5	1.19	0.90	272	15.13	14.50	14.81	82	59	1.19	0.109	100.603	0.067	1.403	0.536	0.330	3.710	1.719	1.651	1.685	1.184	0.501	1.874	**1.619**	**1.619**
30/09/2013 00:00	14.2	88	1003.70	51.9	1.31	16.60	273	14.32	14.13	14.23	94	78	1.31	0.105	100.370	0.067	1.445	0.522	0.331	4.097	1.632	1.613	1.622	1.394	0.228	1.817	**1.257**	**1.257**
01/10/2013 00:00	15.2	95	1002.55	7.5	1.57	14.60	274	15.27	15.12	15.19	97	90	1.57	0.111	100.255	0.067	1.535	0.520	0.313	4.915	1.735	1.718	1.727	1.614	0.113	0.261	**0.309**	**0.309**
02/10/2013 00:00	16.3	93	1001.74	64.6	1.53	17.30	275	16.40	16.11	16.25	97	84	1.53	0.118	100.174	0.067	1.519	0.538	0.304	4.746	1.866	1.831	1.848	1.671	0.177	2.262	**1.472**	**1.472**
03/10/2013 00:00	15.7	95	1001.17	7.6	0.99	2.10	276	15.80	15.61	15.70	97	93	0.99	0.114	100.117	0.067	1.336	0.562	0.328	3.081	1.795	1.774	1.784	1.695	0.089	0.265	**0.239**	**0.239**
04/10/2013 00:00	13.8	91	1007.39	43.5	1.67	0.00	277	14.13	13.49	13.81	98	75	1.67	0.103	100.739	0.067	1.569	0.494	0.322	5.251	1.612	1.547	1.579	1.362	0.217	1.524	**1.120**	**1.120**
05/10/2013 00:00	12.4	84	1019.82	38.0	1.35	0.10	278	12.76	12.08	12.42	96	61	1.35	0.095	101.982	0.068	1.460	0.489	0.350	4.269	1.474	1.410	1.442	1.126	0.316	1.330	**1.122**	**1.122**
06/10/2013 00:00	14.9	93	1021.77	13.9	1.07	0.30	279	15.14	14.62	14.88	96	86	1.07	0.109	102.177	0.068	1.364	0.541	0.337	3.343	1.721	1.664	1.693	1.539	0.154	0.486	**0.436**	**0.436**
07/10/2013 00:00	16.5	88	1020.33	53.9	2.35	0.40	280	16.73	16.36	16.55	96	81	2.35	0.120	102.033	0.068	1.798	0.495	0.281	7.295	1.905	1.860	1.883	1.665	0.218	1.888	**1.382**	**1.382**
08/10/2013 00:00	14.2	87	1024.33	10.7	1.59	0.10	281	14.45	13.98	14.21	95	73	1.59	0.105	102.433	0.068	1.539	0.500	0.325	4.969	1.646	1.596	1.621	1.359	0.262	0.375	**0.610**	**0.610**
09/10/2013 00:00	10.2	79	1025.10	19.3	1.76	0.00	282	10.49	9.86	10.17	89	58	1.76	0.083	102.510	0.068	1.598	0.433	0.355	5.587	1.269	1.216	1.243	0.909	0.333	0.676	**0.954**	**0.954**
10/10/2013 00:00	6.8	79	1028.46	8.4	1.11	0.10	283	7.18	6.39	6.79	91	54	1.11	0.068	102.846	0.068	1.379	0.419	0.422	3.585	1.014	0.961	0.988	0.711	0.277	0.294	**0.541**	**0.541**
11/10/2013 00:00	7.3	85	1028.91	12.9	0.98	0.00	284	7.74	6.92	7.33	94	71	0.98	0.070	102.891	0.068	1.333	0.435	0.424	3.148	1.054	0.997	1.025	0.843	0.183	0.453	**0.441**	**0.441**
12/10/2013 00:00	10.7	84	1024.43	26.9	1.11	0.00	285	10.81	10.56	10.68	92	73	1.11	0.086	102.443	0.068	1.379	0.477	0.379	3.533	1.296	1.275	1.285	1.059	0.226	0.941	**0.752**	**0.752**
13/10/2013 00:00	10.7	88	1017.66	20.4	0.66	0.20	286	10.89	10.57	10.73	95	76	0.66	0.086	101.766	0.068	1.224	0.509	0.401	2.091	1.303	1.276	1.290	1.101	0.188	0.714	**0.521**	**0.521**
14/10/2013 00:00	9.0	85	1013.66	25.5	0.77	0.00	287	9.40	8.59	9.00	96	66	0.77	0.078	101.366	0.067	1.260	0.477	0.415	2.443	1.180	1.117	1.148	0.925	0.223	0.894	**0.652**	**0.652**
15/10/2013 00:00	6.6	88	1011.67	0.2	0.78	28.60	288	7.08	6.09	6.58	98	64	0.78	0.067	101.167	0.067	1.266	0.441	0.442	2.518	1.007	0.941	0.974	0.783	0.191	0.008	**0.216**	**0.216**
16/10/2013 00:00	11.6	85	1004.49	17.0	2.35	0.10	289	11.84	11.26	11.55	97	67	2.35	0.090	100.449	0.067	1.798	0.429	0.318	7.424	1.388	1.336	1.362	1.113	0.249	0.596	**0.843**	**0.843**
17/10/2013 00:00	10.3	89	1010.81	23.2	0.74	16.50	290	10.80	9.86	10.33	96	76	0.74	0.084	101.081	0.067	1.252	0.499	0.400	2.350	1.295	1.217	1.256	1.076	0.180	0.811	**0.574**	**0.574**
18/10/2013 00:00	13.0	94	1005.06	-5.4	2.14	8.10	291	13.12	12.86	12.99	97	87	2.14	0.098	100.506	0.067	1.728	0.459	0.313	6.735	1.510	1.484	1.497	1.376	0.120	-0.188	**0.168**	**0.168**
19/10/2013 00:00	13.6	91	996.94	22.2	1.30	2.50	292	13.96	13.34	13.65	97	80	1.30	0.102	99.694	0.066	1.441	0.516	0.336	4.072	1.594	1.531	1.563	1.380	0.182	0.778	**0.651**	**0.651**
20/10/2013 00:00	12.2	88	995.32	35.0	2.08	9.10	293	12.57	11.89	12.23	97	75	2.08	0.094	99.532	0.066	1.707	0.453	0.320	5.558	1.456	1.392	1.424	1.221	0.203	1.226	**0.982**	**0.982**
21/10/2013 00:00	12.7	94	994.01	33.2	1.91	1.80	294	13.01	12.45	12.73	98	87	1.91	0.096	99.401	0.066	1.651	0.469	0.322	6.027	1.499	1.445	1.472	1.360	0.112	1.163	**0.763**	**0.763**
22/10/2013 00:00	14.1	90	986.21	15.0	1.40	0.40	295	14.37	13.89	14.13	95	78	1.40	0.104	98.621	0.066	1.476	0.519	0.326	4.386	1.637	1.587	1.612	1.392	0.220	0.526	**0.587**	**0.587**
23/10/2013 00:00	9.8	82	997.38	27.7	2.50	2.40	296	10.11	9.49	9.80	95	61	2.50	0.081	99.738	0.066	1.851	0.398	0.325	7.966	1.237	1.187	1.212	0.941	0.271	0.971	**1.088**	**1.088**
24/10/2013 00:00	10.0	91	1007.51	3.0	1.81	14.80	297	10.25	9.69	9.97	98	84	1.81	0.082	100.751	0.067	1.616	0.431	0.352	5.762	1.249	1.203	1.226	1.114	0.112	0.105	**0.272**	**0.272**
25/10/2013 00:00	13.5	92	996.14	16.8	2.08	7.40	298	13.76	13.25	13.50	95	85	2.08	0.101	99.614	0.066	1.706	0.472	0.310	6.519	1.573	1.522	1.548	1.392	0.156	0.589	**0.593**	**0.593**
26/10/2013 00:00	10.5	90	995.73	38.0	2.07	8.30	299	10.83	10.20	10.52	97	77	2.07	0.085	99.573	0.066	1.703	0.429	0.335	6.567	1.298	1.245	1.271	1.103	0.168	1.331	**0.941**	**0.941**
27/10/2013 00:00	10.7	84	987.06	23.4	4.14	2.10	300	10.94	10.36	10.65	94	67	4.14	0.086	98.706	0.066	2.407	0.351	0.270	13.133	1.308	1.258	1.283	1.029	0.254	0.820	**1.185**	**1.185**
28/10/2013 00:00	8.1	85	991.60	0.7	3.55	0.00	301	8.35	7.92	8.14	93	71	3.55	0.074	99.160	0.066	2.207	0.336	0.301	11.364	1.099	1.067	1.083	0.886	0.197	0.026	**0.681**	**0.681**
29/10/2013 00:00	6.4	81	1011.99	-20.0	2.77	3.70	302	6.71	6.04	6.37	94	63	2.77	0.066	101.199	0.067	1.941	0.336	0.342	8.921	0.982	0.938	0.960	0.750	0.210	-0.699	**0.405**	**0.405**
30/10/2013 00:00	8.1	91	1013.12	6.0	2.00	0.80	303	8.47	7.67	8.07	96	79	2.00	0.073	101.312	0.067	1.680	0.393	0.361	6.401	1.108	1.049	1.078	0.941	0.137	0.210	**0.400**	**0.400**
31/10/2013 00:00	8.9	86	1011.46	-5.3	2.41	0.10	304	9.27	8.61	8.94	93	68	2.41	0.077	101.146	0.067	1.818	0.387	0.337	7.678	1.169	1.118	1.144	0.918	0.226	-0.187	**0.513**	**0.513**
01/11/2013 00:00	6.6	89	1006.58	-23.4	0.71	5.10	305	6.97	6.32	6.65	97	75	0.71	0.067	100.658	0.067	1.243	0.447	0.445	2.299	1.000	0.956	0.978	0.839	0.139	-0.818	**-0.223**	**0.000**
02/11/2013 00:00	6.2	87	991.98	-4.8	4.18	1.10	306	6.54	5.84	6.19	98	72	4.18	0.065	99.198	0.066	2.422	0.291	0.293	13.482	0.971	0.925	0.948	0.803	0.145	-0.169	**0.524**	**0.524**
03/11/2013 00:00	5.9	84	996.65	-19.0	2.76	0.00	307	6.10	5.68	5.89	93	69	2.76	0.064	99.665	0.066	1.939	0.333	0.344	8.912	0.941	0.914	0.928	0.750	0.178	-0.665	**0.323**	**0.323**
04/11/2013 00:00	3.7	87	995.84	-17.6	1.08	1.70	308	4.01	3.42	3.71	98	68	1.08	0.056	99.584	0.066	1.366	0.383	0.451	3.502	0.814	0.780	0.797	0.659	0.138	-0.617	**-0.018**	**0.000**
05/11/2013 00:00	8.4	85	994.36	-22.0	3.77	1.50	309	8.57	8.22	8.40	97	76	3.77	0.075	99.436	0.066	2.282	0.331	0.293	12.062	1.115	1.089	1.102	0.952	0.150	-0.771	**0.275**	**0.275**
06/11/2013 00:00	7.5	93	997.63	-5.8	1.60	0.10	310	7.66	7.42	7.54	97	86	1.60	0.071	99.763	0.066	1.546	0.409	0.382	5.147	1.048	1.031	1.040	0.951	0.089	-0.201	**0.092**	**0.092**
07/11/2013 00:00	6.0	84	1003.42	-9.6	2.32	0.20	311	6.30	5.62	5.96	93	70	2.32	0.065	100.342	0.067	1.789	0.351	0.363	7.484	0.955	0.911	0.933	0.758	0.175	-0.337	**0.357**	**0.357**
08/11/2013 00:00	4.4	85	1003.77	1.2	1.82	0.50	312	4.84	3.93	4.38	92	71	1.82	0.059	100.377	0.067	1.619	0.352	0.401	5.903	0.862	0.809	0.836	0.678	0.157	0.040	**0.386**	**0.386**
09/11/2013 00:00	2.4	87	1004.31	2.9	0.95	9.40	313	2.74	1.99	2.37	95	76	0.95	0.052	100.431	0.067	1.322	0.369	0.477	3.095	0.744	0.705	0.725	0.618	0.107	0.101	**0.195**	**0.195**
10/11/2013 00:00	4.7	93	1015.98	-19.2	1.31	0.50	314	5.05	4.43	4.74	98	84	1.31	0.060	101.598	0.068	1.445	0.380	0.429	4.246	0.875	0.838	0.857	0.778	0.078	-0.672	**-0.113**	**0.000**
11/11/2013 00:00	11.9	92	1017.61	-18.8	1.74	0.10	315	11.99	11.76	11.88	98	80	1.74	0.092	101.761	0.068	1.591	0.460	0.339	5.487	1.402	1.381	1.391	1.237	0.154	-0.657	**-0.016**	**0.000**
12/11/2013 00:00	6.3	86	1029.25	-4.7	1.79	1.20	316	6.66	5.90	6.28	94	64	1.79	0.066	102.925	0.068	1.607	0.374	0.389	5.756	0.978	0.929	0.953	0.750	0.204	-0.166	**0.395**	**0.395**
13/11/2013 00:00	4.5	88	1028.39	15.4	2.50	0.00	317	4.86	4.10	4.48	96	74	2.50	0.059	102.839	0.068	1.850	0.318	0.369	8.112	0.864	0.819	0.841	0.713	0.129	0.538	**0.556**	**0.556**
14/11/2013 00:00	7.4	76	1031.01	-8.2	3.08	0.00	318	7.62	7.22	7.42	85	68	3.08	0.071	103.101	0.069	2.048	0.334	0.325	9.893	1.045	1.017	1.031	0.788	0.244	-0.286	**0.687**	**0.687**
15/11/2013 00:00	7.9	83	1035.54	-0.3	1.34	0.00	319	8.02	7.76	7.89	86	78	1.34	0.073	103.554	0.069	1.454	0.420	0.399	4.283	1.074	1.056	1.065	0.873	0.192	-0.009	**0.324**	**0.324**
16/11/2013 00:00	8.9	87	1031.70	-7.2	1.35	0.40	320	8.99	8.72	8.85	92	84	1.35	0.077	103.170	0.069	1.461	0.434	0.387	4.325	1.147	1.127	1.137	1.000	0.137	-0.252	**0.120**	**0.120**
17/11/2013 00:00	9.5	95	1023.30	-9.2	0.72	3.60	321	9.71	9.31	9.51	98	88	0.72	0.080	102.330	0.068	1.246	0.485	0.413	2.305	1.204	1.172	1.188	1.104	0.084	-0.321	**-0.076**	**0.000**
18/11/2013 00:00	5.5	90	1014.43	-25.4	1.46	0.00	322	5.87	5.20	5.53	98	75	1.46	0.063	101.443	0.067	1.495	0.384	0.412	4.707	0.927	0.884	0.906	0.781	0.125	-0.889	**-0.100**	**0.000**
19/11/2013 00:00	2.0	81	1019.68	-31.1	2.27	1.50	323	2.24	1.78	2.01	90	66	2.27	0.051	101.968	0.068	1.772	0.296	0.397	7.429	0.718	0.695	0.706	0.550	0.157	-1.088	**0.140**	**0.140**
20/11/2013 00:00	5.6	80	1010.27	-4.4	3.60	0.00	324	5.84	5.41	5.63	92	63	3.60	0.063	101.027	0.067	2.224	0.298	0.316	11.627	0.925	0.898	0.911	0.704	0.207	-0.152	**0.715**	**0.715**
21/11/2013 00:00	2.3	81	1016.12	-6.1	1.61	0.00	325	2.46	2.05	2.25	88	71	1.61	0.051	101.612	0.068	1.546	0.329	0.434	5.249	0.729	0.708	0.719	0.570	0.148	-0.215	**0.267**	**0.267**
22/11/2013 00:00	0.6	87	1024.23	-10.8	0.58	0.00	326	0.98	0.18	0.58	96	77	0.58	0.046	102.423	0.068	1.197	0.361	0.534	1.907	0.656	0.619	0.637	0.549	0.088	-0.377	**-0.047**	**0.000**
23/11/2013 00:00	0.2	95	1029.53	-40.2	0.56	0.00	327	0.47	-0.13	0.17	97	91	0.56	0.045	102.953	0.068	1.190	0.355	0.542	1.844	0.632	0.605	0.618	0.581	0.038	-1.406	**-0.462**	**0.000**
24/11/2013 00:00	5.3	93	1035.15	-44.2	0.60	0.00	328	5.48	5.18	5.33	98	82	0.60	0.062	103.515	0.069	1.205	0.428	0.475	1.947	0.902	0.883	0.893	0.803	0.090	-1.547	**-0.579**	**0.000**
25/11/2013 00:00	3.5	85	1041.20	-26.4	0.44	0.00	329	3.78	3.29	3.53	92	71	0.44	0.056	104.120	0.069	1.149	0.411	0.512	1.422	0.801	0.773	0.787	0.640	0.147	-0.923	**-0.273**	**0.000**
26/11/2013 00:00	3.8	87	1041.57	-22.3	1.18	0.00	330	4.02	3.62	3.82	92	77	1.18	0.057	104.157	0.069	1.401	0.368	0.451	3.836	0.814	0.792	0.803	0.678	0.125	-0.780	**-0.071**	**0.000**
27/11/2013 00:00	6.0	90	1038.24	-25.5	0.74	0.60	331	6.15	5.76	5.95	97	77	0.74	0.065	103.824	0.069	1.252	0.427	0.457	2.393	0.945	0.920	0.932	0.810	0.122	-0.894	**-0.248**	**0.000**
28/11/2013 00:00	7.0	96	1037.42	-48.7	0.64	0.10	332	7.19	6.80	6.99	98	91	0.64	0.069	103.742	0.069	1.219	0.450	0.451	2.067	1.015	0.988	1.001	0.946	0.056	-1.706	**-0.716**	**0.000**
29/11/2013 00:00	7.1	81	1031.98	-53.0	2.77	0.00	333	7.28	6.95	7.11	90	72	2.77	0.069	103.198	0.069	1.943	0.342	0.339	8.914	1.021	0.998	1.010	0.817	0.193	-1.854	**-0.051**	**0.000**
30/11/2013 00:00	5.8	92	1033.31	-28.2	1.46	0.40	334	5.97	5.56	5.76	97	87	1.46	0.064	103.331	0.069	1.498	0.383	0.412	4.725	0.933	0.907	0.920	0.846	0.074	-0.986	**-0.233**	**0.000**
01/12/2013 00:00	7.0	92	1035.19	-19.8	0.73	0.10	335	7.11	6.84	6.97	98	85	0.73	0.069	103.519	0.069	1.247	0.444	0.445	2.339	1.010	0.991	1.000	0.914	0.086	-0.695	**-0.219**	**0.000**
02/12/2013 00:00	5.9	94	1033.00	-30.0	0.43	0.10	336	6.00	5.72	5.86	98	89	0.43	0.064	103.300	0.069	1.146	0.449	0.481	1.389	0.935	0.917	0.926	0.865	0.061	-1.051	**-0.432**	**0.000**
03/12/2013 00:00	5.2	91	1028.03	1.8	1.26	0.40	337	5.56	4.87	5.21	96	84	1.26	0.062	102.803	0.068	1.427	0.387	0.429	4.062	0.907	0.865	0.886	0.796	0.090	0.063	**0.181**	**0.181**
04/12/2013 00:00	3.9	87	1032.34	-41.9	1.70	0.70	338	4.18	3.56	3.87	96	72	1.70	0.057	103.234	0.069	1.580	0.344	0.416	5.541	0.824	0.789	0.806	0.675	0.131	-1.468	**-0.203**	**0.000**
05/12/2013 00:00	6.3	81	1025.94	-38.9	4.44	0.10	339	6.55	6.10	6.32	90	75	4.44	0.066	102.594	0.068	2.509	0.278	0.288	14.300	0.971	0.942	0.956	0.788	0.168	-1.362	**0.314**	**0.314**
06/12/2013 00:00	6.4	90	1029.67	-48.6	2.05	0.00	340	6.58	6.17	6.37	95	78	2.05	0.066	102.967	0.068	1.698	0.363	0.375	6.611	0.973	0.946	0.960	0.829	0.131	-1.700	**-0.293**	**0.000**

07/12/2013 00:00	6.1	90	1025.25	-40.9	1.50	0.00	341	8.39	5.87	6.13	95	81	1.50	0.065	102.525	0.068	1.510	0.388	0.405	4.836	0.961	0.927	0.944	0.829	0.114	-1.432	-0.331	0.000
08/12/2013 00:00	8.7	87	1021.81	-60.8	2.56	0.10	342	9.00	8.49	8.74	93	80	2.56	0.076	102.181	0.068	1.871	0.375	0.334	8.185	1.148	1.109	1.129	0.975	0.154	-2.127	-0.379	0.000
09/12/2013 00:00	8.6	88	1023.25	-22.4	1.62	0.20	343	8.96	8.34	8.65	96	79	1.62	0.076	102.325	0.068	1.552	0.418	0.375	5.186	1.145	1.098	1.121	0.979	0.142	-0.784	-0.052	0.000
10/12/2013 00:00	10.7	87	1022.34	-17.2	2.85	0.00	344	10.76	10.59	10.67	94	76	2.85	0.086	102.234	0.068	1.970	0.390	0.310	9.052	1.292	1.277	1.284	1.091	0.193	-0.600	0.308	0.308
11/12/2013 00:00	9.8	84	1020.73	-51.6	1.87	1.60	345	9.93	9.76	9.84	92	79	1.87	0.082	102.073	0.068	1.635	0.423	0.353	5.945	1.222	1.208	1.215	1.038	0.177	-1.807	-0.395	0.000
12/12/2013 00:00	11.6	93	1014.39	-39.9	2.47	1.60	346	11.73	11.56	11.65	96	82	2.47	0.091	101.439	0.067	1.840	0.422	0.314	7.808	1.377	1.363	1.370	1.219	0.151	-1.397	-0.219	0.000
13/12/2013 00:00	8.5	85	1011.46	-37.6	3.45	16.30	347	8.75	8.28	8.52	94	72	3.45	0.075	101.146	0.067	2.173	0.340	0.304	11.027	1.129	1.093	1.111	0.920	0.191	-1.317	0.191	0.191
14/12/2013 00:00	8.9	87	1010.00	-15.9	4.55	2.20	348	9.13	8.58	8.86	93	78	4.55	0.077	101.000	0.067	2.546	0.310	0.271	14.517	1.158	1.116	1.137	0.971	0.166	-0.556	0.482	0.482
15/12/2013 00:00	8.4	87	1008.24	-32.5	3.03	4.60	349	8.75	8.05	8.40	96	77	3.03	0.075	100.824	0.067	2.029	0.355	0.318	9.680	1.129	1.077	1.103	0.951	0.151	-1.137	0.062	0.062
16/12/2013 00:00	5.0	84	1011.82	-49.6	2.32	0.00	350	5.27	4.76	5.02	95	75	2.32	0.061	101.182	0.067	1.790	0.336	0.371	7.521	0.889	0.858	0.873	0.741	0.133	-1.737	-0.214	0.000
17/12/2013 00:00	1.6	83	1017.06	-50.8	1.15	16.60	351	2.13	1.12	1.62	93	73	1.15	0.049	101.706	0.068	1.392	0.344	0.471	3.781	0.712	0.662	0.687	0.568	0.119	-1.777	-0.398	0.000
18/12/2013 00:00	8.4	88	992.00	-40.7	3.73	2.90	352	8.64	8.07	8.36	95	73	3.73	0.075	99.200	0.066	2.268	0.333	0.294	11.934	1.121	1.078	1.099	0.921	0.178	-1.424	0.152	0.152
19/12/2013 00:00	2.1	84	997.85	-34.9	3.55	3.70	353	2.30	1.89	2.10	91	76	3.55	0.051	99.785	0.066	2.208	0.257	0.336	11.628	0.721	0.700	0.711	0.593	0.118	-1.221	0.147	0.147
20/12/2013 00:00	6.9	87	1008.06	-7.6	4.91	10.70	354	7.22	6.65	6.94	94	73	4.91	0.069	100.806	0.067	2.670	0.277	0.271	15.789	1.017	0.978	0.998	0.831	0.167	-0.265	0.639	0.639
21/12/2013 00:00	6.5	84	1001.49	-3.5	4.49	2.00	355	6.80	6.21	6.50	91	76	4.49	0.067	100.149	0.067	2.528	0.284	0.283	14.470	0.988	0.949	0.968	0.807	0.161	-0.124	0.626	0.626
22/12/2013 00:00	3.0	84	1003.54	-19.6	4.01	9.60	356	3.17	2.74	2.95	87	78	4.01	0.054	100.354	0.067	2.365	0.254	0.316	13.092	0.767	0.744	0.755	0.623	0.133	-0.687	0.374	0.374
23/12/2013 00:00	7.9	87	980.65	2.4	4.26	0.30	357	8.14	7.59	7.86	94	78	4.26	0.072	98.065	0.065	2.449	0.312	0.281	13.657	1.083	1.043	1.063	0.913	0.150	0.084	0.603	0.603
24/12/2013 00:00	3.3	75	968.21	-37.1	5.24	0.00	358	3.62	3.05	3.34	89	59	5.24	0.055	96.821	0.064	2.783	0.235	0.275	17.081	0.792	0.761	0.776	0.572	0.204	-1.300	0.654	0.654
25/12/2013 00:00	-1.8	95	980.44	-25.6	0.66	7.00	359	-1.27	-2.36	-1.82	98	91	0.66	0.040	98.044	0.065	1.223	0.331	0.547	2.174	0.557	0.513	0.535	0.505	0.030	-0.896	-0.261	0.000
26/12/2013 00:00	3.4	88	986.99	-26.7	2.95	6.00	360	3.71	3.02	3.37	94	75	2.95	0.055	98.699	0.066	2.002	0.295	0.352	9.595	0.797	0.759	0.778	0.656	0.122	-0.933	0.138	0.138
27/12/2013 00:00	5.4	79	973.78	-48.1	7.58	0.00	361	5.74	5.11	5.43	86	73	7.58	0.063	97.378	0.065	3.576	0.213	0.220	24.493	0.918	0.879	0.899	0.713	0.186	-1.683	0.643	0.643
28/12/2013 00:00	2.0	85	995.76	-27.1	2.59	13.00	362	2.18	1.73	1.96	90	75	2.59	0.050	99.576	0.066	1.881	0.288	0.379	8.481	0.715	0.692	0.704	0.580	0.124	-0.949	0.125	0.125
29/12/2013 00:00	4.0	90	1007.88	-7.3	2.61	20.40	363	4.25	3.66	3.95	94	82	2.61	0.057	100.788	0.067	1.886	0.311	0.365	8.465	0.827	0.794	0.811	0.712	0.098	-0.257	0.224	0.224
30/12/2013 00:00	6.7	88	999.16	-32.9	3.23	16.00	364	6.96	6.47	6.71	95	79	3.23	0.068	99.916	0.066	2.100	0.326	0.321	10.409	0.999	0.966	0.982	0.853	0.129	-1.150	0.055	0.055
31/12/2013 00:00	5.2	88	991.36	-38.4	2.71	4.40	365	5.59	4.84	5.21	94	79	2.71	0.062	99.136	0.066	1.922	0.327	0.350	8.775	0.909	0.863	0.886	0.764	0.121	-1.343	-0.067	0.000
01/01/2014 00:00	5.8	91	979.63	-23.4	2.94	2.10	1	6.07	5.54	5.80	95	87	2.94	0.064	97.963	0.065	2.000	0.329	0.335	9.495	0.940	0.906	0.923	0.839	0.084	-0.819	-0.003	0.000
02/01/2014 00:00	5.9	86	984.69	-33.2	2.98	2.80	2	6.27	5.62	5.95	92	72	2.98	0.065	98.469	0.065	2.014	0.329	0.333	9.619	0.953	0.911	0.932	0.762	0.170	-1.163	0.163	0.163
03/01/2014 00:00	5.6	75	980.27	4.6	6.28	4.80	3	5.96	5.21	5.59	88	66	6.28	0.063	98.027	0.065	3.137	0.236	0.244	20.302	0.933	0.885	0.909	0.697	0.212	0.161	1.085	1.085
04/01/2014 00:00	2.3	86	988.86	-3.1	1.75	7.50	4	2.62	1.94	2.28	96	76	1.75	0.051	98.886	0.066	1.594	0.329	0.421	5.712	0.738	0.703	0.720	0.618	0.103	-0.109	0.211	0.211
05/01/2014 00:00	6.3	90	987.20	-5.9	2.63	5.10	5	6.60	5.91	6.25	94	84	2.63	0.066	98.720	0.066	1.895	0.346	0.345	8.486	0.975	0.929	0.952	0.846	0.106	-0.206	0.239	0.239
06/01/2014 00:00	8.7	80	978.51	-7.8	6.03	1.20	6	8.99	8.34	8.67	87	72	6.03	0.076	97.851	0.065	3.051	0.277	0.237	19.279	1.147	1.098	1.123	0.891	0.232	-0.273	0.984	0.984
07/01/2014 00:00	7.6	83	991.93	0.2	4.90	12.30	7	7.86	7.39	7.63	89	75	4.90	0.071	99.193	0.066	2.664	0.289	0.267	15.701	1.063	1.029	1.046	0.857	0.189	0.008	0.796	0.796
08/01/2014 00:00	4.8	92	1006.56	-8.6	1.61	1.70	8	5.06	4.60	4.83	97	80	1.61	0.060	100.656	0.067	1.548	0.368	0.409	5.217	0.876	0.848	0.862	0.762	0.100	-0.302	0.103	0.103
09/01/2014 00:00	3.3	91	1007.45	-15.4	2.18	1.50	9	3.62	3.04	3.33	97	80	2.18	0.055	100.745	0.067	1.740	0.320	0.391	7.091	0.792	0.760	0.776	0.685	0.091	-0.538	0.079	0.079
10/01/2014 00:00	5.1	91	1008.79	-34.3	1.67	0.00	10	5.45	4.82	5.14	95	87	1.67	0.061	100.879	0.067	1.569	0.368	0.403	5.414	0.900	0.862	0.881	0.801	0.080	-1.201	-0.268	0.000
11/01/2014 00:00	1.4	89	1018.31	-14.8	1.09	3.30	11	1.81	0.98	1.39	96	78	1.09	0.049	101.831	0.068	1.370	0.344	0.479	3.570	0.696	0.656	0.676	0.586	0.090	-0.516	-0.024	0.000
12/01/2014 00:00	6.4	89	1006.12	-19.4	2.80	1.00	12	6.62	6.15	6.38	95	82	2.80	0.066	100.612	0.067	1.954	0.336	0.340	9.036	0.976	0.945	0.960	0.849	0.111	-0.679	0.114	0.114
13/01/2014 00:00	2.8	90	999.31	-36.9	1.56	5.10	13	3.15	2.52	2.83	94	80	1.56	0.053	99.931	0.066	1.531	0.343	0.429	5.092	0.766	0.732	0.749	0.650	0.099	-1.293	-0.229	0.000
14/01/2014 00:00	2.6	96	1000.21	-36.6	1.45	2.00	14	2.86	2.36	2.61	98	91	1.45	0.052	100.021	0.067	1.493	0.346	0.438	4.730	0.750	0.724	0.737	0.696	0.041	-1.282	-0.358	0.000
15/01/2014 00:00	7.8	92	988.83	-30.3	2.09	8.80	15	8.04	7.53	7.78	97	75	2.09	0.072	98.883	0.066	1.710	0.391	0.356	6.694	1.076	1.039	1.057	0.907	0.150	-1.060	-0.056	0.000
16/01/2014 00:00	5.3	92	980.39	-26.7	1.06	0.80	16	5.58	5.07	5.33	97	86	1.06	0.062	98.039	0.065	1.361	0.412	0.432	3.434	0.909	0.877	0.893	0.816	0.077	-0.934	-0.271	0.000
17/01/2014 00:00	4.8	92	985.10	-13.1	1.70	10.40	17	5.04	4.65	4.84	97	85	1.70	0.060	98.510	0.066	1.579	0.368	0.400	5.518	0.875	0.851	0.863	0.784	0.078	-0.458	0.004	0.004
18/01/2014 00:00	3.0	95	986.15	-0.8	1.20	0.40	18	3.13	2.93	3.03	98	90	1.20	0.054	98.615	0.066	1.409	0.368	0.448	3.926	0.765	0.754	0.760	0.714	0.046	-0.027	0.071	0.071
19/01/2014 00:00	2.0	91	992.58	-7.1	1.09	0.10	19	2.31	1.76	2.04	95	85	1.09	0.051	99.258	0.066	1.371	0.359	0.468	3.574	0.721	0.694	0.708	0.636	0.071	-0.248	0.031	0.031
20/01/2014 00:00	2.7	89	1006.95	-12.0	1.57	2.30	20	3.07	2.41	2.74	94	69	1.57	0.053	100.695	0.067	1.533	0.340	0.430	5.115	0.762	0.726	0.744	0.604	0.140	-0.421	0.165	0.165
21/01/2014 00:00	7.0	90	999.88	-8.3	1.99	0.20	21	7.14	6.78	6.96	95	82	1.99	0.069	99.988	0.066	1.677	0.381	0.369	6.399	1.012	0.987	0.999	0.884	0.116	-0.291	0.162	0.162
22/01/2014 00:00	5.1	88	1004.86	-22.2	2.39	2.20	22	5.42	4.85	5.14	94	75	2.39	0.061	100.486	0.067	1.811	0.337	0.366	7.723	0.899	0.863	0.881	0.743	0.138	-0.778	0.129	0.129
23/01/2014 00:00	4.8	87	1013.41	-1.6	2.75	9.70	23	5.00	4.68	4.84	96	78	2.75	0.060	101.341	0.067	1.934	0.316	0.353	8.902	0.872	0.853	0.863	0.750	0.113	-0.055	0.338	0.338
24/01/2014 00:00	9.1	94	1007.74	-6.1	2.76	6.10	24	9.24	8.95	9.10	98	83	2.76	0.078	100.774	0.067	1.939	0.375	0.322	8.809	1.167	1.145	1.156	1.045	0.111	-0.214	0.234	0.234
25/01/2014 00:00	6.0	83	1011.48	-0.6	3.92	18.20	25	6.36	5.66	6.01	94	73	3.92	0.065	101.148	0.067	2.333	0.292	0.303	12.644	0.959	0.913	0.936	0.779	0.157	-0.020	0.596	0.596
26/01/2014 00:00	4.8	83	994.47	-18.3	5.22	6.90	26	5.13	4.42	4.77	96	61	5.22	0.060	99.447	0.066	2.773	0.247	0.272	16.899	0.880	0.838	0.859	0.671	0.188	-0.639	0.707	0.707
27/01/2014 00:00	4.5	86	983.18	-19.6	5.92	5.00	27	4.81	4.29	4.55	92	81	5.92	0.059	98.318	0.065	3.013	0.231	0.255	19.197	0.861	0.830	0.845	0.730	0.115	-0.687	0.404	0.404
28/01/2014 00:00	5.7	89	980.30	-20.7	5.01	1.42	28	5.86	5.58	5.72	94	84	5.01	0.064	98.030	0.065	2.704	0.265	0.272	16.179	0.926	0.908	0.917	0.816	0.101	-0.726	0.253	0.253

Site B

(Co. Monaghan)

Date	Measured Rainfall mm/day	Total Effluent loading (l)	LP Effluent Loading (l)	LP Effluent Loading (mm)	DD Effluent Loading (l)	DD Effluent Loading (mm)	LP Total Hydraulic Loading mm/day	DD Total Hydraulic Loading mm/day	Calculated ET_0 mm/day	Calculated SMD (mm)	Available SMD (mm)	ET actual mm/day	Effective Rainfall	ET actual mm/day (LP)	ET actual mm/day (DD)	Effective Hydraulic Loading LP (mm)	Effective Hydraulic Loading DD (mm)
02/11/2012	12.9	349.64	140.82	1.88	208.82	2.29	14.78	15.19	0.64	-10.00	0.00	0.64	12.26	0.64	0.64	14.13	14.55
03/11/2012	0.6	437.05	176.03	2.35	261.03	2.87	2.95	3.47	0.72	-9.46	0.54	0.72	0.00	0.72	0.72	2.23	2.74
04/11/2012	0.3	524.46	211.23	2.82	313.23	3.44	3.12	3.74	0.58	-8.54	1.46	0.58	0.00	0.58	0.58	2.54	3.16
05/11/2012	0.5	437.05	176.03	2.35	261.03	2.87	2.85	3.37	0.46	-7.96	2.04	0.46	0.00	0.46	0.46	2.39	2.91
06/11/2012	0.1	437.05	176.03	2.35	261.03	2.87	2.45	2.97	0.71	-7.10	2.90	0.71	0.00	0.71	0.71	1.18	2.22
07/11/2012	1.4	524.46	211.23	2.82	313.23	3.44	4.22	4.84	0.73	-7.29	2.71	0.73	0.00	0.73	0.73	3.49	4.11
08/11/2012	1.7	349.64	140.82	1.88	208.82	2.29	3.58	3.99	0.60	-7.76	2.24	0.60	0.00	0.60	0.60	2.62	3.40
09/11/2012	7.7	437.05	176.03	2.35	261.03	2.87	10.05	10.57	0.53	-10.00	0.00	0.53	7.17	0.53	0.53	9.51	10.03
10/11/2012	0.3	349.64	140.82	1.88	208.82	2.29	2.18	2.59	0.39	-9.27	0.73	0.39	0.00	0.39	0.39	1.79	2.21
11/11/2012	2	437.05	176.03	2.35	261.03	2.87	4.35	4.87	0.34	-10.00	0.00	0.34	1.67	0.34	0.34	4.01	4.53
12/11/2012	6.1	524.46	211.23	2.82	313.23	3.44	8.92	9.54	0.49	-10.00	0.00	0.49	5.61	0.49	0.49	8.43	9.05
13/11/2012	9.6	437.05	176.03	2.35	261.03	2.87	11.95	12.47	0.56	-10.00	0.00	0.56	9.04	0.56	0.56	11.38	11.90
14/11/2012	8.2	349.64	140.82	1.88	208.82	2.29	10.08	10.49	0.43	-10.00	0.00	0.43	7.77	0.43	0.43	9.65	10.07
15/11/2012	0.6	437.05	176.03	2.35	261.03	2.87	2.95	3.47	0.41	-9.67	0.33	0.41	0.00	0.41	0.41	2.54	3.06
16/11/2012	1.4	524.46	211.23	2.82	313.23	3.44	4.22	4.84	0.48	-10.00	0.00	0.48	0.92	0.48	0.48	3.74	4.36
17/11/2012	0.1	524.46	211.23	2.82	313.23	3.44	2.92	3.54	0.15	-9.12	0.88	0.15	0.00	0.15	0.15	2.77	3.39
18/11/2012	9.3	349.64	140.82	1.88	208.82	2.29	11.18	11.59	0.42	-10.00	0.00	0.42	8.88	0.42	0.42	10.76	11.17
19/11/2012	7.5	349.64	140.82	1.88	208.82	2.29	9.38	9.79	0.73	-10.00	0.00	0.73	6.77	0.73	0.73	8.64	9.06
20/11/2012	3.7	437.05	176.03	2.35	261.03	2.87	6.05	6.57	0.56	-10.00	0.00	0.56	3.14	0.56	0.56	5.48	6.00
21/11/2012	0.1	349.64	140.82	1.88	208.82	2.29	1.98	2.39	0.22	-9.04	0.96	0.22	0.00	0.22	0.22	1.76	2.18
22/11/2012	4.5	437.05	176.03	2.35	261.03	2.87	6.85	7.37	0.84	-10.00	0.00	0.84	3.66	0.84	0.84	6.01	6.53
23/11/2012	1.6	437.05	176.03	2.35	261.03	2.87	3.95	4.47	0.35	-10.00	0.00	0.35	1.25	0.35	0.35	3.60	4.12
24/11/2012	1	349.64	140.82	1.88	208.82	2.29	2.88	3.29	0.18	-10.00	0.00	0.18	0.82	0.18	0.18	2.70	3.11
25/11/2012	0.2	349.64	140.82	1.88	208.82	2.29	2.08	2.49	0.07	-9.52	0.48	0.07	0.00	0.07	0.07	2.00	2.42
26/11/2012	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.34	-8.94	1.06	0.34	0.00	0.34	0.34	2.00	2.52
27/11/2012	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.46	-8.10	1.90	0.46	0.00	0.46	0.46	1.89	2.41
28/11/2012	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.05	-7.14	2.86	0.05	0.00	0.05	0.05	1.79	2.82
29/11/2012	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.20	-6.60	3.41	0.20	0.00	0.20	0.20	2.02	3.24
30/11/2012	1	349.64	140.82	1.88	208.82	2.29	2.88	3.29	0.23	-6.89	3.11	0.23	0.00	0.23	0.23	1.41	2.25
01/12/2012	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.01	-6.16	3.84	0.01	0.00	0.01	0.01	0.00	0.74
02/12/2012	2.3	524.46	211.23	2.82	313.23	3.44	5.12	5.74	0.27	-7.95	2.05	0.27	0.00	0.27	0.27	4.84	5.47
03/12/2012	2.8	524.46	211.23	2.82	313.23	3.44	5.62	6.24	0.02	-9.98	0.02	0.02	2.76	0.02	0.02	5.60	6.22
04/12/2012	1.6	437.05	176.03	2.35	261.03	2.87	3.95	4.47	0.29	-10.00	0.00	0.29	1.31	0.29	0.29	3.66	4.18
05/12/2012	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.00	-9.21	0.79	0.00	0.00	0.00	0.00	2.82	3.44
06/12/2012	14.6	349.64	140.82	1.88	208.82	2.29	16.48	16.89	0.47	-10.00	0.00	0.47	14.13	0.47	0.47	16.01	16.42
07/12/2012	0.2	437.05	176.03	2.35	261.03	2.87	2.55	3.07	0.16	-9.23	0.77	0.16	0.00	0.16	0.16	2.39	2.91
08/12/2012	0.2	349.64	140.82	1.88	208.82	2.29	2.08	2.49	0.31	-8.77	1.23	0.31	0.00	0.31	0.31	1.77	2.18
09/12/2012	1.6	437.05	176.03	2.35	261.03	2.87	3.95	4.47	0.13	-9.56	0.44	0.13	1.04	0.13	0.13	3.82	4.34
10/12/2012	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.04	-8.94	1.06	0.04	0.00	0.04	0.04	2.30	2.82
11/12/2012	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.10	-8.39	1.61	0.10	0.00	0.10	0.10	2.72	3.34
12/12/2012	1.4	524.46	211.23	2.82	313.23	3.44	4.22	4.84	0.34	-9.20	0.80	0.34	0.26	0.34	0.34	3.88	4.50
13/12/2012	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.12	-8.36	1.64	0.12	0.00	0.12	0.12	2.22	2.74
14/12/2012	10.7			2.59		2.86	13.29	13.56	0.60	-10.00	0.00	0.60	10.10	0.60	0.60	12.69	12.96
15/12/2012	0.3			2.59		2.86	2.89	3.16	0.37	-9.20	0.80	0.37	0.00	0.37	0.37	2.52	2.79
16/12/2012	1			2.59		2.86	3.59	3.86	0.36	-9.33	0.67	0.36	0.00	0.36	0.36	3.23	3.50
17/12/2012	9.7			2.59		2.86	12.29	12.56	0.31	-10.00	0.00	0.31	9.39	0.31	0.31	11.98	12.25

18/12/2012	0.1			2.59		2.86	2.69	2.96	0.22	-9.29	0.71	0.22	0.00	0.22	0.22	2.47	2.74
19/12/2012	10.7			2.59		2.86	13.29	13.56	0.50	-10.00	0.00	0.50	10.20	0.50	0.50	12.79	13.06
20/12/2012	0.4			2.59		2.86	2.99	3.26	0.27	-9.40	0.60	0.27	0.00	0.27	0.27	2.72	2.99
21/12/2012	0.4	437.05	176.03	2.35	261.03	2.87	2.75	3.27	0.34	-9.03	0.98	0.34	0.00	0.34	0.34	2.41	2.92
22/12/2012	12.8	524.46	211.23	2.82	313.23	3.44	15.62	16.24	0.65	-10.00	0.00	0.65	12.16	0.65	0.65	14.97	15.59
23/12/2012	0.3	437.05	176.03	2.35	261.03	2.87	2.65	3.17	0.64	-9.16	0.84	0.64	0.00	0.64	0.64	2.01	2.53
24/12/2012	0.8	524.46	211.23	2.82	313.23	3.44	3.62	4.24	0.31	-8.82	1.19	0.31	0.00	0.31	0.31	3.30	3.93
25/12/2012	0.8	524.46	211.23	2.82	313.23	3.44	3.62	4.24	0.08	-8.80	1.20	0.08	0.00	0.08	0.08	3.53	4.16
26/12/2012	8.8	437.05	176.03	2.35	261.03	2.87	11.15	11.67	0.69	-10.00	0.00	0.69	8.11	0.69	0.69	10.45	10.97
27/12/2012	1	524.46	211.23	2.82	313.23	3.44	3.82	4.44	0.16	-9.81	0.19	0.16	0.65	0.16	0.16	3.66	4.28
28/12/2012	5.3	349.64	140.82	1.88	208.82	2.29	7.18	7.59	0.92	-10.00	0.00	0.92	4.39	0.92	0.92	6.26	6.68
29/12/2012	4.5	524.46	211.23	2.82	313.23	3.44	7.32	7.94	0.49	-10.00	0.00	0.49	4.01	0.49	0.49	6.83	7.45
30/12/2012	7.5	437.05	176.03	2.35	261.03	2.87	9.85	10.37	0.59	-10.00	0.00	0.59	6.91	0.59	0.59	9.26	9.78
31/12/2012	3.3	524.46	211.23	2.82	313.23	3.44	6.12	6.74	0.44	-10.00	0.00	0.44	2.86	0.44	0.44	5.68	6.30
01/01/2013	1	437.05	176.03	2.35	261.03	2.87	3.35	3.87	0.37	-10.00	0.00	0.37	0.63	0.37	0.37	2.98	3.50
02/01/2013	0.6	524.46	211.23	2.82	313.23	3.44	3.42	4.04	0.67	-9.73	0.27	0.67	0.00	0.67	0.67	2.75	3.37
03/01/2013	0.9	437.05	176.03	2.35	261.03	2.87	3.25	3.77	0.61	-9.46	0.54	0.61	0.00	0.61	0.61	2.64	3.16
04/01/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.76	-8.36	1.65	0.76	0.00	0.76	0.76	2.05	2.68
05/01/2013	2.2	437.05	176.03	2.35	261.03	2.87	4.55	5.07	0.43	-9.29	0.71	0.43	1.06	0.43	0.43	4.12	4.64
06/01/2013	8	437.05	176.03	2.35	261.03	2.87	10.35	10.87	0.34	-10.00	0.00	0.34	7.66	0.34	0.34	10.00	10.52
07/01/2013	21.4	524.46	211.23	2.82	313.23	3.44	24.22	24.84	0.52	-10.00	0.00	0.52	20.88	0.52	0.52	23.70	24.32
08/01/2013	1.7	349.64	140.82	1.88	208.82	2.29	3.58	3.99	0.07	-10.00	0.00	0.07	1.63	0.07	0.07	3.51	3.92
09/01/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.05	-9.43	0.57	0.05	0.00	0.05	0.05	2.77	3.39
10/01/2013	0.9	437.05	176.03	2.35	261.03	2.87	3.25	3.77	0.30	-9.79	0.21	0.30	0.39	0.30	0.30	2.95	3.47
11/01/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.21	-8.99	1.01	0.21	0.00	0.21	0.21	1.66	2.08
12/01/2013	0.2	437.05	176.03	2.35	261.03	2.87	2.55	3.07	0.29	-8.48	1.52	0.29	0.00	0.29	0.29	2.26	2.78
13/01/2013	1.2	437.05	176.03	2.35	261.03	2.87	3.55	4.07	0.21	-8.89	1.11	0.21	0.00	0.21	0.21	3.34	3.86
14/01/2013	2.5	349.64	140.82	1.88	208.82	2.29	4.38	4.79	0.12	-10.00	0.00	0.12	2.38	0.12	0.12	4.26	4.68
15/01/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.16	-9.38	0.62	0.16	0.00	0.16	0.16	1.72	2.13
16/01/2013	2.4	437.05	176.03	2.35	261.03	2.87	4.75	5.27	0.42	-10.00	0.00	0.42	1.98	0.42	0.42	4.32	4.84
17/01/2013	1.1	349.64	140.82	1.88	208.82	2.29	2.98	3.39	0.38	-10.00	0.00	0.38	0.72	0.38	0.38	2.59	3.01
18/01/2013	20.7	437.05	176.03	2.35	261.03	2.87	23.05	23.57	0.52	-10.00	0.00	0.52	20.18	0.52	0.52	22.53	23.05
19/01/2013	1.1	524.46	211.23	2.82	313.23	3.44	3.92	4.54	0.35	-10.00	0.00	0.35	0.75	0.35	0.35	3.56	4.19
20/01/2013	0.1	437.05	176.03	2.35	261.03	2.87	2.45	2.97	0.39	-9.25	0.75	0.39	0.00	0.39	0.39	2.06	2.58
21/01/2013	0.2	524.46	211.23	2.82	313.23	3.44	3.02	3.64	0.33	-8.56	1.44	0.33	0.00	0.33	0.33	2.69	3.31
22/01/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.24	-7.73	2.27	0.24	0.00	0.24	0.24	2.11	2.63
23/01/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.40	-6.99	3.01	0.40	0.00	0.40	0.40	1.28	2.32
24/01/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.33	-6.09	3.91	0.33	0.00	0.33	0.33	1.39	2.63
25/01/2013	16	349.64	140.82	1.88	208.82	2.29	17.88	18.29	0.71	-10.00	0.00	0.71	15.29	0.71	0.71	17.17	17.58
26/01/2013	6.6	524.46	211.23	2.82	313.23	3.44	9.42	10.04	0.53	-10.00	0.00	0.53	6.07	0.53	0.53	8.89	9.51
27/01/2013	10.8	437.05	176.03	2.35	261.03	2.87	13.15	13.67	0.47	-10.00	0.00	0.47	10.33	0.47	0.47	12.68	13.20
28/01/2013	7.2	437.05	176.03	2.35	261.03	2.87	9.55	10.07	1.30	-10.00	0.00	1.30	5.90	1.30	1.30	8.25	8.77
29/01/2013	2.8	437.05	176.03	2.35	261.03	2.87	5.15	5.67	0.83	-10.00	0.00	0.83	1.97	0.83	0.83	4.31	4.83
30/01/2013	10.6	437.05	176.03	2.35	261.03	2.87	12.95	13.47	0.75	-10.00	0.00	0.75	9.85	0.75	0.75	12.20	12.72
31/01/2013	8.6	524.46	211.23	2.82	313.23	3.44	11.42	12.04	1.10	-10.00	0.00	1.10	7.50	1.10	1.10	10.31	10.94
01/02/2013	0.6	349.64	140.82	1.88	208.82	2.29	2.48	2.89	0.85	-9.00	1.00	0.85	0.00	0.85	0.85	1.63	2.05
02/02/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.47	-7.65	2.35	0.47	0.00	0.47	0.47	1.88	2.40
03/02/2013	6.2	611.87	246.44	3.29	365.44	4.01	9.49	10.21	0.60	-10.00	0.00	0.60	5.60	0.60	0.60	8.89	9.62
04/02/2013	3.6	437.05	176.03	2.35	261.03	2.87	5.95	6.47	0.63	-10.00	0.00	0.63	2.97	0.63	0.63	5.32	5.83
05/02/2013	8	524.46	211.23	2.82	313.23	3.44	10.82	11.44	0.75	-10.00	0.00	0.75	7.25	0.75	0.75	10.07	10.69

06/02/2013	0.3	349.64	140.82	1.88	208.82	2.29	2.18	2.59	0.72	-9.05	0.95	0.72	0.00	0.72	0.72	1.46	1.87
07/02/2013	6.4	524.46	211.23	2.82	313.23	3.44	9.22	9.84	0.64	-10.00	0.00	0.64	5.76	0.64	0.64	8.58	9.20
08/02/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.72	-8.86	1.14	0.72	0.00	0.72	0.72	1.63	2.15
09/02/2013	8	437.05	176.03	2.35	261.03	2.87	10.35	10.87	0.60	-10.00	0.00	0.60	7.40	0.60	0.60	9.74	10.26
10/02/2013	17.2	524.46	211.23	2.82	313.23	3.44	20.02	20.64	0.47	-10.00	0.00	0.47	16.73	0.47	0.47	19.55	20.17
11/02/2013	0.6	437.05	176.03	2.35	261.03	2.87	2.95	3.47	0.59	-9.63	0.37	0.59	0.00	0.59	0.59	2.36	2.88
12/02/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.61	-8.54	1.46	0.61	0.00	0.61	0.61	1.27	1.68
13/02/2013	12.2	437.05	176.03	2.35	261.03	2.87	14.55	15.07	0.67	-10.00	0.00	0.67	11.53	0.67	0.67	13.87	14.39
14/02/2013	0.5	349.64	140.82	1.88	208.82	2.29	2.38	2.79	0.94	-9.33	0.67	0.94	0.00	0.94	0.94	1.43	1.85
15/02/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.72	-7.88	2.12	0.72	0.00	0.72	0.72	2.10	2.72
16/02/2013	0.4	437.05	176.03	2.35	261.03	2.87	2.75	3.27	0.91	-7.07	2.93	0.91	0.00	0.91	0.91	1.25	2.29
17/02/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.15	-5.66	4.34	1.15	0.00	1.15	1.15	0.00	0.00
18/02/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.08	-4.01	5.99	1.08	0.00	1.08	1.08	0.00	0.00
19/02/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.79	-2.42	7.58	0.79	0.00	0.79	0.79	0.00	0.00
20/02/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.97	-1.13	8.87	0.97	0.00	0.97	0.97	0.00	0.00
21/02/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.10	0.34	10.34	1.10	0.00	1.10	1.10	0.00	0.00
22/02/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.99	1.94	11.94	0.99	0.00	0.99	0.99	0.00	0.00
23/02/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.73	3.43	13.43	0.73	0.00	0.73	0.73	0.00	0.00
24/02/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.72	4.66	14.66	0.72	0.00	0.72	0.72	0.00	0.00
25/02/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.98	5.88	15.88	0.98	0.00	0.98	0.98	0.00	0.00
26/02/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.89	7.36	17.36	0.89	0.00	0.89	0.89	0.00	0.00
27/02/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.58	8.75	18.75	0.58	0.00	0.58	0.58	0.00	0.00
28/02/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	2.095	9.82	19.82	2.10	0.00	2.10	2.10	0.00	0.00
01/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.049	12.42	22.42	1.02	0.00	1.05	1.05	0.00	0.00
02/03/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	0.850	13.94	23.94	0.82	0.00	0.84	0.85	0.00	0.00
03/03/2013	0.1	349.64	140.82	1.88	208.82	2.29	1.98	2.39	0.441	15.16	25.16	0.42	0.00	0.43	0.43	0.00	0.00
04/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.510	16.08	26.08	0.48	0.00	0.49	0.49	0.00	0.00
05/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.645	17.06	27.06	1.53	0.00	1.57	1.58	0.00	0.00
06/03/2013	6.2	349.64	140.82	1.88	208.82	2.29	8.08	8.49	0.715	12.89	22.89	0.69	0.00	0.71	0.71	0.00	0.00
07/03/2013	3.8	349.64	140.82	1.88	208.82	2.29	5.68	6.09	0.360	10.28	20.28	0.36	0.00	0.36	0.36	0.00	0.00
08/03/2013	6.1	437.05	176.03	2.35	261.03	2.87	8.45	8.97	0.489	5.04	15.04	0.49	0.00	0.49	0.49	0.00	0.00
09/03/2013	0.4	349.64	140.82	1.88	208.82	2.29	2.28	2.69	0.275	5.63	15.63	0.28	0.00	0.28	0.28	0.00	0.00
10/03/2013	0.2	437.05	176.03	2.35	261.03	2.87	2.55	3.07	0.910	6.20	16.20	0.91	0.00	0.91	0.91	0.00	0.00
11/03/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.600	7.61	17.61	1.60	0.00	1.60	1.60	0.00	0.00
12/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.062	9.71	19.71	1.06	0.00	1.06	1.06	0.00	0.00
13/03/2013	0.5	524.46	211.23	2.82	313.23	3.44	3.32	3.94	1.934	10.77	20.77	1.92	0.00	1.93	1.93	0.00	0.00
14/03/2013	2.2	437.05	176.03	2.35	261.03	2.87	4.55	5.07	1.298	10.99	20.99	1.29	0.00	1.30	1.30	0.00	0.00
15/03/2013	2.1	524.46	211.23	2.82	313.23	3.44	4.92	5.54	1.612	10.68	20.68	1.60	0.00	1.61	1.61	0.00	0.00
16/03/2013	2	437.05	176.03	2.35	261.03	2.87	4.35	4.87	1.320	10.78	20.78	1.31	0.00	1.32	1.32	0.00	0.00
17/03/2013	2.3	437.05	176.03	2.35	261.03	2.87	4.65	5.17	1.046	10.29	20.29	1.04	0.00	1.05	1.05	0.00	0.00
18/03/2013	1.3	349.64	140.82	1.88	208.82	2.29	3.18	3.59	1.172	10.53	20.53	1.17	0.00	1.17	1.17	0.00	0.00
19/03/2013	0.1	437.05	176.03	2.35	261.03	2.87	2.45	2.97	0.829	12.10	22.10	0.81	0.00	0.83	0.83	0.00	0.00
20/03/2013	0.5	524.46	211.23	2.82	313.23	3.44	3.32	3.94	0.517	12.91	22.91	0.50	0.00	0.52	0.52	0.00	0.00
21/03/2013	3	437.05	176.03	2.35	261.03	2.87	5.35	5.87	1.090	10.91	20.91	1.08	0.00	1.09	1.09	0.00	0.00
22/03/2013	14.9	437.05	176.03	2.35	261.03	2.87	17.25	17.77	0.267	-2.41	7.59	0.27	7.04	0.27	0.27	11.73	12.77
23/03/2013	0.2	349.64	140.82	1.88	208.82	2.29	2.08	2.49	0.264	-1.84	8.16	0.26	0.00	0.26	0.26	0.00	0.00
24/03/2013	0.2	349.64	140.82	1.88	208.82	2.29	2.08	2.49	0.512	-1.28	8.72	0.51	0.00	0.51	0.51	0.00	0.00
25/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.086	-0.26	9.74	1.09	0.00	1.09	1.09	0.00	0.00
26/03/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.294	1.32	11.32	1.29	0.00	1.29	1.29	0.00	0.00

27/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.776	3.12	13.12	1.78	0.00	1.78	1.78	0.00	0.00
28/03/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.372	5.39	15.39	1.37	0.00	1.37	1.37	0.00	0.00
29/03/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.534	7.26	17.26	1.53	0.00	1.53	1.53	0.00	0.00
30/03/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.131	9.30	19.30	1.13	0.00	1.13	1.13	0.00	0.00
31/03/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.024	10.93	20.93	1.01	0.00	1.02	1.02	0.00	0.00
01/04/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.758	12.44	22.44	0.74	0.00	0.76	0.76	0.00	0.00
02/04/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	2.446	13.68	23.68	2.36	0.00	2.42	2.44	0.00	0.00
03/04/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	3.506	16.54	26.54	3.28	0.00	3.36	3.38	0.00	0.00
04/04/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.535	20.32	30.32	2.27	0.00	2.33	2.35	0.00	0.00
05/04/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	2.732	23.09	33.09	2.37	0.00	2.45	2.47	0.00	0.00
06/04/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.302	25.96	35.96	2.78	0.00	2.84	2.85	0.00	0.00
07/04/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.645	29.24	39.24	1.33	0.00	1.37	1.38	0.00	0.00
08/04/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.402	31.07	41.07	1.90	0.00	1.94	1.95	0.00	0.00
09/04/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.918	33.46	43.46	1.47	0.00	1.51	1.52	0.00	0.00
10/04/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.018	35.43	45.43	0.76	0.00	0.79	0.79	0.00	0.00
11/04/2013	5.6	349.64	140.82	1.88	208.82	2.29	7.48	7.89	0.724	31.09	41.09	0.57	0.00	0.58	0.59	0.00	0.00
12/04/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.394	32.16	42.16	1.09	0.00	1.12	1.13	0.00	0.00
13/04/2013	6	437.05	176.03	2.35	261.03	2.87	8.35	8.87	1.569	27.75	37.75	1.29	0.00	1.33	1.34	0.00	0.00
14/04/2013	6.7	437.05	176.03	2.35	261.03	2.87	9.05	9.57	3.168	22.84	32.84	2.76	0.00	2.84	2.85	0.00	0.00
15/04/2013	6.1	437.05	176.03	2.35	261.03	2.87	8.45	8.97	2.832	20.00	30.00	2.55	0.00	2.62	2.63	0.00	0.00
16/04/2013	1.3	349.64	140.82	1.88	208.82	2.29	3.18	3.59	4.168	21.75	31.75	3.68	0.00	3.76	3.77	0.00	0.00
17/04/2013	18.8	349.64	140.82	1.88	208.82	2.29	20.68	21.09	1.938	7.13	17.13	1.94	0.00	1.94	1.94	3.49	4.32
18/04/2013	8.6	437.05	176.03	2.35	261.03	2.87	10.95	11.47	2.936	0.96	10.96	2.94	0.00	2.94	2.94	0.00	0.43
19/04/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.527	4.40	14.40	3.53	0.00	3.53	3.53	0.00	0.00
20/04/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.902	8.43	18.43	2.90	0.00	2.90	2.90	0.00	0.00
21/04/2013	4.3	437.05	176.03	2.35	261.03	2.87	6.65	7.17	3.370	7.53	17.53	3.37	0.00	3.37	3.37	0.00	0.00
22/04/2013	0.8	349.64	140.82	1.88	208.82	2.29	2.68	3.09	2.883	10.60	20.60	2.87	0.00	2.88	2.88	0.00	0.00
23/04/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.012	13.96	23.96	1.93	0.00	1.97	1.98	0.00	0.00
24/04/2013	4.6	437.05	176.03	2.35	261.03	2.87	6.95	7.47	1.924	11.80	21.80	1.89	0.00	1.92	1.92	0.00	0.00
25/04/2013	5.5	437.05	176.03	2.35	261.03	2.87	7.85	8.37	3.779	8.69	18.69	3.78	0.00	3.78	3.78	0.00	0.00
26/04/2013	3.2	437.05	176.03	2.35	261.03	2.87	5.55	6.07	2.864	9.77	19.77	2.86	0.00	2.86	2.86	0.00	0.00
27/04/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.801	13.13	23.13	3.68	0.00	3.75	3.77	0.00	0.00
28/04/2013	2.6	349.64	140.82	1.88	208.82	2.29	4.48	4.89	2.500	14.71	24.71	2.38	0.00	2.43	2.44	0.00	0.00
29/04/2013	1.7	437.05	176.03	2.35	261.03	2.87	4.05	4.57	3.537	15.89	25.89	3.33	0.00	3.41	3.43	0.00	0.00
30/04/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.166	19.72	29.72	2.86	0.00	2.92	2.93	0.00	0.00
01/05/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	4.139	23.08	33.08	3.60	0.00	3.69	3.72	0.00	0.00
02/05/2013	0.1	349.64	140.82	1.88	208.82	2.29	1.98	2.39	2.528	27.08	37.08	2.10	0.00	2.14	2.15	0.00	0.00
03/05/2013	6.4	524.46	211.23	2.82	313.23	3.44	9.22	9.84	1.426	23.27	33.27	1.24	0.00	1.28	1.29	0.00	0.00
04/05/2013	0.5	349.64	140.82	1.88	208.82	2.29	2.38	2.79	2.587	24.51	34.51	2.21	0.00	2.26	2.27	0.00	0.00
05/05/2013	0.7	437.05	176.03	2.35	261.03	2.87	3.05	3.57	2.069	26.52	36.52	1.73	0.00	1.78	1.79	0.00	0.00
06/05/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.062	28.75	38.75	1.67	0.00	1.71	1.72	0.00	0.00
07/05/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	5.033	30.93	40.93	3.98	0.00	4.10	4.12	0.00	0.00
08/05/2013	3.1	524.46	211.23	2.82	313.23	3.44	5.92	6.54	2.275	32.31	42.31	1.77	0.00	1.83	1.85	0.00	0.00
09/05/2013	11.9	349.64	140.82	1.88	208.82	2.29	13.78	14.19	2.204	22.67	32.67	1.92	0.00	1.97	1.98	0.00	0.00
10/05/2013	8.1	349.64	140.82	1.88	208.82	2.29	9.98	10.39	3.203	17.00	27.00	2.98	0.00	3.04	3.05	0.00	0.00
11/05/2013	5.1	437.05	176.03	2.35	261.03	2.87	7.45	7.97	4.197	15.38	25.38	3.97	0.00	4.07	4.09	0.00	0.00
12/05/2013	3.5	524.46	211.23	2.82	313.23	3.44	6.32	6.94	1.530	16.35	26.35	1.43	0.00	1.48	1.49	0.00	0.00
13/05/2013	6.2	524.46	211.23	2.82	313.23	3.44	9.02	9.64	4.387	12.08	22.08	4.30	0.00	4.39	4.39	0.00	0.00
14/05/2013	3	349.64	140.82	1.88	208.82	2.29	4.88	5.29	3.965	13.88	23.88	3.81	0.00	3.89	3.90	0.00	0.00

