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An Investigation into the Performance of Highly Permeable Subsoils and Reed Bed Treatment Systems in Treating Domestic Wastewater in Ireland

by

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A Thesis Submitted for the Degree of Doctor of Philosophy
to the University of Dublin, Trinity College

June, 2009

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DECLARATION

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EXECUTIVE SUMMARY

In Ireland, domestic wastewater from over one-third of the population, or approximately 400,000 dwellings, is treated by on-site systems. Given that over 25% of all water supplies in the country is currently provided by groundwater, it is critical to protect this resource from contamination since the percolate released from on-site wastewater treatment systems enters the underlying groundwater which can, in turn, migrate under natural gradients toward points of exposure for receptors of concern, e.g. humans and drinking water supplies. Ireland's Environmental Protection Agency (EPA) has published recommendations aimed at defining subsoil conditions that will provide an acceptable level of treatment for on-site wastewater in order to protect such groundwater resources from contamination. One of the crucial elements of this risk assessment approach is the percolation test. This is required to ascertain the assimilation capacity of the subsoil and is represented in terms of a 'T-value' which is obtained from the standard falling head percolation test. A low T-value (1 to 5) denotes a coarse-grained soil that is highly permeable in nature – typically sand or gravel, while a high T-value (40 to 50) is more indicative of a less permeable clay-based soil. Currently, one of the growing concerns amongst water authorities, practitioners and other bodies surrounds the discharge of on-site effluent into the more freely draining soils (with T-values of between 1 and 5), where although permitted under the current guidelines, there exists an intuitive feeling that the effluent is percolating at an excessive rate. This ultimately creates the risk of insufficient nutrient and pathogenic removal in the subsoil's vadose zone and an increased potential for groundwater contamination. In cases where septic tank effluent is deemed unsuitable for immediate discharge to subsoil (e.g. high water table, shallow bedrock), secondary effluent can be achieved by an alternative system such as a horizontal subsurface-flow reed bed prior to further ptreatment in the subsoil. Despite this, there is reluctance in Ireland amongst a number of local authorities to permit the use of wetlands as viable treatment systems given the scarcity of reliable long-term performance data relevant to Ireland and its climate, and the little information or guidance provided in the EPA wastewater treatment manual, *Treatment Systems for Single Houses*.

A three year research study, funded by the EPA, was undertaken to examine and compare the performance of highly permeable subsoils, with a T-value of between 1 and 5, in treating septic tank effluent and secondary treated effluents from a packaged rotating biological contactor (RBC) plant and horizontal subsurface-flow reed bed. The performance efficiency of the horizontal flow reed bed as both a secondary and tertiary treatment on-site system was also assessed. Two sites were identified on the basis of fulfilling EPA recommendations for site suitability and satisfying the project's criteria and on-site wastewater treatment systems were installed on both. Septic tank effluent, secondary effluent and reed bed effluent samples were obtained using composite samplers. To assess the attenuation capacity of the subsoil, soil moisture samples at a number of predetermined depths in the vadose zone were obtained from both suction lysimeters and zero-tension samplers installed in the percolation area. Chemical (COD, BOD_5, TN, NH_4-N, NO_2-N, NO_3-N, PO_4-P, Cl) and bacteriological (total coliforms, *E. coli*) analyses were carried out on all of the samples while virus injection trials were performed using a range of bacteriophage surrogates (MS2, ΦX174 and PR772). A side study of the fate and transport of endocrine disrupting chemicals (EDCs) in proprietary treatment systems and in the subsurface environment was also completed. This involved analysis for a number of steroid oestrogens, the organic oxygen compound - bisphenol A, and the consumer product chemical, caffeine.

Results showed all three percolation areas to be over-designed based on EPA guidelines owing to the lower than anticipated hydraulic loads. It was found that the installation of the packaged RBC plant greatly reduced the organic and biological load on the subsequent percolation area. The net absence of any significant biomat layer resulted in a hydraulic load vastly greater than the design long term acceptance rate (LTAR) being exerted on the percolation trenches. With limited effluent residence time in the highly permeable vadose zone, the ensuing effect was a greater nitrogen loading in the percolate at the minimum point of discharge to groundwater than that recorded in the percolation area receiving septic tank effluent. The majority of the attenuation of the organic and pathogen load from both sites was seen to occur in the distribution gravel and in the first 0.35m of subsoil while the set of oestrogens, with the exception of oestriol, were found to significantly degrade in the subsoil environment to nominal levels. There was more evidence of faecal

contamination at depth on the percolation area receiving secondary effluent than that receiving septic tank effluent, despite the lower bacterial influent load. As such, it is recommended that in cases where the T-value falls between 3 and 5, an additional subsoil depth of 0.6m (i.e. an increase from 0.6m to 1.2m) be made compulsory on sites receiving secondary treated effluent to reduce the risk of microbial contamination of groundwater.

Tracer studies using Rhodamine WT and a number of phages showed the hydraulic behaviour of both reed beds to be satisfactory, with MS2 shown to be a particularly suitable wetland biotracer owing to high recovery levels. Both beds showed high retention in organic and bacteriological constituents but were limiting in terms of nutrient removal.

With respect to contaminant concentrations recorded at the minimum points of discharge to groundwater in the subsoils under review, no appreciable benefit appears to be gained by the installation of a secondary treatment reed bed prior to subsoil polishing when compared to the findings from the parallel conventional septic tank system under investigation.

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ABBREVIATIONS

AET	Actual Evapotranspiration
AWI	Air-Water Interface
BOD	Biochemical Oxygen Demand
BOD_5	Five-day Biochemical Oxygen Demand
CEC	Cation Exchange Capacity
COD	Chemical Oxygen Demand
CV	Coefficient of Variation
CWS	Constructed Wetland Systems
DST	Defined Substrate Technology
EDC	Endocrine Disrupting Chemical
EPA	Environmental Protection Agency (Ireland)
ERF	Effective Rainfall
ET_o	Reference Evapotranspiration
FWS	Free Water Surface
GSI	Geological Survey of Ireland
GWPS	Groundwater Protection Scheme
HLR	Hydraulic Loading Rate
HRT	Hydraulic Retention Time
IEP	Isoelectric Point
LOD	Limits of Detection
MF	Membrane Filtration
MPN	Most Probable Number
nHRT	Nominal Hydraulic Retention Time
OD	Outside Diameter
PFU	Plaque Forming Units
RBC	Rotating Biological Contactor
RF	Rainfall
RSD	Relative Standard Deviation
RWT	Rhodamine WT

SMD	Soil Moisture Deficit
SS	Suspended Solids
SSF	Subsurface Flow
TC	Total Coliforms
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TPB	Triple Phase Boundary
TSB	Trypticase Soy Broth
TSS	Total Suspended Solids
VFA	Volatile Fatty Acid

NOMENCLATURE

RBE	Reed Bed Effluent
SE	Secondary Effluent
STE	Septic Tank Effluent

1. INTRODUCTION

1.1 Background

Wastewater infrastructure in Ireland includes a continuum of technologies designed for scales of application that span from small decentralised systems serving individual homes in rural and suburban areas, to large centralised systems serving municipalities in densely populated urban areas. Early versions of decentralised or onsite wastewater treatment systems (e.g. cesspool) were often designed with simple and short-term goals of waste disposal to prevent direct human contact and to achieve basic public health and environmental protection. In the early 1900's, system design evolved to include raw wastewater pre-treatment in a tank-based unit (e.g. septic tank) followed by disposal through a soil drainfield. As modern appliances have become more commonplace, high water-use plumbing fixtures have resulted in increased domestic wastewater flows and a need for more careful siting, design and implementation of on-site systems to achieve a dual target of disposal and purification.

In recent times, concerns over groundwater quality in Ireland have been highlighted due to the risks posed by human activities with contamination arising from both diffuse (generally agricultural) and point sources, particularly farmyards (manure and silage storage) and on-site wastewater treatment systems. Indeed, recent statistics (EPA, 2008a) have revealed that 36% of private group water schemes showed evidence of faecal contamination, with a much higher proportion expected for unregulated single house well supplies. It is likely that there are areas in Ireland where more than 70% of private wells have contained faecal bacteria at some time during their use (Daly, 2003). On-site treatment and disposal of domestic sewage is the only method of wastewater renovation for approximately 400 000 Irish dwellings, which equates to over one third of the population (Department of the Environment and Local Government *et al.*, 1999). With such a high percentage of households unconnected to a centralised sewerage network, on-site sewage disposal is thought to be a significant contributor to groundwater pollution, essentially endangering the quality of the resource. Given that groundwater, in turn, provides over 25% of all drinking water supplies in Ireland through public and private wells (EPA, 2005), the risk to public health is real and

emphasises the need to protect this resource from any risks of contamination posed by such systems.

The conventional septic tank treatment process (Figure 1.1) generally involves domestic wastewater (excluding roof or road drainage) flowing into a two-chambered tank in which primary sedimentation occurs alongside some anaerobic digestion. The effluent is then distributed into a suitable soil percolation (or infiltration) area where further physical, chemical and biological treatment processes occur prior to groundwater discharge. Whilst the prevailing anaerobic conditions in a septic tank provide limited treatment and breakdown of organics and nutrients, it is the migration of pathogenic bacteria and infectious viruses that provides the single greatest threat to groundwater in Ireland. The unsaturated subsoil of the percolation area's vadose zone acts as a porous media biofilter, performing straining and filtration functions together with sorption and ion exchange, in preventing the migration of the effluent's main constituents of concern to the underlying aquifer. The role of the percolation area and its inherent subsoil characteristics, therefore, is critical in providing a sufficient contaminant attenuation zone and ensuring long-term protection from groundwater pollution. This is made all the more pertinent as the number and density of on-site wastewater treatment systems continues to rise in Ireland. While the consequences of groundwater pollution from on-site systems is far-reaching, there also exists a risk of contamination to surface water bodies from the same source owing to insufficient permeability in the subsoil to take the effluent load. Surface ponding may result with associated health risks, together with potential discharge/runoff of effluent pollutants to surface water. The nutrient load in the effluent (either as direct discharge or from groundwater baseflow) can contribute to eutrophication in sensitive water bodies, whilst contamination of water sources by human enteric pathogens can promote the outbreak of disease.

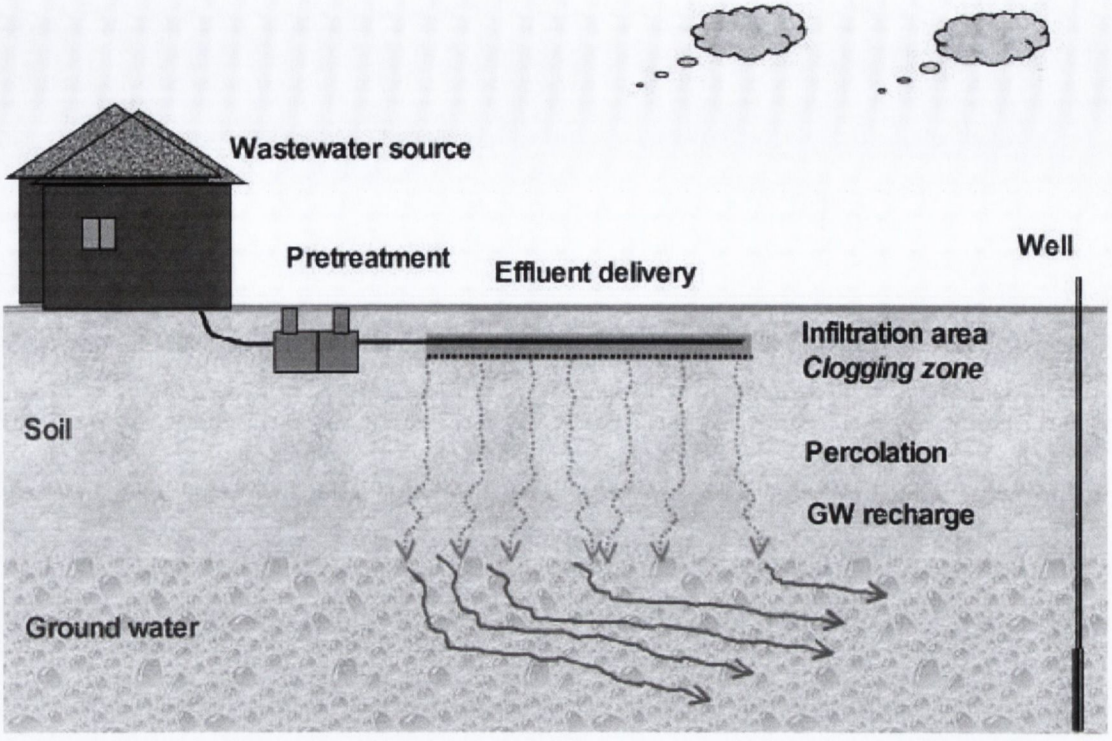


Figure 1.1 Illustration of typical conventional septic tank treatment system and pathway for potential contaminant migration to groundwater resource (Van Cuyk *et al.*, 2001)

In those situations where the subsoil renders a site unsuitable for a conventional septic tank system, modifications to the treatment system are available. A filter, such as an intermittent sand filter, peat filter or an array of constructed wetland configurations, can be constructed downstream of the septic tank. The effluent would pass through one of these processes and on to a polishing filter prior to disposal. Another option is the installation of a packaged wastewater treatment system. These systems, which produce a superior quality of effluent for disposal, generally consist of a primary settlement tank and an aeration tank followed by a secondary clarifier. The aeration tank contains the micro organisms, either in suspension or attached to an inert media, which are responsible for degradation of organic matter.

Despite the many options of domestic wastewater disposal now available on the market, the understanding and predictability of disposal processes as a function of design, installation/operation, and environmental factors, as well as the risk of inadequate function and its effects, have not been fully elucidated. This has been primarily due to the complex and dynamic relationships between hydraulic and purification processes in the

unsaturated subsoil and the factors that control their behaviour prior to groundwater discharge. As a result, current guidelines have potential gaps and shortcomings that can preclude rational system design to predictably and reliably achieve specific performance goals.

1.2 Research Context

In recent years, two documents have been published by government agencies in relation to on-site wastewater treatment systems and groundwater protection. The Environmental Protection Agency (EPA) guidance manual *Wastewater Treatment Manual: Treatment Systems for Single Houses* (EPA, 2000) provides guidelines for the selection, design, operation and maintenance of these systems to enable continued sustainable development in Ireland while *Groundwater Protection Schemes* (Department of the Environment and Local Government *et al.*, 1999) aims to maintain the quantity and quality of groundwater and in some cases improve it, by applying a risk assessment-based approach to groundwater protection and sustainable development.

1.2.1 Wastewater Treatment Manual: Treatment Systems for Single Houses

In response to calls for greater guidance and clarity regarding on-site wastewater treatment systems in Ireland so as to ensure continuing sustainable development, the EPA published *Treatment Systems for Single Houses* (EPA, 2000) which would assist planning authorities, developers, system manufacturers, system designers, installers and operators in the design, operation and maintenance of on-site systems for single houses. A single house system is categorised as a dwelling house of up to 10 people with toilet, living, sleeping, bathing, cooking and eating facilities.

One of the key elements of the guidance manual is an intensive site assessment procedure to ascertain whether it is suitable for wastewater disposal. This assessment, comprising a desk study followed by an on-site visual trial hole inspection and percolation test, determines the vulnerability of local groundwater resources and identifies receptors potentially at risk. The percolation test is also required to determine the assimilation capacity of the subsoil. It is recommended that the percolation rate

obtained from the standard percolation test (the so-called T-value) for subsoils receiving septic tank wastewater effluent must fall within the specified range of 1min per 25mm to 50min per 25mm of water level fall (i.e. 1 to 50). In addition, a minimum unsaturated subsoil depth of 1.2m below a septic tank percolation area should exist before the site may be deemed suitable for on-site treatment of domestic wastewater effluent from a conventional septic tank design. Where subsoil T-values fall outside the range 1 to 50, or the minimum unsaturated subsoil depth of 1.2m does not exist, a second percolation test (the P-test) should be carried out from ground level. If the resulting P value is in the range 1 to 50 then the guidance manual suggests installing some form of secondary treatment process, providing that there is 0.6m of unsaturated subsoil for percolation of the secondary effluent. These packaged treatment systems [e.g. rotating biological contactor (RBC), sequencing batch reactor (SBR)] provide secondary treatment aerobic degradation either by fixed film or suspended growth microbial processes. Other options promoted in the guidelines are the construction of a secondary treatment stage in-situ such as an intermittent stratified sand filter or a reed bed prior to polishing in the subsoil environment.

The EPA Guidelines have developed over the past eight years and have been adopted by most Local Authorities. The document is in the process of a significant revision en route to its status being enhanced to a regulatory Code of Practice, whereby it will legally replace a previous standard relating to septic tanks, the SR6 document (NSAI, 1991).

1.2.2 Groundwater Protection Schemes

A national groundwater protection scheme, jointly developed by the Geological Survey of Ireland (GSI), the Department of Environment and Local Government (DoELG) and the EPA, focuses on the concepts of risk and risk management. A *source-pathway-target* model (Figure 1.2) is used for the scheme; the *source* being the potentially polluting activity, the *pathway* being the unsaturated subsoil and its susceptibility or vulnerability to groundwater contamination, and the *target* being the groundwater resource, generally assumed to be the aquifer, or other receptors such as a water supply well or spring (Misstear and Daly, 2000).

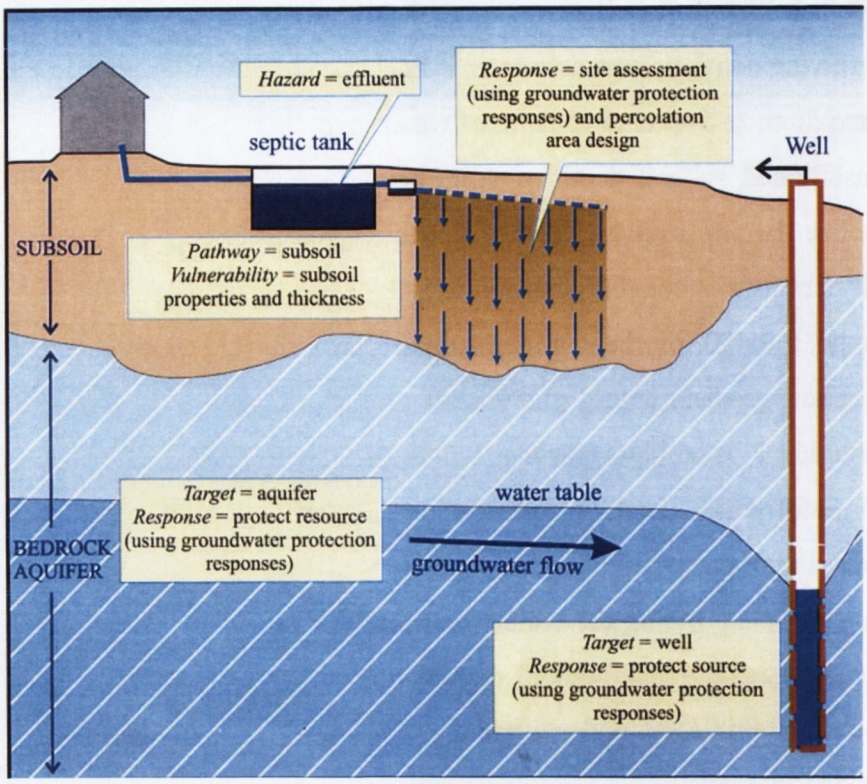


Figure 1.2 Schematic diagram illustrating the *source-pathway-target* model and how the elements of risk are applied to groundwater protection (Department of the Environment and Local Government *et al.*, 1999)

The value of the different groundwater resources across Ireland has been categorised by the GSI into regionally important, locally important or poor aquifers. Source protection areas have also been delineated around large individual wells or springs used for water supply or industrial purposes. Moreover, the vulnerability of groundwater has been mapped and is based on a combination of the time of travel of the effluent to the target, the relative quantity of contaminants that reach the groundwater and the attenuation capacity of the percolating medium, and is divided into four categories: extreme, high, moderate or low. The permeability governs the transmission rate of a fluid through the subsoil, and hence the period in which attenuation of contaminants can take place by physical, chemical and biological processes. So although a number of factors are taken into account in the classification of vulnerability, research has shown that permeability is the most important influence (Fitzsimons and Misstear, 2006; Misstear *et al.*, 2008). A matrix of vulnerability against resource or source protection area has then been defined as a Groundwater Protection Response for different land use activities

(Department of the Environment and Local Government et al., 1999), such as land spreading of sewage sludge, landfill sites and on-site treatment systems.

1.2.3 Previous Studies

In order to build on the findings of the earlier research and to address information gaps, which had been identified since the publication of the EPA Guidance Manual (2000), further research work was commissioned by the EPA in 2000 under the Environmental Research, Technological Development and Innovation (ERTDI) Programme 2000–2006. This work was carried out by the Department of Civil Structural & Environmental Engineering at Trinity College, Dublin. The project studied four separate sites with different subsoil permeabilities and found that the septic tank and percolation system provided a comparable treatment performance with respect to groundwater protection to a packaged secondary treatment system (Gill *et al.*, 2005). The use of stratified sand filters was also studied, both as a secondary treatment process and also as a tertiary treatment process, and appropriate design criteria were proposed. Their performance was found to be slightly superior to that of the percolation areas on both sites receiving septic tank and secondary treated effluent respectively.

Finally, further work has been carried out by the Department of Civil Engineering, NUI Galway to develop an interpolated method for T-test where high values, i.e. greater than 50 (low permeability) are expected. This test has been confirmed on several sites by the Trinity College research team to give a good approximation of the standard T-test results.

1.2.4 Recent Developments

The EU Water Framework Directive (2000/60/EC) requires an integrated view of the water cycle and its components, whereby groundwater and surface water can no longer be viewed in isolation, but as components in the overall water balance of a river basin. Such an integrated approach now requires water management to be considered on a River Basin District (RBD) catchment scale. Development and implementation of RBD management plans require an understanding of the hydrological cycle and how human pressures may impact on both groundwater and surface waters. Hence, risk assessments are needed for different generic pollutant sources, with on-site wastewater treatment

systems having long been suspected as the cause of continuing contamination of both ground and surface water bodies. As such, the Department of Environment Heritage and Local Government has recently commissioned the Western River Basin District to identify on-site treatment systems as a potential pressure and to develop a risk assessment methodology.

1.3 Scope of Research

1.3.1 Aims and Objectives

The project has been prepared in response to a number of areas which the EPA have recently identified as being of immediate concern in the field of on-site wastewater treatment. Although allowed in the current EPA manual (EPA, 2000), the discharge of domestic effluent into highly permeable freely-draining soil seems to attract a degree of scepticism both from local councils, practitioners and other bodies who intuitively feel that the effluent is percolating at an excessive rate. This ultimately creates the risk of an insufficient level of nutrient and pathogen removal in the vadose zone and an increased potential for groundwater contamination. Most on-site research to date has been carried out in continental climates on sandy subsoils or under controlled laboratory conditions with little field research previously carried out in a temperate maritime climate or on the heterogeneous subsoils of north-western Europe, which are largely a result of recent glaciation. The results are also difficult to extrapolate to an Irish context due to indeterminate percolation rates and different climatic conditions.

Another shortcoming of the EPA guidance manual is a robust and clear understanding of the design of and processes involved in constructed wetlands with respect to an Irish climate. Currently there is reluctance in Ireland amongst a number of local authorities to permit the use of wetlands as stand-alone secondary treatment systems given the scarcity of reliable long-term performance data relevant to Ireland and its climate, and their apparent poor treatment performance in winter (Healy and Cawley, 2002). The most common type wetland in use in Northern Europe is the horizontal subsurface flow reed bed which is regarded as especially good in the removal of Biochemical Oxygen Demand (BOD), suspended solids (SS) and pathogenic organisms. However, the majority of research, to date, has been carried out using domestic wastewaters with low

(50 – 150 mg L^{-1}) BOD inflow concentrations (Vymazal, 2001), probably due to the use of combined (surface, rain and wastewater) sewer systems (Griggs and Grant, 2001). Undiluted septic tank effluent in Ireland, for comparison, has a BOD of between 150 and 400 mg L^{-1} (Henry, 1990; Gray, 1995).

The aim of this research project was therefore to carry out a series of rigorous long term on-site trials in order to enhance the understanding of the hydraulic and purification processes involved and the performance of highly permeable subsoils in the wastewater treatment of typical domestic effluent from septic tanks and other small-scale secondary treatment applications. As part of the same trials the performance efficiency of horizontal subsurface flow reed bed treatment systems in treating both septic tank and secondary effluents was also analysed.

As such, the trials were specifically designed with the following objectives:

a) To monitor the hydraulic and purification performance of highly permeable subsoils (T-value < 5) in terms of the attenuation of chemical pollutants and pathogenic organisms in on-site *septic tank effluent.*

b) To monitor the hydraulic and purification performance of highly permeable subsoils (T-value < 5) in terms of the attenuation of chemical pollutants and pathogenic organisms in on-site *secondary treated effluent.*

c) To determine the efficacy and sustainability of horizontal subsurface flow reed beds operating as secondary treatment systems for on-site *septic tank effluent.*

d) To determine the efficacy and sustainability of horizontal subsurface flow reed beds operating as tertiary treatment systems for on-site *secondary treated effluent.*

1.3.2 Methodology and Work Programme

To fulfil the objectives set out in Section 1.3.1, the project was divided into two distinct sub-projects, each consisting of an initial desk study which was then followed by on-site field trials. The sites were chosen according to the site assessment procedure as set

out in Treatment Systems for Single Houses (EPA, 2000) and the trials were designed to be of a minimum of two years duration to capture seasonal variations.

A summary of the project, as was carried out, is presented below:

Sub-project 1 Three parallel on-site trials at sites in Kilrainy, Co. Kildare (Site A) and Redcross, Co. Wicklow (Site B) of minimum 24 months duration where single-house wastewater effluent was discharged into a standard percolation area.

- Site A: septic tank effluent into subsoil with T-value of 3.7.
- Site A: secondary treated effluent from a horizontal subsurface flow reed bed into subsoil with T-value of 3.7.
- Site B: secondary treated effluent from a rotating biological contactor (RBC) into subsoil with T-value of 4.5.

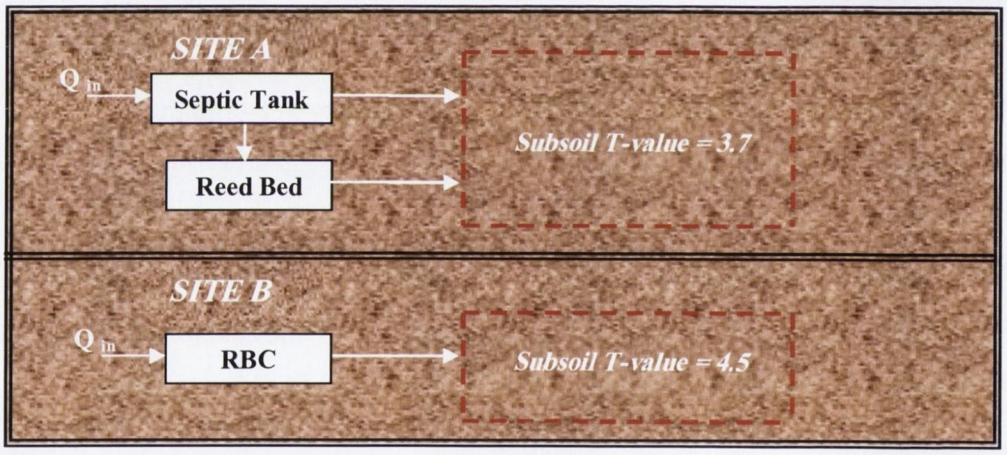


Figure 1.2 Process flow diagrams of Sub-project 1

Sub-project 2 Two parallel on-site trials at sites in Kilrainy, Co. Kildare (Site A) and Redcross, Co. Wicklow (Site B) of minimum 24 months duration where single-house wastewater effluent was discharged into a horizontal subsurface flow reed bed.

- Site A: septic tank effluent into a secondary treatment horizontal subsurface flow reed bed.
- Site B: secondary effluent into a tertiary treatment horizontal subsurface flow reed bed.

1.4 Thesis Outline

Chapters 2 and 3 contain an extensive literature review focusing on the two keys areas of research: (i) 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 and (ii) the design characteristics and performance efficiency of in-situ horizontal subsurface flow reed bed treatment systems as both an alternative secondary and tertiary treatment process for on-site waste disposal applications.

Chapters 4 and 5 describe the site selection, construction and instrumentation processes as well as the sampling and analysis methodologies. Chapter 6 presents the on-site field results of the pollutant and hydraulic loadings from the source unit treatment process on each site that provide the basis upon which the subsequent subsoil treatment or horizontal subsurface flow reed beds can be assessed. Chapter 7 presents analysis of the chemical, bacteriological and viral results from the high permeability subsoil unit treatment process on both sites in purifying three different quality effluents. The performance efficiency of the on-site constructed horizontal flow reed beds in treating both primary and secondary treated domestic effluent in the context of an Irish setting is detailed in Chapter 8.

In Chapter 9, the results from comparable treatment systems are discussed and conclusions drawn while further observations together with recommendations for future research are included in Chapter 10.

2. ON-SITE WASTEWATER TREATMENT AND SUBSOIL ATTENUATION PROCESSES

2.1 Introduction

Organic matter, ammoniacal compounds and a variety of toxic chemicals are all undesirable substances found in significant amounts in domestic wastewater. While the risks posed by the infiltration of nitrate to ground and surface waters have been widely documented in the past, it is the biological constituents of the wastewater, namely pathogenic bacteria, infectious viruses and protozoa that are, as Daly (2003) states, now the single greatest threat to groundwater in Ireland and which in turn pose huge health risks to the general public in the form of waterborne diseases. The subsoil environment in an on-site wastewater treatment system acts as the protective or attenuating zone with regard to contamination of groundwater, and has the potential to achieve high treatment efficiencies. However, the understanding and predictability of performance with respect to the removal of chemical and, more particularly, biological contaminants in the soil remains limited. The degree of microbial contamination of groundwater in Ireland is very high with, in many areas, at least 30% of private domestic and farm wells polluted by faecal bacteria and in some highly vulnerable areas more than 50% polluted. Several investigations have attributed the decline in our water quality to indiscriminate use of septic tank systems in soils unsuited for adequate domestic waste treatment. Therefore, understanding the properties of the percolating medium (i.e. the soil) and how each group of wastewater constituents act in the soil medium is imperative in order to reduce such levels of groundwater contamination and ensure the safe supply of drinking water to the public.