15/05/2013	1	524.46	211.23	2.82	313.23	3.44	3.82	4.44	3.839	17.19	27.19	3.56	0.00	3.67	3.70	0.00	0.00
16/05/2013	5.4	437.05	176.03	2.35	261.03	2.87	7.75	8.27	2.421	15.85	25.85	2.28	0.00	2.34	2.35	0.00	0.00
17/05/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	5.218	18.63	28.63	4.77	0.00	4.87	4.89	0.00	0.00
18/05/2013	6.3	437.05	176.03	2.35	261.03	2.87	8.65	9.17	0.763	17.60	27.60	0.71	0.00	0.72	0.73	0.00	0.00
19/05/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.530	18.80	28.80	1.40	0.00	1.44	1.45	0.00	0.00
20/05/2013	0.1	524.46	211.23	2.82	313.23	3.44	2.92	3.54	1.645	20.60	30.60	1.47	0.00	1.52	1.53	0.00	0.00
21/05/2013	0.7	349.64	140.82	1.88	208.82	2.29	2.58	2.99	4.136	21.87	31.87	3.64	0.00	3.72	3.74	0.00	0.00
22/05/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	3.156	26.02	36.02	2.65	0.00	2.72	2.74	0.00	0.00
23/05/2013	0.5	349.64	140.82	1.88	208.82	2.29	2.38	2.79	4.150	28.67	38.67	3.37	0.00	3.45	3.47	0.00	0.00
24/05/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	4.516	32.54	42.54	3.50	0.00	3.60	3.63	0.00	0.00
25/05/2013	0.7	524.46	211.23	2.82	313.23	3.44	3.52	4.14	4.868	35.84	45.84	3.61	0.00	3.75	3.78	0.00	0.00
26/05/2013	2.1	349.64	140.82	1.88	208.82	2.29	3.98	4.39	3.496	37.85	47.85	2.52	0.00	2.59	2.60	0.00	0.00
27/05/2013	14	524.46	211.23	2.82	313.23	3.44	16.82	17.44	4.585	26.87	36.87	3.81	0.00	3.94	3.97	0.00	0.00
28/05/2013	1.2	437.05	176.03	2.35	261.03	2.87	3.55	4.07	4.006	29.98	39.98	3.21	0.00	3.30	3.32	0.00	0.00
29/05/2013	2.6	524.46	211.23	2.82	313.23	3.44	5.42	6.04	7.352	31.09	41.09	5.80	0.00	6.01	6.05	0.00	0.00
30/05/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	6.860	37.39	47.39	4.98	0.00	5.17	5.22	0.00	0.00
31/05/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.753	42.87	52.87	1.85	0.00	1.90	1.91	0.00	0.00
01/06/2013	0.9	524.46	211.23	2.82	313.23	3.44	3.72	4.34	3.663	44.32	54.32	2.41	0.00	2.51	2.53	0.00	0.00
02/06/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	3.247	47.22	57.22	2.04	0.00	2.11	2.13	0.00	0.00
03/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.355	49.76	59.76	2.02	0.00	2.08	2.10	0.00	0.00
04/06/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	6.833	52.28	62.28	3.94	0.00	4.10	4.14	0.00	0.00
05/06/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	6.013	56.73	66.73	3.20	0.00	3.34	3.38	0.00	0.00
06/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	5.298	60.43	70.43	2.63	0.00	2.73	2.75	0.00	0.00
07/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	7.627	63.56	73.56	3.54	0.00	3.69	3.72	0.00	0.00
08/06/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	7.349	67.60	77.60	3.12	0.00	3.29	3.33	0.00	0.00
09/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	7.211	71.22	81.22	2.80	0.00	2.93	2.96	0.00	0.00
10/06/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	5.435	74.51	84.51	1.93	0.00	2.06	2.08	0.00	0.00
11/06/2013	9.4	524.46	211.23	2.82	313.23	3.44	12.22	12.84	1.736	67.54	77.54	0.74	0.00	0.79	0.80	0.00	0.00
12/06/2013	4.7	349.64	140.82	1.88	208.82	2.29	6.58	6.99	2.898	64.08	74.08	1.33	0.00	1.39	1.40	0.00	0.00
13/06/2013	5.8	524.46	211.23	2.82	313.23	3.44	8.62	9.24	4.328	60.11	70.11	2.16	0.00	2.28	2.31	0.00	0.00
14/06/2013	7.5	437.05	176.03	2.35	261.03	2.87	9.85	10.37	3.151	55.27	65.27	1.72	0.00	1.80	1.82	0.00	0.00
15/06/2013	1.7	437.05	176.03	2.35	261.03	2.87	4.05	4.57	4.702	55.79	65.79	2.55	0.00	2.66	2.68	0.00	0.00
16/06/2013	0.2	524.46	211.23	2.82	313.23	3.44	3.02	3.64	3.357	58.64	68.64	1.72	0.00	1.82	1.84	0.00	0.00
17/06/2013	1.7	437.05	176.03	2.35	261.03	2.87	4.05	4.57	2.568	59.17	69.17	1.31	0.00	1.37	1.38	0.00	0.00
18/06/2013	0	437.05	176.03	2.35	261.03	2.87	2.35	2.87	6.023	60.97	70.97	2.95	0.00	3.09	3.13	0.00	0.00
19/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	5.259	64.42	74.42	2.40	0.00	2.50	2.52	0.00	0.00
20/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.513	67.32	77.32	1.50	0.00	1.57	1.58	0.00	0.00
21/06/2013	1.8	437.05	176.03	2.35	261.03	2.87	4.15	4.67	4.498	67.52	77.52	1.91	0.00	2.02	2.04	0.00	0.00
22/06/2013	8.1	349.64	140.82	1.88	208.82	2.29	9.98	10.39	4.101	61.83	71.83	1.98	0.00	2.05	2.07	0.00	0.00
23/06/2013	1.9	437.05	176.03	2.35	261.03	2.87	4.25	4.77	2.322	62.41	72.41	1.11	0.00	1.16	1.17	0.00	0.00
24/06/2013	0.9	524.46	211.23	2.82	313.23	3.44	3.72	4.34	3.478	63.11	73.11	1.63	0.00	1.73	1.75	0.00	0.00
25/06/2013	0	349.64	140.82	1.88	208.82	2.29	1.88	2.29	4.032	65.24	75.24	1.80	0.00	1.88	1.90	0.00	0.00
26/06/2013	0	524.46	211.23	2.82	313.23	3.44	2.82	3.44	5.509	67.55	77.55	2.34	0.00	2.49	2.53	0.00	0.00
27/06/2013	5.2	349.64	140.82	1.88	208.82	2.29	7.08	7.49	1.517	65.19	75.19	0.68	0.00	0.71	0.71	0.00	0.00
28/06/2013	0.6	437.05	176.03	2.35	261.03	2.87	2.95	3.47	2.179	65.77	75.77	0.96	0.00	1.01	1.03	0.00	0.00
29/06/2013	0.5	437.05	176.03	2.35	261.03	2.87	2.85	3.37	3.477	66.73	76.73	1.50	0.00	1.59	1.60	0.00	0.00
30/06/2013	1.8	524.46	211.23	2.82	313.23	3.44	4.62	5.24	2.384	66.93	76.93	1.03	0.00	1.09	1.11	0.00	0.00
01/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	4.102	68.46	78.46	1.70	0.00	1.78	1.80	0.00	0.00
02/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.020	70.67	80.67	0.40	0.00	0.43	0.43	0.00	0.00

03/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.284	71.57	81.57	1.26	0.00	1.32	1.34	0.00	0.00
04/07/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	4.468	73.33	83.33	1.64	0.00	1.76	1.79	0.00	0.00
05/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	4.547	75.47	85.47	1.57	0.00	1.68	1.70	0.00	0.00
06/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	4.704	77.54	87.54	1.53	0.00	1.64	1.66	0.00	0.00
07/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	6.092	79.56	89.56	1.85	0.00	1.97	1.99	0.00	0.00
08/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	7.573	81.92	91.92	2.13	0.00	2.27	2.30	0.00	0.00
09/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	6.886	84.55	94.55	1.75	0.00	1.91	1.95	0.00	0.00
10/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	7.614	86.80	96.80	1.77	0.00	1.91	1.94	0.00	0.00
11/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	6.903	89.06	99.06	1.45	0.00	1.61	1.64	0.00	0.00
12/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	7.302	91.01	101.01	1.39	0.00	1.56	1.60	0.00	0.00
13/07/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	4.696	92.90	102.90	0.80	0.00	0.94	0.96	0.00	0.00
14/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	6.870	94.20	104.20	1.09	0.00	1.21	1.24	0.00	0.00
15/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	3.438	95.79	105.79	0.49	0.00	0.57	0.59	0.00	0.00
16/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.738	96.77	106.77	0.49	0.00	0.56	0.58	0.00	0.00
17/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	6.921	97.77	107.77	0.85	0.00	1.01	1.04	0.00	0.00
18/07/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	7.072	99.11	109.11	0.77	0.00	0.97	1.01	0.00	0.00
19/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	7.377	100.38	110.38	0.71	0.00	0.85	0.88	0.00	0.00
20/07/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	7.175	101.59	111.59	0.60	0.00	0.74	0.77	0.00	0.00
21/07/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.805	102.70	112.70	0.20	0.00	0.27	0.29	0.00	0.00
22/07/2013	0.20	524.46	211.23	2.82	313.23	3.44	3.02	3.64	4.446	103.20	113.20	0.30	0.00	0.43	0.46	0.00	0.00
23/07/2013	0.80	524.46	211.23	2.82	313.23	3.44	3.62	4.24	4.334	103.20	113.20	0.29	0.00	0.42	0.44	0.00	0.00
24/07/2013	0.40	349.64	140.82	1.88	208.82	2.29	2.28	2.69	3.647	103.59	113.59	0.23	0.00	0.30	0.32	0.00	0.00
25/07/2013	12.06	349.64	140.82	1.88	208.82	2.29	13.94	14.35	3.181	92.27	102.27	0.56	0.00	0.62	0.64	0.00	0.00
26/07/2013	0.60	437.05	176.03	2.35	261.03	2.87	2.95	3.47	4.645	92.73	102.73	0.80	0.00	0.91	0.94	0.00	0.00
27/07/2013	1.21	349.64	140.82	1.88	208.82	2.29	3.08	3.50	6.358	92.82	102.82	1.09	0.00	1.21	1.24	0.00	0.00
28/07/2013	3.02	437.05	176.03	2.35	261.03	2.87	5.36	5.88	4.643	91.40	101.40	0.86	0.00	0.97	1.00	0.00	0.00
29/07/2013	13.47	437.05	176.03	2.35	261.03	2.87	15.81	16.33	3.778	79.30	89.30	1.16	0.00	1.25	1.27	0.00	0.00
30/07/2013	3.42	349.64	140.82	1.88	208.82	2.29	5.29	5.71	4.042	77.54	87.54	1.31	0.00	1.39	1.40	0.00	0.00
31/07/2013	33.57	349.64	140.82	1.88	208.82	2.29	35.44	35.86	1.902	45.78	55.78	1.22	0.00	1.26	1.27	0.00	0.00
01/08/2013	7.24	437.05	176.03	2.35	261.03	2.87	9.58	10.10	2.294	40.27	50.27	1.60	0.00	1.65	1.67	0.00	0.00
02/08/2013	1.81	349.64	140.82	1.88	208.82	2.29	3.69	4.10	4.810	40.56	50.56	3.34	0.00	3.43	3.45	0.00	0.00
03/08/2013	1.81	437.05	176.03	2.35	261.03	2.87	4.16	4.67	4.368	42.59	52.59	2.94	0.00	3.05	3.07	0.00	0.00
04/08/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	5.648	46.04	56.04	3.61	0.00	3.77	3.81	0.00	0.00
05/08/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	4.929	50.15	60.15	2.95	0.00	3.09	3.12	0.00	0.00
06/08/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.321	53.60	63.60	1.87	0.00	1.94	1.95	0.00	0.00
07/08/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.623	55.97	65.97	1.42	0.00	1.48	1.49	0.00	0.00
08/08/2013	2.01	437.05	176.03	2.35	261.03	2.87	4.36	4.88	3.775	55.88	65.88	2.04	0.00	2.13	2.15	0.00	0.00
09/08/2013	1.01	437.05	176.03	2.35	261.03	2.87	3.35	3.87	3.405	57.42	67.42	1.79	0.00	1.87	1.89	0.00	0.00
10/08/2013	0.20	349.64	140.82	1.88	208.82	2.29	2.08	2.49	3.277	59.51	69.51	1.65	0.00	1.72	1.73	0.00	0.00
11/08/2013	2.01	349.64	140.82	1.88	208.82	2.29	3.89	4.30	3.856	59.65	69.65	1.94	0.00	2.01	2.03	0.00	0.00
12/08/2013	1.61	437.05	176.03	2.35	261.03	2.87	3.95	4.47	3.778	60.49	70.49	1.87	0.00	1.96	1.98	0.00	0.00
13/08/2013	0.40	349.64	140.82	1.88	208.82	2.29	2.28	2.69	2.816	62.45	72.45	1.34	0.00	1.39	1.40	0.00	0.00
14/08/2013	1.41	437.05	176.03	2.35	261.03	2.87	3.75	4.27	1.792	62.89	72.89	0.84	0.00	0.89	0.90	0.00	0.00
15/08/2013	11.86	437.05	176.03	2.35	261.03	2.87	14.21	14.72	1.497	52.37	62.37	0.86	0.00	0.90	0.91	0.00	0.00
16/08/2013	0.20	349.64	140.82	1.88	208.82	2.29	2.08	2.49	3.851	53.53	63.53	2.17	0.00	2.25	2.26	0.00	0.00
17/08/2013	1.61	349.64	140.82	1.88	208.82	2.29	3.49	3.90	3.799	54.60	64.60	2.10	0.00	2.18	2.19	0.00	0.00
18/08/2013	1.61	437.05	176.03	2.35	261.03	2.87	3.95	4.47	3.599	55.60	65.60	1.96	0.00	2.04	2.06	0.00	0.00
19/08/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	4.070	58.05	68.05	2.11	0.00	2.19	2.21	0.00	0.00
20/08/2013	2.41	437.05	176.03	2.35	261.03	2.87	4.76	5.28	2.547	58.26	68.26	1.32	0.00	1.38	1.39	0.00	0.00

21/08/2013	0.80	524.46	211.23	2.82	313.23	3.44	3.62	4.24	2.731	59.27	69.27	1.39	0.00	1.46	1.48	0.00	0.00
22/08/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.361	61.16	71.16	1.15	0.00	1.20	1.21	0.00	0.00
23/08/2013	6.23	349.64	140.82	1.88	208.82	2.29	8.11	8.52	1.565	56.58	66.58	0.84	0.00	0.87	0.87	0.00	0.00
24/08/2013	0.20	437.05	176.03	2.35	261.03	2.87	2.55	3.07	2.535	57.71	67.71	1.33	0.00	1.38	1.40	0.00	0.00
25/08/2013	0.20	524.46	211.23	2.82	313.23	3.44	3.02	3.64	2.736	59.34	69.34	1.39	0.00	1.46	1.48	0.00	0.00
26/08/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.790	61.22	71.22	0.87	0.00	0.91	0.91	0.00	0.00
27/08/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	3.543	62.60	72.60	1.68	0.00	1.76	1.78	0.00	0.00
28/08/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.566	64.78	74.78	1.16	0.00	1.22	1.23	0.00	0.00
29/08/2013	0.20	349.64	140.82	1.88	208.82	2.29	2.08	2.49	2.469	66.24	76.24	1.08	0.00	1.13	1.14	0.00	0.00
30/08/2013	0.60	349.64	140.82	1.88	208.82	2.29	2.48	2.90	1.996	67.21	77.21	0.85	0.00	0.89	0.90	0.00	0.00
31/08/2013	0.60	437.05	176.03	2.35	261.03	2.87	2.95	3.47	3.727	67.96	77.96	1.57	0.00	1.65	1.67	0.00	0.00
01/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.404	70.03	80.03	0.96	0.00	1.01	1.02	0.00	0.00
02/09/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.782	71.49	81.49	1.07	0.00	1.14	1.15	0.00	0.00
03/09/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	3.906	73.06	83.06	1.44	0.00	1.55	1.58	0.00	0.00
04/09/2013	0.20	349.64	140.82	1.88	208.82	2.29	2.08	2.49	3.764	74.80	84.80	1.32	0.00	1.40	1.41	0.00	0.00
05/09/2013	1.41	349.64	140.82	1.88	208.82	2.29	3.28	3.70	3.333	75.22	85.22	1.16	0.00	1.22	1.24	0.00	0.00
06/09/2013	1.81	437.05	176.03	2.35	261.03	2.87	4.16	4.67	2.888	75.07	85.07	1.01	0.00	1.08	1.09	0.00	0.00
07/09/2013	10.65	437.05	176.03	2.35	261.03	2.87	13.00	13.52	1.019	65.93	75.93	0.45	0.00	0.47	0.48	0.00	0.00
08/09/2013	3.02	437.05	176.03	2.35	261.03	2.87	5.36	5.88	2.008	63.86	73.86	0.93	0.00	0.97	0.98	0.00	0.00
09/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.211	65.29	75.29	0.99	0.00	1.03	1.04	0.00	0.00
10/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.533	66.78	76.78	1.10	0.00	1.14	1.15	0.00	0.00
11/09/2013	0.60	437.05	176.03	2.35	261.03	2.87	2.95	3.47	1.137	67.77	77.77	0.48	0.00	0.51	0.51	0.00	0.00
12/09/2013	5.03	349.64	140.82	1.88	208.82	2.29	6.90	7.32	1.192	63.72	73.72	0.55	0.00	0.57	0.58	0.00	0.00
13/09/2013	0.40	437.05	176.03	2.35	261.03	2.87	2.75	3.27	1.690	64.37	74.37	0.77	0.00	0.81	0.82	0.00	0.00
14/09/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.984	65.65	75.65	1.32	0.00	1.39	1.41	0.00	0.00
15/09/2013	13.07	437.05	176.03	2.35	261.03	2.87	15.41	15.93	1.852	54.40	64.40	1.03	0.00	1.07	1.08	0.00	0.00
16/09/2013	9.65	349.64	140.82	1.88	208.82	2.29	11.53	11.94	2.068	46.29	56.29	1.32	0.00	1.36	1.36	0.00	0.00
17/09/2013	4.42	349.64	140.82	1.88	208.82	2.29	6.30	6.71	1.214	43.68	53.68	0.81	0.00	0.83	0.83	0.00	0.00
18/09/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.252	44.99	54.99	1.46	0.00	1.52	1.53	0.00	0.00
19/09/2013	8.24	349.64	140.82	1.88	208.82	2.29	10.12	10.53	2.055	38.71	48.71	1.47	0.00	1.50	1.51	0.00	0.00
20/09/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.621	40.67	50.67	1.82	0.00	1.88	1.89	0.00	0.00
21/09/2013	0.20	437.05	176.03	2.35	261.03	2.87	2.55	3.07	1.364	42.79	52.79	0.92	0.00	0.95	0.96	0.00	0.00
22/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.643	44.21	54.21	1.08	0.00	1.11	1.12	0.00	0.00
23/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	3.225	45.79	55.79	2.07	0.00	2.13	2.14	0.00	0.00
24/09/2013	0.20	437.05	176.03	2.35	261.03	2.87	2.55	3.07	1.022	48.16	58.16	0.63	0.00	0.66	0.66	0.00	0.00
25/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.675	49.29	59.29	0.41	0.00	0.42	0.43	0.00	0.00
26/09/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.415	50.20	60.20	0.25	0.00	0.26	0.26	0.00	0.00
27/09/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.704	50.95	60.95	1.01	0.00	1.05	1.07	0.00	0.00
28/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.204	52.46	62.46	1.27	0.00	1.31	1.32	0.00	0.00
29/09/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.046	54.22	64.22	1.14	0.00	1.18	1.19	0.00	0.00
30/09/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.528	55.86	65.86	0.29	0.00	0.30	0.30	0.00	0.00
01/10/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	0.833	56.65	66.65	0.44	0.00	0.46	0.47	0.00	0.00
02/10/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.846	57.59	67.59	0.97	0.00	1.01	1.02	0.00	0.00
03/10/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.575	59.06	69.06	0.29	0.00	0.30	0.31	0.00	0.00
04/10/2013	1.21	349.64	140.82	1.88	208.82	2.29	3.08	3.50	1.645	58.65	68.65	0.84	0.00	0.88	0.88	0.00	0.00
05/10/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.932	59.99	69.99	0.97	0.00	1.01	1.02	0.00	0.00
06/10/2013	1.61	349.64	140.82	1.88	208.82	2.29	3.49	3.90	1.482	59.85	69.85	0.74	0.00	0.77	0.78	0.00	0.00
07/10/2013	3.62	437.05	176.03	2.35	261.03	2.87	5.96	6.48	1.184	57.48	67.48	0.62	0.00	0.65	0.66	0.00	0.00
08/10/2013	0.20	437.05	176.03	2.35	261.03	2.87	2.55	3.07	1.443	58.40	68.40	0.74	0.00	0.78	0.79	0.00	0.00

09/10/2013	0.20	349.64	140.82	1.88	208.82	2.29	2.08	2.49	1.465	59.44	69.44	0.74	0.00	0.77	0.77	0.00	0.00
10/10/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	2.034	60.68	70.68	1.00	0.00	1.04	1.05	0.00	0.00
11/10/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	2.054	62.19	72.19	0.98	0.00	1.03	1.04	0.00	0.00
12/10/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.103	63.67	73.67	0.51	0.00	0.53	0.54	0.00	0.00
13/10/2013	0.00	437.05	176.03	2.35	261.03	2.87	2.35	2.87	1.016	64.68	74.68	0.46	0.00	0.48	0.49	0.00	0.00
14/10/2013	0.00	524.46	211.23	2.82	313.23	3.44	2.82	3.44	1.891	65.64	75.64	0.84	0.00	0.89	0.90	0.00	0.00
15/10/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.613	66.98	76.98	0.69	0.00	0.72	0.73	0.00	0.00
16/10/2013	26.33	349.64	140.82	1.88	208.82	2.29	28.21	28.62	0.307	41.84	51.84	0.21	0.00	0.21	0.22	0.00	0.00
17/10/2013	0.20	437.05	176.03	2.35	261.03	2.87	2.55	3.07	1.221	42.35	52.35	0.83	0.00	0.85	0.86	0.00	0.00
18/10/2013	12.86	437.05	176.03	2.35	261.03	2.87	15.21	15.73	0.295	30.81	40.81	0.23	0.00	0.24	0.24	0.00	0.00
19/10/2013	1.81	524.46	211.23	2.82	313.23	3.44	4.62	5.25	1.243	29.74	39.74	1.00	0.00	1.03	1.04	0.00	0.00
20/10/2013	3.22	349.64	140.82	1.88	208.82	2.29	5.09	5.51	0.790	28.02	38.02	0.65	0.00	0.66	0.67	0.00	0.00
21/10/2013	13.07	349.64	140.82	1.88	208.82	2.29	14.94	15.36	0.426	16.10	26.10	0.40	0.00	0.41	0.41	0.00	0.00
22/10/2013	2.61	437.05	176.03	2.35	261.03	2.87	4.96	5.48	1.361	14.39	24.39	1.30	0.00	1.33	1.34	0.00	0.00
23/10/2013	2.61	349.64	140.82	1.88	208.82	2.29	4.49	4.91	1.383	13.58	23.58	1.33	0.00	1.36	1.37	0.00	0.00
24/10/2013	0.40	437.05	176.03	2.35	261.03	2.87	2.75	3.27	1.266	15.01	25.01	1.20	0.00	1.23	1.24	0.00	0.00
25/10/2013	11.06	437.05	176.03	2.35	261.03	2.87	13.40	13.92	1.646	5.65	15.65	1.65	0.00	1.65	1.65	0.00	0.00
26/10/2013	3.02	349.64	140.82	1.88	208.82	2.29	4.89	5.31	0.672	4.78	14.78	0.67	0.00	0.67	0.67	0.00	0.00
27/10/2013	4.42	349.64	140.82	1.88	208.82	2.29	6.30	6.71	1.058	1.53	11.53	1.06	0.00	1.06	1.06	0.00	0.00
28/10/2013	3.62	437.05	176.03	2.35	261.03	2.87	5.96	6.48	1.271	-0.53	9.47	1.27	0.00	1.27	1.27	0.00	0.00
29/10/2013	4.02	349.64	140.82	1.88	208.82	2.29	5.90	6.31	0.919	-2.77	7.23	0.92	0.00	0.92	0.92	0.00	0.46
30/10/2013	3.02	437.05	176.03	2.35	261.03	2.87	5.36	5.88	0.626	-4.37	5.63	0.63	0.00	0.63	0.63	1.45	2.49
31/10/2013	0.80	524.46	211.23	2.82	313.23	3.44	3.62	4.24	0.992	-4.05	5.95	0.99	0.00	0.99	0.99	0.00	0.74
01/11/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	1.204	-2.56	7.44	1.20	0.00	1.20	1.20	0.00	0.00
02/11/2013	6.03	349.64	140.82	1.88	208.82	2.29	7.91	8.32	0.590	-6.88	3.12	0.59	2.32	0.59	0.59	6.08	6.91
03/11/2013	2.81	437.05	176.03	2.35	261.03	2.87	5.16	5.68	1.198	-8.61	1.39	1.20	0.22	1.20	1.20	3.96	4.48
04/11/2013	0.20	437.05	176.03	2.35	261.03	2.87	2.55	3.07	1.092	-7.11	2.89	1.09	0.00	1.09	1.09	0.91	1.95
05/11/2013	5.03	349.64	140.82	1.88	208.82	2.29	6.90	7.32	0.493	-10.00	0.00	0.49	4.53	0.49	0.49	6.41	6.82
06/11/2013	0.60	524.46	211.23	2.82	313.23	3.44	3.42	4.04	0.285	-9.61	0.39	0.29	0.00	0.29	0.29	3.13	3.76
07/11/2013	1.81	437.05	176.03	2.35	261.03	2.87	4.16	4.67	0.784	-10.00	0.00	0.78	1.02	0.78	0.78	3.37	3.89
08/11/2013	0.00	349.64	140.82	1.88	208.82	2.29	1.88	2.29	0.811	-8.72	1.28	0.81	0.00	0.81	0.81	1.07	1.48
09/11/2013	2.41	349.64	140.82	1.88	208.82	2.29	4.29	4.70	0.618	-9.82	0.18	0.62	1.61	0.62	0.62	3.67	4.09
10/11/2013	2.41	437.05	176.03	2.35	261.03	2.87	4.76	5.28	0.810	-10.00	0.00	0.81	1.60	0.81	0.81	3.95	4.47
11/11/2013	3.42	349.64	140.82	1.88	208.82	2.29	5.29	5.71	0.574	-10.00	0.00	0.57	2.84	0.57	0.57	4.72	5.14
12/11/2013	0.00	437.05			437.05	4.80	0.00	4.80	1.019	-8.93	1.07	1.02	0.00	1.02	1.02	0.00	3.78
13/11/2013	2.21	349.64			349.64	3.84	2.21	6.05	0.332	-9.62	0.38	0.33	1.50	0.33	0.33	1.50	5.72
14/11/2013	2.41	437.05			437.05	4.80	2.41	7.21	0.548	-10.00	0.00	0.55	1.86	0.55	0.55	1.86	6.66
15/11/2013	0.00	437.05			437.05	4.80	0.00	4.80	0.563	-8.95	1.05	0.56	0.00	0.56	0.56	0.00	4.24
16/11/2013	0.00	349.64			349.64	3.84	0.00	3.84	0.552	-7.89	2.11	0.55	0.00	0.55	0.55	0.00	3.29
17/11/2013	7.24	349.64			349.64	3.84	7.24	11.07	0.191	-10.00	0.00	0.19	7.05	0.19	0.19	7.05	10.88
18/11/2013	1.61	437.05			437.05	4.80	1.61	6.41	0.689	-10.00	0.00	0.69	0.92	0.69	0.69	0.92	5.72
19/11/2013	2.01	349.64			349.64	3.84	2.01	5.85	0.730	-10.00	0.00	0.73	1.28	0.73	0.73	1.28	5.12
20/11/2013	5.43	437.05			437.05	4.80	5.43	10.23	0.525	-10.00	0.00	0.52	4.90	0.52	0.52	4.90	9.70
21/11/2013	0.00	524.46			524.46	5.76	0.00	5.76	0.672	-8.98	1.02	0.67	0.00	0.67	0.67	0.00	5.09
22/11/2013	0.00	349.64			349.64	3.84	0.00	3.84	0.733	-7.80	2.20	0.73	0.00	0.73	0.73	0.00	3.11
23/11/2013	0.00	349.64			349.64	3.84	0.00	3.84	0.611	-6.57	3.43	0.61	0.00	0.61	0.61	0.00	3.23
24/11/2013	0.40	437.05			437.05	4.80	0.40	5.20	0.311	-5.86	4.14	0.31	0.00	0.31	0.31	0.00	4.89

25/11/2013	0.00	437.05			437.05	4.80	0.00	4.80	0.296	-5.05	4.95	0.30	0.00	0.30	0.30	0.00	4.35
26/11/2013	0.00	349.64			349.64	3.84	0.00	3.84	0.239	-4.25	5.75	0.24	0.00	0.24	0.24	0.00	1.69
27/11/2013	0.00	524.46			524.46	5.76	0.00	5.76	0.250	-3.51	6.49	0.25	0.00	0.25	0.25	0.00	4.78
28/11/2013	0.80	437.05			437.05	4.80	0.80	5.60	0.265	-3.57	6.43	0.27	0.00	0.27	0.27	0.00	3.70
29/11/2013	0.80	349.64			349.64	3.84	0.80	4.64	0.266	-3.61	6.39	0.27	0.00	0.27	0.27	0.00	1.82
30/11/2013	0.20	349.64			349.64	3.84	0.20	4.04	0.531	-3.04	6.96	0.53	0.00	0.53	0.53	0.00	0.39
01/12/2013	0.40	349.64			349.64	3.84	0.40	4.24	0.328	-2.41	7.59	0.33	0.00	0.33	0.33	0.00	0.16
02/12/2013	0.00	349.64			349.64	3.84	0.00	3.84	0.297	-1.59	8.41	0.30	0.00	0.30	0.30	0.00	0.00
03/12/2013	0.80	174.82			174.82	1.92	0.80	2.72	0.187	-1.59	8.41	0.19	0.00	0.19	0.19	0.00	0.00
04/12/2013	1.01	262.23			262.23	2.88	1.01	3.88	0.498	-1.91	8.09	0.50	0.00	0.50	0.50	0.00	0.00
05/12/2013	2.21	174.82			174.82	1.92	2.21	4.13	0.276	-3.12	6.88	0.28	0.00	0.28	0.28	0.00	0.00
06/12/2013	2.01	262.23			262.23	2.88	2.01	4.89	0.274	-4.36	5.64	0.27	0.00	0.27	0.27	0.00	1.85
07/12/2013	0.20	262.23			262.23	2.88	0.20	3.08	0.286	-3.78	6.22	0.29	0.00	0.29	0.29	0.00	0.00
08/12/2013	2.21	174.82			174.82	1.92	2.21	4.13	0.098	-5.21	4.79	0.10	0.00	0.10	0.10	0.00	1.16
09/12/2013	0.00	262.23			262.23	2.88	0.00	2.88	0.422	-4.61	5.39	0.42	0.00	0.42	0.42	0.00	0.00
10/12/2013	0.00	174.82			174.82	1.92	0.00	1.92	0.406	-3.69	6.31	0.41	0.00	0.41	0.41	0.00	0.00
11/12/2013	0.00	87.41			87.41	0.96	0.00	0.96	0.403	-2.78	7.22	0.40	0.00	0.40	0.40	0.00	0.00
12/12/2013	1.81	87.41			87.41	0.96	1.81	2.77	0.151	-3.69	6.31	0.15	0.00	0.15	0.15	0.00	0.00
13/12/2013	3.42	349.64	349.64	4.66			8.08		0.599	-6.45	3.55	0.60	0.00	0.60	0.60	7.48	0.00
14/12/2013	12.26	262.23	262.23	3.50			15.76		0.127	-10.00	0.00	0.13	12.13	0.13	0.13	15.63	0.00
15/12/2013	3.62	437.05	437.05	5.83			9.44		0.374	-10.00	0.00	0.37	3.24	0.37	0.37	9.07	0.00
16/12/2013	2.01	262.23	262.23	3.50			5.51		0.416	-10.00	0.00	0.42	1.59	0.42	0.42	5.09	0.00
17/12/2013	0.60	262.23	262.23	3.50			4.10		0.426	-9.69	0.31	0.43	0.00	0.43	0.43	3.67	0.00
18/12/2013	16.3	349.64	349.64	4.66			20.96		0.242	-10.00	0.00	0.24	16.06	0.24	0.24	20.72	0.00
19/12/2013	4.8	262.23	262.23	3.50			8.30		0.338	-10.00	0.00	0.34	4.46	0.34	0.34	7.96	0.00
20/12/2013	4.9	437.05	437.05	5.83			10.73		0.171	-10.00	0.00	0.17	4.73	0.17	0.17	10.56	0.00
21/12/2013	6.7	437.05	437.05	5.83			12.53		0.125	-10.00	0.00	0.12	6.58	0.12	0.12	12.40	0.00
22/12/2013	3.3	349.64	349.64	4.66			7.96		0.316	-10.00	0.00	0.32	2.98	0.32	0.32	7.65	0.00
23/12/2013	13.4	524.46	524.46	6.99			20.39		0.281	-10.00	0.00	0.28	13.12	0.28	0.28	20.11	0.00
24/12/2013	10.1	611.87	611.87	8.16			18.26		0.199	-10.00	0.00	0.20	9.90	0.20	0.20	18.06	0.00
25/12/2013	0	437.05	437.05	5.83			5.83		0.458	-9.30	0.70	0.46	0.00	0.46	0.46	5.37	0.00
26/12/2013	8.3	349.64	349.64	4.66			12.96		0.459	-10.00	0.00	0.46	7.84	0.46	0.46	12.50	0.00
27/12/2013	8.2	611.87	611.87	8.16			16.36		0.240	-10.00	0.00	0.24	7.96	0.24	0.24	16.12	0.00
28/12/2013	0.6	437.05	437.05	5.83			6.43		0.364	-9.86	0.14	0.36	0.10	0.36	0.36	6.06	0.00
29/12/2013	8.7	349.64	349.64	4.66			13.36		0.403	-10.00	0.00	0.40	8.30	0.40	0.40	12.96	0.00
30/12/2013	14.3	1048.92	1048.92	13.98			28.28		0.451	-10.00	0.00	0.45	13.85	0.45	0.45	27.83	0.00
31/12/2013	7.7	611.87	611.87	8.16			15.86		0.370	-10.00	0.00	0.37	7.33	0.37	0.37	15.49	0.00
01/01/2014	3.2	262.23	262.23	3.50			6.70		0.125	-10.00	0.00	0.12	3.08	0.12	0.12	6.57	0.00
02/01/2014	3.4	349.64	349.64	4.66			8.06		0.481	-10.00	0.00	0.48	2.92	0.48	0.48	7.58	0.00
03/01/2014	9	524.46	524.46	6.99			15.99		0.401	-10.00	0.00	0.40	8.60	0.40	0.40	15.59	0.00
04/01/2014	0.3	524.46	524.46	6.99			7.29		0.333	-9.40	0.60	0.33	0.00	0.33	0.33	6.96	0.00
05/01/2014	6	349.64	349.64	4.66			10.66		0.234	-10.00	0.00	0.23	5.77	0.23	0.23	10.43	0.00
06/01/2014	2.5	437.05	437.05	5.83			8.33		0.411	-10.00	0.00	0.41	2.09	0.41	0.41	7.92	0.00
07/01/2014	2.7	349.64	349.64	4.66			7.36		0.403	-10.00	0.00	0.40	2.30	0.40	0.40	6.96	0.00
08/01/2014	0.4	262.23	262.23	3.50			3.90		0.433	-9.50	0.50	0.43	0.00	0.43	0.43	3.46	0.00
09/01/2014	0	349.64	349.64	4.66			4.66		0.593	-8.56	1.44	0.59	0.00	0.59	0.59	4.07	0.00
10/01/2014	2	262.23	262.23	3.50			5.50		0.310	-9.47	0.53	0.31	1.16	0.31	0.31	5.19	0.00
11/01/2014	1.7	349.64	349.64	4.66			6.36		0.564	-10.00	0.00	0.56	1.14	0.56	0.56	5.80	0.00
12/01/2014	5.7	349.64	349.64	4.66			10.36		0.131	-10.00	0.00	0.13	5.57	0.13	0.13	10.23	0.00

13/01/2014	0.1	349.64	349.64	4.66	4.76	0.331	-9.47	0.53	0.33	0.00	0.33	0.33	4.43	0.00
14/01/2014	5.3	349.64	349.64	4.66	9.96	0.097	-10.00	0.00	0.10	5.20	0.10	0.10	9.86	0.00
15/01/2014	7	611.87	611.87	8.16	15.16	0.303	-10.00	0.00	0.30	6.70	0.30	0.30	14.85	0.00
16/01/2014	0.3	349.64	349.64	4.66	4.96	0.477	-9.50	0.50	0.48	0.00	0.48	0.48	4.48	0.00
17/01/2014	0.3	262.23	262.23	3.50	3.80	0.368	-8.82	1.18	0.37	0.00	0.37	0.37	3.43	0.00
18/01/2014	2.8	349.64	349.64	4.66	7.46	0.151	-10.00	0.00	0.15	2.65	0.15	0.15	7.31	0.00
19/01/2014	5	349.64	349.64	4.66	9.66	0.283	-10.00	0.00	0.28	4.72	0.28	0.28	9.38	0.00
20/01/2014	0.4	349.64	349.64	4.66	5.06	0.798	-9.62	0.38	0.80	0.00	0.80	0.80	4.26	0.00
21/01/2014	5.2	349.64	349.64	4.66	9.86	0.234	-10.00	0.00	0.23	4.97	0.23	0.23	9.63	0.00
22/01/2014	0.2	349.64	349.64	4.66	4.86	0.517	-9.47	0.53	0.52	0.00	0.52	0.52	4.34	0.00

measured values

Date	Temp	Humidity	Pressure	Net Rad.	Windspeed	Rainfall	J	Temp			Humidity		u_2	Δ	P	γ	A	B	C	D	$e^0(T_{max})$	$e^0(T_{min})$	e_s	e_a	e_s-e_a	Rn	ET_0	ET (no neg)
	C	%	mb	W/m2	m/s	mm		max	min	mean	max	min	m/s	kPa/C	kPa	kPa/C	(1+0.34*u	Δ/[Δ+γ*A)	γ/[Δ+γ*A)	900/(Tm+273)*	kPa	kPa	kPa	kPa	kPa	mm/day	mm/day	mm/day
daily	average	average	average	average	average	sum		max	min	mean	max	min																
28/02/2013 00:00	8.6	86	1034.89	114.19	0.08	0	59	14.1	3.1	8.61	99	72	0.08	0.076	103.489	0.069	1.027	0.517	0.470	0.258	1.613	0.762	1.188	0.958	0.230	3.997	**2.095**	**2.095**
01/03/2013 00:00	5.2	80	1032.96	62.46	0.06	0	60	12.2	-1.8	5.16	96	64	0.06	0.062	103.296	0.069	1.021	0.467	0.522	0.196	1.416	0.534	0.975	0.710	0.266	2.186	**1.049**	**1.049**
02/03/2013 00:00	4.9	79	1028.97	50.77	0.06	0	61	10.6	-0.8	4.93	94	63	0.06	0.061	102.897	0.068	1.019	0.465	0.525	0.180	1.281	0.577	0.929	0.675	0.254	1.777	**0.850**	**0.850**
03/03/2013 00:00	2.5	79	1021.60	27.91	0.06	0.1	62	7.6	-2.6	2.48	94	64	0.06	0.052	102.160	0.068	1.020	0.429	0.560	0.192	1.042	0.504	0.773	0.570	0.203	0.977	**0.441**	**0.441**
04/03/2013 00:00	3.1	81	1011.37	31.76	0.06	0	63	7.2	-1.0	3.10	93	68	0.06	0.054	101.137	0.067	1.020	0.441	0.548	0.195	1.014	0.569	0.791	0.609	0.182	1.111	**0.510**	**0.510**
05/03/2013 00:00	4.4	85	1003.53	99.98	0.07	0	64	12.8	-4.0	4.42	99	70	0.07	0.059	100.353	0.067	1.024	0.462	0.525	0.232	1.481	0.455	0.968	0.744	0.224	3.499	**1.645**	**1.645**
06/03/2013 00:00	6.3	91	999.04	40.75	0.09	6.2	65	9.4	3.2	6.30	96	85	0.09	0.066	99.904	0.066	1.032	0.490	0.494	0.305	1.177	0.770	0.974	0.870	0.104	1.426	**0.715**	**0.715**
07/03/2013 00:00	7.0	95	994.14	19.99	0.10	3.8	66	8.4	5.6	7.01	98	91	0.10	0.069	99.414	0.066	1.033	0.502	0.482	0.316	1.105	0.909	1.007	0.948	0.059	0.700	**0.360**	**0.360**
08/03/2013 00:00	7.2	96	993.64	27.24	0.12	6.1	67	9.1	5.4	7.25	99	93	0.12	0.070	99.364	0.066	1.041	0.504	0.477	0.384	1.153	0.899	1.026	0.981	0.045	0.953	**0.489**	**0.489**
09/03/2013 00:00	4.5	92	1002.24	16.17	0.12	0.4	68	6.5	2.5	4.49	99	85	0.12	0.059	100.224	0.067	1.039	0.460	0.520	0.375	0.966	0.732	0.849	0.773	0.076	0.566	**0.275**	**0.275**
10/03/2013 00:00	1.9	78	1010.30	59.10	0.13	0.2	69	6.0	-2.2	1.92	92	63	0.13	0.050	101.030	0.067	1.046	0.417	0.558	0.441	0.938	0.519	0.729	0.534	0.194	2.068	**0.910**	**0.910**
11/03/2013 00:00	0.0	62	1018.22	113.56	0.12	0	70	4.5	-4.6	-0.04	78	45	0.12	0.044	101.822	0.068	1.041	0.386	0.590	0.399	0.841	0.436	0.638	0.359	0.279	3.975	**1.600**	**1.600**
12/03/2013 00:00	-0.6	77	1018.69	77.42	0.07	0	71	7.8	-9.1	-0.63	92	61	0.07	0.043	101.869	0.068	1.023	0.381	0.605	0.227	1.059	0.307	0.683	0.464	0.219	2.710	**1.062**	**1.062**
13/03/2013 00:00	3.7	79	1016.45	121.18	0.07	0.5	72	11.8	-4.4	3.70	95	63	0.07	0.056	101.645	0.068	1.025	0.448	0.539	0.241	1.386	0.440	0.913	0.646	0.267	4.241	**1.934**	**1.934**
14/03/2013 00:00	2.5	82	1013.76	84.16	0.11	2.2	73	10.0	-4.9	2.53	94	70	0.11	0.052	101.376	0.067	1.037	0.428	0.552	0.354	1.224	0.425	0.824	0.628	0.196	2.946	**1.298**	**1.298**
15/03/2013 00:00	4.3	76	996.96	97.08	0.12	2.1	74	9.8	-1.2	4.28	96	55	0.12	0.058	99.696	0.066	1.041	0.458	0.521	0.388	1.209	0.559	0.884	0.601	0.283	3.398	**1.612**	**1.612**
16/03/2013 00:00	2.6	80	992.53	84.44	0.06	2	75	9.8	-4.6	2.60	99	61	0.06	0.052	99.253	0.066	1.022	0.437	0.551	0.211	1.215	0.433	0.824	0.585	0.239	2.955	**1.320**	**1.320**
17/03/2013 00:00	4.1	86	988.08	63.77	0.08	2.3	76	8.5	-0.4	4.06	97	75	0.08	0.057	98.808	0.066	1.026	0.460	0.526	0.244	1.111	0.593	0.852	0.705	0.148	2.232	**1.046**	**1.046**
18/03/2013 00:00	2.6	85	993.04	75.23	0.08	1.3	77	9.2	-4.0	2.57	98	71	0.08	0.052	99.304	0.066	1.027	0.436	0.549	0.262	1.161	0.453	0.807	0.634	0.173	2.633	**1.172**	**1.172**
19/03/2013 00:00	2.3	85	999.01	53.79	0.10	0.1	78	5.0	-0.4	2.33	94	76	0.10	0.052	99.901	0.066	1.034	0.429	0.553	0.324	0.873	0.595	0.734	0.611	0.123	1.883	**0.829**	**0.829**
20/03/2013 00:00	3.1	88	1006.09	32.55	0.08	0.5	79	5.6	0.7	3.15	96	80	0.08	0.054	100.609	0.067	1.027	0.441	0.544	0.255	0.907	0.644	0.776	0.672	0.104	1.139	**0.517**	**0.517**
21/03/2013 00:00	3.5	86	1008.03	68.64	0.13	3	80	6.2	0.8	3.48	95	77	0.13	0.055	100.803	0.067	1.045	0.442	0.534	0.435	0.947	0.646	0.797	0.672	0.125	2.402	**1.090**	**1.090**
22/03/2013 00:00	2.1	93	1000.13	17.17	0.16	14.9	81	3.6	0.5	2.06	95	91	0.16	0.051	100.013	0.067	1.053	0.420	0.551	0.514	0.790	0.635	0.712	0.661	0.051	0.601	**0.267**	**0.267**
23/03/2013 00:00	1.7	87	1009.48	16.69	0.12	0.2	82	2.7	0.7	1.71	93	80	0.12	0.050	100.948	0.067	1.042	0.415	0.562	0.406	0.741	0.644	0.693	0.596	0.097	0.584	**0.264**	**0.264**
24/03/2013 00:00	1.5	72	1015.79	32.55	0.12	0.2	83	2.7	0.3	1.47	85	59	0.12	0.049	101.579	0.068	1.041	0.410	0.567	0.399	0.741	0.622	0.681	0.483	0.198	1.139	**0.512**	**0.512**
25/03/2013 00:00	2.4	70	1019.64	69.64	0.13	0	84	5.5	-0.8	2.39	82	57	0.13	0.052	101.964	0.068	1.043	0.423	0.554	0.414	0.905	0.578	0.742	0.495	0.247	2.437	**1.086**	**1.086**
26/03/2013 00:00	1.9	74	1019.35	86.00	0.10	0	85	4.9	-1.1	1.90	84	63	0.10	0.050	101.935	0.068	1.035	0.417	0.563	0.340	0.864	0.565	0.715	0.510	0.205	3.010	**1.294**	**1.294**
27/03/2013 00:00	1.0	70	1017.13	121.97	0.10	0	86	7.3	-5.3	1.01	87	53	0.10	0.047	101.713	0.068	1.033	0.404	0.576	0.322	1.025	0.412	0.718	0.451	0.268	4.269	**1.776**	**1.776**
28/03/2013 00:00	0.6	74	1015.36	95.38	0.10	0	87	6.8	-5.6	0.60	89	58	0.10	0.046	101.536	0.068	1.032	0.399	0.583	0.313	0.986	0.403	0.695	0.465	0.229	3.338	**1.372**	**1.372**
29/03/2013 00:00	1.1	63	1011.51	103.88	0.10	0	88	7.3	-5.2	1.05	73	52	0.10	0.048	101.151	0.067	1.034	0.406	0.574	0.333	1.024	0.415	0.719	0.417	0.302	3.636	**1.534**	**1.534**
30/03/2013 00:00	0.8	64	1013.21	76.85	0.08	0	89	6.2	-4.5	0.81	82	46	0.08	0.047	101.321	0.067	1.028	0.403	0.580	0.272	0.945	0.436	0.691	0.396	0.294	2.690	**1.131**	**1.131**
31/03/2013 00:00	0.5	68	1011.15	69.94	0.11	0	90	5.9	-5.0	0.49	82	53	0.11	0.046	101.115	0.067	1.036	0.397	0.582	0.348	0.930	0.423	0.677	0.420	0.257	2.448	**1.024**	**1.024**
01/04/2013 00:00	-0.4	68	1011.55	52.87	0.12	0	91	4.4	-5.2	-0.45	79	56	0.12	0.043	101.155	0.067	1.039	0.382	0.595	0.382	0.834	0.413	0.624	0.397	0.227	1.851	**0.758**	**0.758**
02/04/2013 00:00	2.9	66	1017.97	157.33	0.10	0	92	10.4	-4.6	2.90	80	52	0.10	0.053	101.797	0.068	1.035	0.433	0.548	0.332	1.265	0.433	0.849	0.502	0.347	5.506	**2.446**	**2.446**
03/04/2013 00:00	4.8	61	1023.12	211.47	0.08	0	93	14.5	-4.9	4.82	89	32	0.08	0.060	102.312	0.068	1.029	0.462	0.523	0.273	1.653	0.425	1.039	0.454	0.586	7.401	**3.506**	**3.506**
04/04/2013 00:00	3.1	65	1023.72	161.48	0.08	0	94	13.2	-6.9	3.12	89	40	0.08	0.054	102.372	0.068	1.027	0.437	0.549	0.258	1.513	0.364	0.938	0.464	0.474	5.652	**2.535**	**2.535**
05/04/2013 00:00	3.7	70	1024.20	171.16	0.07	0	95	14.5	-7.1	3.70	96	44	0.07	0.056	102.420	0.068	1.025	0.446	0.541	0.235	1.651	0.359	1.005	0.535	0.470	5.991	**2.732**	**2.732**
06/04/2013 00:00	3.2	66	1024.73	211.04	0.08	0	96	15.1	-8.8	3.16	92	40	0.08	0.054	102.473	0.068	1.027	0.437	0.548	0.255	1.719	0.314	1.016	0.488	0.528	7.387	**3.302**	**3.302**
07/04/2013 00:00	2.6	71	1015.78	106.01	0.10	0	97	9.4	-4.3	2.56	93	49	0.10	0.052	101.578	0.068	1.032	0.429	0.553	0.310	1.182	0.444	0.813	0.496	0.317	3.710	**1.645**	**1.645**
08/04/2013 00:00	5.0	72	1003.93	142.59	0.11	0	98	12.0	-1.9	5.04	89	54	0.11	0.061	100.393	0.067	1.038	0.468	0.512	0.363	1.403	0.530	0.967	0.615	0.352	4.991	**2.402**	**2.402**
09/04/2013 00:00	5.8	70	1000.96	110.26	0.10	0	99	11.5	0.2	5.83	83	56	0.10	0.064	100.096	0.067	1.035	0.482	0.501	0.335	1.355	0.618	0.987	0.636	0.351	3.859	**1.918**	**1.918**
10/04/2013 00:00	3.0	85	1001.09	64.63	0.08	0	100	9.3	-3.4	2.96	96	73	0.08	0.054	100.109	0.067	1.026	0.440	0.546	0.252	1.175	0.474	0.824	0.656	0.168	2.262	**1.018**	**1.018**
11/04/2013 00:00	4.5	93	993.23	43.83	0.09	5.6	101	7.8	1.3	4.51	97	88	0.09	0.059	99.323	0.066	1.029	0.465	0.520	0.276	1.055	0.670	0.862	0.789	0.073	1.534	**0.724**	**0.724**
12/04/2013 00:00	4.5	81	997.97	83.92	0.07	0	102	10.9	-1.8	4.53	97	65	0.07	0.059	99.797	0.066	1.022	0.466	0.523	0.213	1.301	0.535	0.918	0.682	0.236	2.937	**1.394**	**1.394**
13/04/2013 00:00	4.3	81	999.24	94.42	0.13	6	103	12.1	-3.5	4.33	99	63	0.13	0.058	99.924	0.066	1.045	0.457	0.520	0.431	1.415	0.472	0.943	0.679	0.264	3.305	**1.569**	**1.569**
14/04/2013 00:00	12.3	81	994.02	154.24	0.20	6.7	104	16.2	8.3	12.25	96	65	0.20	0.094	99.402	0.066	1.069	0.570	0.402	0.639	1.843	1.094	1.468	1.124	0.344	5.398	**3.168**	**3.168**
15/04/2013 00:00	12.1	74	1002.31	136.99	0.17	6.1	105	16.5	7.8	12.13	94	53	0.17	0.093	100.231	0.067	1.057	0.570	0.407	0.528	1.875	1.057	1.466	0.994	0.472	4.795	**2.832**	**2.832**
16/04/2013 00:00	8.9	63	1003.34	219.91	0.23	1.3	106	15.8	1.9	8.89	83	43	0.23	0.077	100.334	0.067	1.077	0.518	0.448	0.718	1.800	0.703	1.251	0.679	0.573	7.697	**4.168**	**4.168**
17/04/2013 00:00	8.8	83	994.96	102.16	0.17	18.8	107	16.1	1.5	8.78	96	70	0.17	0.077	99.496	0.066	1.058	0.522	0.451	0.546	1.825	0.681	1.253	0.966	0.287	3.575	**1.938**	**1.938**
18/04/2013 00:00	8.3	82	1004.92	160.08	0.15	8.6	108	12.7	3.8	8.28	94	69	0.15	0.074	100.492	0.067	1.051	0.514	0.462	0.482	1.472	0.803	1.137	0.885	0.252	5.603	**2.936**	**2.936**
19/04/2013 00:00	8.7	73	1027.04	190.08	0.08	0	109	17.2	0.3	8.74	94	51	0.08	0.076	102.704	0.068	1.027	0.521	0.466	0.255	1.961	0.624	1.293	0.793	0.499	6.653	**3.527**	**3.527**
20/04/2013 00:00	8.2	68	1026.65	157.76	0.13	0	110	14.8	1.6	8.19	86	50	0.13	0.074	102.665	0.068	1.045	0.509	0.470	0.425	1.684	0.684	1.184	0.715	0.469	5.522	**2.902**	**2.902**
21/04/2013 00:00	9.9	73	1015.09	174.86	0.13	4.3	111	15.2	4.7	9.93	91	54	0.13	0.082	101.509	0.068	1.044	0.538	0.443	0.412	1.726	0.852	1.289	0.854	0.435	6.120	**3.370**	**3.370**
22/04/2013 00:00	11.1	75	1010.23	143.75	0.15	0.8	112	17.2	5.0	11.12	95	55	0.15	0.088	101.023	0.067	1.050	0.555	0.424	0.466	1.967	0.872	1.420	0.955	0.464	5.031	**2.883**	**2.883**
23/04/2013 00:00	10.9	74	1016.97	100.71	0.11	0	113	15.4	6.5	10.95	86	61	0.11	0.087	101.697	0.068	1.037	0.554	0.430	0.349	1.752	0.966	1.359	0.950	0.409	3.525	**2.012**	**2.012**
24/04/2013 00:00	10.1	78	1020.37	98.76	0.11	4.6	114	14.6	5.7	10.13	94	61	0.11	0.083	102.037	0.068	1.037	0.541	0.443	0.350	1.657	0.917	1.287	0.936	0.351	3.457	**1.924**	**1.924**
25/04/2013 00:00	8.5	72	1021.18	204.55	0.08	5.5	115	15.6	1.5	8.55	97	47	0.08	0.076	102.118	0.068	1.028	0.520	0.467	0.265	1.777	0.679	1.228	0.747	0.481	7.159	**3.779**	**3.779**
26/04/2013 00:00	5.3	68	1019.78	170.33	0.11	3.2	116	11.2	-0.7	5.28	93	43	0.11	0.062	101.978	0.068	1.038	0.468	0.513	0.359	1.331	0.582	0.957	0.557	0.400	5.961	**2.864**	**2.864**
27/04/2013 00:00	9.2	64	1020.89	200.84	0.09	0	117	17.8	0.7	9.20	86	42	0.09	0.078	102.089	0.068	1.031	0.529	0.457	0.295	2.032	0.641	1.336	0.702	0.634	7.029	**3.801**	**3.801**
28/04/2013 00:00	7.9	78	1012.09	137.09	0.14	2.6	118	13.1	2.7	7.89	96	60	0.14	0.073	101.209	0.067	1.046	0.508	0.471	0.433	1.503	0.744	1.123	0.808	0.315	4.798	**2.500**	**2.500**
29/04/2013 00:00	7.4	68	1016.93	197.18	0.12	1.7	119	14.2	0.6	7.39	89	47	0.12	0.070	101.693	0.068	1.042	0.500	0.480	0.394	1.614	0.639	1.127	0.664	0.463	6.901	**3.537**	**3.537**
30/04/2013 00:00	7.7	71	1026.02	175.16	0.07	0	120	17.7	-2.4	7.68	96	46	0.07	0.072	102.602	0.068	1.025	0.506	0.482	0.239	2.028	0.513	1.271	0.713	0.558	6.131	**3.166**	**3.166**
01/05/2013 00:00	9.7	64	1024.50	216.20	0.09	0	121	17.6	1.8	9.71	92	36	0.09	0.081	102.450	0.068	1.032	0.535	0.451	0.297	2.010	0.698	1.354	0.683	0.671	7.567	**4.139**	**4.139**
02/05/2013 00:00	8.8	73	1021.63	134.19	0.12	0.1	122	16.5	1.2	8.85	91	54	0.12	0.077	102.163	0.068	1.041	0.521	0.460	0.388	1.882	0.664	1.273	0.810	0.463	4.697	**2.528**	**2.528**
03/05/2013 00:00	9.7	89	1012.77	74.53	0.17	6.4	123	12.5	7.0	9.75	96	81	0.17	0.081	101.277	0.067	1.057	0.532	0.442	0.536	1.449	1.002	1.225	1.068	0.158	2.609	**1.426**	**1.426**
04/05/2013 00:00	9.7	78	1011.64	134.51	0.13	0.5	124	14.8	4.6	9.72	97	58	0.13	0.081	101.164	0.067	1.043	0.535	0.445	0.406	1.688	0.848	1.268	0.901	0.367	4.708	**2.587**	**2.587**
05/05/2013 00:00	12.8	79	1015.61	98.90	0.15	0.7	125	16.2	9.4	12.79	95	62	0.15	0.097	101.561	0.068	1.051	0.577	0.403	0.471	1.844	1.176	1.510	1.130	0.380	3.461	**2.069**	**2.069**
06/05/2013 00:00	12.7	78	1015.87	98.90	0.11	0	126	18.3	7.2	12.73	90	66	0.11	0.096	101.587	0.068	1.036	0.579	0.406	0.337	2.099	1.015	1.557	1.150	0.408	3.462	**2.062**	**2.062**
07/05/2013 00:00	12.9	74	1012.03	243.04	0.10	0	127	21.0	4.7	12.85	95	53	0.10	0.097	101.203	0.067	1.032	0.583	0.404	0.299	2.489	0.854	1.671	1.065	0.606	8.506	**5.033**	**5.033**
08/05/2013 00:00	10.9	82	995.25	114.25	0.16	3.1	128	15.1	6.6	10.87	94	70	0.16	0.087	99.525	0.066	1.054	0.554	0.423	0.506	1.715	0.977	1.346	1.060	0.287	3.999	**2.275**	**2.275**
09/05/2013 00:00	9.6	85	991.45	114.91	0.14	11.9	129	13.8	5.4	9.56	93	76	0.14	0.080	99.145	0.066	1.047	0.537	0.442	0.439	1.573	0.895	1.234	1.014	0.220	4.022	**2.204**	**2.204**

10/05/2013 00:00	10.2	75	1003.45	164.35	0.14	8.1	130	14.3	6.1	10.19	97	53	0.14	0.083	100.345	0.067	1.047	0.543	0.436	0.444	1.626	0.943	1.284	0.888	0.396	5.752	3.203	3.203
11/05/2013 00:00	8.9	78	1007.60	225.03	0.13	5.1	131	14.2	3.7	8.93	94	61	0.13	0.077	100.760	0.067	1.043	0.525	0.455	0.405	1.615	0.796	1.206	0.867	0.339	7.876	4.197	4.197
12/05/2013 00:00	8.1	84	1009.50	83.17	0.12	3.5	132	12.5	3.7	8.09	95	73	0.12	0.073	100.950	0.067	1.040	0.513	0.469	0.378	1.449	0.795	1.122	0.907	0.216	2.911	1.530	1.530
13/05/2013 00:00	7.8	76	1006.65	243.45	0.16	6.2	133	13.0	2.6	7.78	92	59	0.16	0.072	100.665	0.067	1.054	0.505	0.469	0.514	1.498	0.734	1.116	0.780	0.336	8.521	4.387	4.387
14/05/2013 00:00	9.0	76	998.62	210.30	0.12	3	134	16.4	1.7	9.04	92	60	0.12	0.078	99.862	0.066	1.041	0.529	0.452	0.381	1.863	0.690	1.277	0.876	0.400	7.361	3.965	3.965
15/05/2013 00:00	8.1	76	999.18	209.28	0.10	1	135	14.0	2.3	8.11	94	58	0.10	0.074	99.918	0.066	1.036	0.517	0.467	0.335	1.593	0.719	1.156	0.800	0.356	7.325	3.839	3.839
16/05/2013 00:00	7.5	82	998.70	133.91	0.08	5.4	136	13.7	1.4	7.52	93	70	0.08	0.071	99.870	0.066	1.028	0.510	0.477	0.265	1.563	0.675	1.119	0.861	0.258	4.687	2.421	2.421
17/05/2013 00:00	9.0	74	1010.04	277.60	0.08	0	137	20.7	-2.7	9.03	97	50	0.08	0.078	101.004	0.067	1.026	0.530	0.458	0.244	2.445	0.502	1.473	0.855	0.619	9.716	5.218	5.218
18/05/2013 00:00	8.1	89	1009.76	41.42	0.07	6.3	138	10.4	5.7	8.08	97	80	0.07	0.073	100.976	0.067	1.023	0.517	0.473	0.218	1.263	0.918	1.091	0.951	0.140	1.450	0.763	0.763
19/05/2013 00:00	12.3	86	1013.63	74.78	0.06	0	139	15.8	8.7	12.26	97	74	0.06	0.094	101.363	0.067	1.020	0.577	0.415	0.183	1.799	1.124	1.461	1.211	0.251	2.617	1.530	1.530
20/05/2013 00:00	12.6	89	1018.60	80.07	0.09	0.1	140	16.5	8.8	12.64	96	81	0.09	0.096	101.860	0.068	1.029	0.579	0.409	0.272	1.876	1.132	1.504	1.303	0.201	2.802	1.645	1.645
21/05/2013 00:00	14.2	78	1021.80	194.56	0.09	0.7	141	20.4	7.9	14.16	94	61	0.09	0.105	102.180	0.068	1.031	0.599	0.389	0.288	2.401	1.065	1.733	1.233	0.500	6.810	4.136	4.136
22/05/2013 00:00	10.3	74	1023.89	162.85	0.10	0	142	16.0	4.5	10.25	93	54	0.10	0.084	102.389	0.068	1.036	0.542	0.442	0.333	1.815	0.844	1.330	0.883	0.447	5.700	3.156	3.156
23/05/2013 00:00	8.0	67	1021.26	228.79	0.11	0.5	143	14.1	1.9	7.98	83	51	0.11	0.073	102.126	0.068	1.037	0.509	0.474	0.353	1.607	0.699	1.153	0.700	0.453	8.008	4.150	4.150
24/05/2013 00:00	11.7	67	1020.53	224.23	0.09	0	144	19.8	3.6	11.70	87	46	0.09	0.091	102.053	0.068	1.031	0.565	0.422	0.291	2.308	0.791	1.550	0.875	0.675	7.848	4.516	4.516
25/05/2013 00:00	11.7	73	1021.84	242.36	0.09	0.7	145	19.7	3.8	11.75	95	50	0.09	0.091	102.184	0.068	1.031	0.565	0.421	0.292	2.290	0.804	1.547	0.954	0.592	8.483	4.868	4.868
26/05/2013 00:00	14.5	76	1015.15	162.08	0.11	2.1	146	19.8	9.3	14.51	95	56	0.11	0.107	101.515	0.068	1.036	0.604	0.382	0.334	2.305	1.168	1.736	1.200	0.536	5.673	3.496	3.496
27/05/2013 00:00	11.6	72	997.41	226.28	0.12	14	147	18.7	4.5	11.63	94	49	0.12	0.091	99.741	0.066	1.042	0.567	0.415	0.395	2.161	0.844	1.502	0.926	0.576	7.920	4.585	4.585
28/05/2013 00:00	12.7	76	1001.43	192.99	0.08	1.2	148	21.2	4.1	12.69	96	56	0.08	0.096	100.143	0.067	1.026	0.585	0.405	0.239	2.522	0.822	1.672	1.101	0.571	6.755	4.006	4.006
29/05/2013 00:00	16.2	71	1012.16	330.48	0.09	2.6	149	24.5	7.8	16.15	97	45	0.09	0.117	101.216	0.067	1.031	0.628	0.361	0.286	3.067	1.062	2.065	1.205	0.859	11.567	7.352	7.352
30/05/2013 00:00	15.0	74	1018.72	316.72	0.09	0	150	24.4	5.7	15.05	92	55	0.09	0.110	101.872	0.068	1.030	0.612	0.377	0.275	3.051	0.917	1.984	1.261	0.723	11.085	6.860	6.860
31/05/2013 00:00	10.8	71	1023.01	139.03	0.08	0	151	18.2	3.5	10.85	92	50	0.08	0.086	102.301	0.068	1.027	0.553	0.435	0.255	2.093	0.784	1.438	0.884	0.555	4.866	2.753	2.753
01/06/2013 00:00	11.2	74	1026.61	184.47	0.09	0.9	152	19.3	3.2	11.24	92	55	0.09	0.089	102.661	0.068	1.031	0.557	0.430	0.286	2.237	0.768	1.503	0.969	0.534	6.457	3.663	3.663
02/06/2013 00:00	14.2	74	1029.86	152.38	0.09	0	153	19.6	8.7	14.19	90	57	0.09	0.105	102.986	0.068	1.030	0.598	0.390	0.274	2.287	1.128	1.707	1.159	0.548	5.333	3.247	3.247
03/06/2013 00:00	17.2	78	1031.71	148.14	0.06	0	154	22.8	11.7	17.24	94	62	0.06	0.124	103.171	0.069	1.020	0.640	0.353	0.183	2.777	1.372	2.075	1.506	0.569	5.185	3.355	3.355
04/06/2013 00:00	16.4	70	1028.35	306.60	0.07	0	155	27.0	5.8	16.41	97	43	0.07	0.119	102.835	0.068	1.024	0.629	0.362	0.215	3.572	0.921	2.246	1.215	1.032	10.731	6.833	6.833
05/06/2013 00:00	14.5	71	1022.06	280.08	0.07	0	156	26.0	3.0	14.53	94	48	0.07	0.107	102.206	0.068	1.024	0.606	0.385	0.217	3.363	0.760	2.062	1.165	0.897	9.803	6.013	6.013
06/06/2013 00:00	15.4	72	1022.45	242.05	0.06	0	157	26.1	4.7	15.38	95	49	0.06	0.112	102.245	0.068	1.022	0.618	0.374	0.200	3.383	0.851	2.117	1.233	0.884	8.472	5.298	5.298
07/06/2013 00:00	16.6	70	1025.17	340.90	0.07	0	158	28.4	4.7	16.56	96	43	0.07	0.120	102.517	0.068	1.024	0.632	0.360	0.217	3.871	0.855	2.363	1.243	1.120	11.931	7.627	7.627
08/06/2013 00:00	15.5	65	1022.53	335.30	0.06	0	159	28.1	2.8	15.45	92	37	0.06	0.113	102.253	0.068	1.022	0.618	0.373	0.201	3.798	0.748	2.273	1.047	1.226	11.736	7.349	7.349
09/06/2013 00:00	15.1	69	1015.55	330.86	0.08	0	160	26.4	3.8	15.13	96	42	0.08	0.111	101.555	0.068	1.026	0.615	0.375	0.242	3.444	0.805	2.124	1.109	1.015	11.580	7.211	7.211
10/06/2013 00:00	14.1	68	1010.84	254.25	0.10	0	161	23.0	5.3	14.15	83	53	0.10	0.105	101.084	0.067	1.033	0.601	0.386	0.302	2.808	0.891	1.849	1.114	0.736	8.899	5.435	5.435
11/06/2013 00:00	15.2	88	1004.80	79.08	0.08	9.4	162	20.0	10.4	15.22	96	79	0.08	0.111	100.480	0.067	1.028	0.618	0.372	0.257	2.338	1.264	1.801	1.530	0.271	2.768	1.736	1.736
12/06/2013 00:00	15.3	83	1003.41	131.95	0.06	4.7	163	21.8	8.8	15.30	97	68	0.06	0.112	100.341	0.067	1.020	0.621	0.371	0.180	2.606	1.135	1.870	1.436	0.434	4.618	2.898	2.898
13/06/2013 00:00	13.7	82	1007.21	205.11	0.09	5.8	164	19.9	7.5	13.72	96	67	0.09	0.102	100.721	0.067	1.030	0.597	0.391	0.278	2.328	1.038	1.683	1.278	0.405	7.179	4.328	4.328
14/06/2013 00:00	12.6	79	1003.93	152.38	0.11	7.5	165	18.6	6.5	12.58	94	64	0.11	0.096	100.393	0.067	1.038	0.580	0.405	0.348	2.147	0.970	1.558	1.143	0.416	5.333	3.151	3.151
15/06/2013 00:00	13.2	70	1000.43	223.13	0.12	1.7	166	20.0	6.5	13.24	94	45	0.12	0.099	100.043	0.067	1.042	0.589	0.395	0.384	2.335	0.968	1.652	0.980	0.671	7.810	4.702	4.702
16/06/2013 00:00	13.2	79	1009.29	160.48	0.07	0.2	167	20.8	5.6	13.16	96	61	0.07	0.099	100.929	0.067	1.023	0.590	0.401	0.212	2.449	0.908	1.679	1.183	0.496	5.617	3.357	3.357
17/06/2013 00:00	14.2	86	1016.18	120.48	0.06	1.7	168	20.1	8.3	14.22	96	76	0.06	0.105	101.618	0.068	1.021	0.604	0.388	0.191	2.354	1.097	1.726	1.421	0.304	4.217	2.568	2.568
18/06/2013 00:00	16.1	74	1015.25	270.87	0.07	0	169	26.5	5.6	16.07	99	48	0.07	0.117	101.525	0.068	1.024	0.628	0.364	0.222	3.468	0.910	2.189	1.283	0.906	9.480	6.023	6.023
19/06/2013 00:00	13.9	72	1017.09	248.04	0.08	0	170	22.8	5.0	13.90	95	49	0.08	0.103	101.709	0.068	1.026	0.598	0.392	0.241	2.776	0.873	1.824	1.095	0.730	8.681	5.259	5.259
20/06/2013 00:00	16.0	73	1011.36	157.22	0.07	0	171	23.3	8.7	16.02	93	52	0.07	0.116	101.136	0.067	1.024	0.628	0.363	0.220	2.863	1.127	1.995	1.268	0.726	5.503	3.513	3.513
21/06/2013 00:00	16.6	75	1007.61	199.60	0.10	1.8	172	21.6	11.6	16.60	95	54	0.10	0.120	100.761	0.067	1.033	0.634	0.354	0.304	2.579	1.366	1.972	1.345	0.627	6.986	4.498	4.498
22/06/2013 00:00	14.4	86	996.36	191.54	0.12	8.1	173	18.1	10.7	14.40	94	77	0.12	0.106	99.636	0.066	1.042	0.606	0.378	0.389	2.073	1.288	1.681	1.404	0.277	6.704	4.101	4.101
23/06/2013 00:00	10.8	79	1012.63	117.37	0.12	1.9	174	13.9	7.8	10.84	94	63	0.12	0.086	101.263	0.067	1.041	0.552	0.430	0.386	1.585	1.059	1.322	0.997	0.325	4.108	2.322	2.322
24/06/2013 00:00	13.3	75	1023.82	166.61	0.07	0.9	175	20.0	6.6	13.27	93	56	0.07	0.100	102.382	0.068	1.025	0.588	0.402	0.228	2.337	0.971	1.654	1.106	0.548	5.831	3.478	3.478
25/06/2013 00:00	13.9	79	1028.13	191.26	0.07	0	176	22.6	5.1	13.86	96	61	0.07	0.103	102.813	0.068	1.025	0.595	0.395	0.228	2.739	0.880	1.810	1.258	0.552	6.694	4.032	4.032
26/06/2013 00:00	13.6	78	1032.68	263.71	0.07	0	177	23.6	3.6	13.63	97	58	0.07	0.102	103.268	0.069	1.023	0.591	0.400	0.210	2.917	0.792	1.854	1.230	0.624	9.230	5.509	5.509
27/06/2013 00:00	12.6	91	1027.88	74.35	0.08	5.2	178	17.2	7.9	12.56	97	85	0.08	0.096	102.788	0.068	1.029	0.576	0.412	0.265	1.964	1.067	1.515	1.352	0.163	2.602	1.517	1.517
28/06/2013 00:00	14.4	82	1021.14	101.50	0.11	0.6	179	18.0	10.7	14.35	95	69	0.11	0.106	102.114	0.068	1.036	0.601	0.385	0.332	2.067	1.285	1.676	1.323	0.352	3.552	2.179	2.179
29/06/2013 00:00	17.4	80	1022.45	152.15	0.10	0.5	180	24.7	10.2	17.42	94	65	0.10	0.126	102.245	0.068	1.034	0.641	0.347	0.308	3.104	1.242	2.173	1.593	0.580	5.325	3.477	3.477
30/06/2013 00:00	14.3	74	1016.68	109.78	0.14	1.8	181	17.9	10.7	14.30	93	54	0.14	0.105	101.668	0.068	1.046	0.599	0.384	0.425	2.045	1.290	1.667	1.152	0.515	3.842	2.384	2.384
01/07/2013 00:00	15.0	70	1014.28	188.35	0.10	0.00	182	20.5	9.5	14.98	83	57	0.10	0.110	101.428	0.067	1.034	0.611	0.376	0.315	2.413	1.183	1.798	1.179	0.619	6.592	4.102	4.102
02/07/2013 00:00	12.7	87	1001.49	48.55	0.11	0.00	183	15.4	9.9	12.65	95	78	0.11	0.096	100.149	0.067	1.039	0.581	0.403	0.359	1.753	1.217	1.485	1.262	0.223	1.699	1.020	1.020
03/07/2013 00:00	15.6	83	1006.52	149.00	0.10	0.00	184	20.5	10.6	15.58	96	69	0.10	0.113	100.652	0.067	1.034	0.621	0.367	0.308	2.418	1.279	1.848	1.448	0.400	5.215	3.284	3.284
04/07/2013 00:00	16.7	76	1014.82	198.33	0.13	0.00	185	20.6	12.9	16.74	95	56	0.13	0.121	101.482	0.067	1.045	0.632	0.352	0.416	2.425	1.486	1.956	1.385	0.571	6.942	4.468	4.468
05/07/2013 00:00	18.5	75	1026.25	195.18	0.11	0.00	186	25.9	11.2	18.55	87	62	0.11	0.134	102.625	0.068	1.036	0.654	0.334	0.325	3.334	1.333	2.333	1.613	0.720	6.831	4.547	4.547
06/07/2013 00:00	17.1	78	1027.97	208.18	0.11	0.00	187	24.7	9.6	17.15	89	66	0.11	0.124	102.797	0.068	1.038	0.636	0.351	0.348	3.117	1.192	2.155	1.559	0.595	7.286	4.704	4.704
07/07/2013 00:00	22.1	78	1033.88	247.40	0.07	0.00	188	29.2	15.1	22.15	94	62	0.07	0.162	103.388	0.069	1.022	0.698	0.295	0.199	4.050	1.716	2.883	2.062	0.821	8.659	6.092	6.092
08/07/2013 00:00	22.2	75	1034.22	306.94	0.06	0.00	189	32.7	11.7	22.22	95	54	0.06	0.163	103.422	0.069	1.020	0.699	0.295	0.179	4.954	1.375	3.165	1.991	1.174	10.743	7.573	7.573
09/07/2013 00:00	23.1	75	1030.01	274.65	0.06	0.00	190	34.2	12.0	23.10	97	53	0.06	0.171	103.001	0.068	1.019	0.710	0.285	0.172	5.382	1.401	3.391	2.106	1.286	9.613	6.886	6.886
10/07/2013 00:00	21.0	74	1027.40	313.81	0.07	0.00	191	31.4	10.7	21.05	98	50	0.07	0.153	102.740	0.068	1.022	0.687	0.306	0.202	4.593	1.287	2.940	1.779	1.161	10.983	7.614	7.614
11/07/2013 00:00	22.2	79	1025.93	279.29	0.06	0.00	192	32.1	12.3	22.21	99	58	0.06	0.163	102.593	0.068	1.020	0.701	0.293	0.183	4.779	1.432	3.106	2.095	1.011	9.775	6.903	6.903
12/07/2013 00:00	22.2	67	1024.70	294.02	0.06	0.00	193	33.1	11.3	22.21	97	36	0.06	0.163	102.470	0.068	1.021	0.701	0.293	0.186	5.067	1.338	3.203	1.561	1.641	10.291	7.302	7.302
13/07/2013 00:00	19.6	76	1026.87	198.14	0.06	0.00	194	27.3	11.9	19.64	89	63	0.06	0.142	102.687	0.068	1.020	0.671	0.323	0.182	3.637	1.396	2.517	1.767	0.750	6.935	4.696	4.696
14/07/2013 00:00	18.5	67	1025.39	295.44	0.07	0.00	195	28.2	8.7	18.46	95	38	0.07	0.133	102.539	0.068	1.023	0.656	0.336	0.210	3.824	1.127	2.475	1.262	1.214	10.340	6.870	6.870
15/07/2013 00:00	18.0	76	1024.36	148.91	0.08	0.00	196	24.4	11.5	17.97	91	61	0.08	0.130	102.436	0.068	1.026	0.649	0.342	0.239	3.056	1.360	2.208	1.551	0.657	5.212	3.438	3.438
16/07/2013 00:00	20.7	69	1023.92	153.66	0.07	0.00	197	26.1	15.3	20.71	85	53	0.07	0.150	102.392	0.068	1.025	0.683	0.309	0.225	3.387	1.737	2.562	1.636	0.926	5.378	3.738	3.738
17/07/2013 00:00	21.4	71	1026.06	283.07	0.07	0.00	198	30.1	12.8	21.42	94	47	0.07	0.156	102.606	0.068	1.023	0.691	0.302	0.203	4.260	1.475	2.868	1.695	1.173	9.908	6.921	6.921
18/07/2013 00:00	21.7	73	1027.89	288.21	0.06	0.00	199	33.2	10.2	21.66	96	49	0.06	0.158	102.789	0.068	1.019	0.694	0.300	0.169	5.078	1.240	3.159	1.840	1.320	10.087	7.072	7.072
19/07/2013 00:00	21.9	73	1026.11	299.26	0.07	0.00	200	32.6	11.3	21.91	98	48	0.07	0.160	102.611	0.068	1.023	0.697	0.296	0.210	4.905	1.336	3.121	1.832	1.289	10.474	7.377	7.377

20/07/2013 00:00	21.2	77	1023.50	295.30	0.07	0.00	201	30.3	12.0	21.16	92	61	0.07	0.154	102.350	0.068	1.025	0.688	0.304	0.221	4.327	1.400	2.863	1.963	0.900	10.336	**7.175**	**7.175**
21/07/2013 00:00	16.7	81	1019.61	124.47	0.07	0.00	202	23.0	10.5	16.71	96	66	0.07	0.121	101.961	0.068	1.023	0.635	0.357	0.208	2.804	1.265	2.035	1.533	0.502	4.356	**2.805**	**2.805**
22/07/2013 00:00	19.7	84	1014.02	186.79	0.07	0.20	203	28.9	10.6	19.74	95	72	0.07	0.143	101.402	0.067	1.023	0.674	0.319	0.209	3.971	1.280	2.626	2.038	0.588	6.538	**4.446**	**4.446**
23/07/2013 00:00	20.6	80	1009.94	179.06	0.09	0.80	204	25.5	15.7	20.60	94	66	0.09	0.149	100.994	0.067	1.029	0.684	0.307	0.262	3.267	1.780	2.524	1.915	0.609	6.267	**4.334**	**4.334**
24/07/2013 00:00	18.8	78	1008.66	154.80	0.09	0.40	205	24.1	13.5	18.78	96	59	0.09	0.135	100.866	0.067	1.032	0.662	0.328	0.286	3.004	1.542	2.273	1.626	0.647	5.418	**3.647**	**3.647**
25/07/2013 00:00	19.6	80	1008.13	133.31	0.06	12.06	206	25.6	13.6	19.59	95	65	0.06	0.142	100.813	0.067	1.020	0.674	0.319	0.181	3.273	1.560	2.416	1.805	0.612	4.666	**3.181**	**3.181**
26/07/2013 00:00	19.1	78	1009.44	196.83	0.06	0.60	207	26.2	11.9	19.06	98	57	0.06	0.138	100.944	0.067	1.022	0.667	0.326	0.198	3.405	1.393	2.399	1.653	0.746	6.889	**4.645**	**4.645**
27/07/2013 00:00	19.5	73	1005.92	267.33	0.07	1.21	208	27.8	11.2	19.47	95	51	0.07	0.141	100.592	0.067	1.024	0.672	0.320	0.218	3.730	1.328	2.529	1.582	0.947	9.357	**6.358**	**6.358**
28/07/2013 00:00	18.6	78	1000.86	197.76	0.07	3.02	209	26.4	10.8	18.62	97	58	0.07	0.134	100.086	0.067	1.023	0.663	0.329	0.212	3.444	1.297	2.370	1.628	0.743	6.922	**4.643**	**4.643**
29/07/2013 00:00	16.9	84	1004.61	167.02	0.08	13.47	210	21.7	12.2	16.93	96	72	0.08	0.122	100.461	0.067	1.026	0.641	0.350	0.238	2.588	1.421	2.005	1.614	0.391	5.846	**3.778**	**3.778**
30/07/2013 00:00	14.7	78	1008.87	186.99	0.09	3.42	211	21.4	7.9	14.67	93	62	0.09	0.108	100.887	0.067	1.029	0.609	0.379	0.268	2.552	1.067	1.809	1.287	0.522	6.545	**4.042**	**4.042**
31/07/2013 00:00	13.3	87	1008.33	90.62	0.06	33.57	212	19.5	7.0	13.29	98	75	0.06	0.100	100.833	0.067	1.021	0.593	0.399	0.192	2.271	1.005	1.638	1.344	0.294	3.172	**1.902**	**1.902**
01/08/2013 00:00	18.0	87	1000.85	98.77	0.12	7.24	213	22.3	13.6	17.97	95	78	0.12	0.130	100.085	0.067	1.041	0.652	0.335	0.373	2.699	1.557	2.128	1.792	0.336	3.457	**2.294**	**2.294**
02/08/2013 00:00	18.2	74	998.79	206.32	0.17	1.81	214	23.1	13.2	18.16	86	62	0.17	0.131	99.879	0.066	1.056	0.651	0.330	0.511	2.830	1.516	2.173	1.529	0.644	7.221	**4.810**	**4.810**
03/08/2013 00:00	16.3	71	1007.71	194.20	0.14	1.81	215	21.3	11.3	16.33	86	55	0.14	0.118	100.771	0.067	1.047	0.628	0.356	0.427	2.538	1.341	1.939	1.274	0.665	6.797	**4.368**	**4.368**
04/08/2013 00:00	18.4	70	1011.24	241.61	0.09	0.00	216	26.8	10.1	18.43	92	47	0.09	0.133	101.124	0.067	1.030	0.657	0.333	0.276	3.526	1.232	2.379	1.395	0.984	8.456	**5.648**	**5.648**
05/08/2013 00:00	16.7	74	1011.46	218.91	0.07	0.00	217	23.5	9.9	16.66	91	56	0.07	0.120	101.146	0.067	1.025	0.636	0.355	0.226	2.890	1.216	2.053	1.362	0.691	7.662	**4.929**	**4.929**
06/08/2013 00:00	16.6	78	1013.46	147.41	0.08	0.00	218	21.8	11.5	16.63	94	62	0.08	0.120	101.346	0.067	1.026	0.635	0.356	0.239	2.607	1.355	1.981	1.445	0.536	5.159	**3.321**	**3.321**
07/08/2013 00:00	15.6	78	1015.70	118.90	0.05	0.00	219	21.4	9.8	15.58	95	60	0.05	0.113	101.570	0.068	1.017	0.623	0.371	0.160	2.541	1.212	1.877	1.338	0.539	4.161	**2.623**	**2.623**
08/08/2013 00:00	16.2	74	1014.66	167.91	0.09	2.01	220	24.8	7.7	16.24	98	49	0.09	0.118	101.466	0.067	1.030	0.629	0.360	0.276	3.123	1.053	2.088	1.281	0.807	5.877	**3.775**	**3.775**
09/08/2013 00:00	16.6	78	1019.16	151.63	0.08	1.01	221	21.2	11.9	16.57	96	60	0.08	0.120	101.916	0.068	1.028	0.632	0.358	0.257	2.518	1.397	1.957	1.426	0.531	5.307	**3.405**	**3.405**
10/08/2013 00:00	16.0	79	1019.79	147.85	0.08	0.20	222	21.0	11.0	15.97	93	64	0.08	0.116	101.979	0.068	1.027	0.625	0.365	0.247	2.481	1.310	1.896	1.403	0.492	5.175	**3.277**	**3.277**
11/08/2013 00:00	15.3	81	1016.51	176.93	0.10	2.01	223	20.4	10.1	15.27	94	67	0.10	0.111	101.651	0.068	1.035	0.614	0.373	0.323	2.401	1.236	1.819	1.385	0.433	6.193	**3.856**	**3.856**
12/08/2013 00:00	14.6	77	1017.95	175.25	0.09	1.61	224	20.6	8.6	14.62	96	57	0.09	0.107	101.795	0.068	1.032	0.606	0.382	0.296	2.425	1.120	1.773	1.229	0.544	6.134	**3.778**	**3.778**
13/08/2013 00:00	16.5	84	1020.66	125.82	0.08	0.40	225	22.0	10.9	16.49	97	70	0.08	0.119	102.066	0.068	1.026	0.632	0.359	0.234	2.649	1.307	1.978	1.561	0.417	4.404	**2.816**	**2.816**
14/08/2013 00:00	15.7	90	1016.62	81.37	0.08	1.41	226	20.4	11.0	15.69	99	81	0.08	0.114	101.662	0.068	1.029	0.621	0.368	0.264	2.397	1.311	1.854	1.620	0.234	2.848	**1.792**	**1.792**
15/08/2013 00:00	16.9	93	1010.40	66.32	0.12	11.86	227	20.5	13.2	16.86	98	87	0.12	0.122	101.040	0.067	1.041	0.635	0.350	0.374	2.413	1.517	1.965	1.793	0.172	2.321	**1.497**	**1.497**
16/08/2013 00:00	17.4	78	1011.72	168.11	0.09	0.20	228	23.7	11.1	17.40	96	59	0.09	0.126	101.172	0.067	1.032	0.644	0.345	0.288	2.929	1.321	2.125	1.498	0.627	5.884	**3.851**	**3.851**
17/08/2013 00:00	18.0	77	1001.43	162.83	0.13	1.61	229	24.3	11.7	17.98	97	57	0.13	0.130	100.143	0.067	1.044	0.651	0.334	0.403	3.031	1.374	2.202	1.530	0.672	5.699	**3.799**	**3.799**
18/08/2013 00:00	15.2	80	1006.77	164.31	0.10	1.61	230	20.8	9.7	15.23	96	64	0.10	0.111	100.677	0.067	1.035	0.616	0.371	0.319	2.451	1.203	1.827	1.362	0.465	5.751	**3.599**	**3.599**
19/08/2013 00:00	16.2	75	1018.37	182.29	0.10	0.00	231	22.5	9.9	16.19	94	55	0.10	0.117	101.837	0.068	1.035	0.626	0.361	0.323	2.724	1.219	1.971	1.322	0.649	6.380	**4.070**	**4.070**
20/08/2013 00:00	17.2	77	1022.43	110.98	0.11	2.41	232	22.0	12.5	17.21	97	57	0.11	0.124	102.243	0.068	1.037	0.638	0.349	0.335	2.637	1.445	2.041	1.452	0.589	3.884	**2.547**	**2.547**
21/08/2013 00:00	18.3	90	1017.80	118.16	0.12	0.80	233	22.4	14.3	18.32	100	80	0.12	0.132	101.780	0.068	1.040	0.652	0.334	0.366	2.701	1.629	2.165	1.895	0.270	4.136	**2.731**	**2.731**
22/08/2013 00:00	16.6	88	1016.58	105.26	0.06	0.00	234	21.0	12.3	16.63	100	76	0.06	0.120	101.658	0.068	1.022	0.635	0.357	0.199	2.485	1.427	1.956	1.658	0.298	3.684	**2.361**	**2.361**
23/08/2013 00:00	16.2	93	1011.72	70.29	0.07	6.23	235	19.5	13.0	16.22	100	85	0.07	0.118	101.172	0.067	1.025	0.630	0.361	0.230	2.264	1.494	1.879	1.709	0.170	2.460	**1.565**	**1.565**
24/08/2013 00:00	14.9	85	1014.89	116.81	0.07	0.20	236	20.3	9.6	14.93	100	70	0.07	0.109	101.489	0.067	1.024	0.613	0.378	0.218	2.379	1.194	1.786	1.430	0.357	4.088	**2.535**	**2.535**
25/08/2013 00:00	18.1	86	1019.50	118.43	0.06	0.20	237	23.4	12.9	18.14	100	72	0.06	0.131	101.950	0.068	1.020	0.654	0.339	0.179	2.873	1.489	2.181	1.779	0.402	4.145	**2.736**	**2.736**
26/08/2013 00:00	15.6	86	1021.59	81.46	0.06	0.00	238	18.7	12.5	15.59	95	76	0.06	0.113	102.159	0.068	1.020	0.621	0.372	0.182	2.155	1.448	1.801	1.507	0.295	2.851	**1.790**	**1.790**
27/08/2013 00:00	17.6	84	1021.42	155.01	0.07	0.00	239	25.2	10.1	17.63	97	71	0.07	0.127	102.142	0.068	1.022	0.647	0.346	0.204	3.202	1.234	2.218	1.735	0.483	5.426	**3.543**	**3.543**
28/08/2013 00:00	14.1	82	1022.84	120.42	0.07	0.00	240	20.4	7.7	14.09	100	63	0.07	0.104	102.284	0.068	1.025	0.599	0.391	0.235	2.403	1.054	1.728	1.284	0.445	4.215	**2.566**	**2.566**
29/08/2013 00:00	16.8	85	1018.32	109.24	0.11	0.20	241	21.7	12.0	16.83	96	73	0.11	0.122	101.832	0.068	1.036	0.634	0.353	0.331	2.588	1.403	1.996	1.618	0.377	3.823	**2.469**	**2.469**
30/08/2013 00:00	13.5	83	1017.12	93.83	0.12	0.60	242	20.9	6.1	13.53	97	68	0.12	0.101	101.712	0.068	1.040	0.589	0.395	0.372	2.476	0.944	1.710	1.300	0.410	3.284	**1.996**	**1.996**
31/08/2013 00:00	13.3	72	1027.70	178.27	0.10	0.60	243	20.8	5.8	13.34	86	58	0.10	0.100	102.770	0.068	1.033	0.586	0.401	0.307	2.461	0.925	1.693	1.111	0.582	6.239	**3.727**	**3.727**
01/09/2013 00:00	14.6	75	1028.23	110.74	0.13	0.00	244	18.6	10.6	14.64	85	64	0.13	0.108	102.823	0.068	1.044	0.601	0.382	0.406	2.147	1.282	1.714	1.232	0.483	3.876	**2.404**	**2.404**
02/09/2013 00:00	19.3	85	1025.71	117.45	0.13	0.00	245	25.4	13.2	19.33	96	73	0.13	0.140	102.571	0.068	1.044	0.662	0.324	0.397	3.250	1.519	2.385	1.916	0.469	4.111	**2.782**	**2.782**
03/09/2013 00:00	15.5	75	1024.47	177.51	0.11	0.00	246	23.1	7.9	15.51	94	55	0.11	0.113	102.447	0.068	1.036	0.616	0.371	0.330	2.832	1.065	1.948	1.279	0.669	6.213	**3.906**	**3.906**
04/09/2013 00:00	15.0	74	1016.26	171.81	0.10	0.20	247	24.2	5.8	15.02	95	52	0.10	0.110	101.626	0.068	1.034	0.611	0.376	0.311	3.027	0.922	1.975	1.225	0.750	6.013	**3.764**	**3.764**
05/09/2013 00:00	13.9	76	1014.31	156.44	0.06	1.41	248	21.3	6.6	13.93	100	51	0.06	0.103	101.431	0.067	1.022	0.600	0.392	0.199	2.525	0.975	1.750	1.131	0.619	5.475	**3.333**	**3.333**
06/09/2013 00:00	10.2	79	1013.30	148.19	0.06	1.81	249	20.6	-0.1	10.24	100	57	0.06	0.083	101.330	0.067	1.021	0.548	0.443	0.196	2.421	0.607	1.514	0.994	0.520	5.187	**2.888**	**2.888**
07/09/2013 00:00	9.2	94	1010.42	54.23	0.09	10.65	250	11.2	7.3	9.22	100	88	0.09	0.079	101.042	0.067	1.030	0.532	0.455	0.281	1.327	1.022	1.174	1.095	0.080	1.898	**1.019**	**1.019**
08/09/2013 00:00	11.7	84	1012.64	99.36	0.07	3.02	251	17.0	6.4	11.70	100	67	0.07	0.091	101.264	0.067	1.025	0.568	0.421	0.237	1.943	0.958	1.450	1.130	0.321	3.478	**2.008**	**2.008**
09/09/2013 00:00	11.6	84	1019.47	110.10	0.07	0.00	252	18.5	4.7	11.57	100	67	0.07	0.090	101.947	0.068	1.024	0.565	0.425	0.224	2.124	0.853	1.489	1.138	0.351	3.853	**2.211**	**2.211**
10/09/2013 00:00	13.9	83	1026.99	119.82	0.08	0.00	253	19.8	8.0	13.90	96	69	0.08	0.103	102.699	0.068	1.028	0.595	0.394	0.259	2.302	1.076	1.689	1.311	0.378	4.194	**2.533**	**2.533**
11/09/2013 00:00	14.8	90	1023.19	52.47	0.08	0.60	254	18.6	11.0	14.80	97	82	0.08	0.109	102.319	0.068	1.027	0.608	0.381	0.246	2.144	1.312	1.728	1.515	0.213	1.836	**1.137**	**1.137**
12/09/2013 00:00	13.2	95	1017.46	57.47	0.08	5.03	255	18.5	7.9	13.20	99	91	0.08	0.099	101.746	0.068	1.029	0.587	0.401	0.267	2.132	1.064	1.598	1.497	0.101	2.012	**1.192**	**1.192**
13/09/2013 00:00	9.7	85	1019.80	88.49	0.05	0.40	256	16.1	3.3	9.69	98	72	0.05	0.081	101.980	0.068	1.017	0.539	0.453	0.160	1.830	0.773	1.301	1.037	0.264	3.097	**1.690**	**1.690**
14/09/2013 00:00	11.4	79	1018.92	149.36	0.06	0.00	257	19.9	2.8	11.36	100	58	0.06	0.089	101.892	0.068	1.022	0.563	0.428	0.205	2.320	0.750	1.535	1.048	0.487	5.227	**2.984**	**2.984**
15/09/2013 00:00	10.5	81	1001.76	93.13	0.16	13.07	258	15.6	5.4	10.50	97	65	0.16	0.085	100.176	0.067	1.054	0.547	0.430	0.503	1.769	0.899	1.334	1.011	0.323	3.260	**1.852**	**1.852**
16/09/2013 00:00	9.1	79	1001.46	108.62	0.11	9.65	259	13.7	4.5	9.12	94	63	0.11	0.078	100.146	0.067	1.038	0.530	0.452	0.359	1.568	0.844	1.206	0.891	0.315	3.802	**2.068**	**2.068**
17/09/2013 00:00	10.2	89	997.97	62.13	0.08	4.42	260	13.1	7.3	10.18	98	79	0.08	0.083	99.797	0.066	1.028	0.549	0.438	0.263	1.506	1.022	1.264	1.095	0.168	2.174	**1.214**	**1.214**
18/09/2013 00:00	10.2	82	1006.18	115.42	0.08	0.00	261	16.2	4.3	10.23	99	64	0.08	0.083	100.618	0.067	1.028	0.548	0.440	0.259	1.838	0.831	1.334	0.999	0.335	4.040	**2.252**	**2.252**
19/09/2013 00:00	12.7	81	1006.32	98.60	0.11	8.24	262	17.6	7.8	12.67	97	65	0.11	0.096	100.632	0.067	1.037	0.581	0.404	0.342	2.010	1.056	1.533	1.165	0.368	3.451	**2.055**	**2.055**
20/09/2013 00:00	13.9	75	1015.84	122.80	0.10	0.00	263	19.5	8.3	13.86	87	62	0.10	0.103	101.584	0.068	1.033	0.596	0.391	0.303	2.261	1.092	1.677	1.176	0.501	4.298	**2.621**	**2.621**
21/09/2013 00:00	14.5	88	1018.72	62.95	0.10	0.20	264	19.8	9.3	14.55	97	78	0.10	0.107	101.872	0.068	1.035	0.604	0.383	0.319	2.314	1.168	1.741	1.469	0.272	2.203	**1.364**	**1.364**
22/09/2013 00:00	17.0	77	1024.19	71.24	0.09	0.00	265	22.1	11.9	17.02	90	63	0.09	0.123	102.419	0.068	1.031	0.636	0.353	0.281	2.665	1.393	2.029	1.466	0.563	2.493	**1.643**	**1.643**
23/09/2013 00:00	18.6	84	1021.08	138.29	0.07	0.00	266	25.9	11.4	18.62	97	71	0.07	0.134	102.108	0.068	1.024	0.659	0.333	0.216	3.332	1.347	2.339	1.836	0.503	4.840	**3.225**	**3.225**
24/09/2013 00:00	16.0	90	1014.66	45.87	0.06	0.20	267	18.6	13.4	16.00	98	82	0.06	0.116	101.466	0.067	1.020	0.628	0.365	0.179	2.144	1.535	1.840	1.632	0.208	1.606	**1.022**	**1.022**
25/09/2013 00:00	15.0	94	1011.84	30.99	0.05	0.00	268	16.8	13.2	15.01	98	89	0.05	0.110	101.184	0.067	1.017	0.616	0.377	0.160	1.911	1.520	1.716	1.595	0.120	1.085	**0.675**	**0.675**
26/09/2013 00:00	12.8	94	1014.21	19.91	0.07	0.00	269	14.2	11.5	12.81	98	90	0.07	0.097	101.421	0.067	1.024	0.584	0.406	0.218	1.615	1.353	1.484	1.390	0.094	0.697	**0.415**	**0.415**
27/09/2013 00:00	15.2	88	1012.96	77.81	0.06	0.00	270	21.9	8.5	15.22	99	77	0.06	0.111	101.296	0.067	1.021	0.618	0.374	0.190	2.628	1.112	1.870	1.562	0.308	2.723	**1.704**	**1.704**
28/09/2013 00:00	15.0	82	1008.48	100.50	0.06	0.00	271	22.7	7.4	15.03	98	65	0.06	0.110	100.848	0.067	1.022	0.616	0.376	0.198	2.756	1.028	1.892	1.399	0.492	3.517	**2.204**	**2.204**

29/09/2013 00:00	15.4	82	1006.79	92.76	0.07	0.00	272	20.6	10.2	15.39	90	74	0.07	0.112	100.679	0.067	1.024	0.621	0.370	0.223	2.427	1.243	1.835	1.457	0.378	3.247	2.046	2.046
30/09/2013 00:00	12.6	85	1004.12	24.65	0.08	0.00	273	15.6	9.6	12.61	93	76	0.08	0.096	100.412	0.067	1.026	0.583	0.406	0.241	1.772	1.196	1.484	1.230	0.255	0.863	0.528	0.528
01/10/2013 00:00	14.0	95	1003.13	39.18	0.10	0.00	274	15.8	12.1	13.95	98	92	0.10	0.103	100.313	0.067	1.034	0.600	0.387	0.310	1.795	1.412	1.604	1.518	0.086	1.371	0.833	0.833
02/10/2013 00:00	17.4	84	1000.93	79.56	0.12	0.00	275	21.4	13.5	17.45	97	70	0.12	0.126	100.093	0.067	1.039	0.645	0.341	0.357	2.550	1.545	2.048	1.642	0.406	2.785	1.846	1.846
03/10/2013 00:00	15.7	97	1000.16	25.97	0.09	0.00	276	16.8	14.7	15.75	99	94	0.09	0.114	100.016	0.067	1.031	0.625	0.363	0.287	1.917	1.668	1.793	1.727	0.066	0.909	0.575	0.575
04/10/2013 00:00	14.7	94	1006.11	76.29	0.06	1.21	277	18.5	10.8	14.68	100	87	0.06	0.108	100.611	0.067	1.022	0.612	0.380	0.201	2.132	1.299	1.716	1.577	0.139	2.670	1.645	1.645
05/10/2013 00:00	14.1	84	1017.39	90.14	0.09	0.00	278	19.1	9.1	14.12	99	68	0.09	0.104	101.739	0.068	1.032	0.599	0.388	0.292	2.215	1.157	1.686	1.326	0.360	3.155	1.932	1.932
06/10/2013 00:00	16.2	92	1018.96	66.66	0.12	1.61	279	19.5	12.9	16.21	99	85	0.12	0.117	101.896	0.068	1.041	0.625	0.360	0.376	2.264	1.491	1.877	1.700	0.177	2.333	1.482	1.482
07/10/2013 00:00	16.3	90	1017.19	52.57	0.14	3.62	280	18.8	13.7	16.25	99	80	0.14	0.118	101.719	0.068	1.047	0.624	0.359	0.430	2.169	1.569	1.869	1.644	0.225	1.840	1.184	1.184
08/10/2013 00:00	12.5	85	1022.81	70.04	0.09	0.20	281	16.0	9.0	12.52	99	71	0.09	0.095	102.281	0.068	1.029	0.576	0.412	0.269	1.819	1.150	1.485	1.215	0.270	2.452	1.443	1.443
09/10/2013 00:00	8.6	78	1024.01	78.15	0.11	0.20	282	12.9	4.3	8.57	97	59	0.11	0.076	102.401	0.068	1.036	0.517	0.466	0.339	1.485	0.829	1.157	0.840	0.317	2.735	1.465	1.465
10/10/2013 00:00	8.2	78	1028.77	110.91	0.08	0.00	283	14.7	1.7	8.21	96	59	0.08	0.074	102.877	0.068	1.027	0.513	0.474	0.250	1.671	0.693	1.182	0.825	0.356	3.882	2.034	2.034
11/10/2013 00:00	7.0	85	1030.12	116.76	0.06	0.00	284	16.4	-2.4	6.99	100	69	0.06	0.069	103.012	0.069	1.022	0.496	0.494	0.205	1.859	0.513	1.186	0.898	0.288	4.087	2.054	2.054
12/10/2013 00:00	8.3	88	1025.89	59.93	0.07	0.00	285	14.6	2.0	8.28	100	76	0.07	0.074	102.589	0.068	1.025	0.515	0.473	0.231	1.660	0.704	1.182	0.983	0.199	2.098	1.103	1.103
13/10/2013 00:00	8.9	88	1018.31	54.13	0.06	0.00	286	13.6	4.3	8.93	100	75	0.06	0.077	101.831	0.068	1.019	0.528	0.463	0.176	1.556	0.829	1.192	0.998	0.194	1.894	1.016	1.016
14/10/2013 00:00	9.2	81	1014.16	99.75	0.06	0.00	287	16.2	2.2	9.21	100	62	0.06	0.079	101.416	0.067	1.020	0.533	0.458	0.190	1.845	0.715	1.280	0.929	0.351	3.491	1.891	1.891
15/10/2013 00:00	8.9	87	1011.77	85.71	0.06	0.00	288	17.2	0.7	8.95	100	73	0.06	0.077	101.177	0.067	1.021	0.530	0.461	0.198	1.965	0.642	1.303	1.038	0.265	3.000	1.613	1.613
16/10/2013 00:00	8.3	94	1003.83	16.41	0.06	26.33	289	10.9	5.6	8.27	100	88	0.06	0.074	100.383	0.067	1.022	0.521	0.468	0.207	1.307	0.910	1.109	1.030	0.078	0.574	0.307	0.307
17/10/2013 00:00	12.1	90	1009.16	59.52	0.08	0.20	290	18.4	5.8	12.14	100	79	0.08	0.093	100.916	0.067	1.026	0.575	0.414	0.241	2.122	0.925	1.523	1.300	0.223	2.083	1.221	1.221
18/10/2013 00:00	10.3	94	1004.76	14.77	0.11	12.86	291	13.0	7.6	10.29	98	90	0.11	0.084	100.476	0.067	1.036	0.547	0.437	0.335	1.499	1.042	1.270	1.185	0.085	0.517	0.295	0.295
19/10/2013 00:00	12.8	89	995.58	59.42	0.08	1.81	292	17.3	8.3	12.83	97	81	0.08	0.097	99.558	0.066	1.026	0.588	0.401	0.244	1.979	1.097	1.538	1.333	0.204	2.080	1.243	1.243
20/10/2013 00:00	11.3	93	993.49	39.23	0.09	3.22	293	14.3	8.2	11.28	97	88	0.09	0.089	99.349	0.066	1.030	0.566	0.422	0.275	1.631	1.090	1.361	1.247	0.114	1.373	0.790	0.790
21/10/2013 00:00	11.5	97	993.36	21.10	0.07	13.07	294	13.9	9.1	11.50	98	95	0.07	0.090	99.336	0.066	1.025	0.570	0.419	0.231	1.584	1.159	1.372	1.320	0.051	0.739	0.426	0.426
22/10/2013 00:00	14.4	87	984.47	62.28	0.11	2.61	295	17.4	11.4	14.40	96	78	0.11	0.106	98.447	0.065	1.036	0.610	0.376	0.335	1.992	1.344	1.668	1.422	0.246	2.180	1.361	1.361
23/10/2013 00:00	8.1	84	994.64	74.39	0.10	2.61	296	12.5	3.7	8.12	98	70	0.10	0.074	99.464	0.066	1.034	0.518	0.466	0.323	1.449	0.799	1.124	0.899	0.225	2.604	1.383	1.383
24/10/2013 00:00	7.9	91	1007.67	69.35	0.06	0.40	297	17.0	-1.3	7.85	100	81	0.06	0.072	100.767	0.067	1.022	0.514	0.476	0.207	1.934	0.557	1.245	1.062	0.184	2.427	1.266	1.266
25/10/2013 00:00	14.2	88	994.74	76.31	0.11	11.06	298	17.8	10.6	14.17	98	77	0.11	0.105	99.474	0.066	1.037	0.604	0.382	0.339	2.033	1.276	1.654	1.408	0.247	2.671	1.646	1.646
26/10/2013 00:00	9.3	88	992.58	34.47	0.11	3.02	299	12.2	6.5	9.35	96	80	0.11	0.079	99.258	0.066	1.037	0.536	0.447	0.348	1.421	0.967	1.194	1.033	0.161	1.207	0.672	0.672
27/10/2013 00:00	10.1	82	982.38	52.46	0.16	4.42	300	13.6	6.6	10.05	92	71	0.16	0.083	98.238	0.065	1.053	0.545	0.432	0.494	1.553	0.971	1.262	0.998	0.264	1.836	1.058	1.058
28/10/2013 00:00	9.3	80	988.36	65.24	0.11	3.62	301	12.5	6.1	9.33	97	63	0.11	0.079	98.836	0.066	1.038	0.537	0.446	0.354	1.451	0.945	1.198	0.915	0.283	2.283	1.271	1.271
29/10/2013 00:00	6.7	90	1009.29	52.09	0.09	4.02	302	11.0	2.4	6.67	98	81	0.09	0.067	100.929	0.067	1.032	0.493	0.491	0.306	1.312	0.724	1.018	0.886	0.132	1.823	0.919	0.919
30/10/2013 00:00	5.9	91	1009.93	36.07	0.10	3.02	303	11.9	-0.2	5.86	97	84	0.10	0.064	100.993	0.067	1.034	0.480	0.502	0.325	1.392	0.604	0.998	0.877	0.120	1.262	0.626	0.626
31/10/2013 00:00	7.2	83	1007.70	54.22	0.14	0.80	304	11.9	2.6	7.22	95	71	0.14	0.070	100.770	0.067	1.047	0.498	0.479	0.442	1.390	0.735	1.062	0.843	0.220	1.898	0.992	0.992
01/11/2013 00:00	6.0	83	1004.41	68.78	0.10	0.00	305	12.5	-0.6	5.96	100	65	0.10	0.065	100.441	0.067	1.033	0.483	0.500	0.314	1.449	0.586	1.017	0.764	0.253	2.407	1.204	1.204
02/11/2013 00:00	3.8	89	988.53	35.62	0.11	6.03	306	10.0	-2.4	3.76	100	78	0.11	0.056	98.853	0.066	1.038	0.452	0.527	0.366	1.225	0.510	0.868	0.733	0.135	1.247	0.590	0.590
03/11/2013 00:00	4.0	83	995.00	72.75	0.09	2.81	307	11.1	-3.1	4.01	100	66	0.09	0.057	99.500	0.066	1.032	0.456	0.527	0.305	1.321	0.487	0.904	0.679	0.224	2.546	1.198	1.198
04/11/2013 00:00	3.6	89	994.64	67.84	0.06	0.20	308	11.5	-4.2	3.63	100	78	0.06	0.056	99.464	0.066	1.022	0.453	0.535	0.208	1.355	0.447	0.901	0.752	0.149	2.374	1.092	1.092
05/11/2013 00:00	4.9	92	991.70	29.11	0.08	5.03	309	7.3	2.6	4.91	100	83	0.08	0.061	99.170	0.066	1.029	0.472	0.514	0.271	1.020	0.735	0.877	0.791	0.087	1.019	0.493	0.493
06/11/2013 00:00	4.8	94	995.46	16.82	0.09	0.60	310	7.7	1.9	4.78	98	89	0.09	0.060	99.546	0.066	1.032	0.468	0.516	0.301	1.049	0.700	0.874	0.810	0.065	0.589	0.285	0.285
07/11/2013 00:00	4.8	85	999.54	45.97	0.13	1.81	311	10.2	-0.6	4.81	96	74	0.13	0.060	99.954	0.066	1.043	0.465	0.513	0.411	1.248	0.584	0.916	0.742	0.174	1.609	0.784	0.784
08/11/2013 00:00	3.9	84	1001.20	49.61	0.07	0.00	312	9.2	-1.4	3.91	95	73	0.07	0.057	100.120	0.067	1.024	0.455	0.532	0.234	1.167	0.551	0.859	0.687	0.171	1.736	0.811	0.811
09/11/2013 00:00	3.2	90	1002.38	38.88	0.07	2.41	313	7.7	-1.2	3.24	100	80	0.07	0.055	100.238	0.067	1.023	0.445	0.543	0.217	1.049	0.560	0.805	0.700	0.105	1.361	0.618	0.618
10/11/2013 00:00	3.0	89	1014.15	51.83	0.08	2.41	314	8.9	-3.0	2.98	100	78	0.08	0.054	101.415	0.067	1.028	0.437	0.548	0.265	1.143	0.491	0.817	0.691	0.126	1.814	0.810	0.810
11/11/2013 00:00	9.9	87	1015.01	28.95	0.11	3.42	315	12.7	7.0	9.85	98	76	0.11	0.082	101.501	0.067	1.037	0.538	0.445	0.344	1.471	1.001	1.236	1.049	0.186	1.013	0.574	0.574
12/11/2013 00:00	6.4	81	1027.04	58.08	0.09	0.00	316	10.4	2.3	6.39	95	67	0.09	0.066	102.704	0.068	1.031	0.485	0.500	0.290	1.265	0.723	0.994	0.767	0.227	2.033	1.019	1.019
13/11/2013 00:00	4.5	85	1024.32	18.62	0.14	2.21	317	8.6	0.4	4.49	96	74	0.14	0.059	102.432	0.068	1.047	0.453	0.523	0.444	1.117	0.627	0.872	0.715	0.158	0.652	0.332	0.332
14/11/2013 00:00	6.2	76	1028.97	30.01	0.11	2.41	318	8.5	4.0	6.23	86	65	0.11	0.066	102.897	0.068	1.036	0.481	0.501	0.341	1.110	0.811	0.960	0.709	0.251	1.050	0.548	0.548
15/11/2013 00:00	8.4	85	1033.41	29.97	0.09	0.00	319	10.5	6.2	8.37	88	81	0.09	0.075	103.341	0.069	1.032	0.513	0.472	0.302	1.270	0.951	1.110	0.933	0.178	1.049	0.563	0.563
16/11/2013 00:00	10.2	88	1029.14	27.72	0.11	0.00	320	12.8	7.6	10.20	98	77	0.11	0.083	102.914	0.068	1.039	0.539	0.443	0.363	1.473	1.047	1.260	1.080	0.180	0.970	0.552	0.552
17/11/2013 00:00	5.5	99	1021.87	11.36	0.05	7.24	321	9.1	1.8	5.48	100	97	0.05	0.063	102.187	0.068	1.018	0.476	0.515	0.168	1.157	0.698	0.928	0.910	0.017	0.398	0.191	0.191
18/11/2013 00:00	4.3	89	1013.37	41.97	0.07	1.61	322	8.9	-0.2	4.35	100	78	0.07	0.058	101.337	0.067	1.025	0.458	0.528	0.241	1.140	0.602	0.871	0.746	0.125	1.469	0.689	0.689
19/11/2013 00:00	2.6	88	1017.43	47.12	0.10	2.01	323	6.8	-1.6	2.62	100	75	0.10	0.053	101.743	0.068	1.035	0.428	0.552	0.338	0.990	0.544	0.767	0.643	0.124	1.649	0.730	0.730
20/11/2013 00:00	4.3	84	1008.98	30.84	0.14	5.43	324	6.7	1.9	4.28	97	71	0.14	0.058	100.898	0.067	1.046	0.454	0.522	0.441	0.981	0.699	0.840	0.687	0.153	1.080	0.525	0.525
21/11/2013 00:00	1.3	84	1016.83	44.99	0.09	0.00	325	7.8	-5.2	1.30	97	70	0.09	0.048	101.683	0.068	1.030	0.410	0.573	0.289	1.058	0.415	0.736	0.571	0.165	1.575	0.672	0.672
22/11/2013 00:00	0.0	87	1024.35	52.69	0.05	0.00	326	7.2	-7.2	-0.03	100	73	0.05	0.044	102.435	0.068	1.016	0.391	0.600	0.151	1.014	0.355	0.684	0.547	0.137	1.844	0.733	0.733
23/11/2013 00:00	4.2	96	1028.95	38.20	0.06	0.00	327	9.9	-1.6	4.15	100	91	0.06	0.058	102.895	0.068	1.020	0.453	0.536	0.195	1.223	0.542	0.882	0.827	0.055	1.337	0.611	0.611
24/11/2013 00:00	6.6	97	1034.99	18.04	0.04	0.40	328	8.5	4.6	6.55	100	94	0.04	0.067	103.499	0.069	1.015	0.489	0.503	0.142	1.109	0.849	0.979	0.946	0.033	0.631	0.311	0.311
25/11/2013 00:00	5.7	94	1040.38	17.46	0.06	0.00	329	7.6	3.8	5.72	100	87	0.06	0.064	104.038	0.069	1.020	0.474	0.516	0.185	1.045	0.803	0.924	0.856	0.068	0.611	0.296	0.296
26/11/2013 00:00	6.2	97	1039.94	13.90	0.09	0.00	330	7.8	4.7	6.25	100	93	0.09	0.066	103.994	0.069	1.030	0.480	0.505	0.284	1.055	0.856	0.956	0.919	0.037	0.487	0.239	0.239
27/11/2013 00:00	7.4	97	1037.00	14.05	0.08	0.00	331	9.4	5.4	7.37	100	93	0.08	0.070	103.700	0.069	1.026	0.499	0.489	0.245	1.177	0.895	1.036	0.995	0.041	0.492	0.250	0.250
28/11/2013 00:00	9.0	95	1036.08	14.09	0.07	0.80	332	10.2	7.7	8.98	98	91	0.07	0.077	103.608	0.069	1.025	0.523	0.465	0.230	1.245	1.054	1.150	1.083	0.067	0.493	0.265	0.265
29/11/2013 00:00	6.4	88	1029.84	14.37	0.11	0.80	333	8.2	4.7	6.41	100	75	0.11	0.066	102.984	0.068	1.036	0.483	0.499	0.345	1.084	0.853	0.968	0.833	0.135	0.503	0.266	0.266
30/11/2013 00:00	5.3	94	1032.32	31.87	0.07	0.20	334	9.4	1.1	5.26	100	88	0.07	0.062	103.232	0.069	1.024	0.468	0.519	0.228	1.179	0.662	0.921	0.850	0.071	1.116	0.531	0.531
01/12/2013 00:00	8.0	94	1034.19	17.99	0.06	0.40	335	10.3	5.8	8.02	100	88	0.06	0.073	103.419	0.069	1.020	0.510	0.480	0.189	1.252	0.919	1.086	1.011	0.075	0.629	0.328	0.328
02/12/2013 00:00	6.8	87	1031.41	16.23	0.09	0.00	336	7.8	5.8	6.83	94	80	0.09	0.068	103.141	0.069	1.030	0.491	0.494	0.283	1.060	0.924	0.992	0.858	0.134	0.568	0.297	0.297
03/12/2013 00:00	7.5	91	1025.62	9.64	0.11	0.80	337	9.3	5.6	7.47	95	86	0.11	0.071	102.562	0.068	1.038	0.500	0.482	0.362	1.175	0.910	1.042	0.937	0.105	0.338	0.187	0.187
04/12/2013 00:00	2.1	87	1030.07	32.71	0.08	1.01	338	6.3	-2.1	2.12	97	77	0.08	0.051	103.007	0.068	1.029	0.419	0.565	0.274	0.957	0.523	0.740	0.622	0.118	1.145	0.498	0.498
05/12/2013 00:00	3.9	77	1021.93	13.57	0.16	2.21	339	8.1	-0.3	3.92	92	61	0.16	0.057	102.193	0.068	1.056	0.442	0.528	0.535	1.079	0.600	0.839	0.605	0.234	0.475	0.276	0.276
06/12/2013 00:00	4.5	87	1027.13	15.86	0.09	2.01	340	8.8	0.1	4.46	98	76	0.09	0.059	102.713	0.068	1.029	0.456	0.529	0.277	1.135	0.615	0.875	0.733	0.142	0.555	0.274	0.274
07/12/2013 00:00	4.9	92	1022.07	16.69	0.12	0.20	341	8.2	1.7	4.91	96	87	0.12	0.061	102.207	0.068	1.041	0.461	0.518	0.394	1.085	0.688	0.886	0.802	0.084	0.584	0.286	0.286
08/12/2013 00:00	9.2	92	1017.41	3.83	0.18	2.21	342	11.0	7.4	9.23	97	86	0.18	0.079	101.741	0.068	1.063	0.522	0.450	0.587	1.314	1.033	1.173	1.066	0.107	0.134	0.098	0.098