One of the most critical scenarios from a hydrogeological perspective is when the receiving subsoil for the percolating effluent is highly permeable (freely-draining). In this case, it is clear the risk of nitrate, bacterial and/or viral contamination of the groundwater is potentially high due to the increased percolation rate and the absence of a suitably high adsorptive clay mineral content in the soil matrix.

This chapter begins with an outline of the components of the conventional septic tank treatment system including the design and treatment performance specifications of

each. The importance of the biomat and the underlying subsoil environment is highlighted with the latter investigated further through examination of subsoil characteristics, which includes an outline of the BS5930 classification scheme and a synopsis of the background to Irish subsoils. Finally, the factors and processes contributing to contaminant attenuation in the vadose zone and the fate of the main constituents in septic tank effluent (STE) are examined.

2.2 Conventional Septic Tank Treatment Systems

The primary arrangement for on-site and decentralised wastewater treatment is a conventional septic tank treatment system, consisting of septic tank pre-treatment followed by discharge of the STE to a subsurface disposal field. The latter is more commonly referred to as a percolation area in Ireland. During this stage of the treatment, the effluent infiltrates and percolates through the vadose zone of the percolation area, undergoing a number of physical, chemical and biological processes before entry to the underlying groundwater.

At the household source, raw sewage comprising of water from the laundry, bath and kitchen sink (grey water) and body wastes (black water) is fed to the tank usually by gravity flow. Canter & Knox (1985) report that on average, black water contributes about 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 household units. In the past, concerns have been expressed regarding the high concentrations of household detergents and inorganic salts in grey water and the detrimental effect they might have on the efficiency of the treatment process within the septic tank. Thus, in certain systems the grey water is being piped directly to a separate soil treatment system. Current opinion, however, dismisses this notion with Grant and Moodie (1995) suggesting that the average concentrations of detergents and inorganic salts will not adversely affect the proper functioning of a septic tank. Consequently, it is recommended that all wastes should be piped to the septic tank, although any type of runoff (rain from roofs, pavements etc.) should be diverted to land drain in order to minimise the volume of waste to be treated, avoid dilution of the wastewater and prevent hydraulic overloading of the system.

2.2.1 Septic Tank Design and Performance

The design and construction of the septic tank is critical to maximise its performance efficiency as part of the on-site treatment system. In this respect, tanks are normally sized based on the design flow, with 1/3 of the tank volume responsible for providing a 24-hour hydraulic retention time and the other 2/3 set aside for scum and sludge accumulation. This effectively yields a total tank volume equal to 3 times the daily flow volume (Baumann *et al.*, 1978 (cited in Siegrist *et al.*, 2000)). The EPA (2000) state that the septic tank must be of sufficient volume to provide a hydraulic retention time in excess of 24 hours at maximum sludge depth and scum accumulation to facilitate BOD and solids removal from the wastewater. The level of sludge accumulation, of course, is dependent on the number of occupants in the household. Taking all this into account, BS6297 (1983) and EPA (2000) recommend that the tank capacity be calculated using the following equation:

$$C = 180P + 2000 \qquad \text{(Eqn. 2.1)}$$

where, C = capacity of the tank (litres)

P = design population

This assumes that the tank is desludged at least once every 12 month period. In Ireland, a minimum capacity of 2 720 litres should be provided, which effectively equates to a design for a minimum population of 4 people (EPA, 2000).

Multi-chamber tank configurations are deemed to be superior to single-chamber tanks of the same size producing effluent with up to 50% less SS and BOD (Laak, 1980). Tanks with two interconnected compartments, in particular, are now most commonly used with the benefits over single chamber tanks largely due to hydraulic isolation and to the reduction or elimination of inter-chamber mixing (Canter and Knox, 1985).

The successful operation of the septic tank is centred on maintaining quiescent conditions ideal for the settlement of solids (both organic and inorganic) and to aid the development of anaerobic conditions for the treatment of both the accumulated solids (sludge) and the non-settleable constituents in domestic wastewater. The sludge is partially digested by anaerobic micro organisms with the liberation of gases, principally carbon dioxide (CO_2) and methane (CH_4). Oils, greases, fats and soaps in the wastewater

float to the surface aided by these gases, forming a thick scum over the liquid mass and providing an indication that the tank is functioning properly (Daly *et al.*, 1993). This floating scum layer helps the tank's operation in a number of ways. Firstly, it prevents oxygen transfer through the air-water interface, thus maintaining ideal anaerobic conditions, while it also insulates the tank by preventing heat loss. There exists a popular misconception that septic tanks treat domestic wastewater to a standard that does not require further treatment. What they do provide is a consistent effluent that can be readily treated. The main purpose of septic tank treatment with respect to STE quality is in reducing the SS concentration and to a lesser extent the BOD, thereby preventing accelerated soil clogging in the subsequent percolation area.

In terms of performance, a well constructed and maintained septic tank can be expected to remove between 15 – 30% of the BOD and retain between 50 – 70% solids. However, Canter and Knox (1985) cite research by Viraraghavan (1976) who found that BOD and Chemical Oxygen Demand (COD) removal efficiencies were about 50% while total suspended solids removal was less than 25%. A study by Lawrence (1973) recorded less than a 15% reduction in BOD and a 34 – 35% reduction of SS. Research in Ireland by Keenan (1983) and Henry (1990) yielded average effluent BOD concentrations of 268 mg L^{-1} and 564 mg L^{-1} respectively. Corresponding SS concentrations ranged from 138 mg L^{-1} – 198 mg L^{-1}. Elsewhere, it is suggested a typical effluent from a septic tank contains about 80 mg SS L^{-1} (Patterson *et al.*, 1971; Goldstein and Wenk, 1972; EPA, 2000).

The anaerobic environment within the septic tank is largely ineffective in reducing the nutrient loading of the wastewater. Nitrogen in the influent domestic wastewater is mainly in the form of organic nitrogen (org-N) and ammonium (NH_4), the sum of which yields the TKN. Under anaerobic conditions, much of this org-N is converted to readily oxidisable ammonium ions (NH_4^+). Bauer *et al.* (1979) measured a mean wastewater influent concentration of 38 mg L^{-1} for TKN [32% NH_4^+ : 68% org-N] whilst a similar mean effluent TKN concentration of 40 mg L^{-1} [75% NH_4^+ : 25% org-N] was also recorded. Therefore although the septic tank environment promotes the conversion of org-N to NH_4^+, it is ineffective with respect to total nitrogen (TN) removal across the

process. It should be noted that nitrate (NO_3) concentrations in septic tanks are very low, and usually zero, due to the lack of aerobic conditions.

The anaerobic digestion process also converts most of the influent phosphorous, in the form of both organic and condensed phosphate (polyphosphate), to soluble orthophosphate (PO_4^{3-}) which passes out in the effluent. Wilhelm *et al.* (1994) reported that approximately 76% of the TP in the STE was in its PO_4^{3-} form. Canter & Knox (1985) cite research carried out by Bouma (1979) who states that a typical TP concentration passing from the septic tank is about 15 mg L^{-1} of which approximately 85% is in PO_4^{3-} form. Bauer *et al.* (1979) measured mean TP concentrations in influent wastewater to septic tank systems serving single houses of 25 mg L^{-1} [35% inorganic-P (PO_4^{3-}) : 65% org-P]. Salvato (1992) in septic tank research carried out in Florida recorded a mean figure of 15 mg PO_4^{3-} L^{-1} in STEs. Keenan (1983) recorded mean TP concentrations of 16 mg L^{-1} while Henry (1990) recorded mean PO_4^{3-} concentrations of 29 mg L^{-1} and 50 mg L^{-1}. While septic tank influent quality in Ireland differs from the more generally dilute sewage in North America (Gray, 1995), the processes involved in the septic tank are the same and so it would be reasonable to expect similar behaviour of the nutrients under Irish conditions.

The extent of pathogen removal is limited, of course, given the septic tank's primary goal of solids removal. Meschke and Sobsey (1998) suggest a greater number of the protozoan cysts and helminth ova may be removed than bacteria or viruses during this process due to their much larger size. In contrast, Gerba & Goyal (1985) report that none of the protozoan cysts are removed at this primary stage, but quote percentage removal rates of 50 – 90% for both bacteria and helminth eggs. Feachem *et al.* (1983) contend that removal efficiencies for all four pathogen groups range from 0 – 2 log-unit (0 – 99%) in the septic tank. A number of sources report the level of faecal coliforms in STE at $10^6 – 10^8$ MPN $100mL^{-1}$ (Canter and Knox, 1985, Scherer and Mitchell, 1982).

From this evidence, it is clear that typical STE possesses a high pollutant potential that requires further treatment prior to discharge to watercourses or groundwater.

2.2.2 Percolation Area and Subsoil Treatment

Upon exiting the septic tank, the effluent is piped to a distribution box where it is evenly split and channelled into an engineered distribution trench for discharge into the underlying subsoil. Attempts to distribute the flow equally between trenches or areas of a bed using distribution boxes and 100 mm diameter perforated drain pipe are commonly made, but have often been shown to be ineffective (Otis *et al.*, 1978, cited in Siegrist *et al.*, 2000), thus affecting the successful operation of the treatment system. In properly implemented on-site wastewater treatment systems, advanced treatment for many wastewater constituents of concern is possible in an unsaturated subsoil with suitable permeability. This is achieved through 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) (Figure 2.1). As such, the soil treatment system, or percolation area, is the most important component of the conventional septic tank system as it is here that the majority of treatment occurs.

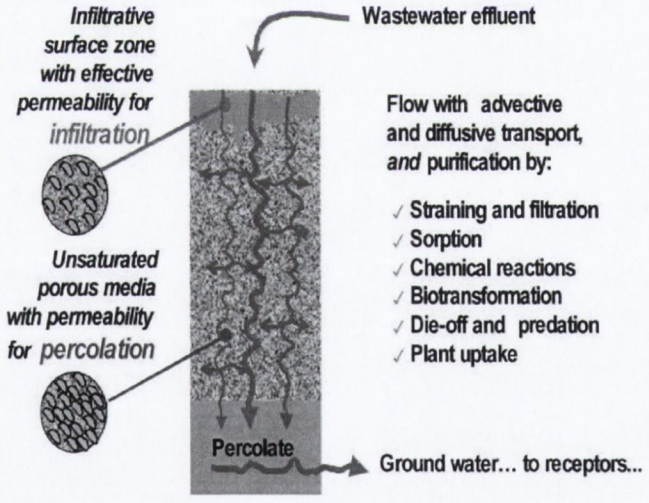


Figure 2.1 Illustration of hydraulic and purification processes occuring during wastewater infiltration and percolation in soil treatment systems (Van Cuyk *et al.*, 2001)

Research has shown that greater than 90% removal efficiencies can be achieved for organic constituents (BOD, COD and SS), micro organisms and viruses in suitable soils. Pathogen removal efficiencies may even be very high yielding near complete removal of

faecal coliform bacteria and greater than 4 log (99.99%) reduction in viruses (Emerick *et al.*, 1997 (cited in Siegrist *et al.*, 2000); Stevik *et al.*, 1999 and Van Cuyk *et al.*, 2001). Viraraghavan and Warnock (1976) reported that the soil had the ability to reduce 75 – 90% of the total suspended solids, BOD, COD and soluble organic carbon in the STE. However, the removal of nutrients (N and P) has been found to be more limited and variable (USEPA, 1980; Jenssen and Siegrist, 1990; Van Cuyk *et al.*, 2001).

Typically a percolation area consists of a series of narrow, relatively shallow trenches or mounds filled with a porous medium (usually gravel). The following equation is used for drainage trench area calculations (Payne and Butler, 1993):

$$A = P \, x \, V_p \, x \, 0.25 \qquad \text{(Eqn. 2.2)}$$

where,

A = Floor area (m^2) of subsurface drainage trench

P = The number of people served by the tank

V_p = the percolation value of the subsoil (sec mm^{-1})

In Ireland, a cross-section of a trench system is shown in Figure 2.2. Trenches are shallow, level excavations usually about 800 mm deep and 450 mm wide. The bottom is filled with 20 – 30mm washed gravel over which the percolation pipe, maximum length of 20 m per trench, is laid at a 1 in 200 slope. The pipe is then surrounded by more of the gravel which is covered with a suitable semi-permeable geotextile to prevent the backfill from clogging the aggregate. About 20 m of 100 mm piping is required per person (EPA, 2000). The porous medium is used to:

- maintain the structure of the trenches;
- provide partial treatment of the effluent by facilitating biomat formation;
- distribute the effluent to the infiltrative soil surfaces and
- provide temporary storage capacity during peak flows.

(Kreissel, 1982)

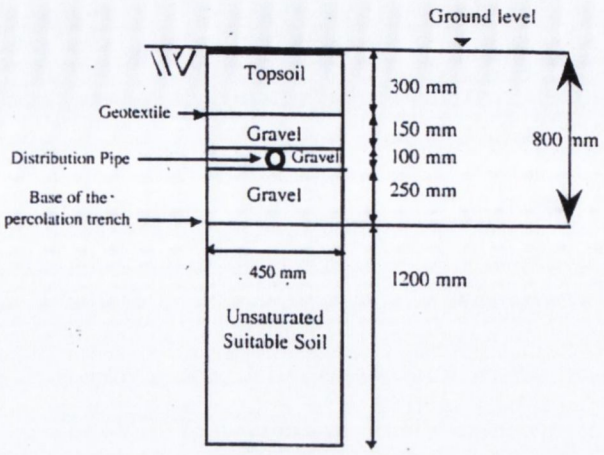


Figure 2.2 Section of a percolation trench (EPA, 2000)

Work by Cotteral and Norris (1969) and Laak *et al.* (1974) identified that the most important factors affecting the performance of a soil absorption system are subsoil properties, biomat formation and loading rate. Subsoil properties will be examined in more detail in Section 2.3.

2.2.3 Biomat Development and Loading Rates

The mechanisms governing contaminant attenuation and hydraulic performance of a soil percolation system are complex, especially in an Irish context given the inherent variability and heterogeneity of our soils and aquifers. Despite the growing body of research on these systems, the relationship between how they perform hydraulically and how this is interlinked with treatment efficacy is still not well understood, particularly with respect to different soil types and loading rates into the trenches. What is recognised though is that the formation of and active role played by a 'clogging layer', more commonly referred to as a biomat, is inextricably linked to both the hydraulics and attenuation capacity of the subsoil. The biomat zone is a heterogenous layer comprised of accumulated suspended solids and organic matter from the applied effluent and the by-products of microbial activity (e.g. polysaccharide residues) (Baveye *et al.* 1998; Siegrist and Boyle, 1987).

Many studies have highlighted the importance in the formation and development of this 'clogging layer', or biomat, at the infiltrative surface along the base and wetted sides of the percolation trenches and deemed it to be a crucial factor in the retention of the

effluents' constituents through processes such as enhanced sorption, nitrification and biological decay (Bouma *et al.*, 1972; Gill *et al.*, 2005, Van Cuyk *et al.*, 2005, Van Cuyk and Siegrist, 2007). The formation and development of this biomat zone is a dynamic process that is influenced by a combination of physical, chemical and biological processes. Following the physical clogging of the pores in the infiltrative surface during effluent application (which usually occurs within the first few months of system operation) anaerobic biological activity has commonly been identified as the main clogging process (Converse and Tyler, 1994). Stimulated by this favorable environment (e.g. anaerobic conditions, high humidity, 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 the 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.

The permeability of a biomat is generally low; Bouma (1975) calculated values of approximately 0.6 mm day^{-1} for clay soils and 2 mm day^{-1} for sandy soils. With time, this may reduce even further owing to increased biomat resistance. As a result, it is the biomat itself that regulates the effluent flow into the underlying soil and becomes the controlling variable in wastewater infiltration rates. The greater the resistance, the lower the flow or infiltration rate through the biomat. Research by Orlob and Butler (1955) on five Californian soils concluded that the infiltration capacity of the soil treatment systems was controlled by the nature of the biomat and not the permeability of the soil. Although the biomat penetrates into the soil subsurface, the majority of it is located on the surface of the soil. This leads to reduced permeability, more uniform infiltration and a concomitant unsaturated flow, almost regardless of hydraulic loading (Van Cuyk *et al.*, 2001).

Beal *et al.* (2005) has comprehensively described the three distinct phases of soil clogging (Figure 2.3) leading to the reduction in infiltration rate as observed by fellow authors (Jones and Lee, 1979; Otis, 1984; Siegrist and Boyle, 1987). Phase I of biomat zone development is characterised by a sharp reduction in infiltration rates following effluent application. This can be attributed to several factors, most notably, physical straining of organic materials and suspended particulates contained in the wastewater

which block the soil pores in the infiltrative surface and impede flow rate through to the unsaturated zone below. Phase II offers a more gradual decrease in infiltration rate with biological activity, stimulated by changes to soil conditions created during Phase I, deemed to be the predominant mechanism of clogging (Siegrist and Boyle, 1987; Van Cuyk *et al.*, 2001). The final phase is represented by a low infiltration rate where some researchers have observed an equilibrium state (i.e. a long term acceptance rate, LTAR) to evolve (Beal *et al.*, 2005). Accumulation of clogging materials at the biomat's surface is balanced out by die-off of pathogens and sloughing of clogging material at the bottom (Siegrist, 1987).

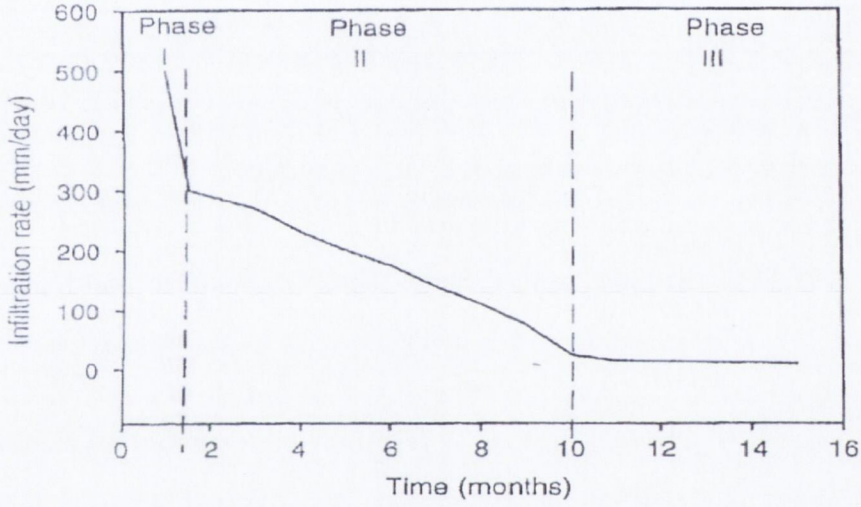


Figure 2.3 Typical schematic pattern of wastewater infiltration rate decline through infiltrative surface over time (Beal *et al.*, 2005 (from Otis, 1984))

If the native sediments are finer-grained than the gravel surrounding the distribution pipe, a 20 to 50 mm thick mat has been seen to occur over time at the infiltrative surface (Anderson *et al.*, 1982 – cited in Wilhelm *et al.*, 1994). However, although unsaturated flow characteristics vary between soils, studies have indicated that the biomat zone acts to regulate the LTAR to within a narrow range, regardless of soil type (Huntzinger Beach and McCray, 2003). This emphasises how closely linked the hydraulic and purification processes are in the biomat and underlying subsoil prior to groundwater recharge.

Biomat development is heavily correlated to wastewater composition. Where a subsoil receives a highly treated effluent (BOD and SS < 20 mg L^{-1}) the development of a biomat will be retarded or absent altogether because the amount of organic matter is

very low. This will have an effect on the infiltration rate with research showing that secondary treated effluent infiltrated at rates 7 – 12 times greater than STE (Loudon *et al.*, 1998). Converse and Tyler (1994) concluded that highly pre-treated wastewaters could be applied at rates 2 – 6 times greater than that recommended for STE and possibly at rates equal to the soil saturated hydraulic conductivity. As a result, biomat genesis must occur to a balanced extent to take advantage of its attenuation capacity without becoming hydraulically too restrictive. If its development is retarded or absent altogether breakdown of pathogens and other constituents of concern may be less than predicted and desired. Conversely, if soil clogging is too excessive, for example due to application of high-strength effluents, clogging can be detrimental by causing hydraulic dysfunction, soil anaerobiosis and reduced treatment (Van Cuyk *et al.*, 2001).

2.3 Subsoil Description and Characteristics

Whilst the importance of the biomat and its inherent properties can not be overstated in terms of the hydraulic and purification performance of the soil treatment system, the characteristics of the underlying percolating medium, namely the soil of the vadose zone, must also be examined in order to predict its capacity to both assimilate and treat the wastewater to an acceptable level.

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 subsoil acts as a filter and protective cap for the underlying aquifer, and therefore is the single most important natural feature influencing groundwater vulnerability and groundwater contamination in Ireland (Department of the Environment and Local Government *et al.*, 1999; Swartz *et al.*, 2003). Subsoils are classified as the 'loose' unlithified sediments present between topsoil and bedrock. 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.

A number of engineering-based methods for subsoil description have been used in other countries which, like Ireland, have significant glacial deposits. These include the Danish Geotechnical Society guidelines, entitled *A Guide to Engineering Geological*

Soil Description (Larson *et al.*, 1995), the *Unified Soil Classification System* (US Bureau of Reclamation, 1998) from the USA, and the *US Department of Agriculture* method for describing topsoils (US Department of Agriculture, Soil Conservation Science, 1993).

The BS5930 method (British Standards Institute, 1981) for describing subsoils was selected in Ireland as a consistent and systematic method of description that also offered the advantage of being widely used by civil engineers and hydrogeologists. With this approach, textural descriptions of fine-grained materials are based on behavioural characteristics, such as plasticity and dilatancy. It also includes a description of the colour, density/compactness, bedding and the presence of discontinuities, where appropriate (Swartz *et al.*, 2003).

2.3.1 Description of Irish Subsoils Under BS5930

Whilst the permeability and thickness of subsoils are the main factors used for determining vulnerability, it is recognised that other material factors such as the particle size distribution, plasticity and dilatancy, and mass factors such as density/compactness, bedding and discontinuities can influence the vulnerability at specific sites.

Particle Size Distribution

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.

Plasticity

Plasticity is the ability of a material to deform, or change shape, without breaking when subject to an external force or pressure. Generally, the more plastic the sample, the higher the clay content of the subsoil, and the lower the permeability. A thread test is carried out on-site during inspection of the trial hole (see Section 4.2.2) to examine the soil plasticity. In summary, the longer a thread (~3 mm in diameter) can be rolled, and

the more pressure it takes to break this thread (like 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 none. 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 the most obvious and easily determined of subsoil characteristics. It can often help in assessing the wetness of subsoil, which is related to the permeability and groundwater situation at a site when used in conjunction with the texture. In general, soils that are well aerated will give a red/brown colour owing to the oxidation of iron to its highest state (Fe^{+3}). Subsoils that are saturated and consequently devoid of oxygen (anaerobic) usually have a grey colour owing to the reduction of iron by bacteria to Fe^{2+}, a non-colour state. Subsoils that have fluctuating wetness conditions, where it is saturated in winter and spring and well aerated in the summer and autumn, develop a distinctive blotchy colour pattern of mixed rust colours and grey colour that is termed 'mottling' Finally, subsoils containing peat or organic matter usually have a dark or blackish colour (Swartz, 1999).

Density/Compactness

The density or compactness of a subsoil affects the permeability and percolation rate. Clearly, the more dense or compact a particular sediment is, the more compressed the pore spaces are, and the lower the relative percolation rate.

Discontinuities

Discontinuities are macropores in the subsoil such as fractures or cracks, which provide a preferential path 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.

Bedding

Far from being a uniform matrix, subsoils often contain beds, laminations or lenses of different sediments (O'Súilleabháin, 2004). This heterogeneity can have a far-reaching impact on water and contaminant movement in the subsurface. For instance, a bed of low permeability clayey sediment in an otherwise coarse grained sediment could hinder the vertical migration of particular contaminants of concern (e.g. pathogens) in the percolating effluent.

2.3.2 Assessment of Subsoil Permeability

Whilst the physical characteristics of the soil provide a useful indication of its behaviour under hydraulic loading, a more vigorous approach is required to accurately measure its permeability. As such, a percolation test is carried out to ascertain the suitability of soil to receive wastewater effluent. In essence, it determines the hydraulic assimilation capacity or permeability of the subsoil surrounding the base of the percolation trench under saturated conditions and provides a route to establishing the LTAR.

The LTAR (in units L m^{-2} d^{-1}), itself, is defined as the amount of pre-treated effluent which the system can infiltrate during its lifetime without water logging or clogging, and is very much based on the measured saturated hydraulic conductivity of the soil. There are a multitude of options available to determine the permeability of a subsoil: a tube permeameter test (k) where a sample of undisturbed soil is taken back to the laboratory for testing under controlled falling head conditions; and two percolation tests carried out in-situ - a falling head test (k_N), and a constant head test (k_C) (Gill, 2007). The relationships between the various permeability coefficients determined by these tests, their subsoil characteristics and the LTAR have been set out in CEN 12566, a seven-part series of European standards on small wastewater treatment systems being

prepared by the European Standards Committee (CEN 2005a, b, c), and are summarised in Table 2.1.

Table 2.1 Relations between *k*-values and LTAR (CEN 2005a)

SOIL TYPE	k m d^{-1} (m s^{-1})	k_N m d^{-1}	k_C m d^{-1}	LTAR (L $m^{-2}d^{-1}$)
Medium & coarse gravel	> 100 (> 1 x 10^{-3})	> 12	n/a	Direct infiltration not permitted
Mixtures of fine gravel & coarse sand	1 to 100 (1x10^{-5} to 1x10^{-3})	0.8 to 12	1.5 to 12	20 to 50
Fine or silty sand or till	0.5 to 10 (6x10^{-6} to 1x10^{-4})	0.6 to 2	0.5 to 1.2	15 to 30
Silt or sandy silt	0.1 to 1 (1x10^{-7} to 1x10^{-5})	0.4 to 0.8	0.15 to 0.5	10 to 15
Silty clay loam	0.01 to 0.1 (1x10^{-7} to 1x10^{-6})	0.1 to 0.4	0.15	10
Silty clay or clay	< 0.001 (< 1x10^{-8})	< 0.1	< 0.15	Direct infiltration not possible

Each test therefore produces its own distinct hydraulic conductivity scale depending on the type of test carried out. In Ireland, however, the EPA have adopted an in-situ "T-test" which is of the same form as the falling head test but does not express the percolation value in terms of a hydraulic conductivity. Instead, it calculates the time for water to drop 25 mm in two pre-soaked, 300 mm square holes, 400 mm deep below the invert level of the proposed percolation pipe. A more detailed outline of the test procedure is presented later in Section 4.2.2.

Research carried out by Mulqueen and Rodgers (2001) on the Irish T-test procedure concluded that it would be more rigorous to convert the T-values into field saturated hydraulic conductivity (k_{fs}) values. This approach was adopted because, while percolation times recorded in consecutive T-tests in the same hole increased, k_{fs} values remain relatively constant. It was therefore felt that k_{fs} was a better measure of the suitability of soils for percolation. The k_{fs} is then expressed as the inverse of the

percolation rate times a constant, thus allowing the percolation rate from the T-test to be directly related to the k_{fs} of the soil (Gill, 2008). This relationship is expressed in Eqn. 2.3 and assumes a value of $\alpha = 12$ m^{-1} for soils suitable for percolating septic tank effluent, where $\alpha = k_{fs} / \Phi_m$.

$$k_{fs} = \frac{4.2}{t_m} \quad (m\ d^{-1}) \qquad \text{Eqn. 2.3}$$

where t_m is the T-value (i.e. average time to fall 25mm).

Hence, Gill (2007) has provided a comparison between a range of T-values, field saturated hydraulic conductivities (k_{fs}) and CEN falling head percolation test permeability coefficients (k_N) (Table 2.2).

Table 2.2 Comparison between T-values, field saturated hydraulic conductivities (k_{fs}) and CEN falling head percolation test permeability coefficients (k_N) (adapted from Gill, 2008)

T-value	k_{fs} [0.3 x 0.3 hole] ($m\ d^{-1}$)	k_N ($m\ d^{-1}$)
1	4.2	12.58
20	0.21	0.63
50	0.084	0.25
70	0.06	0.18
90	0.0467	0.14

Further research, involving an in-depth examination of over 400 percolation tests in Ireland, was then carried out by Jackson (2005) to compare the range of measured T-values and typical Irish subsoil types, classified according to BS5930 (1981). The respective T-value ranges were then converted into equivalent k_N permeabilities which can also be compared against the soil types (Table 2.3). For the purposes of this project, subsoils with T-values of between 1 and 5 were sought which, according to Eqn. 2.3, equates to $4.2 \leq k_{fs} \leq 0.84$ and $12.58 \leq k_N \leq 2.52$.

Table 2.3 Subsoil classification against T-values for 400 Irish T-tests (Jackson, 2005)

BS5930 Soil classification	T-value (inter-quartile range)	k_N (m d^{-1})
GRAVEL	3 to 10	4.2 to 1.26
SAND	4 to 15	3.15 to 0.84
SILT	12 to 33	1.05 to 0.38
SILT / CLAY	12 to 43	1.05 to 0.29
CLAY	37 to 76	0.34 to 0.17

2.3.3 Background to Irish Subsoils

Most Irish soils are derived from glacial drift and are relatively young in age. They are derived from the Quaternary period, the shortest and most recent geological period covering the last 1.6 million years of the Earth's history. This epoch started at a time of global cooling in northern Europe, marking the onset of what is commonly known as the Ice Age. The action of the ice sheets put the final shape on the Irish landscape, providing the parent material for more than 90% of our mineral soils covering much of the bedrock surface with up to 50 m in thickness of tills and gravels. These subsoils play an important role in the underground part of the hydrological cycle, either as aquifers or in the way they affect water percolating into underlying rock aquifers.

Irish soils are very varied in type, differing not only between one part of the country and another, but sometimes even within a single field. The main subsoil groups dominating the landscape of Ireland are:

- Tills
- Glaciofluvial sands and gravels
- Glaciolacustrine deposits
- Alluvium
- Peat

Till, otherwise known as boulder clay, is the most common and widespread Quaternary subsoil type. It is often tightly packed, unsorted, unbedded, possessing many different particle and clast sizes and types which are often angular and subangular.

The Quaternary deposits of highest permeability are the various types of sands and gravels, namely *glaciofluvial sands and gravels* and esker sands and gravels. These were deposited by running water as the ice sheets began to melt and decay. Where these deposits are sufficiently thick, extensive, saturated and clean, they are considered to be aquifers in their own right. Where these deposits are not sufficiently extensive, or perhaps saturated, they are still important as they allow a high proportion of recharge water to enter an underlying rock aquifer with which they are in hydraulic continuity. It is these regions that most of the important sand and gravel aquifers have been located and are likely to be located in the future (Daly, 1985).

Glaciolacustrine deposits consist of sorted gravel, sand silt and clay and are normally found in wide flat plains, or in small depressions in the landscape.

Alluvium is a product of river flow and flooding and is usually of sand/silt grade. It may however contain gravel beds depending on its location. Because it occurs in river flood plains alluvium is not frequently encountered in septic tank installation, however any house built close to a river may be close enough to the flood plain for it to be considered as a potential site for an on-site wastewater treatment system.

The onset of the warmer postglacial period (about 14 000 years ago) saw the disintegration of the ice sheets and the initiation of *peat* development in the many lake basins predominating the landscape. Extensive peat formation consists mostly of vegetation which has only partially decomposed and reflects excessively moist conditions. In Ireland, peat usually overlies badly drained glaciolacustrine silts and clays.

2.4 Factors and Processes Affecting Subsoil Treatment Performance

2.4.1 Physical Factors and Processes

(i) Permeability

For effective treatment of STE by the subsoil the permeability of the porous medium is critical as it aids in controlling the flow of the percolating effluent and thus contact time between the STE and soil particles and associated biofilms. Laminar flow through a

homogeneous isotropic saturated or unsaturated soil is described by Darcy's law (Domenico and Schwartz, 1998):

$$v = -k\frac{dh}{dl} \qquad \text{(Eqn. 2.3)}$$

where, v = the volumetric flow rate per unit surface area (m s^{-1})

k = the hydraulic conductivity (m s^{-1})

$\frac{dh}{dl}$ = the hydraulic gradient

For convective transport of pollutants in the subsoil, the linear velocity of the water rather than the Darcy velocity should be considered (Bouwer, 1984). The linear seepage of water in a porous medium can be approximated as:

$$v_m = \frac{v}{n_e} \qquad \text{(Eqn. 2.4)}$$

where, v_m = linear seepage (m s^{-1})

v = Darcy velocity (m s^{-1})

n_e = effective porosity, i.e. the porosity available for fluid flow

The hydraulic conductivity, which may be considered as a measure of the ease with which liquid flows through a given medium, is dependent both upon the physical properties of the flowing liquid and the characteristics of the transmitting medium. The physical properties of STE, i.e. viscosity, density and specific weight, are practically constant, so the hydraulic conductivity may be considered as a function of the permeability of the medium alone. The main soil properties that affect permeability are its degree of saturation and subsoil geometry.

Unsaturated flow through the vadose zone, i.e. between the percolation trenches and groundwater table, is crucial in downward movement and attenuation of microbial and chemical pollutants. These unsaturated conditions, essential in terms of residence time of the STE and promotion of an aerobic environment for treatment processes, can be achieved by the application of a suitable loading rate in the percolation trenches which

is a minute fraction of the soil's saturated hydraulic conductivity. In the saturated zone, the driving force for groundwater flow is hydraulic head, defined as the sum of the elevation head and the pressure head. When a soil is saturated, all of the pores are water-filled, pressure head is positive and conductivity is maximal. When the soil dries out some of the pores become air-filled and thus the conductive portion of the soil's cross-sectional area diminishes. These air-filled pores are assumed to act like solid particles inhibiting fluid flow (Hillel, 1998). As desaturation develops, the first pores to empty are the largest ones, thus confining flow to the smaller less conductive pores. These large empty pores must then be circumvented by the percolating fluid increasing flow path tortuosity. Thus, it is essential to remember that while Darcy's law can be used to describe flow in the unsaturated subsoil, the unsaturated hydraulic conductivity, $K\theta_v$, is not constant. Furthermore, under unsaturated conditions the pressure heads are less than atmospheric, i.e. water is held in suction – capillary forces bind water to the soil particles, and effluent flow, therefore, may occur either as film creep along the walls of wide pores or as tube flow through narrow water-filled pores. The closer proximity of the STE to the solid phase in the unsaturated material and the longer residence time can be expected to enhance removal of pathogens and chemicals from the percolating fluid.

Although there is not a universally accepted working relationship between grain-size and permeability, widespread research (Hazen, 1892; Loudon, 1952; Norris and Fidler, 1965; Masch and Denny, 1966; Summers and Weber, 1984; Shepherd, 1989; Schuh and Cline, 1990; Alyamani and Sen, 1993) has shown that a strong correlation exists between permeability and some representative grain diameter. While permeability of coarse gained sediments is greater than fine grain sediments, all other things being equal, grain-size alone does not dictate the permeability of the sediment as orientation of the particles, degree of sorting within the sediment and presence of preferential flow paths also have an effect. Research has shown that the permeability generally decreases for poorly sorted sediments (Hazen, 1892; Fraser, 1935; Carman, 1939; Krumbein and Monk, 1942; Beard and Weyl, 1973). It must be noted with respect to unsaturated flow, however, that at low volumetric water contents the relationships that hold true in saturated flow may be invalid. For example, at lower volumetric water contents, coarse materials may have very few saturated pores and could thus have a lower unsaturated

hydraulic conductivity than finer grained sediments which would have more saturated pores (Fetter, 1994).

(ii) Filtration

Particle size distribution also plays an important part in the removal of suspended solids, including bacteria, from the STE by acting as an effluent filter. There are three filtration mechanisms (McDowell-Boyer *et al.*, 1986):

- *Surface Filtration* – occurs at soil surface when particles are too large to penetrate the soil resulting in biomat formation,
- *Straining* – particles small enough to enter the soil pores are removed by mechanical straining as the effluent percolates through the subsoil,
- *Physico-Chemical Filtration* - this occurs when very small particles, i.e. where the ratio of soil grain diameter to that of the particulate is greater than twenty, are retained if the attractive forces predominate when the particles collide with the soil.

Siegrist *et al.* (2000) refer to research by Updegraff (1983) who found that straining becomes an effective mechanism when the average cell size is greater than the grain size d_5 (d_5 is the particle diameter at which 5% of the particles in mass are smaller). Hagedorn (1984) reports that bacterial travel is limited by physical straining or filtration, with the degree of retention inversely proportional to the particle size of the soil. However, Johnson and Atwater (1988) report on a study which found that a coarser–textured sand is just as effective overall as a loamy sand in removing coliform bacteria, although the fine-textured material is more effective in the first 150 mm. Filtering starts with the trapping of the larger suspended particles at the surface or at some depth. Individual particles may be blocked in the pores or several particles may interact to form a bridge in the pore that prevents further movement of these particles in the direction of flow. Once movement of the larger suspended particles has been blocked, these particles themselves begin to function as a filter and trap successively smaller suspended particles (Canter and Knox, 1985). Bouwer (1984) reported that bridging occurred when the diameter of the suspended particle was larger than 0.2 times the diameter of the particles constituting the porous medium. Depending on how particles in the porous medium were packed, bridging also occurred if the diameter of

the suspended material was more than 0.07 times that of the particles in the medium. When the size of the suspended particles was less than 0.07 times the particle size of the medium, the suspended particles moved through the medium without bridging or blocking.

2.4.2 Chemical Factors and Processes

Adsorption and Ion Exchange

Adsorption is the physical and/or chemical process in which a substance accumulates at a solid-liquid interface (Mihelcic, 1999). It is a key factor in the removal of phosphates, ammonium, organic compounds, bacteria and viruses from STE. Adsorption is particularly important in soils that contain clay as the very small size of clay particles, their generally platy shapes and the occurrence of large surface area per given volume make them ideal sorption sites (Gerba and Bitton, 1984). The presence of iron (Fe), aluminium (Al) and hydrous oxides coating the subsoil clay minerals and coating on the weathered surfaces of ferromagnesium minerals also provides excellent sorption sites (Miller and Wolf, 1975). The process results from the differential forces of attraction or repulsion occurring among molecules or ions of different phases at their exposed surfaces (Hillel, 1998). A chemical species passes from one bulk phase to the surface of another where it accumulates without penetrating the structure of this second phase. Desorption refers to the reverse of this process where the chemical species breaks free from the mineral surface. Because adsorption removes contaminants from the percolate, even if only temporarily, it acts to slow the movement of the contaminant through the subsoil. The term 'retardation' has thus been commonly used to describe the effects of contaminant adsorption. On the other hand, the movement of micro organisms through soil and the subsurface has been observed to rapidly increase following rainfall events through desorption (Gerba & Bitton, 1984). It is important to make the distinction between adsorption, which is a superficial attachment or repulsion, and absorption, which involves the transfer of a molecule from one phase to another, via their interface, resulting in the alteration of the composition of the second phase (O'Súilleabháin, 2004).

Clay particles are of colloidal nature and, when dry, neutralising counter-ions are attached to their surfaces. When wetted, they display negatively charged surfaces that

attract and adsorb cations (Bouwer, 1984). The cations of the electrostatic double layer created in the process can be replaced by other cations in the STE. This process is called cation exchange and may be regarded as a form of adsorption (adsorption mainly applies to organic compounds while ion exchange applies to inorganic compounds). The smaller the cation and the higher its charge, the more strongly it is adsorbed and the more readily it replaces more weakly held cations (Bouwer, 1984). Of the more common cations in soil systems, Li^+ is the most weakly held, followed in order of increasing bond strength by Na^+, H^+, NH_4^+, Mg^{2+}, Ca^{2+} and Al^{3+}. Cation exchange reactions are rapid and reversible; therefore, the composition of the exchange complex responds to frequent changes in the composition and concentration of a percolating solution (Hillel, 1998).

Precipitation

Precipitation is the separation of an insoluble product when two solutions are mixed together. It occurs in soils when the soluble orthophosphate (PO_4^{3-}) present in the percolating STE, or sorbed onto soil colloids, react with ions in the soil solution. The efficiency of this precipitation process, described as phosphate fixation, depends on the cations present and the soil pH. In strongly acidic soils, there are sufficient aluminium, iron and manganese ions in solution to cause the precipitation of all dissolved phosphate ions. Zanini *et al.* (1998) report that constant nitrification also generates acidity which can increase the number of cations present. In alkaline soils, phosphates react quickly with calcium to form a sequence of products of decreasing solubility, e.g. phosphate can react with calcium carbonate to form monocalcium phosphate, dicalcium phosphate and then tricalcium phosphate which is less soluble.

2.4.3 Biological Factors and Processes

Organic Matter Decomposition

Microbial decomposition of organic matter under the infiltrative surface of the vadose zone proceeds most rapidly in the aerobic pockets where micro organisms in the subsoil use oxygen as their terminal electron acceptor to convert the organic molecules in the STE to carbon dioxide, water and energy production. This is represented by:

$$(CH_2O) + O_2 \Rightarrow CO_2 + H_2O + energy \qquad \text{(Eqn. 2.1)}$$

Oxygen is supplied to the vadose zone by diffusion in the soil atmosphere. Insufficient supply of oxygen to this group of bacteria will greatly reduce the performance of aerobic biological oxidation. However, if the oxygen supply is not limited, aerobic degradation will be governed by the amount of active organic matter available to the organisms. As aerobic micro organisms cannot function in localised anaerobic zones within the subsoil treatment system, anaerobic or facultative organisms, such as methanogenic bacteria, become dominant. Anaerobic decomposition involves the degradation of insoluble organic compounds, in the absence of oxygen, to carbon dioxide and methane with only a small amount of bacterial growth. The process is generally considered as a two-phase process, the *non-methanogenic* phase followed by a *methanogenic* phase. It is more accurate, however, to describe the process as being comprised of three discrete stages:

(i) Hydrolosis — conversion of the biodegradable particulate matter (proteins, fats, polysaccharides) in the STE to its soluble form by the heterogeneous group of facultative and obligate (anaerobic) hydrolytic bacteria.

(ii) Acidogenesis — conversion of the hydrolysed substrate to organic acids and alcohols, hydrogen and carbon dioxide by facultative and obligate acidogenic and acetogenic bacteria.

(iii) Methanogenesis — conversion of the end-products of acid fermentation (acetate, hydrogen and carbon dioxide) to gases, mainly methane and carbon dioxide, by several different species of obligate methanogenic bacteria.

The methanogenic micro organisms grow at a much slower rate than the acidogenic and acetogenic type (Gray, 1994). This difference in growth rate, linked with a greater sensitivity to environmental factors, results in the methanogenic bacteria becoming the major factor controlling the overall rate of anaerobic decomposition.

Mineralisation, Nitrification and Denitrification

As described earlier in Section 2.2.1, the nitrogen content in STE is typically 70% to 90% ammonium and 10% to 30% organic nitrogen (Lance, 1972; Gold and Sims,

2000). Organic nitrogen contains amine groups that are broken down by soil micro organisms by a process called mineralisation into simple amino compounds, which are then hydrolised, releasing nitrogen in the form of ammonium (NH_4^+). At a shallow depth in most subsoils, the ammonium concentration in the STE will quickly convert to nitrite (NO_2^-) before transforming to nitrate (NO_3^-). Nitrification ($NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$) is an aerobic reaction performed primarily by obligate autotrophic organisms and NO_3^- is the predominant end product (Bouma, 1979). The process is dependent on soil characteristics, percolation rate, loading rate, distance to bedrock, and distance to groundwater. Furthermore, Van Buuren *et al.*, 1999) states that nitrification can be limited by low temperatures or by lack of alkalinity. The process can be split into steps, the first of which involves the conversion of NH_4^+ to NO_2^- by *Nitrosomonas* bacteria, a specific group of autotrophic bacteria. This reaction is followed sharply by the transformation of NO_2^- to NO_3^- by another group of autrotrophic bacteria, *Nitrobacter*, resulting in a net increase in pH owing to the production of hydrogen ions (H^+).

Denitrification is another important nitrogen transformation in the subsurface environment underlying the percolation area. If the percolate enters an anaerobic pocket, or zone of reduced oxygen concentration, accompanied by appropriate bacteria and a supply of readily available carbon in the form of organic substrate, it will denitrify. The biological process involved, in which NO_3^- is converted to either nitrous oxide gas (N_2O), nitric oxide gas (NO) or nitrogen gas (N_2) is performed primarily by ubiquitous facultative heterotrophs which use NO_3^- as an electron acceptor in the absence of oxygen. The proportion of the three main gaseous products seems to be dependent on the prevalent pH, temperature, degree of oxygen depletion, and concentration of NO_3^- and NO_2^- ions (Brady and Weil, 2002). N_2 is generally produced under anaerobic conditions while under conditions of low pH, reduced oxygen and high NO_2^- and NO_3^-, it is generally NO and N_2 that are produced. Accordingly, denitrification is the only mechanism by which the NO_3^- concentration in the oxidised percolate can be decreased (Canter and Knox, 1985).

2.5 Fate and Transport of Key Pollutant Groups in the Vadose Zone

2.5.1 Organic Chemicals and Suspended Solids

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. Volatilisation and adsorption, followed by microbial degradation, are the main processes for removal of soluble biodegradable organic chemicals (Siegrist *et al.*, 2000). Suspended solids, including organic and mineral matter, can be removed through a combination of physical straining and biological degradation processes (Reed *et al.*, 1995). The large surface area of soil particles also provides a great potential for biofilm development which is largely responsible for straining and trapping the biodegradable organic chemicals of the STE at the infiltrative surface. 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). In a field study of two sites, O'Súilleabháin (2004) recorded a mean COD load reduction of 82% between the septic tank and a depth of 0.3 m in the unsaturated subsoil below the infiltrative surface. The study suggests that COD attenuation occurred within the distribution gravel of the percolation trench rather than the subsoil. Pell and Nyberg (1989) reported maximum efficiency with respect to removal of organic matter as early as 2 to 3 weeks from the onset of system operation. Others report a period of 2 to 3 months before the biological degradation potential is fully developed (Van Cuyk *et al.*, 2001). When viewed over their long service lives though, most onsite wastewater treatment systems can be expected to reliably achieve very high removal of organic chemicals and SS (Effert *et al.*, 1985; Soltman, 1990).

2.5.2 Nitrogen

Several factors influence how effectively nitrogen is assimilated in the subsoil environment of the vadose zone. The redox status, soil microbial composition, and a source of organic C are the key aspects that determine the degree of TN removal in subsoil treatment systems (Wilhelm *et al.*, 1994). Nitrogen removal mechanisms during subsoil treatment include mineralisation, volatilisation, cation exchange, incorporation into microbial biomass, nitrification, denitrification and matrix adsorption. 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). The two forms of nitrogen that are of concern to the contamination of groundwater and surface waters 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 (Harman *et al.*, 1996).

Ammonium is the main form of N in STE which is discharged to the percolation area for subsoil treatment. 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 exchange sites available in the subsoil (O'Súilleabháin 2004). It can be difficult to quantify NH_4-N retention as it can be masked by oxidation and other interactions (Wilhelm *et al.*, 1994), but some experiments have demonstrated that as high as 50 – 85% of fixed ammonium may be unavailable or only slowly available to nitrifiers (Nommik and Vahtras, 1982).

Under the aerobic conditions of the subsoil treatment system ammonium will undergo nitrification. Autotrophic bacteria in the subsoil use O_2 as the electron acceptor in the oxidation of NH_4-N to NO_3-N. In general, near complete nitrification should be achieved in properly installed systems with the process normally occuring very rapidly within the first 0.3m of soil below the infiltrative surface (Siegrist *et al.*, 2000). However, 1 – 2 months are required from the onset of effluent infiltration to generate a full population of nitrifiers (Pell and Nyberg, 1989; Van Cuyk *et al.*, 2001). Swift conversion to NO_3-N is thought to occur once the effluent infiltrates into the unsaturated, aerobic zone underlying the biomat (Aravena *et al.*, 1993; Wilhelm et al., 1994). Whelan and Barrow (1984) found that nitrification was inhibited by the

anaerobic state of the biomat layer, but once the effluent passed through the biomat, nitrification was almost complete within half a metre. Others described similar results with virtually complete nitrification occurring within a few centimetres of the bottom of the biomat zone (Cogger *et al.*, 1988; Pell and Nyberg, 1989; Gerritse *et al.*, 1995). 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 NO_3-N L^{-1} in the tank to less than 1 mg NO_3-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. 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.

In the absence of oxygen, nitrate can be lost from the system by denitrification if a sufficient supply of organic C is available. However, removal of nitrate is not efficient in the aerobic, low C soil conditions of the vadose zone, as these conditions inhibit denitrification and subsequent gaseous loss of N. Optimal conditions for this process are generally limited, therefore, to small anaerobic pockets in the unsaturated subsoil or the biomat itself; hence, TN removal is generally low in the subsoil environment ranging from 10 – 20% (Siegrist and Jenssen, 1989; Wilhelm *et al.*, 1994; Converse, 1999). There is some evidence though to suggest removal of TN can occur. Cromer (2001) reported markedly reduced nitrate concentrations within 10 – 20 m from the percolation trench located in a sandy soil in Hobart, Tasmania. Gerritse *et al.* (1995), using a mass balance of inorganic N and bromide, reported ~80% of N to have been lost within 10 m of travel in sandy soil in Perth, Western Australia. They concluded that N additions to catchment waterways were originating to a much greater extent from agricultural sources compared to non-sewered areas.

In general though, loss of N during subsoil treatment is usually poor and elevated nitrate concentrations in groundwater associated with onsite wastewater treatment systems have been well documented. Tracer experiments have revealed that nitrate, with detected concentrations exceeding the drinking water standard of 10 mg L^{-1} as N (Converse *et al.*, 1994; Anderson *et al.*, 1994), can travel in aquifers underlying the

percolation area in relatively well-defined, narrow plumes which have been recorded to be up to 130 m in length (Robertson *et al.*, 1991) but may extend up to 200 m (Valiela *et al.*, 1997).

2.5.3 Phosphorus

The main forms of P in STE are 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 form. The organic phosphorus in the effluent can be subject to mineralisation, in a way similar to organic nitrogen, resulting in the production of soluble inorganic phosphate (Brady and Weil, 2002). The geochemical mechanisms influencing the availability of P in and below the subsoil treatment system are adsorption/desorption, precipitation/dissolution, and biological immobilisation (Beal *et al.*, 2005). Most studies indicate, however, that effective P immobilisation occurs in the soil (including those that are coarse-textured) within a few metres of the percolation trench and significant movement of P is therefore rare (Reneau *et al.*, 1989; Robertson and Harman, 1999). Of course there are exceptions, with some research identifying leaching of P to groundwater in areas with sandy soil and shallow water tables and in phosphorus saturated soils (Breeuwsma *et al.*, 1995).

While the role of the biomat on P removal is poorly understood, clearly some retention of P would occur during the development phase of the biomat zone (Beal *et al.*, 2005). Phosphate removal is certainly indirectly influenced by the biomat, if not directly. Sub-biomat soil conditions such as redox and pH, which are important in P retention processes, are manipulated substantially by the extent of biomat development at the infiltrative surface. Magdoff *et al.* (1974) found greater P removal in soil columns with well-developed biomats compared with columns with poorly developed or absent biomats. Changes to pH conditions in, and just below the biomat, were suggested as one factor contributing to this difference.

Phosphate attenuation in the subsurface environment is generally controlled by soil adsorption and mineral precipitation reactions which can be considered in two general categories: initial adsorption reactions and much slower precipitation reactions that regenerate additional adsorptive surfaces occurring both from phosphate in solution and

from phosphate previously sorbed (Lance, 1984). It is more strongly retained by the soil matrix under conditions of high pH and oxidation status. In acidic soils, reactions that fix phosphorus involve mostly Al, Fe or Mn, either as dissolved ions, as oxides, or as hydrous oxides. In alkaline and calcareous soils, the reactions primarily involve precipitation, or adsorption to the iron impurities on the surfaces of carbonates and clays. At moderate pH values, adsorption to the edges of kaolinite or on the iron oxide coating on kaolinite clays plays an important role (Brady and Weil, 2002). Arias *et al.* (2001) report 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. At lower pH levels, they suggest that precipitation as Fe and Al phosphates becomes increasingly important. It is clear, therefore, that the capacity of soil to fix phosphate is dependent on the presence of Fe, Al, Mn and Ca.

The sorption capacity of soils with respect to phosphorus varies greatly. With regard to a porous medium, the potential for P-sorption is dependent on the mineral composition, which determines the metal types and content, and the degree of weathering of the particle surfaces, which renders the metals in an oxide or hydrous state where they are able to react with phosphorus compounds (Jenssen, 2001). It is further suggested in the study that a quartz sand receiving STE would probably become saturated after a few months while the sorption capacity of a weathered sand or fine grained soil may hold for a period of 10 years or more. Initial P-removal efficiency is often high but then decreases after some time as the P-sorption capacity of the sand is used up. Calcareous sands have been reported to have a good ability to retain P via rapid sorption then slow precipitation of phosphate with calcium to form amorphous crystalline minerals (Wilhelm *et al.*, 1994). As a result most of the phosphorus in the STE was removed in the first three months after leaving the septic tank. Phosphate attenuation on noncalcareous sites monitored by Robertson (2003) appeared to be as a direct result of the development of acidic conditions and elevated Al concentrations which subsequently caused the precipitation of Al-P minerals. 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 unlimited capacity to fix phosphate, provided that the solution and soil chemistry is conducive 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 table would have been seen to increase as sorption sites were used up.

2.5.4 Pathogens

While organic matter, ammoniacal compounds and a variety of toxic chemicals are all undesirable substances found in significant amounts in STE, it is its biological constituents, namely pathogenic bacteria, infectious viruses and protozoa that are potentially the greatest risk to groundwater contamination. With an estimated 200,000 wells and springs in use in Ireland (Wright, 1999), the survival of pathogens under unsaturated and saturated conditions is a major concern in the protection of groundwater resources. In addition, private household wells may be more vulnerable to microbiological contamination as they are, in general, less carefully maintained and tested less frequently for water sanitary quality. Moreover, although minimum setback distances between a household well and the closest septic tank system have been regulated, the total number of these systems surrounding a household may still result in substantial loading of human faecal wastes in proximity of a well.

The term pathogenic is applied to those organisms that either produce or are involved in the production of a disease. STE contains many different types of micro organisms, the majority of which are enteric in origin; that is, they are excreted in faecal matter, contaminate the environment and then gain access to new hosts through ingestion (i.e. the faecal-oral route) with the potential to cause disease.

Waterborne pathogens can be classified broadly into five groups of micro organisms 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. Macler and Merckle (2000) have suggested there are over 100 different pathogenic species that have the potential to contaminate groundwater. Efficiency of pathogen removal for an optimally functioning on-site wastewater treatment system may reach 9 $\log_{10}$ (99.9999999%) (Scandura and Sobsey, 1997). The large size of helmith ova would most likely retard their movement with water in a soil-pore matrix (Burge and Marsh, 1978) and, as such, these microbes are recognised to be of little concern to the pollution of ground waters from onsite wastewater treatment systems. Public health-concerns surrounding waterborne disease have instead concentrated upon the potential impact of viral, bacterial and protozoan species. Of the three, bacteria and viruses are thought to pose the greatest contaminant threat to groundwater, with their ability to migrate significant distances in the subsurface initiating significant health risks and promoting potential outbreaks of waterborne disease. Each organism has different characteristics and different resistances to environmental settings and features (Table 2.1), all of which will be discussed.

Table 2.1 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

Bacteria

Bacteria are the most numerous of the microbial pathogens found in domestic wastewater (Pepper *et al*, 1996). They are single-cell prokaryotic (devoid of a nuclear membrane) organisms, and contain a colloidal suspension of proteins, carbohydrates and a cytoplasm of RNA and DNA.

Three indicator groups are normally used to indicate faecal contamination; *Escherichia coli* or faecal coliforms, faecal streptococci, and *Clostridium prefringens.* The latter is the least common indicator used in domestic wastewater analysis. In general, when *E.*

coli and faecal streptococci are absent, the presence of *Clostridium prefringens* indicates remote or intermittent pollution (Gray, 1994). While coliform bacteria are indicator organisms of faecal contamination and possible presence of pathogens, it is widely accepted that the group is diverse and that some genera also exist as normal inhabitants in water and soil (growing and reproducing on organic matter), which have not been impacted by faecal pollution (Viessmann & Hammer, 1993, Stevens *et al.*, 2003). Consequently, despite its continued widespread use as a bacterial indicator, doubts persist surrounding the suitability and accuracy level of total coliforms (TC). Accordingly, of more value is identifying those coliforms that are exclusively faecal in nature. Due to its well known growth characteristics and behaviour in the environment, *E. coli* has become the mainstay bacterial indicator in the water industry. Its presence in a water sample is taken as a specific indicator of faecal contamination and the possible presence of enteric pathogens. In terms of survival, *E. coli* can live for several weeks under ideal conditions and are far more easily detected than the other indicator bacteria. The drawback, however, is that viruses, protozoal cysts and helminth eggs are more persistent and thus other methods are required for their determination (Viessman and Hammer, 1993).

A number of sources report the level of faecal coliforms in STE at $10^6 - 10^8$ MPN 100 mL^{-1}. In a study of selected faecal bacterial populations in septic tank effluents from five systems, Ziebell *et al.* (1974) observed mean population densities of 3.4×10^6 100 mL^{-1} for total coliforms, 4.2×10^5 100 mL^{-1} for fecal coliforms and 3.8×10^3 100 mL^{-1} for faecal streptococci.

Reduction in bacterial concentrations following addition of STE to the underlying soil of the percolation area is dependent upon a number of factors including flow conditions, survival rates of the microbes, temperature of the soil environment, soil moisture content, soil pH, extent of biomat development, sunlight, particle size distribution and degree of soil structure. These factors, the most important of which will be discussed in more detail, and their influence on the fate of bacterial organisms in the subsoil are summarised in Table 2.2.

Table 2.2 Factors Affecting Survival of Enteric Bacteria in Soil (adapted from Cronin & Pedley, 2002; Gerba *et al.*, 1975)

Factor	Influence on Survival	Influence on Migration
Moisture Content	Greater survival time in moist soils and during times of high rainfall	Bacterial migration usually increases under saturated flow conditions
Temperature	Longer survival at low temperatures; longer survival in winter than in summer	Unknown
Microbial Activity	The presence of indigenous micro organisms appears to reduce the survival time of enteric bacteria. Possible synergism with some protozoa may extend survival times	Unknown
pH	Shorter survival time in acid soils (pH 3-5) than in alkaline soil. Most enteric bacteria will survive the longest at near neutral pH	Low pH will encourage adsorption to soils and the aquifer matrix. The tendency of bacteria to bind to surfaces may reduce the risk of desorption at high pH
Organic Matter	The presence of organic matter may act as a source of nutrients for bacteria, promoting growth and extended survival	Organic matter may condition solid surfaces and promote bacterial adsorption
Sunlight	Shorter survival time at soil surface	Unknown
Association with Soil	Adsorption onto solid surfaces increases survival times	Bacteria interacting with the soil particles are inhibited from migration through the soil matrix
Soil Properties	Probably related to the degree of bacterial adsorption	Greater migration in coarse textured soils ; soils with charged surfaces such as clays adsorb bacteria
Bacteria Type	Different species of bacteria vary in their susceptibility to inactivation by physical, chemical and biological factors	Variation may also occur between strains of the same bacterial species

Flow of the percolate through the unsaturated subsoil of the vadose zone is regarded as vitally important in the downward movement and attenuation of microbial pathogens. Unsaturated flow is critical since this controls contact between wastewater constituents and soil particles and associated biofilms, allowing an adequate period for treatment processes to occur (Van Cuyk *et al.*, 2001). The effluent travels at a slow rate in unsaturated soil, as flow is along a thin and tortuous path along the surface of soil particles (Cave & Kolsky, 1999). The low-velocity of this flow is seen as a crucial factor against faecal pollution in the underlying aquifer. Flow is much more rapid in the

saturated zone, as the effluent flows directly through the soil pores. Thus, a key factor that affects removal and elimination of the key constituents of concern in the percolate is the maximisation of the effluent residence time between the source of contamination and the point of water abstraction (Cave & Kolsky, 1999).

Conditions that contribute to unsaturated flow and the maximisation of effluent residence time include uniform effluent distribution, well (but not too freely) drained soils, moisture deficits, and the development of a biomat layer. The importance of the latter can not be overstated, especially in a highly permeable medium such as sand or gravel, where it is regarded as the first line of defence against the migration of pathogenic organisms in the subsoil.