09/12/2013 00:00	9.1	86	1020.33	20.92	0.16	0.00	343	11.1	7.2	9.12	94	78	0.16	0.078	102.033	0.068	1.054	0.522	0.454	0.503	1.317	1.015	1.166	0.991	0.175	0.732	**0.422**	**0.422**
10/12/2013 00:00	10.3	84	1018.98	19.19	0.15	0.00	344	12.1	8.6	10.31	90	78	0.15	0.084	101.898	0.068	1.050	0.541	0.437	0.466	1.408	1.114	1.261	1.051	0.211	0.672	**0.406**	**0.406**
11/12/2013 00:00	10.1	86	1017.84	19.45	0.14	0.00	345	12.0	8.1	10.06	90	81	0.14	0.083	101.784	0.068	1.048	0.538	0.441	0.448	1.401	1.082	1.242	1.054	0.187	0.681	**0.403**	**0.403**
12/12/2013 00:00	11.8	91	1011.05	6.24	0.15	1.81	346	13.7	10.0	11.84	98	83	0.15	0.092	101.105	0.067	1.050	0.565	0.414	0.464	1.568	1.226	1.397	1.252	0.146	0.218	**0.151**	**0.151**
13/12/2013 00:00	7.2	82	1007.88	31.04	0.16	3.42	347	12.6	1.9	7.23	94	70	0.16	0.070	100.788	0.067	1.055	0.497	0.477	0.519	1.455	0.701	1.078	0.839	0.239	1.086	**0.599**	**0.599**
14/12/2013 00:00	5.3	90	1004.93	5.75	0.17	12.26	348	10.5	0.2	5.33	97	83	0.17	0.062	100.493	0.067	1.059	0.468	0.503	0.558	1.268	0.619	0.944	0.827	0.117	0.201	**0.127**	**0.127**
15/12/2013 00:00	6.1	89	1004.75	20.28	0.15	3.62	349	10.6	1.6	6.08	98	79	0.15	0.065	100.475	0.067	1.050	0.481	0.494	0.472	1.274	0.686	0.980	0.839	0.141	0.710	**0.374**	**0.374**
16/12/2013 00:00	3.7	87	1008.55	24.81	0.15	2.01	350	6.7	0.7	3.71	93	80	0.15	0.056	100.855	0.067	1.050	0.444	0.530	0.483	0.982	0.643	0.812	0.692	0.121	0.868	**0.416**	**0.416**
17/12/2013 00:00	2.4	85	1013.57	26.43	0.13	0.60	351	7.4	-2.7	2.35	95	74	0.13	0.052	101.357	0.067	1.045	0.423	0.552	0.435	1.031	0.500	0.765	0.619	0.147	0.925	**0.426**	**0.426**
18/12/2013 00:00	7.0	87	987.26	10.98	0.21	16.3	352	10.4	3.7	7.02	99	74	0.21	0.069	98.726	0.066	1.070	0.495	0.472	0.660	1.258	0.795	1.026	0.859	0.168	0.384	**0.242**	**0.242**
19/12/2013 00:00	1.5	93	993.25	22.22	0.17	4.8	353	3.3	-0.3	1.47	100	85	0.17	0.049	99.325	0.066	1.059	0.411	0.556	0.568	0.773	0.596	0.684	0.626	0.058	0.778	**0.338**	**0.338**
20/12/2013 00:00	5.0	88	1002.63	7.97	0.19	4.9	354	9.6	0.4	5.01	97	79	0.19	0.061	100.263	0.067	1.065	0.462	0.505	0.620	1.196	0.629	0.913	0.778	0.135	0.279	**0.171**	**0.171**
21/12/2013 00:00	4.8	85	997.16	4.97	0.17	6.7	355	8.0	1.5	4.78	97	73	0.17	0.060	99.716	0.066	1.059	0.461	0.509	0.564	1.074	0.683	0.878	0.723	0.155	0.174	**0.125**	**0.125**
22/12/2013 00:00	1.6	92	999.01	20.52	0.17	3.3	356	3.2	0.0	1.62	98	85	0.17	0.049	99.901	0.066	1.057	0.413	0.556	0.546	0.769	0.612	0.691	0.627	0.064	0.718	**0.316**	**0.316**
23/12/2013 00:00	5.1	90	976.93	14.85	0.18	13.4	357	9.8	0.5	5.14	100	79	0.18	0.061	97.693	0.065	1.060	0.471	0.499	0.569	1.212	0.632	0.922	0.795	0.127	0.520	**0.281**	**0.281**
24/12/2013 00:00	2.5	91	962.57	11.29	0.21	10.1	358	4.8	0.3	2.52	100	82	0.21	0.052	96.257	0.064	1.071	0.432	0.530	0.680	0.860	0.622	0.741	0.664	0.077	0.395	**0.199**	**0.199**
25/12/2013 00:00	1.9	88	977.73	29.37	0.10	0	359	5.6	-1.9	1.86	97	78	0.10	0.050	97.773	0.065	1.033	0.427	0.555	0.316	0.911	0.531	0.721	0.613	0.108	1.028	**0.458**	**0.458**
26/12/2013 00:00	2.2	90	983.86	29.19	0.12	8.3	360	6.3	-1.9	2.18	100	80	0.12	0.051	98.386	0.065	1.042	0.428	0.549	0.406	0.954	0.530	0.742	0.647	0.095	1.022	**0.459**	**0.459**
27/12/2013 00:00	4.3	88	966.00	12.21	0.24	8.2	361	6.6	1.9	4.26	94	81	0.24	0.058	96.600	0.064	1.083	0.455	0.503	0.789	0.974	0.702	0.838	0.724	0.114	0.427	**0.240**	**0.240**
28/12/2013 00:00	2.1	89	992.77	23.11	0.13	0.6	362	4.2	0.1	2.14	95	83	0.13	0.051	99.277	0.066	1.045	0.425	0.551	0.429	0.824	0.615	0.720	0.634	0.085	0.809	**0.364**	**0.364**
29/12/2013 00:00	3.3	88	1004.29	24.14	0.14	8.7	363	8.6	-2.0	3.31	97	78	0.14	0.055	100.429	0.067	1.048	0.439	0.535	0.460	1.118	0.528	0.823	0.692	0.131	0.845	**0.403**	**0.403**
30/12/2013 00:00	5.3	91	997.33	26.16	0.10	14.3	364	8.2	2.5	5.31	100	81	0.10	0.062	99.733	0.066	1.032	0.475	0.508	0.309	1.084	0.730	0.907	0.804	0.103	0.916	**0.451**	**0.451**
31/12/2013 00:00	4.5	87	988.23	21.05	0.15	7.7	365	6.9	2.1	4.54	95	79	0.15	0.059	98.823	0.066	1.051	0.462	0.513	0.483	0.997	0.713	0.855	0.733	0.123	0.737	**0.370**	**0.370**
01/01/2014 00:00	3.2	93	978.54	7.20	0.11	3.2	1	5.3	1.1	3.20	100	86	0.11	0.054	97.854	0.065	1.038	0.446	0.533	0.365	0.894	0.660	0.777	0.714	0.063	0.252	**0.125**	**0.125**
02/01/2014 00:00	4.9	89	981.11	27.54	0.15	3.4	2	8.6	1.2	4.92	99	79	0.15	0.061	98.111	0.065	1.049	0.470	0.506	0.470	1.118	0.668	0.893	0.772	0.121	0.964	**0.481**	**0.481**
03/01/2014 00:00	4.8	82	974.07	20.89	0.24	9	3	6.1	3.6	4.82	96	68	0.24	0.060	97.407	0.065	1.080	0.463	0.498	0.763	0.939	0.789	0.864	0.698	0.166	0.731	**0.401**	**0.401**
04/01/2014 00:00	2.0	93	986.69	21.52	0.09	0.3	4	4.5	-0.4	2.03	100	85	0.09	0.051	98.669	0.066	1.032	0.428	0.555	0.303	0.840	0.593	0.716	0.653	0.063	0.753	**0.333**	**0.333**
05/01/2014 00:00	4.5	91	983.74	12.88	0.15	6	5	9.8	-0.7	4.53	97	84	0.15	0.059	98.374	0.065	1.050	0.463	0.512	0.478	1.212	0.579	0.895	0.790	0.106	0.451	**0.234**	**0.234**
06/01/2014 00:00	6.2	82	973.54	20.64	0.22	2.5	6	8.6	3.9	6.25	87	77	0.22	0.066	97.354	0.065	1.073	0.486	0.479	0.694	1.114	0.810	0.962	0.781	0.181	0.722	**0.411**	**0.411**
07/01/2014 00:00	6.7	88	987.25	21.21	0.20	2.7	7	8.4	5.1	6.74	95	81	0.20	0.068	98.725	0.066	1.067	0.492	0.477	0.632	1.099	0.879	0.989	0.863	0.126	0.743	**0.403**	**0.403**
08/01/2014 00:00	3.7	94	1005.06	26.95	0.09	0.4	8	6.8	0.5	3.68	100	88	0.09	0.056	100.506	0.067	1.032	0.449	0.534	0.302	0.991	0.635	0.813	0.753	0.059	0.943	**0.433**	**0.433**
09/01/2014 00:00	2.5	92	1005.40	38.40	0.09	0	9	6.6	-1.6	2.53	100	83	0.09	0.052	100.540	0.067	1.029	0.431	0.552	0.282	0.976	0.545	0.760	0.677	0.083	1.344	**0.593**	**0.593**
10/01/2014 00:00	3.7	95	1006.70	19.13	0.08	2	10	8.0	-0.6	3.71	100	89	0.08	0.056	100.670	0.067	1.029	0.449	0.535	0.276	1.076	0.584	0.830	0.771	0.059	0.670	**0.310**	**0.310**
11/01/2014 00:00	1.4	91	1016.56	38.24	0.08	1.7	11	5.5	-2.6	1.43	100	82	0.08	0.049	101.656	0.068	1.026	0.413	0.573	0.249	0.903	0.503	0.703	0.622	0.081	1.338	**0.564**	**0.564**
12/01/2014 00:00	3.5	89	1004.17	6.53	0.15	5.7	12	7.2	-0.2	3.53	100	78	0.15	0.056	100.417	0.067	1.052	0.442	0.531	0.497	1.017	0.604	0.811	0.699	0.112	0.229	**0.131**	**0.131**
13/01/2014 00:00	0.9	92	997.37	22.37	0.09	0.1	13	5.6	-3.9	0.87	100	84	0.09	0.047	99.737	0.066	1.030	0.407	0.575	0.293	0.908	0.459	0.684	0.611	0.073	0.783	**0.331**	**0.331**
14/01/2014 00:00	0.0	94	997.57	6.46	0.07	5.3	14	6.0	-6.0	0.00	98	89	0.07	0.044	99.757	0.066	1.023	0.396	0.591	0.218	0.935	0.390	0.663	0.607	0.055	0.226	**0.097**	**0.097**
15/01/2014 00:00	5.8	94	985.95	16.97	0.13	7	15	9.2	2.4	5.82	100	87	0.13	0.064	98.595	0.066	1.043	0.484	0.495	0.406	1.167	0.726	0.946	0.870	0.076	0.594	**0.303**	**0.303**
16/01/2014 00:00	5.0	90	979.65	27.74	0.09	0.3	16	8.3	1.8	5.05	95	85	0.09	0.061	97.965	0.065	1.030	0.477	0.508	0.284	1.093	0.697	0.895	0.795	0.099	0.971	**0.477**	**0.477**
17/01/2014 00:00	4.6	95	983.30	22.03	0.07	0.3	17	6.6	2.7	4.63	99	91	0.07	0.060	98.330	0.065	1.024	0.470	0.517	0.231	0.974	0.740	0.857	0.809	0.048	0.771	**0.368**	**0.368**
18/01/2014 00:00	3.3	97	985.44	9.35	0.06	2.8	18	4.7	1.9	3.31	100	93	0.06	0.055	98.544	0.066	1.021	0.450	0.538	0.206	0.856	0.700	0.778	0.748	0.030	0.327	**0.151**	**0.151**
19/01/2014 00:00	2.2	95	990.62	18.37	0.08	5	19	4.2	0.3	2.23	97	93	0.08	0.051	99.062	0.066	1.027	0.431	0.554	0.257	0.825	0.623	0.724	0.686	0.038	0.643	**0.283**	**0.283**
20/01/2014 00:00	3.8	88	1004.71	49.42	0.09	0.4	20	7.5	0.0	3.76	98	78	0.09	0.056	100.471	0.067	1.032	0.450	0.533	0.304	1.037	0.611	0.824	0.704	0.120	1.730	**0.798**	**0.798**
21/01/2014 00:00	5.5	92	997.25	12.84	0.14	5.2	21	8.3	2.8	5.54	97	86	0.14	0.063	99.725	0.066	1.048	0.475	0.501	0.459	1.094	0.746	0.920	0.832	0.088	0.450	**0.234**	**0.234**
22/01/2014 00:00	4.9	88	1001.77	30.18	0.11	0.2	22	8.7	1.2	4.91	95	80	0.11	0.061	100.177	0.067	1.038	0.467	0.514	0.364	1.122	0.664	0.893	0.764	0.129	1.056	**0.517**	**0.517**
23/01/2014 00:00	3.1	91	1010.17	16.17	0.12	2.6	23	5.2	1.0	3.09	97	85	0.12	0.054	101.017	0.067	1.042	0.436	0.541	0.402	0.882	0.657	0.770	0.694	0.076	0.566	**0.263**	**0.263**

APPENDIX E

SOAKAWAY

RESULTS

Site A

(Co. Kilkenny)

Sample ID	Depth	Date	Volume	COD	Ecoli	Total Coli	TN	NH_4	NO_3	NO_2	Kjeldahl N	PO_4	Cl	pH
S1.1	1.2	07/12/2011	50	45	40	18600	10.02	1.2	<2.0	0.03	6.79	0.1		8.3
S1.1	1.2	02/02/2012	20	2	< 50	> 120980	< 10	0.14	0.4	0.26	< 9.20	0.2	61	7.55
S1.1	1.2	22/02/2012	20	53	< 20	< 687	23	< 0.05	3.2	< 0.02	< 20	3	45	7.62
S1.1	1.2	15/03/2012	20	53	< 1	973	23	< 0.05	3.2	0.01	19.8	3	45	8.10
S1.1	1.2	11/04/2012												
S1.1	1.2	08/05/2012												
S1.1	1.2	30/05/2012												
S1.1	1.2	26/06/2012												
S1.1	1.2	17/07/2012												
S1.1	1.45	07/12/2011												
S1.1	1.45	02/02/2012	20	64	101	> 120980	< 10	0.38	0.4	0.06	< 9.16	0.13	0	7.62
S1.1	1.45	22/02/2012												
S1.1	1.45	15/03/2012	40	47.3	< 1	740	11	< 0.05	3.2	0.44	7.3	0.0	17	8.07
S1.1	1.45	11/04/2012												
S1.1	1.45	08/05/2012												
S1.1	1.45	30/05/2012												
S1.1	1.45	26/06/2012	250	12.7	< 1	> 24196	< 10	0.10	0.6	0.02	< 9.28	0.5	25	7.79
S1.1	1.45	17/07/2012	100	11.1	< 1	25.9	< 10	< 0.39	< 1.0	0.02	< 8.59	0.03	28	7.52
S1.1	1.8	07/12/2011	80	73	41	5475	19.6	0.5	1.4	0.06	17.64	< 1		8.35
S1.1	1.8	02/02/2012	400	13	20.2	1903.8	< 10	< 0.05	0.1	0.19	< 9.66	< 1.00	17	7.81
S1.1	1.8	22/02/2012	40	5	< 20	547.5	6	0.03	6.6	0.03	1	1.2	19	7.61
S1.1	1.8	15/03/2012	100	5	< 1	544.5	6	0.03	6.6	0.03	< 1	1.2	19	8.21
S1.1	1.8	11/04/2012	100	43.9	10	> 12098	11	0.28	7.6	< 0.02	3.12	<1.00	23	7.15
S1.1	1.8	08/05/2012	80	30.1	0	3715	24	< 0.05	4.1	< 0.02	19.83	0.10	44	8.02
S1.1	1.8	30/05/2012	30	44.4	< 1	104	2	0.04	1.3	0.03	1	< 1.0	34	8.12
S1.1	1.8	26/06/2012	250	4.5	< 1	4352	< 10	0.08	1.3	0.03	< 8.59	0.01	23	7.74
S1.1	1.8	17/07/2012	100	3.0	< 1	17329.0	< 10	< 0.16	2.5	< 0.03	< 7.31	0.32	36	7.49
S1.2	1.2	07/12/2011												
S1.2	1.2	02/02/2012	25	5	< 50.0	19841	11	0.11	3.7	0.26	6.93	0.34	61	7.71
S1.2	1.2	22/02/2012												
S1.2	1.2	15/03/2012												
S1.2	1.2	11/04/2012	50	35.5	0	452	20	1.27	4.5	0.04	15.5	<1.00	47	7.14
S1.2	1.2	08/05/2012	50	32.8	0	7415	18	0.6	5.5	0.05	11.9	< 1.00	44	7.94

S1.2	1.2	30/05/2012	50	53.6	< 1	40	< 10	0.05	0.3	< 0.02	< 9.63	< 1.0	44	8.08
S1.2	1.2	26/06/2012	50	19.8	< 1	> 24196	< 10	0.10	2.7	0.03	< 7.17	0.3	29	8.12
S1.2	1.2	17/07/2012	40	12.8	< 1	1553.0	3	0.19	< 1.0	0.02	1.79	0.36	24	7.94
S1.2	1.45	07/12/2011												
S1.2	1.45	02/02/2012	15	46	< 50.0	1066.5	< 10	< 0.05	4.6	0.09	< 5.26	0.44	67	7.72
S1.2	1.45	22/02/2012												
S1.2	1.45	15/03/2012	100	45.2	< 1	153	21	0.05	3.3	0.25	17.4	1.3	64	8.06
S1.2	1.45	11/04/2012												
S1.2	1.45	08/05/2012												
S1.2	1.45	30/05/2012												
S1.2	1.45	26/06/2012	300	4.7	< 1	3873	< 10	0.98	0.7	0.02	< 8.30	0.1	33	7.88
S1.2	1.45	17/07/2012	50	2.6	< 1	248.1	12	0.23	< 1.0	<0.02	10.75	< 1.00	30	8.03
S1.2	1.8	07/12/2011	100	35	0	213	3.52	1.4	0.8	0.06	1.26	< 1		8.36
S1.2	1.8	02/02/2012												
S1.2	1.8	22/02/2012												
S1.2	1.8	15/03/2012	150	36.6	< 1	50	31	0.05	2.6	0.05	28.3	0.8	27	8.23
S1.2	1.8	11/04/2012												
S1.2	1.8	08/05/2012												
S1.2	1.8	30/05/2012												
S1.2	1.8	26/06/2012	200	<4	< 1	345	< 10	0.22	0.7	0.01	< 9.07	0.8	19	8.02
S1.2	1.8	17/07/2012	150	6.4	< 1	88.4	< 10	0.13	< 1.0	<0.02	< 8.85	0.24	18	7.61
S2.1	1.2	07/12/2011	150	<10	30	100	11.1	0.3	2.2	0.03	8.57	< 1		7.15
S2.1	1.2	02/02/2012	800	31	< 10.0	143.5	10	0.59	9.1	0.27	0.04	0.1	57	7.51
S2.1	1.2	22/02/2012												
S2.1	1.2	15/03/2012	80	14.2	< 1	369	9	0.36	6.2	0.15	2.3	0.3	65	8.43
S2.1	1.2	11/04/2012												
S2.1	1.2	08/05/2012												
S2.1	1.2	30/05/2012												
S2.1	1.2	26/06/2012	250	36.2	< 1	> 24196	< 10	3.75	0.3	0.03	< 5.92	3.2	54	7.32
S2.1	1.2	17/07/2012	100	47.1	1	3255.0	< 10	6.9	< 1.0	<0.02	< 2.08	1.07	67	7.21
S2.1	1.45	07/12/2011	650	16	10	2481	4.2	2.3	1.8	0.05	0.05	0.46		7.3
S2.1	1.45	02/02/2012	900	25	< 10.0	96	12	3.19	8	0.72	0.09	1.32	54	7.63
S2.1	1.45	22/02/2012												
S2.1	1.45	15/03/2012	100	42	< 1	50	10	5.74	9.5	0.29	-5.5	3.5	68	8.78

S2.1	1.45	11/04/2012											
S2.1	1.45	08/05/2012	250	25.9	50	50	71	0.03	3.8	0.08	67.1	2.20	54	7.15
S2.1	1.45	30/05/2012	80	39.8	< 1	584	< 10	1.2	5.8	0.07	< 2.93	< 1.0	85	7.81
S2.1	1.45	26/06/2012	300	44.2	6.40	4352	< 10	3.26	3.3	0.14	< 3.30	5.6	52	7.04
S2.1	1.45	17/07/2012	80	46.6	2	579.4	< 10	5.15	< 1.0	<0.02	< 3.83	3.53	66	7.39
S2.1	1.8	07/12/2011	350	26	0	3252	2.42	1	1.4	0.01	0.01	< 1		7.34
S2.1	1.8	02/02/2012	300	3	< 10.0	210.9	< 10	3.13	2.4	0.26	< 4.21	< 1.00	72	7.61
S2.1	1.8	22/02/2012	200	13	< 20	< 29	5	3.88	< 1	0.03	< 0	<1	75	7.57
S2.1	1.8	15/03/2012	100	47.6	< 1	258	6	2.19	0.8	0.08	2.93	0.0	73	8.08
S2.1	1.8	11/04/2012	100	39.2	0	1141	41	0.58	29.8	0.3	10.3	0.15	98	7.56
S2.1	1.8	08/05/2012	200	22.5	0	0	58	3.61	14.3	0.39	39.7	1.40	118	7.14
S2.1	1.8	30/05/2012	30	49.1	< 1	6260	12	2.87	8.3	0.32	1	3.7	132	7.72
S2.1	1.8	26/06/2012	200	34.1	< 1	2755	< 10	3.21	4.9	0.05	< 1.84	3.27	51	6.92
S2.1	1.8	17/07/2012	200	48.6	< 1	24196.0	< 10	7.9	< 1.0	0.05	< 1.05	4.84	62	7.37
S2.2	1.2	07/12/2011	100	25	10	1600	13.92	<2.0	<2.0	0.01	9.91	5.14		7.48
S2.2	1.2	02/02/2012												
S2.2	1.2	22/02/2012												
S2.2	1.2	15/03/2012												
S2.2	1.2	11/04/2012												
S2.2	1.2	08/05/2012												
S2.2	1.2	30/05/2012												
S2.2	1.2	26/06/2012	120	7.7	< 1	9804	< 10	0.1	3.2	0.01	< 6.69	0.37	1	7.05
S2.2	1.2	17/07/2012	100	<4	2	759.8	3	0.16	< 1.0	<0.02	1.82	0.29	10	7.02
S2.2	1.45	07/12/2011	120	47	0	134	4.88	0.7	<2.0	0.04	2.14	5.72		7.63
S2.2	1.45	02/02/2012	50	<10	< 10.0	62.6	< 10	0.07	2.3	0.18	< 7.45	< 1.00	34	8.22
S2.2	1.45	22/02/2012												
S2.2	1.45	15/03/2012	250	11.6	< 1	789.5	25.1	0.00	2.5	0.01	22.6	0.1	34	8.08
S2.2	1.45	11/04/2012												
S2.2	1.45	08/05/2012	80	42.1	50	2815	9	3.94	8.3	0.15	-3.4	0.05	106	7.09
S2.2	1.45	30/05/2012	100	50.8	< 1	194	6	0.06	4.7	0.02	1	0.10	62	7.42
S2.2	1.45	26/06/2012	200	<4	< 1	> 24196	< 10	0.02	0.4	0.02	< 9.56	0.11	2	7.09
S2.2	1.45	17/07/2012	150	5.0	< 1	24196.0	4	0.05	< 1.0	<0.02	2.93	< 1.00	11	7.20
S2.2	1.8	07/12/2011	200	25	10	10	4.52	<2.0	<2.0	0.01	0.51	0.05		7.45
S2.2	1.8	02/02/2012	250	6	< 10.0	156.3	< 10	0.21	< 1	0.18	< 8.61	0.06	270	8.19

S2.2	1.8	22/02/2012	50	5	< 20	< 37	1	0.14	< 1	< 0.02	< 0	<1	210	8.21
S2.2	1.8	15/03/2012	200	21.5	1442.1	>120980	12	< 0.05	0.4	0.01	11.54	< 1.0	135	8.07
S2.2	1.8	11/04/2012												
S2.2	1.8	08/05/2012	150	32.6	50	805	6	0.01	4.1	0.05	1.8	0.02	38	7.16
S2.2	1.8	30/05/2012	80	50.0	< 1	506	11	< 0.0	< 1.0	0.01	10	< 1.0	50	7.44
S2.2	1.8	26/06/2012	300	28.6	< 1	> 24196	< 10	1.33	0.50	0.03	< 8.14	0.74	24	7.01
S2.2	1.8	17/07/2012	100	12.6	< 1	24196.0	< 10	< 1.3	< 1.0	<0.02	< 7.71	0.33	25	7.08
S3.1	1.2	07/12/2011												
S3.1	1.2	02/02/2012	300	74	20.2	1274	< 10	0.37	0.4	0.19	< 9.04	0.05	2960	7.5
S3.1	1.2	22/02/2012	200	53	< 20	1119.9	2	0.17	< 1	0.02	< 1	1.50	3260	7.44
S3.1	1.2	15/03/2012	350	14.6	< 1	4793	5	0.03	0.2	0.06	4.71	1.1	4550	7.89
S3.1	1.2	11/04/2012	500	23.9	0	1265	24	1.38	2.0	0.08	20.5	< 1.00	710	7.56
S3.1	1.2	08/05/2012												
S3.1	1.2	30/05/2012	100	49.8	< 1	25994	< 10	0.04	< 1.0	0.01	< 8.95	< 1.0	2550	7.31
S3.1	1.2	26/06/2012	500	4.6	2.10	650	< 10	0.74	0.70	0.04	< 8.52	0.40	2840	7.32
S3.1	1.2	17/07/2012	600	28.3	< 1	152.3	< 10	0.25	< 1.0	<0.02	< 8.73	0.02	1940	7.11
S3.1	1.45	07/12/2011												
S3.1	1.45	02/02/2012	600	87	9.9	> 24196	< 10	0.35	0.1	0.17	< 9.38	< 1.00	2330	7.4
S3.1	1.45	22/02/2012	150	61	< 20	> 2419.6	7	1.68	< 1	0.03	< 4	3.20	2360	7.45
S3.1	1.45	15/03/2012	250	9.4	< 1	7762.5	10	2.17	0.7		7.13	5.9	2820	8.06
S3.1	1.45	11/04/2012	150	38.3	0	277	4	1.18	< 1	0.02	1.8	0.26	2920	7.04
S3.1	1.45	08/05/2012	400	44.1	0	2050	3	0.1	1.0	0.08	1.8	0.01	2420	7.42
S3.1	1.45	30/05/2012	50	46.4	4	> 48392	< 10	0.25	< 1.0	0.07	< 8.68	0.1	2640	7.36
S3.1	1.45	26/06/2012	100	34.2	4.10	662	< 10	0	0.20	0.02	< 9.78	0.09	3220	7.29
S3.1	1.45	17/07/2012	150	<4	< 1	45.7	3	1.13	< 1.0	<0.02	0.85	0.15	3140	7.24
S3.2	1.2	07/12/2011												
S3.2	1.2	02/02/2012	250	65	20.1	> 24196	< 10	0.12	< 1	0.19	< 8.69	< 1.00	1250	7.44
S3.2	1.2	22/02/2012	500	183	< 20	> 2419.6	3	1.06	< 1	0.03	< 1	0.40	3540	7.01
S3.2	1.2	15/03/2012	1000	28.4	< 1	278	13	0.09	< 1	0.03	11.88	1.1	4660	7.36
S3.2	1.2	11/04/2012	1000	11.9	3.1	812	5	1.35	0.1	0.03	3.52	0.73	3000	7.18
S3.2	1.2	08/05/2012	1000	17.3	0	255	15	0.66	0.2	0.09	14.1	0.71	2610	7.04
S3.2	1.2	30/05/2012	850	44.9	< 1	14540	4	1.36	< 1.0	0.07	2	< 1.0	2590	7.09
S3.2	1.2	26/06/2012	1000	<4	9.80	11196	< 10	1.40	0.30	0.01	< 8.29	0.41	3100	7.1
S3.2	1.2	17/07/2012	900	<4	< 1	23.5	< 10	1.55	< 1.0	<0.02	< 7.43	0.35	3060	7.10

S3.2	1.45	07/12/2011													
S3.2	1.45	02/02/2012	250	52	9.9	5172.1	< 10	0.03	< 1	0.18	< 8.79	0.1	1870	7.41
S3.2	1.45	22/02/2012	300	65	< 20	204.6	2	< 0.05	< 1	0.01	< 1	<1	1870	7.23
S3.2	1.45	15/03/2012	1000	9.9	< 1	1698	7	0.41	0.0	0.02	6.57	0.3	2900	7.38
S3.2	1.45	11/04/2012	1000	39.1	1	185	2	0.35	< 1	0.01	0.6	0.82	3040	7.04
S3.2	1.45	08/05/2012	1100	26.3	0	50	4	2.61	1.7	0.04	-0.4	0.40	2590	7.17
S3.2	1.45	30/05/2012	1000	44.0	< 1	386	5	0.04	< 1.0	0.03	4	< 1.0	2610	7.15
S3.2	1.45	26/06/2012	900	5.3	< 1	108	< 10	0.19	1.10	0.04	< 8.67	< 1.00	2800	7.09
S3.2	1.45	17/07/2012	900	37.2	< 1	275.5	6	0.53	< 1.0	<0.02	4.45	0.02	3120	7.14
S3.2	1.8	07/12/2011													
S3.2	1.8	02/02/2012	1000	44	< 10.0	> 24196	< 10	< 0.05	0.2	0.18	< 9.57	< 1.00	2010	7.46
S3.2	1.8	22/02/2012	1000	<10	< 20	> 2419.6	1	< 0.05	< 1	0.02	< 0	<1	2160	7.31
S3.2	1.8	15/03/2012	1100	3	< 1	3891	17	< 0.05	0.2	0.01	16.74	0.5	3400	7.25
S3.2	1.8	11/04/2012	1000	10.2	0	1724	2	0.33	< 1	0.1	0.57	0.19	2880	7.08
S3.2	1.8	08/05/2012	1100	44	0	1065	12	0.16	0.2	0.02	11.6	< 1.00	2370	7.08
S3.2	1.8	30/05/2012	1000	44.2	< 1	40	2	0.05	1.4	0.05	1	< 1.0	2750	7.14
S3.2	1.8	26/06/2012	1000	24.0	8.40	480	< 10	0.26	1.10	0.09	< 8.55	< 1.00	3360	7.11
S3.2	1.8	17/07/2012	1000	11.1	< 1	365.4	12	0.29	0.5	0.03	11.18	< 1.00	3100	7.09

Site B

(Co. Monaghan)

Sample ID	Date	Volume ml	COD mg/l	E-Coli per 100ml	Total Coli per 100ml	TN mg/l	NH_4 mg/l	NO_3 mg/l	NO_2 mg/l	Kjeldahl N (organic N)	PO_4 mg/l	Cl mg/l	pH
S1.1	29/11/2011	500	< 10	10	43520	2.96	0.1	0.8	0.02	2.0	20.25		7.25
S1.1	25/01/2012	500	< 10	< 10	638.2	87	0.36	< 1.00	0.03	85.61	> 10.00	3	7.54
S1.1	15/02/2012	350	4	< 20	690.2	< 10	0.02	< 1	0.01	8.97	< 1	3	7.07
S1.1	06/03/2012	280	12	< 2	4	3	< 0.05	0.7	0.06	2.19	< 0.05	5	7.29
S1.1	28/03/2012	250	0.7	2	144.9	8	0.03	1.00	0.03	6.94	0.63	9	7.35
S1.1	17/04/2012	-	-	-	-	-	-	-	-	-	-	-	-
S1.1	15/05/2012	300	3.1	< 1	< 1	6	< 0.05	0.50	< 0.02	5.43	0.02	9	7.02
S1.1	19/06/2012	250	21	< 1	41.9	7	<0.05	0.90	0.01	6.04	0.10	8	7.15
S1.1	10/07/2012	250	8	9.7	> 24196	< 10	0.42	1.00	0.25	8.33	1.60	31	7.11
S1.1	09/08/2012	250	22	< 1	19863	22.7	0.83	< 1	0.04	20.8	0.15	11	7.05
S1.1	29/11/2011	500	< 10	5	2950	32.8	0.08	2.2	0.01	30.5	< 0.25		7.46
S1.1	25/01/2012	200	< 10	< 10	230.7	83	0.27	1.50	0.08	81.15	> 10.00	9	7.65
S1.1	15/02/2012	300	22	< 20	20	4	< 0.05	< 1	0.01	2.94	< 1	2	7.03
S1.1	06/03/2012	250	100	< 2	40	41	< 0.05	< 1	0.04	39.91	< 0.05	9	7.3
S1.1	28/03/2012	200	5.6	< 1.0	186.9	29	0.11	0.10	0.06	28.73	0.10	10	7.5
S1.1	17/04/2012	200	4	< 1	1634	5	< 0.05	1.20	0.20	3.55	0.02	19	7
S1.1	15/05/2012	250	3.5	< 1	1	3	2.12	0.09	< 0.02	0.77	0.01	8	7.09
S1.1	19/06/2012	250	15	< 1	579.4	2	0.07	0.60	0.02	1.31	0.60	14	7.17
S1.1	10/07/2012	200	3	0	20	2	0.12	< 1	0.21	0.67	0.23	6	7.21
S1.1	09/08/2012	250	91	< 1	24196	11.4	0.09	< 1	0.01	10.3	0.12	9	7.03
S1.1	29/11/2011	150	< 10	5	29090	9.8	0.44	0.8	0.02	8.5	7.15		8
S1.1	25/01/2012	50	< 10	51.6	1211.2	94	0.33	1.30	0.05	92.32	> 10.00	21	7.82
S1.1	15/02/2012	230	14	< 20	< 20.0	9	< 0.05	< 1	0.01	7.94	< 1	4	7.15
S1.1	06/03/2012	200	2	2	103	11	0.02	0.2	0.03	10.75	< 0.05	4	7.53
S1.1	28/03/2012	200	3.7	12.5	451	4	< 0.05	1.90	0.04	2.01	0.29	<10	7.32
S1.1	17/04/2012	200	2	1.0	5099	< 10	< 0.05	0.20	< 0.02	9.73	0.07	18	7.15

S1.1	15/05/2012	200	9.9	< 1	2	5	3.05	< 1	< 0.02	0.93	0.02	12	7.26
S1.1	19/06/2012	200	16	< 1	648.8	< 10	0.05	0.80	0.01	9.14	0.40	11	7.55
S1.1	10/07/2012	100	< 10	0	5172	< 10	< 0.05	< 1	0.21	8.74	1.41	8	7.87
S1.1	09/08/2012	200	48	< 1	4352	8.2	< 0.05	< 1	0.01	7.1	0.18	10	7.77
S1.2	29/11/2011	35	< 10	0	85.5	6.76	0.37	1.4	0.02	5.0	>25		8.1
S1.2	25/01/2012	30	< 10	< 10	20.2	109	0.32	1.20	0.06	107.42	> 10.00	0	8.01
S1.2	15/02/2012	175	< 10	< 20	81.8	< 10	< 0.05	< 1	< 0.02	8.93	< 1	3	7.62
S1.2	06/03/2012	200	<10	< 2	6	4	0.04	< 1	0.03	2.93	0.04	5	7.79
S1.2	28/03/2012	3	*only enough sample for Cl⁻*									9	
S1.2	17/04/2012	300	4	< 1	811	1	< 0.05	0.06	< 0.02	0.87	0.08	18	7.62
S1.2	15/05/2012	60	27.2	< 1	4.1	< 10	3.26	< 1	< 0.02	5.72	0.03	7	8.27
S1.2	19/06/2012	100	34	< 1	4884	4	0.14	3.50	0.02	0.34	0.60	6	7.93
S1.2	10/07/2012	80	6	5	461.1	< 10	0.06	1.40	0.01	8.53	1.74	5	7.86
S1.2	09/08/2012	50	< 10	< 1	180	14.7	0.67	< 1	< 0.02	13.0	0.29	8	7.4
S1.2	29/11/2011	160	< 10	0	14390	17.9	0.52	0.4	0.02	17.0	0.1		7.64
S1.2	25/01/2012	30	< 10	< 10	1316.9	95	0.33	1.60	0.05	93.02	> 10.00	44	7.87
S1.2	15/02/2012	200	< 10	< 20	20	< 10	< 0.05	< 1	< 0.02	8.93	< 1	2	7.65
S1.2	06/03/2012	200	11	< 2	61	5	< 0.05	< 1	0.03	3.92	0.33	4	7.82
S1.2	28/03/2012	150	13.6	40.2	326.7	4	0.01	0	0.03	3.96	0.37	8	7.38
S1.2	17/04/2012	150	9.9	< 1	2279	< 10	< 0.05	0.60	< 0.02	9.33	0.08	17	7.64
S1.2	15/05/2012	200	34.7	< 1	< 1	< 10	3.61	1.20	< 0.02	5.17	0.03	6	7.28
S1.2	19/06/2012	150	56	< 1	1413.6	4	0.04	0.10	0.01	3.85	0.50	5	7.81
S1.2	10/07/2012	100	< 10	0	1119.9	< 10	< 0.05	< 1	0.21	8.74	0.04	3	7.82
S1.2	09/08/2012	100	8	< 1	29.2	25.7	< 0.05	1.00	< 0.02	24.6	0.14	8	7.77
S1.2	29/11/2011	900	< 10	0	16640	21.6	0.1	1.0	0.02	20.5	0.05		7.51
S1.2	25/01/2012	500	< 10	< 10	52.1	87	0.28	0.70	0.04	85.98	13.04	0	7.77
S1.2	15/02/2012	1100	< 10	< 20	20	1	0.01	0.50	< 0.02	0.47	< 1	3	7.59

S1.2	06/03/2012	1000	<10	< 2	20	7	0.01	0.4	0.07	6.52	0.06	6	7.31
S1.2	28/03/2012	600	5.5	1	96.9	14	0.00	0	0.01	13.99	0.20	7	7.88
S1.2	17/04/2012	600	<4	< 1	1299.7	< 10	< 0.05	< 1	< 0.02	8.93	0.02	17	7.62
S1.2	15/05/2012	900	0.3	< 1	1	7	3.57	< 1	< 0.02	2.41	< 1	15	7.27
S1.2	19/06/2012	400	8	< 1	59.1	2	<0.05	0.80	0.00	1.15	1.00	9	7.64
S1.2	10/07/2012	500	< 10	0	307.6	3	< 0.05	1.00	0.01	1.94	1.38	2	7.81
S1.2	09/08/2012	1000	44	< 1	307.6	26.8	< 0.05	0.10	< 0.02	26.6	0.21	4	7.14

S2.1	29/11/2011	0											
S2.1	25/01/2012	50	< 10	< 10	573.1	93	0.54	1.80	0.15	90.51	> 10.00	140	8.15
S2.1	15/02/2012	60	66	< 20	< 20.0	5	0.05	5.50	0.01	-0.56	< 1	55	7.8
S2.1	06/03/2012	50	62	< 20	265	19	0.13	6.6	0.08	12.19	0.77	67	7.7
S2.1	28/03/2012	0											
S2.1	17/04/2012	0											
S2.1	15/05/2012	0											
S2.1	19/06/2012	0											
S2.1	10/07/2012	0											
S2.1	09/08/2012	0											

S2.1	29/11/2011	250	63	0	13540	12	1.9	2.6	0.02	7.5	>25		7.34
S2.1	25/01/2012	400	< 10	< 10	30.6	92	0.96	1.20	0.04	89.80	> 10.00	> 250	7.81
S2.1	15/02/2012	80	25	< 20	< 20.0	< 10	0.61	< 1	0.03	8.36	< 1	675	7.64
S2.1	06/03/2012	250	20	< 2	20	6	0.28	< 1	0.04	4.68	0.02	625	7.71
S2.1	28/03/2012	180	29.1	< 1.0	184.9	< 10	0.17	0.10	0.09	9.64	0.70	675	7.97
S2.1	17/04/2012	180	20.9	< 1	3681	< 10	0.16	< 1	< 0.02	8.82	0.07	610	7.76
S2.1	15/05/2012	500	8.3	< 1	< 1	3	0.25	< 1	< 0.02	1.73	0.40	660	7.60
S2.1	19/06/2012	250	52	< 1	175	1	0.43	0.20	0.03	0.34	1.50	400	7.51
S2.1	10/07/2012	200	< 10	3.1	12033	< 10	< 0.05	1.20	< 0.02	8.73	0.08	348	7.40
S2.1	09/08/2012	230	60	< 1	214.3	13.5	0.29	0.50	< 0.02	12.7	0.25	630	7.4

S2.1	29/11/2011	300	< 10	5	36540	-	0.05	1.2	0.07	-	8.75		7.31
S2.1	25/01/2012	400	< 10	10	2105.2	103	0.91	0.90	0.03	101.16	> 10.00	> 250	7.36
S2.1	15/02/2012	900	31	< 20	< 20.0	< 10	0.86	< 1	0.02	8.12	< 1	352	7.45
S2.1	06/03/2012	250	<10	< 2	< 2	3	1.13	< 1	0.08	0.79	0.04	354	7.63
S2.1	28/03/2012	250	34.2	< 1.0	96.9	< 10	1.19	< 1	0.03	7.78	0.05	425	7.51
S2.1	17/04/2012	250	25.9	< 1	5717	< 10	1.07	< 1	< 0.02	7.91	0.02	365	7.95
S2.1	15/05/2012	400	<4	< 1	< 1	2	0.78	< 0	< 0.02	0.90	< 1	395	7.63
S2.1	19/06/2012	300	42	< 1	410.6	< 10	0.72	0.10	0.05	9.13	1.70	460	7.53
S2.1	10/07/2012	250	< 10	1	248.1	2	0.03	0.40	0.22	1.35	0.10	295	7.15
S2.1	09/08/2012	250	72	< 1	15.6	54.8	0.59	< 1	< 0.02	53.2	0.27	570	7.22
S2.2	29/11/2011	400	< 10	5	111990	1.96	0.16	0.6	0.02	1.2	0.15		7.07
S2.2	25/01/2012	300	< 10	< 10	62	93	0.3	1.10	0.40	91.20	> 10.00	24	7.52
S2.2	15/02/2012	500	< 10	< 20	< 20.0	3	< 0.05	< 1	0.02	1.93	< 1	23	7.04
S2.2	06/03/2012	500	<10	< 2	20	3	< 0.05	< 1	0.02	1.93	< 0.05	18	7.8
S2.2	28/03/2012	500	4	< 1.0	121.1	13	< 0.05	< 1	0.01	11.94	0.10	23	7.5
S2.2	17/04/2012	500	18.5	< 1	14136	< 10	< 0.05	< 1	< 0.02	8.93	0.07	25	7.67
S2.2	15/05/2012	500	1.7	< 1	2	4	3.87	< 1	< 0.02	-0.89	< 1	32	7.38
S2.2	19/06/2012	350	19	< 1	770.1	< 10	<0.05	< 1	0.00	8.95	< 1	23	7.61
S2.2	10/07/2012	300	< 10	2	3076	< 10	0.04	0.10	< 0.02	9.84	0.31	16	7.26
S2.2	09/08/2012	600	47	1	172	16.0	0.69	0.30	< 0.02	15.0	0.07	10	7.17
S2.2	29/11/2011	200	< 10	0	24890	15.6	0.15	1.2	0.03	14.2	18.5		7.01
S2.2	25/01/2012	300	< 10	< 10	135	97	0.3	1.30	0.06	95.34	4.88	26	7.53
S2.2	15/02/2012	1000	7	< 20	20	< 10	0.03	< 1	< 0.02	8.95	< 1	8	7.02
S2.2	06/03/2012	1000	<10	< 2	< 2	14	< 0.05	< 1	0.04	12.91	< 0.05	6	7.5
S2.2	28/03/2012	800	10.4	< 1.0	20.2	3	0.04	< 1	0.01	1.95	0.25	12	7.47
S2.2	17/04/2012	800	<4	< 1	3877	1	< 0.05	0.50	< 0.02	0.43	0.01	21	7.62
S2.2	15/05/2012	600	5.8	< 1	1	< 10	2.24	< 1	< 0.02	6.74	0.02	26	7.76
S2.2	19/06/2012	300	82	< 1	109	< 10	<0.05	< 1	0.01	8.94	< 1	10	7.49

S2.2	10/07/2012	400	< 10	8.5	2339	< 10	0.36	1.70	0.26	7.68	1.45	8	7.29
S2.2	09/08/2012	500	19	< 1	61.3	16.8	0.05	< 1	< 0.02	15.7	0.17	9	7.06
S2.2	29/11/2011	400	< 10	10	2180	21.9	0.07	1.6	0.01	20.2	>25		6.8
S2.2	25/01/2012	500	< 10	< 10	419.5	88	0.31	1.60	0.04	86.05	11.34	3	7.71
S2.2	15/02/2012	450	8	< 20	40.4	< 10	< 0.05	< 1	< 0.02	8.93	< 1	7	7.18
S2.2	06/03/2012	400	12	< 2	20	7	0.03	< 1	0.03	5.94	< 0.05	6	7.44
S2.2	28/03/2012	450	6.8	1	62.6	3	0.00	< 1	0.01	1.99	0.05	8	7.54
S2.2	17/04/2012	450	<4	1.0	4541	< 10	< 0.05	0.40	< 0.02	9.53	0.08	18	7.66
S2.2	15/05/2012	400	3.8	< 1	1	< 10	2.39	< 1	< 0.02	6.59	0.06	25	7.29
S2.2	19/06/2012	400	44	1	93.3	2	0.07	< 1	0.00	0.93	< 1	11	7.5
S2.2	10/07/2012	300	< 10	43.2	387.3	4	0.76	< 1	0.04	2.20	1.66	10	7.24
S2.2	09/08/2012	600	83	< 1	1299.7	35.6	0.07	0.10	< 0.02	35.4	0.05	10	7.14
S3.1	29/11/2011	250	< 10	15	2500	21.2	0.13	0.8	< 0.02	20.3	0.10		7.41
S3.1	25/01/2012	250	< 10	10	1401.2	89	0.32	1.40	0.08	87.20	> 10.00	34	7.68
S3.1	15/02/2012	300	23	< 20	20	< 10	< 0.05	0.30	0.02	9.63	< 1	24	7.42
S3.1	06/03/2012	300	<10	20	40	11	< 0.05	< 1	0.04	9.91	0.22	28	7.49
S3.1	28/03/2012	350	12.4	2	20.1	4	0.01	< 1	0.02	2.97	0.24	33	7.5
S3.1	17/04/2012	350	17.4	< 1	4225	< 10	< 0.05	0.60	< 0.02	9.33	0.00	40	7.62
S3.1	15/05/2012	900	<4	< 1	< 1	7	3.69	< 1	< 0.02	2.29	0.02	18	6.92
S3.1	19/06/2012	250	32	1	770.1	< 10	<0.05	< 1	0.00	8.95	0.50	50	7.55
S3.1	10/07/2012	300	< 10	0	307.6	< 10	0.05	0.02	0.21	9.72	5.52	92	7.29
S3.1	09/08/2012	600	50	< 1	55.4	48.9	0.06	< 1	< 0.02	47.8	0.14	8	7.11
S3.1	29/11/2011	200	< 10	15	520	-	0.22	1.2	0.01	-	< 0.25		7.38
S3.1	25/01/2012	170	< 10	20.2	8608	86	0.29	0.10	0.05	85.56	> 10.00	1	7.64
S3.1	15/02/2012	300	35	< 20	456.2	< 10	< 0.05	< 1	0.02	8.93	< 1	17	7.38
S3.1	06/03/2012	300	136	61	1961	5	< 0.05	< 1	0.02	3.93	0.17	19	7.2
S3.1	28/03/2012	250	12.7	6.1	2281.8	4	< 0.05	0	0.02	3.93	1.10	28	7.38

S3.1	17/04/2012	250	1.8	3.1	579.4	1	< 0.05	0.30	< 0.02	0.63	0.11	37	7.67
S3.1	15/05/2012	500	25.8	< 1	13.2	10	2.81	1.10	< 0.02	6.07	0.08	14	7.25
S3.1	19/06/2012	400	41	2	501.2	< 10	<0.05	< 1	0.01	8.94	0.30	66	7.39
S3.1	10/07/2012	250	< 10	7.5	1872	2	0.02	1.10	0.21	0.67	1.42	47	7.28
S3.1	09/08/2012	700	17	1	770.1	13.9	1.29	0.30	< 0.02	12.3	0.08	102	7.09
S3.1	29/11/2011	80	< 10	15	21870	11	0.33	2.2	0.01	8.5	< 0.25		7.97
S3.1	25/01/2012	30	< 10	9.9	2909.3	102	0.32	1.30	0.06	100.32	12.38	13	7.58
S3.1	15/02/2012	180	5	< 20	82.6	< 10	0.01	< 1	< 0.02	8.97	< 1	3	7.65
S3.1	06/03/2012	180	240	< 2	146	2	0.04	< 1	0.02	0.94	< 0.05	9	7.46
S3.1	28/03/2012	150	29.6	1	196.7	3	0.00	< 1	0.01	1.99	0.21	5	7.39
S3.1	17/04/2012	150	<4	< 1	9294	1	< 0.05	0.05	< 0.02	0.88	0.03	19	7.78
S3.1	15/05/2012	200	42.9	< 1	2	3	2.14	0.80	< 0.02	0.04	0.11	38	7.70
S3.1	19/06/2012	350	56	< 1	1413.6	< 10	<0.05	1.60	0.01	8.34	0.40	6	7.72
S3.1	10/07/2012	250	< 10	3.1	> 24196	< 10	0.04	0.90	0.22	8.84	1.79	4	7.14
S3.1	09/08/2012	1000	66	< 1	2282	26.7	0.08	1.00	< 0.02	25.6	0.17	119	7.81
S3.2	29/11/2011	250	< 10	0	5460	5.17	0.53	1.0	< 0.02	3.6	< 0.25		7.22
S3.2	25/01/2012	900	< 10	10	1160.2	92	0.29	2.00	0.05	89.66	7.12	79	7.41
S3.2	15/02/2012	1000	< 10	< 20	40.4	< 10	< 0.05	0.10	< 0.02	9.83	< 1	71	7.17
S3.2	06/03/2012	1000	<10	40	288	12	< 0.05	< 1	0.05	10.90	0.10	64	7.59
S3.2	28/03/2012	1000	11	< 1.0	437.1	6	0.01	< 1	0.01	4.98	0.26	82	7.4
S3.2	17/04/2012	1000	<4	2.0	1046.2	< 10	< 0.05	0.50	< 0.02	9.43	0.06	88	7.61
S3.2	15/05/2012	900	0.3	< 1	14.4	7	1.67	< 1	< 0.02	4.31	0.03	27	6.92
S3.2	19/06/2012	600	38	< 1	66.3	< 10	<0.05	< 1	0.01	8.94	0.10	132	7.15
S3.2	10/07/2012	500	< 10	0	325.5	< 10	0.04	< 1	< 0.02	8.94	0.01	118	6.87
S3.2	09/08/2012	500	36	< 1	> 2419.6	18.1	< 0.05	< 1	< 0.02	17.0	0.15	130	6.74
S3.2	29/11/2011	1000	< 10	2560	>241960	4.82	0.86	1.2	0.01	2.8	0.25		7.35
S3.2	25/01/2012	650	< 10	137.9	120978.5	86	0.3	1.90	0.07	83.73	4.04	105	7.36

S3.2	15/02/2012	1100	< 10	< 20	15830.6	< 10	0.08	< 1	0.05	8.87	< 1	58	7.16
S3.2	06/03/2012	1000	12	170	1733	11	< 0.05	< 1	0.04	9.91	0.02	76	7.35
S3.2	28/03/2012	900	13.4	5	1334.4	< 10	0.03	0.10	0.02	9.85	1.21	77	7.39
S3.2	17/04/2012	900	<4	50.4	> 24196	58	< 0.05	15.40	< 0.02	42.53	0.07	96	7.6
S3.2	15/05/2012	1000	<4	< 1	< 1	7	2.30	< 1	< 0.02	3.68	0.03	16	7.06
S3.2	19/06/2012	900	29	< 1	488.4	< 10	0.15	< 1	0.01	8.84	0.20	120	7.11
S3.2	10/07/2012	800	< 10	0	2046	1	0.04	0.30	< 0.02	0.64	0.03	126	7.19
S3.2	09/08/2012	400	52	< 1	1119.9	22.3	1.26	< 1	< 0.02	20.0	0.21	11	6.79
S3.2	29/11/2011	500	< 10	65	22470	4.42	0.11	0.8	< 0.02	3.5	< 0.25		7.35
S3.2	25/01/2012	1100	< 10	10	2480.9	94	0.3	1.50	0.05	92.15	4.66	99	7.47
S3.2	15/02/2012	1000	1	< 20	373.8	< 10	0.02	< 1	< 0.02	8.96	< 1	81	7.21
S3.2	06/03/2012	1000	20	< 2	102	13	0.03	< 1	0.04	11.93	< 0.05	85	7.28
S3.2	28/03/2012	1100	4.8	1	240.5	5	0.00	1.80	0.02	3.18	0.03	84	7.31
S3.2	17/04/2012	1100	<4	17.9	2300	1	< 0.05	0.60	< 0.02	0.33	0.05	96	7.59
S3.2	15/05/2012	1000	<4	< 1	28.8	6	1.92	< 1	< 0.02	3.06	0.07	90	7.01
S3.2	19/06/2012	1000	6	< 1	613.1	< 10	<0.05	0.20	0.01	9.74	2.10	145	7.05
S3.2	10/07/2012	800	< 10	0	235.9	4	< 0.05	0.30	0.20	3.45	< 0.05	146	7.66
S3.2	09/08/2012	200	< 10	< 1	> 2419.6	27.9	< 0.05	0.80	< 0.02	27.0	0.17	32	6.8
S4.1	29/11/2011												
S4.1	25/01/2012												
S4.1	15/02/2012												
S4.1	06/03/2012												
S4.1	28/03/2012												
S4.1	17/04/2012	250	44	< 1	220.9	5	1.94	0.10	0.03	2.93	0.08	14	7.76
S4.1	15/05/2012	150	40.6	< 1	14.8	4	0.97	0.9	0.03	2.10	0.12	82	7.32
S4.1	19/06/2012	400	9	1	435.2	< 10	0.13	1.60	0.02	8.25	1.20	65	7.51
S4.1	10/07/2012	350	16	0	10.8	< 10	0.00	< 1	0.21	8.79	1.67	47	7.01
S4.1	09/08/2012	1000	89	1	16.9	18.4	0.11	0.60	< 0.02	17.7	0.17	24	7.2

S4.1	29/11/2011												
S4.1	25/01/2012												
S4.1	15/02/2012												
S4.1	06/03/2012												
S4.1	28/03/2012												
S4.1	17/04/2012												
S4.1	15/05/2012	180	29	< 1	24.1	4	0.82	1	0.03	2.15	0.02	103	7.33
S4.1	19/06/2012	500	28	< 1	1956	< 10	0.27	< 1	0.01	8.72	1.10	71	7.4
S4.1	10/07/2012	400	71	0	248.1	< 10	0.17	< 1	0.01	8.82	0.23	14	6.99
S4.1	09/08/2012	900	< 10	< 1	16.9	33.9	0.20	0.70	< 0.02	33.0	0.21	99	7.16
S4.1	29/11/2011												
S4.1	25/01/2012												
S4.1	15/02/2012												
S4.1	06/03/2012												
S4.1	28/03/2012												
S4.1	17/04/2012												
S4.1	15/05/2012	800	17	< 1	13.4	5	1.00	< 1	0.07	2.93	< 1	21	7.39
S4.1	19/06/2012	1000	19	< 1	4352	< 10	0.21	< 1	0.01	8.78	0.7	46	7.28
S4.1	10/07/2012	900	10	0	30.5	< 10	0.19	< 1	0.22	8.59	0.12	4	7.00
S4.1	09/08/2012	1100	41	< 1	344.8	12.1	0.23	0.30	< 0.02	11.6	0.29	13	6.99

Site C

(Briarleas, Co. Meath)

Sample ID	Depth	Date	Volume	Total Coli	E Coli	COD	TN	NH_4	NO_3	NO_2	PO_4	Cl	PH
Lys 1	1.15	09/05/2013	0										
Lys 1	1.15	16/05/2013	40			52	0.6	1.28	0.3	0.04	50.2	39	
Lys 1	1.15	31/05/2013	30	>24196	504	44	8	1.4	13.9	0.06	6.29	33	
Lys 1	1.15	13/06/2013	85	>48392	>48392	27	1.3	1.94	< 1	0.05	0.56	44	8.67
Lys 1	1.15	03/07/2013	70	10950	1024	<10.0	4.04	0.05	2.6	0.09	0.02	42	
Lys 1	1.15	17/07/2013		3570	316	<28.0	1.43	0.04	1.3	0.06	<0.05	50	
Lys 1	1.15	07/08/2013	45	39726	4284	38	2.17	0.15	9	0.08		86	
Lys 1	1.15	13/09/2013	0										
Lys 1	1.15	15/10/2013	0										
Lys 1	1.15	14/11/2013	50	>24196	2098	39	1.76	0.92	< 1	0.02	0.35	150	
Lys 1	1.15	18/12/2013	75	96	10	7	2.52	0.08	1.5		<0.05	101	
Lys 1	1.15	16/01/2014	75	3873	< 10	25.2	0.6	0.03	0.4	0	0.08	140	
Lys 2	1.5	09/05/2013	80	12033	1067	57	0	1.32	1.4		0.69	84	8.81
Lys 2	1.5	16/05/2013	0										
Lys 2	1.5	31/05/2013	130	2792	62	<10	3	1.37	< 1.0	0.01	0.13	86	
Lys 2	1.5	13/06/2013	140	3912	244	9	< 0.50	0.07	< 1	0	0.14	79	8.02
Lys 2	1.5	03/07/2013	125	1672	710	11	1.11	0.12	2.7	0.01	0.03	74	
Lys 2	1.5	17/07/2013		288	82	15	4.05	0.09	0.2	0.03	1.66	78	
Lys 2	1.5	07/08/2013	0										
Lys 2	1.5	13/09/2013	65			73	9.72	0.04	2.6	0.08	1.13	77	
Lys 2	1.5	15/10/2013	30	768	126	42	38.5	0.05	36.6	0.02	0.35	101	
Lys 2	1.5	14/11/2013	200	>24196	162.4	9	18.4	<0.05	17.9	0.02	0.13	114	
Lys 2	1.5	18/12/2013	100	86	< 10	3	23	0.04	23.1		<0.05	107	
Lys 2	1.5	16/01/2014	130	1203.3	< 1	25.4	13	<0.05	15.1	0.02	0.02	122	
Lys 3	1.2	09/05/2013	75	379	41	56.8	32	1.85	0.8		0.14	72	8.05
Lys 3	1.2	16/05/2013	100			52.8	10.3	2.36	2.4	0.08	0.41	72	8.07
Lys 3	1.2	31/05/2013	35	2909	< 1	23	70	3.4	6.5	0.16	0.31	67	
Lys 3	1.2	13/06/2013	155	5226	102	32	13	3.36	9.2	0.14	0.17	79	8.41
Lys 3	1.2	03/07/2013	20	6510	3446	50	20.8	0.37	18	0.13		53	
Lys 3	1.2	17/07/2013		172	< 20.0	21	24.2	0.11	38	0.11	1.2	66	
Lys 3	1.2	07/08/2013	0										
Lys 3	1.2	13/09/2013	0										
Lys 3	1.2	15/10/2013	0										

Lys 3	1.2	14/11/2013	50	2382	96	13	79.4	<0.05	72.3	0.02	0.21	94	
Lys 3	1.2	18/12/2013	100	452	354	13	86.8	0.07	84.6		0.07	91	
Lys 3	1.2	16/01/2014	400	10.9	< 1	10	2.65	1.02	2.2	0.04	0.07	71	
Lys 4	1.05	09/05/2013											
Lys 4	1.05	16/05/2013	60			49.2	0.5	0.79	22.8	0.08	0.18	58	8.07
Lys 4	1.05	31/05/2013	10									464	
Lys 4	1.05	13/06/2013	45	6896	126	22	24	0.31	27.1	0.08		44	
Lys 4	1.05	03/07/2013	30	6260	1760	8	21.2	0.06	17.1	0.06	<0.05	25	
Lys 4	1.05	17/07/2013		754	622	27	23.8	<0.05	79			45	
Lys 4	1.05	07/08/2013	0										
Lys 4	1.05	13/09/2013	0										
Lys 4	1.05	15/10/2013	10	4165	865	54	82.2		74.1	0.03	0.6	59	
Lys 4	1.05	14/11/2013	20	8704	390	63	84	<0.05	79.9	0.01	0.06	83	
Lys 4	1.05	18/12/2013	0										
Lys 4	1.05	16/01/2014	15	40	< 1	27.2	68.2	0.07	61.7	0.01	0.87	55	
Lys 5	1.2	09/05/2013	220	265	20	52.4	41	>3	25.6		0.87	67	8.69
Lys 5	1.2	16/05/2013	160			18.7	0.5	1.98	17.5	0.07	0.16	82	8.12
Lys 5	1.2	31/05/2013	200	235.9	1	37	33	6.2	21	0.02	0.25	66	
Lys 5	1.2	13/06/2013	165	5599.5	31	21	36	6.6	91	0.03	0.24	73	8.22
Lys 5	1.2	03/07/2013	150	2034	378	14	79.8	4	41.5	0.07	<0.05	72	
Lys 5	1.2	17/07/2013		768	62	20	50.4	1.77	7.1	1.18	0.17	64	
Lys 5	1.2	07/08/2013	25	602	370	105						192	
Lys 5	1.2	13/09/2013	70			44	94.3	0.02	81.6	0.04	0.07	112	
Lys 5	1.2	15/10/2013	50	728	<20	30	58.7	0	53.6	0.03	0.45	69	
Lys 5	1.2	14/11/2013	225	>2420	23	7	47.8	<0.05	45.2	0.02	0.33	85	
Lys 5	1.2	18/12/2013	200	77.6	39.9	5	45.9	<0.05	45.2		0.25	79	
Lys 5	1.2	16/01/2014	200	204.6	< 1	7.4	17.9	<0.05	22.2	0	0.11	72	
Piez 1	1.1	09/05/2013	50	24196	10	59.9	24	1.6	0.5		0.85	70	7.99
Piez 1	1.1	16/05/2013	125			16.1	10	9	1.3	0.07	0.21	72	8.22
Piez 1	1.1	31/05/2013	110	104	< 1	42	18	>3.0	0.6	0.04	0.26	81	
Piez 1	1.1	13/06/2013	110	107	10	19	8	6.6	< 1	0.14	0.9	84	8.37
Piez 1	1.1	03/07/2013	120	>24196.0	794	<10.0	6.62	5	0.2	0.2	0.98	79	
Piez 1	1.1	17/07/2013		12262	172	8	6.45	1.28	1.4	0.08	0.02	61	
Piez 1	1.1	07/08/2013	95	962	60	19	3.04	2.23	2.3	0.21		93	

Piez 1	1.1	13/09/2013	20			51	24.2	1.78	17.6	0.13	0.16	65	
Piez 1	1.1	15/10/2013	200	10.9	2	27	2.94	0.01	1	0	0.8	27	
Piez 1	1.1	14/11/2013	70	14136	663	10	31.8	0.78	30.1	0	2.85	84	
Piez 1	1.1	18/12/2013	50	13734	613.1	11	22	0.69	21.9		0.04	84	
Piez 1	1.1	16/01/2014	140	1203.3	613.1	12	21	1.68	20.4	0.03	0.06	90	
Piez 2	2.1	09/05/2013	200	4106	158	55.6	0	0.39	1.4		6.23	42	8.43
Piez 2	2.1	16/05/2013	195			6.1	0.5	0.17	2.9	0.12	0.2	41	8.36
Piez 2	2.1	31/05/2013	>200	2488	10	28	9	0.36	4	0.12	0.13	39	
Piez 2	2.1	13/06/2013	220	131	< 10	5	2.2	0.59	7.9	0.03	<0.05	44	7.93
Piez 2	2.1	03/07/2013	250	546	< 10	35	13.1	0.88	14	0.03	0.12	52	
Piez 2	2.1	17/07/2013		3450	< 20	16	11	0.32	11.1	0.06	0.18	43	
Piez 2	2.1	07/08/2013	240	7746	< 20	3	5.22	0.14	6	0.03		44	
Piez 2	2.1	13/09/2013	250			46	12.9	0.19	3.9	0.02	0.01	43	
Piez 2	2.1	15/10/2013	250	7.3	1	12	4.9	0.05	3.3	0	0.15	40	
Piez 2	2.1	14/11/2013	250	547.5	7.5	19	25.8	0.09	25.6	0.01	<0.05	62	
Piez 2	2.1	18/12/2013	250	579.4	65.7	2	18.5	0.1	21.3		<0.05	52	
Piez 2	2.1	16/01/2014	250	>2419.6	77.1	23.2	12.5	0.06	14.4	0.04	0.06	64	
Piez 3	1.7	09/05/2013	100	1523	20	54	0	3.3	3.1		>	45	8.53
Piez 3	1.7	16/05/2013	160			29.8	16	17	3.7	0.11	0.1	68	7.83
Piez 3	1.7	31/05/2013	>200	< 1	< 1	32	20	17	8.5	0.09	1.15	60	
Piez 3	1.7	13/06/2013	240	10	10	<10	16	3.3	15.4	0.07	6.44	67	7.87
Piez 3	1.7	03/07/2013	250	335	42.5	61	13.9	2.06	13.2	0.13	0.44	49	
Piez 3	1.7	17/07/2013		104	20	9	15.4	1.2	12	0.04	0.41	33	
Piez 3	1.7	07/08/2013	250	1920	40	3	6.16	1.33	8.7	0.03		30	
Piez 3	1.7	13/09/2013	250			39	11.8	1.48	4.9	0.13	0.01	36	
Piez 3	1.7	15/10/2013	250	> 2419.6	< 1	8	6.91	1.85	3.8	0	0.3	25	
Piez 3	1.7	14/11/2013	250	727	16.1	13	21.6	0.51	20.2	0	<0.05	71	
Piez 3	1.7	18/12/2013	250	105.4	55.6	14	22.5	0.06	25.4		<0.05	68	
Piez 3	1.7	16/01/2014	250	131.4	8.6	12	4.37	0.08	5.6	0.01	0.03	70	
Piez 4	2.75	09/05/2013	80	860	393	48.8	25	0.39	1		<	37	
Piez 4	2.75	16/05/2013	245			13.8	0.5	0.17	0	0.1	0.23	39	7.96
Piez 4	2.75	31/05/2013	>200	252.5	47.5	15	1	0.44	0.1	0.03	0.29	37	
Piez 4	2.75	13/06/2013	215	81.5	5	14	0.6	0.33	< 1	0.11	0.26	41	8.12
Piez 4	2.75	03/07/2013	250	12098	657	31	1.41	0.09	<1.0	0.02	0.14	33	

Piez 4	2.75	17/07/2013		> 24196.0	10	0	2.65	0.84	0.4	0.05	0.35	28	
Piez 4	2.75	07/08/2013	240	4374	< 20	< 10.0	6.85	0.39	1	0.04		53	
Piez 4	2.75	13/09/2013	250			41	4.61	0.42	0.4	0	0	31	
Piez 4	2.75	15/10/2013	250	> 2419.6	< 1	5	1.38	0.05	0.5	0	0.55	32	
Piez 4	2.75	14/11/2013	250	488.4	13.5	13	2.79	0.14	0.9	0	0.06	34	
Piez 4	2.75	18/12/2013	250	78.9	27.5	14	1.87	0.14	1.3		<0.05	44	
Piez 4	2.75	16/01/2014	250	2419.6	461.1	2.2	4.13	0	1.9	0.02	0.02	43	
Piez 5	1.1	09/05/2013	70	657	201	56.7	24	0.18	5.8		5.31	47	8.43
Piez 5	1.1	16/05/2013	200			14.3	0.5	0.65	1.7	0.12	1	38	7.49
Piez 5	1.1	31/05/2013	200	15.5	< 1	27	8	0.11	2.6	0.12	0.38	43	
Piez 5	1.1	13/06/2013	240	10	< 5	0<10	1.3	0.99	3.7	0.36	<0.05	44	7.73
Piez 5	1.1	03/07/2013	250	5231	214	15	5.01	0.74	6.1	0.18	1.49	51	
Piez 5	1.1	17/07/2013		1871	< 10	14	9.3	0.12	6	0.23	0.55	39	
Piez 5	1.1	07/08/2013	240	172	< 20	< 10.0	3.9	0.47	2.2	0.18		49	
Piez 5	1.1	13/09/2013	250			47	9.78	0.09	2.2	0.01	0.01	50	
Piez 5	1.1	15/10/2013	30	1986.3	62	4	3.34	0.5	2	0.04	0.1	62	
Piez 5	1.1	14/11/2013	250	435.2	19.9	16	2.91	0.16	1.7	0.01	0.06	39	
Piez 5	1.1	18/12/2013	150	209.8	178.5	11	1.15	0.04	1.4		<0.05	41	
Piez 5	1.1	16/01/2014	250	770.1	67	8	0.113	<0.05	1.3	0	0.07	45	
Piez 6	2	09/05/2013	80	860	20	60.3	0	0.02	2.2		0.23	24	7.96
Piez 6	2	16/05/2013	285			6.2	0.5	0.65	2.6	0.13	0.35	26	8.09
Piez 6	2	31/05/2013	>200	5	< 1		8	0.32	2.6	0.03	0.29	24	
Piez 6	2	13/06/2013	215	43	10	<10	0.7	0.35	1.8	0.006	0.3	23	8
Piez 6	2	03/07/2013	250	491.5	67.5	20	2.96	0.11	3.7	0.15	1.14	29	
Piez 6	2	17/07/2013		31	<10.0	<10.0	5.88	0.19	3.7	0.28	0.25	34	
Piez 6	2	07/08/2013	250	20	< 20	20	3.97	0.2	2.3	0.06		40	
Piez 6	2	13/09/2013	250			59	9.39	0.08	3.4	0.02	0	38	
Piez 6	2	15/10/2013	250	179.3	< 1	2	4.23	0	2.9	0.07	0.7	26	
Piez 6	2	14/11/2013	250	45	2	14	7.1	0.18	3.7	0	0.19	32	
Piez 6	2	18/12/2013	250	4.1	3.1	0	4.81	0.01	4.9		<0.05	33	
Piez 6	2	16/01/2014	250	99	71.2	5.6	1.39	<0.05	2.9	0	0.07	43	

ST		09/05/2013	7.74E+06	1.28E+06	621	83	16.75	1.3		23.2	54	7.83
ST		16/05/2013			669	71	68.5	0.7	0.1	15.7	76	7.47
ST		31/05/2013	7.50E+05	5.20E+05	690	68	44.4	< 1.0	0.15	9.15	296	
ST		13/06/2013	6.51E+05	3.76E+05	360	55	61	< 1	0.19	9.65	65	7.37
ST		03/07/2013	8.41E+06	2.54E+06	670	78	67	0.9	0.31	10	104	
ST		17/07/2013	1.38E+07	5.74E+06	145	29.22	86	0.9	0.14	10.3	88	
ST		07/08/2013	2.45E+07	4.99E+06	525	73.4	83	1.7	0.1		37	
ST		13/09/2013	9.35E+06	2.41E+06	711	89.8	90	1.3	0.02	10.4	116	
ST		15/10/2013	3.23E+07	8.05E+06	750	65.4	60	1.4	0	9.0	98	
ST		14/11/2013	5.21E+07	2.62E+07	678	84.7	62.8	1.6	0.02	13.15	109	
ST		18/12/2013	1.33E+07	6.50E+06	702	54.8	31	1.1		10.3	102	
ST		16/01/2014	4.95E+06	3.10E+05	499	81.6	75	1.4	0	11.2	91	
US Well	10	09/05/2013	504	10	29.3	16	< 0.05	7.4		0.01	38	8.88
US Well	10	16/05/2013			0.9	0.5	0.02	7.6	0	0.02	42	8.59
US Well	10	31/05/2013	387.3	< 1	<10	8.1	0.04	1.9	0.01	<0.05	44	
US Well	10	13/06/2013	16.8	< 1	9<10	8.7	< 0.05	8.6	0.01	0.01	44	8.69
US Well	10	03/07/2013	21.1	< 1	23	6.59	<0.05	7.4	0.00	0.08	42	
US Well	10	17/07/2013	3.1	< 1	7	8.6	<0.05	8.8	0.01	0.05	42	
US Well	10	07/08/2013	43.1	< 1	< 10.0	2.47	<0.05	1.9	< 0.02		44	
US Well	10	13/09/2013	17.9	< 1	8	3.31	0	2.1	0.01	0.01	40	
US Well	10	15/10/2013									35	
US Well	10	14/11/2013									39	
US Well	10	18/12/2013									40	
US Well	10	16/01/2014									38	
DS Stream		09/05/2013	4884	959	37.4	23	< 0.05	3.8		0.04	33	8.14
DS Stream		16/05/2013			0.4	0.5	0.04	4	0.02	0.03	37	8.24
DS Stream		31/05/2013	1246	236.5	<10	3.4	0.01	0.8	0.03	0.39	36	
DS Stream		13/06/2013	>12098	>12098	17	2	0.02	< 1.70	0	0.11	30	8.69
DS Stream		03/07/2013	4902	479.5	<10.0	2.89	<0.05	2.4	0.01	0.52	32	
DS Stream		17/07/2013	4902	441	<10.0	4.41	<0.05	3.5	0.05	3.16	29	
DS Stream		07/08/2013	5599.5	727.5	23	2.47	0.01	2.5	0.01		37	
DS Stream		13/09/2013	2640	224	15	3.6	<0.05	3.3	0.02	0.73	32	
DS Stream		15/10/2013									30	
DS Stream		14/11/2013									33	
DS Stream		18/12/2013									31	
DS Stream		16/01/2014	1299.7	365.4	3.2	5.17	0.02	5.1	0.01	0.08	37	

Site D

(Irishtown, Co. Meath)

Sample ID	Depth	Date	Volume	Total Coli	E Coli	COD	TN	NH_4	NO_3	NO_2	PO_4	Cl	PH
Lys 1	1.95	09/05/2013											
Lys 1	1.95	16/05/2013											
Lys 1	1.95	31/05/2013											
Lys 1	1.95	13/06/2013											
Lys 1	1.95	03/07/2013											
Lys 1	1.95	17/07/2013											
Lys 1	1.95	07/08/2013											
Lys 1	1.95	13/09/2013											
Lys 1	1.95	15/10/2013											
Lys 1	1.95	14/11/2013											
Lys 1	1.95	18/12/2013											
Lys 1	1.95	16/01/2014											
Lys 2	1.95	09/05/2013											
Lys 2	1.95	16/05/2013											
Lys 2	1.95	31/05/2013	10				62	1.56		1		173	
Lys 2	1.95	13/06/2013	20						90.5			90	
Lys 2	1.95	03/07/2013	15	3745	3065	76	55.7		72		3.2	92	
Lys 2	1.95	17/07/2013				126	41.4		16.7			43	
Lys 2	1.95	07/08/2013	20	> 96784	> 96784	530						152	
Lys 2	1.95	13/09/2013											
Lys 2	1.95	15/10/2013											
Lys 2	1.95	14/11/2013											
Lys 2	1.95	18/12/2013	120	18.7	1	38	55.8	0.02	58.6	< 0.00	0.14		
Lys 2	1.95	16/01/2014											
Lys 3	2.5	09/05/2013											
Lys 3	2.5	16/05/2013											
Lys 3	2.5	31/05/2013	210	269	10	17	16	0.17	5.7	0.07	2.05	19	
Lys 3	2.5	13/06/2013	45	1607	31			2.62	88		1.58	94	
Lys 3	2.5	03/07/2013	10	7500	260	150							
Lys 3	2.5	17/07/2013				63							
Lys 3	2.5	07/08/2013											

Lys 3	2.5	13/09/2013											
Lys 3	2.5	15/10/2013											
Lys 3	2.5	14/11/2013											
Lys 3	2.5	18/12/2013	150										
Lys 3	2.5	16/01/2014	250	579.4	17.5	61.4	81.3		52.6	< 0.00	1.32	122	
Lys 4	2.1	09/05/2013											
Lys 4	2.1	16/05/2013	35			43.6	0.5	1.64	26.4	0.2	1.48	135	
Lys 4	2.1	31/05/2013	5			22			41			55	
Lys 4	2.1	13/06/2013											
Lys 4	2.1	03/07/2013											
Lys 4	2.1	17/07/2013											
Lys 4	2.1	07/08/2013											
Lys 4	2.1	13/09/2013											
Lys 4	2.1	15/10/2013											
Lys 4	2.1	14/11/2013											
Lys 4	2.1	18/12/2013	10			48	51.7	0.15	51.7		0.2		
Lys 4	2.1	16/01/2014											
Lys 5	1.75	09/05/2013	70	> 24190	369	50.2		0.62	39.3		0.41	153	8.35
Lys 5	1.75	16/05/2013											
Lys 5	1.75	31/05/2013	5			29						15	
Lys 5	1.75	13/06/2013	40						49		0.79	65	
Lys 5	1.75	03/07/2013	10	10935	3745	80	36.8		24		1.75	49	
Lys 5	1.75	17/07/2013											
Lys 5	1.75	07/08/2013											
Lys 5	1.75	13/09/2013											
Lys 5	1.75	15/10/2013											
Lys 5	1.75	14/11/2013											
Lys 5	1.75	18/12/2013											
Lys 5	1.75	16/01/2014	40	1720	296	24.8	31.3	0.08	26.3	0.04	1.02	166	
Piez 6	1.6	09/05/2013	80	> 24190	8664	40		2.29	0.9		0.5	68	7.95
Piez 6	1.6	16/05/2013	40			36.8	0.5	2.91	2.6	0.1	0.35	57	
Piez 6	1.6	31/05/2013	20	48392	8212	41	22			0.01	0.33	45	

Piez 6	1.6	13/06/2013	80	> 48392	39726	340	14	1.4		0.07	0.1	185	7.86
Piez 6	1.6	03/07/2013	80	1976	196	495	11.3	13	0.8	0.03	0.00	56	
Piez 6	1.6	17/07/2013		79452	972	165	24.1	12.6	5.1	0.1		70	
Piez 6	1.6	07/08/2013	70	> 96784	27468	190	19.5	30	5.6	0.28		83	
Piez 6	1.6	13/09/2013											
Piez 6	1.6	15/10/2013											
Piez 6	1.6	14/11/2013											
Piez 6	1.6	18/12/2013											
Piez 6	1.6	16/01/2014											
Lys 7	1.85	09/05/2013	70	4106	41	54.5		0.15	52.8		0.17	202	8.13
Lys 7	1.85	16/05/2013	105			47.7	36.5	0.72	52.5	0.1	0.07	196	
Lys 7	1.85	31/05/2013	50	213	10	12	52	1.64	6.5	0.07	0.85	222	
Lys 7	1.85	13/06/2013	60	1014	75	23	22	1.37	47.5	0.06	0.2	326	7.88
Lys 7	1.85	03/07/2013	65	104	40	62	26.5	0.03	33	0.01	0.04	220	
Lys 7	1.85	17/07/2013		19608	3578	48	60.4	0.71	10.5	0.06	0.82	246	
Lys 7	1.85	07/08/2013	40	10412	1772	105	67.5	1.41	58	0.06		258	
Lys 7	1.85	13/09/2013											
Lys 7	1.85	15/10/2013											
Lys 7	1.85	14/11/2013											
Lys 7	1.85	18/12/2013	15	1115	50	80	82.6	0.04	80.6		0.52		
Lys 7	1.85	16/01/2014	170	185	15.8	37.6	45.5		46.9	< 0.00	0.14	255	
Lys 8	2.6	09/05/2013											
Lys 8	2.6	16/05/2013											
Lys 8	2.6	31/05/2013	10				15					107	
Lys 8	2.6	13/06/2013	30						27.3	0.08	2.06	151	
Lys 8	2.6	03/07/2013	10	3485	1920	154		0.35	24.4	0.05	0.02		
Lys 8	2.6	17/07/2013		48392	25994	80	26.6	0.24	26.8			133	
Lys 8	2.6	07/08/2013	35	684	336	39	26.4	0.61	34	0.07		187	
Lys 8	2.6	13/09/2013	3				10.5		2.5				
Lys 8	2.6	15/10/2013											
Lys 8	2.6	14/11/2013											
Lys 8	2.6	18/12/2013	150	579.4	55.6	44	91.2	0.05	90.2		0.61		

Lys 8	2.6	16/01/2014	60	512	20	18.6	45.6	0.07	47.3	< 0.00	0.3	171	
Lys 9	1.1	09/05/2013	15	1467	< 1	56.6		0.09	48.5				
Lys 9	1.1	16/05/2013	45			48.5	0.5	1.34	77.1	0.1	0.23	191	8.51
Lys 9	1.1	31/05/2013	25	19608	20	< 10	3		88.5			183	
Lys 9	1.1	13/06/2013	30			< 50			25	0.04	0.5	207	
Lys 9	1.1	03/07/2013	10	1310	865	126		0.15	24.3	0.05	0.25		
Lys 9	1.1	17/07/2013		5430	540	198							
Lys 9	1.1	07/08/2013	20	1772	296	150						138	
Lys 9	1.1	13/09/2013											
Lys 9	1.1	15/10/2013											
Lys 9	1.1	14/11/2013											
Lys 9	1.1	18/12/2013	40	904	170	33	13	0.09	12.7		0.2		
Lys 9	1.1	16/01/2014	20	1310	< 50	92.2	70.1	0.09	51.8	< 0.02	0.48	209	
ST		09/05/2013		1.88E+06	3.42E+05	126	95	3.8	2.6		29.25	89	7.9
ST		16/05/2013				152	141	123	0.7	0.33	20.3	113	7.65
ST		31/05/2013		3.10E+05	3.10E+05	495	165	129.5	2.9	0.14	25.9	120	
ST		13/06/2013		1.00E+05	1.00E+05	220	230	252		0.34	54.2	150	9.02
ST		03/07/2013		9.61E+05	5.27E+05	435	82.4	222	1.7	0.12	26.8	153	
ST		17/07/2013		5.04E+06	3.18E+06	245	300	304	2.5	0.27	18.4	203	
ST		07/08/2013		1.56E+06	2.74E+05	355	210	312	2.1	0.09		243	
ST		13/09/2013		4.46E+06	1.92E+06	270	226	225		0.34	26.0	150	8.62
ST		15/10/2013		3.91E+06	1.12E+06	312	281	272	1.6	0.05	23.5	203	7.99
ST		14/11/2013		1.76E+06	7.10E+05	288	214	210	1.5	0.1	25.1	243	7.58
ST		18/12/2013											
ST		16/01/2014											

US Well	09/05/2013										
US Well	16/05/2013			3.3	13.5	0.01	9.4	0.01	0.01	59	8.39
US Well	31/05/2013	25.6	1	<10	7.8	-	14.9	0	0.05	58	
US Well	13/06/2013	37.8	< 1	8	5.5	< 0.05	6.2	< 0.02	0.5	62	7.74
US Well	03/07/2013	<1.0	<1.0	35	8.62	< 0.05	8.7	< 0.02	0.05	58	
US Well	17/07/2013	5.2	< 1	1	4.75	< 0.05	7.1	0.02	0.03	57	
US Well	07/08/2013	2	< 1	< 10.0	5.6	< 0.05	8.4	< 0.02		56	
US Well	13/09/2013										
US Well	15/10/2013										
US Well	14/11/2013										

Site E

(Co. Westmeath)

Sample ID	Depth	Date	Volume	Total Coli	E Coli	COD	TN	NH_4	NO_3	NO_2	Organic N	PO_4	Cl	PH
Lys 1	1.6	07/03/2013	50	242	< 20	39	12	0.08	1.1	0.25	10.57	0.22	640	7.56
Lys 1	1.6	11/04/2013	25	346	< 20	50.6	7.9	0.7	5.4	0.03	1.77	0.75	149	
Lys 1	1.6	09/05/2013	0											
Lys 1	1.6	16/05/2013	10											
Lys 1	1.6	31/05/2013	40	> 24196	< 10	<10	42	0.35	7.4	0.05	34.2	0.84	1152	
Lys 1	1.6	13/06/2013	40	> 48392	15402		15	0.18	12.4			0.69	1135	
Lys 1	1.6	03/07/2013	25	> 48392	40	96	n/e	1.99	8.6	0.03		0.5	1080	
Lys 1	1.6	17/07/2013	0											
Lys 1	1.6	07/08/2013	40	1292	< 40	188	38.5	2.27	28.1	0.06			945	
Lys 1	1.6	18/09/2013	30			109	63.8	0.05	51.6	0.07	12.08	1.35	990	
Lys 1	1.6	15/10/2013	20	48392	< 20	48	72.3	0.1	63	0.06	9.14	1.65	278	
Lys 1	1.6	21/11/2013	5	6455	< 50	95	29.6		25.6			1.5	184	
Lys 1	1.6	05/12/2013	10	86645	< 50	73	17.2	0.22	14.6	0.15	2.23	1.15	240	
Lys 1	1.6	14/01/2014	25	12976	524	78	27.6	0.23	11.7	0.25	15.42	0.75	78	
Lys 2	1.6	07/03/2013	200	193.5	0	16.9	21	0.07	20.3	0.02	0.61	0.31	45	
Lys 2	1.6	11/04/2013	75	10	< 10	14.7	51.4	0.34	49.5	0.05	1.51	0.42	153	
Lys 2	1.6	09/05/2013	80	563	< 10	27.1	0	0.16	25			2.82	174	8.51
Lys 2	1.6	16/05/2013	0											
Lys 2	1.6	31/05/2013	50	809	< 10	55	90	2.1	71.5	0.03	16.37	> 5.0	153	
Lys 2	1.6	13/06/2013	45	6510	40			0.37	66			0.6	230	
Lys 2	1.6	03/07/2013	15	> 48380	292	159	68.3	0.86	73			4.05	213	
Lys 2	1.6	17/07/2013		39216	< 40.0	<20.0								
Lys 2	1.6	07/08/2013	25	920	40	129	50.8	n/e	68.5				298	
Lys 2	1.6	18/09/2013	20			76	84.5	0	84	0.02	0.48	0.95	302	
Lys 2	1.6	15/10/2013	20	48392	< 20	42	115	0.5	106	0.03	8.47	1.2	111	
Lys 2	1.6	21/11/2013	5	10230	< 50	70	134	0.02	130.5	0.00	3.48	1.25	118	
Lys 2	1.6	05/12/2013	10	60165	< 50	61	17.5	0.07	14	0.05	3.38	2.75	71	
Lys 2	1.6	14/01/2014	40	> 48392	82	52	10.9	0.09	7.3	0.02	3.49	0.8	38	7.35
Lys 3	1.7	07/03/2013	100	202.8	< 2	27.9	53	0.54	48.5	0.03	3.93	0.41	150	
Lys 3	1.7	11/04/2013	175	13.4	< 1	19.9	49.8	0.5	48.5	0.04	0.76	1.06	112	
Lys 3	1.7	09/05/2013	210	1725	< 10	59.15	150	0.01	> 25.0			0.55	138	8.26
Lys 3	1.7	16/05/2013	165			38.1	0.5	0.08	86.7	0.02		0.76	101	8.68
Lys 3	1.7	31/05/2013	75	556	< 5	33	79	1.72	65	0.04	12.24	2.66	91	
Lys 3	1.7	13/06/2013	60	> 24196	583	25	63	0.03	60.5	0.05	2.42	1.51	87	
Lys 3	1.7	03/07/2013	45	> 48380	768	64	59.1	0.22	91	0.09	-32.21	0.53	91	
Lys 3	1.7	17/07/2013		> 96784	5256	99	70.5	0.43	93.5	0.09		0.15	94	

Lys 3	1.7	07/08/2013	50	580	< 40	39	62.2	0.22	78.5	0.03			131	
Lys 3	1.7	18/09/2013	40			52	119	0	117.5	0.02	1.48	0.51	124	
Lys 3	1.7	15/10/2013	25	5510	< 20	11	156	0.25	148	0.02	7.73	1.6	130	
Lys 3	1.7	21/11/2013	10	2645	< 50	77	21.4	0.1	19	0.01	2.29	1.15	44	
Lys 3	1.7	05/12/2013	20	28272	16328	34	53.4	0.02	53.2	0.03	0.15	1	53	
Lys 3	1.7	14/01/2014	30	> 48392	746	64	57.9	0.6	52.5	0.03	4.77	0.4	70	
Lys 4	1.2	07/03/2013	0											
Lys 4	1.2	11/04/2013	0											
Lys 4	1.2	09/05/2013	0											
Lys 4	1.2	16/05/2013	10										33	
Lys 4	1.2	31/05/2013	5										21	
Lys 4	1.2	13/06/2013	0											
Lys 4	1.2	03/07/2013	0											
Lys 4	1.2	17/07/2013	15	8392	< 40.0				11.5				6	
Lys 4	1.2	07/08/2013	0											
Lys 4	1.2	18/09/2013	0											
Lys 4	1.2	15/10/2013	0											
Lys 4	1.2	21/11/2013	0											
Lys 4	1.2	05/12/2013	0											
Lys 4	1.2	14/01/2014												
Lys 5	3	07/03/2013	40	320	< 20	23.6	75	1.08	72.5	0.11	1.31	0.22	92	8.01
Lys 5	3	11/04/2013	30	126	< 20	17.4	64.2	0.02	63.5	0.03	0.65	2.91	103	
Lys 5	3	09/05/2013	0											
Lys 5	3	16/05/2013	40			48.3	72	0.65	0.2	0.11	71.04	0.87	92	
Lys 5	3	31/05/2013	45	> 24196	< 10	<10	63	2.16	72	< 0.02	-11.18	0.89	98	
Lys 5	3	13/06/2013	105	> 48392	102	27	162	0.09	66	0.07	95.84	5.92	99	8.56
Lys 5	3	03/07/2013	25	> 48380	1024	68	n/e	0.39	77.5	0.08		0.56	93	
Lys 5	3	17/07/2013		208	40	72	67.8		81.5				87	
Lys 5	3	07/08/2013	130	13792	< 40	93	53.4	1.55	53.5	0.04			75	
Lys 5	3	18/09/2013	10			106	118	11.92	96	0.61	9.47	3.9	89	
Lys 5	3	15/10/2013	0											
Lys 5	3	21/11/2013	5	> 120980	1395	10	33.7	0.35	31	0.04	2.31	1	36	
Lys 5	3	05/12/2013	0											
Lys 5	3	14/01/2014												
Lys 6	1.9	07/03/2013	50	148	< 20	16.1	20	0.36	18.6	0.02	1.02	0.16	39	7.64
Lys 6	1.9	11/04/2013	90	717	< 10	16.1	34.7	0.27	32.7	0.02	1.71	0.52	108	
Lys 6	1.9	09/05/2013	0											
Lys 6	1.9	16/05/2013	10										8	

Lys 6	1.9	31/05/2013	50	> 24196	< 10	162	48	0.39	58.5	0.17	-11.06	> 5.0	113	
Lys 6	1.9	13/06/2013	55	6152	20	25	63	0.06	41	0.04	21.9	0.5	105	
Lys 6	1.9	03/07/2013	45	> 48380	82	3	57.7	0.03	52	0.04	5.63	0.71	96	
Lys 6	1.9	17/07/2013		11020	40	139	102	0.24	96	0.16		2.74	98	
Lys 6	1.9	07/08/2013	35	620	< 40	54	53.4	0.23	84.5	0.14			112	
Lys 6	1.9	18/09/2013	20			222	153	7.2	150	1.06	-5.26	6.5	134	
Lys 6	1.9	15/10/2013	10	> 120950	205	110	107	4.4	99	0.05	3.55	6.85	132	
Lys 6	1.9	21/11/2013	0											
Lys 6	1.9	05/12/2013	50	> 24196	1178	31	104	0.05	99.5	0.02	4.43	0.5	104	7.53
Lys 6	1.9	14/01/2014												
Lys 7	1.3	07/03/2013	25	214	< 20	24.7	25	0.06	22.6		2.34	0.35	25	
Lys 7	1.3	11/04/2013	140	230.6	< 2	15.8	31.5	0.16	30.1	0.02	1.22	0.56	32	
Lys 7	1.3	09/05/2013	15	19863	31	55.5	5		1.1					
Lys 7	1.3	16/05/2013	45			53.2	0.5	0.56	60.6	0.07			113	
Lys 7	1.3	31/05/2013	10										32	
Lys 7	1.3	13/06/2013	50	290.9	< 10	143	89	0.19	8.5	0.28	80.03	1.17	105	
Lys 7	1.3	03/07/2013	5										11	
Lys 7	1.3	17/07/2013	0											
Lys 7	1.3	07/08/2013	0											
Lys 7	1.3	18/09/2013	0											
Lys 7	1.3	15/10/2013	0											
Lys 7	1.3	21/11/2013	5	> 120950	7825	95	17	0.05	15.1	0.00	1.85	1.55	188	
Lys 7	1.3	05/12/2013	20	> 120980	< 50	62	121	0.08	117.5	0.08	3.34	3.3	83	
Lys 7	1.3	14/01/2014												
Well		07/03/2013		18.3	< 1	5.4	3	0.03	2.4	0.01	0.56	0.02	10	
Well		11/04/2013		14.6	< 1	5.1	2.5	0.01	2.4	0	0.09	0.01	7	
Well		09/05/2013		860	< 10	48.6	0	<0.05	3			0.17	8	8
Well		16/05/2013				3.4	3.6	0.01	2.6	0	0.99	0.05	10	8.46
Well		31/05/2013		980.4	< 1	< 10	2.5	< 0.50	2.5	< 0.02	-0.52	0	10	
Well		13/06/2013		980.4	< 1	5	0.6	0.01	2.4	0	-1.81	6.01	12	8.54
Well		03/07/2013		204.6	< 1	3	2.99	0.28	2.1	<0.02	0.59	<0.00	9	
Well		17/07/2013		488.4	< 1	16	3.32	0.03	2.8	0.02		<0.00	8	
Well		07/08/2013		816.4	4.1	1	3.96	0.02	2	0.01			4	
Well		18/09/2013				21	17.3	0.00	2.2	0	15.1	0.09	12	
Well		15/10/2013		248.1	< 1	2	2.7	0.00	2.6	0.01	0.09	0.05	5	
Well		21/11/2013		181.1	< 1	3	3.54	0.01	3.4	0.00	0.13	0.00	13	
Well		05/12/2013		261.3	< 1	2	3.35	0.00	2.3	0.00	1.05	0.00	12	
Well		14/01/2014												

STE	07/03/2013	1.08E+07	4.50E+06	113.7	138	0.23	2.1	0.96	134.71	10.68	146	
STE	11/04/2013	1.08E+07	4.10E+06	106.4	80.4	33.3	2.2	0.06	44.84	15.5	133	
STE	09/05/2013	3.84E+06	1.23E+05	453	209	3.5	1.5			24.95	112	8.23
STE	16/05/2013			438	117	0.5	1.1	0.28	115.12	28.7	88	7.73
STE	31/05/2013	3.53E+06	< 10000	605	159	96.5	< 1	0.36	61.14	15.9	120	
STE	13/06/2013	1.22E+07	5.80E+06	550	125	136	4.9	0.27	-16.17	19.65	120	7.81
STE	03/07/2013	6.43E+06	6.20E+05	560	137.4	131	2.7	0.34	3.36	15.4	125	
STE	17/07/2013											
STE	07/08/2013	1.72E+07	2.30E+06	455	103.6	139	2	0.16			162	
STE	18/09/2013	9.06E+06	3.83E+06	777	173.4	143	17.2	0.02	13.18	20.3	118	7.92
STE	15/10/2013											
STE	21/11/2013	1.79E+07	4.95E+06	395	88.4	67	< 1	0.05	20.35	13.8	146	7.45
STE	05/12/2013	2.25E+07	2.33E+06	554	107	104	2.4	0.36	0.24	10.6	124	
STE	14/01/2014	4.73E+06	3.10E+05	672	112.8	81	1	0.3	30.5	8.8	108	

Site F

(Fermoy, Co. Cork)

ID	Depth (m)	Date	Volume	Total C.	Ecoli	COD	TN	NH_4	NO_3	NO_2	Inorganic	Organic	PO_4	Cl	pH
Lys 1	1.4	15/01/2013	130	10.3	0	50	11.2	0.2	10.9	0.02	11.12	0.08	0.09	58	7.37
Lys 1	1.4	26/02/2013	75	4.1	0	45	5.9	0.09	5.2	0.06	5.35	0.55	0.11	26	8.38
Lys 1	1.4	22/03/2013	50	20.1	0	30	17	0.1	13.6	0.01	13.71	3.29	0.02	113	8.59
Lys 1	1.4	08/04/2013	50	1	0	29	17.6	0.07	16.9	0.03	17	0.60	0.34	82	9.05
Lys 1	1.4	12/05/2013													
Lys 1	1.4	21/06/2013	50	24196	0	35	40	0.09	27.8	0.07	27.96	12.04	0.34	78	
Lys 1	1.4	23/07/2013	25	2708	0	286	47.7	0.35	34.3	0.09	34.74	12.96	0.65	204	8.19
Lys 1	1.4	13/08/2013	10	48392	5226	325	39.7		37.8	0.09	37.89	1.81		91	
Lys 1	1.4	02/09/2013	30	20924	182	125	45.5	0.06	42.9	0.02	42.98	2.52	0.18	121	7.62
Lys 1	1.4	06/10/2013	30	39726	0	99	52.7	0.07	46.5	0.01	46.58	6.12	0.03	116	
Lys 1	1.4	24/11/2013	50	1153	30	215	33.7	0.01	27.6	0.01	27.62	6.08	0.11	55	
Lys 1	1.4	10/12/2013	15	1045	0	213	22.3	0.02	16.5	0.02	16.54	5.76	0.08	47	
Lys 2	2	15/01/2013	170	46	0	21	8.3	0.11	8.1	0.03	8.24	0.06	0.04	42	7.5
Lys 2	2	26/02/2013	0												
Lys 2	2	22/03/2013	125	321.4	275.2	37	11.6	0.07	9.8	0.01	9.88	1.72	0.01	35	8.60
Lys 2	2	08/04/2013	2												
Lys 2	2	12/05/2013	40	987	30	30	12.1	0.08	10.7	0.01	10.79	1.31	0.18	23	
Lys 2	2	21/06/2013	100	24196	20	30	13.7	0.02	12.7	0.03	12.75	0.95	0.11	19	
Lys 2	2	23/07/2013	15	1585	0	142	21.5	0.1	17.4	0.07	17.57	3.93	0.45	50	8.08
Lys 2	2	13/08/2013	20	48392	6896	110	17.5	0.13	13.9	0.07	14.1	3.4	0.5	20	
Lys 2	2	02/09/2013													
Lys 2	2	06/10/2013	40	24196	109	29	15.9	0.04	13	0	13.04	2.86	0.09	11	
Lys 2	2	24/11/2013													
Lys 2	2	10/12/2013													
Lys 3	2.95	15/01/2013	150	36.1	0	5	4.8	0.11	4.6	0.03	4.74	0.06	0.03	9	7.37
Lys 3	2.95	26/02/2013													
Lys 3	2.95	22/03/2013	175	1046.2	770.1	13	4.2	0.06	4.1	0.01	4.17	0.03	0.16	15	8.48
Lys 3	2.95	08/04/2013	160	14.4	2	10	4.2	0.1	3.7	0.08	3.88	0.32	0.29	18	7.96
Lys 3	2.95	12/05/2013													
Lys 3	2.95	21/06/2013													
Lys 3	2.95	23/07/2013	25	48392	512	64	9.45	0.06	6	0.23	6.29	3.16	0.56	15	8.35
Lys 3	2.95	13/08/2013	20	24196	378	114	36.2	2.88	32.4	0.23	35.51	0.69	0.61	22	
Lys 3	2.95	02/09/2013	0												
Lys 3	2.95	06/10/2013	15	41485	50	41	12.9	0.04	10.2	0.04	10.28	2.62	0.09	10	
Lys 3	2.95	24/11/2013													
Lys 3	2.95	10/12/2013													
Lys 4	1.9	15/01/2013	180	5	0	20	10.5	0.08	10.3	0.04	10.42	0.08	0.05	35	7.49
Lys 4	1.9	26/02/2013	160	4.1	0	15	7.2	0.02	6.5	0.01	6.53	0.67	0.01	18	8.28
Lys 4	1.9	22/03/2013	175	146.7	137.6	16	7.4	0.04	6.9	0.01	6.95	0.45	0.05	27	8.68
Lys 4	1.9	08/04/2013	70	1	0	17	6.9	0.06	6.6	0.02	6.68	0.22	0.29	22	8.26
Lys 4	1.9	12/05/2013	60	282	10	16	7.5	0.06	6.2	0.02	6.28	1.22	0.04	10	
Lys 4	1.9	21/06/2013	100	24196	0	18	9.6	0.01	6.6	0.03	6.64	2.96	0.09	13	
Lys 4	1.9	23/07/2013	35	3912	150	28	10.3	0.08	8	0.02	8.1	2.2	0.11	11	8.36
Lys 4	1.9	13/08/2013	30	24196	41	60	11.1	0.5	10.4	0.02	10.92	0.18	0.12	17	
Lys 4	1.9	02/09/2013	50	9208	20	21	22.2	0.05	20.3	0.01	20.36	1.84	0.09	15	7.95
Lys 4	1.9	06/10/2013	50	24196	0	15	34.1	0.1	33.3	0.08	33.48	0.62	0.27	30	
Lys 4	1.9	24/11/2013	70	987	31	12	19.7	0.05	16.6	0.02	16.67	3.03	0.16	18	
Lys 4	1.9	10/12/2013	30	794	20	88	11.3	0.01	9.3	0.02	9.33	1.97			

Lys 5	1.8	15/01/2013													
Lys 5	1.8	26/02/2013													
Lys 5	1.8	22/03/2013	140	922.2	821.2	37	13.7	0.04	11.8	0.02	11.86	1.84	0.05	35	9.00
Lys 5	1.8	08/04/2013													
Lys 5	1.8	12/05/2013	40	24196	73	44	19	0.31	15.2	0.32	15.83	3.17	0.27	27	
Lys 5	1.8	21/06/2013	100	24196	0	40	26.2	0.03	24.1	0.05	24.18	2.02	0.05	39	
Lys 5	1.8	23/07/2013	30	8704	0	127	35.7	0.26	27.4	0.12	27.78	7.92	3.54	28	8.6
Lys 5	1.8	13/08/2013	10	14540	482	52	20.7		17.4	0.12	17.52	3.18		8	8.6
Lys 5	1.8	02/09/2013													
Lys 5	1.8	06/10/2013													
Lys 5	1.8	24/11/2013	80	669	30	45	32.1	0.18	22.3	0.01	22.49	9.61	1.31	21	
Lys 5	1.8	10/12/2013	2				8.2		5.2		5.2	3	1.8	12	
Lys 6	2.2	15/01/2013													
Lys 6	2.2	26/02/2013	120	0	0	23	9.7	0.01	7.7	0.01	7.72	1.98	0.02	31	8.38
Lys 6	2.2	22/03/2013	50	512.2	305.1	32	6	0.07	5.2	0.03	5.3	0.7	0.06	12	8.93
Lys 6	2.2	08/04/2013													
Lys 6	2.2	12/05/2013	60	24196	31	34	23.6	2.33	15.9	0.69	18.92	4.68	0.75	20	
Lys 6	2.2	21/06/2013	100	24196	22	26	29.8	1.38	24.8	0.6	26.78	3.02	0.62	8	
Lys 6	2.2	23/07/2013	75	39726	20	34	21.9	0.1	20.2	0.07	20.37	1.53	2.99	25	7.84
Lys 6	2.2	13/08/2013													
Lys 6	2.2	02/09/2013													
Lys 6	2.2	06/10/2013													
Lys 6	2.2	24/11/2013													
Lys 6	2.2	10/12/2013	2				10.2		7.1		7.1		1.6	10	
Lys 7	1.9	15/01/2013													
Lys 7	1.9	26/02/2013	150	1	0	41	17	0.08	12.8	0.02	12.9	4.1	0.06	119	8.38
Lys 7	1.9	22/03/2013	130	2022.3	228.9	37	8.1	0.08	6.8	0.02	6.9	1.2	0.05	24	8.47
Lys 7	1.9	08/04/2013													
Lys 7	1.9	12/05/2013	10			43	14.5	1.1	12.6	0.22	13.92	0.58	0.31	29	
Lys 7	1.9	21/06/2013													
Lys 7	1.9	23/07/2013													
Lys 7	1.9	13/08/2013	10	20530	1065	112	20.3		16.1		16.1			15	
Lys 7	1.9	02/09/2013													
Lys 7	1.9	06/10/2013													
Lys 7	1.9	24/11/2013													
Lys 7	1.9	10/12/2013	50	2172	244	97	8.49	0.05	6.6	0.05	6.7	1.79	0.16	13	
Lys 8	2	15/01/2013	200	22.9	0	27	29.3	1.93	16.8	0.09	18.82	10.48	0.52	23	7.8
Lys 8	2	26/02/2013													
Lys 8	2	22/03/2013	250	1011.2	27.5	36	12.2	0.18	11.5	0.01	11.69	0.51	0.13	20	8.27
Lys 8	2	08/04/2013	25	13.5	0	33	9.2	0.17	8.7	0.11	8.98	0.22	0.41	20	8.72
Lys 8	2	12/05/2013	100	24196	0	34	11.7	0.09	10.3	0.01	10.4	1.3	0.34	24	
Lys 8	2	21/06/2013	75	24196	20	44	25.8	0.8	18.9	0.66	20.36	5.44	2.75	18	
Lys 8	2	23/07/2013	60	48392	40	108	36.9	0.3	32.3	0.14	32.74	4.16	2.6	17	8.7
Lys 8	2	13/08/2013													
Lys 8	2	02/09/2013	40	1338	20	98	31.2	0.3	28.7	0.14	29.14	2.06	1.75	21	8.2
Lys 8	2	06/10/2013													
Lys 8	2	24/11/2013													
Lys 8	2	10/12/2013													

DS Well	n/a	15/01/2013	11	0	4	3.2	0.03	2.9	0.01	2.94	0.26	0.02	13	7.37
DS Well	n/a	26/02/2013	0	0	1	9.6	0.01	8.6	0.00	8.61	0.99	0.01	18	8.24
DS Well	n/a	22/03/2013	8.4	0	16	3.5	0.07	3.2	0.01	3.28	0.22	0.05	17	8.23
DS Well	n/a	08/04/2013	2	0	3	3.6	0.01	2.5	0.00	2.51	1.09	0.15	19	7.35
DS Well	n/a	12/05/2013	0	0	4	1.2	0.02	0.2	0.00	0.22	0.98	0.01	18	
DS Well	n/a	21/06/2013	19.9	0	1	2.6	0.05	2.4	0.01	2.46	0.14	0	5	
DS Well	n/a	23/07/2013	20.3	0	1	9.71	0.01	8.4	0.01	8.42	1.29	0.03	11	7.66
DS Well	n/a	13/08/2013	4.1	0	8	3.51	0.00	3.3	0.03	3.33	0.18	0.07	9	
DS Well	n/a	02/09/2013	11	0	1	5.6	0.01	4.9	0.01	4.92	0.68	0.03	8	7.51
DS Well	n/a	06/10/2013	18.7	0	1	1.81	0.03	0.4	0.00	0.43	1.38	0.05	15	
DS Well	n/a	24/11/2013	19.1	0	2	2.1	0.03	0.8	0.00	0.83	1.27	0.07	19	
DS Well	n/a	10/12/2013	7.2	0	9	4.74	0.00	4.4	0.00	4.4	0.34	0.01	8	

ALTERNATIVE INFILTRATION SYSTEMS

Site A

(Co. Kilkenny)

ID	Depth	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Organic	PO4	Cl
LP 1.1 Red	1.2	09/11/2012											
LP 1.1 Red	1.2	04/12/2012											
LP 1.1 Red	1.2	22/01/2013	40	40.4	< 20	< 4.0	3.0	0.01	1.5	0.04	1.45	0.37	1
LP 1.1 Red	1.2	20/02/2013											
LP 1.1 Red	1.2	21/03/2013											
LP 1.1 Red	1.2	18/04/2013											
LP 1.1 Red	1.2	28/05/2013											
LP 1.1 Red	1.2	25/06/2013											
LP 1.1 Red	1.2	19/07/2013	75										22
LP 1.1 Red	1.2	30/07/2013											
LP 1.1 Red	1.2	15/08/2013											
LP 1.1 Red	1.2	20/09/2013											
LP 1.1 Red	1.2	01/10/2013											
LP 1.1 Red	1.2	19/11/2013	20										21
LP 1.1 Red	1.2	02/12/2013											
LP 1.1 Red	1.2	17/12/2013	1										14
LP 1.1 Red	1.2												
LP 1.1 Red	1.2	29/01/2013	180										19
LP 1.1 Blue	1.5	09/11/2012											
LP 1.1 Blue	1.5	04/12/2012	10	< 50	< 50	< 4							
LP 1.1 Blue	1.5	22/01/2013	30	< 20.0	< 20	< 4.0	2.8	0.02	1.3	0.01	1.47	0.15	3
LP 1.1 Blue	1.5	20/02/2013											
LP 1.1 Blue	1.5	21/03/2013											
LP 1.1 Blue	1.5	18/04/2013	5										16
LP 1.1 Blue	1.5	28/05/2013	**3**						0.9				107
LP 1.1 Blue	1.5	25/06/2013											
LP 1.1 Blue	1.5	19/07/2013											
LP 1.1 Blue	1.5	30/07/2013											
LP 1.1 Blue	1.5	15/08/2013											
LP 1.1 Blue	1.5	20/09/2013											
LP 1.1 Blue	1.5	01/10/2013											

LP 1.1 Blue	1.5	19/11/2013											
LP 1.1 Blue	1.5	02/12/2013	5										45
LP 1.1 Blue	1.5	17/12/2013	20										30
LP 1.1 Blue	1.5												
LP 1.1 Blue	1.5	29/01/2013	1000										20
LP 1.1 Black	1.8	09/11/2012	60	21.3	12	13.6	1.29	0.05	0.6	0.01	0.63	< 0.05	48
LP 1.1 Black	1.8	04/12/2012	220	28.8	< 1	< 4	1.03	0.08	0.1	0.01	0.84	0.33	< 10
LP 1.1 Black	1.8	22/01/2013	75	73.8	< 10	< 4.0	0.8	0	0.4	0.03	0.37	0.07	11
LP 1.1 Black	1.8	20/02/2013	180										10
LP 1.1 Black	1.8	21/03/2013	25			23.7		0.9	0.1			1.89	19
LP 1.1 Black	1.8	18/04/2013	10										18
LP 1.1 Black	1.8	28/05/2013											
LP 1.1 Black	1.8	25/06/2013											
LP 1.1 Black	1.8	19/07/2013	250										7
LP 1.1 Black	1.8	30/07/2013											
LP 1.1 Black	1.8	15/08/2013											
LP 1.1 Black	1.8	20/09/2013											
LP 1.1 Black	1.8	01/10/2013	60	48392	< 20	227	1.57	0.05	0.1	0	1.42	0.05	19
LP 1.1 Black	1.8	19/11/2013	130										20
LP 1.1 Black	1.8	02/12/2013	100										15
LP 1.1 Black	1.8	17/12/2013	180										16
LP 1.1 Black	1.8												
LP 1.1 Black	1.8	29/01/2013	300										13
LP 1.2 Red	1.2	09/11/2012	45	131.4	4.1	14	16.7	1.86	14.3	0.07	0.47	0.41	27
LP 1.2 Red	1.2	04/12/2012	500	816.4	< 1	54.8	12.7	0.24	12.2	0.02	0.24	0.07	< 10
LP 1.2 Red	1.2	22/01/2013	250	233.4	< 1	< 4.0	4.7	0.58	4.0	0.01	0.11	0.23	46
LP 1.2 Red	1.2	20/02/2013	60										41
LP 1.2 Red	1.2	21/03/2013	50	816.4	< 20	10.5		2.92	1.2	0.03		0.78	57
LP 1.2 Red	1.2	18/04/2013	**40**	8704	< 20	20.1	8.05	3.95	2.1	0.01	1.99	2.73	63
LP 1.2 Red	1.2	28/05/2013	**30**	864	< 20	14.2	5.25	0.56	2.6	0.01	2.08	0.66	75
LP 1.2 Red	1.2	25/06/2013	50	14540	40	27	8.89	0.89	3.4	0	4.60	0.5	18
LP 1.2 Red	1.2	19/07/2013	300	32.7	< 1	21	22.3	0.21	21.0	0.04	1.05	0.41	77

LP 1.2 Red	1.2	30/07/2013											
LP 1.2 Red	1.2	15/08/2013											
LP 1.2 Red	1.2	20/09/2013	25			39	31.1	0.2	29.3	0.05	1.55	0.15	59
LP 1.2 Red	1.2	01/10/2013	10	> 120980	< 50	188	33.4	0.72	29	0.23	3.45	0.2	72
LP 1.2 Red	1.2	19/11/2013	140	> 24196	10	10	68	0.05	36.4	0.01		0.37	91
LP 1.2 Red	1.2	02/12/2013	25	> 120980	< 50	25	27.4	0.58	21.6	0.03		5.3	72
LP 1.2 Red	1.2	17/12/2013	40			36	22.1	0.08	21.1	0.01		1.37	50
LP 1.2 Red	1.2												
LP 1.2 Red	1.2	29/01/2013	500	32.7	< 1	15	32.9	< 0.05	28	0.01		2.02	110
LP 1.2 Blue	1.5	09/11/2012	1000	1413.6	16.1	28.9	17.3	3.52	3.9	0.60	9.28	3.6	60
LP 1.2 Blue	1.5	04/12/2012	850	2909	< 1	39.6	16.9	> 3	1.7	0.17	12.03	3.58	27
LP 1.2 Blue	1.5	22/01/2013	250	3255.4	3.1	10.1	25	> 3.0	0.4	0.08	21.52	4.75	64
LP 1.2 Blue	1.5	20/02/2013	600										73
LP 1.2 Blue	1.5	21/03/2013	300	307.6	< 1	30.6		18.2	0.3	0.1		6.4	74
LP 1.2 Blue	1.5	18/04/2013	**500**	5170	3	39.8	32.6	22.58	3.4	0.03	6.59	6.12	73
LP 1.2 Blue	1.5	28/05/2013	**950**	3046	< 1	31.9	29.1	24.6	2	0.01	2.49	7.9	89
LP 1.2 Blue	1.5	25/06/2013	50	22398	< 10	42.5	14.2	1.98	0.3	0	11.92	5.5	76
LP 1.2 Blue	1.5	19/07/2013	250	2419.6	435.2	23	37.8	16	3.8	0.2	17.80	4.1	88
LP 1.2 Blue	1.5	30/07/2013											
LP 1.2 Blue	1.5	15/08/2013	250	42.7	< 1	77	87.7	40	42.7	1.76	3.24	1.82	82
LP 1.2 Blue	1.5	20/09/2013	20			86	104	0.3	87.6	0.01	16.09	0.45	58
LP 1.2 Blue	1.5	01/10/2013	75	48392	< 20	96	108	8	92	0.72	7.28	3.4	86
LP 1.2 Blue	1.5	19/11/2013	150	> 24196	< 10	8	62.4	0.29	60.9	0.02		6.6	79
LP 1.2 Blue	1.5	02/12/2013	40	12262	< 20	28	26.4	0.05	21.5	0.01		2.94	84
LP 1.2 Blue	1.5	17/12/2013	20	> 120980	< 50	32	20.6	0.06	19.7	0.02		0.53	43
LP 1.2 Blue	1.5												
LP 1.2 Blue	1.5	29/01/2013	1000	9.8	< 1	10	31.6	< 0.05	30.8	0.06		0.29	92
LP 1.2 Black	1.8	09/11/2012	100	62.2	31.5	< 4	1.39	0.05	0.9	0.02	0.42	0.06	14
LP 1.2 Black	1.8	04/12/2012	240	461	< 1	53.5	2.98	0.09	2.3	0.01	0.58	0.16	< 10
LP 1.2 Black	1.8	22/01/2013	70	< 20.0	< 20	< 4.0	4.2	0.0	4.0	0.03	0.17	0.18	25
LP 1.2 Black	1.8	20/02/2013	210										22
LP 1.2 Black	1.8	21/03/2013	125	71.8	< 2	10.7		0.2	2.5	0.05		0.05	36

LP 1.2 Black	1.8	18/04/2013	**150**	2419.6	18.1	39.2	1.69	0.02	1.4	0.01	0.26	6.8	55
LP 1.2 Black	1.8	28/05/2013	**50**			47.1	3.8	0.4	3.0	0.02	0.38	0.01	98
LP 1.2 Black	1.8	25/06/2013	30	9768	< 20	16.5	6.22	0.14	2.0	0.02	4.06	2.05	69
LP 1.2 Black	1.8	19/07/2013	250	261.3	135.4	15	5.18	0.12	3.3	0.01	1.75	0.01	71
LP 1.2 Black	1.8	30/07/2013											
LP 1.2 Black	1.8	15/08/2013											
LP 1.2 Black	1.8	20/09/2013	1				19.3						
LP 1.2 Black	1.8	01/10/2013	60	48392	< 10	48	38.7	0.02	28.8	0.02	9.86	0.01	47
LP 1.2 Black	1.8	19/11/2013	40	1989	< 10	7	16.5	0.05	14.6	< 0.02		0.02	58
LP 1.2 Black	1.8	02/12/2013	50	126	< 20	21	26.2	< 0.05	21.2	0.02		0.61	56
LP 1.2 Black	1.8	17/12/2013	50	> 48392	< 20	23	18.1	0.04	17.9	0.01		0.09	23
LP 1.2 Black	1.8												
LP 1.2 Black	1.8	29/01/2013	900	18.7	< 1	8	32.9	< 0.05	32	0		< 0.05	82
LP 2.1 Red	1.2	09/11/2012											
LP 2.1 Red	1.2	04/12/2012	30	10	< 10	49.8	2.12	0.11	1.8	0.05	0.16	0.27	< 10
LP 2.1 Red	1.2	22/01/2013											
LP 2.1 Red	1.2	20/02/2013	**75**	< 5	< 5	0.3	3.7	0.05	3.2	0.02	0.43	0.05	15
LP 2.1 Red	1.2	21/03/2013											
LP 2.1 Red	1.2	18/04/2013											
LP 2.1 Red	1.2	28/05/2013	**5**				2.7		3.8				24
LP 2.1 Red	1.2	25/06/2013											
LP 2.1 Red	1.2	19/07/2013	250										55
LP 2.1 Red	1.2	30/07/2013	30	34658	< 20	67	23.18	0.17	22.7	0.2	0.11	0.55	89
LP 2.1 Red	1.2	15/08/2013											
LP 2.1 Red	1.2	20/09/2013											
LP 2.1 Red	1.2	01/10/2013											
LP 2.1 Red	1.2	19/11/2013	50	3873	< 10	15	16.7	0.26	14.9	< 0.02		0.50	33
LP 2.1 Red	1.2	02/12/2013	25	> 120980	< 50	36	26	0.05	21.6	0.01		0.81	58
LP 2.1 Red	1.2	17/12/2013	2										35
LP 2.1 Red	1.2												
LP 2.1 Red	1.2	29/01/2013	600										29
LP 2.1 Blue	1.5	09/11/2012											

LP 2.1 Blue	1.5	04/12/2012	600	195.6	< 1	15.3	2.03	0.05	1.5	0.00	0.48	0.05	< 10
LP 2.1 Blue	1.5	22/01/2013	500	10	< 1	< 4.0	1.9	< 0.05	1.7	0.01	0.14	0.14	7
LP 2.1 Blue	1.5	20/02/2013	**180**	17.1	< 1	2.8	9.4	< 0.05	8.5	0.02	0.83	0.05	13
LP 2.1 Blue	1.5	21/03/2013											
LP 2.1 Blue	1.5	18/04/2013											
LP 2.1 Blue	1.5	28/05/2013											
LP 2.1 Blue	1.5	25/06/2013											
LP 2.1 Blue	1.5	19/07/2013	200										36
LP 2.1 Blue	1.5	30/07/2013	30	476	< 10	37	20.28	0.04	19.3	0.03	0.91	0.24	83
LP 2.1 Blue	1.5	15/08/2013											
LP 2.1 Blue	1.5	20/09/2013											
LP 2.1 Blue	1.5	01/10/2013											
LP 2.1 Blue	1.5	19/11/2013	140	1545	< 50	12	18.8	0.05	16.8	< 0.02		0.17	29
LP 2.1 Blue	1.5	02/12/2013	25	> 120980	< 50	32	23.9	< 0.05	22.5	0.03		0.66	46
LP 2.1 Blue	1.5	17/12/2013	10										29
LP 2.1 Blue	1.5												
LP 2.1 Blue	1.5	29/01/2013	1000										23
LP 2.1 Black	1.8	09/11/2012											
LP 2.1 Black	1.8	04/12/2012	300	70.3	< 1	3.3	2.68	0.05	2.1	0.01	0.52	4.28	< 10
LP 2.1 Black	1.8	22/01/2013	250	21.3	< 1	< 4.0	2.5	0.01	2.3	0.01	0.18	0.05	10
LP 2.1 Black	1.8	20/02/2013	**400**	< 1	< 1	1.8	1.2	0.03	1.1	0.02	0.05	0.07	11
LP 2.1 Black	1.8	21/03/2013											
LP 2.1 Black	1.8	18/04/2013											
LP 2.1 Black	1.8	28/05/2013	**40**			8.8	2.56	0.04	2.2	0.00	0.32	0.01	34
LP 2.1 Black	1.8	25/06/2013											
LP 2.1 Black	1.8	19/07/2013											
LP 2.1 Black	1.8	30/07/2013	50	82	< 10	23	26.4	0.16	26.2	0.01	0.03	0.08	75
LP 2.1 Black	1.8	15/08/2013											
LP 2.1 Black	1.8	20/09/2013	2				1.24		0.5				
LP 2.1 Black	1.8	01/10/2013											
LP 2.1 Black	1.8	19/11/2013	10	492	< 20	10	15.6	0.01	13.9	< 0.02		0.14	23
LP 2.1 Black	1.8	02/12/2013	40	> 48392	< 20	29	17.5	< 0.05	16.8	0.02		0.09	22

LP 2.1 Black	1.8	17/12/2013	50										15
LP 2.1 Black	1.8												
LP 2.1 Black	1.8	29/01/2013	500										22
LP 2.2 Red	1.2	09/11/2012	75	387.3	8.4	12.8	11	0.03	10.1	0.01	0.86	< 0.05	21
LP 2.2 Red	1.2	04/12/2012	700	727	< 1	< 4	8.6	0.2	8.2	0.01	0.19	< 0.05	3
LP 2.2 Red	1.2	22/01/2013	400	< 10.0	< 10	3.4	6.5	0.41	6.0	0.04	0.05	< 0.05	46
LP 2.2 Red	1.2	20/02/2013	300										65
LP 2.2 Red	1.2	21/03/2013	50	148.3	< 20	26.7		0.85	12.8	0.07		0.19	62
LP 2.2 Red	1.2	18/04/2013	**60**	2247	1	19.7	31.3	0.09	30.4	0.03	0.78	6.13	53
LP 2.2 Red	1.2	28/05/2013	**30**	3744	20	41.1	27.2	0.09	24.7	0.01	2.40	0.05	76
LP 2.2 Red	1.2	25/06/2013											
LP 2.2 Red	1.2	19/07/2013	300	727	< 1	12.3	20	0.04	19.0	0.02	0.94	0.23	66
LP 2.2 Red	1.2	30/07/2013											
LP 2.2 Red	1.2	15/08/2013	25	727	< 20	29	24.4	0.52	21.3	0.2	2.38	0.28	58
LP 2.2 Red	1.2	20/09/2013	25			56	24.3	0.45	23.7	0.02	0.13	0.45	48
LP 2.2 Red	1.2	01/10/2013											
LP 2.2 Red	1.2	19/11/2013	50										59
LP 2.2 Red	1.2	02/12/2013											
LP 2.2 Red	1.2	17/12/2013	50	984	< 10	26	27.7	0.07	27.5	0.02		0.44	62
LP 2.2 Red	1.2												
LP 2.2 Red	1.2	29/01/2013	1000										40
LP 2.2 Blue	1.5	09/11/2012	25	613.1	< 1.0	3.6	11.9	0.15	11.6		0.15	0.1	24
LP 2.2 Blue	1.5	04/12/2012	1000	1258	< 1	21.3	5.7	0.17	4.8	0.04	0.69	0.42	< 10
LP 2.2 Blue	1.5	22/01/2013	1100	< 10.0	< 1	< 4.0	14.1	0.04	13.3	0.02	0.74	< 0.05	48
LP 2.2 Blue	1.5	20/02/2013	600										52
LP 2.2 Blue	1.5	21/03/2013											
LP 2.2 Blue	1.5	18/04/2013	**20**	3448	< 20	21.9	8.62	0.16	8.4	0.05	0.01	0.55	51
LP 2.2 Blue	1.5	28/05/2013	**25**			34.5	12.9	0.07	12.4	0.10	0.33	0.18	53
LP 2.2 Blue	1.5	25/06/2013											
LP 2.2 Blue	1.5	19/07/2013	300	73.8	< 1	6.2	13.1	0.17	10.7	0.20	2.03	0.09	52
LP 2.2 Blue	1.5	30/07/2013											
LP 2.2 Blue	1.5	15/08/2013											

LP 2.2 Blue	1.5	20/09/2013	20			30	17.5	0.45	14.7	0.02	2.33	0.35	44
LP 2.2 Blue	1.5	01/10/2013	20	55995	< 50	103	24.2	0.01	17.9	0.06	6.23	0.02	73
LP 2.2 Blue	1.5	19/11/2013	2										52
LP 2.2 Blue	1.5	02/12/2013	5										59
LP 2.2 Blue	1.5	17/12/2013	30	196	< 20	16	26.7	< 0.05	24.6	0.01		0.09	60
LP 2.2 Blue	1.5												
LP 2.2 Blue	1.5	29/01/2013	1000										25
LP 2.2 Black	1.8	09/11/2012	100	248.9	22.8	9.8	1.96	0.16	1.6	0.02	0.18	0.5	15
LP 2.2 Black	1.8	04/12/2012	300	214.3	< 1	15	3.16	0.05	2.3	0.01	0.80	4.78	< 10
LP 2.2 Black	1.8	22/01/2013	200	2.0	< 1	< 4.0	4.0	0.02	3.6	0.03	0.35	0.04	35
LP 2.2 Black	1.8	20/02/2013	300										44
LP 2.2 Black	1.8	21/03/2013	35			14.4		0.06	3.5	0.1		0.01	59
LP 2.2 Black	1.8	18/04/2013	**150**	613.1	< 1	18.2	9.24	0.04	8.9	0.01	0.29	0.15	60
LP 2.2 Black	1.8	28/05/2013	**25**			8.7	9.49	0.02	7.6	0	1.87	0.10	49
LP 2.2 Black	1.8	25/06/2013											
LP 2.2 Black	1.8	19/07/2013	250	16.1	< 1	5.9	8.07	0.4	3	0.02	4.65	0.03	17
LP 2.2 Black	1.8	30/07/2013											
LP 2.2 Black	1.8	15/08/2013											
LP 2.2 Black	1.8	20/09/2013	40			79	15.3	0.6	13.1	0.01	1.59	0.05	40
LP 2.2 Black	1.8	01/10/2013	40	48392	< 20	103	22.6	0.1	19.6	0.07	2.83	0	67
LP 2.2 Black	1.8	19/11/2013	110										25
LP 2.2 Black	1.8	02/12/2013	80										41
LP 2.2 Black	1.8	17/12/2013	120	980.4	< 1	15	18.3	< 0.05	14.1	0.01		0.04	20
LP 2.2 Black	1.8												
LP 2.2 Black	1.8	29/01/2013	600										25
LP 3.1 Red	1.2	09/11/2012	45	< 10	< 10	6.4	6.08	0.05	5.2	0.02	0.81	0.37	0
LP 3.1 Red	1.2	04/12/2012											
LP 3.1 Red	1.2	22/01/2013											
LP 3.1 Red	1.2	20/02/2013											
LP 3.1 Red	1.2	21/03/2013											
LP 3.1 Red	1.2	18/04/2013											
LP 3.1 Red	1.2	28/05/2013											