Ó Suilleabháin (2004) carried out microbiological analysis on two sites with different subsoil permeabilities in County Kildare, Ireland to investigate any variation in bacterial transport in the vadose zone. The first site, whose subsoil varied from sandy CLAY (w/silt) between 0.3 m and 0.9 m, and sandy SILT (w/clay) between 0.9 m and 2.1 m, consisted of a conventional septic tank system (septic tank and percolation area). Results showed almost complete removal of enteric bacteria over the 12-month research period with inactivation/die-off, filtration and adsorption cited as the three main mechanisms for removal. The installation of a secondary treatment peat filter system on the second site greatly reduced the bacterial loading on its percolation area. Despite achieving similarly impressive removal in bacterial concentrations in the subsoil, there was more evidence of faecal contamination, at depth, on this site despite a lower bacterial influent load. Particle size and BS5930 analysis of soil samples taken from the second site showed it to have higher sand and lower fines content, even though it had a higher T-value (i.e. indicating a less permeable medium). It is, therefore, possible that greater grain size, and consequently pore size, facilitated the movement of bacteria through the subsoil. In addition, tracer tests carried out suggested that the reduced organic loading on the trenches of the second site resulting from the installation of the secondary treatment system had inhibited the formation of a biomat along the base of the trenches.

Ziebell *et al.* (1974) also highlighted the microbiological significance of the biomat layer when he noticed a considerable reduction in coliform and streptococcal indicator

bacteria numbers with depth below a percolation trench. Upon dissection of the properly-functioning percolation area located in a sandy soil, indicator bacteria enumerations showed that the high levels of organisms present in the STE were increased approximately fivefold in the soil of the clogged zone at the base of the trench. However, soil samples collected 300 mm lateral to and 80 mm below the trench produced coliform levels 100-fold less than the STE, and samples collected 300 mm lateral to and 380 mm below the trench yielded values 3 000-fold less than in the STE.

Tare and Bokil (1982) examined the effect of various particle size distributions on removal of bacteria in columns from 75 to 750 mm in length. Sand, silt and clay particles were mixed at various ratios from 0 to 100% sand. Bacterial attenuation was greatest in mixtures with higher percentages of clay and silt particles. It was concluded that a mixture of 40% < 75μm and 60% > 75 μm soil particles was the most efficient mixture for attenuation of bacteria.

Bitton *et al.* (1974) examined movement of two strains of *klebsiella aerogenes* in 20 mm diameter, 115 mm long soil columns. Columns were filled with four soils ranging in particle size distributions from 90% sand to 58% clay. Different bacteria strains displayed different degrees of retention while sandy soils were shown to be less efficient in bacteria removal than soils with higher clay contents. The highest degree of bacterial attenuation occurred at lower pH values, while soil water content was positively correlated with depth in which the bacteria moved. It was anticipated that both adsorption and filtering of bacteria were occurring.

Several studies have shown relationships between bacterial survival and temperature, or soil moisture content. Kibbey *et al.* (1978) examined the survival of *faecal streptococci* in five soils under various soil moisture contents and temperatures. Soil moisture contents ranged from saturation to air-dried, while temperatures ranged from 4 to 37 °C. Bacteria were found to survive longer under cooler moister conditions regardless of the soil type. Longer survival under cooler conditions was related to the lower activity of the competitive soil organisms. On average, a 95% reduction in bacteria occurred within 53 days for 4 of the soils. In the other soil, 5% of bacteria were still alive after 120 days upon which series of freeze-thaw treatments was found to substantially reduce bacterial numbers. Groundwater Protection Schemes (DoELG et al., 1999) in Ireland

delineate an inner (SI) and outer (SO) protection area within the zone of contribution of groundwater sources in an attempt to protect them from potential degradation. The SI is designed to protect against the effects of anthroprogenic activities that might contaminate the source, e.g. microbial pollution caused by the disposal of domestic effluent. The area is defined by a 100-day time of travel (TOT) from any point below the watertable to the source or, where necessary, an arbitrary fixed radius of 300m. As persistence of pathogenic bacteria in the subsoils is species specific, these protection criteria can both under and overprotect the source from microbial contamination. While coliform bacteria will reach a 99.9% elimination in less than 8 days and *E. coli* will attain the same level of elimination in 50 days, *Salmonella typhi* can survive more than 100 days, *Salmonella typhimurium* approximately 230 days and *Yersinia sp.* approximately 200 days at temperatures below 15 °C and oligotrophic conditions (US EPA, 1993). Research by Harvey *et al.* (1995) (cited in Domenico and Schwartz, 1998) found that bacterial transport over 1 000 metres is possible in plumes containing organic contaminants.

Viruses

Viruses are among the most important and potentially most hazardous of the pathogens found in domestic wastewater. This is due to their small size, which ranges from 10 – 100 nm in comparison to the other pathogenic groups, and their potential mobility through the vadose zone and during advective groundwater flow. More than 100 types of human pathogenic viruses may be present in faecally polluted water while viral numbers have been detected in concentrations in excess of $10^3 - 10^4$ PFU L^{-1} in untreated wastewater (Toze, 1997).

Viruses themselves are obligate intracellular parasites, which means 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 $10^8 - 10^{12}$ per gram may be excreted in faeces (Pepper *et al.*, 1996). These consist of small, single-stranded RNA viruses and include the poliovirus types 1 and 2, multiple strains of echovius 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, conjuctivitis, 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 *et al.*, 1996). Rotaviruses are the most infectious of all the enteric viruses (Gerba *et al.*, 1996) and thus can be considered to be a high health risk group if present in wastewaters. Children under the age of two, the elderly and the immuno-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 waterborne human viruses previously discussed are more difficult to assay (Sinton *et al.,* 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 marker as to the presence of viruses (Kott *et al.*, 1974; Marzouk *et al.*, 1980; Armon *et al.*, 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 *et al.*, 2005). Those 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 *et al.*, 1989). In addition they have similar physical properties in size, shape, morphology, physiochemistry and isoelectric points to enteric viruses (Table 2.3). Sizes may range from 20 to 350 nm, though some may have a total length of over 1 000 nm. They are abundant in wastewater, ranging from $10^5 - 10^7$ PFU mL^{-1} and up to about 10^8 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 2.3 Characteristics of viruses and possible phage surrogates (adapted from Lytle *et al.*, 1991 and Collins *et al.*, 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 (Figure 2.5), 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 2.4). Both have been found to be in abundance in raw sewage and STE (Deborde *et al.*, 1998; Zhang *et al.*, 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.

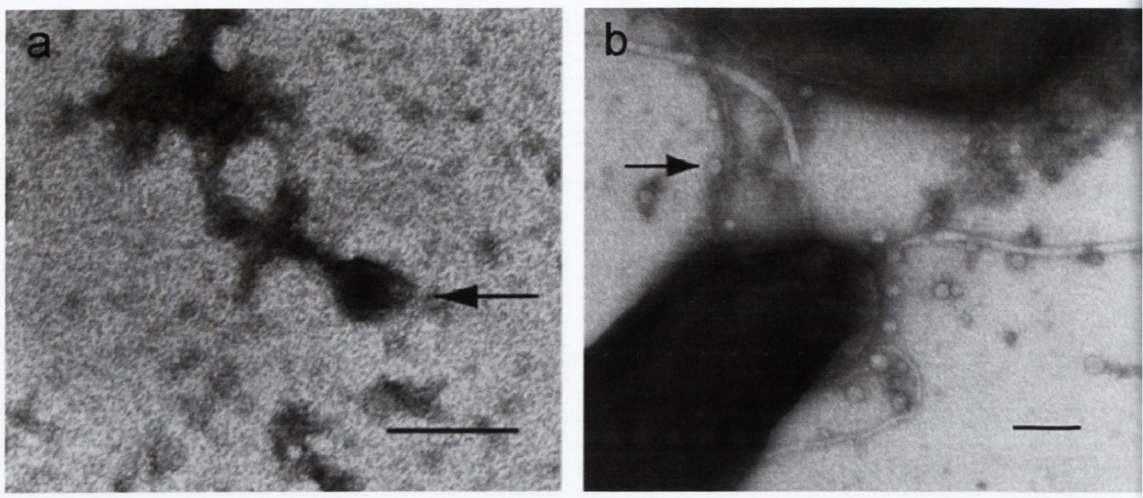


Figure 2.5 Transmission electron microscopy (TEM) images of (a) somatic coliphages and (b) male-specific coliphages (scale bars represent 100 nm) (Zhang *et al.*, 2007)

Table 2.4 Groupings and characteristics of bacteriophages (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 (icosahedral 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 (VanDuin, 1988) and a low isoelectric point (IEP) of 3.9 (Zerda, 1982, as cited in Gerba, 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 in Ackerman 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 virus (HBV) (42 nm diameter) and Human Immunodeficiency virus (HIV) (10nm diameter). Results from Jin *et al.* (1997) also suggest that 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) but no studies have yet been carried out using the phage as an indicator of human enteric viruses in soil-aquifer treatment. Originally isolated from a wastewater treatment system in Pretoria, South Africa, little had been known about the structure of PR772, other than that it could be surmised to be highly similar to PRD1 on the basis of the overall similarity of *Tectiviridae* family phages (Coetzee *et al.*, 1979). However, Lute *et al.*, (2004), in an in-depth study on the comparison of the two phages, discovered that PR772 and PRD1 were structurally very similar and their genomes revealed their DNA sequences to be 97.2% identical. PRD1 is an icosahedral double-stranded DNA somatic *Salmonella typhimurium* phage from the *Tectiviridae* family with diameter 62 nm and an IEP of between 3 and 4 (Powelson *et al.*, 1993). It is therefore modeled on the larger enteric viral pathogens, e.g. rotaviruses (80 nm diameter) and adenoviruses (80 – 110 nm diameter), although it may differ to the latter in surface charge. Unlike other members of the family *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*.

A myriad of studies (Bales *et al.*, 1991; Jin *et al.*, 1997; Woessner *et al.*, 2001; Guan *et al.*, 2003; Van Cuyk and Siegrist, 2007) have been carried out on the extent of virus removal in both unsaturated and saturated soils, groundwaters, and its transport through soil in association with the movement of wastewater. In all cases, there are various factors controlling the transport pattern of viruses (Table 2.5). The most important of

these include soil type, pH, organic matter, presence of cations, degree of pore saturation, and virus type. In many instances, the mechanisms influencing the inactivation or protection of viruses are unknown and require more research. In some cases, it is difficult to consider the factors separately as interactions between them undoubtedly occur.

Table 2.5 Factors influencing virus fate in the subsurface environment (adapted from Yates and Jury, 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 micro organisms: however, adsorption to the surface of bacteria can be protective	Unknown
Moisture Content	Some viruses persist longer in moist soils than dry soils	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 values	Generally, low pH favours adsorption and high pH results in virus desorption from soil particles
Virus Association with Soil	In many cases, survival is prolonged by adsorption to soil: however the opposite has 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 soil: 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 physiochemical 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 hydraulic loads and flow rates

Although viral inactivation readily occurs in the soil, adsorption of viruses to soils is considered to be the most important factor in removing viruses after land treatment of wastewater. However, the adsorption of viruses should not be confused with their inactivation since adsorption is not permanent and can be reversed by the ionic

characteristic of the percolating wastewater (Bales *et al.*, 1993); this reverse phenomena being termed desorption. Virus particles may be removed by soil adsorption to clay, organic matter and other negatively charged material such as iron and aluminium oxides. Soils themselves offer a large number of sites for viruses to be adsorbed. However, soils are complex environments and qualitative changes in their textural components (sand, silt, clay, organic matter, iron oxides) undoubtedly influence their sorptive capacity towards viruses (Gerba and Bitton, 1984). It is generally agreed in literature studies that fine-textured soils retain viruses more effectively than sandy soils, since the soil clay mineral fraction displays a highly sorptive capacity towards viruses as a result of its high surface area and high cation exchange capacity (CEC).

Forces responsible for the sorption of viruses include electrostatic attraction and repulsion, Van der Waals forces, covalent-ionic interactions, and hydrophobic effects (Jin et al., 2000). At a low soil pH, viruses are positively charged and are adsorbed like cations (e.g. Ca^{++}, Mg^{++}, Na^{+}) to negatively charged colloidal particles. 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). Any sharp increase in the pH may enhance the detachment and, therefore, the mobility of the viruses that are attached to the soil matrix. However, it should be noted that most soils have enormous buffering capacity to maintain a pH balance, thereby averting the release of viruses (US EPA, 2003). From this, it is tempting to conclude that virus adsorption increases with decreasing pH whereas as the soil pH becomes more alkaline virus adsorption decreases. The relationship between virus adsorption and pH is not clear-cut, however, because of many complicating factors. The pH of the soil, as conventionally measured, does not necessarily reflect the pH at the surface of soil colloidal particles such as clays (Gerba and Bitton, 1984). Also, various soil components (clay, sand, oxides of Fe and Al) display different isoelectric points (Gerba and Bitton, 1984). However its importance in virus fate in the subsurface can not be overestimated. Goyal and Gerba (1979) reported that among several soil characteristics including texture, OM content, soil, pH, resin-extractable phosphorous (P), Total Al, and exchangeable Al contents, soil pH was the most significant factor affecting virus sorption.

Another controlling factor that may affect permanent viral sorption is heavy rainfall, which can induce saturated soil conditions or significant conductivity (ionic strength) changes (Yates, 1987). Wastewater effluents have a higher conductivity (500 – 600 μmhos cm^{-1}) than distilled water (2 – 10 μmhos cm^{-1}) or rainwater (20 – 40 μmhos cm^{-1}) (Gerba and Bitton, 1984). The result is that it is possible for previously adsorbed viruses to be eluted by rainwater during heavy rainfalls, allowing them to be transported with the percolating rainwater and increasing the potential risk of groundwater contamination. Nicosia *et al.* (2001) conducted a study to assess the removal of bacteriophage PRD1 after passage through 0.6 m (2 feet) of unsaturated fine sand in a drainfield loaded at 36 L m^{-2} d^{-1} (1.2 g ft^{-2} d^{-1}). Attachment of the phage was found to be reversible with slow desorption occuring over time in the sand under wet-season conditions. PRD1 was detected at a breakthrough concentration of 28.1 PFU mL^{-1} at day 2 and peaked at 3.7 x 10^2 PFU mL^{-1} at day 4 after the cell was seeded. Rainfall effects were observed to aid in desorption within the first 10 days of the study. The main mechanisms contributing to virus attenuation were deemed to be inactivation, dilution and dispersion.

Unfortunately, most transport studies with viruses have been carried out in saturated porous media and only a limited number have been conducted under unsaturated flow conditions. Moreover the majority of research has been restricted to column studies under controlled laboratory conditions which do not fully simulate the undisturbed and heterogeneous nature of natural subsoils under field investigation. In the majority of studies carried out, viruses have been found to be removed more extensively during unsaturated transport than during saturated transport. Unsaturated flow increases the efficiency of virus removal due to slower average pore water velocities and increased surface contact per net distance travelled. Conversely, macropore flow and higher pore water velocities associated with saturated conditions reduce adsorption efficiency. Sobsey *et al.* (1980) found that although sandy and inorganic soil materials were poor adsorbents for poliovirus when suspended in wastewater, they removed at least 95% of viruses from intermittently applied wastewater through unsaturated columns. Lance and Gerba (1984), in a column study with loamy sand, found that poliovirus penetrated to a depth of 0.4 m under unsaturated flow conditions compared to 1.6 m under saturated flow conditions. Powelson *et al.* (1990) reported that under saturated conditions MS2 bacteriophage showed little sorption or inactivation by a loamy fine sand, while under

unsaturated conditions, the phage was strongly removed from the soil water. In another column study, Powelson and Gerba (1994) showed that unsaturated flow of sewage effluents removed MS2, PRD1 and polioviruses more than three times compared with saturated flow in a sandy alluvium soil. In addition, the lower the infiltration rate of sewage into soil, the longer the retention of viruses within the unsaturated zone. This results in more efficient virus removal. Green (1976) showed that viruses suspended in septic tank effluents were retained more efficiently by sand mounds as the flow rate of sewage decreased. This point was also reinforced by Bouma (1979) when he showed that when polio-virus type 1 was added to STE and applied to 0.6 m long sand columns, it was effectively removed provided the flow rate did not exceed 50 mm day^{-1}. As with bacterial removal, maintaining unsaturated flow appears to be critical to good removal. This not only decreases low flow velocities but also creates better contact between percolating water and potential adsorption sites.

The effect of hydrophobic interactions with the soil matrix and Van der Waal's forces, in the adsorption of viruses, might be enhanced in unsaturated flow because the largest pores are no longer available for transport and the viruses are moving closer to the particle surfaces (Lance and Gerba, 1984). However, Powelson *et al.* (1990) dismissed this possibility based on their calculations of the sizes of water-filled pores which apparently were much larger than the size of the virus. Instead they concluded that the strong removal of the bacteriophage MS2 in their unsaturated system was caused by inactivation, presumably due to the presence of an *air-water interface* (AWI), a phenomenon later elucidated by Wan *et al.* (1994) and found to be also responsible for significant bacterial sorption in unsaturated sand column experiments. Several other bacteriophages (T_1, T_3, T_5, EMC virus, and Semliki Forest virus) were also found to be inactivated at the AWI in an experiment conducted by Trouwborst *et al.* (1974). More recently, batch experiments were conducted in both polypropylene (PP) and glass centrifuge tubes to study the role of an AWI in bacteriophage sorption experiments using MS2 and ϕX174 (Thompson *et al*, 1998). Results indicated that the site of MS2 inactivation was not simply the AWI itself, but more so the interface at which the liquid, solid (wall of the experiment vessel), and gas phases meet (referred to as the triple-phase boundary [TPB]). Interestingly enough, ϕX174 was not affected by either the AWI or the TPB in this study. One possible reason that MS2 would more likely to be pushed towards the hydrophobic AWI than ϕX174 is its lower isoelectric point

value. It is suggested the differences in the surface and structural characteristics of the virus capsid proteins as being a possible explanation for the greater stability of ϕX174 with respect to MS2.

The presence of organic matter (OM), whether soluble or insoluble, is seen as another factor in the adsorption of viruses in the soil with research showing its effect to yield varying results. Soluble organic materials are known to compete with viruses and bacteria for adsorption sites (Gerba and Bitton, 1984). On the other hand, many researchers have found that organic materials can act as potential adsorbers to viruses in the correct soil conditions. Gross and Mitchell (1985) examined the effectiveness of sand columns, constructed to simulate a sand filter, in removing viruses applied in STE. In columns treated with STE for 3 months prior to introduction of viruses, viruses showed a breakthrough when virus-loading rates were increased to 3.3×10^7 PFU L^{-1}. Columns that were not preconditioned with STE showed no virus breakthrough. Most viruses were attenuated in the upper part, at depths of 25 to 38 mm (1 to 1.5 inches) from the top of the column. A number of field studies have since confirmed that organic matter not only hinders adsorption of viruses but also results in elution of those already adsorbed (Canter and Knox, 1985). Pieper *et al.* (1997) concluded high organic matter content was the primary factor hindering PRD1 transport in a contaminated sandy aquifer. Powelson *et al.* (1993), whose aim was to assess the effects of secondary versus tertiary effluent on virus removal through sandy alluvium near Tucson, Arizona, found that significantly greater removal of PRD1 occurred with the former.

Although it is thought their contribution to viral contamination of groundwater is minimal, it is conceivable that suspended particles could absorb viruses and facilitate their transport. Chu *et al.* (2003) confirmed that suspending mineral colloids were present in outflow samples taken from the five soil columns tested and suggested it was possible that viruses were sorbed on the suspended colloids and subsequently transported through the columns.

Other factors such as metal oxides have been shown to play a significant role in virus sorption and inactivation. Given the presence of iron (Fe) oxides and exchangeable aluminium (Al) in soils it has been suggested they have the potential to be used as hydrological barriers. Chu *et al.* (2002), in a research study to investigate inactivation

and sorption of bacteriophages MS-2 and ϕX174 during saturated and unsaturated transport in five different soils, found that significantly greater virus removal occurred in the unsaturated columns than in the saturated columns in two soils containing high metal oxides content. Sand coated with goethite, however, was found to dominate the removal of the viruses over the effect of unsaturated flow.

Protozoa

Protozoa are motile, microscopic organisms that are usually single-cells (Yates & Jury, 1988). The most common species which are recognised as causing waterborne enteric disease in humans are G*iardia lamblia* and *Cryptosporidium.* They are a topical issue in relation to the use and treatment of surface water for human consumption although little has been written on their persistence in the subsoil or the threat they pose to contamination of groundwater resources (Ó Suilleabháin, 2004). They are of lesser concern than bacteria and viruses since they are relatively large in size (1 – 100 μm) and therefore are removed more efficiently by the subsoil or the organically-composed biomat formation in onsite treatment. In fact, as a source of energy, protozoa often consume smaller-sized bacterial cells.

3. HORIZONTAL SUBSURFACE FLOW REED BED TREATMENT SYSTEMS

3.1 Introduction

An alternative or additional type of on-site secondary treatment process is required when a conventional septic tank system is deemed an unsuitable option for discharge of effluent to groundwater. Such an event may occur when hydrogeological conditions on site are inappropriate, namely (1) the assimilation capacity of the receiving subsoil is unacceptable, and (2) an insufficient depth of unsaturated subsoil for treatment is present, owing to shallow (and often fissured) bedrock or high water table. Secondary treatment systems may take the form of mechanical aeration systems, passively aerated filter systems and constructed wetland systems (CWS). Whereas the former may provide an alternative to septic tank treatment systems, filter and wetland systems must be preceded by a septic tank. In all cases the final level of treatment must consist of a polishing filter in order to reduce the concentration of pathogenic micro organisms in the treated wastewater prior to groundwater discharge (EPA, 2000).

Of the aforementioned alternative treatment options for single house applications, CWS have been receiving much attention lately with a keen focus on quantifying their effectiveness in an Irish climate and analysing their design specifications. They are now recognised as a simple, low energy, low cost, aesthetically pleasing and, most notably, sustainable wastewater treatment technology for both on-site secondary and tertiary treatment. A multitude of wetland configurations exist based on the direction of flow (horizontal or vertical), the degree of saturation (free water surface or subsurface flow) and/or the type of media used (soil, gravel or a combination of both). Of interest to this project are horizontal subsurface flow reed bed (SSF) treatment systems which are most widely used in many parts of Europe (including Ireland) for secondary treatment of domestic wastewater from single houses and small communities (EPA, 1999).

3.2 Background

In Ireland, application of wetland technology is in its infancy relative to North America and other European countries. It is only in the last decade that we have seen a

significant introduction of constructed wetland technology as a sewage treatment system to single households and small rural communities and as a tertiary treatment to larger villages and towns (Healy and Cawley, 2002). The publication of the Irish Environmental Protection Agency (EPA) guidance document *Wastewater Treatment Manual: Treatment Systems for Single Houses* (EPA, 2000) has seen a vast improvement in on-site standards, with greater clarity given to selection, design, operation and maintenance of a variety of wastewater treatment systems. Although limited detail is currently included in the guidelines on constructed wetlands, the number of wetland practitioners in Ireland has increased with a nationwide drive in many residential projects, from eco-villages to single houses, to incorporate more sustainable solutions. According to an inventory survey carried out in 2005 at University College Dublin, there are now about 140 constructed wetland sites in Ireland (Babatunde *et al.*, 2008).

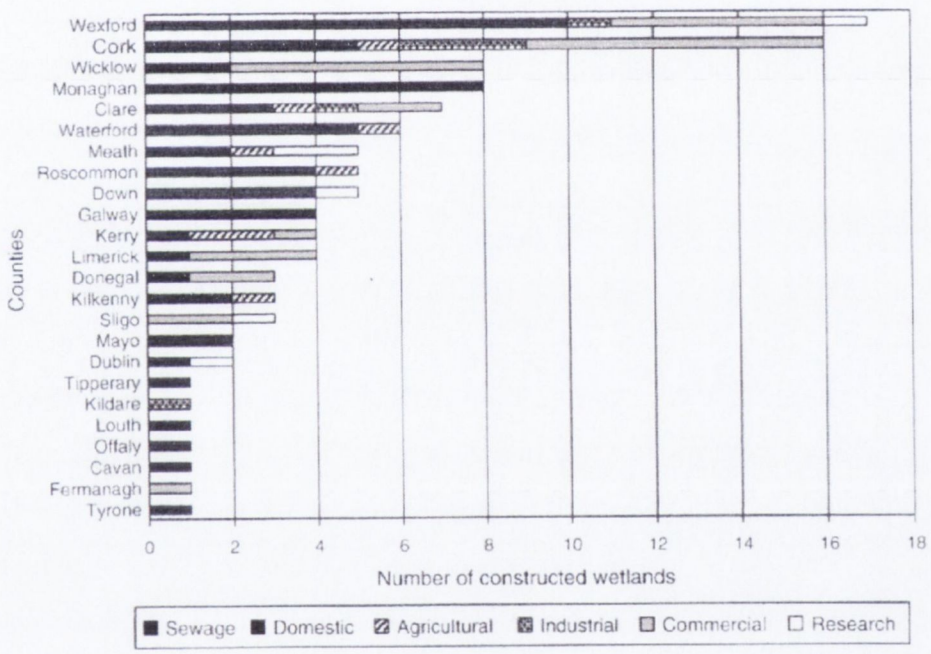


Figure 3.1 Distribution and application of CWS across Irish counties (Babatunde *et al.*, 2008)

In many cases, these wetlands are being recommended as an add-on polishing filter to either conventional secondary treatment systems at the town and village scale or to septic tank systems at the household and small community scale, particularly in areas of sensitive receiving waters. There does exist, however, some reluctance on the part of a number of local water authorities in Ireland to permit the use of reed beds as stand-

alone secondary treatment systems. This is understandable given the scarcity of reliable long-term performance data relevant to Ireland and its climate, and their apparent poor winter treatment performance (Healy & Cawley, 2002). To coincide with this, several other uncertainties still remain with regard to the design sizing and performance of wetland systems, including:

- suitability of the existing design rationale for HF reed beds
- adaptation period for new systems to reach optimum treatment;
- finite life span for phosphorous removal
- uncertainty of the capacity to cope with peak loads

3.3 Types of Constructed Wetland Systems

The arrangement of CWS can be classified in a number of ways depending on the level of treatment required, from degree of saturation to direction of water flow through the bed. Two types are commonly categorised: the subsurface-flow (SSF) reed bed - based on either a horizontal or vertical flow design, where wastewater flows through a permeable media (usually gravel) below the surface layer of the bed; and the free water surface (FWS) wetland – where the water surface in the system is open to the atmosphere. In the context of choosing the optimal configuration, careful consideration of both the desired final effluent quality and the availability of land are essential. It is even common often to combine different types of beds into "hybrid systems", usually to deal with specific wastewaters in the most effective manner. Nevertheless, subsurface flow reed beds are thought to have several advantages over FWS wetlands. If the water level is maintained below the media surface there is little risk of odours and exposure. In addition, the media in subsurface flow systems provides greater available surface area for treatment than the FWS concept and therefore its design area can be smaller for the same wastewater conditions.

3.3.1 Subsurface Flow Reed Bed Treatment Systems

Horizontal Flow Reed Bed Treatment Systems

In horizontal SSF reed beds the incoming effluent enters via an inlet pipe distributor, flowing slowly through a porous medium (gravel more often than soil) in a horizontal

path under the surface level of the bed until it reaches the outlet zone where it is collected and discharged via a level control arrangement (Figure 3.2). The bed is lined with an impervious material to prevent infiltration through the subsoil.

The most frequently used aquatic macrophyte in these systems is the common reed (*Phragmites australis*) (IWA, 2000). Other species that may be used are reed canarygrass (*Phalaris arundinacea*), sweet mannagrass (*Glyceria maxima*), cattails (*Typha spp.*), bulrushes (*Scripus spp.*) or the yellow flag (*Iris pseudocorus*).

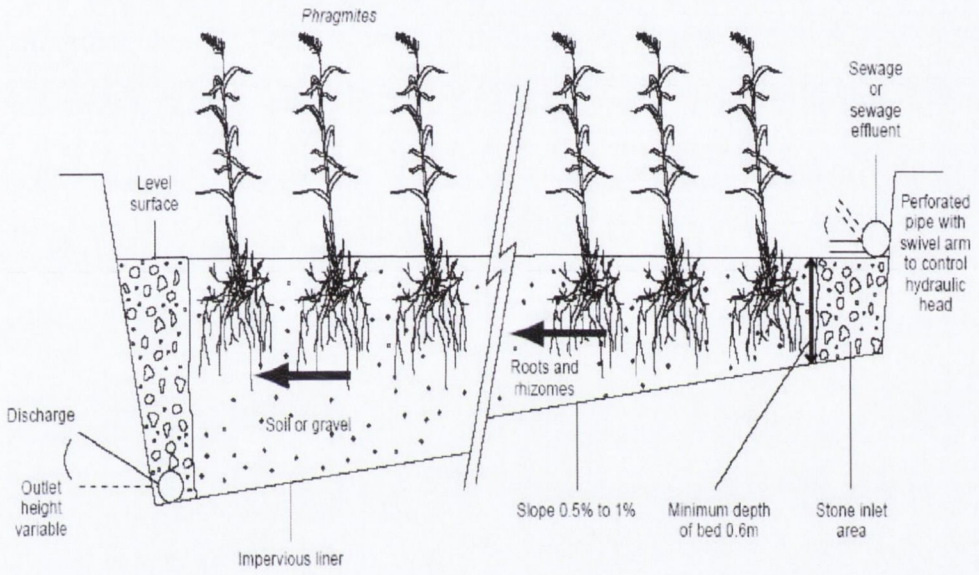


Figure 3.2 Cross-section of a horizontal subsurface flow reed bed treatment system (EPA, 2000)

The purpose of the plant species in a gravel bed is twofold. Firstly, through the vertical and horizontal growth of the rhizomes, the reed plants are thought to open up the bed to provide a hydraulic pathway. However, this assertion has not, as yet, been demonstrated in practice (Conley *et al.*, 1991). The alternative thinking is that any postulated hydraulic pathways may in fact be detrimental to treatment, with reduced surface contact promoting wastewater channeling (Griggs and Grant, 2001). Of more note, perhaps, is the contention that a significant level of oxygen is passed from the atmosphere down through the leaf and stem structure of the rhizomes and out through the roots, to promote prominent aerobic conditions in the bed. In theory, this aerobic environment is ideal for the breakdown of organic compounds by bacteria attached to

the rhizomes and media surface. However, despite a number of laboratory and field trials, opinions vary as to the significance of the oxygen release from the roots. The consensus suggests that the effect is far less significant than originally thought (Armstrong and Armstrong, 1988; Griggs and Grant, 2001). Although the oxygen transfer has been shown to take place, indications are that the transfer capacity of the reeds is insufficient to ensure aerobic decomposition in the rhizosphere; hence the breakdown of organic compounds is carried out predominantly by anoxic and anaerobic microbes. Any limited aerobic treatment is assumed to take place close to the roots and rhizomes which pass oxygen (Cooper *et al.*, 1996).

Table 3.1 Advantages and disadvantages of horizontal SSF reed beds for on-site secondary treatment (adapted from Griggs and Grant, 2001)

Advantages	**Disadvantages**
Good suspended solids and pathogen removal	Minimal nitrification (NH_4-N removal)
Simple construction	Anaerobic effluent
Minimal fall required	Odour can be an issue
Requires little maintenance (e.g. weeding and infrequent reed cutting)	Solids in the wastewater can cause premature blockage
Weed control possible by surface flooding	Larger area requirement than vertical flow reed bed treatment systems
Easily fitted into landscape	

Horizontal SSF beds are being used to provide secondary and/or tertiary treatment (final polishing) in on-site systems. They are particularly good for suspended solids and pathogen removal and degrade organic loadings while it is also possible to achieve biological denitrification in the system when they are employed at the tertiary stage. Other advantages include simple construction, the requirement of little maintenance and their aesthetic attributes while there is a need for only a minimal headloss given the gravity flow conditions. This is offset by their inability to nitrify the treating effluent owing to the predominantly anoxic bed environment (Table 3.1).

Vertical Flow Reed Bed Treatment Systems

Vertical flow reed beds comprise of a flat bed of either gravel of varying sizes topped with sand (Figure 3.3), or a filter medium of purely sand with a d_{10} of between 0.25 and 1.2 mm, a d_{60} of between 1 and 4 mm, and uniformity coefficient ($U = d_{60}/d_{10}$) of less than 3.5 (Brix, 2004). Like the horizontal SSF reed beds, vertical flow systems can be planted with *Phragmites australis* or similar species already outlined.

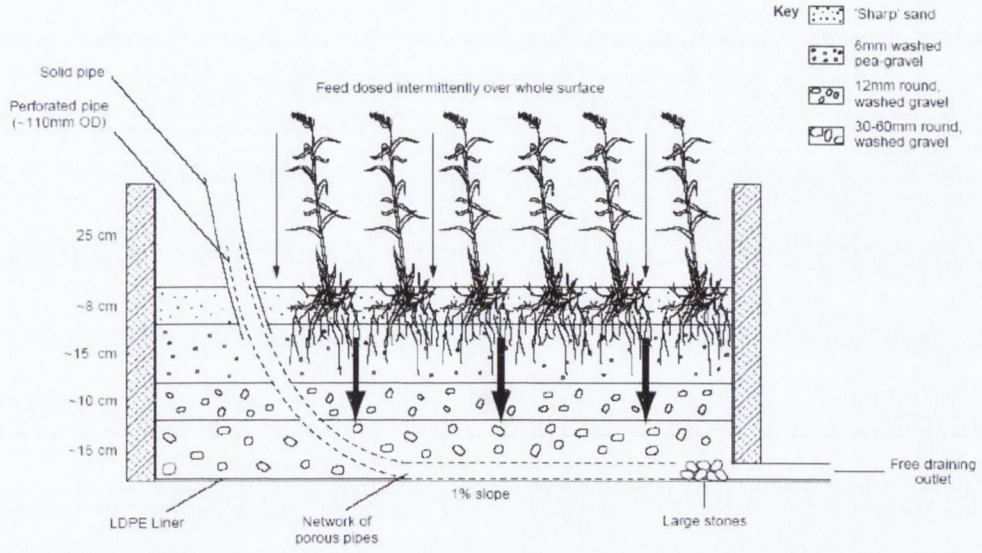


Figure 3.3 Cross-section of a vertical flow reed bed treatment system (Cooper *et al.*, 1996)

The wastewater to be treated is distributed evenly over the surface of the bed on an intermittent basis by a network of pressurized distribution pipes. It gradually percolates vertically through the different media layers of the bed and is collected by a drainage network at the base. These drainage pipes should be aerated by vertical pipes extending into the atmosphere. The bed drains completely free, allowing air to refill the bed. The next dose of wastewater traps this air which, together with the aeration caused by the rapid dosing on the bed, leads to good oxygen transfer and hence the ability to decompose BOD_5 and to nitrify ammonia nitrogen (Cooper *et al.*, 1996). The bacteria that remove the organic load and perform nitrification are in the biofilm growing on the sand and gravel particles in the bed.

The main advantage attached to the use of vertical flow reed beds is in the area of treatment performance over and above its low area requirement compared to the

horizontal SSF configuration (their design is based on an area approximately 2 – 3 times less than their horizontal counterparts). They can achieve BOD_5 removal at much higher loading rates compared to the horizontal SSF beds and they are capable of complete nitrification as tertiary or secondary treatment systems. Set against this is the large headloss the bed incurs on the overall treatment system, the power requirement of the dosing pump and its associated maintenance (Table 3.2).

Table 3.2 Advantages and disadvantages of vertical flow reed beds for on-site secondary treatment (adapted from Griggs & Grant, 2001)

Advantages	Disadvantages
High levels of organic removal	Requires a fall of at least 1m
Good levels of nitrification	Sand specification is critical
Lower area requirement than horizontal flow beds	Construction and distribution details are critical
Blockage likely to be in the easily removed surface layer	Requires regular maintenance; typically weekly inspection
Tolerant of solids in the wastewater	Localised odour caused by raw wastewater on the surface of the bed
Aerobic effluent	Cannot be flooded for weed control unlike horizontal flow beds

Hybrid Reed Bed Treatment Systems

Hybrid reed bed treatment systems involve the combination of both horizontal and vertical flow beds in series to achieve a more purified effluent. There has been a long-standing debate as to whether to place vertical flow bed(s) before or after the horizontal flow reed bed(s). In sites with more stringent effluent quality demands for the removal of nitrogen and phosphorous, systems should be selected which consist of vertical flow bed(s) with intermittent loading followed by horizontal flow bed(s). This serves the purpose of removing suspended solids from an already well oxidised effluent (low effluent BOD_5 and NH_4-N). In addition this sequence of arrangement is deemed superior as vertical systems are more tolerant of blockage. It will also achieve the

additional benefit of removing further nitrogen by endogenous denitrification (Cooper, 2001) – a reaction where when organic matter is very low in the sewage, other internal carbon sources are used for the breakdown operation. The effluent from the vertical stage of a reed bed system may have quite high levels of TSS and BOD_5 but these should be in the form of humus solids, which are then easily settled out in a horizontal SSF reed bed. The alternative option of placing a horizontal flow before a vertical flow bed is based on the assertion that the former type will remove any solids that could block the sand in the vertical beds (Griggs and Grant, 2001). So although there are different traditions of reed bed sequences, there are no overwhelming reasons to conclude than one performs better than another.

3.3.2 Free Water Surface Wetland Systems

In free water surface (FWS) wetland systems, water flows over the soil surface from an inlet to an outlet point. Typical water depths range from a few centimetres up to a metre. Three different types of vegetation can be used in FWS wetlands: emergent macrophytes, free-floating macrophytes and submerged macrophytes (Table 3.3).

Table 3.3 Vegetation type and water column contact in FWS wetlands

Constructed Wetland Type	Type of Vegetation	Section in Contact with Water Column
Free water surface (FWS)	Emergent	Stem, limited leaf contact
	Floating	Root zone, some stem / tubers
	Submerged	Photosynthetic part, possibly root zone

The plants that are most often used are persistent emergent plants (Figure 3.4) whose roots are supported in the wetland's soil medium. These include bulrushes (*Scripus* spp.), spike-rush (*Eleocharis* spp), sedges (*Cyperus* spp. and *Carex* spp.), rushes (*Juncus* spp.), common reed (*Phragmites australis*), reed canarygrass (*Phalaris arundinacea*), sweet mannagrass (*Glyceria maxima*) and cattails (*Typha* spp.). In general, FWS wetlands are very appropriate for polishing secondary and tertiary effluent. They are also ideal for providing habitat and in this sense exhibit more biodiversity than subsurface flow reed bed treatment systems. The environment in FWS

wetlands is generally aerobic at, and near, the surface. In contrast, deeper zones tend to be dominated by anaerobic microbial processes in the absence of light. As such ammonia is oxidised in the aerobic zones near the surface and nitrate is converted to free nitrogen or nitrous oxide in the anaerobic zones at depth.

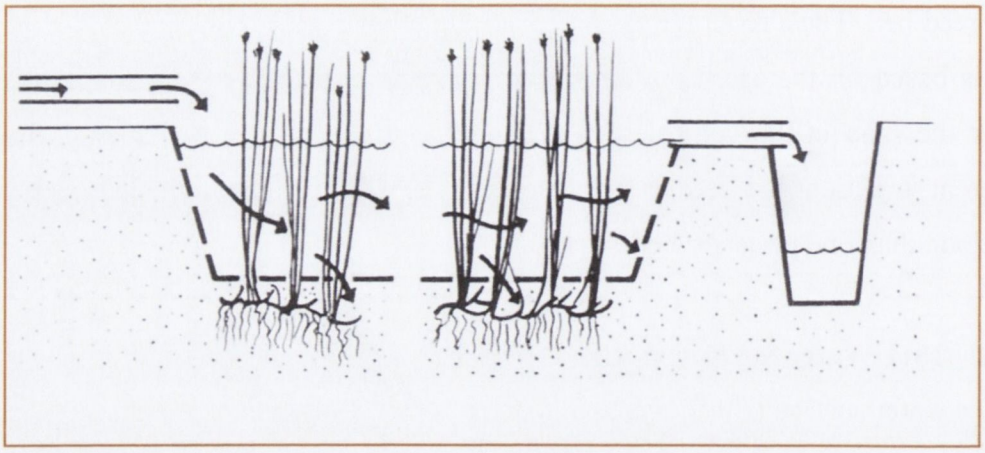


Figure 3.4 Emergent macrophyte FWS treatment system (Brix, 1993)

Attached and suspended microbial growth is responsible for the removal of soluble BOD_5 while suspended solids are effectively removed by settling and becoming trapped within the bed of the wetland due to lowered flow velocities. Settleable organics are rapidly removed by quiescent conditions, deposition and filtration (IWA, 2000). The advantages of FWS wetlands are that their construction and running costs are low while their operation and maintenance are straightforward. On the other hand, a large footprint is needed for these systems (typically twice the design size for subsurface flow). This is because the wastewater to be treated is not forced to pass through any media and can thus channel through the water body with little interaction - effectively relying only on residence time as the main degradative process. Exposure to potential human contact given the visible water surface poses a potentially high health risk also.

3.4 Horizontal Flow Reed Bed Design

The design sizing and description of constructed wetlands involves two principal features: pollutant removal and hydraulics (IWA, 2000). Multiple models have been devised to calculate the necessary wetland dimensions, many of which are deterministic, meaning that the equations purport to represent the wetland output

concentrations (C_o) in response to inlet concentrations (C_i), flow rate (Q), and area (A) or volume (V). These are the five fundamental variables of wetland performance. However, wetland performance also includes a good measure of variability that is not predicted by the average values of these variables. That variability is caused by unpredictable events, such as fluctuations in input flows and concentrations, and by changes in internal storage, as well as by weather conditions (IWA, 2000).

3.4.1 Area Sizing

Since CWS are not mass-produced, off-the-shelf treatment devices, there is a need for a reliable design approach that affords confidence in the prediction of performance. In wetlands the assumption has been made that a pollutant passes undispersed as a plug through the bed (plug flow), declining exponentially to a background concentration on route. First-order kinetics assume ideal plug flow behaviour with steady-state conditions for influent, flow and concentrations and predict an exponential profile between inlet and outlet. The current design approach for horizontal SSF reed beds is thus normally based on this concept.

This first order model adopted for design was presented by Kadlec (Kadlec and Knight, 1996) as the "k-C*" model. It is given as:

$$q\frac{dC}{dy} = k(C - C^*) \qquad \text{(Eqn. 3.1)}$$

where, y = fractional distance from inlet to outlet (unitless)

C = chemical concentration (mg L^{-1})

k = areal removal rate constant (m d^{-1} or m yr^{-1})

C^* = background chemical concentration (mg L^{-1})

$q = \frac{Q}{A}$ = hydraulic loading rate, HLR (m d^{-1})

For batch-loaded systems, a material balance with Eqn. 3.1 describing removal results in:

$$\frac{C_{out} - C^*}{C_{in} - C^*} = e^{-kt} \qquad \text{(Eqn. 3.2)}$$

where, C_{in} = influent chemical concentration (mg L^{-1})

C_{out} = effluent chemical concentration (mg L^{-1})

t = treatment time or HRT (days)

This equation is based on the assumption that many processes occur on an equal basis in wetlands. Thus, the coefficient, k, has units of velocity and can be recognised as being similar to a "settling velocity" coefficient used in sedimentation models (Mitsch and Gosselink, 2000). This exponent can often be regrouped to define a volumetric rate constant (k_v):

$$k_v = \frac{k}{\varepsilon d} \qquad \text{(Eqn. 3.3)}$$

where ε = substrate porosity = $\dfrac{\text{Volume of Voids}}{\text{Total Wetland Volume}} = \dfrac{V_v}{V_T}$

d = depth of the wetland (m)

Removal of biochemical oxygen demand (BOD_5) in both subsurface and surface flow wetlands is described with first-order plug flow kinetics. Integrating Eqn. 3.1 over the entire length of the wetland and rearranging, the calculation for wetland area can be expressed as a first-order areal model:

$$A = \frac{Q}{k_{BOD5}}(\ln C_{in} - \ln C_{out}) \qquad \text{(Eqn. 3.4)}$$

where k_{BOD5} = BOD_5 areal removal rate constant (m d^{-1} or m yr^{-1})

Although a background BOD_5 concentration (C^*) always exists (see Table 3.4) in wetlands, references deem it negligible enough to exclude in horizontal flow reed bed design. The breakdown and removal of BOD_5 (organic compounds) in the wastewater is carried out through the action of microbial growth on the media (like an attached growth biological reactor) and plant roots. One of the limitations of this areal-based approach is that, as the required effluent concentration approaches the minimum pollutant concentration, the predicted area for the treatment increases exponentially, leading to over-estimates of the required area in cases near the pollutant concentration

limit. However, this is not seen as a problem when designing for single-house systems, given the associated low hydraulic loads. On the other hand, limitations do exist regarding this design approach in that meteorological effects, which can vary significantly depending on time of day, location and type of climate, are not taken into account in the kinetics.

Kickuth originally proposed a value of 0.19 m d^{-1} for the BOD_5 rate constant k_{BOD5} (Boon, 1985). This would result in a specific area of approximately 2.2 m^2 PE^{-1} for sewage of strength 200 mg BOD_5 L^{-1}, effluent of 20 mg BOD_5 L^{-1} and a daily flow of 180 L PE^{-1}. However, measurements taken from operational horizontal SSF reed beds have since shown that k_{BOD5} is lower (IWA, 2000). Schierup *et al.* (1990) reported a value of 0.083 m d^{-1} from 49 systems providing secondary treatment in Denmark. Cooper *et al.* (1996) reported k_{BOD5} values in the range 0.067 – 0.1 m d^{-1} for the same level of treatment on the basis of measurements in systems in the UK. The key point with this variability is that literature values of the rate constant have not taken into account external factors which may have a significant effect on the system. In some instances, water budget information was not collected. In other cases atmospheric losses and gains were not significant. Therefore water mass balance effects are the cause of some fraction of the variability in rate constant data (IWA, 2000).

Brix (1998) pointed out that in theory, the *k*-value should be a constant, and therefore ideally be independent of inlet concentration and loading rate. However, he discovered k_{BOD5} increased with BOD_5 mass loading rate from a number of soil-based wetlands in Denmark. It was also found that rate constants generally increase with hydraulic loading rate (Figure 3.5). This is due in part to the existence of background concentrations, which create this effect in input/output data analysis and also through influences such as the velocity dependence of mass transfer and non-plug-flow detention time distributions. The latter is a hydraulic issue which will be further discussed in Section 3.6.1. In addition, as the effluent point of the treatment wetland moves farther out along the plateau, the rate constant, determined as the slope of the logarithmic model, is seen to reduce (Figure 3.6).

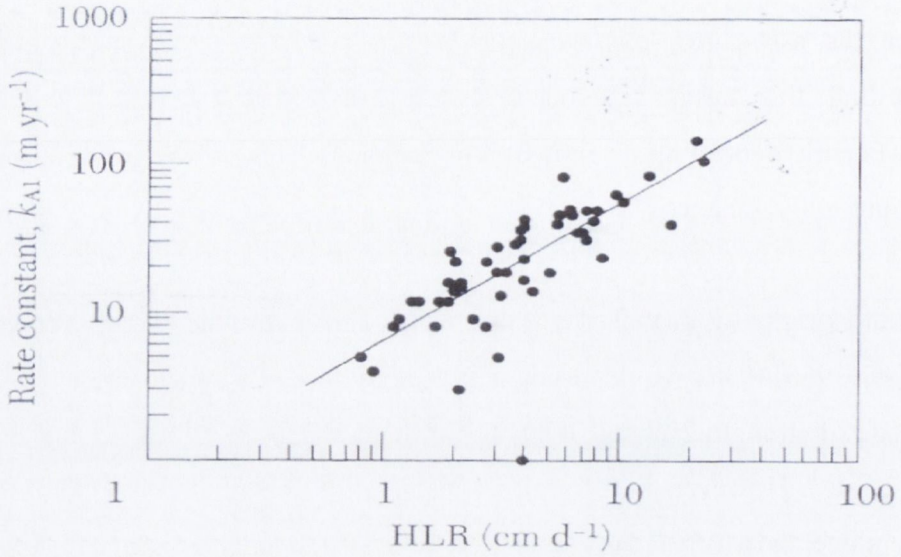


Figure 3.5 Hydraulic Loading Rate (HLR) effect on BOD_5 rate constants – results from Danish soil-based wetlands, for the one-parameter, area-based rate constant $k = 6.9(HLR)^{0.92}$ (IWA, 2000)

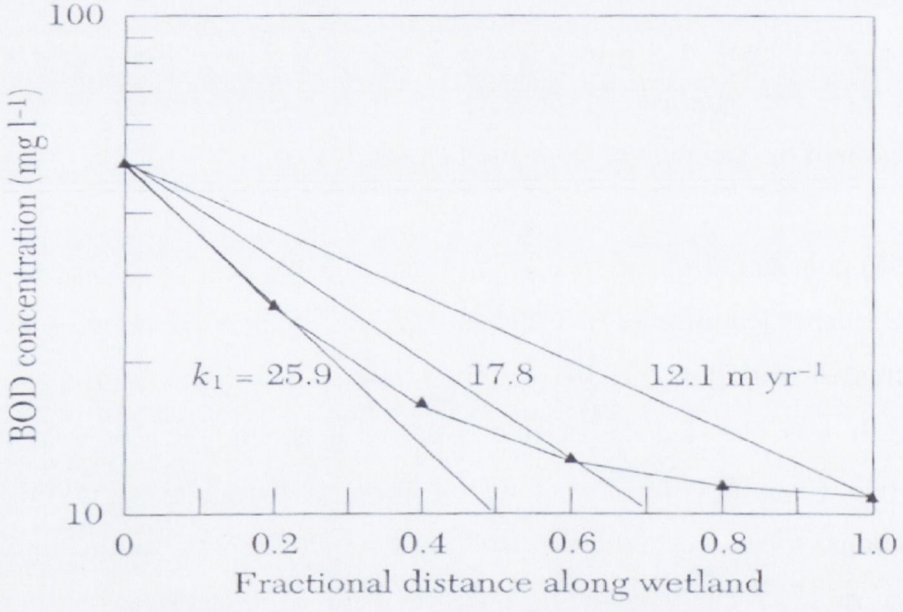


Figure 3.6 BOD_5 rate constants from input/output data from Listowel channel 4 in 1983/1984. Points show average annual data, and the lines show the k-C* model for different values of k_1. [$k = 38$ m yr^{-1}; $C^* = 10.5$ mg L^{-1}; $R^2 = 0.999$] (IWA, 2000)

According to Birkedal *et al.*, (1993) and as part of the European Design Guidelines (Cooper *et al.*, 1996), the rate constant, k_{BOD5} is also temperature dependent and is calculated from the rate constant at 20 °C and a temperature correction factor (θ) :

$$k_{BOD(t)} = k_{BOD(20)}(\theta)^{(t-20)} \qquad \text{(Eqn. 3.5)}$$

In effect, the temperature correction factor causes the rate of reaction predicted by the model to either increase ($\theta > 1$) or decrease ($\theta < 1$) with temperature. A value of 1.1 has been recommended in the European Design Guidelines (Cooper *et al.*, 1996) suggesting an increase in performance with rising temperature.

A value of k_{BOD5} = 0.1 m d^{-1} is now generally taken for secondary treatment horizontal SSF reed beds in Europe, which equates to a bed surface area (A) of approximately 5 m^2 PE^{-1}. Water Research Centre (WRc) recommends this design area for such applications (Cooper *et al.*, 1996). For tertiary HF beds the same design procedure outlined has been adopted but with a reduced area of between 0.7 m^2 PE^{-1} and 1 m^2 PE^{-1}. A k_{BOD5} value of 0.31 m d^{-1} has been suggested in this case (Cooper *et al.*, 1996).

Kadlec and Knight (1996) advocate the use of global parameters they determined as a result of analysing the performance of all FWS wetlands and horizontal SSF beds listed in the North American Data Base (NADB) (Knight *et al.*, 1993). Kadlec and Knight's statistical analysis of the available data is comprehensive but the authors point out that caution should be used in applying their so-called global parameter values to new systems. The global parameters they used are shown in Table 3.4. An important point is that according to Kadlec and Knight (1996) the rate constant is related only to the wetland surface area. Temperature changes are considered significant for nitrogen removal only.

Table 3.4 Preliminary global rate constants and background concentrations for both FWS wetlands and horizontal SSF reed beds based on performance data from the NADB (Kadlec and Knight, 1996)

Parameter	BOD_5	TSS	Org-N	NH_4	NO_3	TN	TP[a]	FC
For free water surface (FWS) wetlands:								
k_{20} ($m\ d^{-1}$)	0.09	2.73[b]	0.05	0.05	0.1	0.06	0.03	0.2
C*($mg\ L^{-1}$)	3.5 + 0.053C	5.1 + 0.16C_i	1.5	0	0	1.5	0.02	300[c]
For subsurface flow (SSF) reed beds:								
k_{20} ($m\ d^{-1}$)	0.49	2.73[b]	0.1	0.09	0.14	0.07	0.03	0.26
C*($mg\ L^{-1}$)	3.5 + 0.053C	7.8 + 0.063C_i	1.5	0	0	1.5	0.02	10[c]

[a] for non forested wetlands
[b] rough unsubstantiated estimate, settling rate determination preferred (Kadlec and Knight, 1996)
[c] central tendency of widely variable values

From the available data, several empirical regression equations were subsequently produced by Kadlec and Knight (1996) to predict outflow concentrations, C_o based on inflow concentrations, C_i and hydraulic retention time (HRT) (Table 3.5).

Table 3.5 Empirical equations for the estimation of outflow concentrations (C_o) or wetland areas (A) in FWS and horizontal SSF reed beds based on inflow concentrations (C_i) and HRT. Correlation coefficient (R^2) and number of wetlands used in analysis (n) are also provided (Kadlec and Knight, 1996)

Constituent	Equation	R^2 (n)
BOD_5		
Subsurface flow (soil-based)	$Co = 1.87 + 0.11Ci$	0.74 (73)
Subsurface flow (gravel-based)	$Co = 1.4 + 0.33Ci$	0.48 (100)
Surface flow	$Co = 4.7 + 0.173Ci$	0.62 (440)
Total Suspended Solids (TSS)		
Subsurface Flow	$Co = 4.7 + 0.09Ci$	0.67 (77)
Surface Flow	$Co = 5.1 + 0.158Ci$	0.23 (1 582)

Ammonia Nitrogen (NH_4-N)		
Subsurface Flow	$Co = 3.3 + 0.46Ci$	0.63
Surface Flow	$Co = 0.336Ci^{0.728}q^{0.456}$	0.44 (542)
Nitrate Nitrogen (NO_3-N)		
Subsurface Flow	$Co = 0.62Ci$	0.80 (95)
Surface Flow	$Co = 0.093Ci^{0.474}q^{0.745}$	0.35 (553)
Total Nitrogen (TN)		
Subsurface Flow	$Co = 2.6 + 0.46Ci + 0.124q$	0.45 (135)
Surface Flow	$Co = 0.409Ci + 0.122q$	0.48 (408)
Total Phosphorous (TP)		
Subsurface Flow	$Co = 0.51Ci^{1.1}$	0.64 (90)
Surface Flow	$Co = 0.195Ci^{0.91}q^{0.53}$	0.77 (373)

Reed *et al.* (1995) suggests a similar first-order plug flow equation for those pollutants that are removed primarily by biological processes, including biochemical oxygen demand (BOD_5), ammonia (NH_4-N) and nitrate (NO_3-N).

The design basis for horizontal SSF reed beds has thus led to "rule of thumb" sizings being estimated from a range of studies, summarised in Table 3.6.

Table 3.6 Typical rule of thumb design parameters for horizontal SSF reed beds

Reference	Areal Requirement (m^2 PE^{-1})	Influent Type	Person Equivalent Volume (L d^{-1})	Target Removal Parameter
DLWC (1998)	2.5 – 5.0	Primary	250	BOD_5 & TSS
UK Systems in DLWC (1998)	5.0	Primary	250	BOD_5
UK Systems in DLWC (1998)	0.5 – 1.0	Secondary	250	BOD_5 and some N
Marshall (1999)	3.0 (tropical) 3.75 (sub-	Septic Tank	150	Not Given

	tropical) 4.5 (temperate)			
Williams *et al.* (1995)	1.0	Secondary	100	Ammoniacal-N

An alternative non-kinetic approach to the sizing of horizontal SSF beds has been suggested by the US EPA (1993) which is based on the premise that in a temperate climate, the annual BOD_5 removal rate approximates 2.5 kg m^{-2} yr^{-1}. A calculation for the annual BOD_5 removal (BOD_{rvd}) for the wetland is first determined by:

$$BOD_{rvd} = 365[(C_i - C_o)(\frac{Q}{1000})] \quad \text{(Eqn. 3.6)}$$

The wetland area is then calculated by

$$A = \frac{BOD_{rvd}}{2.5} \quad \text{(Eqn. 3.7)}$$

This also gives a design figure of approximately 5 m^2 PE^{-1} based on a flow of 180 L p^{-1} d^{-1}. Other model types, especially those employing Monod kinetics, diffusion and biofilm processes, or rate retardation have been proposed for predicting wetland behaviour (Mitchell and McNevin, 2001: Wynn and Liehr, 2001; Marsili-Libelli and Checchi, 2005). While many of these models have been shown, through various studies, to offer conceptually superior alternatives and underscore the lack of an accepted standard model, the (k - C*) first order plug flow models still remains the most widely used for predicting wetland performance (IWA, 2000). This is despite their obvious deficiencies, which will be highlighted in more detail in Section 3.6.1.

3.4.2 Depth

In terms of bed depth, most UK and European systems have been built 0.6 m deep at the inlet with the outlet end being deeper to fit in with the slope selected. This figure was chosen as it is the maximum depth to which the roots of the *Phragmites australis* species are known to grow and thus the liner is protected from any potential rhizome penetration. Maximizing the root depth is thought to be important as the depth of

potential substrate aeration as a result of macrophyte O_2 transport is at its greatest, accordingly.

3.4.3 Width/Cross Sectional Area of Inlet

Further dimensions required in the design of a HF reed bed are the bed's length and width. To achieve this, the cross-sectional area at the inlet of the bed is calculated using Darcy's Law (Eqn. 3.8). The width can thus be determined, dictated by the fact that the inlet depth has already been set at 0.6 m depth. This equation takes into account the hydraulic conductivity of the media and thus aims to ensure subsurface flow in the bed. Two important assumptions have also been made in applying the formula:

1) the hydraulic gradient can be used instead of the slope, and
2) the hydraulic conductivity will stabilize at 10^{-3} m s^{-1} in the established reed bed

$$A_c = \frac{Q_s}{k_f \frac{dH}{ds}} \qquad \text{(Eqn. 3.8)}$$

where A_c = cross-sectional area of the bed, (m^2)

Q_s = average flow rate of sewage, (m^3 s^{-1})

k_f = hydraulic conductivity of the fully-developed bed, m s^{-1}

$\frac{dH}{ds}$ = base slope of bed

Worth noting is that the bed width and cross sectional area are independent of temperature (climate) and organic loading since they are controlled by the hydraulic characteristics of the media (US EPA, 1998).

3.4.4 Media Selection

One of the major flaws associated with Kickuth's early root-zone method design was the media selection and its hydraulic conductivity (k_f). Using cohesive soils as the bed substrate, Kickuth indicated that a fully-developed horizontal SSF reed bed would have a k_f of approximately 3×10^{-3} m s^{-1}. This has not been borne out by experience, however, and the advice by WRc (Cooper *et al.*, 1996) not to assume a hydraulic conductivity of greater than that of the original media has been followed for UK plants

built in the past 10 years. In fact, in many cases, it is sensible to use a k_f value somewhat less than the initial value on the basis that suspended solids may block the voids in the bed (Cooper *et al*, 1996). Unfortunately, in the mid 1980s several wetlands were built using soil medium where it was assumed that k_f would increase. Some of these beds suffered from surface flow leading to channelling and scouring of the surface which resulted in areas of the beds being starved of water and hence leading to poor reed growth. This invariably led to channeling (short-circuiting) and hence reduced treatment. As a result, gravel became the medium of choice since it allowed through-flow of water from the start. It was postulated that if the gravel beds filtered out solids and started to block the voids this might be counterbalanced by the roots and rhizomes opening up the bed. A k_f value of 1×10^{-3} m s^{-1} is now recommended for gravel beds and these systems have performed successfully throughout Europe. Typical gravel sizes are 3 – 6 mm, 5 – 10 mm and 6 – 12 mm and it is recommended that the gravel is washed first to remove fines (Cooper *et al.*, 1996). The bed surface must always be kept level to prevent potential surface flow while the base slope of the bed should be between 0.5% and 2% to fit the idealised hydraulic gradient of between 2 and 5% (Cooper *et al.*, 1996). A series of iterations can be carried out by altering the length, width and base slope of the bed to obtain the desired hydraulic gradient. The hydraulic conductivity, however, must remain constant in all calculations.

3.4.5 Liners

A range of impervious materials can be used to line the wetland – plastic, HDPE, synthetic butyl rubber or even bentonite. Natural lining can also be adopted once the local soil has a hydraulic conductivity of 1×10^{-8} m s^{-1}, or less, and as such a high clay content, so that the face can be compacted (or "puddled") to provide an adequate seal.