LP 3.1 Red	1.2	25/06/2013											
LP 3.1 Red	1.2	19/07/2013	150	2419.6	< 1	11.9	22.5	0.6	20.6	0.03	1.27	0.03	80
LP 3.1 Red	1.2	30/07/2013	30	104	< 10	15.0	6.5	2.33	3.9	0.08	0.19	0.27	94
LP 3.1 Red	1.2	15/08/2013	15	48392	< 20	27.0	23.8	0.34	21.7	0.02	1.74	0.30	74
LP 3.1 Red	1.2	20/09/2013											
LP 3.1 Red	1.2	01/10/2013	5			9	9.17		5.3	0.35	3.52		43
LP 3.1 Red	1.2	19/11/2013	10										41
LP 3.1 Red	1.2	02/12/2013	5										62
LP 3.1 Red	1.2	17/12/2013	10										32
LP 3.1 Red	1.2												
LP 3.1 Red	1.2	29/01/2013	700	1732.9	< 1	8	24.5	< 0.05	24	0.01		1.1	94
LP 3.1 Blue	1.5	09/11/2012											
LP 3.1 Blue	1.5	04/12/2012	1000	275.5	< 1	< 4	5.66	0.04	5.3	0.01	0.31	0.07	< 10
LP 3.1 Blue	1.5	22/01/2013	800	< 10.0	< 1	< 4.0	4.8	< 0.05	4.7	0.01	0.04	< 0.05	21
LP 3.1 Blue	1.5	20/02/2013	**320**	3.1	< 1	3.1	6.3	< 0.05	5.5	0.01	0.74	0.04	26
LP 3.1 Blue	1.5	21/03/2013											
LP 3.1 Blue	1.5	18/04/2013											
LP 3.1 Blue	1.5	28/05/2013											
LP 3.1 Blue	1.5	25/06/2013	30	36924	< 20	10.1	19.3	0.01	13.7	0.027	5.56	0.04	88
LP 3.1 Blue	1.5	19/07/2013	200	34.5	1	8.2	5.73	0.11	3.4	0.01	2.21	0.00	63
LP 3.1 Blue	1.5	30/07/2013	90	146	10	51	31.6	5.1	14	0.5	12.00	0.37	86
LP 3.1 Blue	1.5	15/08/2013											
LP 3.1 Blue	1.5	20/09/2013											
LP 3.1 Blue	1.5	01/10/2013	5			197	16.2		17.7	0.2			59
LP 3.1 Blue	1.5	19/11/2013	10										34
LP 3.1 Blue	1.5	02/12/2013	5										47
LP 3.1 Blue	1.5	17/12/2013	10										26
LP 3.1 Blue	1.5												
LP 3.1 Blue	1.5	29/01/2013	1000	20	< 1	7	30.9	< 0.05	29.7	0.01		0.46	90
LP 3.1 Black	1.8	09/11/2012											
LP 3.1 Black	1.8	04/12/2012	75	96	< 10	< 4	4.37	0.04	3.7	0.01	0.62	2.19	< 10
LP 3.1 Black	1.8	22/01/2013	40	< 20.0	< 20	< 4.0	6.7	0.01	6.0	0.04	0.65	0.07	13

LP 3.1 Black	1.8	20/02/2013	**140**	10.4	< 1	2.5	2.2	0.17	1.2	0.04	0.79	0.02	19
LP 3.1 Black	1.8	21/03/2013											
LP 3.1 Black	1.8	18/04/2013											
LP 3.1 Black	1.8	28/05/2013											
LP 3.1 Black	1.8	25/06/2013	60	15402	< 10	8.7	9.37	0.01	4.9	0.03	4.43	0.00	74
LP 3.1 Black	1.8	19/07/2013	200	14.6	< 1	5.4	4.06	0.1	2.1	0.01	1.85	0.00	48
LP 3.1 Black	1.8	30/07/2013	30	2086	< 20	9	33.6	0.03	32.8	0.04	0.73	0.03	73
LP 3.1 Black	1.8	15/08/2013											
LP 3.1 Black	1.8	20/09/2013											
LP 3.1 Black	1.8	01/10/2013	100	24196	< 10	104	26.9	0.01	14.8	0.01	12.08	0	50
LP 3.1 Black	1.8	19/11/2013	50										29
LP 3.1 Black	1.8	02/12/2013											
LP 3.1 Black	1.8	17/12/2013	80										18
LP 3.1 Black	1.8												
LP 3.1 Black	1.8	29/01/2013	900	38.9	< 1	1	29.2	< 0.05	28.6	0.01		0.15	76
LP 4.1 Red	1.2	09/11/2012	45	6.3	< 1.0	6.7	14.1	0.12	13.2	0.04	0.74	0.05	37
LP 4.1 Red	1.2	04/12/2012	800	62	< 1	9.2	4.81	0.03	3.95	0.00	0.83	0.06	< 10
LP 4.1 Red	1.2	22/01/2013	600	2.0	< 1	< 4.0	4.0	< 0.05	3.6	0.01	0.34	0.07	49
LP 4.1 Red	1.2	20/02/2013	**100**	< 2	< 2	0.1	8	0.08	7.3	0.02	0.6	0.05	44
LP 4.1 Red	1.2	21/03/2013											
LP 4.1 Red	1.2	18/04/2013	**10**	20460	1	22.9	11.9	0.25	10.7	0.05	0.90	0.21	57
LP 4.1 Red	1.2	28/05/2013											
LP 4.1 Red	1.2	25/06/2013	50	34658	< 10	27.8	16.4	0.2	11.3	0.11	4.79	0.98	61
LP 4.1 Red	1.2	19/07/2013	75										46
LP 4.1 Red	1.2	30/07/2013											
LP 4.1 Red	1.2	15/08/2013	15	825	< 50	55	13.2		8.3	0.01	4.89	1.28	42
LP 4.1 Red	1.2	20/09/2013											
LP 4.1 Red	1.2	01/10/2013											
LP 4.1 Red	1.2	19/11/2013	90	> 24196	< 10	16	13.3	0.05	13.3	0		0.17	64
LP 4.1 Red	1.2	02/12/2013	20	19365	< 50	29	14.28	< 0.05	9.9	0.02		0.9	72
LP 4.1 Red	1.2	17/12/2013	80	> 24196	< 10	27	17.7	0.04	14.9	0.01		0.16	48
LP 4.1 Red	1.2												

LP 4.1 Red	1.2	29/01/2013	600	> 2420	< 1	9	22.9	< 0.05	22.2	0.01		0.06	70
LP 4.1 Blue	1.5	09/11/2012											
LP 4.1 Blue	1.5	04/12/2012	1100	387.3	1	< 4	4.67	0.12	4.5	0.00	0.05	4.83	< 10
LP 4.1 Blue	1.5	22/01/2013	800	1	< 1	< 4.0	10.2	1.58	5.2	0.04	3.38	0.34	46
LP 4.1 Blue	1.5	20/02/2013	**600**	1	< 1	8	3.7	0.5	3.1	0.01	0.09	0.83	60
LP 4.1 Blue	1.5	21/03/2013	**175**	29.5	< 1	16.1		5.1	5.1	0.01		0.51	58
LP 4.1 Blue	1.5	18/04/2013	**400**	816.4	3	21.7	27.1	2.48	22.1	0.09	2.43	0.43	52
LP 4.1 Blue	1.5	28/05/2013	**25**			6.6	38.9	0.65	32.1	0.00	6.15	0.12	64
LP 4.1 Blue	1.5	25/06/2013	40	20924	< 10	16.7	11.3	0.01	8.3	0.20	2.79	0.31	38
LP 4.1 Blue	1.5	19/07/2013	250										36
LP 4.1 Blue	1.5	30/07/2013											
LP 4.1 Blue	1.5	15/08/2013											
LP 4.1 Blue	1.5	20/09/2013											
LP 4.1 Blue	1.5	01/10/2013	10	120980	< 50	120	18.7	0.02	2.4	0.1	16.18		73
LP 4.1 Blue	1.5	19/11/2013	120	354	< 10	11	11.8	0.05	9.1	0.01		0.1	62
LP 4.1 Blue	1.5	02/12/2013	50	9945	< 50	20	11.06	< 0.05	10.6	0.05		0.56	34
LP 4.1 Blue	1.5	17/12/2013	150	517.2	< 1	18	8.43	< 0.03	7.9	0.02		0.01	31
LP 4.1 Blue	1.5												
LP 4.1 Blue	1.5	29/01/2013	1000	261.3	< 1	5	17.5	< 0.05	16.9	0		0.04	64
LP 4.1 Black	1.8	09/11/2012	30	24.3	4.1	21	1.45	0.07	0.5	0.02	0.86	0	6
LP 4.1 Black	1.8	04/12/2012	130	920.8	< 1	1.8	1.67	0.04	0.8	0.00	0.83	0.86	< 10
LP 4.1 Black	1.8	22/01/2013	50	< 20.0	< 20	< 4.0	1.5	0.42	1.0	0.02	0.06	0.01	10
LP 4.1 Black	1.8	20/02/2013	**190**	2	< 1	2.4	2.3	0.02	2.2	0.01	0.07	0.05	11
LP 4.1 Black	1.8	21/03/2013	**15**			5.7		0.38	2.2	0.02		0.05	35
LP 4.1 Black	1.8	18/04/2013	**15**	4320	< 50	25.4	3.24	0.16	1.0	0.00	2.08	0.14	23
LP 4.1 Black	1.8	28/05/2013											
LP 4.1 Black	1.8	25/06/2013	40	18416	< 20	7.8	6.88	0.02	3.6	0.07	3.19	0.24	37
LP 4.1 Black	1.8	19/07/2013	50										19
LP 4.1 Black	1.8	30/07/2013											
LP 4.1 Black	1.8	15/08/2013											
LP 4.1 Black	1.8	20/09/2013	3				17.5		12.3		5.20		

LP 4.1 Black	1.8	01/10/2013	50	31062	124	56	6.19	0.01	5.6	0.02	0.56	0	56
LP 4.1 Black	1.8	19/11/2013	100	41	< 10	10	19.8	0.02	17.7	0.02		0.05	59
LP 4.1 Black	1.8	02/12/2013	40	6510	< 20	15	7.32	< 0.05	5.5	0.01		0.19	26
LP 4.1 Black	1.8	17/12/2013	40	52	< 10	7	5.86	0.01	5.8	0.02		< 0.05	20
LP 4.1 Black	1.8												
LP 4.1 Black	1.8	29/01/2013	200	110	< 1	4	17.8	< 0.05	17	0.02		0.02	46

ID	Depth	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Organic	PO4	Cl
DR 1 Red	1.2	09/11/2012	40	5.2	5.2	22.1	5.48	0.04	4.9	0.03	0.51	0.16	18
DR 1 Red	1.2	04/12/2012	350	179.3	< 1	< 4	3.17	0.03	2.3	0.00	0.84	0.12	< 10
DR 1 Red	1.2	22/01/2013	50	< 20.0	< 20	< 4.0	5.5	0.02	4.6	0.01	0.87	0.11	29
DR 1 Red	1.2	20/02/2013											
DR 1 Red	1.2	21/03/2013											
DR 1 Red	1.2	18/04/2013											
DR 1 Red	1.2	28/05/2013	40	316	< 10								
DR 1 Red	1.2	25/06/2013	20	7746	< 20	49.2	3.7	0	2.6	0.02	1.08	0.09	63
DR 1 Red	1.2	19/07/2013	25										33
DR 1 Red	1.2	30/07/2013	20	14540	< 20	71			3.3				46
DR 1 Red	1.2	15/08/2013											
DR 1 Red	1.2	20/09/2013											
DR 1 Red	1.2	01/10/2013											
DR 1 Red	1.2	19/11/2013	20	1414	< 10	21	5.22	0.11	3.7	0.00		0.12	35
DR 1 Red	1.2	02/12/2013	40	> 48392	20	26	7.66	< 0.05	3.8	0.03		0.56	62
DR 1 Red	1.2	17/12/2013	40	14540	< 20	35	9.63	0.05	8.1	0.02		0.05	38
DR 1 Red	1.2												
DR 1 Red	1.2	29/01/2013	1000	25.9		10	19.3	< 0.05	18.5	0.01		0.08	36
DR 1 Blue	1.5	09/11/2012											
DR 1 Blue	1.5	04/12/2012	1000	866.4	6	< 4	2.86	0.04	1.9	0.00	0.92	0.06	< 10
DR 1 Blue	1.5	22/01/2013	500	2.0	< 1	< 4.0	2.0	< 0.05	1.7	0.02	0.23	< 0.05	14
DR 1 Blue	1.5	20/02/2013	**300**	1	< 1	3.8	3.1	0.03	2.2	0.00	0.87	0.04	21
DR 1 Blue	1.5	21/03/2013											
DR 1 Blue	1.5	18/04/2013											
DR 1 Blue	1.5	28/05/2013											
DR 1 Blue	1.5	25/06/2013	40	7368	< 10	18.9	3.46	0.02	4.8	0.03		0.04	61
DR 1 Blue	1.5	19/07/2013	50										18
DR 1 Blue	1.5	30/07/2013	30	1290	< 10	65	7.76	0.12	6.9		0.74	1.10	46
DR 1 Blue	1.5	15/08/2013											
DR 1 Blue	1.5	20/09/2013											
DR 1 Blue	1.5	01/10/2013	5	120980	< 50	129	13.5	1.35	8.7	1.00	2.45		41

DR 1 Blue	1.5	19/11/2013	50	100	< 50	15	3.73	0.03	3.1	0.04		0.08	34
DR 1 Blue	1.5	02/12/2013	40	17328	< 20	22	6.62	< 0.05	5.8	0.00		0.47	48
DR 1 Blue	1.5	17/12/2013	20	2900	< 20	9	8.26	< 0.05	8.16	0.02		< 0.05	31
DR 1 Blue	1.5												
DR 1 Blue	1.5	29/01/2013	1000	27.5		7	16.8	< 0.05	16.4	0.01		0.06	44
DR 1 Black	1.8	09/11/2012											
DR 1 Black	1.8	04/12/2012	1000	933	< 1	9.2	2.2	0.11	1.8	0.00	0.29	< 0.05	< 10
DR 1 Black	1.8	22/01/2013	300	6.2	< 1	< 4.0	5.4	< 0.05	4.9	0.02	0.43	0.01	23
DR 1 Black	1.8	20/02/2013	**300**	4.1	< 1	1.2	5.6	0	5.2	0.01	0.39	0.02	24
DR 1 Black	1.8	21/03/2013	**20**			4.2		0.05	0.2	0.02		0.70	42
DR 1 Black	1.8	18/04/2013											
DR 1 Black	1.8	28/05/2013											
DR 1 Black	1.8	25/06/2013	60	4196	< 10	7.2	2.58	0	1.7	0.02	0.86	0.02	55
DR 1 Black	1.8	19/07/2013											
DR 1 Black	1.8	30/07/2013	20	370	< 20	45	9.66		9.5		0.16	0.90	
DR 1 Black	1.8	15/08/2013											
DR 1 Black	1.8	20/09/2013	10			22	12.3		11.9	0.03	0.37	0.30	39
DR 1 Black	1.8	01/10/2013											
DR 1 Black	1.8	19/11/2013	100	20	< 20	14	2.01	0.03	1.3	0.00		0.02	29
DR 1 Black	1.8	02/12/2013	40	1918	< 20	8	3.46	0.02	1.8	0.04		0.34	34
DR 1 Black	1.8	17/12/2013	20	492	< 20	7	8.23	< 0.05	8.2	0.02		< 0.05	28
DR 1 Black	1.8												
DR 1 Black	1.8	29/01/2013	500	950.4		< 10	16	< 0.05	15.6	0.00		0.03	40
DR 2 Red	1.2	09/11/2012	85	1046.2	< 1.0	11.3	1.8	0.09	1.1	0.01	0.60	5.95	24
DR 2 Red	1.2	04/12/2012	800	770.1	< 1	36.1	1.42	0.06	0.2	0.00	1.16	< 0.05	3
DR 2 Red	1.2	22/01/2013	600	4.1	< 1	< 4.0	0.9	< 0.05	0.4	0.01	0.44	< 0.05	50
DR 2 Red	1.2	20/02/2013	300										39
DR 2 Red	1.2	21/03/2013	20			5		0.29	0.5	0.01		0.05	11
DR 2 Red	1.2	18/04/2013	**20**	3970	< 20	15.1	0.42	0.05	0.2	0.01	0.16	0.05	48
DR 2 Red	1.2	28/05/2013	30	172	< 10								
DR 2 Red	1.2	25/06/2013	10	6896	< 50	31.5	18.9	0.01	18.2	0.02	0.67	0.07	57
DR 2 Red	1.2	19/07/2013											

DR 2 Red	1.2	30/07/2013	20	9222	< 20	167			2.9				
DR 2 Red	1.2	15/08/2013											
DR 2 Red	1.2	20/09/2013											
DR 2 Red	1.2	01/10/2013											
DR 2 Red	1.2	19/11/2013	100										66
DR 2 Red	1.2	02/12/2013	180	727	< 1	42	57.6	2.23	53.8	0.05		1.15	60
DR 2 Red	1.2	17/12/2013	250	1553.1	< 1	44	54.6	0.11	50.4	0.01		0.03	70
DR 2 Red	1.2												
DR 2 Red	1.2	29/01/2013	500	90.6		15	51.6	< 0.05	50.1	0.00		0.09	76
DR 2 Blue	1.5	09/11/2012											
DR 2 Blue	1.5	04/12/2012	250	> 24196	1	< 4	1.17	0.56	0.4	0.01	0.20	0.21	< 10
DR 2 Blue	1.5	22/01/2013	180	62.6	< 1	< 4.0	1.1	0.23	0.1	0.01	0.76	0.02	30
DR 2 Blue	1.5	20/02/2013	180										49
DR 2 Blue	1.5	21/03/2013	25			3.3		0.2	1.8	0.26		0.16	28
DR 2 Blue	1.5	18/04/2013	**10**	850	< 50	35.6	0.32	0.1	0.2	0.01	0.01	0.12	50
DR 2 Blue	1.5	28/05/2013											
DR 2 Blue	1.5	25/06/2013	20	3720	< 20	13.3	6.71	0.03	3.1	0.03	3.55	0.03	45
DR 2 Blue	1.5	19/07/2013	250	248.1	< 1	6.9	10.6	1.46	7.3	0.05	1.79	0.31	63
DR 2 Blue	1.5	30/07/2013	20	10344	< 50	20	6.68		6.5		0.18	0.13	45
DR 2 Blue	1.5	15/08/2013											
DR 2 Blue	1.5	20/09/2013											
DR 2 Blue	1.5	01/10/2013											
DR 2 Blue	1.5	19/11/2013	2										63
DR 2 Blue	1.5	02/12/2013	30	486	< 20	18	32.4	< 0.05	26.2	< 0.02		0.47	40
DR 2 Blue	1.5	17/12/2013	200	261.3	< 1	36	53.1	< 0.05	52.7	0.02		0.01	68
DR 2 Blue	1.5												
DR 2 Blue	1.5	29/01/2013	500	91.1		14	50.3	< 0.05	49.7	0.01		0.05	72
DR 2 Black	1.8	09/11/2012											
DR 2 Black	1.8	04/12/2012	230	> 24196	7.5	32.9	2.34	0.06	0.5	0.01	1.77	0.05	16
DR 2 Black	1.8	22/01/2013	75	253	1	< 4.0	1.2	0.32	0.1	0.06	0.72	0.04	43
DR 2 Black	1.8	20/02/2013	200										42
DR 2 Black	1.8	21/03/2013											

DR 2 Black	1.8	18/04/2013	**40**	217.2	< 10	12.8	0.68	0.03	0.4	0.01	0.24	0.14	5
DR 2 Black	1.8	28/05/2013											
DR 2 Black	1.8	25/06/2013											
DR 2 Black	1.8	19/07/2013	200	686.7	< 1	3.3	7.77	1.18	3.4	0.00	3.19	0.05	40
DR 2 Black	1.8	30/07/2013											
DR 2 Black	1.8	15/08/2013											
DR 2 Black	1.8	20/09/2013	25	455	< 50	27	15.30	0.45	13.4	0.02	1.43	0.15	29
DR 2 Black	1.8	01/10/2013											
DR 2 Black	1.8	19/11/2013	500										14
DR 2 Black	1.8	02/12/2013	80	201	< 10	14	32	0.05	28.7	0.05		0.31	35
DR 2 Black	1.8	17/12/2013	500	> 2420	< 1	24	40.4	< 0.05	40.1	< 0.02		< 0.05	48
DR 2 Black	1.8												
DR 2 Black	1.8	29/01/2013	500	124.6		8	45.5	< 0.05	45.0	0.02		0.02	72
DR 3 Red	1.2	09/11/2012	25	148.3	< 1.0	21.2	3.08	0.5	2		0.58	0.29	8
DR 3 Red	1.2	04/12/2012	350	11199	< 1	9.5	1.76	0.15	1	0.01	0.60	4.68	< 10
DR 3 Red	1.2	22/01/2013	220	< 10.0	< 1	< 4.0	1.0	0.03	0.6	0.02	0.35	0.04	11
DR 3 Red	1.2	20/02/2013											
DR 3 Red	1.2	21/03/2013											
DR 3 Red	1.2	18/04/2013											
DR 3 Red	1.2	28/05/2013											
DR 3 Red	1.2	25/06/2013											
DR 3 Red	1.2	19/07/2013											
DR 3 Red	1.2	30/07/2013	10	670	< 50	52			4.3				80
DR 3 Red	1.2	15/08/2013											
DR 3 Red	1.2	20/09/2013											
DR 3 Red	1.2	01/10/2013											
DR 3 Red	1.2	19/11/2013	35	> 48392	< 20	22	6.56	0.05	5.8	0.01		0.36	47
DR 3 Red	1.2	02/12/2013	40										39
DR 3 Red	1.2	17/12/2013	1										50
DR 3 Red	1.2												
DR 3 Red	1.2	29/01/2013	300										60

DR 3 Blue	1.5	09/11/2012	45	8.4	1	< 4	2.04	0.09	1.8	0.01	0.14	0	11
DR 3 Blue	1.5	04/12/2012	1000	> 2419.6	< 1	2.5	4.29	0.09	3.8	0.01	0.39	0.15	< 10
DR 3 Blue	1.5	22/01/2013	500	20	< 1	< 4.0	8.3	< 0.05	7.4	0.01	0.84	0.01	29
DR 3 Blue	1.5	20/02/2013	**300**	4.1	< 1	2.2	2	0.01	1.9	0.02	0.07	0.01	29
DR 3 Blue	1.5	21/03/2013											
DR 3 Blue	1.5	18/04/2013	**20**	1165	< 50	13.2	1.02	0.08	0.5	0.01	0.43	0.06	22
DR 3 Blue	1.5	28/05/2013	**20**			46.9	8	0.03	7.8	0.02	0.15	0.02	33
DR 3 Blue	1.5	25/06/2013											
DR 3 Blue	1.5	19/07/2013	75	9768	< 10	5.5	9.22	1.1	3.5	0.01	4.61	0.07	82
DR 3 Blue	1.5	30/07/2013	20	5226	< 20	41	8.4		8		0.40	0.18	51
DR 3 Blue	1.5	15/08/2013											
DR 3 Blue	1.5	20/09/2013	25	444	< 20	63	30	1.9	20.8		7.30	0.30	31
DR 3 Blue	1.5	01/10/2013	50	48392	< 20	128	13	0.02	3.6	0.05	9.33	0.05	64
DR 3 Blue	1.5	19/11/2013	80	> 48392	< 20	12	4.68	0.05	3.8	< 0.02		< 0.07	29
DR 3 Blue	1.5	02/12/2013	60										22
DR 3 Blue	1.5	17/12/2013	150										45
DR 3 Blue	1.5												
DR 3 Blue	1.5	29/01/2013	1000										50
DR 3 Black	1.8	09/11/2012											
DR 3 Black	1.8	04/12/2012	50	1443	< 10	14.2	1.78	0.24	0.7	0.04	0.80	0.21	< 10
DR 3 Black	1.8	22/01/2013	50	40.5	< 10	< 4.0	2.2	0.14	1.5	0.05	0.51	0.05	25
DR 3 Black	1.8	20/02/2013	**175**	< 20	< 20	1.5	2.1	0.06	1.4	0.01	0.63	0.01	14
DR 3 Black	1.8	21/03/2013	**25**			< 4		0.6	0.2	0.05		0.04	28
DR 3 Black	1.8	18/04/2013	**20**	1470	< 20	22.8	2.56	0.02	1.1	0.01	1.43	0.01	4
DR 3 Black	1.8	28/05/2013	**40**			11.5	5.42	0.01	2.1	0.01	3.30	0.01	60
DR 3 Black	1.8	25/06/2013											
DR 3 Black	1.8	19/07/2013	250	292.8	< 1	4.2	8.45	0.26	3.4	0.01	4.78	0.01	43
DR 3 Black	1.8	30/07/2013											
DR 3 Black	1.8	15/08/2013											
DR 3 Black	1.8	20/09/2013											
DR 3 Black	1.8	01/10/2013											
DR 3 Black	1.8	19/11/2013	70	48392	< 20	6	9.5	0.03	9.2	< 0.02		0.07	23

DR 3 Black	1.8	02/12/2013	5										14
DR 3 Black	1.8	17/12/2013	20										43
DR 3 Black	1.8												
DR 3 Black	1.8	29/01/2013	300										46
DR 4 Red	1.2	09/11/2012	100	> 2419.6	< 1.0	16.6	1.89	0.08	1.5	0.02	0.29	0.02	13
DR 4 Red	1.2	04/12/2012	300	1467	< 1	< 4	1.86	0.03	1.7	0.01	0.12	0.92	< 10
DR 4 Red	1.2	22/01/2013	300	20.2	< 1	< 4.0	2.7	< 0.05	2.1	0.02	0.53	< 0.05	7
DR 4 Red	1.2	20/02/2013	60										16
DR 4 Red	1.2	21/03/2013	140	62.6	< 2	11.5		0.8	13.4	0.01		0.03	19
DR 4 Red	1.2	18/04/2013	30										11
DR 4 Red	1.2	28/05/2013											
DR 4 Red	1.2	25/06/2013											
DR 4 Red	1.2	19/07/2013	50										56
DR 4 Red	1.2	30/07/2013											
DR 4 Red	1.2	15/08/2013	5	292.8	< 100	34	7.21		3.3		3.91		22
DR 4 Red	1.2	20/09/2013	20	395	< 50	9	11.5		9.5	0.01	1.99	0.20	5
DR 4 Red	1.2	01/10/2013											
DR 4 Red	1.2	19/11/2013	60										31
DR 4 Red	1.2	02/12/2013	40										50
DR 4 Red	1.2	17/12/2013	5										52
DR 4 Red	1.2												
DR 4 Red	1.2	29/01/2013	600										58
DR 4 Blue	1.5	09/11/2012											
DR 4 Blue	1.5	04/12/2012	800	1986.3	4.1	17.4	1.94	0.04	1.7	0.02	0.18	0.28	< 10
DR 4 Blue	1.5	22/01/2013	180	10	< 1	< 4.0	5.1	0.06	4.1	0.03	0.91	0.1	20
DR 4 Blue	1.5	20/02/2013	200										21
DR 4 Blue	1.5	21/03/2013	70			8.3		0.94	2	0.02		0.05	7
DR 4 Blue	1.5	18/04/2013	40										18
DR 4 Blue	1.5	28/05/2013											
DR 4 Blue	1.5	25/06/2013											
DR 4 Blue	1.5	19/07/2013	50										44
DR 4 Blue	1.5	30/07/2013	20	14540	< 20	40	9.04		8.4		0.64	0.20	56

DR 4 Blue	1.5	15/08/2013	10	140.4	< 50	23	5.59		2.2		3.39		18
DR 4 Blue	1.5	20/09/2013	25	578	< 20	5	5.65		5.4	0.00	0.25	0.10	8
DR 4 Blue	1.5	01/10/2013											
DR 4 Blue	1.5	19/11/2013	90										19
DR 4 Blue	1.5	02/12/2013	40										23
DR 4 Blue	1.5	17/12/2013	50										37
DR 4 Blue	1.5												
DR 4 Blue	1.5	29/01/2013	600										46
DR 4 Black	1.8	09/11/2012											
DR 4 Black	1.8	04/12/2012	1100	799	< 1	2.4	3.35	0.04	3.2	0.00	0.11	< 0.05	< 10
DR 4 Black	1.8	22/01/2013	200	< 10.0	< 1	< 4.0	9.6	0.0	8.9	0.02	0.68	0.01	19
DR 4 Black	1.8	20/02/2013	500										20
DR 4 Black	1.8	21/03/2013											
DR 4 Black	1.8	18/04/2013											
DR 4 Black	1.8	28/05/2013											
DR 4 Black	1.8	25/06/2013											
DR 4 Black	1.8	19/07/2013											
DR 4 Black	1.8	30/07/2013	10	15380	< 50	36							155
DR 4 Black	1.8	15/08/2013											
DR 4 Black	1.8	20/09/2013											
DR 4 Black	1.8	01/10/2013	20	48392	< 20	10	7.99	0.12	1.3	0.22	6.35	0.18	24
DR 4 Black	1.8	19/11/2013	10										18
DR 4 Black	1.8	02/12/2013	5										19
DR 4 Black	1.8	17/12/2013	50										30
DR 4 Black	1.8												
DR 4 Black	1.8	29/01/2013	600										32
DR 5 Red	1.2	09/11/2012											
DR 5 Red	1.2	04/12/2012	600	344.8	< 1	< 4	1.98	0.05	1	0.00	0.93	0.1	< 10
DR 5 Red	1.2	22/01/2013	400	< 20.0	< 1	< 4.0	2.4	< 0.05	2.2	0.01	0.14	0.03	20
DR 5 Red	1.2	20/02/2013	50	< 10.0	< 10	< 4.0	2.1	< 0.05	2.0	0.02	0.03	< 0.05	17
DR 5 Red	1.2	21/03/2013	900	40.2	< 1	< 4.0	0.3	0.01	0.0	0.02	0.27	0.01	42
DR 5 Red	1.2	18/04/2013											

DR 5 Red	1.2	28/05/2013	**10**			20.4	5.68	0.01	5.6		0.07	0.01	42
DR 5 Red	1.2	25/06/2013											
DR 5 Red	1.2	19/07/2013	250	40.4	< 1	10.3	13	0.23	11.9	0.01	0.86	0.09	59
DR 5 Red	1.2	30/07/2013											
DR 5 Red	1.2	15/08/2013											
DR 5 Red	1.2	20/09/2013											
DR 5 Red	1.2	01/10/2013											
DR 5 Red	1.2	19/11/2013											
DR 5 Red	1.2	02/12/2013	75										51
DR 5 Red	1.2	17/12/2013	30										45
DR 5 Red	1.2												
DR 5 Red	1.2	29/01/2013	1000										46
DR 5 Blue	1.5	09/11/2012	75	517.2	16.8	22.7	2.35	0.06	2	0.02	0.27	10.9	14
DR 5 Blue	1.5	04/12/2012	700	6.2	< 1	< 4	2.31	0.04	1	0.00	1.27	0.61	< 10
DR 5 Blue	1.5	22/01/2013	50	< 10.0	< 10	< 4.0	2.1	< 0.05	2.0	0.02	0.03	< 0.05	17
DR 5 Blue	1.5	20/02/2013	900	40.2	< 1	< 4.0	0.3	0.01	0.0	0.02	0.27	0.01	42
DR 5 Blue	1.5	21/03/2013	**300**	1	< 1	3.1	1.8	0.04	1.3	0.01	0.45	0.14	28
DR 5 Blue	1.5	18/04/2013	**20**	1115	< 20	36.6	1	0.11	0.4	0.10	0.39	0.13	26
DR 5 Blue	1.5	28/05/2013	**40**			3.1	2.33	0.02	1.6	0.00	0.71	0.02	46
DR 5 Blue	1.5	25/06/2013	70	8196	< 10	16.4	5.76	0.03	4.6	0.01	1.12	0.09	64
DR 5 Blue	1.5	19/07/2013	20	< 20.0	< 20	5.6	10.9	0.11	9.6	0.00	1.19	0.05	30
DR 5 Blue	1.5	30/07/2013											
DR 5 Blue	1.5	15/08/2013											
DR 5 Blue	1.5	20/09/2013											
DR 5 Blue	1.5	01/10/2013	10	120980	< 50	76	4.87	0.02	4.6	0.1	0.15		14
DR 5 Blue	1.5	19/11/2013	50										18
DR 5 Blue	1.5	02/12/2013	10										24
DR 5 Blue	1.5	17/12/2013	20										40
DR 5 Blue	1.5												
DR 5 Blue	1.5	29/01/2013	1000										44
DR 5 Black	1.8	09/11/2012											
DR 5 Black	1.8	04/12/2012	1000	21.6	< 1	14.1	1.23	0.05	0.5	0.02	0.66	0.13	5

DR 5 Black	1.8	22/01/2013	900	40.2	< 1	< 4.0	0.3	0.01	0.0	0.02	0.27	0.01	42
DR 5 Black	1.8	20/02/2013	**1000**	5.2	< 1	0.8	1.1	0.07	0.8	0.02	0.21	0.01	40
DR 5 Black	1.8	21/03/2013	10			14.7		0.7	3	0.02		0.25	12
DR 5 Black	1.8	18/04/2013	**10**	1090	< 50	26.8	2.71	0	1.0		1.71	0.05	6
DR 5 Black	1.8	28/05/2013											
DR 5 Black	1.8	25/06/2013	50	3666	< 10	9.4	3.74	0.01	2.5	0.05	1.18	0.08	45
DR 5 Black	1.8	19/07/2013	50	172.2	18.3	4.1	3.46	0.05	2.2	0.02	1.19	0.00	25
DR 5 Black	1.8	30/07/2013											
DR 5 Black	1.8	15/08/2013	30	< 20.0	< 20	25	8.93	0.02	5.0	0.01	3.90	0.18	14
DR 5 Black	1.8	20/09/2013											
DR 5 Black	1.8	01/10/2013	50	48392	< 20	147	8.19	0.1	3	0.2	4.89	0.4	23
DR 5 Black	1.8	19/11/2013	75										16
DR 5 Black	1.8	02/12/2013	30										10
DR 5 Black	1.8	17/12/2013	30										17
DR 5 Black	1.8												
DR 5 Black	1.8	29/01/2013	700										40
DR 6 Red	1.2	09/11/2012											
DR 6 Red	1.2	04/12/2012	500	224.7	< 1	31.1	2.23	0.04	2.1	0.00	0.09	0.25	< 10
DR 6 Red	1.2	22/01/2013	50	< 10.0	< 10	< 4.0	6.0	< 0.05	5.8	0.04	0.11	0.13	13
DR 6 Red	1.2	20/02/2013	800										6
DR 6 Red	1.2	21/03/2013											
DR 6 Red	1.2	18/04/2013											
DR 6 Red	1.2	28/05/2013	**30**			30.6	5.4	0.05	0.7	0.02	4.59	0.01	15
DR 6 Red	1.2	25/06/2013											
DR 6 Red	1.2	19/07/2013											
DR 6 Red	1.2	30/07/2013											
DR 6 Red	1.2	15/08/2013											
DR 6 Red	1.2	20/09/2013											
DR 6 Red	1.2	01/10/2013	50	48392	< 20	141	11	0.01	11.4	0.02			45
DR 6 Red	1.2	19/11/2013	50	> 48392	40	43	24.7	1.67	20.3	0.02		0.18	76
DR 6 Red	1.2	02/12/2013	20	31062	< 20	45	44.8	0.05	35.3	0.01		0.8	58
DR 6 Red	1.2	17/12/2013	160	248.1	< 1	37	40.5	0.6	38.1	0.05		0.19	70

DR 6 Red	1.2												
DR 6 Red	1.2	29/01/2013	1000	> 2420	13.2	14	20	< 0.05	19.1	0.02		0.13	80
DR 6 Blue	1.5	09/11/2012	60	36.8	2	24.1	2.64	0.05	2.1	0.01	0.48	2.17	9
DR 6 Blue	1.5	04/12/2012	1000	980.4	1	15.8	2.91	0.09	2.5	0.00	0.32	0.14	< 10
DR 6 Blue	1.5	22/01/2013	280	< 10.0	< 10	< 4.0	5.5	< 0.05	5.4	0.02	0.03	< 0.05	16
DR 6 Blue	1.5	20/02/2013	500										19
DR 6 Blue	1.5	21/03/2013											
DR 6 Blue	1.5	18/04/2013	20										17
DR 6 Blue	1.5	28/05/2013											
DR 6 Blue	1.5	25/06/2013											
DR 6 Blue	1.5	19/07/2013											
DR 6 Blue	1.5	30/07/2013	30	2792	< 10	69	8.2	0.18	7.2	0.09	0.73	0.33	56
DR 6 Blue	1.5	15/08/2013											
DR 6 Blue	1.5	20/09/2013	10	795	< 50		9.04		8.8		0.24	0.15	5
DR 6 Blue	1.5	01/10/2013											
DR 6 Blue	1.5	19/11/2013	80	> 24196	< 10	22	19.73	0.05	16.7	0.01		0.06	50
DR 6 Blue	1.5	02/12/2013	20	5380	< 50	40	15.4	0.09	14.2	< 0.02		0.58	40
DR 6 Blue	1.5	17/12/2013	100	1098	< 10	31	35.6	< 0.06	32.7	< 0.02		0.16	50
DR 6 Blue	1.5												
DR 6 Blue	1.5	29/01/2013	600	172.6		10	18.9	< 0.05	18.5	0.00		0.07	70
DR 6 Black	1.8	09/11/2012											
DR 6 Black	1.8	04/12/2012	1100	28.5	< 1	< 4	6.9	0.05	5.6	0.00	1.25	< 0.05	< 10
DR 6 Black	1.8	22/01/2013	400	20.2	< 1	< 4.0	14.7	< 0.05	14.6	0.02	0.03	< 0.05	18
DR 6 Black	1.8	20/02/2013	900										19
DR 6 Black	1.8	21/03/2013	40			5.1		0.9	1.1	0.03		0.11	21
DR 6 Black	1.8	18/04/2013	30										23
DR 6 Black	1.8	28/05/2013											
DR 6 Black	1.8	25/06/2013											
DR 6 Black	1.8	19/07/2013	75										15
DR 6 Black	1.8	30/07/2013											
DR 6 Black	1.8	15/08/2013											
DR 6 Black	1.8	20/09/2013	25	356	< 20	8	8.87		7.4	0.03	1.44	0.40	6

DR 6 Black	1.8	01/10/2013											
DR 6 Black	1.8	19/11/2013	100	1664	< 10	11	24.9	0.02	24.6	0.01		0.04	35
DR 6 Black	1.8	02/12/2013	40	554	< 20	16	9.92	0.04	9.4	0.00		0.49	28
DR 6 Black	1.8	17/12/2013	80	> 24196	41	14	22.8	< 0.05	20.5	0.02		0.04	49
DR 6 Black	1.8												
DR 6 Black	1.8	29/01/2013	1000	42		< 10	11.9	< 0.05	11.3	0.01		0.04	48

ID	Depth	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Organic	PO4	Cl
DR 1	0.3	09/11/2012											
DR 1	0.3	04/12/2012											
DR 1	0.3	22/01/2013											
DR 1	0.3	20/02/2013											
DR 1	0.3	21/03/2013	**60**	> 24196.0	< 10	35.4		0.03	0.5	0.02		0.06	51
DR 1	0.3	18/04/2013	**30**	572	< 10	40.5	3.62	0.1	3.5	0.01	0.01	0.63	23
DR 1	0.3	28/05/2013	**25**	492	10	15	3.31	0.41	0.7	0.01	2.19	0.02	36
DR 1	0.3	25/06/2013											
DR 1	0.3	19/07/2013	2										33
DR 1	0.3	30/07/2013											
DR 1	0.3	15/08/2013	5	1248.1	< 50		10.6		6.9		3.70		22
DR 1	0.3	20/09/2013	5			156	11.4	1.4	8.8		1.20		79
DR 1	0.3	01/10/2013	1				18			0.7	17.3		65
DR 1	0.3	19/11/2013	10	10070	< 50	227	13.2	0.14	10.9	0.02		1.83	29
DR 1	0.3	02/12/2013	30	> 48392	< 20	83	15.9	< 0.05	15.7	< 0.02		0.71	36
DR 1	0.3	17/12/2013	10			48	24.5	0.05	21.9	0.01		0.1	31
DR 1	0.3												
DR 1	0.3	29/01/2013	60	214.3		11	20.8	< 0.05	18.3			0.13	30
DR 2	0.3	09/11/2012											
DR 2	0.3	04/12/2012											
DR 2	0.3	22/01/2013											
DR 2	0.3	20/02/2013	10										53
DR 2	0.3	21/03/2013	**40**	265	< 10	31.4		0.06	0.1	0.04		0.05	37
DR 2	0.3	18/04/2013	**30**	3000	< 10	50.7	1.39	0.28	0.9	0.01	0.20	0.22	51
DR 2	0.3	28/05/2013	**25**	2419.6	20	29.9	5.53	0.08	4.7	0.00	0.75	0.20	12
DR 2	0.3	25/06/2013											
DR 2	0.3	19/07/2013											
DR 2	0.3	30/07/2013											
DR 2	0.3	15/08/2013	3	1686.7	< 100		12.2		7.2		5.00		16
DR 2	0.3	20/09/2013	5			188	26.7	1.05	23.6		2.05	2.15	84
DR 2	0.3	01/10/2013	10	120980	< 50	180	55.3	0.2	48.2	0.32	6.58	0.15	146

DR 2	0.3	19/11/2013	20	> 48392	20	189	54.9	0.5	52.2	0.05		1.43	60
DR 2	0.3	02/12/2013	40	> 48392	< 20	68	49.8	< 0.05	49.6	< 0.02		0.57	38
DR 2	0.3	17/12/2013	25			40	63.9	0.11	62.5	0.02		0.15	37
DR 2	0.3												
DR 2	0.3	29/01/2013	70	461.1		46	54.9	< 0.05	46.5			0.2	78
DR 3	0.3	09/11/2012											
DR 3	0.3	04/12/2012											
DR 3	0.3	22/01/2013											
DR 3	0.3	20/02/2013	**45**	31	< 10	27	2.4	0.02	1.2	0.04	1.14	0.02	18
DR 3	0.3	21/03/2013											
DR 3	0.3	18/04/2013	**50**	3586	< 10	16.7	3.36	0.12	1.4	0.01	1.83	0.21	30
DR 3	0.3	28/05/2013	**20**	1182	< 20	17.5	2.68	0.02	2.2	0.02	0.44	0.01	16
DR 3	0.3	25/06/2013											
DR 3	0.3	19/07/2013											
DR 3	0.3	30/07/2013											
DR 3	0.3	15/08/2013	2	1488.4	< 100				5.7				19
DR 3	0.3	20/09/2013	5			84	14.80	0.75	11.8		2.25		75
DR 3	0.3	01/10/2013	90	48392	< 20	9	8.02		4.4	0.12	3.5	0.12	58
DR 3	0.3	19/11/2013	20	> 48392	< 20	112	28.9	0.32	18.9	0.04		1.06	33
DR 3	0.3	02/12/2013	40	> 48392	< 20	82	24.8	< 0.05	24	0.01		0.58	47
DR 3	0.3	17/12/2013	40	15402	< 20	50	27.4	0.08	26.3	0.02		0.14	37
DR 3	0.3												
DR 3	0.3	29/01/2013	80	1553.1		36	20.6	< 0.05	18.9	0.00		0.14	30
DR 6	0.3	09/11/2012											
DR 6	0.3	04/12/2012											
DR 6	0.3	22/01/2013											
DR 6	0.3	20/02/2013											
DR 6	0.3	21/03/2013	60	389	< 10	32		2.48	0.6	0.02		0.60	52
DR 6	0.3	18/04/2013	**50**	2100	< 10	45.5	2.33	0.38	1.8	0.10	0.05	0.04	20
DR 6	0.3	28/05/2013	**10**	605	< 20	44	8.27	0.03	3.7		4.54	0.01	5
DR 6	0.3	25/06/2013											
DR 6	0.3	19/07/2013											

DR 6	0.3	30/07/2013												
DR 6	0.3	15/08/2013												
DR 6	0.3	20/09/2013												
DR 6	0.3	01/10/2013												
DR 6	0.3	19/11/2013	10	> 120980	< 50	256	12	0.14	5.2	0.04		0.77	38	
DR 6	0.3	02/12/2013	10	> 120980	< 50	96	11.6	0.11	7.5	0.01		1.22	54	
DR 6	0.3	17/12/2013	25			47	20.9	0.09	16.1	0.02		1.12	42	
DR 6	0.3													
DR 6	0.3	29/01/2013	75	> 2420	1	18	22.5	< 0.05	20.8	0.01		0.15	36	

	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Organic	PO4	Cl
UP/S	19/10/2012	250	702.7	86							0.1	14
UP/S	09/11/2012											
UP/S	04/12/2012	250	225	< 1	9.9	1.56	0.14	1.2	0.01	0.21	0.07	< 10
UP/S	22/01/2013	250	4.1	< 1	< 4.0	1.5	0.18	0.9	0.02	0.40	0.08	15
UP/S	20/02/2013	250	8.4	< 1	0.4	3.2	0.36	2.3	0.02	0.52	0.03	6
UP/S	21/03/2013	250	8.1	< 1	< 4		0.3	1.1	0.01		0.09	8
UP/S	18/04/2013											
UP/S	28/05/2013											
UP/S	25/06/2013											
UP/S	19/07/2013											
UP/S	30/07/2013											
UP/S	15/08/2013											
UP/S	20/09/2013											
UP/S	01/10/2013											
UP/S	19/11/2013											
UP/S	02/12/2013											
UP/S	17/12/2013	120	6.3	< 1	3	1.8	< 0.05	1.4	< 0.02		< 0.05	5
UP/S												
UP/S	29/01/2013	250	4.1		< 10	1.51	< 0.05	< 1	0.01		0.00	10
DD	19/10/2012	250	9803.9	41.3							0.1	13
DD	09/11/2012											
DD	04/12/2012	250	> 2419.6	6.5	40.6	1.39	0.41	0.6	0.09	0.29	0.09	< 10
DD	22/01/2013	250	250.3	10	< 4.0	1.0	0.01	0.7	0.03	0.26	0.02	6
DD	20/02/2013	250	63.7	2	3.5	4.9	0.04	3.6	0.04	1.22	0.02	4
DD	21/03/2013	250	248.1	< 1	3.5		0.9	0.8	0.02		0.07	35
DD	18/04/2013	120	517.2	2	49.8	15.2	2.13	1	0.03	12.04	0.21	27

DD	28/05/2013	**25**	316	< 1	2.2	4.7	0.05	0.8	0.02	3.85		22
DD	25/06/2013											
DD	19/07/2013											
DD	30/07/2013											
DD	15/08/2013											
DD	20/09/2013											
DD	01/10/2013											
DD	19/11/2013	150	53.7	< 1	3	3.32	0.08	2.4	0.02		0.03	9
DD	02/12/2013	170	71	< 1	5	4.01	< 0.05	3.8	< 0.02		0.02	11
DD	17/12/2013	150	11	< 1.0	10	3.2	< 0.05	2.9	< 0.02	0.39	0.05	12
DD												
DD	29/01/2013	250	2419.6	1	< 10	1.59	< 0.05	0.7	0.00		0.19	18
LP	19/10/2012	250	4611.1	404.4							0.03	10
LP	09/11/2012	250	145	< 1.0	9.2	2.13	0.56	1.1	0.08	0.39	0.12	15
LP	04/12/2012	250	341	< 1	17.6	2.03	0.87	0.2	0.05	0.91	0.1	< 10
LP	22/01/2013	250	220	9.9	< 4.0	3.7	< 0.05	3.4	0.01	0.24	0.09	3
LP	20/02/2013	250	80.5	< 1	2.7	2.3	0.1	1.5	0.02	0.68	0.02	8
LP	21/03/2013	250	261.3	< 1	2.8		0.8	0.8	0.02		0.80	14
LP	18/04/2013											
LP	28/05/2013											
LP	25/06/2013											
LP	19/07/2013											
LP	30/07/2013											
LP	15/08/2013											
LP	20/09/2013											
LP	01/10/2013											
LP	19/11/2013											

LP	02/12/2013											
LP	17/12/2013	120	9.5	< 1	9	2.3	< 0.05	2.8	< 0.02		0.01	11
LP												
LP	29/01/2013	250	727		< 10	0.63	< 0.05	< 1	0.00		0.47	12

Site B

(Co. Monaghan)

ID	Depth	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Organic	PO4	Cl
LP 1.1 Red	1.2	10/10/2012											
LP 1.1 Red	1.2	13/11/2012	300	67	< 1	9.6	4.64	0.08	1.1	0.01	3.45	0.06	60
LP 1.1 Red	1.2	06/12/2012	300	57.3	16.1	< 4.0	4.79	0.01	2.9	0.00	1.88	0.01	130
LP 1.1 Red	1.2	10/01/2013	200	204.6	< 1	55	3.1	< 0.05	2.98	0	0.07	0.19	169
LP 1.1 Red	1.2	28/02/2013	300										239
LP 1.1 Red	1.2	26/03/2013	140										147
LP 1.1 Red	1.2	23/04/2013	300										267
LP 1.1 Red	1.2	21/05/2013	300										79
LP 1.1 Red	1.2	27/06/2013	250										282
LP 1.1 Red	1.2	26/07/2013	200										518
LP 1.1 Red	1.2	20/08/2013	250										294
LP 1.1 Red	1.2	24/09/2013	200										
LP 1.1 Red	1.2	04/10/2013	150										
LP 1.1 Red	1.2	12/11/2013	200										149
LP 1.1 Red	1.2	28/11/2013	250										160
LP 1.1 Red	1.2	12/12/2013	300										169
LP 1.1 Red	1.2	10/01/2014	250										152
LP 1.1 Red	1.2	24/01/2014	300										188
LP 1.1 Blue	1.5	10/10/2012											
LP 1.1 Blue	1.5	13/11/2012	250	19.9	1	13.2	2.96	0.06	0.7	0.01	2.19	1.95	61
LP 1.1 Blue	1.5	06/12/2012	400	156.5	57.3	< 4.0	2.25	0.03	1	0.01	1.21	0.08	94
LP 1.1 Blue	1.5	10/01/2013	300	< 1	< 1	102	2.38	0	1.7	0.02	0.66	0.08	162
LP 1.1 Blue	1.5	28/02/2013	250										192
LP 1.1 Blue	1.5	26/03/2013	50										159
LP 1.1 Blue	1.5	23/04/2013	200										196
LP 1.1 Blue	1.5	21/05/2013	200										34
LP 1.1 Blue	1.5	27/06/2013	120										269
LP 1.1 Blue	1.5	26/07/2013	200										528
LP 1.1 Blue	1.5	20/08/2013	250										277
LP 1.1 Blue	1.5	24/09/2013	200										
LP 1.1 Blue	1.5	04/10/2013	60										
LP 1.1 Blue	1.5	12/11/2013	150										156
LP 1.1 Blue	1.5	28/11/2013	150										140

LP 1.1 Blue	1.5	12/12/2013	200										149
LP 1.1 Blue	1.5	10/01/2014	200										161
LP 1.1 Blue	1.5	24/01/2014	150										156
LP 1.1 Black	1.8	10/10/2012											
LP 1.1 Black	1.8	13/11/2012	700	142.1	< 1	< 4.0	1	0.23	0.3	0.01	0.46	0.02	55
LP 1.1 Black	1.8	06/12/2012	250	307.6	172.3	< 4.0	2.61	0.22	1.5	0.00	0.89	0	139
LP 1.1 Black	1.8	10/01/2013	500	4.1	< 1	57	3.1	0.06	2.2	0.01	0.83	< 0.05	219
LP 1.1 Black	1.8	28/02/2013	600										137
LP 1.1 Black	1.8	26/03/2013	100										189
LP 1.1 Black	1.8	23/04/2013	400										266
LP 1.1 Black	1.8	21/05/2013	400										34
LP 1.1 Black	1.8	27/06/2013	500										250
LP 1.1 Black	1.8	26/07/2013	250										618
LP 1.1 Black	1.8	20/08/2013	300										262
LP 1.1 Black	1.8	24/09/2013	200										
LP 1.1 Black	1.8	04/10/2013	60										
LP 1.1 Black	1.8	12/11/2013	120										117
LP 1.1 Black	1.8	28/11/2013	200										115
LP 1.1 Black	1.8	12/12/2013	220										111
LP 1.1 Black	1.8	10/01/2014	150										104
LP 1.1 Black	1.8	24/01/2014	200										98
LP 1.2 Red	1.2	10/10/2012											
LP 1.2 Red	1.2	13/11/2012	210	193.5	< 1	13.9	2.91	0.09	1.2	0.02	1.60	0.01	151
LP 1.2 Red	1.2	06/12/2012	200	6.3	< 1	4.4	3.01	0.09	1.8	0.01	1.11	0.11	202
LP 1.2 Red	1.2	10/01/2013	300	4.1	< 1	43	3.32	0.3	2.8	0.01	0.21	0.05	243
LP 1.2 Red	1.2	28/02/2013	**200**	2	< 1	9.1	4.8	0.05	3.4	0.01	1.34	0.03	123
LP 1.2 Red	1.2	26/03/2013	**400**	0	< 1	7		0.02	4.9	0.01		0.05	194
LP 1.2 Red	1.2	23/04/2013	**300**	21.3	< 1	18.8	7.24	1.39	4.6	0.01	1.24	0.58	220
LP 1.2 Red	1.2	21/05/2013	**500**	21.3	< 1	5.1	12.2	0.05	9.7	0.01	2.44	0.09	166
LP 1.2 Red	1.2	27/06/2013	**250**	410.6	< 1	2.6	19.7	2.5	16.9	0.17	0.13	0.17	291
LP 1.2 Red	1.2	26/07/2013	600										402
LP 1.2 Red	1.2	20/08/2013	**300**	228.2	< 1	19	14.3	2.09	12.1	0.00	0.11	0.00	292
LP 1.2 Red	1.2	24/09/2013	**200**	1203.3	< 1	581	7.8	0.05	7.7	0.02	0.03	0.14	
LP 1.2 Red	1.2	04/10/2013	10										

LP 1.2 Red	1.2	12/11/2013	250	84.5	< 1	32	22.8	0.05	15.6	0.03	7.12	0.06	181
LP 1.2 Red	1.2	28/11/2013	500	125.9	< 1		9.98	0.05	9	0.02	0.91	0.19	298
LP 1.2 Red	1.2	12/12/2013	400	686.7	2	51	15.9	0.08	13.9	0.03	1.89	0.05	188
LP 1.2 Red	1.2	10/01/2014	500										179
LP 1.2 Red	1.2	24/01/2014	400	151.5	< 1	39	8.17	0.05	7.6	0.01		0.06	162
LP 1.2 Blue	1.5	10/10/2012											
LP 1.2 Blue	1.5	13/11/2012	250	4082	7.4	10.4	0.596	0.25	0.1	0.01	0.24	0.04	68
LP 1.2 Blue	1.5	06/12/2012	300	224.7	8.5	8.8	1.56	0.07	0.2	0.01	1.28	0.36	98
LP 1.2 Blue	1.5	10/01/2013	250	5.2	< 1	49	1.67	0.06	0.2	0.01	1.40	< 0.05	141
LP 1.2 Blue	1.5	28/02/2013	300	2	< 1	11	1	0.03	< 1.0	0.01	-0.04	< 0.05	173
LP 1.2 Blue	1.5	26/03/2013	150	15.8	< 1	3.9		0.05	1.9	0.05		0.06	183
LP 1.2 Blue	1.5	23/04/2013	220	12.1	< 1	19	4.15	0.21	0.5	0.01	3.43	< 0.05	181
LP 1.2 Blue	1.5	21/05/2013	300	12.1	< 1	2.6	4.17	0.04	1.8	0.01	2.32	0.33	106
LP 1.2 Blue	1.5	27/06/2013	180	160.7	< 1	2.9	14.75	2.01	12.6	0.03	0.11	0.04	280
LP 1.2 Blue	1.5	26/07/2013	300										320
LP 1.2 Blue	1.5	20/08/2013	250	1553.1	< 1	15	9.69	2.47	7.1	0.10	0.02	0.18	272
LP 1.2 Blue	1.5	24/09/2013	60	11198.7	< 10	120	4.66	0.03	4.5	0.01	0.12	1.01	
LP 1.2 Blue	1.5	04/10/2013	120	2472	< 20	9	10.6	0.01	8.5			0.09	169
LP 1.2 Blue	1.5	12/11/2013	100	74	< 10	22	12	0.04	9.4	< 0.02	2.54	< 0.05	165
LP 1.2 Blue	1.5	28/11/2013	200	120.1	< 1		9.18	0.04	7.7	0	1.44	< 0.05	275
LP 1.2 Blue	1.5	12/12/2013	200	435.2	2	44	14.2	0.03	10.5	0.03	3.64	0.04	252
LP 1.2 Blue	1.5	10/01/2014	300										141
LP 1.2 Blue	1.5	24/01/2014	250	9.7	< 1	25	6.44	0.09	5.9	0		0.11	138
LP 1.2 Black	1.8	10/10/2012											
LP 1.2 Black	1.8	13/11/2012	80	> 12980	< 10	3.9	1.73	0.05	0.2	0.01	1.47	0	75
LP 1.2 Black	1.8	06/12/2012	400	866.4	11.1	2.2	0.621	0.07	0.3	0.01	0.24	0.04	62
LP 1.2 Black	1.8	10/01/2013	350	10.7	< 1	32	1.6	< 0.05	< 1	0.01	0.54	< 0.05	83
LP 1.2 Black	1.8	28/02/2013	600	1	< 1	5.6	1.3	0.02	< 1.0	0.01	0.27	0.01	174
LP 1.2 Black	1.8	26/03/2013	40	< 20	< 10	7.7		0.06	1.6	0.02		0.05	159
LP 1.2 Black	1.8	23/04/2013	100	17.2	< 2	21.4	3.96	0.19	0.1	0.01	3.66	0.05	172.00
LP 1.2 Black	1.8	21/05/2013	125	17.2	< 1	6.4	2.56	0.02	1.2	0.01	1.33	0.09	89
LP 1.2 Black	1.8	27/06/2013	250	78	< 1	3.4	17.24	0.29	16.2	0.01	0.74	0.07	206
LP 1.2 Black	1.8	26/07/2013	50										256
LP 1.2 Black	1.8	20/08/2013	125	2406.7	< 1	37	2.55	1.41	0.9	0.00	0.24	0.00	204

LP 1.2 Black	1.8	24/09/2013	**50**	727.3	< 10	86	0.22	0	0.1	0.00	0.12	0.78	
LP 1.2 Black	1.8	04/10/2013	0										
LP 1.2 Black	1.8	12/11/2013	**50**	20	< 10	14	9.59	0.01	7.7	< 0.02	1.86	0	128
LP 1.2 Black	1.8	28/11/2013	**120**	23.3	< 1		4.48	< 0.05	3.9	0.01	0.52	0.02	214
LP 1.2 Black	1.8	12/12/2013	**150**	261.3	1	38	10.8	0	7	0.01	3.79	0.01	125
LP 1.2 Black	1.8	10/01/2014	**150**										112
LP 1.2 Black	1.8	24/01/2014	**200**	18.7	< 1	10	4.79	0.05	2.4	0.01		0.08	116
LP 2.1 Red	1.2	10/10/2012											
LP 2.1 Red	1.2	13/11/2012	250	19.9	< 1	4.6	1.91	0.05	1.7	0.02	0.14	0.07	43
LP 2.1 Red	1.2	06/12/2012	250	866.4	5.2	3.6	2.3	0.02	2.2	0.01	0.07	0.03	57
LP 2.1 Red	1.2	10/01/2013	300	155.3	< 1	50	3.75	0.18	3.1	0	0.47	0.05	71
LP 2.1 Red	1.2	28/02/2013	300										145
LP 2.1 Red	1.2	26/03/2013	200										122
LP 2.1 Red	1.2	23/04/2013	300										215
LP 2.1 Red	1.2	21/05/2013	300										134
LP 2.1 Red	1.2	27/06/2013	**200**	11	< 1	2.1	14.1	2.6	10.8	0.02	0.68	0.08	315
LP 2.1 Red	1.2	26/07/2013	**350**	325.5	< 1	74	16.6	0.01	15.3	0.00	1.29	0.00	321
LP 2.1 Red	1.2	20/08/2013	200										252
LP 2.1 Red	1.2	24/09/2013	200										
LP 2.1 Red	1.2	04/10/2013	**300**	1818	< 20	21	18.1	0.03	17.6			0.09	113
LP 2.1 Red	1.2	12/11/2013	**500**	648.8	< 1	12	36.9	0.57	26.3	< 0.02	10.01	< 0.05	143
LP 2.1 Red	1.2	28/11/2013	**250**	> 2419.6	< 1	32	17.38	0.1	15.4	0	1.88	0.07	234
LP 2.1 Red	1.2	12/12/2013	**300**	> 2419.6	< 1	41	12.9	< 0.05	11.9	0.02	0.93	0.11	212
LP 2.1 Red	1.2	10/01/2014	**300**										206
LP 2.1 Red	1.2	24/01/2014	**250**	30.1	< 1	25	5.59	0.02	3.5	0.01		0.06	185
LP 2.1 Blue	1.5	10/10/2012											
LP 2.1 Blue	1.5	13/11/2012	300	9.7	< 1	11	2.15	0.07	1.6	0.02	0.46	0.01	105
LP 2.1 Blue	1.5	06/12/2012	800	220.9	4.1	2.1	2.47	0.06	1.9	0.02	0.49	0.04	128
LP 2.1 Blue	1.5	10/01/2013	1000	16.9	< 1	31	2.68	0.04	2.5	0	0.14	< 0.05	164
LP 2.1 Blue	1.5	28/02/2013	1200										170
LP 2.1 Blue	1.5	26/03/2013	150										135
LP 2.1 Blue	1.5	23/04/2013	500										257
LP 2.1 Blue	1.5	21/05/2013	500										93
LP 2.1 Blue	1.5	27/06/2013	**500**	4.1	< 1	1.3	17.1	1.66	13.3	0.01	2.13	0.10	302