3.4.6 Aspect Ratio

The length/width ratio, otherwise known as the aspect ratio, is one of the principal determinants of the hydraulic profile of a reed bed. As there is a headloss between the wetland's inlet and outlet, the profile must be contained properly within. Debate has arisen over the correlation between the aspect ratio and the occurrence of short-circuiting in the bed. Plug-flow conditions are regarded as the most favorable for treatment efficiency but research has shown the kinetics to be otherwise (see Section 4.6.1). While Griggs & Grant (2001) recommend a length to width ratio of about 4:1 to

encourage plug flow of the water through the bed, many other tracer tests of reed beds have invalidated the presumption that high aspect ratios would favour a more efficient flow pattern. Indeed studies have repeatedly demonstrated that an increasing aspect ratio delays the effluent breakthrough time but the spread of the response curve is similar for lower and higher aspect ratios (Fisher, 1990; Netter, 1994). Bounds *et al.* (1998) found that there was no significant difference in TSS and COD removal in three parallel horizontal SSF beds with aspect ratios of 4 : 1, 10 : 1 and 30 : 1. This implies that contaminant removal is not so dependent on the shape of the bed. More of a key factor, it appears, in promoting optimal flow conditions and a favourable treatment environment is the inlet and outlet arrangements.

3.4.7 Inlet and Outlet Configurations

The objective in horizontal SSF reed beds is to obtain even flow distribution across the full cross-sectional area of the inlet end of the bed. To achieve this, various inlet structure configurations have been designed, including surface and subsurface manifolds, open trenches perpendicular to the direction of the flow and simple single-point weir boxes (IWA, 2000). Current practice on the Irish market for on-site secondary treatment horizontal SSF beds is to install either (i) an inlet tee connecting to risers with V-notch weirs at 0.5 – 2 m spacings across the width of the bed or (ii) an inlet tee with horizontal exit points at 0.5 – 2 m spacings across the width of the bed. The latter (Figure 3.7) is the recommended choice for secondary treatment given the potential for high solids accumulation from the STE at the base of the riser pipes in option (i). In tertiary treatment applications either (i) or (ii) is feasible given the reduced organic loading to the bed.

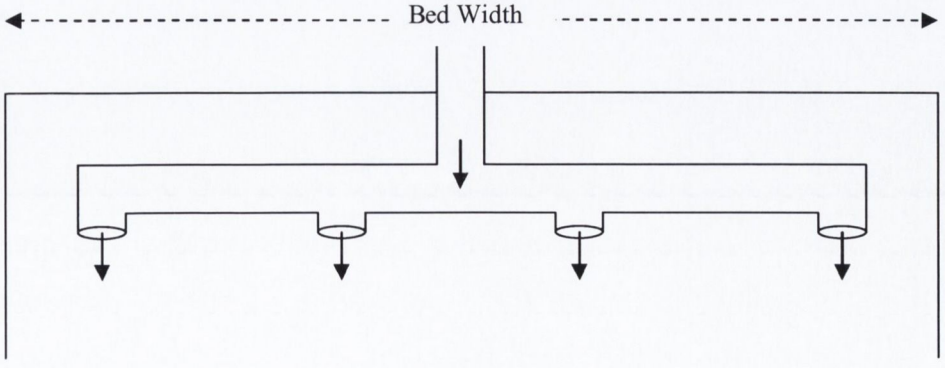


Figure 3.7 Recommended inlet configuration for horizontal SSF reed bed (plan view)

It is also recommended to place large graded stones (50 – 200 mm) around the inlet and outlet area to improve the local distribution of the wastewater on entry and exit. A wire-mesh gabion can be used to precisely define the inlet (and outlet) area during construction. At the outlet end, most systems have a perforated pipe placed at the base of the bed which leads to a sump where the water level is controlled by either a swivelling elbow or a socketed pipe (Figures 3.8(a) and (b)).

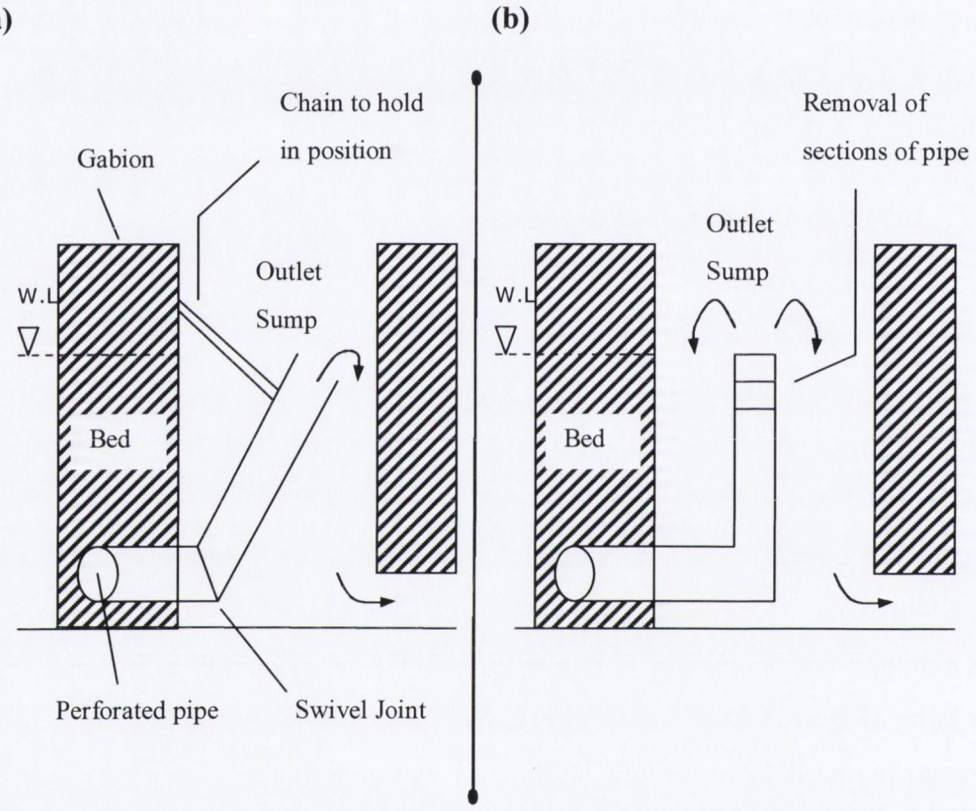


Figure 3.8 **(a)** Swivelling elbow and **(b)** Socketed pipe outlet designs (Cooper *et al.*, 1996)

3.5 Reed Bed Treatment Mechanisms and System Performance

Pollutant removal within reed beds occur via a complex variety of natural physical, biological and chemical processes (Kadlec, 1999). Biologically, they are far more diverse than conventional biological treatment systems given their exposure to and integration with the natural environment. The most important removal mechanisms are summarised below (Table 3.7).

Table 3.7 Predominant removal mechanisms in reed bed treatment systems (adapted from Cooper *et al.*, 1996)

Wastewater Constituent	Removal Mechanism
Organic Matter	Aerobic Microbial Degradation
	Anaerobic Microbial Degradation
Total Suspended Solids	Sedimentation
	Filtration
Nitrogen	Ammonification/Microbial Nitrification
	Denitrification
	Plant Uptake
	Matrix Adsorption
	Ammonia Volatilisation
Phosphorous	Matrix Sorption & Precipitation
	Plant Uptake
Pathogens	Sedimentation
	Filtration
	Natural Die-off
	Predation
	UV Irradiation
	Root Excretion of Antiobiotics

3.5.1 Organic Matter

Many processes within wetland systems are fuelled from inputs of inorganic carbon and the microbial degradation of organic carbon (Davison *et al.*, 2002). Organics can be broadly separated into two categories – those that are settleable (particulate) and those that are soluble (dissolved). Settleable organics are rapidly removed on initial entry to the reed bed through filtration and sedimentation. The complete removal of carbon, however, requires the production of volatile carbon compounds (CO_2 and CH_4) through microbial respiration (Kadlec and Knight, 1996). Aerobic degradation of organic matter produces CO_2 and H_2O and is carried out principally by aerobic chemoheterotrophs, which oxidize organics and release ammonia. The oxygen required for aerobic degradation in reed beds is supplied from two sources - directly from the atmosphere by diffusion and through oxygen transfer from the macrophyte roots into the rhizosphere.

However, it has been reported that little oxygen in fact escapes from the roots of the macrophytes. Initial oxygen release rate estimates for *Phragmites australis* ranged from 5 – 25 g m^{-2} d^{-1} but field measurements have shown rates to be much lower and variable. Brix (1990) and Brix and Schierup (1990) reported only 0.02 g m^{-2} d^{-1}, Gries *et al.* (1990) found 1 – 2 g m^{-2} d^{-1} and Armstrong *et al.* (1990) reported release rates as high as 5 – 12 g m^{-2} d^{-1}. Regardless of the magnitude of oxygen release to the rhizosphere, the aerobic conditions are restricted to the microzones adjacent to fine lateral roots and therefore reduction and breakdown in organics is primarily carried out by the prevailing anaerobes on the bed's media.

It is difficult to quantify the ratio between aerobic and anaerobic degradation in wetland systems. Ottová *et al.* (1997) found that the numbers of aerobic heterotrophic bacteria in wastewater entering horizontal flow reed beds were higher than anaerobic ones but anaerobic bacteria prevail in the outflowing effluent. This indicates that aerobic bacteria naturally die-off as a result of unfavourable anaerobic or anoxic conditions during the passage through the bed media.

The extent of organic degradation is most commonly indicated by the reduction in BOD_5 or COD levels across the wastewater and is very much dependent on the strength of the influent to the bed in many cases. Of the numerous papers published discussing horizontal SSF beds, most receive diluted wastewater (BOD_5 < 150 mg L^{-1}) probably due to the commonly occurring, but illegal, practice of builders connecting the household's roof water into the wastewater treatment system network network. Undiluted STE in comparison, has a BOD_5 of between 150 and 400 mg L^{-1} (Griggs and Grant, 2001). Vymazal (2002) found that the average treatment efficiency for BOD_5 removal in 24 horizontal flow systems receiving primary effluent in the Czech Republic is 88% and the final effluent BOD_5 concentration to be 10.5 mg L^{-1}. This correlates with similar findings from other countries worldwide (Table 3.8) with the exception of North America, whose lower efficiency is as a result of the lower influent BOD_5 concentrations. Removal of COD is generally lower than that for BOD_5 due to presence of non or low-biodegradable pollutants.

Table 3.8 Comparison of mean influent and effluent organic matter concentrations, removal efficiencies and organic loading rates in horizontal SSF reed beds of different countries

Parameter	*Influent*	*Effluent*	*Efficiency (%)*	*n*
BOD_5 concentration (mg L^{-1})				
Czech Republic (1)	87.2	10.5	88.0	55
Denmark and UK (2)	97.0	13.1	86.5	80
Spain (3)	173	32	74.2	13
North America (4)	27.5	8.6	68.5	34
Germany-Bavaria (5)	106	21.6	79.6	7
Poland (6)	110	18.1	83.5	6
Slovenia (7)	107	11.3	89.0	3
Sweden (8)	80.5	5.9	92.7	3
BOD_5 surface loading rate (g BOD_5 m^{-2} d^{-1})				
Czech Republic (1)	3.18	0.45	83.5	49
Denmark and UK (2)	4.8	0.89	80	66
Spain (3)	10.5	3.1	68.6	9
North America (4)	2.92	1.08	63	29
Poland (6)	3.77	0.71	81.2	6
Slovenia (7)	5.39	0.55	89	3
Sweden (8)	2.24	0.31	86.2	2
COD concentration (mg L^{-1})				
Czech Republic (1)	211	53	75.0	53
Denmark (2)	264	64.7	75.0	59
Spain (3)	347	84	66	13
Germany-Bavaria (5)	234	69.4	70.3	7
Poland (6)	283	101	64.3	6
Slovenia (7)	200	35.7	82.0	3
COD surface loading rate (g COD m^{-2} d^{-1})				
Czech Republic (1)	8.64	2.25	74	48
Denmark (2)	12.7	3.02	76	48
Spain (3)	22.6	8.6	57.8	9
Poland (6)	9.62	3.9	59.5	6
Slovenia (7)	10.4	1.84	82	3

n = number of reed beds under analysis

Sources: (1) Vymazal (2002); (2) Brix (1994a) and Schierup *et al.* (1990); (3) Puigagut *et al.* (2007); (4) Kadlec and Knight (1996); (5) Borner *et al.* (1998); (6) Kowalik and Obarska-Pempkowiak (1998); (7) Urbanc-Bercic *et al.* (1998); (8) Sundblad (1998)

While Vymazal (2002) and comparable research from other authors suggest a high performing system with low organic influent concentrations, little work has been carried out to assess the efficiency of small-scale horizontal SSF systems receiving undiluted STE.

3.5.2 Total Suspended Solids

Suspended particulate matter, measured as total suspended solids (TSS), not retained in a pre-treatment device (i.e. a septic tank) is effectively removed in reed beds via sedimentation and filtration (Reed *et al.*, 1995). Sedimentation occurs within stagnant water-filled microzones of the bed substratum (Kadlec & Knight, 1996). Removal efficiencies for established reed beds are high, generally greater than 70% with effluent concentrations typically below 20 mg L^{-1} (Reed *et al.*, 1995). Table 3.9 details findings for TSS removal across a number of different countries, all showing similar efficiency levels. The corresponding critical hydraulic retention time (HRT) for achieving TSS removal efficiencies above this percentage appears to be 2 days (Gearheart, 1992).

Table 3.9 Comparison of average influent and effluent concentration, mass loading rates and removal efficiencies of TSS in horizontal SSF reed beds of different countries

	Influent	*Effluent*	*Efficiency (%)*	*n*
TSS Concentration (mg L^{-1})				
Czech Republic (1)	64.8	10.2	84.3	42
Denmark and UK (2)	98.6	13.6	86.2	77
Spain (3)	173.3	22	87.8	3
North America (4)	48.2	10.3	78.6	34
Poland (6)	140	38.6	77.4	6
Loading Rate (g m^{-2} d^{-1})				
Czech Republic (1)	36.4	4.2	88.5	36
Denmark and UK (2)	52.2	10.6	79.7	51
North America (4)	48.1	12.8	73.4	29
Poland (6)	36.2	13.7	62.2	6

Sources as in Table 3.8

In the case of horizontal SSF systems the vast majority of TSS removal occurs at the inlet or within the first metre of the bed as a result of particle adhesion to both the

media and associated biofilms. This, in effect, negates the importance of TSS being used as a criterion for wetland design. Nevertheless, the fate of TSS in wetlands should not be understated. Studies have shown, notably Reed and Brown (1992), accumulation of organic solids occurs preferentially at the head of the reed bed. Their agglomeration within interstitial spaces of the gravel matrix upon entry may have negative implications on the maintenance of an effective hydraulic conductivity (Tanner and Sukias, 1995). In the event of excessive pore space clogging, flow velocities within the bed increase and as a result the hydraulic residence time (HRT) shortens. Treatment performance and in particular pathogen removal efficiency suffers as a consequence. In time this could potentially lead to partial surface flow of wastewater on the bed. As such this is one of the major disadvantages associated with horizontal SSF systems. The rate of solids accumulation within the bed initially depends on the influent solids loading rate, but ultimately relies on the chemical and microbiological degradation rate of organic solids (Blazejewski and Murat-Blazejewski, 1997). Thus, the role of a pre-treatment device, such as a properly functioning septic tank or mechanical unit, is crucial at the front end of the system in considerably reducing the occurrence of interstitial clogging.

3.5.3 Nitrogen

Nitrogen (N) removal capacity of horizontal SSF reed beds is an important design criterion that has not yet been fully explored when treating domestic wastewater.

In secondary treatment beds, the influent STE contains very low concentrations of NO_3-N and high concentrations of NH_4-N and TKN. Approximately 75 - 85% of the TKN consists of NH_4-N. The removal of NH_4-N in the reed bed is limited by a lack of oxygen and is restricted to aerobic microzones in the close vicinity of macrophyte roots and rhizomes. Ottova *et al.* (1997) found negligible numbers of nitrifiers in wastewater while significant numbers of nitrifiers were present on roots and rhizomes. Because of the predominance of NH_4-N and TKN in the effluent, these parameters are therefore most important in determining N removal rates. Removal of total, inorganic and organic nitrogen in horizontal SSF beds across a range of countries is presented in Table 3.10. Treatment efficiencies for total N removal across the countries were very similar, averaging 41.0% and 36.2% in terms of concentration and surface loading, respectively. Both Czech Republic and North American systems showed a high degree of Org-N

removal owing to mineralisation which, according to Kadlec and Knight (1996), proceeds kinetically more rapidly than nitrification. NH_4-N removal rates were found to be similar to total N, averaging 43.4% and 46.2% in terms of concentration and surface loading, respectively. It is thought that given the prevailing anaerobic conditions of the bed, removal of NH_4-N is restricted to aerobic microzones in the close vicinity of macrophyte roots and rhizomes. The poor removal of NH_4-N in North American systems may be related to the low incoming concentrations recorded. Removal of oxidized inorganic nitrogen (NO_3-N and NO_2-N), i.e. denitrification, appears to vary considerably with results from Czech Republic systems, even showing an average effluent concentration higher than the influent one. This is most likely due to a combination of (i) some beds showing increased levels of nitrification creating additional NO_3-N but failing to denitrify the effluent due to unfavorable oxygen conditions, and (ii) the complex interconversions between different nitrogen species and transfers between storage compartments. The effect of seasonality on nitrogen removal is also significant and is further discussed in Section 3.6.2.

Table 3.10 Comparison of averages of influent and effluent, and removal efficiencies of total nitrogen, organic nitrogen, ammoniacal nitrogen, and oxidized inorganic nitrogen in horizontal SSF reed beds of different countries. Mass loading rates (g m^{-2} d^{-1}) and mass removal efficiencies are included in parentheses (adapted from Vymazal, 2002)

	Total-N	***Org-N***	***NH_4-N***	***$NO_3 + NO_2$***
Influent (mg L^{-1})				
Czech Republic (1)	46.4 (24.5)	8.16 (4.15)	28.1 (13.1)	5.06 (4.12)
Denmark and UK (2)	36.6 (11.5)	-	21.0 (9.3)	4.07 (1.65)
North America (4)	18.9 (13.2)	10.11 (7.28)	5.98 (7.0)	4.40 (3.10)
Poland (6)	46.1 (15.8)	-	-	-
Slovenia (7)	-	-	28.7 (15.1)	-
Sweden (8)	25.3 (15.8)	-	-	-
Effluent (g m^{-2} d^{-1})				
Czech Republic (1)	27.1 (15.0)	2.87 (4.15)	16.1 (8.2)	5.16 (3.35)
Denmark and UK (2)	20.9 (7.8)	-	14.1 (3.3)	2.11 (0.68)
North America (4)	8.4 (7.35)	4.03 (7.28)	4.51 (6.4)	1.35 (1.21)
Poland (6)	34.8 (12.5)	-	-	-
Slovenia (7)	-	-	7.7 (3.9)	-
Sweden (8)	15.1 (8.7)	-	-	-

Efficiency (%)				
Czech Republic (1)	41.6 (38.9)	64.8 (59.8)	42.7 (37.4)	-1.9 (18.7)
Denmark and UK (2)	42.9 (32.2)	-	32.9 (64.5)	48.2 (58.8)
North America (4)	55.6 (44.3)	60.1 (55.6)	24.6 (8.6)	69.3 (61.0)
Poland (6)	24.5 (20.9)	-	-	-
Slovenia (7)	-	-	73.2 (74.1)	-
Sweden (8)	40.3 (44.9)	-	-	-

Sources as in Table 3.8

While theoretical removal models such as the first order areal k-C* model proposed by Kadlec and Knight (1996) were developed principally for BOD_5 and SS removal, the suggestion was that the same kinetics could be applied to the removal of NH_4-N in wetland systems. However, most of these models are unable to accurately predict the concentrations of different forms of nitrogen discharged, or account for seasonal and stochastic variability in system response (Kadlec, 1999). Analysis on an input-output basis is confounded by temporal factors related to the detention of nitrogen within the large internal wetland storages and by the uncertainty of seasonal uptake and release. Moreover, it is unlikely that water detention time appropriately reflects delays in the dynamic and stationary compartments (the substrate, sediments and plants) of the wetland. That is, the nitrogen residence time will vary markedly (and likely to be far greater than the water detention time) depending on how many times it has been "parked" and recycled in various active or passive storage compartments during its passage through the wetland (Kadlec *et al.*, 2005). These interactions and subsequent transformations in nitrogen, shown in Figure 3.9, occur along a spatial gradient from wetland inlet to outlet. For instance, a nitrogen atom that enters in its NH_4-N form may be taken up at an upstream location by sorption or by biological uptake, only to be later released by desorption or biomass decomposition. That same atom may later be detained again in a solid compartment, and again released to downstream advective transport (Kadlec *et al.*, 2005). This concept has been termed "spiraling" (Newbold *et al.*, 1983) and is one of the central concepts of solute dynamics. The tightness (or conversely the length) of the spiral, and the intensity and nature of the transformations that occur in each cycle will affect the retentiveness and removal rate of elements in the system (Kadlec *et al.*, 2005). Howard-Williams (1985) noted that the nutrient removal capacity of wetlands was a function of their large storage reservoirs and short spiral

lengths. Kadlec *et al.* (2005) introduced a stable isotope ^{15}N to a HF reed bed as NH_4 as a means of exploring and investigating nitrogen processing and exchanges in wetlands. It was concluded that interpretation of nitrogen dynamics in wetlands must include the nitrogen spiral through the wetland The increased N residence time relative to the hydraulic detention time will result in long delays of treatment system response to changes in N loading and attenuation of short-term fluctuations in loading.

As such, the transformation and removal of nitrogen involves a complex set of processes and relations which, in quantification terms, is still poorly understood. Given that conditions in horizontal SSF reed beds are usually anoxic and/or anaerobic, nitrification is generally considered to be the rate-limiting step for N removal unless the wastewater is pre-nitrified. Most NO_3-N and NO_2-N generated by nitrification will be removed by denitrification immediately. The process is restricted to areas adjacent to roots and rhizomes where oxygen leaks to the filtration media (Vymazal, 2005).

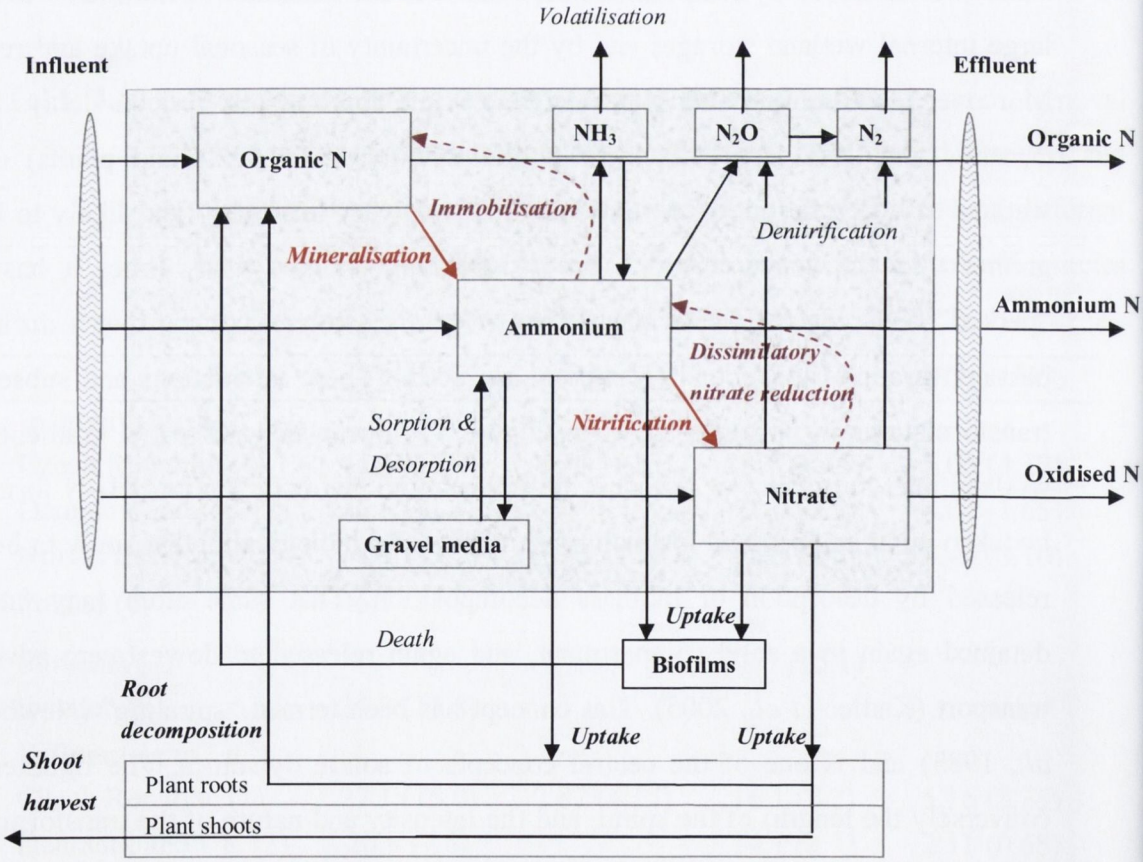


Figure 3.9 Schematic of the nitrogen processes and the flows of different nitrogen forms in horizontal SSF reed bed treatment systems (Tanner *et al.*, 2002).

Decomposition, sedimentation and mineralisation processes in the wetlands are believed to convert a significant fraction of the Org-N to NH_4-N (Mayo and Mutamba, 2004).

Plant assimilation only accounts for a small percent of the total N removal when the nitrogen load is high (Tanner *et al.* 1995), which is the case in most horizontal SSF beds treating domestic STE. Thable (1984) estimated that only 5 – 10% of the wastewater nitrogen load was incorporated into the plant biomass. That is why in most cases plants are not harvested. Ammonia volatilisation, a physico-chemical process where ammonia in the ammonium-ammonia equilibrium (NH_3-N) is transported to the gas phase, is usually small if wastewater pH is below 8 and temperatures are moderate (Reddy and Patrick 1984). Ion exchange of NH_4-N on cation exchange sites of the matrix is not considered to be a long term sink for NH_4-N removal as sorption of NH_4-N is presumed to be rapidly reversible (Brix, 1993b).

The effect of biofilm and organic matter on nitrogen dynamics has also been examined. Micro organisms which attach on different parts of bed plants and media form a biofilm layer which plays an important role in wastewater nitrogen removal (Thammarat and Polprasert, 1997). Bigambo *et al.* (2005) examined this effect of biofilm on nitrogen dynamics and found that there was no significant difference in org-N effluent concentrations when biofilm biomass was considered or rejected. On the other hand, biofilm activities appeared to have significant influence on NH_4-N and any NO_3-N transformation. Their model indicated that both the effluent NH_4-N and NO_3-N loading increased in the absence of a biofilm. In addition, TN removal appeared to be influenced more by growth of biofilm on plants rather than on aggregates (6 – 25 mm diameter gravel). When plant biofilm and suspended biomasses were considered TN removal of 38.1% was observed compared with 25.1% when aggregate-biofilm and suspended biomasses were considered. This, it is assumed, is due to plants having greater surface areas and active sites for effective biofilm growth.

Conversion of NO_3-N to N_2O-N (denitrification) is the primary objective in tertiary HF reed beds treating secondary effluent. While organic carbon is supplied to the sediment by plants in the beds, several studies have shown that the supply of the organic matter often limits denitrification when concentrations of NO_3-N are high (Burgoon, 2001;

Ingersoll and Baker, 1998). Other environmental factors that may influence rates of denitrification may be summarised as absence of oxygen, redox potential, media moisture, pH value, presence of denitrifying bacteria and the presence of overlying water (Vymazal, 1995).

3.5.4 Phosphorus

As is the case for nitrogen, reed beds with horizontal subsurface flow usually do not remove high amounts of phosphorus from wastewater as suitable conditions for its removal are lacking in these systems.

As is the case for nitrogen processing, reed beds may be visualized as consisting of several compartments in order to understand phosphorus cycling. These include water, plants, microbiota, sediment/litter and media. If not already achieved in pre-treatment, biological oxidation of phosphorus within reed beds initially converts most phosphorus species to an orthophosphate (soluble) form (i.e. $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}) (Cooper *et al.*, 1996). From there, key removal mechanisms include adsorption onto the bed's media, precipitation/fixation reactions, bacterial action and biomass uptake (IWA, 2000; Reed *et al.*, 1995). Factors such as grain size distribution, redox potential, pH and presence of Fe, Al and Ca minerals also play a crucial role in the extent of phosphorus removal.

Phosphorus adsorption is the process by which orthophosphate (PO_4^{3-}) is chemically bound to solid particulate matter. It can be viewed as a two stage process. Initial phosphorus removal occurs via a process known as ion exchange resulting from the electrostatic attraction of phosphate ions to positively charged sites existing within the bed's media. The second stage of phosphorus removal within the wetland is termed ligand exchange, where phosphate displaces water or hydroxyls from the surface of Fe and Al hydrous oxides. This process is characterised by an initial rapid adsorption rate that decreases with time. The reason for this drop-off is that given the continual influx of phosphorus-rich wastewater and the presence of the environmental conditions required for phosphorus adsorption within reed beds, sites available for adsorption increasingly become saturated. As such, adsorption of orthophosphate is a finite process as once the media is saturated the reed bed has reached storage capacity and it can no longer function effectively for P removal. This has been referred to as the 'ageing phenomena' in wetlands that receive wastewater (Kadlec, 1985). As a result, the media

(e.g. pea gravel, crushed stones, soil) would have to be either washed or, more probably, replaced in order to remove further P intake. The knowledge of P-adsorption capacity of the material can be used to estimate the maximum amount of phosphorus that can be taken and/or removed from a given wastewater, while it cannot provide an accurate estimation of the longevity of a wastewater treatment system.

The efficiency of horizontal SSF reed beds for phosphorus removal from a number of different countries is presented in Table 3.11. Phosphorus removal in terms of concentrations varies between 26.7 and 58.3%, most probably as a result of the different media types used and level of oxides present. Media with very low Fe and Al contents have been shown to yield low phosphorus removal rates. Maehlum and Jenssen (1998) reported that the overall phosphorus removal efficiency can amount to >90% when special media are used, e.g. lightweight ceramic particle aggregates.

Table 3.11 Comparison of averages of influent and effluent, mass loading rates and removal efficiencies of total phosphorus in horizontal SSF reed beds of different countries (adapted from Vymazal, 2002)

	Influent	*Effluent*	*Efficiency (%)*	*n*
Concentration (mg L^{-1})				
Czech Republic (1)	6.57	3.22	51.0	32
Denmark and UK (2)	8.60	6.30	26.7	67
North America (4)	4.41	2.97	32.7	8
Poland (6)	7.65	4.10	46.4	5
Sweden	5.03	2.10	58.3	3
Loading Rate (g m^{-2} d^{-1})				
Czech Republic (1)	3.06	1.76	42.5	30
Denmark and UK (2)	3.30	2.60	21.2	50
North America (4)	5.14	4.00	22.2	8
Poland (6)	2.72	1.60	41.2	5
Sweden	4.04	1.56	61.4	2

Sources as in Table 3.8

Many previous studies have been conducted to investigate the potential of various materials to remove P from wastewater. Various media including limestone, shale, slag,

gravel, fly ash, blast furnace slag, light-expanded clay aggregates (LECA), and other artificial materials have been used in reed beds (Mann, 1997; Drizo *et al.*, 1997; Johannson, 1997). A shale-based constructed wetland (Drizo *et al.*, 1997) with or without reeds (*Phragmites australis*) was reported to have 98 – 100% P-removal capacity.

Reed beds are not designed for the removal of phosphorus by macrophyte uptake and subsequent harvesting. Field experience suggests that the amount of phosphorus which could be removed by harvesting accounts only for a small percentage of the total phosphorus removed in the planted beds. This amount is usually < 10% and in most cases < 5% (Vymazal, 1999; Obarska-Pempkowiak, 1999). Furthermore, removal of phosphorous is limited because the litter formed by decomposing vegetation stays on the surface of the substrate and is thus not in contact with the wastewater (typically maintained 100 to 150 mm below the surface). Given that horizontal SSF beds are usually not harvested, P is leached out after senescence.

3.5.5 Pathogens

While many studies have been focused on removing the organic load and other contaminants from domestic wastewater, limited attention has been paid to examining the efficacy of horizontal SSF reed beds for the removal of enteric pathogens. Like subsoil treatment, wetland systems are known to offer a suitable combination of physical, chemical and biological factors for the removal of pathogenic organisms. A large fraction of pathogens are removed in reed beds during the passage of wastewater through the system by sedimentation and filtration. Chemical factors include oxidation, exposure to biocides excreted by a number of plants, and sorption to organic matter. The biological removal mechanisms may include antimicrobial activity of root exudates, predation by nematodes and protests, activity of lytic bacteria or viruses, retention in biofilms, and natural die-off. Studies on indicator organisms such as faecal organisms, bacteriophages and other viral indicator organisms (Vymazal *et al.*, 2001, Thurston *et al.*, 2001, Vega *et al.*, 2003) have shown reed bed systems capable of removal efficiencies of 90 – 99.95% (i.e. 1 log-unit – 3.4 log-unit).

Detailed studies at five Czech secondary horizontal SSF systems revealed that the retention of coliform and fecal coliform bacteria is very high (> 95%) and exceeds

common retention values for conventional systems (Ottova *et al.*, 1997). Neralla *et al.* (2000) and Steer *et al.* (2002) reported 99% removal of faecal coliforms while Mashauri *et al.* (2000) reported 90% removal of total coliforms. Rivera *et al.* (1995) found *E. coli* removal of 31 – 91% in the rhizosphere but only 0 – 35% in the unplanted controls. However, caution must be taken regarding these high efficiencies in reed beds as the discharging effluent pathogen population may still be above limits (typically 1 000 CFU 100 mL^{-1}).

Gersberg *et al.* (1987) showed that seeded MS2 bacteriophage and seeded poliovirus were removed more efficiently in a wetland than were the indigenous F-specific RNA bacteriophages. The seeded phages underwent more than a 3 log-unit removal (99.9%) at high influent concentrations (> 10^4 PFU mL^{-1}) compared to a 2 log-unit removal (99%) for the indigenous phages. Parasitic protozoa and helminths have been removed from reed bed systems with varying success; some have showed removal efficiencies of up to 100% for a range of parasites (Rivera *et al.*, 1995). Thurston *et al.* (2001) showed *Giardia* cysts and *Cryptosporidium* oocysts were reduced by an average of 87.8% and 64.2%, respectively.

Up to the present, studies on faecal virus removal in tertiary reed beds have focused on the comparison between the inactivation of viruses and that of more traditional faecal microbial indicators (i.e., faecal coliforms) (Williams *et al.*, 1995; Gerba *et al.*, 1999; Garcia *et al.*, 2003). The general conclusion is that the coliphages tested have a lower inactivation rate than conventional bacterial indicators. In a study by Garcia *et al.* (2003) on tertiary treatment horizontal SSF beds in Spain, the microbial inactivation ratio ranged between 0.1 and 2.7 log-units for faecal coliforms and from 0.5 to 1.7 log-units for somatic coliphages in beds with coarser granular material (5 – 25 mm), while it ranged between 0.7 and 3.4 log-units for faecal coliforms and from 0.9 to 2.6 log-units for somatic coliphages in beds with finer material (2 – 13 mm). Furthermore, the authors suggested a specific surface area of approximately 3 m^2 PE^{-1} to reach 2 – 3 log-units of faecal coliforms and somatic coliphages. In a tertiary treatment reed bed receiving secondary effluent (Thurston *et al.*, 2001), it was found that total coliforms, faecal coliforms and coliphages were reduced by an average of 98.8%, 98.2% and 95.2%, respectively. The effect of HRT on system performance has been examined in

some detail and found to be an important factor in coliform removal. This is discussed further in Section 3.6.1.

3.6 Factors Affecting Reed Bed Treatment Performance

A number of specific factors, both in-situ and ex-situ, can control the pollutant removal processes operating within reed beds. Among the most important are:

- the effects of evapotranspiration
- the length of time wastewater spends within the reed bed (hydraulic residence time - HRT) and the hydraulic loading rate (HLR)
- the climate and season, as represented by temperature, and age of the system
- the presence and type of macrophyte species used
- the type and size of media used

3.6.1 Evapotranspiration and Hydraulic Parameters

Meteorological effects can have a significant additional impact on treatment performance. Seasonally variable wastewater flows can combine with seasonally variable rain, evaporation and transpiration rates and have a considerable impact on the water budget of a wetland system and thus on the mass balance of elements entering and leaving the wetland system. A number of water balance studies have shown that evapotranspiration (ET) is the largest hydrological flux through many wetland types during the summer months. In general, it follows a diurnal cycle, with maximum ET during early afternoon and ET at its minimum after dusk. Outflow can cease during the day for this extreme example. For purposes of contaminant mass balancing, the overall water balance carried out is given as:

$$Q_o = Q_i + (P - ET_{reed})A \qquad \text{(Eqn. 3.9)}$$

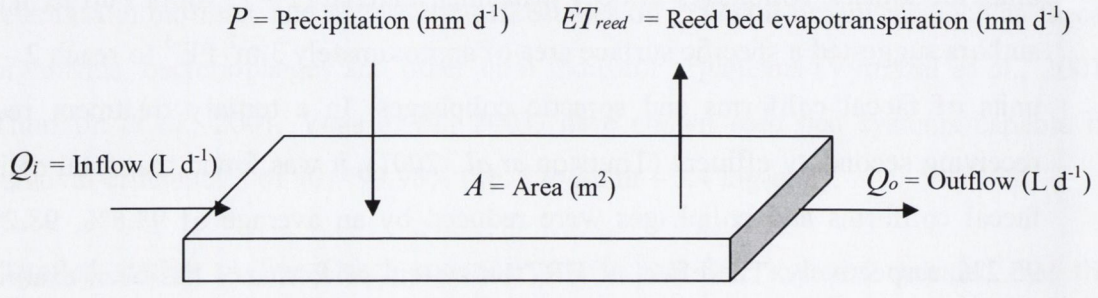


Figure 3.10 Water budget and content for reed bed treatment systems

Other potential mass balance elements in wetlands (infiltration to groundwater, bank loss rate, catchment runoff rate) are omitted; the wetland bottom and sides have impervious membranes meaning that the terms regarding infiltration to groundwater and bank loss rate are considered null while the catchment runoff rate is also ignored since wetlands are designed to receive only wastewater flows.

The FAO Penman-Monteith method (FAO, 1998) is the standard approach for determination of reference evapotranspiration (ET_o). Given that this variable is based on a reference surface similar to short green grass with an assumed height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo of 0.23, a suitable season dependent crop coefficient (K_c) needs to be established in order to estimate the evapotranspiration related to a gravel-based reed bed (ET_{reed}) as per Eqn. 3.10:

$$ET_{reed} = K_c ET_o \qquad \text{(Eqn. 3.10)}$$

The determination of this crop coefficient is very much climate specific and can vary depending on the size of the reed bed. An extensive perusal of literature has shown there to be, in some cases, a lack of understanding of the importance of water balance in reed bed performance, whilst in some instances, water budget information was not even collected prior to analysis. Calculation of a suitable crop coefficient for reed beds has therefore seldom been carried out. In field research by Davison *et al.* (2002) in a subtropical climate (New South Wales, Australia), two reed beds, each of area 8.8 m^2, produced crop coefficients with respect to ET_o (averaged over the year) of 0.93 and 1.4. In a follow-on study, Davison *et al.* (2005) found that annual crop coefficients relative to class A Pan Evaporation varied from 1.9 in the first year to 2.6 in the second. Currently, in planning new reed beds in the UK or in managing the hydrology of existing reed beds, a crop coefficient of 1.4 and the use of Penman-Monteith reference evapotranspiration estimates from a specific reference site is suggested (Hawke and Jose, 1996) due to the paucity of information on the subject. IWA (2000) states that the simplest estimator is that wetland ET_o is roughly equal to lake evaporation, which in turn is roughly equal to 80% of class A Pan Evaporation. It is unclear, however, whether this is aimed at subsurface or surface flow wetlands, presumably the latter. The overriding difficulty is that most reed bed evapotranspiration studies have been carried

out in areas with a different climate from that of Ireland, mainly in central Europe and Australia; therefore the data are not easily transferable.

A good design model for constructed wetlands should be able to describe and predict wetland hydraulics, since this directly affects the treatment performance of the wetland. In essence, the hydraulic characteristics of a wetland ultimately determine to what degree a given volume of wastewater is treated. As specified earlier, current design procedures for wetlands such as soil or gravel-based horizontal SSF systems are based on the simple assumptions of plug flow and first-order decay of pollutants. This has been described using Darcy's Equation governing water flow through a permeable media (Eqn. 3.8). However, in reality this supposition is never the case. The current design criteria appears open-ended, not so much in its prediction of treatment efficiency but more that it is somewhat limited in describing the hydraulic characteristics of horizontal SSF systems due to the influence of macrophyte roots and rhizomes, litter fall and, most significantly, the accumulation of organic substrate within the reed bed media. Although plug flow design procedures appear to yield adequately functional wetlands, it is thought they result in over-design and provide insufficient descriptions of the pollutant removal mechanisms which occur within them (King *et al.*, 1997).

Two other hydraulic effects that can have very important consequences for data interpretation and design are the hydraulic loading rate (HLR) and the hydraulic retention time (HRT).

The HLR of reed beds, (determined using Eqn. 3.11), quantitatively describes the amount of water entering the system over a given time period (IWA, 2000). Consequently, the HLR of reed beds determines the approximate time wastewater spends within the system – a relationship strongly governing the extent of pollutant removal within a reed bed system (Reed *et al.*, 1995).

$$HLR = \frac{Q_i}{A} \qquad \text{(Eqn. 3.11)}$$

where HLR = Hydraulic Loading Rate (mm day^{-1})

Q_i = influent flow rate (L day^{-1})

A = surface area of treatment device (m^2)

Effectiveness of removal processes such as sedimentation, filtration and adsorption to remove chemical and biological contaminants in reed bed treatment systems relies on an adequate contact time with the substrate and vegetation. This contact time can be determined from the hydraulic retention time (HRT); hence, the accurate determination of retention time becomes an essential tool in predicting reed bed performance. The time wastewater spends within the reed bed can be calculated theoretically, using Eqn. 3.12, to give the nominal Hydraulic Residence Time (nHRT or t_n) of a given volume of wastewater assuming plug flow kinetics (IWA, 2000). The equation takes into account climatic factors (evapotranspiration and precipitation) that influence the actual residence time. For example, in hot dry weather the evaporative loss of water from wetlands may be high, increasing the time wastewater spends within the reed bed. On the other hand, in wet weather wetlands may actually collect water, decreasing the time wastewater resides within the reed bed.

$$t_n = \frac{LWd\rho}{\left(\frac{Q_i + Q_o}{2}\right)} \qquad \text{(Eqn. 3.12)}$$

where, t_n = nominal Hydraulic Residence Time (days)

L = length of wetland (m)

W = width of wetland (m)

d = depth of wetland (m)

ρ = porosity of wetland (% expressed as a decimal)

Q_i = influent flow rate ($m^3\ day^{-1}$)

Q_o = effluent flow rate ($m^3\ day^{-1}$)

However, as there exists a risk of potential short-circuiting and the ineffective spreading of the wastewater as it passes through the reed bed, calculations of the nominal hydraulic retention time are not always realistic. In practice, t_n is the period during which all parcels of the water entering the reed bed at a certain point of time would flow at an equal velocity through the bed. In reality, however, this is never the case as the inflowing water has many residence times, i.e. a residence time distribution (RTD), of which the function can be measured by injecting dissolved inert tracer material (e.g. rhodamine WT, lithium or bromide) into the bed's inlet and then measuring the tracer

concentration as a function of time at the bed's outlet (Kadlec and Knight, 1996). Accordingly, the actual HRT (labelled the mean HRT, t_m, by Persson and Wittgren, 2004 – see Figure 3.11) can be determined, while the time when the maximum tracer concentration occurs (t_p) can also be plotted. The distribution of the HRT along the x-axis is the RTD curve (Figure 3.11).

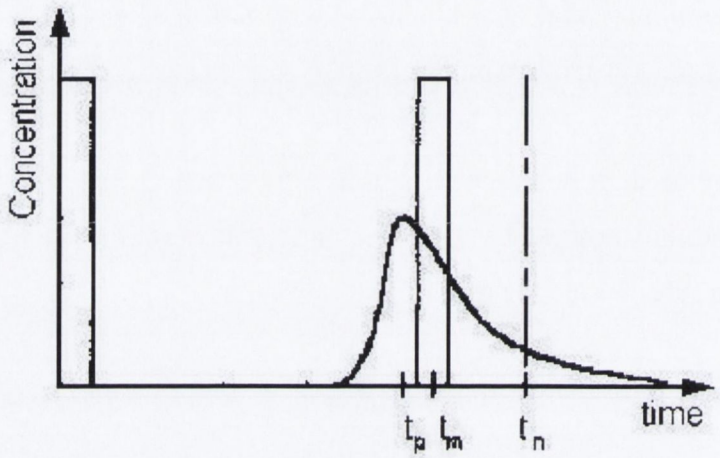


Figure 3.11 Tracer concentration time distribution, where t_p is the peak time for the concentration curve and t_m is the mean (or actual) HRT for the curve. The nominal retention time, t_n, is always larger than the mean retention time, t_m (adapted from Persson and Wittgren, 2004).

Mathematically, plug flow can be defined as a residence time distribution with a variance (σ^2) equal to zero, i.e. no dispersion other than advection, and a quotient between t_m and t_n which equals unity, i.e. no dead zones. As presented by Persson *et al.* (1999), the closer the peak value (t_p) of an RTD curve is to t_n, the better the hydraulic efficiency (λ) of the reed bed is:

$$\lambda = \frac{t_p}{t_n} \qquad \text{(Eqn. 3.13)}$$

The higher the λ, the better the water flowing through a wetland utilises the available volume, and thus the higher portion of the water is efficiently involved with the retention processes occurring in the wetland.

Several tracer studies have intensively investigated the hydraulic characteristics of HF reed beds with a number of researchers concluding that plug flow does not adequately describe the water regime through these systems, e.g. Bowmer (1987), Bavor *et al.* (1988) and Kadlec (1993). The occurrence of preferential flow pathways and 'dead zones', both within a reed bed's profile and along its length were indeed identified. In a study using experimental reed bed systems in Australia, Bowmer (1987) found dye concentration time profiles to be largely dispersed and irregular through the gravel profile of the reed bed under investigation. A preferential flow path was also observed at depth during one investigation that eventually developed into a 'dead zone' of water movement. Drizo *et al.* (2000) also found preferential flow within experimental reed beds, reporting a significant difference in water flow rates between 0.10 – 0.20 m and 0.35 m water depth ($p < 0.05$). Dead zone volumes up to as high as 30% have been reported in a number of other studies for horizontal SSF beds (EPA, 1999; El Hamouri *et al.*, 2007).

The effect of evapotranspiration, HLR and HRT on reed bed performance is inextricably linked and, depending on a number of secondary factors, may also be significant. Precipitation has the favorable effect of diluting pollutant concentrations but reduces the time the volume of water is retained in the reed bed. This combination can provide either poorer or better treatment performance depending on the HLR. In those wetlands that are lightly loaded hydraulically (i.e. single-house reed beds), concentration decrease is likely to be less due to the addition of rainfall; while in more heavily loaded systems the outlet effluent can be higher in quality. In both cases, load decrease (measured as percentage mass removal efficiency) is poorer for high rainfall (IWA, 2000). *ET* concentrates pollutants but such scenarios as the ceasing of outflow due to *ET* results in an increase in the HRT of the reed bed. This combination improves concentration decrease in very lightly loaded systems, but diminishes it in heavily loaded systems. In both cases, load decrease is better for high *ET* .

The effect of HLR on organic matter and nutrient removal in HF reed beds has been assessed in several studies (Geller, 1997; Maehlum and Stålnacke, 1999; Da Motta Marques *et al.*, 2001) and the results indicate that lowering the HLR improves the efficiency. Most of the HLRs are in the range of 10 – 100 mm d^{-1}. The influence of water depth, which regulates the HRT, on reed bed performance has also been

examined in a number of studies and revealed contradictory results. Water depth influences treatment efficiency as this parameter is involved in the mass transfer coefficient of oxygen from the atmosphere to the water (Burgoon *et al.*, 1995). Moreover, water depth determines the fraction of water volume which is in contact with the roots of the reeds. In comparing the performance of two horizontal SSF reed beds operating with the same HLR but at different water depths of 0.45 m and 0.3 m, it was found that BOD_5 removal was slightly better at the greater water depth (US EPA, 2000). It is unclear, however, in this study whether this result was due only to the higher HRT of the deeper system. In a prior evaluation of 14 different horizontal SSF systems by US EPA (1993), it was found that the bed with the lowest water depth (0.3 m) showed the second highest NH_4-N removal efficiency. In this study, complete root penetration to the bottom of the beds was observed in the two systems with significant NH_4-N removal capacity (one had a depth of 0.76 m and the other, as stated above, had a depth of 0.3 m). According to the authors, these results strongly support the hypothesis that plant roots in horizontal SSF reed beds are the primary source of oxygen needed for nitrification. Results from Garcia *et al.* (2004) indicated that HLR and water depth were statistically significant factors in the performance of four pairs of horizontal SSF beds in Spain. Beds with a water depth of 0.27 m removed more COD (70 – 80%), BOD_5 (70 – 85%), NH_4-N (40 – 50%) and dissolved reactive phosphorus (DRP) (10 – 22%) than beds with a depth of 0.5 m (60 – 65% for COD, 50 – 60% for BOD_5, 25 – 30% for NH_4-N, and 2 – 10% for DRP). The higher efficiency observed in the shallower beds was related to their less reducing conditions (average redox potential (E) ranging from -351 to -338 mV) than beds with a depth of 0.5 m (-390 to -358 mV). The difference in E status between two bed types seemed to lead to differences in the biochemical processes.

HRT has also shown to be a key factor in microbial removal in horizontal SSF systems. Mashauri *et al.* (1980) observed a positive relationship between faecal coliform inactivation and HRT in a pilot tertiary treatment reed bed, although inactivation results were not satisfactory because in the best case removal was only slightly more than 1 log-unit. The same relationship between the inactivation of *E. coli* and HRT was obtained by Green *et al.* (1997) with a pilot plant operated with five different HRTs in two separate experiments. However, contradictory results were obtained because in one experiment bacteria inactivation was lower with a 2-day HRT than with 1 day, and in

the other experiment inactivation was lower with a 5-day HRT than with 2 days. These contradictions were attributed to the extraordinary variability of the bacteria concentration, especially in the influent. In that study, a full-scale tertiary reed bed was also studied, and it was observed that in rainy periods when the hydraulic load increased (and HRT decreased), the inactivation of *E. coli* was reduced from 1.6 to 2 log-units range in dry periods to values as low as 0.3 log-units. Garcia *et al.* (2003) found the microbial inactivation ratio (for faecal coliforms and somatic coliphages) to rise as the HRT increased until a saturation value (generally at a HRT of 3 days) was reached.

3.6.2 Seasonality, Maturity and Macrophytes

Much debate has arisen into both the seasonal variation in reed bed performance due to suggested temperature dependence and their development in performance as a treatment system over time. The presence or absence of macrophytes and the type of species used is a further important parameter of the thermal environment of reed beds.

As discussed in Section 3.5.3, plant uptake does not play an important role in annual nitrogen removal in the long-run as the nitrogen assimilated by vegetation is released during decomposition of litter. The nutrient uptake capacity of emergent macrophytes ranges between 30 – 150 and 200 – 2 500 kg ha^{-1} yr^{-1} for phosphorus and nitrogen respectively (Brix, 1994a; IWA, 2000). This relatively high rate of nutrient uptake is, however, often insignificant compared to the loading rate to which most reed beds are subjected (Cooper *et al.,* 1996). In his study on nutrient uptake rates of *Phragmites australis*, Brix (1994a) found that nutrient removal solely via plant uptake would require a reed bed surface area of between 30 – 50 m^2 PE^{-1}.

One of the other primary functions of macrophytes is to dampen the effects of various environmental factors such as water temperature, mainly through the attenuation of light and insulation provided by the vegetation. With regard to the latter, Tanner *et al.* (1995) found that planting had little effect on outflow temperatures in winter, but lowered temperatures in summer by 0.5 – 1 °C. Comparisons between planted and unplanted reed beds in the treatment of wastewater have also found planted wetlands to be generally superior in wastewater treatment. Allen *et al.* (2002) found that the effect

of temperature on COD removal in subsurface flow reed beds was modified by presence and type of macrophyte. The relationship between temperature and COD removal was strongly positive in unplanted bed microcosms, positive but weaker in microcosms planted with *Typha latifolia*, neutral with *Schoenoplectus acutus*, and negative with *Carex utriculata*. Differences in COD removal, according to the authors, were associated with species-specific seasonal changes in indicators of root-zone oxidation. In terms of bacterial removal, Decamp *et al.* (1999) found a higher inactivation of *E. coli* in planted beds (average of 2.6 log-units) than in unplanted beds (average of 1.4 log-units). Relatively little research has been carried out to specifically investigate the difference, if any, in performance between each of the common macrophyte species used in CWS. Akratos and Tsihrintzis (2007) compared the removal efficiency of *Typha latifolia* (cattails) and *Phragmites australis* (common reed) in pilot-scale horizontal SSF beds with results indicating the former to perform marginally better with respect to organic (COD and BOD_5) and nutrient (TKN, NH_3-N, PO_4-P and TP) removal. This was found to be consistently the case under a range of specific HRTs (6, 8, 14 and 20 days) and temperatures (2 °C to 26 °C). Conversely, Solano *et al.* (2004) detected no significant differences in reed bed performance when planted with *Typha latifolia* and *Phragmites australis*, emphasizing the relative importance of physicochemical processes operating within the gravel matrix. However, *Typha latifolia* was shown to be by far (almost a factor of 2) the greater producer of biomass (22 tonnes ha^{-1}), which could be utilized as fuel in a small boiler for domestic use.

Headley and Davison (1999) carried out a study on two horizontal SSF reed beds planted with *Phragmites australis* in the sub-tropical climate of North Western Australia, each serving a school of approximately 250 students with a total daily load of 2 500 L d^{-1}. In a domestic situation this would serve an equivalent population of more than 14 people, or between 2 and 3 households (based on Irish EPA (2000) figure of 180 L p^{-1} d^{-1}). The two beds differed in their age with the "young system" in operation for two years compared to the "mature system" which was in its ninth year of running. Pollutant removal efficiencies from both systems showed that there was no consistent trend between seasons in treatment efficiency across all of the water quality parameters. The "young" system showed a marked improvement in TSS, BOD_5 and faecal coliform removal from winter to summer but no such development was seen in the older reed

bed. In fact, Total-N and Total-P removal appeared to decline from winter to summer in both systems with virtually zero Total-P removal in the "mature" system during the summer period. The author failed to specify a reason for this but results seem to negate, with regard to a sub-tropical climate at least, the first order plug flow model predictions traditionally used in reed bed design in which improved performance is predicted as temperatures increase, regardless of age. Likewise, Solano *et al.* (2003) evaluated the treatment performance of a horizontal SSF (planted with *Phragmites australis*) in the central-part of Spain where the climate is Mediterranean semi-arid with annual mean maximum and minimum temperatures of 22 °C and 5 °C, respectively. Results in the second year of operation showed a statistically significant increase in percentage COD (54% to 68%) and BOD_5 (63% to 83%) removal from winter to summer while similar findings were also found for both total coliform (40% to 75%) and faecal coliform (43% to 77%) removal. While the best overall removal rates were obtained when the HLR was at its lowest (75 mm d^{-1}) the seasonal variation trend in percentage removals remained the same regardless of HLR. Conversely, Maehlum and Jenssen (1998) contend that the removal of BOD_5 in horizontal SSFs is steady throughout the year even under cold climate.

In colder climates, it is thought temperature becomes more important in the consideration of the seasonal denitrification potential of reed beds. The reasoning behind this appears strong. According to Kadlec and Knight (1996), during cold winter months there is little nitrogen assimilation in reed beds, a decrease in the release and mineralisation of organic nitrogen, and a decrease in the rate of nitrification and denitrification; thus a decrease in Total-N removal capacity in the winter months is to be expected. A number of studies (Del Bubba *et al.*, 2000; Kadlec, 1999) endorsed this argument citing temperature as the most important factor on the seasonal Total-N removal rate. On the other hand, research carried out in Estonia (Mander *et al.*, 2000) found that the TN removal rate in reed beds varied from 12% to 85% but there was no obvious decrease in winter compared to summer removal rates. Maehlum *et al.* (1999) also found that the difference of removal rates in summer and in winter was only about 10%.

In later research carried out by Headley and Davison (2003) on thirteen reed beds in New South Wales, Australia, correlation analysis found no significant relationship

between BOD_5 reaction rate coefficients and reed bed age. However, if the data were confined to those beds under three years old, a significant positive relationship was found (Figure 3.12). This suggests that reed beds undergo an adaptation period in terms of BOD_5 removal, with performance improving during the first three years of operation but leveling out thereafter.

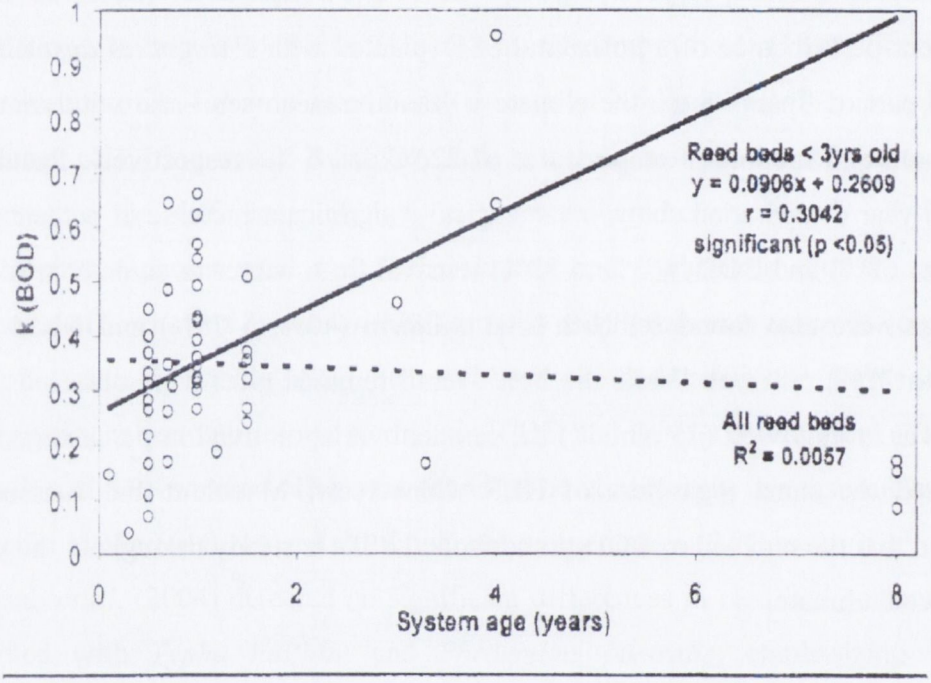


Figure 3.12 BOD reaction rate coefficients versus reed bed age (Headley and Davison, 2003)

Of further interest was the authors' estimation of the temperature correction factor, θ, (see Eqn. 3.5) to be closer to 0.95 for BOD_5 removal, indicating a drop in performance with increasing temperature. This mirrored the findings of Kadlec and Reddy (2001) who reported a mean temperature correction factor of 0.983 based on data from 23 constructed wetlands. Stein *et al.* (2006) reported similar figures for four subsurface flow reed beds planted with different species and tested between 4 °C and 24 °C (θ= 0.945 *(Carex uticuluta)*, 0.957 *(Schoenoplectus acutus)*, 0.953 *(Typha latifolia)* and 0.936 (unplanted)). One contention is that although the decomposition activity of microbes may increase with temperature, the overall effect on BOD_5 removal may be negated or even over-ridden by factors such as the seasonal growth pattern of plants. According to Headley and Davison (2003) Total-N removal was found to be independent of temperature (θ=1) over their experimental range of 14.8 °C to 25 °C.

Removal of phosphorus in horizontal SSF beds is not thought to be temperature dependent (Kadlec and Knight, 1996; Vymazal, 1999) as the most important removal mechanisms are chemical precipitation and physico-chemical sorption, processes that are unrelated to temperature effects (within the relatively small temperature ranges studied). Biological influences on P removal, which are temperature-dependent, are relatively unimportant (Vymazal, 1999).