LP 2.1 Blue	1.5	26/07/2013	**600**	193.5	< 1	5	19.4	0.02	18.4	0.00	0.98	0.00	428
LP 2.1 Blue	1.5	20/08/2013	500										296
LP 2.1 Blue	1.5	24/09/2013	250										
LP 2.1 Blue	1.5	04/10/2013	**300**	> 28392	< 20	20	18	0.01	17.9			0.09	122
LP 2.1 Blue	1.5	12/11/2013	**500**	1553.1	< 1	10	19.4	0.35	16.3	< 0.02	2.73	< 0.05	115
LP 2.1 Blue	1.5	28/11/2013	**250**	> 2419.6	< 1	28	11.04	< 0.05	10.7	0.03	0.26	0.06	136
LP 2.1 Blue	1.5	12/12/2013	**300**	1119.9	< 1	38	19.81	< 0.05	8.6	0.04	1.12	< 0.05	123
LP 2.1 Blue	1.5	10/01/2014	**250**										95
LP 2.1 Blue	1.5	24/01/2014	**300**	90.6	< 1	22	8.15	0.02	5.6	0.02		0.05	81
LP 2.1 Black	1.8	10/10/2012											
LP 2.1 Black	1.8	13/11/2012	320	8.6	< 1	15.4	0.674	0.05	0.1	0.01	0.51	0.01	55
LP 2.1 Black	1.8	06/12/2012	500	6862	5.2	7.7	1.37	0.06	0.7	0.01	0.60	0.02	68
LP 2.1 Black	1.8	10/01/2013	400	9804	< 1	75	3.16	0.14	2.2	0.01	0.81	< 0.05	127
LP 2.1 Black	1.8	28/02/2013	350										60
LP 2.1 Black	1.8	26/03/2013	30										148
LP 2.1 Black	1.8	23/04/2013	300										149
LP 2.1 Black	1.8	21/05/2013	300										84
LP 2.1 Black	1.8	27/06/2013	**200**	307.6	< 1	1.1	10.6	1.59	8.1	0.03	0.88	0.11	292
LP 2.1 Black	1.8	26/07/2013	**200**	> 2419.6	< 1	54	31.4	0.02	12.5	0.00	18.88	0.00	398
LP 2.1 Black	1.8	20/08/2013	175										304
LP 2.1 Black	1.8	24/09/2013	60										
LP 2.1 Black	1.8	04/10/2013	**50**	532	< 20	3	15	0.01	10.3			0.07	197
LP 2.1 Black	1.8	12/11/2013	**200**	248.1	< 1	1	15.1	0.04	13.2	< 0.02	1.84	< 0.05	91
LP 2.1 Black	1.8	28/11/2013	**250**	224.7	< 1	4	9.44	< 0.05	8.1	0	1.29	< 0.05	151
LP 2.1 Black	1.8	12/12/2013	**300**	137.6	< 1	4	6.06	< 0.05	4.5	0.07	1.44	< 0.05	102
LP 2.1 Black	1.8	10/01/2014	**250**										87
LP 2.1 Black	1.8	24/01/2014	**250**	290.9	< 1	3	12.1	0.02	9.9	0.01		0.05	72
LP 3.1 Red	1.2	10/10/2012											
LP 3.1 Red	1.2	13/11/2012	300	53.8	< 1	14.7	6.23	0.05	6	0.02	0.16	0.04	66
LP 3.1 Red	1.2	06/12/2012	900	143.9	1	11.8	2.99	0.02	2.8	0.00	0.17	0.04	45
LP 3.1 Red	1.2	10/01/2013	1000	34.5	< 1	< 10	3.68	0.09	3.46	0.01	0.12	0.24	63
LP 3.1 Red	1.2	28/02/2013	300										38
LP 3.1 Red	1.2	26/03/2013	3										93
LP 3.1 Red	1.2	23/04/2013	300										320

LP 3.1 Red	1.2	21/05/2013	300										228
LP 3.1 Red	1.2	27/06/2013	200										252
LP 3.1 Red	1.2	26/07/2013	500										220
LP 3.1 Red	1.2	20/08/2013	250										179
LP 3.1 Red	1.2	24/09/2013	150										
LP 3.1 Red	1.2	04/10/2013	400										
LP 3.1 Red	1.2	12/11/2013	350										91
LP 3.1 Red	1.2	28/11/2013	400										63
LP 3.1 Red	1.2	12/12/2013	350										71
LP 3.1 Red	1.2	10/01/2014	300										65
LP 3.1 Red	1.2	24/01/2014	300										45
LP 3.1 Blue	1.5	10/10/2012											
LP 3.1 Blue	1.5	13/11/2012	220	1080	< 1	11.3	3.61	0.11	3.2	0.04	0.26	0.03	48
LP 3.1 Blue	1.5	06/12/2012	1100	1986.3	6.3	7.7	3.8	0.09	3.3	0.02	0.39	0.02	38
LP 3.1 Blue	1.5	10/01/2013	900	290.9	< 1	69	3.33	0.05	3.1	0.02	0.16	0.03	53
LP 3.1 Blue	1.5	28/02/2013	300										46
LP 3.1 Blue	1.5	26/03/2013	100										9.2
LP 3.1 Blue	1.5	23/04/2013	500										231
LP 3.1 Blue	1.5	21/05/2013	500										113
LP 3.1 Blue	1.5	27/06/2013	190										239
LP 3.1 Blue	1.5	26/07/2013	600										312
LP 3.1 Blue	1.5	20/08/2013	350										196
LP 3.1 Blue	1.5	24/09/2013	250										
LP 3.1 Blue	1.5	04/10/2013	350										
LP 3.1 Blue	1.5	12/11/2013	300										64
LP 3.1 Blue	1.5	28/11/2013	350										62
LP 3.1 Blue	1.5	12/12/2013	300										61
LP 3.1 Blue	1.5	10/01/2014	250										59
LP 3.1 Blue	1.5	24/01/2014	250										43
LP 3.1 Black	1.8	10/10/2012											
LP 3.1 Black	1.8	13/11/2012	30	5231	< 10	8.5	3.44	0.24	2.7	0.07	0.43	0.04	54
LP 3.1 Black	1.8	06/12/2012	200	248.6	21.8	6.1	2.72	0.06	2.1	0.05	0.51	0.08	51
LP 3.1 Black	1.8	10/01/2013	150	980.4	< 1	63	4.7	< 0.05	4.3	0.01	0.34	< 0.05	44
LP 3.1 Black	1.8	28/02/2013	300										57

LP 3.1 Black	1.8	26/03/2013	10										62
LP 3.1 Black	1.8	23/04/2013	130										59
LP 3.1 Black	1.8	21/05/2013	130										90
LP 3.1 Black	1.8	27/06/2013	180										168
LP 3.1 Black	1.8	26/07/2013	100										222
LP 3.1 Black	1.8	20/08/2013	140										163
LP 3.1 Black	1.8	24/09/2013	70										
LP 3.1 Black	1.8	04/10/2013	0										
LP 3.1 Black	1.8	12/11/2013	50										60
LP 3.1 Black	1.8	28/11/2013	100										42
LP 3.1 Black	1.8	12/12/2013	80										45
LP 3.1 Black	1.8	10/01/2014	120										51
LP 3.1 Black	1.8	24/01/2014	100										39
LP 3.2 Red	1.2	10/10/2012											
LP 3.2 Red	1.2	13/11/2012	350	1203.3	1	17.2	1.47	0.22	1.1	0.04	0.11	0.02	121
LP 3.2 Red	1.2	06/12/2012	200	1299.7	2	2	2.87	0.12	1.9	0.03	0.82	0.04	130
LP 3.2 Red	1.2	10/01/2013	250	5.1	< 1	58	2.91	0.16	2.7	0.01	0.04	0.07	163
LP 3.2 Red	1.2	28/02/2013	**2000**	3.1	< 1	6.5	7.5	0.18	4.0	0.01	3.31	0.04	186
LP 3.2 Red	1.2	26/03/2013	**200**	4.1	< 1	5.2		0.04	7.3	0.01		< 0.05	169
LP 3.2 Red	1.2	23/04/2013	**250**	13.5	< 1	7.4	10.8	1.24	9.2	0.01	0.35	0.28	260
LP 3.2 Red	1.2	21/05/2013	**250**	13.5	< 1	7.9	18.5	0.05	9.1	0.01	9.34	0.31	202
LP 3.2 Red	1.2	27/06/2013	**200**	49.6	< 1	3.1	17.6	2.47	13.7	0.02	1.41	0.03	301
LP 3.2 Red	1.2	26/07/2013	**300**	9.8	< 1	65	12.8	0.03	12.7	0.02	0.05	0.05	406
LP 3.2 Red	1.2	20/08/2013	**250**	21.3	< 1	37	11.9	1.01	6.0	0.00	4.89	0.05	300
LP 3.2 Red	1.2	24/09/2013	**70**	> 24196	< 10	572	14.9	0.05	14.6	0.00	0.00	0.79	
LP 3.2 Red	1.2	04/10/2013	**250**	602	< 20	15	11.4	0.02	13			0.03	166
LP 3.2 Red	1.2	12/11/2013	200										188
LP 3.2 Red	1.2	28/11/2013	250										185
LP 3.2 Red	1.2	12/12/2013	300										169
LP 3.2 Red	1.2	10/01/2014	300				16.7		16.6				133
LP 3.2 Red	1.2	24/01/2014	250										125
LP 3.2 Blue	1.5	10/10/2012											
LP 3.2 Blue	1.5	13/11/2012	250	2405	< 1	13.2	1.78	0.12	1.5	0.02	0.14	0.04	118

LP 3.2 Blue	1.5	06/12/2012	600	204.6	< 1	< 4.0	2.68	0.07	2.3	0.01	0.30	0.01	137
LP 3.2 Blue	1.5	10/01/2013	800	2	< 1	61	4.45	0.25	4	0	0.20	1.04	173
LP 3.2 Blue	1.5	28/02/2013	**2000**	2	< 1	9.8	5.5	0.03	5.2	0.01	0.26	0.04	139
LP 3.2 Blue	1.5	26/03/2013	**500**	1	< 1	2.1		0.03	6.9	0.01		0.02	149
LP 3.2 Blue	1.5	23/04/2013	**500**	4.1	< 1	17.3	9.34	0.34	6.9	0.01	2.09	0	249
LP 3.2 Blue	1.5	21/05/2013	**500**	4.1	< 1	5.4	10.5	0.07	9.6	0.02	0.81	0.03	166
LP 3.2 Blue	1.5	27/06/2013	**400**	83.6	< 1	5.5	17.5	2.39	13.4	0.04	1.67	0.05	254
LP 3.2 Blue	1.5	26/07/2013	**600**	51.2	< 1	1	23.1	0.02	16.9	0.03	6.15	0	490
LP 3.2 Blue	1.5	20/08/2013	**500**	63.8	< 1	14	21.9	1.27	18.8	0.00	1.83	0	318
LP 3.2 Blue	1.5	24/09/2013	**200**	648.8	< 1	332	9	0.04	7.5	0.02	1.44	0.09	
LP 3.2 Blue	1.5	04/10/2013	**500**	3446	< 20	11	6.1	0.01	5.8			0.11	176
LP 3.2 Blue	1.5	12/11/2013	450										134
LP 3.2 Blue	1.5	28/11/2013	500										162
LP 3.2 Blue	1.5	12/12/2013	400										144
LP 3.2 Blue	1.5	10/01/2014	450				10.3		8.9				97
LP 3.2 Blue	1.5	24/01/2014	450										82
LP 3.2 Black	1.8	10/10/2012											
LP 3.2 Black	1.8	13/11/2012	350	> 12980	< 1	3.7	2.72	0.09	2.4	0.07	0.16	0.03	80
LP 3.2 Black	1.8	06/12/2012	500	816.4	1	0.6	4.04	0.08	3.2	0.03	0.73	0.01	101
LP 3.2 Black	1.8	10/01/2013	400	15.6	< 1	18	5.82	< 0.05	5.3	0.01	0.46	0.06	168
LP 3.2 Black	1.8	28/02/2013	**1600**	0	< 1	4.1	5.8	0.03	5.6	0.00	0.17	0.03	127
LP 3.2 Black	1.8	26/03/2013	**225**	13.2	< 1	6.2		0	5.4	0.02		0.01	114
LP 3.2 Black	1.8	23/04/2013	**300**	10.8	< 1	10.7	7.05	0.02	6.7	0.02	0.31	0	152
LP 3.2 Black	1.8	21/05/2013	**50**	10.8	< 10	4.1	9.85	0.02	8.8	0.02	1.01	0.1	120
LP 3.2 Black	1.8	27/06/2013	**500**	105.4	1	6.2	14.6	2.21	9.5	0.04	2.85	0.03	236
LP 3.2 Black	1.8	26/07/2013	**500**	59.4	< 1	64	18.4	0.01	15.9	0.04	2.45	0	452
LP 3.2 Black	1.8	20/08/2013	**350**	93.4	< 1	16	21.3	1.59	18.4	0.03	1.28	0	294
LP 3.2 Black	1.8	24/09/2013	**200**	648.8	< 1	218	10.8	0.03	9.4	0.01	1.36	0.07	
LP 3.2 Black	1.8	04/10/2013	**400**	1666	< 20	10	9.2	0.01	5.4			0.09	116
LP 3.2 Black	1.8	12/11/2013	450										116
LP 3.2 Black	1.8	28/11/2013	400										108
LP 3.2 Black	1.8	12/12/2013	350										96
LP 3.2 Black	1.8	10/01/2014	300				9.1		8.2				84
LP 3.2 Black	1.8	24/01/2014	400										49

LP 4.1 Red	1.2	10/10/2012											
LP 4.1 Red	1.2	13/11/2012	400	> 12980	< 1	23.7	6.35	1.34	4.5	0.1	0.41	0.08	276
LP 4.1 Red	1.2	06/12/2012	250	224.7	51.2	8.1	3.94	0.29	3.6	0.02	0.03	0.01	700
LP 4.1 Red	1.2	10/01/2013	300	3.1	< 1	< 10	5.89	0.09	5.2	0	0.60	0	290
LP 4.1 Red	1.2	28/02/2013	**1200**	1	< 1	7.7	5.6	0.57	4.0	0.02	1.01	0.02	160
LP 4.1 Red	1.2	26/03/2013	**500**	1	< 1	5.4		0.64	11.8	0.01		0.03	512
LP 4.1 Red	1.2	23/04/2013	**500**	3	< 1	13.3	17.9	1.99	13.4	0.02	2.49	0.14	281
LP 4.1 Red	1.2	21/05/2013	**600**	3	< 1	4.3	23.8	0.76	16.5	0.02	6.52	0.06	312
LP 4.1 Red	1.2	27/06/2013	180										259
LP 4.1 Red	1.2	26/07/2013	**300**	104.3	< 1	59	20.8	0.49	19.1	0.67	0.54	0	614
LP 4.1 Red	1.2	20/08/2013	**450**	118.7	< 1	8	20.3	1.9	18.0	0.00	0.40	0	282
LP 4.1 Red	1.2	24/09/2013	**40**	168.8	81.8	579	22.9	0	22.1	0.01	0.79	0.9	
LP 4.1 Red	1.2	04/10/2013	**600**	618	< 20	19	19.9	< 0.05	15.3			0.12	114
LP 4.1 Red	1.2	12/11/2013	**500**	517.2		25	23.8	0.64	22.1	0.08	0.98	0.93	321
LP 4.1 Red	1.2	28/11/2013	**200**	261.3	< 1		23	< 0.05	17.1	0.01	5.84	0.12	352
LP 4.1 Red	1.2	12/12/2013	**250**	155.3	1	47	24.8	< 0.05	20.8	0.02	3.93	0.07	268
LP 4.1 Red	1.2	10/01/2014	**300**										251
LP 4.1 Red	1.2	24/01/2014	**450**	122.3	< 1	51	14.4	0.01	12.8	0.02		0.15	240
LP 4.1 Blue	1.5	10/10/2012											
LP 4.1 Blue	1.5	13/11/2012	330	2737.5	2	25.4	5.18	1.12	3.9	0.05	0.11	0.04	253
LP 4.1 Blue	1.5	06/12/2012	900	57.3	1	5.6	3.03	0.03	2.92	0.02	0.06	0.03	235
LP 4.1 Blue	1.5	10/01/2013	1000	3	< 1	< 10	7.14	0.1	5.3	0	1.74	0	144
LP 4.1 Blue	1.5	28/02/2013	**350**	2	< 1	9.7	8.3	0.06	6.2	0.01	2.03	0.01	218
LP 4.1 Blue	1.5	26/03/2013	**300**	1	< 1	7		0.7	12.2	0.02		0.03	540
LP 4.1 Blue	1.5	23/04/2013	**500**	1	< 1	13.9	17	1.84	7.7	0.02	7.44	0.04	275
LP 4.1 Blue	1.5	21/05/2013	**500**	1	< 1	7.4	23.1	0.21	19.0	0.01	3.88	0.2	268
LP 4.1 Blue	1.5	27/06/2013	250										222
LP 4.1 Blue	1.5	26/07/2013	**500**	> 2420	2	66	17.3	0.07	16.1	0.00	1.13	0.04	364
LP 4.1 Blue	1.5	20/08/2013	**60**	197.1	< 10	62	25.4	1.28	23.2	0.16	0.76	0	266
LP 4.1 Blue	1.5	24/09/2013	**250**	248.1	50.4	269	15.6	0	13.7	0.00	1.90	1.34	
LP 4.1 Blue	1.5	04/10/2013	**450**	1182	< 20	16	16.2	< 0.05	14.2			0.09	177
LP 4.1 Blue	1.5	12/11/2013	**500**	119.1		10	15.1	0.29	13.6	< 0.02	1.19	< 0.05	213
LP 4.1 Blue	1.5	28/11/2013	**250**	78	< 1		18.66	< 0.05	17	0.01	1.6	0.12	323
LP 4.1 Blue	1.5	12/12/2013	**200**	78.9	< 1	33	24	< 0.05	22.8	0.05	1.1	0.05	213

LP 4.1 Blue	1.5	10/01/2014	**300**										186
LP 4.1 Blue	1.5	24/01/2014	**300**	98.7	< 1	32	16.7	0.01	16.6	0.02		0.1	184
LP 4.1 Black	1.8	10/10/2012											
LP 4.1 Black	1.8	13/11/2012	125	365.4	< 1	15.2	3.83	0.5	2.1	0.08	1.15	0.05	87
LP 4.1 Black	1.8	06/12/2012	1100	140.1	1	1.1	2.38	0.3	1.98	0.01	0.09	0.01	98
LP 4.1 Black	1.8	10/01/2013	1000	4.1	< 1	< 10	3.47	0.12	3	0.01	0.34	0.01	140
LP 4.1 Black	1.8	28/02/2013	**900**	0	< 1	3.2	5.2	0.07	5.0	0.01	0.12	0.01	286
LP 4.1 Black	1.8	26/03/2013	**600**	2	< 1	4.1		0.15	9.5	0.02		0.01	263
LP 4.1 Black	1.8	23/04/2013	**600**	4.1	< 1	13	15.3	1.63	12.0	0.02	1.65	0.01	269
LP 4.1 Black	1.8	21/05/2013	**1000**	4.1	< 1	2.4	15.2	0.04	12.8	0.01	2.35	0.04	183
LP 4.1 Black	1.8	27/06/2013	600										210
LP 4.1 Black	1.8	26/07/2013	**600**	461.1	< 1	58	15.9	0.02	15.1	0.01	0.77	0	512
LP 4.1 Black	1.8	20/08/2013	**800**	28.5	< 1	16	19.9	0.91	18.9	0.04	0.05	0	254
LP 4.1 Black	1.8	24/09/2013	**250**	1203.3	86	92	10.1	0	9.7	0.00	0.40	0.46	
LP 4.1 Black	1.8	04/10/2013	**600**	11496	< 20	5	11.9	< 0.05	8.3			0.21	229
LP 4.1 Black	1.8	12/11/2013	**250**	16		4	15.1	0.18	13.9	< 0.02	1	< 0.05	178
LP 4.1 Black	1.8	28/11/2013	**250**	11	< 1		15	< 0.05	14.1	0.01	0.84	0.07	315
LP 4.1 Black	1.8	12/12/2013	**250**	72.3	< 1	30	20.5	< 0.05	16.7	0.02	3.73	< 0.05	236
LP 4.1 Black	1.8	10/01/2014	**300**										184
LP 4.1 Black	1.8	24/01/2014	**400**	21.8	< 1	31	16.3	0.01	12.9	0.01		0.08	151

ID	Depth	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Inorganic	Organic	PO4	Cl
DR 1 Red	1.2	10/10/2012												
DR 1 Red	1.2	13/11/2012	250	235.9	< 1	31.8	1.34	1.15	0.1	0.02	1.27	0.07	0.09	301
DR 1 Red	1.2	06/12/2012	400	435.2	1	21.2	5.93	0.06	5.7	0.1	5.86	0.07	0.31	
DR 1 Red	1.2	10/01/2013	300	38.6	< 1	< 10	4.12	0.3	3.7	0.02	4.02	0.10	0.02	312
DR 1 Red	1.2	28/02/2013	800	1	< 1	11.5	8.3	1.2	6.4	0.06	7.66	0.64	0.01	178
DR 1 Red	1.2	26/03/2013	200	> 2419.6	< 1	31.7		2.09	12.1	0.01	14.2		0.97	
DR 1 Red	1.2	23/04/2013	200	8.4	< 1	27.5	11.4	0.56	0.1	0.03	0.69	10.71	0.43	281
DR 1 Red	1.2	21/05/2013	300	8.4	< 1	13.8	10.7	0.27	10.2	0.05	10.52	0.18	0.43	300
DR 1 Red	1.2	27/06/2013	100	563.3	< 1	2.1	15.12	0.09	13.0	0.05	13.14	1.98	0.29	248
DR 1 Red	1.2	26/07/2013	50	2419.6	< 10	122	11.7	0.12	6.7	0.08	6.9	4.80	0.13	308
DR 1 Red	1.2	20/08/2013	80	9803.9	< 10	29	11.7	1.03	9.9	0.08	11.01	0.69	0.00	285
DR 1 Red	1.2	24/09/2013	200											
DR 1 Red	1.2	04/10/2013	250	6152	< 20	10	7.49	< 0.05	4.1		4.15		0.06	32
DR 1 Red	1.2	12/11/2013	200	920.8		23	12.2	2.15	7.2	< 0.02	9.37	2.83	0.05	223
DR 1 Red	1.2	28/11/2013	200	> 2419.6	< 1		9.08	1.45	4.6	0.02	6.07	3.01	0.23	320
DR 1 Red	1.2	12/12/2013	250	231	< 1	58	14.3	0.09	11.4	0.01	11.5	2.80	0.1	
DR 1 Red	1.2	10/01/2014												
DR 1 Red	1.2	24/01/2014	500	71.7	< 1	39	24.3	0.01	13.8	0	13.81		0.08	240
DR 1 Blue	1.5	10/10/2012												
DR 1 Blue	1.5	13/11/2012	250	310	< 1	14.5	0.734	0.1	0.6	0.01	0.71	0.02	0.05	17
DR 1 Blue	1.5	06/12/2012	1100	2382	< 1	12.5	1.06	0.03	0.8	0.01	0.84	0.22	0.02	59
DR 1 Blue	1.5	10/01/2013	1000	143.9	< 1	< 10	2.36	0.4	1.4	0	1.8	0.56	< 0.05	165
DR 1 Blue	1.5	28/02/2013	1100	14.5	< 1	10.8	3.9	0.47	2.6	0.00	3.07	0.83	< 0.05	228
DR 1 Blue	1.5	26/03/2013	700	12	< 1	4.4		0.04	3.3	0.00	3.34		0.03	206
DR 1 Blue	1.5	23/04/2013	800	4.1	< 1	10.4	5.33	0.27	0.0	0.02	0.29	5.04	< 0.06	165
DR 1 Blue	1.5	21/05/2013	300	4.1	< 1	8.7	4.82	0.05	2.2	0.01	2.26	2.56	< 0.05	94
DR 1 Blue	1.5	27/06/2013	500	10.8	< 1	1.4	3.9	0.03	0.3	0.01	0.34	3.56	0.10	169
DR 1 Blue	1.5	26/07/2013	600	> 2419.6	1	108	5.05	0.08	3.3	0.00	3.38	1.67	0.01	60
DR 1 Blue	1.5	20/08/2013	250	> 2419.6	< 1	10	4.4	1.47	2.4	0.00	3.87	0.53	0.00	36
DR 1 Blue	1.5	24/09/2013	120											
DR 1 Blue	1.5	04/10/2013	500	2024	< 20	9	10.6	< 0.05	4.2		4.25		0.03	11

DR 1 Blue	1.5	12/11/2013	**900**	290.9		14	6.98	2.06	4.4	< 0.02	6.48	0.50	< 0.05	199
DR 1 Blue	1.5	28/11/2013	**250**	> 2419.6	< 1		7.1	0.48	4.5	0.01	4.99	2.11	0.07	206
DR 1 Blue	1.5	12/12/2013	**300**	35.5	< 1	40	12.7	< 0.05	10.2	0	10.25	2.45	0	
DR 1 Blue	1.5	10/01/2014												
DR 1 Blue	1.5	24/01/2014	500	1119.9	< 1	25	20	0.01	12.5	0.01	12.52		0.09	236
DR 1 Black	1.8	10/10/2012												
DR 1 Black	1.8	13/11/2012	230	248.9	4.1	2.9	1.9	0.13	1	0.03	1.16	0.74	0.36	35
DR 1 Black	1.8	06/12/2012	1000	13.9	1	< 4.0	1.64	0.05	1.5	0.01	1.56	0.08	0.1	45
DR 1 Black	1.8	10/01/2013	1000	14.2	< 1	< 10	3.62	0.87	2.6	0	3.47	0.15	0.06	131
DR 1 Black	1.8	28/02/2013	**300**	2419.6	< 1	3.1	4.2	0.07	4.1	0.00	4.17	0.03	0.02	285
DR 1 Black	1.8	26/03/2013	**500**	8.4	< 1	8.4		0.29	7.3	0.01	7.6		0.01	222
DR 1 Black	1.8	23/04/2013	**500**	1	< 1	9.5	4.62	0.12	4.6	0.01	4.73	-0.11	0.01	98
DR 1 Black	1.8	21/05/2013	**250**	1	< 1	2.9	4.79	0.16	3.2	0.00	3.36	1.43	0.07	21
DR 1 Black	1.8	27/06/2013	**600**	238.2	< 1	1.2	12.53	0.14	10.9	0.01	11.05	1.48	0.07	33
DR 1 Black	1.8	26/07/2013	**500**	> 2419.6	< 1	59	5.59	0.02	3.6	0.00	3.62	1.97	0	32
DR 1 Black	1.8	20/08/2013	**500**	> 2419.6	< 1	61	7.52	1.38	0.6	0.02	2	5.52	0	17
DR 1 Black	1.8	24/09/2013	50											
DR 1 Black	1.8	04/10/2013	**100**	1602	< 20	7	9.61	< 0.05	4.8		4.85		0.19	166
DR 1 Black	1.8	12/11/2013	**900**	161.6		11	2.94	< 0.05	1.4	< 0.02	1.47	1.47	< 0.05	137
DR 1 Black	1.8	28/11/2013	**250**	816.4	1	32	6.24	0.08	1.5	0	1.58	4.66	0.04	187
DR 1 Black	1.8	12/12/2013	**300**	21.1	< 1		5.66	< 0.05	4.1	0	4.15	1.51	< 0.05	
DR 1 Black	1.8	10/01/2014												
DR 1 Black	1.8	24/01/2014	400	387.3	< 1	10	11.5	0.03	10	0	10.03		0.05	191
DR 2 Red	1.2	10/10/2012												
DR 2 Red	1.2	13/11/2012	370	38.3	< 1	< 4.0	0.769	0.05	0.1	0.00	0.15	0.62	0.04	41
DR 2 Red	1.2	06/12/2012	750	13.5	2	7.3	0.86	0.05	0.3	0.00	0.35	0.51	0.03	133
DR 2 Red	1.2	10/01/2013	800	8.4	< 1	13	1.45	0.04	1.1	0	1.14	0.31	0.03	233
DR 2 Red	1.2	28/02/2013	900											169
DR 2 Red	1.2	26/03/2013	2											212
DR 2 Red	1.2	23/04/2013	250											288
DR 2 Red	1.2	21/05/2013	250											217
DR 2 Red	1.2	27/06/2013	**200**	49.5	< 1	24.9	3.54	0.1	3.1	0.03	3.23	0.31	0.12	243

DR 2 Red	1.2	26/07/2013	**600**	> 2419.6	1	44	6.46	0.03	3.9	0.02	3.95	2.51	0	234
DR 2 Red	1.2	20/08/2013	500											281
DR 2 Red	1.2	24/09/2013	**200**	> 2419.6	< 1	583	9.1	0	8.2	0.02	8.22	0.88	0.42	
DR 2 Red	1.2	04/10/2013	**900**	486	< 20	9	11.2	< 0.05	10.8		10.85		0.08	162
DR 2 Red	1.2	12/11/2013	**900**	1553.1		4	5.1	1.53	4.3	0.02	5.85	-0.75	0.08	202
DR 2 Red	1.2	28/11/2013	800											185
DR 2 Red	1.2	12/12/2013												
DR 2 Red	1.2	10/01/2014				8								
DR 2 Red	1.2	24/01/2014	600											212
DR 2 Blue	1.5	10/10/2012												
DR 2 Blue	1.5	13/11/2012	350	178.9	2	10.5	0.663	0.11	0.2	0.00	0.31	0.35	0.06	7
DR 2 Blue	1.5	06/12/2012	600	10.7	1	4.1	1.19	0.04	0	0.00	0.04	1.15	0.04	11
DR 2 Blue	1.5	10/01/2013	400	25.9	< 1	47	1.9	0.05	< 1	0	1.05	0.85	< 0.05	43
DR 2 Blue	1.5	28/02/2013	350											155
DR 2 Blue	1.5	26/03/2013	300											234
DR 2 Blue	1.5	23/04/2013	250											291
DR 2 Blue	1.5	21/05/2013	250											166
DR 2 Blue	1.5	27/06/2013	**250**	38.9	< 1	0.4	4.24	2.12	2.1	0.01	4.23	0.01	0.28	219
DR 2 Blue	1.5	26/07/2013	**300**	191.8	< 1	60	1.79	0.04	0.8	0.01	0.85	0.94	0	191
DR 2 Blue	1.5	20/08/2013	250											195
DR 2 Blue	1.5	24/09/2013	**50**	434.7	< 10	400	5.63	0.19	5.4	0.01	5.6	0.03	0.8	
DR 2 Blue	1.5	04/10/2013	**150**	1406	< 20	12	9.41	< 0.05	8.9		8.95		0.1	133
DR 2 Blue	1.5	12/11/2013	**250**	547.5		1	4.6	1.35	3.9	0.02	5.27	-0.67	0.04	181
DR 2 Blue	1.5	28/11/2013	300											164
DR 2 Blue	1.5	12/12/2013												
DR 2 Blue	1.5	10/01/2014												
DR 2 Blue	1.5	24/01/2014	500											200
DR 2 Black	1.8	10/10/2012												
DR 2 Black	1.8	13/11/2012	250	261.3	< 1	6.6	0.587	0.15	0	0.01	0.16	0.43	0.01	15
DR 2 Black	1.8	06/12/2012	800	35.4	2	< 4.0	2.29	0.09	0.2	0.01	0.3	1.99	0.02	33
DR 2 Black	1.8	10/01/2013	1000	5.1	< 1	< 10	4.85	0.89	0.1	0.01	1	3.85	0.01	78
DR 2 Black	1.8	28/02/2013	1200											222

DR 2 Black	1.8	26/03/2013	300											228
DR 2 Black	1.8	23/04/2013	1000											218
DR 2 Black	1.8	21/05/2013	1000											34
DR 2 Black	1.8	27/06/2013	**1000**	150	< 1	0.4	2.82	0.02	2.6	0.01	2.63	0.19	0.14	175
DR 2 Black	1.8	26/07/2013	**700**	387.3	< 1	56	3.92	0.01	2	0.01	2.02	1.90	0	161
DR 2 Black	1.8	20/08/2013	1100											164
DR 2 Black	1.8	24/09/2013	**200**	547.5	12.1	144	1.52	0	1.3	0.01	1.31	0.21	1.05	
DR 2 Black	1.8	04/10/2013	**600**	336	< 20	10	2.88	0.58	0.9		1.48		0.12	191
DR 2 Black	1.8	12/11/2013	**900**	365.4		1	3.4	0.59	2.1	< 0.02	2.71	0.69	0.03	159
DR 2 Black	1.8	28/11/2013	800											156
DR 2 Black	1.8	12/12/2013												
DR 2 Black	1.8	10/01/2014												
DR 2 Black	1.8	24/01/2014	700											185
DR 3 Red	1.2	10/10/2012												
DR 3 Red	1.2	13/11/2012	160	1203.3	6.3	22.2	2.19	0.08	0.2	0.01	0.29	1.90	0.2	6
DR 3 Red	1.2	06/12/2012	300	35.1	6.1	9.9	2.89		0.2	0.01	0.21	2.68	0.13	12
DR 3 Red	1.2	10/01/2013	250	21.1	< 1	< 10	2.14	0.11	0.3	0	0.41	1.73	0.02	29
DR 3 Red	1.2	28/02/2013	300											100
DR 3 Red	1.2	26/03/2013	50											223
DR 3 Red	1.2	23/04/2013	50											256
DR 3 Red	1.2	21/05/2013	50											195
DR 3 Red	1.2	27/06/2013	50											259
DR 3 Red	1.2	26/07/2013	200											326
DR 3 Red	1.2	20/08/2013	80											298
DR 3 Red	1.2	24/09/2013	50											
DR 3 Red	1.2	04/10/2013	**200**	24066	< 20	9	4.59	< 0.05	1.4		1.45		0.01	175
DR 3 Red	1.2	12/11/2013	**100**	7270	< 10	17	9.14	2.73	1.8	< 0.02	4.55	4.59	0.08	213
DR 3 Red	1.2	28/11/2013	**120**	17329	< 10		4	0.25	1.7	0.01	1.96	2.04	< 0.05	323
DR 3 Red	1.2	12/12/2013	**150**	> 2419.6	< 1	63	5.48	< 0.05	12.2	0.01	12.26	-6.78	0.06	
DR 3 Red	1.2	10/01/2014												
DR 3 Red	1.2	24/01/2014	400	209.8	< 1	35	3.36	0.01	0.9	0.01			0.24	182

DR 3 Blue	1.5	10/10/2012												
DR 3 Blue	1.5	13/11/2012	250	1299.7	1	5.7	1.09	0.08	0.2	0.09	0.37	0.72	0.06	11
DR 3 Blue	1.5	06/12/2012	350	235.9	2.1	13.4	0.67	0.04	0.1	0.01	0.15	0.52	0.03	11
DR 3 Blue	1.5	10/01/2013	250	14.4	< 1	39	1.81	0.03	0.2	0	0.23	1.58	0.01	37
DR 3 Blue	1.5	28/02/2013	450											86
DR 3 Blue	1.5	26/03/2013	5											140
DR 3 Blue	1.5	23/04/2013	100											190
DR 3 Blue	1.5	21/05/2013	100											173
DR 3 Blue	1.5	27/06/2013	190											189
DR 3 Blue	1.5	26/07/2013	0											
DR 3 Blue	1.5	20/08/2013	60											101
DR 3 Blue	1.5	24/09/2013	60											
DR 3 Blue	1.5	04/10/2013	0											
DR 3 Blue	1.5	12/11/2013	**25**	3744	< 20	14	5.67	1.53	1.4	< 0.02	2.95	2.72	< 0.05	168
DR 3 Blue	1.5	28/11/2013	**150**	1553.1	< 1		3.72	0.1	1.4	0	1.5	2.22	< 0.05	242
DR 3 Blue	1.5	12/12/2013	**150**	> 2419.6	< 1	39	4.27	< 0.05	0.6	0.01	0.66	3.61	< 0.05	
DR 3 Blue	1.5	10/01/2014												
DR 3 Blue	1.5	24/01/2014	250	686.7	1	25	4.89	0.01	1.7	0.01	1.72		0.05	157
DR 3 Black	1.8	10/10/2012												
DR 3 Black	1.8	13/11/2012	250	307.6	8.5	10.1	0.487	0.12	0.1	0.01	0.23	0.26	0.02	7
DR 3 Black	1.8	06/12/2012	400	235.9	< 1	3	0.663	0.05	0.1	0.00	0.15	0.51	0.03	13
DR 3 Black	1.8	10/01/2013	300	21.8	< 1	< 10	1.56	0.1	< 1	0	1.1	0.46	< 0.05	36
DR 3 Black	1.8	28/02/2013	300											116
DR 3 Black	1.8	26/03/2013	175											186
DR 3 Black	1.8	23/04/2013	200											206
DR 3 Black	1.8	21/05/2013	200											112
DR 3 Black	1.8	27/06/2013	300											186
DR 3 Black	1.8	26/07/2013	200											198
DR 3 Black	1.8	20/08/2013	250											173
DR 3 Black	1.8	24/09/2013	100											
DR 3 Black	1.8	04/10/2013	**150**	4800	< 20	4	5.08	< 0.05	2.4		2.45		0.06	97
DR 3 Black	1.8	12/11/2013	**225**	980.4	< 1	8	2.06	1.3	0.8	< 0.02	2.12	-0.06	< 0.05	125

DR 3 Black	1.8	28/11/2013	**250**	59.4	< 1		3.28	< 0.05	1.3	< 0.02	1.37	1.91	< 0.05	136
DR 3 Black	1.8	12/12/2013	**200**	2419.6	< 1	20	2.4	< 0.05	0.3	0.01	0.36	2.04	0	
DR 3 Black	1.8	10/01/2014												
DR 3 Black	1.8	24/01/2014	300	1413.6	< 1	19	2.85	0	1.5	0	1.5		0.05	140
DR 4 Red	1.2	10/10/2012												
DR 4 Red	1.2	13/11/2012	370	68.9	4.1	13.1	2	1.41	0.1	0.00	1.51	0.49	0.04	189
DR 4 Red	1.2	06/12/2012	1000	145	3.1	35	1.26	0.04	0.1	0.00	0.14	1.12	0.03	176
DR 4 Red	1.2	10/01/2013	900	8.5	< 1	< 10	13.9	< 0.05	0.2	0.01	0.26	13.64	0	284
DR 4 Red	1.2	28/02/2013	**1300**	13.5	< 1	30.7	11.1	1.77	0.3	0.01	2.08	9.02	0.01	139
DR 4 Red	1.2	26/03/2013	**300**	13.2	< 1	8.4		0.24	3.1	0.01	3.35		< 0.05	464
DR 4 Red	1.2	23/04/2013	**800**	1732.9	< 1	28	7.03	1.34	2.5	0.02	3.86	3.17	< 0.03	323
DR 4 Red	1.2	21/05/2013	**300**	1732.9	< 1	28	11.2	0.26	0.2	0.00	0.46	10.74	< 0.19	233
DR 4 Red	1.2	27/06/2013	1											256
DR 4 Red	1.2	26/07/2013	**500**	> 2419.6	< 1	63	4.06	0.09	2.1	0.00	2.19	1.87	< 0.03	474
DR 4 Red	1.2	20/08/2013	**250**	> 2419.6		23	3.23	0.05	0.7	0.00	0.75	2.48	< 0.00	256
DR 4 Red	1.2	24/09/2013	**100**	3075.9	< 1	573	6.3	0	4.2	0.02	4.22	2.08	< 0.57	
DR 4 Red	1.2	04/10/2013	**400**	4494	< 20	21	5.69	< 0.05	3.1		3.15		0.07	228
DR 4 Red	1.2	12/11/2013	200											218
DR 4 Red	1.2	28/11/2013	300											191
DR 4 Red	1.2	12/12/2013												
DR 4 Red	1.2	10/01/2014												
DR 4 Red	1.2	24/01/2014	400											187
DR 4 Blue	1.5	10/10/2012												
DR 4 Blue	1.5	13/11/2012	350	1203.3	113.7	9	1.44	< 0.05	< 1.0	0.01	1.06	0.38	0.07	6
DR 4 Blue	1.5	06/12/2012	900	28.2	< 1	< 10	1.53	0.08	0	0.01	0.09	1.44	0.04	21
DR 4 Blue	1.5	10/01/2013	800	8.6	< 1	< 10	2.19	0.09	0.3	0.01	0.4	1.79	0.04	105
DR 4 Blue	1.5	28/02/2013	**1100**	5.2	< 1	29.3	1.6	0.83	0.7	0.01	1.54	0.06	0.02	261
DR 4 Blue	1.5	26/03/2013	**500**	1	< 1	3.6		0.06	1.2	0.01	1.27		0.01	283
DR 4 Blue	1.5	23/04/2013	**800**	16.1	< 1	11.2	5.91	2.12	1.2	0.02	3.34	2.57	< 0.02	297
DR 4 Blue	1.5	21/05/2013	**300**	16.1	< 1	11.2	4.57	0.38	0.3	0.01	0.69	3.88	< 0.28	136
DR 4 Blue	1.5	27/06/2013	25											213
DR 4 Blue	1.5	26/07/2013	**700**	> 2419.6	< 1	90	9.09	0.02	1.6	0.00	1.62	7.47	< 0.00	242

DR 4 Blue	1.5	20/08/2013	**800**	1203.3		9	4.08	1.37	2.7	0.00	4.07	0.01	< 0.00	217
DR 4 Blue	1.5	24/09/2013	**250**	1299.7	2	274	2.83	0	2.8	0.02	2.82	0.01	< 0.60	
DR 4 Blue	1.5	04/10/2013	**900**	3450	< 20	17	4.33	< 0.05	2.5		2.55		0.12	118
DR 4 Blue	1.5	12/11/2013	500											176
DR 4 Blue	1.5	28/11/2013	800											178
DR 4 Blue	1.5	12/12/2013												
DR 4 Blue	1.5	10/01/2014												
DR 4 Blue	1.5	24/01/2014	600											170
DR 4 Black	1.8	10/10/2012												
DR 4 Black	1.8	13/11/2012	300	101.7	< 1	6.1	1.61	< 0.05	< 1.0	0.00	1.05	0.56	0.01	5
DR 4 Black	1.8	06/12/2012	1100	193.5	1	< 10	1.49	0.04	0	0.00	0.04	1.45	0.04	7
DR 4 Black	1.8	10/01/2013	1000	15.8	< 1	< 10	1.91	0.04	< 1	0	1.04	0.87	< 0.05	43
DR 4 Black	1.8	28/02/2013	**1100**	14.6	< 1	27.7	0.9	0.14	0.3	0.00	0.44	0.46	< 0.05	281
DR 4 Black	1.8	26/03/2013	**900**	4.1	< 1	3.1		0	0.5	0.00	0.5		0.01	195
DR 4 Black	1.8	23/04/2013	**1000**	6.3	< 1	10.1	5.67	1.62	0.4	0.01	2.03	3.64	< 0.00	233
DR 4 Black	1.8	21/05/2013	**300**	6.3	< 1	10.1	4.16	0.15	0.1	0.00	0.25	3.91	< 0.02	95
DR 4 Black	1.8	27/06/2013	300								0			146
DR 4 Black	1.8	26/07/2013	**1000**	> 2419.6	< 1	5	4.64	0.03	0.3	0.00	0.33	4.31	< 0.00	198
DR 4 Black	1.8	20/08/2013	**800**	> 2419.6	1	36	1.81	1.02	0.7	0.00	1.72	0.09	< 0.00	178
DR 4 Black	1.8	24/09/2013	**200**	> 2419.6	< 1	101	16.6	0	0.6	0.01	0.61	15.99	< 0.95	
DR 4 Black	1.8	04/10/2013	**30**	1182	< 20	14	2.36	< 0.05	1.4		1.45		0.72	97
DR 4 Black	1.8	12/11/2013	100											135
DR 4 Black	1.8	28/11/2013	100											111
DR 4 Black	1.8	12/12/2013												
DR 4 Black	1.8	10/01/2014												
DR 4 Black	1.8	24/01/2014	200											153
DR 5 Red	1.2	10/10/2012												
DR 5 Red	1.2	13/11/2012	700	410.6	4.1	21	1.3	0.05	0.7	0.01	0.76	0.54	0.04	38
DR 5 Red	1.2	06/12/2012	250	344.8	1	13	1.73	0.11	1.4	0.02	1.53	0.20	0.06	101
DR 5 Red	1.2	10/01/2013	200	8664	< 1	< 10	7.27	0.06	7.1	0.01	7.17	0.10	< 0.05	121
DR 5 Red	1.2	28/02/2013	500											103
DR 5 Red	1.2	26/03/2013	80											116

DR 5 Red	1.2	23/04/2013	200											174
DR 5 Red	1.2	21/05/2013	200											223
DR 5 Red	1.2	27/06/2013	**100**	224.7	< 10	12.3	3.71	< 0.97	1.3	0.01	2.28	1.43	2.12	109
DR 5 Red	1.2	26/07/2013	250											256
DR 5 Red	1.2	20/08/2013	100											181
DR 5 Red	1.2	24/09/2013	50											
DR 5 Red	1.2	04/10/2013	150											
DR 5 Red	1.2	12/11/2013	100											190
DR 5 Red	1.2	28/11/2013	200											185
DR 5 Red	1.2	12/12/2013												
DR 5 Red	1.2	10/01/2014												
DR 5 Red	1.2	24/01/2014	300											191
DR 5 Blue	1.5	10/10/2012												
DR 5 Blue	1.5	13/11/2012	400	547.5	1	0.9	1.68	0.12	0.8	0.01	0.93	0.75	0.06	24
DR 5 Blue	1.5	06/12/2012	300	123.6	< 1	< 10	1.09	0.08	0.9	0.01	0.99	0.10	0.06	50
DR 5 Blue	1.5	10/01/2013	250	> 24196	< 1	< 10	3.05	0.05	2.4	0	2.45	0.60	< 0.05	94
DR 5 Blue	1.5	28/02/2013	250											105
DR 5 Blue	1.5	26/03/2013	100											81
DR 5 Blue	1.5	23/04/2013	150											77
DR 5 Blue	1.5	21/05/2013	150											210
DR 5 Blue	1.5	27/06/2013	**75**	2480.9	< 10	1.3	4.32	0.08	2.1	0.01	2.19	2.13	0.68	94
DR 5 Blue	1.5	26/07/2013	300											68
DR 5 Blue	1.5	20/08/2013	140											79
DR 5 Blue	1.5	24/09/2013	50											
DR 5 Blue	1.5	04/10/2013	200											
DR 5 Blue	1.5	12/11/2013	200											167
DR 5 Blue	1.5	28/11/2013	250											161
DR 5 Blue	1.5	12/12/2013												
DR 5 Blue	1.5	10/01/2014												
DR 5 Blue	1.5	24/01/2014	300											175

DR 5 Black	1.8	10/10/2012												
DR 5 Black	1.8	13/11/2012	350	12980	< 1	14.5	1.45	0.11	1.1	0.01	1.22	0.23	0.02	35
DR 5 Black	1.8	06/12/2012	400	20	< 1	< 10	2.28	0.05	2.2	0.01	2.26	0.02	0.01	92
DR 5 Black	1.8	10/01/2013	300	8.5	< 1	21	2.61	< 0.05	1.8	0	1.85	0.76	0.05	134
DR 5 Black	1.8	28/02/2013	250											99
DR 5 Black	1.8	26/03/2013	400											59
DR 5 Black	1.8	23/04/2013	500											70
DR 5 Black	1.8	21/05/2013	500											134
DR 5 Black	1.8	27/06/2013	**400**	13.5	< 1	0.5	3.39	0.33	0.8	0.04	1.17	2.22	0.22	81
DR 5 Black	1.8	26/07/2013	700											50
DR 5 Black	1.8	20/08/2013	600											51
DR 5 Black	1.8	24/09/2013	200											
DR 5 Black	1.8	04/10/2013	500											
DR 5 Black	1.8	12/11/2013	350											111
DR 5 Black	1.8	28/11/2013	400											122
DR 5 Black	1.8	12/12/2013												
DR 5 Black	1.8	10/01/2014												
DR 5 Black	1.8	24/01/2014	300											152
DR 6 Red	1.2	10/10/2012												
DR 6 Red	1.2	13/11/2012	220	105	< 1	23.1	0.875	< 0.05	0.8	0.01	0.86	0.01	0.11	13
DR 6 Red	1.2	06/12/2012	600	122.3	< 1	< 10	1.22	0.05	0.3	0.01	0.36	0.86	0.04	35
DR 6 Red	1.2	10/01/2013	400	52.1	< 1	19	1.8	0.2	0.1	0	0.3	1.50	0.01	117
DR 6 Red	1.2	28/02/2013	**1100**	16.6	< 1	29.9	3.7	1.58	2.1	0.01	3.69	0.01	0.02	205
DR 6 Red	1.2	26/03/2013	**80**	51	10	5.3		0.03	2.7	0.01	2.74		0.04	266
DR 6 Red	1.2	23/04/2013	**220**	33.6	< 1	22.2	6.37	1.91	0.2	0.01	2.12	4.25	0.01	294
DR 6 Red	1.2	21/05/2013	**200**	33.6	< 1	22.2	14.8	1.28	0.2	0.01	1.49	13.31	0.12	180
DR 6 Red	1.2	27/06/2013	10											270
DR 6 Red	1.2	26/07/2013	300											596
DR 6 Red	1.2	20/08/2013	**250**	214.3	< 1	29	3.32	2.5	0.7	0.00	3.2	0.12	0	242
DR 6 Red	1.2	24/09/2013	**70**	6488.2	< 10	586	6.51	0	1.2	0.07	1.27	5.24	0.7	
DR 6 Red	1.2	04/10/2013	100											
DR 6 Red	1.2	12/11/2013	200											277

DR 6 Red	1.2	28/11/2013	**180**	> 2420	< 1		5.38	1.19	3.8	0	4.99	0.39	0.17	326
DR 6 Red	1.2	12/12/2013	**200**	231.8	< 1	44	7.37	< 0.05	3.4	< 0.02	3.47	3.9	0.26	
DR 6 Red	1.2	10/01/2014												
DR 6 Red	1.2	24/01/2014	300	980.4	< 1	47	7.37	0.01	6.3	0.01	6.32		0.23	238
DR 6 Blue	1.5	10/10/2012												
DR 6 Blue	1.5	13/11/2012	320	114	1	< 4	1.67	0.09	1.5	0.01	1.6	0.07	0.03	21
DR 6 Blue	1.5	06/12/2012	900	148.3	< 1	12	2.16	0.07	0.4	0.01	0.48	1.68	0.06	70
DR 6 Blue	1.5	10/01/2013	1000	11	< 1	61	1.73	0.09	1.1	0.01	1.2	0.53	< 0.05	216
DR 6 Blue	1.5	28/02/2013	**1100**	8.4	2	27.9	4.9	1.04	3.0	0.01	4.05	0.85	0.02	265
DR 6 Blue	1.5	26/03/2013	**400**	50.4	< 1	5.6		0.03	2.3	0.01	2.34		0.01	265
DR 6 Blue	1.5	23/04/2013	**1000**	32.8	< 1	9.5	3.95	2.01	0.9	0.02	2.93	1.02	0.07	257
DR 6 Blue	1.5	21/05/2013	**1100**	32.8	< 1	9.5	3.12	0.56	1.7	0.01	2.27	0.85	0.05	139
DR 6 Blue	1.5	27/06/2013	400											262
DR 6 Blue	1.5	26/07/2013	50											282
DR 6 Blue	1.5	20/08/2013	**100**	3465.8	< 1	68	2.88	1.61	1.1	0.00	2.71	0.17	0	253
DR 6 Blue	1.5	24/09/2013	**90**	1917.9	< 10	369	3.69	0	1	0.02	1.02	2.67	0.79	
DR 6 Blue	1.5	04/10/2013	100											
DR 6 Blue	1.5	12/11/2013	150											194
DR 6 Blue	1.5	28/11/2013	**250**	2419.6	< 1		4.1	1.34	2.3	< 0.02	3.66	0.44	< 0.05	311
DR 6 Blue	1.5	12/12/2013	**200**	98.5	< 1	32	4.87	< 0.05	2.6	0.01	2.66	2.21	< 0.05	
DR 6 Blue	1.5	10/01/2014												
DR 6 Blue	1.5	24/01/2014	400	1119.9	< 1	15	12.2	0	7.7	0	7.7		0.03	225
DR 6 Black	1.8	10/10/2012												
DR 6 Black	1.8	13/11/2012	250	10.8	< 1	< 4	1.8	0.34	1.4	0.01	1.75	0.05	0.08	13
DR 6 Black	1.8	06/12/2012	900	204.6	1	< 10	1.04	0.07	0.2	0.01	0.28	0.76	0.04	30
DR 6 Black	1.8	10/01/2013	1000	406	< 1	71	2.31	0.06	1.8	0	1.86	0.45	< 0.05	94
DR 6 Black	1.8	28/02/2013	**250**	10.8	< 1	21.5	2.7	0.28	1.8	0.00	2.08	0.62	0.01	253
DR 6 Black	1.8	26/03/2013												
DR 6 Black	1.8	23/04/2013	**1000**	28.1	< 1	5	2.41	1.73	0.2	0.02	1.95	0.46	0.05	280
DR 6 Black	1.8	21/05/2013	**500**	28.1	< 1	5	2.81	0.6	1.1	0.01	1.71	1.10	0.04	132
DR 6 Black	1.8	27/06/2013	500											239
DR 6 Black	1.8	26/07/2013	300											258

DR 6 Black	1.8	20/08/2013	**900**	69.7	< 1	9	21.6	2.41	1.8	0.03	4.24	17.36	0	256
DR 6 Black	1.8	24/09/2013	**250**	> 2420	< 1	23	2.06	0	0.3	0.00	0.3	1.76	1.2	
DR 6 Black	1.8	04/10/2013	100											
DR 6 Black	1.8	12/11/2013	200											173
DR 6 Black	1.8	28/11/2013	**250**	80.9	< 1		2.8	0.45	2.3	0.06	2.81	-0.01	0.01	308
DR 6 Black	1.8	12/12/2013	**250**	79.5	< 1	25	4	< 0.05	2.3	0.01	2.36	1.64	0.02	
DR 6 Black	1.8	10/01/2014												
DR 6 Black	1.8	24/01/2014	350	1413.6	< 1	9	7.26	0	3.9	0	3.9		0.07	202

ID	Depth	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Inorganic	Organic	PO4	Cl
DR 1	0.3	10/10/2012												
DR 1	0.3	13/11/2012												
DR 1	0.3	06/12/2012												
DR 1	0.3	10/01/2013												
DR 1	0.3	28/02/2013												
DR 1	0.3	26/03/2013												
DR 1	0.3	23/04/2013	170	35.5	< 1	32.1	18.1	3	0.3	0.07	3.37	14.73	1.02	274
DR 1	0.3	21/05/2013	200	35.5	< 1	27.2	8.25	1.19	6.9	0.05	8.14	0.11	0.82	312
DR 1	0.3	27/06/2013	175	1528.6	< 1	39	23.16	0.06	22.5	0.14	22.70	0.46	1.62	261
DR 1	0.3	26/07/2013	45	346.2	< 10	124	7.52	0.04	4.5	0.01	4.55	2.97	0.47	249
DR 1	0.3	20/08/2013	10	6295.5	< 50	46	13.8	0.21	7.9	0.01	8.12	5.68	0	267
DR 1	0.3	24/09/2013	10	10713	< 50	367	5.5	1.45	3.8	0.01	5.26	0.24	2.21	
DR 1	0.3	04/10/2013	100			28.3	20.6	0.6	18.3	0.02	18.92	1.68	2.69	329
DR 1	0.3	12/11/2013	100	8164		37	34.2	0.24	30.9	0.07	31.21	2.99	9.6	330
DR 1	0.3	28/11/2013	90	> 24196.0	< 10	19	34.8	< 0.05	33.7	0.03	33.78	1.02	1.81	348
DR 1	0.3	12/12/2013	75	5510	< 20	64	33.2	0.06	32.4	0.04	32.50	0.70	3.4	
DR 1	0.3	10/01/2014												
DR 1	0.3	24/01/2014	140	> 2419.6	< 1	51	24.5	0.06	23.5	0.07	23.63		0.01	353
DR 2	0.3	10/10/2012												
DR 2	0.3	13/11/2012												
DR 2	0.3	06/12/2012												
DR 2	0.3	10/01/2013												
DR 2	0.3	28/02/2013												
DR 2	0.3	26/03/2013												
DR 2	0.3	23/04/2013	180	> 2419.6	< 1	28.2	13.1	0.28	0.9	0.46	1.64	11.46	0.09	291
DR 2	0.3	21/05/2013	200	> 2419.6	< 1	5.1	31.7	0.18	0.1	0.14	0.42	31.28	0.13	295
DR 2	0.3	27/06/2013	75	10	< 10	32.1	22.27	0.56	21.5	0.08	22.14	0.13	1.46	275
DR 2	0.3	26/07/2013	75	195.8	< 10	171	6.7	0.48	1	0.03	1.51	5.19	0	506
DR 2	0.3	20/08/2013	70	6510.8		83	6.5	0.52	1	0.05	1.57	4.93	0.74	258
DR 2	0.3	24/09/2013	20	914.5	< 50	375	3.13	0.45	0.7	0.02	1.17	1.96	2.34	
DR 2	0.3	04/10/2013	15			35.1	15.6	0.5	13.9	0.02	14.42	1.18	2.04	154

DR 2	0.3	12/11/2013	50	> 24196.0		75	3.11	0.1	0.8	0.02	0.92	2.19	0.05	240
DR 2	0.3	28/11/2013	50	3873	< 10	29	3.22	0.09	0.6	0.03	0.72	2.50	0.03	312
DR 2	0.3	12/12/2013	50	366	< 20	61	3.69	0.11	1.2	0.04	1.35	2.34	0.5	
DR 2	0.3	10/01/2014												
DR 2	0.3	24/01/2014	50	11199	< 10	54	5.19	0.11	1.3	0.01	1.42		1.04	259
DR 3	0.3	10/10/2012												
DR 3	0.3	13/11/2012												
DR 3	0.3	06/12/2012												
DR 3	0.3	10/01/2013												
DR 3	0.3	28/02/2013												
DR 3	0.3	26/03/2013												
DR 3	0.3	23/04/2013	150	> 2419.6	< 1	52.1	14	0.51	1.1	0.22	1.83	12.17	0.09	272
DR 3	0.3	21/05/2013	200	> 2419.6	< 1	52.1	7.09	0.38	0.02	0.06	0.46	6.63	0.05	278
DR 3	0.3	27/06/2013	75	2045.9	< 10	28.2	22.15	0.6	21	0.02	21.62	0.53	1.71	270
DR 3	0.3	26/07/2013	30	> 48392.0	< 20	212	33.2	2.82	1.6	0.02	4.44	28.76	1.81	502
DR 3	0.3	20/08/2013	10	> 120980.0	< 50	79	3.56	0.05	1.2	0.01	1.26	2.30	0	271
DR 3	0.3	24/09/2013	20	17240	< 50	93	4.15	0.15	0.6	0.01	0.76	3.39	2.03	
DR 3	0.3	04/10/2013	50			20.2	7.8	0.31	6.9	0.02	7.23	0.57	1.95	133
DR 3	0.3	12/11/2013	50	4884		26	4.1	0.07	1.1	0.02	1.19	2.91	0.05	160
DR 3	0.3	28/11/2013	50	> 24196.0	< 10	108	3.24	0.05	0.09	0.07	0.21	3.03	0.04	302
DR 3	0.3	12/12/2013	50	4700	< 20	70	18.1	0.3	15.8	0.02	16.12	1.98	0.45	
DR 3	0.3	10/01/2014												
DR 3	0.3	24/01/2014	60	614	< 10	32	5.55	0.05	4.9	0.02	4.97		0.09	205
DR 6	0.3	10/10/2012												
DR 6	0.3	13/11/2012												
DR 6	0.3	06/12/2012												
DR 6	0.3	10/01/2013												
DR 6	0.3	28/02/2013												
DR 6	0.3	26/03/2013												
DR 6	0.3	23/04/2013	150	> 2419.6	< 1	53	7.03	0.97	0.8	0.12	1.89	5.14	0.18	281.00
DR 6	0.3	21/05/2013	200	> 2419.6	< 1	53	4.74	0.34	0.4	0.03	0.77	3.97	0.10	317.00
DR 6	0.3	27/06/2013	75	4351.7	< 10	28.2	23.24	0.16	22.3	0.02	22.48	0.76	1.61	298

DR 6	0.3	26/07/2013												
DR 6	0.3	20/08/2013	10	64982.5	< 50	19	9.23	0.17	3.6	0.97	4.74	4.49	0.00	269
DR 6	0.3	24/09/2013	10	38505	< 50	450	2.55	0.05	0.8	0.01	0.86	1.69	1.72	
DR 6	0.3	04/10/2013	50			25.5	10.9	0.12	9.1	0.03	9.25	1.65	1.22	118
DR 6	0.3	12/11/2013												
DR 6	0.3	28/11/2013	40	> 24196.0	< 10	95	11.5	< 0.05	9.8	0.01	9.86	1.64	0.23	299
DR 6	0.3	12/12/2013	40	4448	< 20	64	17.3	0.1	14.7	0.02	14.82	2.48	1.2	
DR 6	0.3	10/01/2014												
DR 6	0.3	24/01/2014	50	24196	< 10	34	4.85	0	2.8	0.02	2.82		0.2	262

BH	Date	Volume	Total C.	Ecoli	COD	TN	NH4	NO3	NO2	Organic	PO4	Cl
UP/S	10/10/2012		23.5	< 1							0.08	
UP/S	13/11/2012		31.5	< 1	7.4	0.563	0.07	0.2	< 0.02	0.27	0.03	12
UP/S	06/12/2012		60.5	< 1	< 10	1.11	0.04	0.1	0.01	0.96	0.04	10
UP/S	10/01/2013		5.5	< 1	< 10	1.84	0.08	< 1	0.01	0.75	< 0.05	11
UP/S	28/02/2013		1	< 1	8.2	0.5	0.01	0.1	0.00	0.39	0.01	6
UP/S	26/03/2013											
UP/S	23/04/2013											
UP/S	21/05/2013											
UP/S	27/06/2013											
UP/S	26/07/2013											
UP/S	20/08/2013											
UP/S	24/09/2013											
UP/S	04/10/2013											
UP/S	12/11/2013											
UP/S	28/11/2013											
UP/S	12/12/2013											
UP/S	10/01/2014											
UP/S	24/01/2014											
DD	10/10/2012		178.9	4.1							0.08	
DD	13/11/2012		15	< 1	9.5	1.04	0.3	0.6	0.01	0.13	0.06	135
DD	06/12/2012		63	< 1	17	0.598	0.09	0.4	0.02	0.09	0.08	52
DD	10/01/2013		172	< 1	< 10	1.63	0.06	0.2	0.01	1.36	0.23	197
DD	28/02/2013		35.5	< 1	27.5	1.8	0.03	0.6	0.01	1.16	0.02	186
DD	26/03/2013		727	< 1	17.4		0.01	0.7	0.05		0.02	233
DD	23/04/2013		1046.2	< 1	14.6	6.6	0.33	1.1	0.04	5.13	0.56	298
DD	21/05/2013											
DD	27/06/2013											
DD	26/07/2013											
DD	20/08/2013											

DD	24/09/2013										
DD	04/10/2013										
DD	12/11/2013										
DD	28/11/2013										
DD	12/12/2013										
DD	10/01/2014										
DD	24/01/2014										
LP	10/10/2012	547.5	< 1							0.09	
LP	13/11/2012	42	< 1	20.3	1.9	0.06	1.1	0.02	0.72	0.58	31
LP	06/12/2012	74	< 1	14	1.23	0.1	0.3	0.01	0.82	0.06	162
LP	10/01/2013	23.5	1	< 10	1.62	0.38	1	0.02	0.22	0.03	91
LP	28/02/2013	1	< 1	19.9	1.7	0.01	0.6	0.01	1.08	0.02	24
LP	26/03/2013	165	< 1	26.1		0.03	0.7	0.03		0.01	46
LP	23/04/2013										
LP	21/05/2013										
LP	27/06/2013										
LP	26/07/2013										
LP	20/08/2013										
LP	24/09/2013										
LP	04/10/2013										
LP	12/11/2013										
LP	28/11/2013										
LP	12/12/2013										
LP	10/01/2014										
LP	24/01/2014										
D 1	10/10/2012	8704	20							1.82	
D 1	13/11/2012	280	10	44.1	2.2	0.15	0.8	0.01	1.24	0.09	6
D 1	06/12/2012	461.1	4.1	< 10	1.52	0.24	0.2	0.02	1.06	0.24	8
D 1	10/01/2013	71.7	< 1	< 10	1.55	0.05	< 1	0.02	0.48	0	20
D 1	28/02/2013	13.5	< 1	17.8	1.6	0.06	1.5	0.02	0.02	0.01	9

D 1	26/03/2013										
D 1	23/04/2013										
D 1	21/05/2013										
D 1	27/06/2013										
D 1	26/07/2013										
D 1	20/08/2013										
D 1	24/09/2013										
D 1	04/10/2013										
D 1	12/11/2013										
D 1	28/11/2013										
D 1	12/12/2013										
D 1	10/01/2014										
D 1	24/01/2014										
D 2	10/10/2012	4448	17.3							0.85	
D 2	13/11/2012	1724	< 1	44.2	2.76	0.58	0.7	0.01	1.47	0.93	9
D 2	06/12/2012	866.4	17.4	< 10	5.63	0.17	0.5	0.03	4.93	0.31	6
D 2	10/01/2013	172	2	< 10	1.31	0.23	< 1	0.03	0.05	0.24	12
D 2	28/02/2013	290.9	14.6	19.4	0.9	0.01	0.2	0.00	0.69	0.00	6
D 2	26/03/2013										
D 2	23/04/2013										
D 2	21/05/2013										
D 2	27/06/2013										
D 2	26/07/2013										
D 2	20/08/2013										
D 2	24/09/2013										
D 2	04/10/2013										
D 2	12/11/2013										
D 2	28/11/2013										
D 2	12/12/2013										
D 2	10/01/2014										
D 2	24/01/2014										

APPENDIX F

Overloading Trials of Alternative Infiltrative Systems

Under normal operating conditions the household effluent at each site was split evenly between the LPP and DD systems which had been installed in parallel. In order to assess the impact of an increase in effluent application overloading trials were carried out. This was achieved by diverting the total volume of household effluent, first to the LPP system for a period of four weeks, then to the DD system for four weeks. During this period the applied load exceeded the design load and therefore the system was deemed to be hydraulically "overloaded". The first overloading trial took place in at Site A in the summer months when evapotranspiration rates were at their highest. Two further overloading trials were then carried (one at Site A and one at Site B) out during the winter months when evapotranspiration rates were at their lowest. Results for each trial are detailed below.

1.1 SITE A - KILKENNY

During the course of the study at Site A, two overloading trials were carried out on each of the installed alternative infiltrative systems. As both systems, the DD and LPP, were installed in parallel at the site, they had been designed based on 50% of the anticipated household effluent load. Previous research projects carried out in Ireland have shown the average effluent production of a rural dwelling to be 110 litres per person per day (O'Luanaigh, 2009). As the recommended design loading outlined in the EPA Code of Practice (EPA, 2009) is much greater than this (150 litres per person per day) an intermediate design value of 120 litres per person per day was assumed. With a PE of 3 each distribution system was therefore designed to treat 180 litres per day. In order to analyse the response of each system to an increase in effluent application, the entire household effluent loading was applied to each individual system for a period of four weeks, i.e. twice the design effluent loading.

These overloading trials were carried out in order to examine the response of the low permeability soils beneath the LPP and DD systems during periods of higher volumes of effluent application. The systems were installed at two sites with T-values of 75 and 73 however it is hoped that they will also be appropriate forms of effluent discharge in soils with higher T-values (>90). The data collected was used to determine the impact on soil moisture levels and recovery times under the higher hydraulic loading rates as well as to determine any potential increase in pollutant migration within the STU as a result of increased soil moisture levels.

The first of these overloading trials commenced on the 19th of July 2013 all of the STE effluent load was diverted to the LPP system for a period of four weeks. Results of the soil moisture response and pollution attenuation during this period are outlined below.

Table 7.44 shows the average effluent loading applied to the LPP system during normal operation in comparison to the average effluent production recorded during the four week overloading trial of the system. Results from the monitoring of the household effluent production showed that the overall effluent production during this trial was approximately 70 L lower than the average daily usage across the overall monitoring period, however the effluent application still exceeded the design loading of 3 mm d^{-1}.

Table 1.1 Increase in loading rate to LPP during overloading trial

Effluent loading regime	LPP (L day^{-1})	LPP (mm day^{-1})
Normal operation	191	3.01
Overloading trial	312	4.92

Figure 7.53 shows the soil moisture levels recorded during the LPP overloading trial. Unfortunately the soil moisture probe and data logger had been recording beneath the DD system prior to the overloading trial. In hindsight a record of the soil moisture levels beneath the LPP preceding the overloading trial would have been useful in ascertaining if the was any step up in soil moisture following the increase in effluent application. From the data available the increase in effluent loading applied to the LPP system appears to have little influence on the soil moisture levels. Table 7.45 shows the mean soil moisture point readings taken from beneath the LPP on the two sampling dates prior to the overloading trial (24/6/2013 and 19/7/13). As illustrated by Figure 7.54, the first increase in soil moisture levels beneath the LPP was as a result of heavy rainfall on the 31/7/2013 again confirming the initial analysis that the degree of subsoil saturation in low permeability conditions is highly influenced by rainfall recharge.

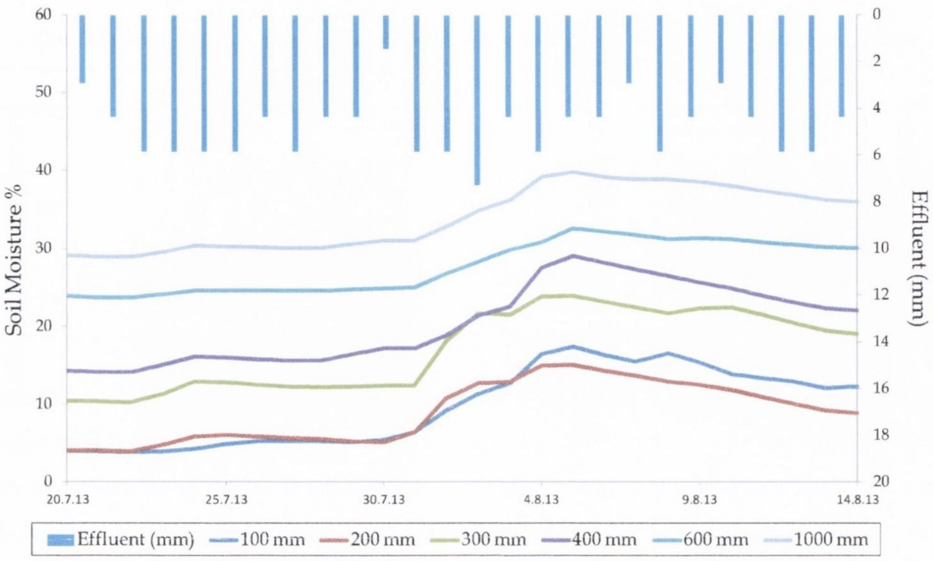


Figure 1.1 Soil moisture response to increase in effluent application

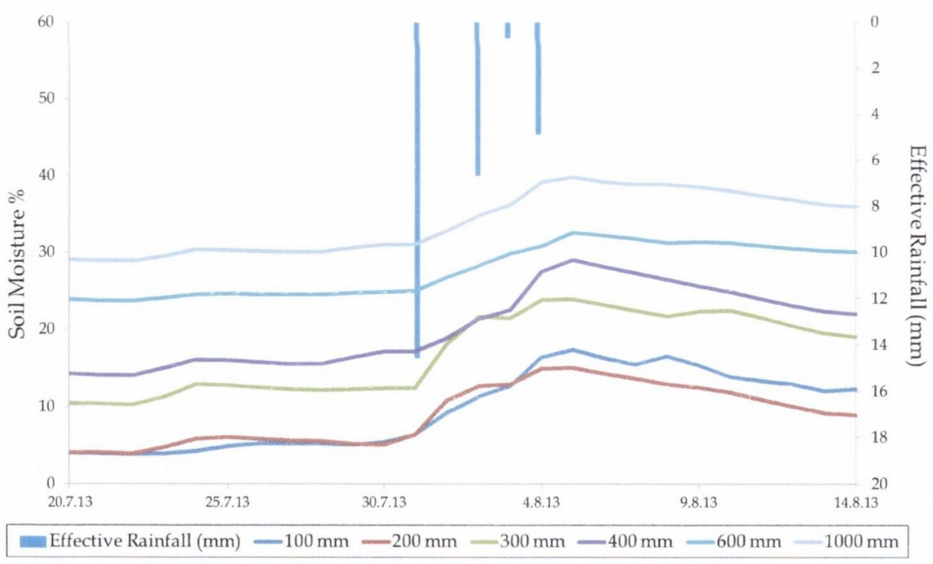


Figure 1.2 Soil moisture response to effective rainfall

Table 1.1 Mean point soil moisture reading beneath LPP on the 24/6/2013 and 19/7/2013

Depth (mm)	Soil Moisture %
100	5.9
200	5.4
300	11.5
400	15.0
600	25.6
1000	26.8

Continuous soil moisture tension data from beneath the LPP system was recorded both before and during the overloading trial. Contrary to what was expected, the soil moisture tension at the 1100 mm depth plane began to increase gradually from the start of July and continued to do so despite the increase in effluent loading from the 19/7/2013 onwards (Figure 7.55). The tensiometer data correlates with the dip in soil moisture data showing a decrease in tension following the high rainfall event on 31/7/2013 (Figure 7.56). As the first overloading trial at Site A took place between July and August a soil moisture deficit existed beneath the LPP allowing the low permeability subsoil to cope with the increased effluent application.

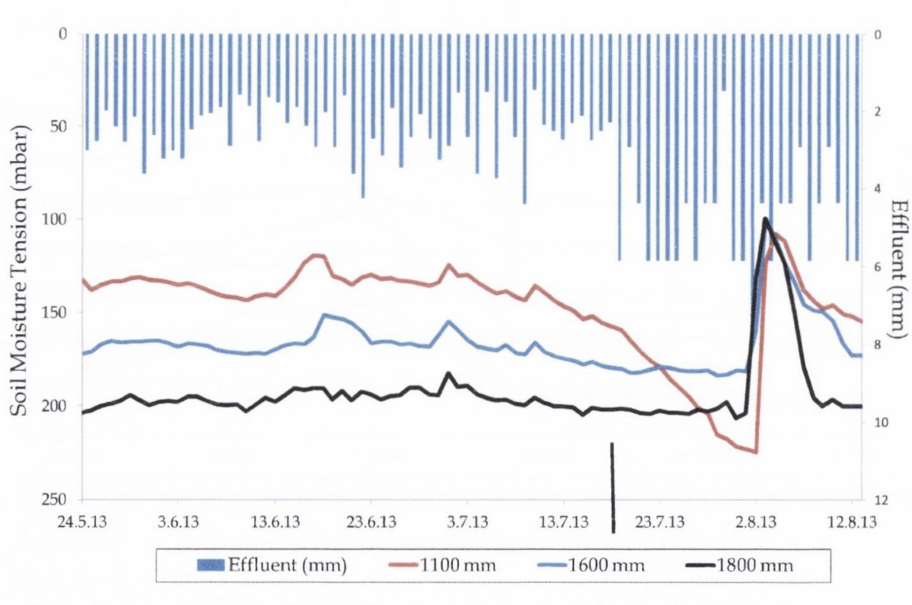


Figure 1.3 Soil moisture tension in response to effluent

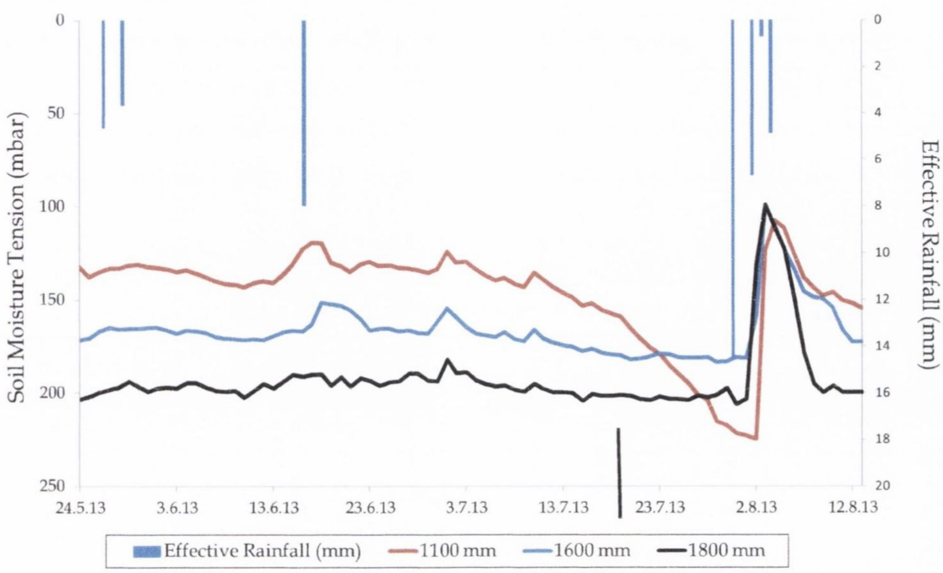


Figure 1.4 Soil moisture tension in response to effective rainfall

The assessment of the treatment performance of the LPP under an increased effluent loading was analysed through the collection of soil moisture samples two week and four weeks after the effluent overloading commenced. Due to the extremely dry conditions at the site during the trial groundwater levels dropped below the base of the boreholes and so upstream/downstream groundwater samples could not be obtained. The conditions also had an adverse impact of the number and volume of samples retrieved (Table 7.46).

Table 1.2 Soil moisture sample retrieval during first LPP overloading trial at Site A

	Potential No. of Samples	No. of Samples Retrieved	Mean Cl Conc. (mg L^{-1})
STE	2	2	238
0.75	12	5	71.4
1.05	12	3	83.7
1.35	12	2	74.0

As with the general sampling of the STU performance, the soil moisture samples that were retrieved were analysed for Cl, COD, TN, NH_4-N, NO_2-N, NO_3-N, PO_4-P as well as Total Coliform and *E. coli*. Results of the Cl analysis show a mean increase at the blue depth (Table 7.46). This was believed to be as a result of the increased influence of preferential pathways within the unsaturated subsoil during the second sampling run (15/8/2013) during which time only a single sample was retrieved from the blue depth plane (LP 1.2 Blue) and no samples were retrieved from the black depth plane.

This was confirmed by the analysis of COD concentrations with greater removal at the red and black depth planes in comparison with the blue plane (Table 7.47). On the whole the mean load remaining at the black depth plane was lower for the trial (3.8 g d^{-1}) than that of the overall system performance (7.2 g d^{-1}) despite the increase in effluent application (although as mentioned above the trial was carried out during a period of very low effective rainfall and the two figures cannot be compared rigorously).

Table 1.3 Reduction in COD load with respect to the STE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt STE influent) (%)
STE	315	72	-	-
0.75	38.6	9.1	62.9	87.3%
1.05	55.0	13.0	59.0	82.0%
1.35	16.0	3.8	68.2	94.7%

The preferential movement of effluent at the L1.2 blue sample location was confirmed by the elevated NH_4-N (40 mg L^{-1}) concentration recorded at this sample location on the 15/8/2013, significantly higher than the average blue depth concentration of 2.6 mg L^{-1} recorded on the previous sampling trip. Table 7.48 presents the overall breakdown of inorganic-N removal with depth over the overloading trial. As with the Cl and COD, an increase in effluent migration was apparent at the *blue* depth plane with a mean load of 4.8 g d^{-1} NH_4-N (Table 7.48) in comparison with just 0.15 g d^{-1} NH_4-N at the same depth for the overall system performance (Table 7.50).

Table 1.4 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
STE	116	36.2	0.22	0.07	1.55	0.5	117.8	36.7
0.75	0.8	0.3	0.10	0.03	15.6	5.0	16.5	5.3
1.05	15.0	4.8	0.76	0.24	25.3	8.1	41.1	13.1
1.35	0.10	0.0	0.03	0.01	29.5	9.4	29.6	9.5

Table 1.5 Average fractionation of total inorganic-N in STE remaining at the three depth planes

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	98.5%	0.19%	1.3%
0.75	5.1%	0.62%	94.3%
1.05	36.6%	1.86%	61.6%
1.35	0.3%	0.08%	99.6%

Table 7.51 presents the overall breakdown in total inorganic-N recorded during the overloading trial with LP1.2 blue excluded which results in a mean load of 0.8 g d^{-1} NH_4-N (only marginally higher than the 0.15 g d^{-1} recorded over the entire sampling period of the LPP at Site A). Table 7.51 shows that despite the increase in the NH_4-N loading the removal of inorganic-N was still high with an overall reduction of 74 % by the black depth with 99.6% of the remaining fraction in nitrified form.

Table 1.6 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the three depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
STE	116	36.2	0.22	0.07	1.55	0.5	117.8	36.7
0.75	0.8	0.3	0.10	0.03	15.6	5.0	16.5	5.3
1.05	2.6	0.8	0.27	0.08	16.7	5.3	19.5	6.2
1.35	0.10	0.0	0.03	0.01	29.5	9.4	29.6	9.5

Table 1.7 Average fractionation of total inorganic-N in STE remaining at the three depth planes

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	98.5%	0.19%	1.3%
0.75	5.1%	0.62%	94.3%
1.05	13.2%	1.36%	85.5%
1.35	0.3%	0.08%	99.6%

Equally, the increase in STE effluent application did not have a detrimental impact of PO_4-P removal at Site A with the unsaturated subsoil maintaining a continually high removal rate of 99.7% by the *black* depth plane (Table 7.52).

Table 1.8 Reduction in PO_4-P at each depth plane at Site A

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt STE influent) (%)
STE	19.3	6.0	-	-
0.75	0.5	0.2	5.8	97.1%
1.05	0.8	0.3	5.7	95.7%
1.35	0.1	0.02	6.0	99.7%

In contrary to the chemical analysis, results of the Total Coliform analysis resulted in the greatest reduction in TC being recorded at the *blue* depth planes (Table 7.53). Closer inspection of the results showed insufficient soil moisture sample volumes at the black depth during the second sampling run resulted in no TC results at this depth on the 15/8/2013 which influenced the overall log-unit removal.

Table 1.9 Reduction in total coliform concentrations with respect to STE at the three depth planes

	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
STE	7.94E+5 - 1.38E+9	9.08E+06	-
0.75	$1.0 \times 10^2 - 4.8 \times 10^4$	2.53E+03	3.6
1.05	$1.5 \times 10^2 - 4.8 \times 10^2$	1.44E+02	4.8
1.35	$8.2 \times 10^1 - 2.1 \times 10^3$	4.14E+02	4.3

The detection of *E. coli* at a contention of 10 MPN 100 mL^{-1} at the blue depth plane (LP3.1) on the 30/7/2013 shows that despite the unsaturated conditions, the migration of enteric bacteria is still possible (Table 7.54). No *E. coli* was detected at the L1.2 blue depth plane despite the evidence of preferential flow.

Table 1.10 Concentrations of *E. coli* across the three depth planes

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	5	5	0	0	0
1.05	3	2	1	0	0
1.35	2	2	0	0	0

Overall, the increase in soil moisture levels between the two sampling dates at Site A (as a result of rainfall recharge) had a limited impact on the treatment performance of the STU. The presence of preferential flow paths appears to be amplified by the increase in effluent application, however overall treatment performance remained high.

Following the completion of the overloading trial of the LPP system the effluent loading was diverted solely to the DD system for a further four weeks on the 15th of August 2013. The results from this period are presented below. The increase in effluent loading to the system in comparison with the normal operation at Site A is shown in Table 7.55. As the tipping bucket was not operational during the overloading trials (fixed in place to divert effluent to designated pump sump) the effluent production of the household to the DD could not be determined and so it has been assumed to be equal to the average total production of the previous four weeks of operation (312 L day^{-1}).

Table 1.11 Increase in effluent loading rate to DD during first overloading trial

Effluent loading regime	DD (L day^{-1})	DD (mm day^{-1})
Normal operation	191	3.01
Overloading trial	312	4.73

Again, due to the timing of the trial in summer, zero effective rainfall was calculated for the site (Figure 7.57). As a result any variation in soil moisture should have been directly attributed to the application of effluent. As outlined above both the continuous soil moisture and tensiometer reading were taken beneath the LPP system in the weeks preceding the DD overloading trial. Again, in hindsight, a record of the soil moisture fluctuations prior to the trial would have been useful in determining the impact of increased effluent application. In the absence of such data the point soil moisture readings were again consulted to determine if an increase is soil moisture occurred as a result of the increased effluent loading. As effluent had been diverted away from the DD for four weeks the readings from the 24/6/2013 and 19/7/2013 were used to give a more accurate estimate of soil moisture during normal operating conditions (Table 7.56).

Table 1.12 Mean point soil moisture reading beneath DD on the 24/6/2013 and 19/7/2013

Depth (mm)	Soil Moisture %
100	16.6
200	23.1
300	24.5
400	24.9
600	27.1
1000	27.7

Figure 7.57 shows a gradual decrease in the soil moisture levels at the 100 mm depth which is thought to occur as a result of evapotranspiration in the absence of effective rainfall. The initial increase may be the residual effect of the high rainfall which fell on the 15/8/2013. Although calculations showed a zero effective rainfall at the site for this day, it may still influence the soil moisture at the 100 mm depth. The application of effluent results in a muted response in soil moisture levels at the upper subsoil horizons (100 to 400 mm depth). The lower depths show little fluctuation in comparison, presumably as a result of the extension of the effluent plume over a wider area by the time it reaches the 600 mm depth. The increase in soil moisture levels as a result of the applied effluent are small (< 5%) in comparison with the responses previously recorded following rainfall recharge (Figure 7.32 showed spikes of > 15 % soil moisture following rainfall events).

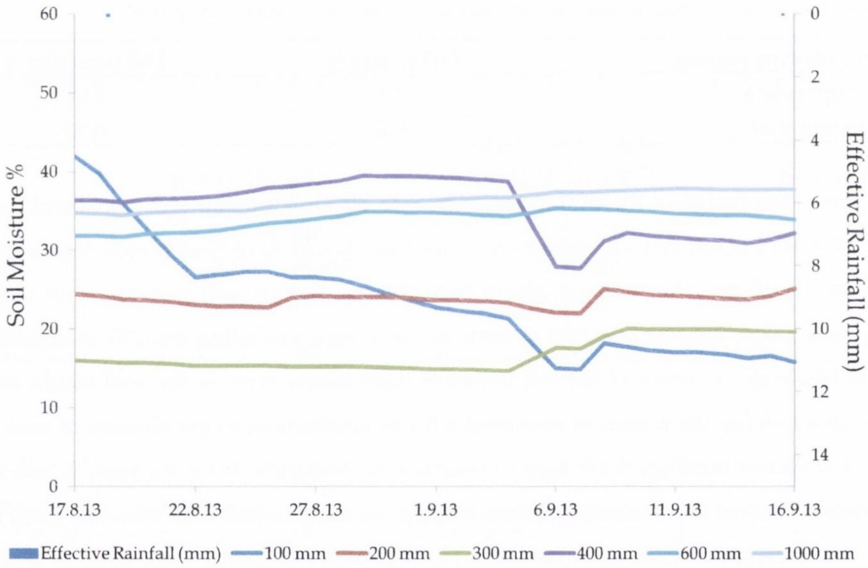


Figure 1.5 Soil moisture variation recorded during period of zero effective rainfall at Site A

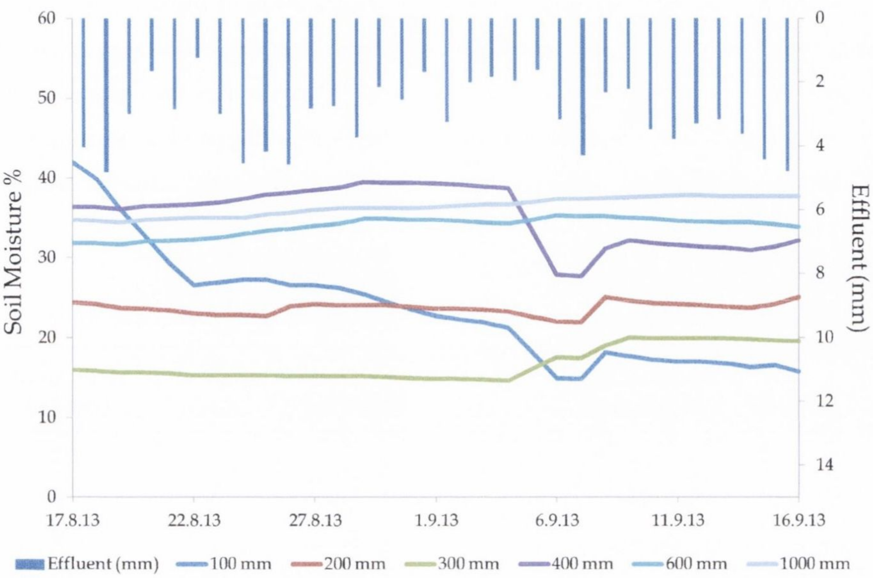


Figure 1.6 Soil moisture variation in response to effluent loading at Site A

Soil moisture tension readings from the same period (Figure 5.79) show a response to effluent application at the upper (*red* depth) with little response apparent at the lower depth planes as the effluent dispersal increases as it percolates through the subsoil.

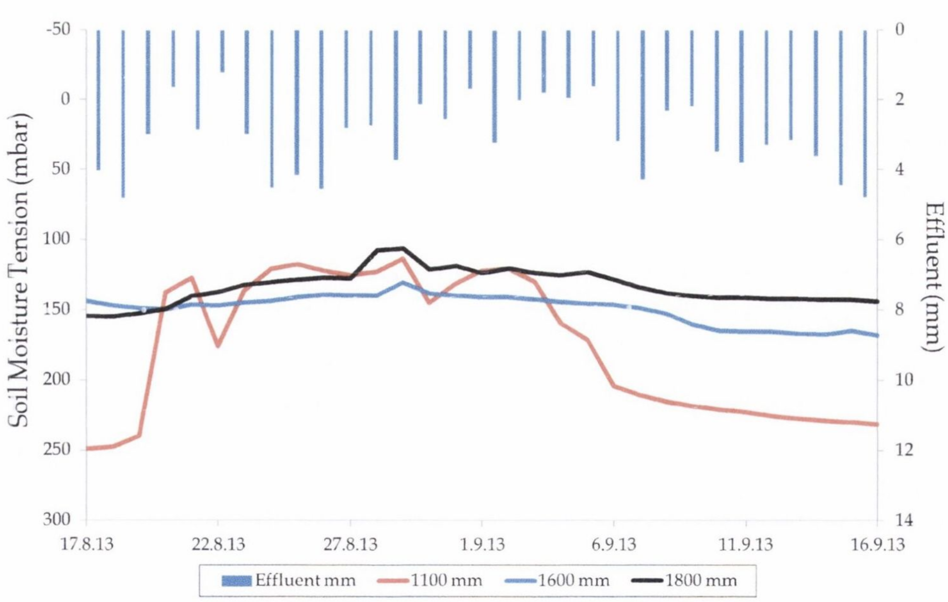


Figure 1.7 Soil moisture tension response beneath DD system at Site A

As with the LPP monitoring, obtaining sufficient soil moisture samples for analysis was again an issue owing to the reduction in soil moisture levels. The extent of the issue was apparent during the first sampling run (5/9/2013 - 6/9/2013) during which the retrieved sample volumes (4 samples of < 5 mL) were so insufficient that no chemical or bacteriological results could be reported. The second sampling run on the 20/9/13 was more successful, with the overall number of samples presented in Table 7.57.

Table 1.13 Soil moisture sample retrieval during first DD overloading trial at Site A

	Potential No. of Samples	**No. of Samples Retrieved**	**Mean Conc. (mg L^{-1})**
STE	2	2	152
0.15	8	3	79
1.00	12	1	5.0
1.30	12	3	14.7
1.60	12	3	24.7

The lack of samples resulted in difficulties in determining the overall treatment beneath the DD for this trial. As shown in Table 7.57, only a single sample was obtained from the *red* depth plane. As such, the mean Cl concentration (5 mg L^{-1}) for that depth plane is unlikely to accurately represent the overall system performance. With this in mind, the results of the chemical and bacteriological analysis are presented below.

The reductions in COD concentrations at each of the depth planes are presented in Table 7.58. Interestingly, the higher hydraulic resulted in only a 16.1% reduction in COD loads at the green depth plane with respect to the applied STE. As outlined above, the large reduction in COD at the red depth plane was not deemed representative across the DD system; of more interest are the reductions by the *blue* and *black* planes which are more in line with the overall system performance but, as with the *green* plane, do indicate a marginal increase in COD concentration with depth as a result of increased effluent application.

As reported in Section 7.4.2 mean loads of 5.4 g d^{-1} and 4.0 g d^{-1} were recorded for the *blue* and *black* planes respectively over the course of the overall study. Table 7.58 shows this rose to 10.6 g d^{-1} and 5.9 g d^{-1} during the overloading trial.

Table 1.14 Reduction in COD concentrations at each depth plane in relation to STE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt STE influent) (%)
STE	170	53.0	-	-
0.15	143	44.5	8.5	16.1%
1.00	9.0	2.8	50.2	94.7%
1.30	34.0	10.6	42.4	80.0%
1.60	19.0	5.9	47.1	88.8%

Excluding the *red* depth plane, results from the overloading study show the reduction in inorganic-N with depth (Table 7.59). As with the overall results for the DD system under normal loading conditions, the reduction in inorganic-N is believed to be as a result of nitrification followed by denitrification. Interestingly, despite a reduction in mean load of inorganic-N applied to the system there is a greater proportion remaining at each depth plane. As removal via denitrification is dependent on the occurrence of anaerobic conditions (at least intermittently) it is believed the drop off in performance during the trial results from a decrease in soil moisture levels at that time of year due to the dry conditions thus reducing the potential for denitrification. Table 7.60 shows the remaining fraction of inorganic-N is in the form of nitrate.

Table 1.15 Mean concentration and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the STE and across the four depth planes

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
STE	111	34.6	0.01	0.00	0.7	0.2	111.7	34.9
0.15	1.1	0.3	0.00	0.00	14.7	4.6	15.8	4.9
1.00	0.0	0.0	0.01	0.00	9.5	3.0	9.5	3.0
1.30	1.9	0.6	0.00	0.00	11.7	3.6	13.6	4.2
1.60	0.45	0.1	0.03	0.01	10.9	3.4	11.4	3.5

Table 1.16 Fractionation of total inorganic-N in STE and across the four depth planes

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
STE	99.4%	0.01%	0.6%
0.15	6.8%	0.00%	93.2%
1.00	0.0%	0.11%	99.9%
1.30	14.0%	0.00%	86.0%
1.60	4.0%	0.23%	95.8%

Results of the PO_4-P analysis also reveal a marginal increase in the recorded concentrations with depth particular in relation to the *green* depth plane (Table 7.61) although this would not be considered cause for concern as it still represents excellent attenuation within the receiving subsoil.

Table 1.17 Reduction in PO_4-P concentrations at each depth plane with respect of STE

	Mean Conc. (mg L^{-1})	**Mean Load (g d^{-1})**	**Cumulative Load Removal (g d^{-1})**	**Net Load removal (wrt STE influent) (%)**
STE	20.6	6.4	-	-
0.15	2.15	0.67	5.76	89.6%
1.00	0.20	0.06	6.36	99.0%
1.30	0.18	0.06	6.37	99.1%
1.60	0.28	0.09	6.34	98.6%

Due to the small sample volumes retrieved from the *green* depth plane bacteriological analysis was not possible. Results from the samples retrieved from the remaining planes are presented below in Table 7.62 which shows that the recorded TC concentrations were lower than those reported for the overall system performance indicating the increase in effluent application did not appear have an adverse impact on bacterial migration.

Table 1.18 Reduction in total coliform concentrations with respect to STE at the three depth planes

	Range (MPN 100 mL^{-1})	**Geometric Mean (MPN 100 mL^{-1})**	**Log-unit Removal**
STE	7.94E+5 - 1.38E+9	9.08E+06	-
1.00	3.95×10^2	3.95E+02	4.4
1.30	$4.4 \times 10^2 - 7.95 \times 10^2$	5.89E+02	4.2
1.60	$3.6 \times 10^2 - 4.6 \times 10^2$	4.02E+02	4.4

This was also reflected in the results presented in Table 7.63. The presence of *E. coli* was not detected at the *red, blue* or *black* planes. However, it should be noted that dilutions of the samples were carried out in order to compensate for the lack of sample volume, increasing the minimal detection limit.

Table 1.19 Concentrations of *E. coli* recorded at the three depth planes

	No. of Samples	**No. of samples with Concentration (MPN 100 mL^{-1})**			
		< 10	**10 - 100**	**100 - 1000**	**> 1000**
1.00	1	1	0	0	0
1.30	3	3	0	0	0
1.60	2	2	0	0	0

On the 1st of October 2013 there was a changeover in the type of effluent applied at Site A. Following a year of operation on STE the system was switched to SE by redirecting the raw household effluent to the previously installed ASP unit instead of the septic tank (see Section 4.2.1). Due to the lack of sample volume retrieved during the summer overloading trial, a second trial commenced on the 19th of November 2013, this time with the entire effluent loading of SE being applied to the DD system. Results from this second overloading trial are presented below.

Figure 7.60 shows an initial increase in soil moisture levels at the start of the overloading period at the higher depth planes which is sustained over the course of the trial. In the absence of effective rainfall this in assumed to be as a result of the increased effluent load. As with the first DD trial, effluent loads had to be estimated based on loadings recorded during subsequent LPP overloading trial. Fluctuation in soil moisture levels beneath the system towards the end of the trial as a result of rainfall recharge are again apartment. This is also evident from the soil moisture tension reported in Figure 7.60. As the results indicate the subsoil remained unsaturated during the course of the trial the main interest in the results of the study is the system's performance in relation to chemical and bacteriological analysis. Mean point soil moisture reading from beneath the system prior to the commencement of the trial are reported in Table 7.64.

Table 1.20 Mean point soil moisture reading beneath DD on the 18/11/2013

Depth (mm)	Soil Moisture %
100	31.4
200	34.0
300	32.5
400	39.3
600	30.2
1000	35.5

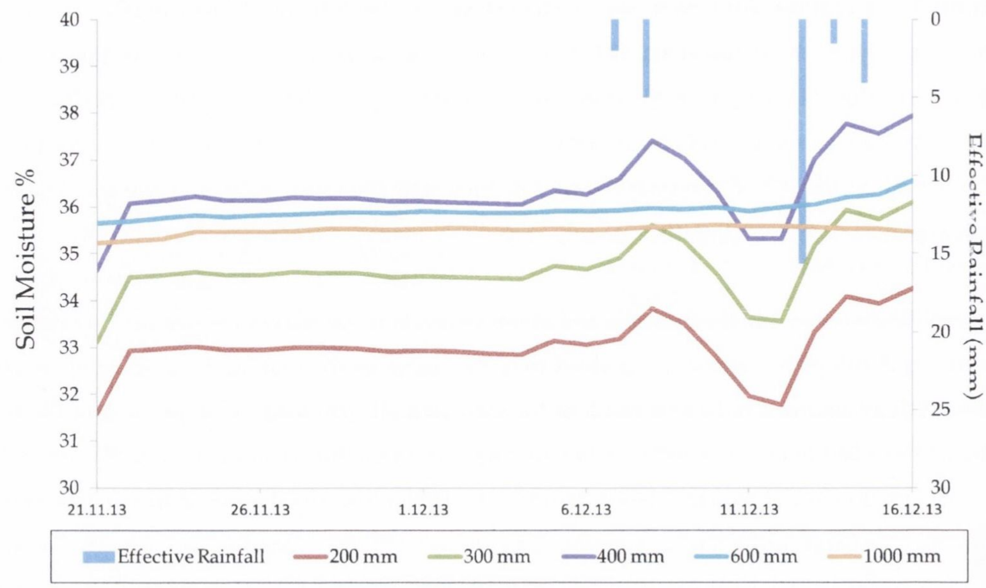


Figure 1.8 Soil moisture response to effective rainfall at Site A

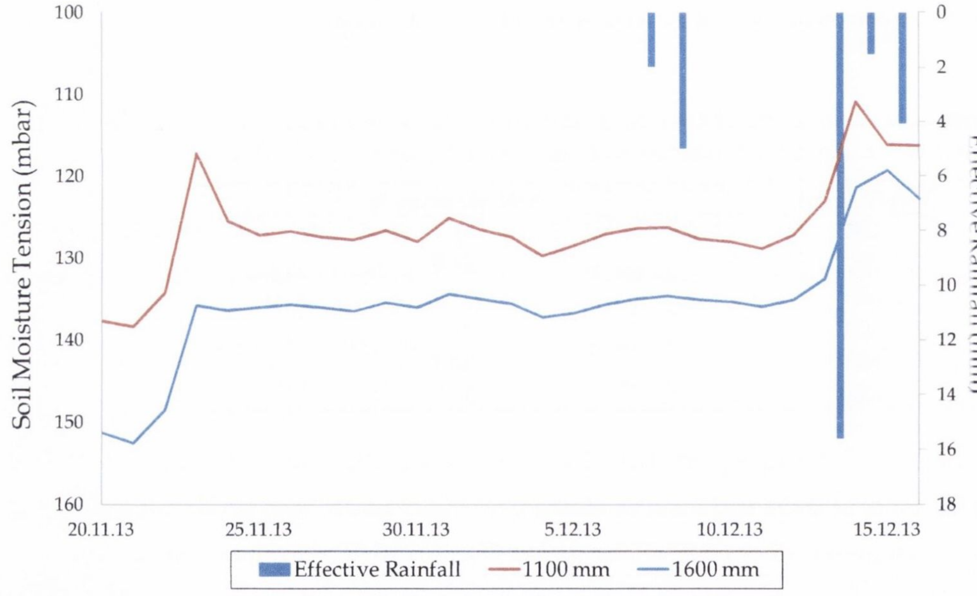


Figure 1.9 Soil moisture tension response to effective rainfall

The increase in effective rainfall during the second overloading trial of the DD system at Ste A meant an increase in soil moisture samples was recorded allowing a more rigorous assessment of the system performance (Table 7.65)

Table 1.21 Soil moisture sample retrieval during second DD overloading trial at Site A

	Potential No. of Samples	No. of Samples Retrieved	Mean Conc. (mg L^{-1})
SE	2	2	84
0.15	8	8	40
1.00	12	11	52.3
1.30	12	12	34.2
1.60	12	12	22.9

A reduction in COD concentration with depth can be seen between the *red* and *black* depth planes.. Despite the reduction in COD applied to the system as a result of the changeover to SE, each of the depth planes recorded an increase in mean load compared with STE application (Table 7.66).

Table 1.22 Reduction in COD concentrations at each depth plane with respect to SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	69	21.5	-	-
0.15	64	20.1	1.5	6.8%
1.00	38.2	11.9	9.6	44.6%
1.30	26.0	8.1	13.4	62.3%
1.60	13.8	4.3	17.2	80.0%

A similar outcome was also recorded in terms of the nitrogen removal beneath the DD system receiving SE. Despite the reduction in the mean inorganic-N loading, the highly nitrified SE (Table 7.68) percolated through the subsoil with the reduction in depth most likely due to increasing dilution. The absence of a significant biodegradable organic concentration in the SE prevents the loss of inorganic-N through denitrification which had been reported during the application of STE (Table 7.67). Alternatively, the absence of significant ammonia concentrations in the SE (and corresponding reduction in total N removal) might be an indication that the Anammox process was the dominant form of N-removal during the previous STE application period of operation.

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Table 1.23 Reduction in inorganic-N at each depth plane

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
SE	1.8	0.6	0.05	0.02	110.8	34.6	112.6	35.1
0.15	0.1	0.0	0.02	0.00	28.0	8.7	28.0	8.7
1.00	0.7	0.2	0.03	0.01	31.6	9.9	32.3	10.1
1.30	0.0	0.0	0.02	0.01	23.3	7.3	23.3	7.3
1.60	0.02	0.0	0.03	0.01	18.1	5.7	18.2	5.7

Table 1.24 Fractionation of the remaining fractions of inorganic-N at each depth plane

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
SE	1.6%	0.04%	98.4%
0.15	0.3%	0.06%	99.7%
1.00	2.2%	0.09%	97.8%
1.30	0.1%	0.07%	99.8%
1.60	0.1%	0.14%	99.8%

PO_4-P concentrations recorded during the overloading of the DD with SE (Table 7.69) showed similar results to those reported with respect to STE (Table 7.38). As with the previous results the greatest proportion of PO_4-P removal occurred above the *green* plane (96.4%) and is believed to be as a result of the high percentage of fine particles in combination with mineral precipitation.

Table 1.25 Reduction in PO_4-P concentration at each depth plane

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	16.1	5.0	-	-
0.15	0.57	0.18	4.83	96.4%
1.00	0.46	0.14	4.86	97.1%
1.30	0.29	0.09	4.92	98.2%
1.60	0.21	0.07	4.94	98.7%

One important result of the changeover from STE to SE effluent at Site A was the increase in TC levels recorded at depth (Table 7.70). Despite a decrease in TC in the applied SE, results showed the geometric mean concentrations recorded at each of the depth planes was higher than when STE was applied. However, as effluent was being loaded at twice the normal rate this increase may be attributed to the increased hydraulic loading rate. In spite of this increase in TC migration the presence of *E. coli* was not detected at any of the depth planes during the application of SE (Table 7.71) which is of significant importance in the ability of the system to prevent against the migration of enteric bacteria to groundwater/surface water sources.

Table 1.26 TC concentration recorded at each depth plane

	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
SE	3.9×10^5 - 6.5×10^7	3.93E+06	-
0.15	1.5×10^4 - 1.2×10^5	4.62E+04	1.9
1.00	2.5×10^2 - 4.8×10^4	4.28E+03	3.0
1.30	2.6×10^2 - 1.7×10^4	1.83E+03	3.3
1.60	2.0×10^2 - 2.4×10^4	1.35E+03	3.5

Table 1.27 *E. coli* concentrations recorded at each depth plane

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.15	8	8	0	0	0
1.00	12	12	0	0	0
1.30	12	12	0	0	0
1.60	12	12	0	0	0

Finally, on the 17th of December 2013, effluent was diverted to the LPP system for the final four weeks. As indicated from the soil moisture potential readings (Figure 7.65), the soil beneath the LPP system (and DD) reached saturation during the winter of 2013/2014. An exceptional increase in rainfall as well as rising groundwater levels from December through to February were a contributory factor. Rainfall was above average across the entire country with Cork Airport (South of Site A) recording its wettest since 1989 (Met Éireann, 2013). Above average rainfall continued into January 2014 with Oakpark (40 km East of Site A) recording it's wettest January since 2007 and almost double its average rainfall (Met Éireann, 2014).

As shown in Figure 7.65, the groundwater levels in the region reached their highest levels since January 2010 (prior to the commencement of the project). During site visits in January 2014, standing water was observed above both systems. Groundwater levels within the boreholes across the sites were recorded at 300 mm below ground level. As a result, the impact off the increased effluent loading on soil moisture levels was difficult to quantify under such conditions.

Figure 7.63 shows the increase in soil moisture levels beneath the LPP system from December 2013 to January 2014. The results show the saturation of the subsoil at all depth planes with further increases at the 300 mm and 400 mm depths during heavy rainfall. This extreme rise in soil moisture levels is believed to indicate the flooding of the LPP coarse gravel trenches. This is supported by the observation of standing water above each of the trenches in January 2014 (Figure 7.62).

As illustrated in Figure 7.64 the impact of effluent application on soil moisture levels was negligible meaning the results offered little insight into the movement of effluent within the subsoil. Despite this the chemical and bacteriological results presented below allow the assessment of contaminant migration beneath under saturated conditions, i.e. worst case scenario conditions.

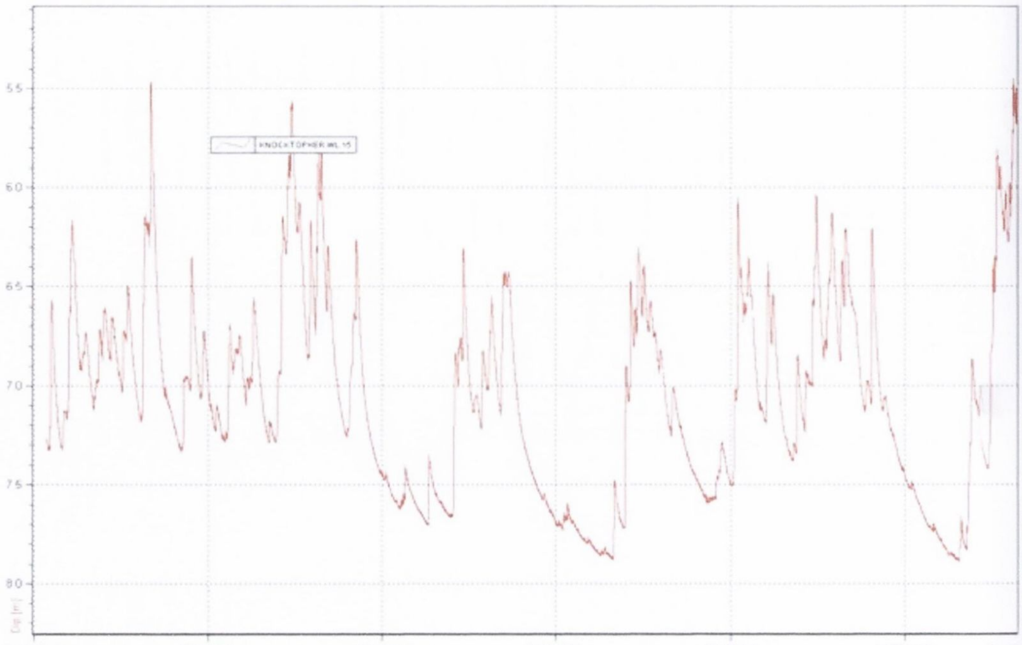

Figure 1.14 Groundwater levels in the Kilkenny region between June 2006 and January 2014

The saturated conditions beneath the system resulted in the retrieval of a full set of soil moisture samples from Site A since the beginning of the monitoring phase at the site (Table 7.72). Cl anaysis of the samples showed the significant dilution of effluent with depth as anticipated. The reduction in COD concentrations at each depth plane presents a similar trend (Table 7.73) with a reduction of 77.7% with respect to SE achieved by the red depth plane.

Table 1.28 Soil moisture sample retrieval during second LPP overloading trial at Site A

	Potential No. of Samples	No. of Samples Retrieved	Mean Conc. (mg L^{-1})
SE	2	2	82
0.75	12	12	73
1.05	12	12	52
1.35	12	12	47

Table 1.29 Reduction in COD concentrations at each depth plane with respect to SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	49	18.2	-	-
0.75	10.7	4.1	14.2	77.7%
1.05	7.3	2.8	15.5	84.8%
1.35	7.0	2.7	15.6	85.4%

Despite the saturated conditions a reduction in inorganic-N (in the form of NO_3-N (Table 7.75)) was not observed beneath the *red* depth plane. On the contrary, in spite of the increased dilution, NO_3-N concentrations remained relatively uniform, i.e. passing directly through the subsoil as discussed previously for the DD.

Table 1.30 Reduction in inorganic-N at each depth plane

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**	**Mean Conc. (mg L^{-1})**	**Mean Load (g d^{-1})**
SE	0.25	0.1	0.05	0.02	84.1	31.3	84.4	31.4
0.75	0.0	0.0	0.01	0.00	24.7	9.4	24.7	9.4
1.05	0.0	0.0	0.01	0.00	25.8	9.8	25.8	9.8
1.35	0.00	0.0	0.01	0.00	25.9	9.8	25.9	9.8

Table 1.31 Fractionation of remaining fractions of inorganic-N at each depth plane

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
SE	0.3%	0.06%	99.6%
0.75	0.0%	0.04%	100.0%
1.05	0.1%	0.04%	99.9%
1.35	0.0%	0.04%	100.0%

PO_4-P removal remained consistent despite the increase in soil moisture levels (Table 7.76).

Table 1.32 Reduction in PO_4-P concentrations with respect to SE

	Mean Conc. (mg L^{-1})	**Mean Load (g d^{-1})**	**Cumulative Load Removal (g d^{-1})**	**Net Load removal (wrt SE influent) (%)**
SE	9.5	3.5	-	-
0.75	1.1	0.4	3.1	88.6%
1.05	0.3	0.1	3.4	97.3%
1.35	0.1	0.0	3.5	99.1%

Finally, assessment of TC and *E. coli* concentrations beneath the LPP system are presented in Table 7.77 and Table 7.78. Recorded TC were low given the assumption that increased subsoil saturation should in theory led to faster bacterial migration. The degree of dilution being applied to the

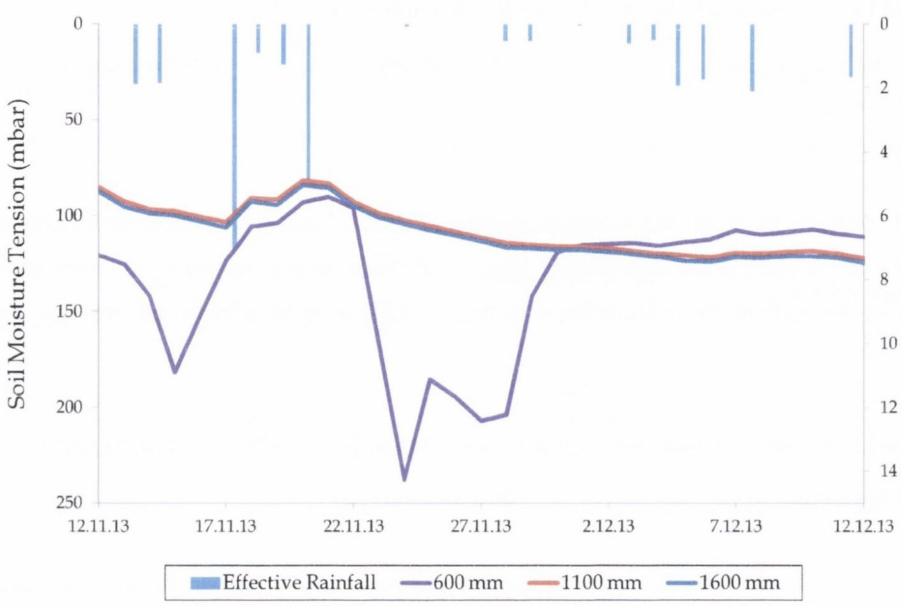

Figure 1.16 Soil moisture tension response to effective rainfall at Site B

Unlike Site A, there were no issue in the retrieval or volume of samples beneath either system a Site B (Table 7.96). A gradual decrease in Cl concentrations with depth showed the influence o effluent dilution as it percolated through the unsaturated subsoil.

Table 1.37 Soil moisture sample retrieval during DD overloading trial at Site B

	Potential No. of Samples	No. of Samples Retrieved	Mean Conc. (mg L^{-1})
SE	2	2	459
0.15	8	8	316
1.00	12	12	255
1.30	12	12	210
1.60	12	12	170

The increase in application of SE to the DD during winter conditions at Site B resulted in a marginal increase in the concentrations of COD recorded at each depth plane (Table 7.97) i relation to the overall system performance. Due to the increase in effective rainfall in conjunctio with very limited evapotranspiration this increase could therefore be attributed to the increased subsoil conductivity due to higher soil moisture levels.

Table 1.38 Reduction in COD concentrations at each depth plane with respect to SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	112	37.3	-	-
0.15	64	21.8	15.4	41.4%
1.00	55	19.1	18.2	48.8%
1.30	37	13.2	24.1	64.7%
1.60	27	9.7	27.5	73.9%

Given that the applied SE to the DD was highly nitrified (Table 7.99) the results in Table 7.98 show a gradual decrease in inorganic-N (NO_3-N) with depth.

Table 1.39 Reduction in inorganic-N concentrations at each depth plane with respect to SE

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
SE	0.95	0.32	0.40	0.13	23.3	7.8	24.7	8.2
0.15	0.11	0.04	0.03	0.01	13.5	4.6	13.7	4.7
1.00	0.05	0.02	0.01	0.00	6.2	2.1	6.2	2.2
1.30	0.01	0.00	0.01	0.00	3.6	1.3	3.6	1.3
1.60	0.01	0.00	0.02	0.01	2.0	0.7	2.0	0.7

Table 1.40 Fractionation of remaining fractions of inorganic-N at each depth plane

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
SE	3.9%	1.62%	94.5%
0.15	0.8%	0.22%	99.0%
1.00	0.8%	0.16%	99.0%
1.30	0.3%	0.28%	99.4%
1.60	0.5%	1.00%	98.5%

Despite the fluctuating soil moisture concentrations following high intensity rainfall events PO_4-P reductions beneath the DD remained high and were consistent with the overall system performance (Table 7.100). As with Site A this removal was accredited to the high percentage clay present in conjunction with a degree of mineral precipitation (Section 7.4.4).

Table 1.41 Reduction in PO_4-P concentrations at each depth plane with respect to SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent (%)
SE	5.3	1.8	-	-
0.15	0.96	0.33	1.43	81.3%
1.00	0.17	0.06	1.70	96.7%
1.30	0.07	0.02	1.74	98.6%
1.60	0.01	0.00	1.76	99.8%

Evidence of increased subsoil conductivity during the winter months as well as the higher hydraulic loading is also apparent from the TC concentrations recorded beneath the DD sysem during the overloading trial at Site B. Table 7.101 shows the geometric mean concentration of each depth plane was slightly elevated in comparison with overall system performance despie a decrease in the applied effluent concentration. As presented in Table 7.102, this increase in TC migration did not correspond with an increase in *E. coli*, with no enteric bacteria detected at any of the depth planes during the course of the trial.

Table 1.42 TC concentrations at each depth plane with respect to SE

	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
SE	$2.8 \times 10^4 - 1.2 \times 10^6$	2.31E+05	-
0.15	$3.7 \times 10^2 - 2.4 \times 10^4$	6.24E+03	1.6
1.00	$2.3 \times 10^2 - 1.7 \times 10^4$	1.54E+03	2.2
1.30	$3.6 \times 10^1 - 2.4 \times 10^3$	6.52E+02	2.5
1.60	$2.1 \times 10^1 - 2.4 \times 10^3$	1.59E+02	3.2

Table 1.43 *E. coli* concentrations at each depth plane

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.15	8	8	0	0	0
1.00	12	12	0	0	0
1.30	12	12	0	0	0
1.60	12	12	0	0	0

Finally, from the 17th of December 2013 to the 24th of January 2014, the site's entire effluent loading was then switched to the LPP system. The results of the overloading trial are outlined below. Subsoil saturation was recorded for the first time beneath the LPP system at Site B during the course of the overloading trial. As with the previously examined systems, the applied effluent loading appeared to have a muted impact on soil moisture, therefore it is believed that the subsoil saturation is primarily as a result of an increase in high intensity rainfall events over the course of the trial.

Table 1.44 Increase in loading rate to LPP during overloading trial

Effluent loading regime	LPP (L day^{-1})	LPP (mm day^{-1})
Normal operation	171	2.3
Overloading trial	401	5.3

Figure 7.75 shows the response in soil moisture levels to effective rainfall and illustrates the intensity and frequency of rainfall events over the course of the overloading trial. Figure 7.76 shows the corresponding decrease in soil moisture tension with saturated conditions being reached at the 1100 mm depth. The persistence of unsaturated conditions at the 1800 mm depth plane indicates that, unlike Site A, the subsoil saturation was not as a result of rising groundwater levels. It also gives an explanation for the reduced number of soil moisture samples retrieved beneath the system at the black depth plane (1800 mm) as presented in Table 7.104.

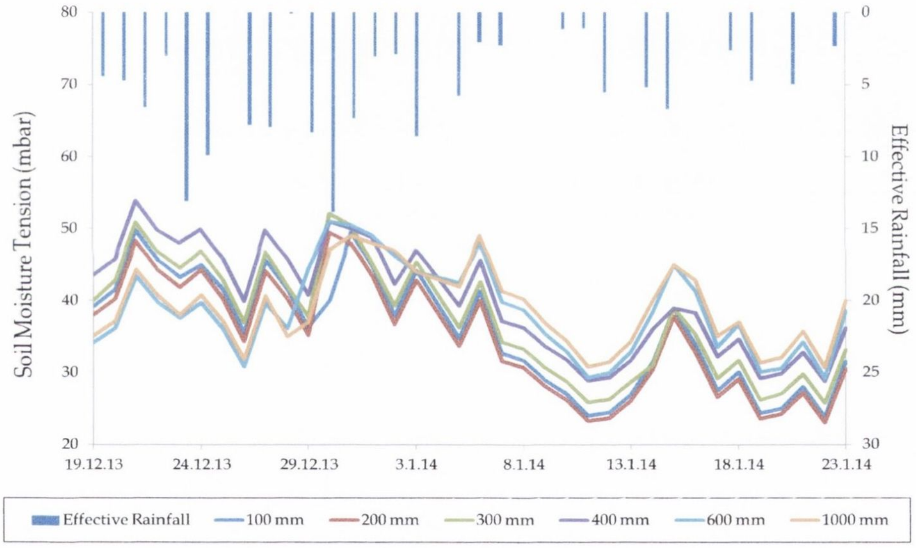

Figure 1.17 Soil moisture in response to effective rainfall

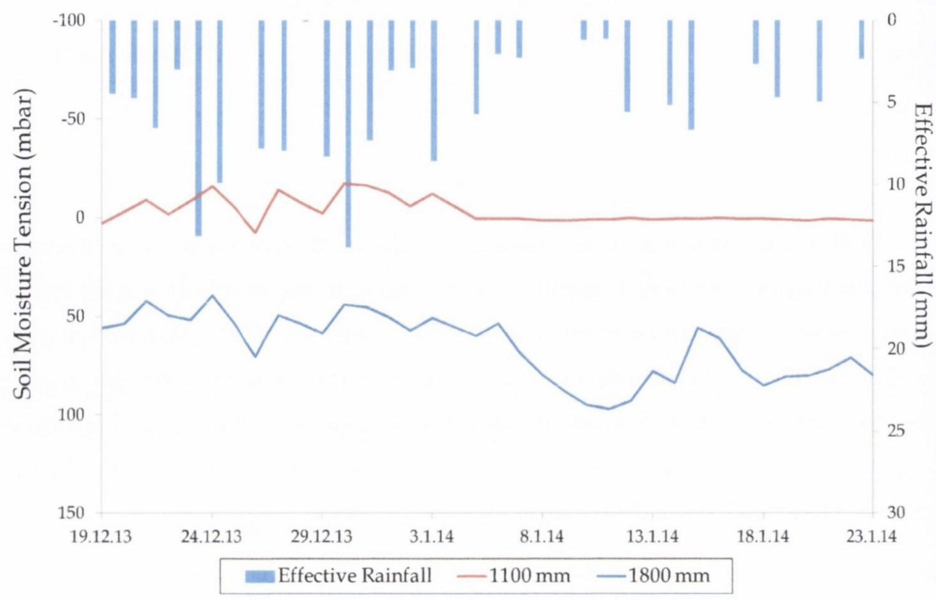

Figure 1.18 Soil moisture in response to effective rainfall

Table 1.45 Soil moisture sample retrieval during LPP overloading trial at Site B

	Potential No. of Samples	No. of Samples Retrieved	Mean Conc. (mg L^{-1})
SE	2	2	434
0.75	12	12	161
1.05	12	12	119
1.35	12	10	81

Analysis of the COD mean loads recorded at each depth plane (Table 7.105) during the overloading trial shows an increase in comparison with the overall treatment performance despite a reduction in the applied effluent of 7.5 g d^{-1}. As with the DD, this is indicative of increased subsoil conductivity with increased soil moisture levels.

Table 1.46 Reduction in COD concentrations at each depth plane with respect to SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	70	28.1	-	-
0.75	38.3	16.1	12.0	42.6%
1.05	26.0	11.0	17.1	60.9%
1.35	14.7	6.2	21.8	77.8%

Again analysis of the movement of inorganic-N indicates that the highly nitrified effluent (Table 7.107) was passing directly through the subsoil from the *red* depth plane without the occurrence of denitrification or plant uptake (Table 7.106). However, as with the previous sites a significant removal between the infiltrative surface and the *red* plane was observed.

Table 1.47 Reduction in inorganic-N concentrations at each depth plane with respect to SE

	NH_4-N		NO_2-N		NO_3-N		Tot. Inorganic-N	
	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})
SE	1.31	0.5	0.54	0.22	16.5	6.6	18.4	7.4
0.75	0.03	0.01	0.01	0.00	8.0	3.3	8.0	3.4
1.05	0.04	0.02	0.01	0.00	7.9	3.3	8.0	3.4
1.35	0.03	0.01	0.01	0.00	8.4	3.6	8.4	3.6

Table 1.48 Fractionation of inorganic-N at each depth plane

	% of total inorganic-N		
	NH_4-N	NO_2-N	NO_3-N
SE	7.1%	2.94%	89.9%
0.75	0.4%	0.12%	99.5%
1.05	0.5%	0.13%	99.4%
1.35	0.4%	0.12%	99.5%

Results from the PO_4-P analysis show that despite the change in soil moisture conditions the high rate of removal between the infiltrative surface and *red* depth plane persist (Table 7.108). The very low concentrations of PO_4-P recorded in the soil moisture samples are unsurprising giving the low load applied to the STU by the SE.

Table 1.49 Reduction in PO_4-P concentrations at each depth plane with respect to SE

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load removal (wrt SE influent) (%)
SE	4.2	1.7	-	-
0.75	0.09	0.04	1.646	97.8%
1.05	0.08	0.03	1.650	98.0%
1.35	0.07	0.03	1.654	98.2%

Despite the increased hydraulic conductivity apparent in the subsoil, TC results from beneath the LPP did not show any increase in concentrations with depth relative to the normal loading conditions (Table 7.109). This is surprising given that the effluent loading intensity from the LPP trenches would be expected to be greater than that of the DD and thus more likely to contribute to increased pollutant migration with depth. Results also reported no detection of *E. coli* at the sampling depth planes (Table 7.110).

Table 1.50 TC concentrations at each depth plane with respect to SE

	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit Removal
SE	2.8×10^{4} - 1.2×10^{6}	2.31E+05	
0.75	3.0×10^{1} - 1.5×10^{2}	8.23E+01	3.4
1.05	9.7×10^{0} - 9.0×10^{1}	4.43E+01	3.7
1.35	1.9×10^{1} - 1.9×10^{2}	4.27E+01	3.7

Table 1.51 *E. coli* concentrations at each depth plane

	No. of Samples	No. of samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 - 100	100 - 1000	> 1000
0.75	12	12	0	0	0
1.05	12	12	0	0	0
1.35	10	10	0	0	0