4. SITE SELECTION AND DESCRIPTION

4.1 Introduction

A set number of criteria were agreed at the outset of the project that needed to be satisfied with respect to site suitability and selection. Two sites were to be chosen with T-values of between 1 and 5 (a range of values indicative of highly permeable subsoil) and a minimum 1.2 m of unsaturated subsoil below the proposed invert of the percolation trenches. It was imperative that site location and trial hole inspections satisfied EPA (2000) guidelines while there had to be a sufficient number of residents (> 3PE) in each dwelling so as to carry out multi-trench analysis and ensure a reasonable effluent flow given that each site was to be split into two distinct on-site treatment systems, each discharging to groundwater. Sites chosen could be from new or existing dwellings but in the case of the former it was imperative that works were to be completed and the dwelling inhabited prior to the commencement of sampling. As an incentive to interested parties, it was agreed amongst the project team to pay for and install, to EPA (2000) specifications, the requisite on-site treatment system on the selected sites.

The three key components of the site assessment and selection procedure are a desk study followed by an on-site visual trial hole inspection and percolation test, all discussed in more detail in the following sections.

4.2 Site Selection Criteria

4.2.1 Desk Study

The main aims of the desk study were to obtain hydrogeological data relevant to assessing site suitability and to identify potential targets at risk (i.e. water resources) from the proposed installation of an on-site treatment system. While it is possible to obtain data on bedrock type, soil type and subsoil type on a small scale, i.e. on a regional or countrywide basis, from relevant publications, the GSI, as part of the Groundwater Protection Scheme (GWPS) framework, have completed individual Groundwater Protection Schemes for 14 counties/regions (Clare, Kildare, Kilkenny,

Laois, Limerick, Meath, Monaghan, North Tipperary, Offaly, Roscommon, South Cork, South Tipperary, Waterford and Wicklow). These schemes provide a land surface zoning map which outlines areas in which groundwater is vulnerable to pollution and areas that have a good groundwater potential. The associated maps (1 : 50 000) provide information on the soil type, subsoil type, bedrock type, aquifer category, vulnerability class and proximity to local wells within these counties. This information, used in conjunction with the Groundwater Protection Response Matrix for Single House Systems (Table 4.1), an integral part of the GWPS, is an essential part of the assessment of site suitability for the installation of a treatment system and also of the type of system to be installed.

Table 4.1 Response Matrix for on-site treatment systems (adapted from Department of the Environment and Local Government *et al.*, 1999)

VULNERABILITY RATING	**RESOURCE PROTECTION AREA Aquifer Category**					
	Regionally Imp		**Locally Imp**		**Poor Aquifers**	
	Rk	**Rf/Rg**	**Lm/Lg**	**LI**	**PI**	**P**
Extreme (E)	$R2^2$	$R2^2$	$R2^1$	$R2^1$	$R2^1$	$R2^1$
High (H)	$R2^1$	R1	R1	R1	R1	R1
Moderate (M)	R1	R1	R1	R1	R1	R1
Low (L)	R1	R1	R1	R1	R1	R1

R1 Acceptable subject to normal good practice (i.e. system selection, construction, operation and maintenance in accordance with EPA (2000).

$R2^1$ Acceptable subject to normal good practice. Where domestic water supplies are located nearby, particular attention should be given to the depth of subsoil over bedrock such that the minimum depths required (EPA, 2000) are met and that the likelihood of microbial pollution is minimised.

$R2^2$ Acceptable subject to normal good practice and the following additional condition:

1) There is a minimum thickness of 2 m unsaturated soil/subsoil beneath the invert of the percolation trench of a conventional septic tank system;

OR

2) A treatment system other than a conventional septic tank system as described in EPA (2000) is installed, with a minimum thickness of 0.6 m unsaturated soil/subsoil with P/T values from 1 to 50 (in addition to the polishing filter which should be a minimum depth of 0.6 m), beneath the invert of the polishing filter (i.e. 1.2 m in total for a soil polishing filter).

While in the methodology outlined in *Wastewater Treatment Manual: Treatment Systems for Single Houses* (EPA, 2000) insists a desk study should precede any on-site assessment this was not a practical option for identification of suitable sites for this project; whereby the on-site evaluation procedure was used to eliminate unsuitable sites and a subsequent desk study confirmed potential suitability.

4.2.2 On-Site Assessment

Visual Assessment

The first part of the on-site assessment was a visual inspection which is a very valuable tool in the selection process and enabled a prompt decision to be made on the suitability of a site for further investigation prior to any disruptive excavation. Some of the factors considered during the visual inspection include the shape, form and slope of the site, the presence of watercourses and/or types of rock outcrops and proximity to adjacent percolation areas and/or houses. Table 4.2 outlines some of these significant factors to be considered during the visual assessment.

Table 4.2 Factors to be considered during a visual assessment (EPA, 2000)

Factor	Significance
Water level in ditches and wells	Indicates depth of unsaturated subsoil
Shape, slope and form of site	May indicate whether water will collect at a site or flow away from the site
Presence of watercourses	May indicate low permeability or a high watertable
Presence and types of rock outcrops	Insufficient depth of subsoil to treat wastewater allowing it to enter the groundwater too fast
Proximity to adjacent percolation areas and/or houses	May indicate too high a loading rate for the locality and/or potential nuisance problems
Land use and type of grassland surface (if applicable)	Indicator of rate of percolation or groundwater levels
Vegetation type	Indicator of rate of percolation or groundwater levels
Proximity to wells on-site and off-site, water supply sources, groundwater, streams, ditches, lakes, surface water ponding, beaches, shellfish areas and wetlands	Indicates targets at risk

Trial Hole

Following completion of the visual assessment a trial hole was excavated to ensure that there was a sufficient depth of unsaturated subsoil below the invert of the proposed percolation trench along its full length (1.2 m for subsoil receiving septic tank effluent and 0.6 m for subsoil receiving secondary effluent). It was essential that the trial hole was not excavated within the boundaries of the proposed percolation area as any subsequent consolidation of the backfilled soil could lead to the buckling of the perforated pipe in the percolation trench, thus inhibiting effluent dispersion along the base of the trench. Any excavation and replacement of subsoil can also create preferential flowpaths within the subsoil matrix which increases the risk of groundwater contamination from percolating wastewater effluent.

The soil and subsoil characteristics (soil texture, structure, preferential flowpaths, soil density, colour, layering) were also examined in the trial hole using BS5930 (British Standards Institute, 1981) as part of this integrated approach of on-site assessment. They provide a better understanding and description of the subsoil matrix and insight into future behaviour of the soil on receipt of wastewater effluent.

Table 4.3 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 the risk to groundwater
Soil density	Influences percolation rate
Colour	Indicative of state of aeration of soil
Layering	Effects percolation rate

Percolation Test

As detailed in Section 2.3.2, a 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 (Figure 4.1). In summary, this T-test procedure involves the excavation of two

holes adjacent to the proposed percolation area. The bottom and sides of the holes are rubbed with a wire brush to remove any smearing or compaction caused during their excavation. Both holes are then filled with clean water early morning, and again late evening, to provide pre-soaking. The following day, the holes are refilled with clear water up to the 400 mm mark and the time noted. The water is allowed to drop to 300 mm and the subsequent time required for the water to drop to 200 mm is recorded. The hole is then refilled to the 300 mm mark and the time required for it to drop to 200 m recorded again. This procedure is then carried out a second time. The average time of the three recordings, i.e. the time required for the water to drop from 300 mm to 200 mm, is divided by four to give the time required for a fall of 25 mm or the t-value for each hole. The average of the t-values is then calculated to give the T-value. To put these T-values in context, a proposed percolation area with a T-value less than 1 minute per 25 mm, or greater than 50 minutes per 25 mm, is deemed to have failed the test.

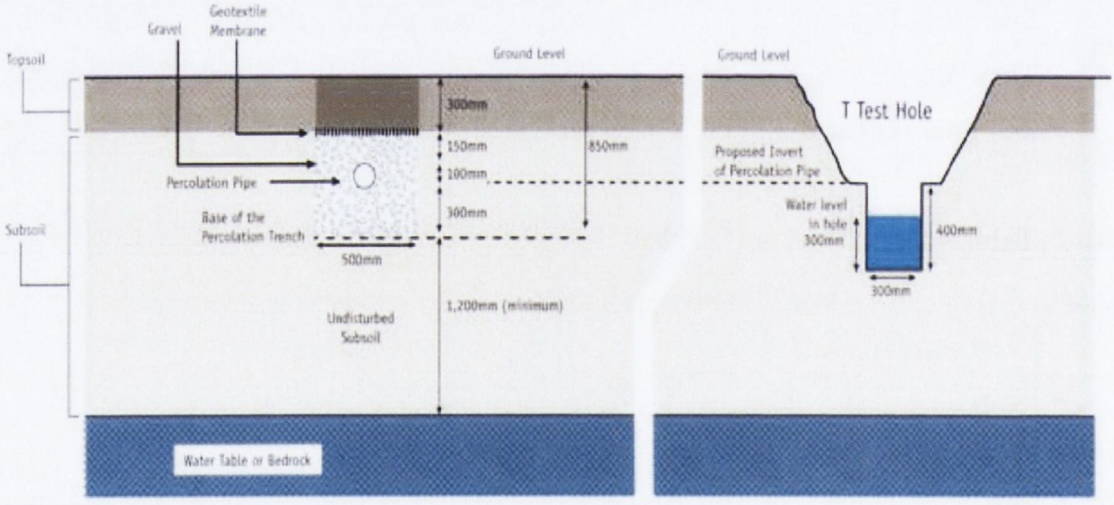


Figure 4.1 Cross-section view of T-test and proposed invert of percolation trenches (EPA, 2008b)

On completion of a satisfactory desk study and site assessment, a site can be considered to be suitable for the installation of an on-site treatment system. However it should be appreciated that both the results from the trial hole inspection and the T-test are location-specific: the subsoil is not an isotropic homogeneous medium and therefore results from both methods of suitability assessment will vary across the site.

4.2.3 Occupancy

The EPA manual calculates the typical daily hydraulic loading to an on-site system for single houses as 180 L per capita. While no reference for this figure is cited in the manual it appears to be based on urban wastewater statistical research in the US which includes significant sewer infiltration (not the case for on-site systems). However, recent field research carried out by Gill *et al.* (2005) on four sites in Ireland showed domestic wastewater generation measured on all sites to be considerably less than the EPA figure, with a per capita hydraulic load on each site of 104.7 L d^{-1}, 60.2 L d^{-1}, 84.2 L d^{-1} and 127.7 L d^{-1}. The most common daily flow recorded was between 100 and 110 L per capita. Nonetheless, the conservative EPA figure is used to determine the required size of a percolation area in conjunction with specified LTARs of 20 L m^{-2} d^{-1} for subsoils receiving STE, and 25 L m^{-2} d^{-1} for subsoils receiving secondary treated effluent.

4.3 Site Selection

Initially, the site identification process took the form of a networking exercise with both friends and family and with other professional contacts such as the GSI and EPA. However, it was decided a media campaign may be the optimal approach to adopt for site identification – a move which ultimately proved the most fruitful. This involved advertising in the local newspapers and displaying posters in local shops. Assistance from the GSI mapping system was greatly beneficial in targeting those geographical areas with hydrogeological characteristics potentially suitable to the needs of the project. Proximity to laboratory facilities in University of Dublin, Trinity College was of utmost importance for sample analysis while it was also desirable from the point of technical support that, if possible, the targeted catchment areas for research sites were within commuting distance (within 1 hour) of the university.

In total, 28 responses were received expressing an interest in the project, with all but one within commuter distance from Dublin. Further investigation, including a visual and (if deemed suitable) on-site assessment, was carried out on 17 of these sites. The remaining 11 were dismissed following communication with the respective homeowners on the basis of either subsoil incongruities or site construction/access difficulties. Following visual assessment on the 17 sites, further sites were ruled out as a

result of additional criteria not being met; insufficient number of residents, presence of extensive shale outcrop (indicating shallow depth to bedrock), vagueness regarding time of site occupancy on newly developed properties, and site restrictions (e.g excessive slope, extensive pipework reconnections). Full on-site assessments including a trial hole and T-tests were then carried out on the 6 remaining sites with 4 deemed unsuitable due to a culmination of high T-values and/or high water table.

4.4 Test Sites

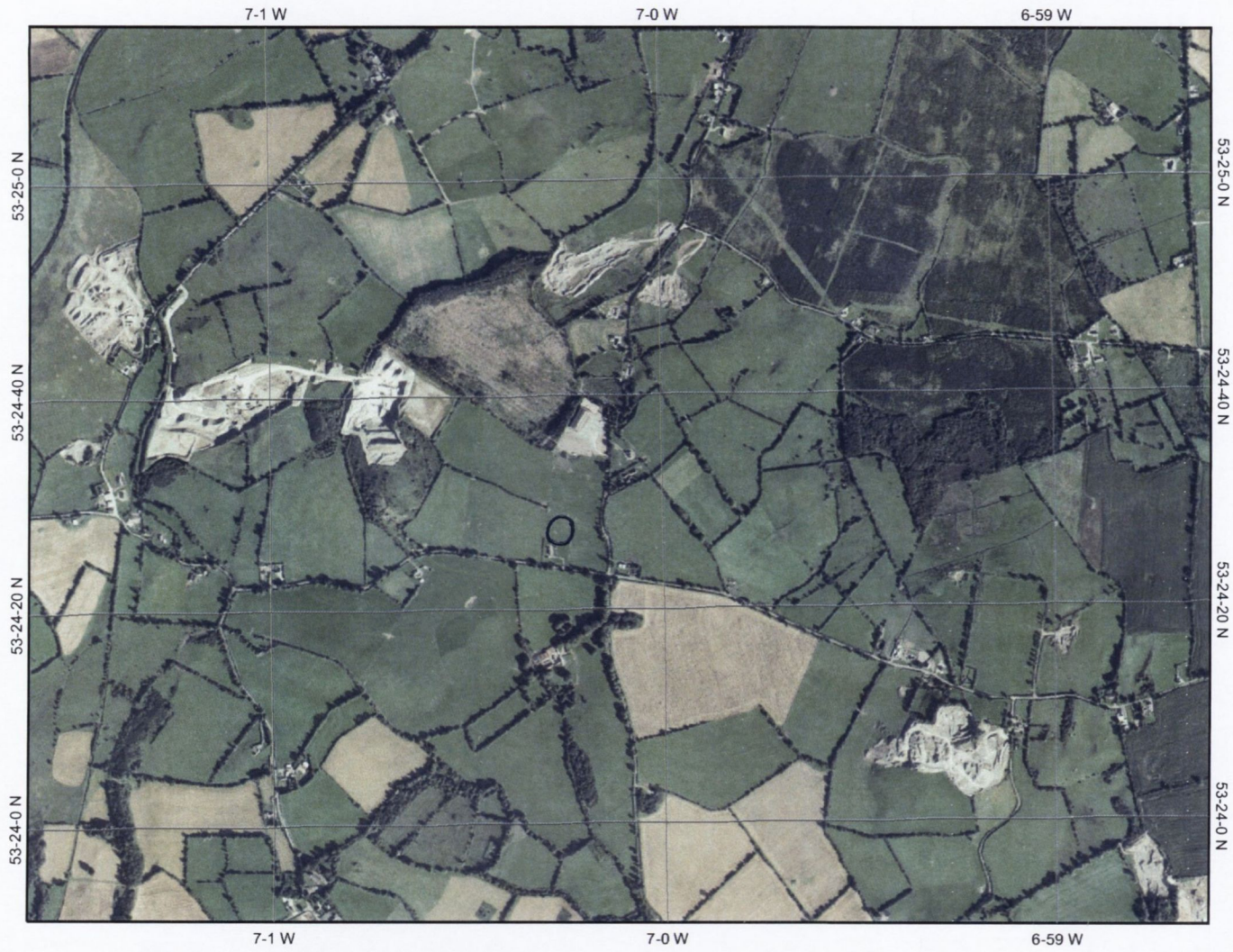
As a result of the site investigation and selection procedures two suitable sites were identified. Site A is located in Kilrainy, near Clonard in Co. Kildare while Site B is situated in Redcross, Co. Wicklow. Both sites were located in undeveloped areas, so it was possible to construct the wastewater treatment systems in undisturbed subsoil. Full on-site assessments of both sites according to EPA guidelines (EPA, 2000), including soil/subsoil texture classification in accordance with BS5930, is provided in Appendix A.

4.4.1 Site A: Kilrainy, Co. Kildare

The existing conventional septic tank system on Site A was failing due to its blocked septic tank which had not been desludged since its installation in 2000. In addition, the existing distribution box was failing to distribute the STE evenly whilst the use of land drain pipework instead of the required PVC sewer pipework in the percolation area had resulted in localised hydraulic overloading.

Subsoil examination of Site A through Teagasc/GSI groundwater mapping shows Kilrainy to lie within a region containing a mixture of till derived chiefly from limestone and glaciofluvial sands and gravels. The area also comprises a variety of beach sands and gravels owing to its proximity to the River Boyne (Figure 4.3). Bedrock is predominantly Dinantian pure unbedded limestone in the area although in the surrounding border of the site it comprises Dinantian pure bedded limestones (Figure 4.4). It lies on a locally important (Ll) aquifer (Figure 4.5).

Figure 4.2 : Site A (Kilrainy) - Aerial View





Legend

0 450 900 1350 m.

Scale: 1:18,020

Map center: 266375, 240339

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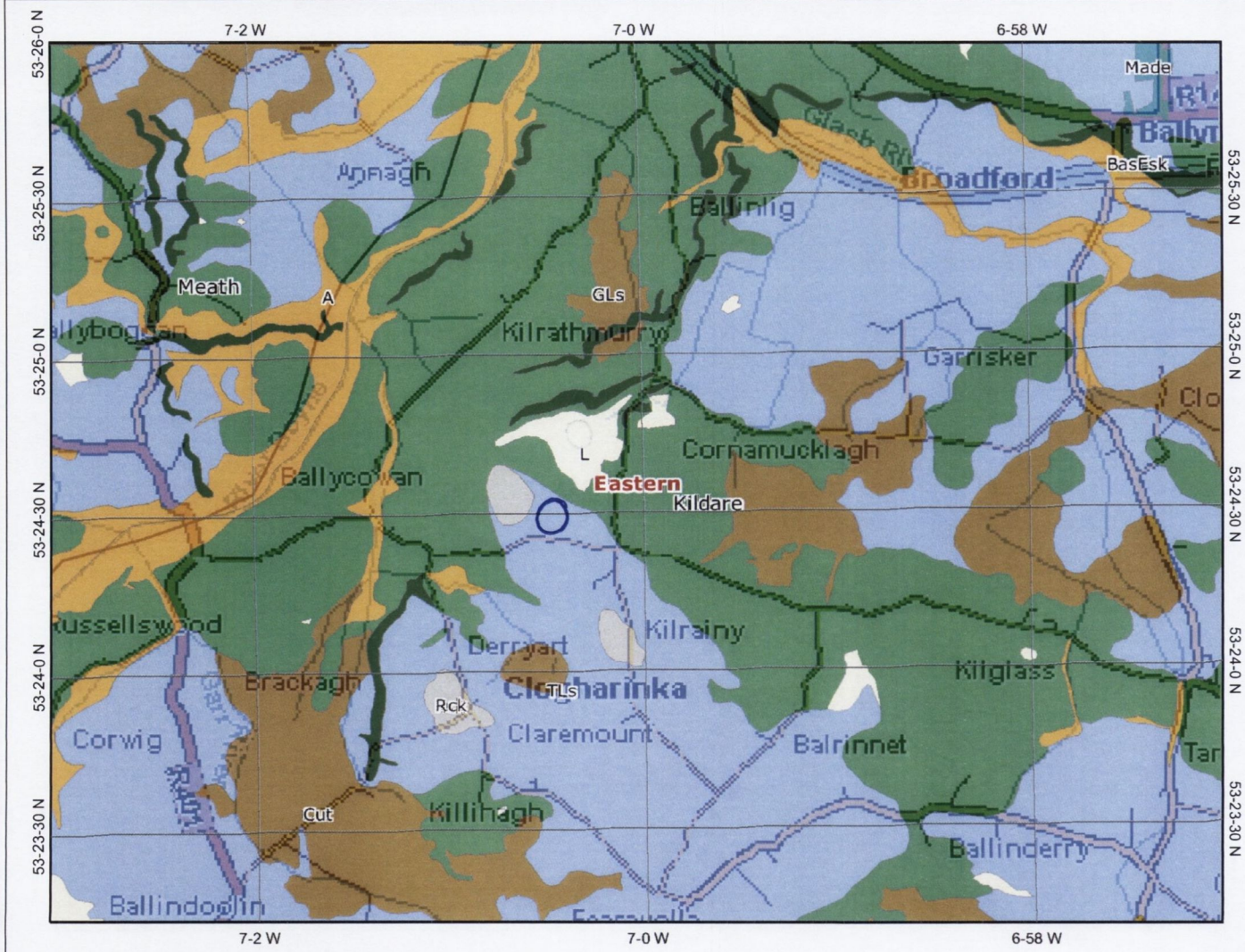
Figure 4.3 : Site A (Kilrainy) - Subsoil Map





Legend

Eastern RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Irish Sea till
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
- Marsh
- Peat
- Scree
- Till derived chiefly from Cambrian sandstones and shales
- Till derived chiefly from Devonian sandstones
- Till derived chiefly from Lower Palaeozoic rocks
- Till derived chiefly from Namurian rocks
- Till derived chiefly from basic igneous rocks
- Till derived chiefly from cherts
- Till derived chiefly from granite
- Till derived chiefly from limestone
- Till derived chiefly from metamorphic rocks
- Water
- Windblown sands
- RBD Boundaries
- County Boundaries

Scale: 1:36,041

Map center: 266463, 240440

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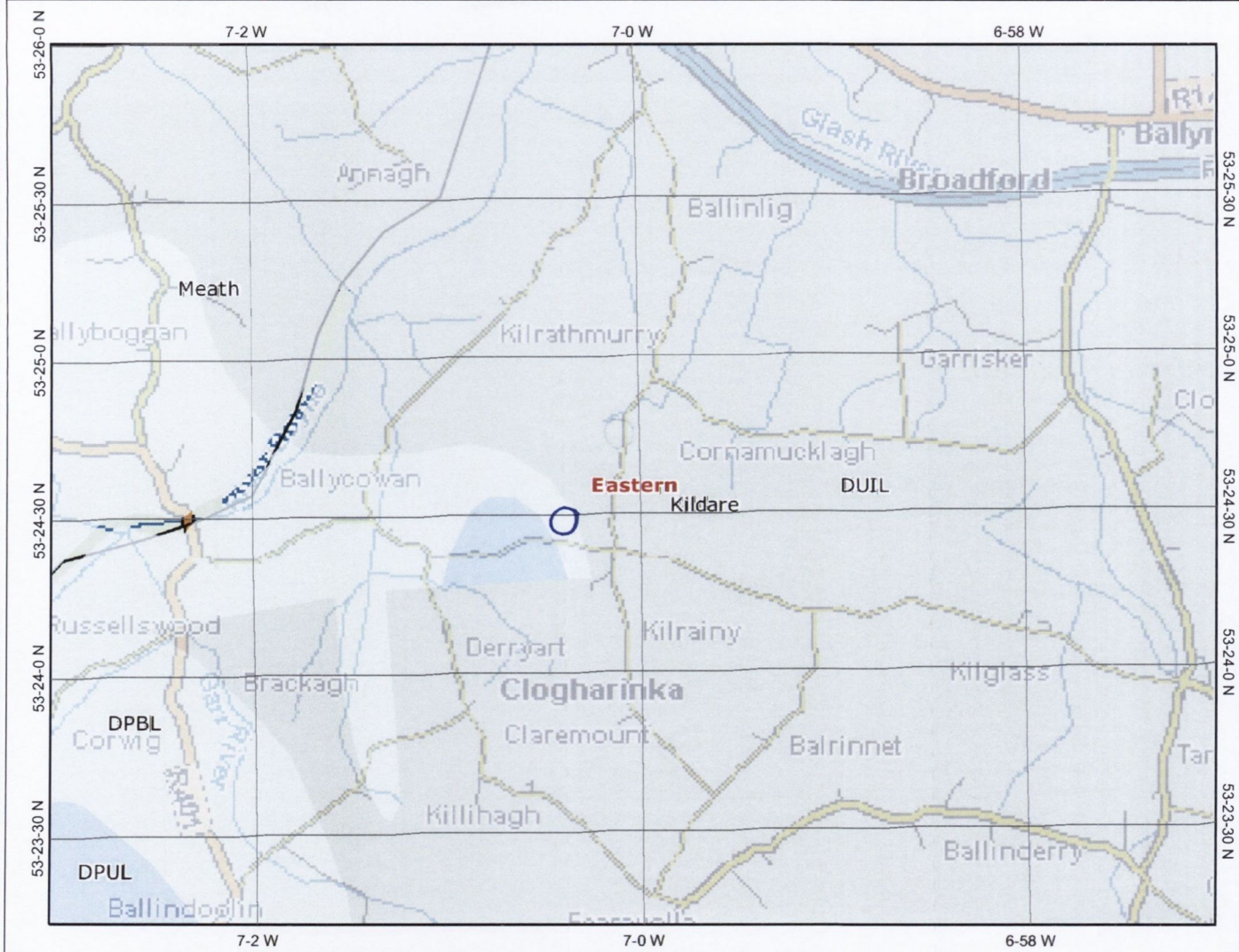
Figure 4.4 : Site A (Kilrainy) - Bedrock Map





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
- 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

Scale: 1:36,041

Map center: 266463, 240440

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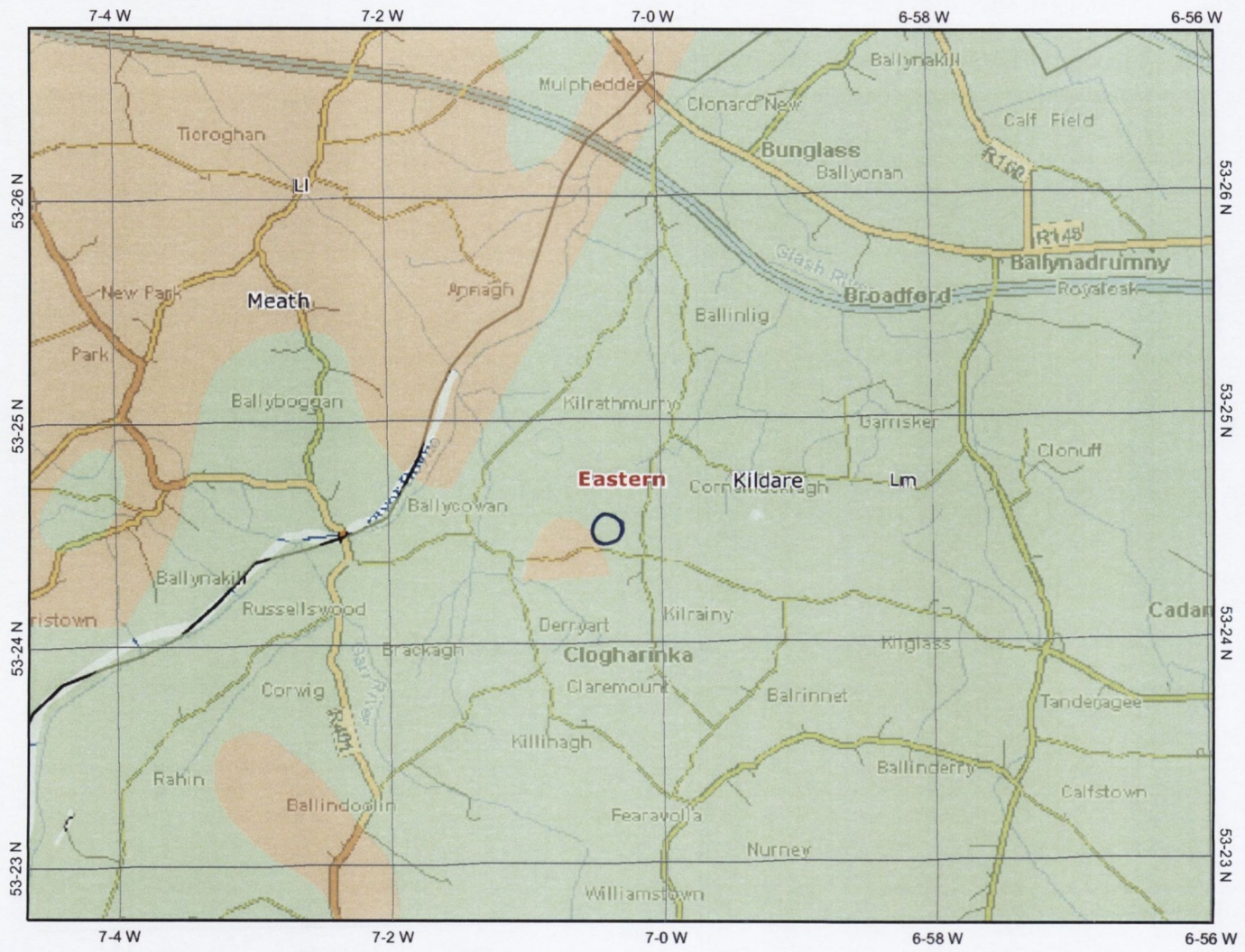
Figure 4.5 : Site A (Kilrainy) - Aquifer Map



Map center: 266172, 240703



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

Scale: 1:51,937

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The excavation of the 2.1 m deep trial hole to ensure sufficient depth of unsaturated subsoil also facilitated the examination of the subsoil profile and characteristics and the completion of the required site characterisation form (Appendix A). Soil/subsoil texture classification was carried out in accordance with BS5930 (1981) with the aid of a flowchart produced by the Groundwater section of the GSI (Appendix A). It was found that the soil profile consisted of five distinctive layers as outlined in Table 4.4.

Grain size distribution curves for sample taken at 1.0, 1.5, 2.0 and 2.1 m below ground level are also provided in Appendix A while a summary of the particle size analysis, including silt and clay content breakdown (sedimentation tests), carried out at these depths is shown in Table 4.5. Samples from the first three depths were important as these were the depths to which it was proposed to install the suction lysimeters and tensiometers. In general, the selection of sampling points within a trial hole for BS5930 classification is dependent on the visual assessment of the exposed material, as it is unfeasible to examine the subsoil texture at small intervals over the entire hole depth.

Therefore, difference in subsoil colour is often used to distinguish between different layers, i.e. layers that appear on visual inspection to be of uniform colour and texture. This was borne out by the change in soil classification from 0.4 to 0.6 m.

Table 4.4 Characterisation of soil profile at Site A

Depth	Soil/Subsoil Texture & Classification	Soil Structure	Density	Colour	Preferential Flowpaths
0.1m	Topsoil CLAY	Crumb		Dark Brown	None Visible
0.2m					
0.3m	Sandy Gravelly CLAY	Crumb	Firm & Compact	Mustard Brown	None Visible
0.4m					
0.5m	Sandy Gravelly SILT/CLAY	Structure-less single grain	Firm & Compact	Brown	None Visible
0.6m					
0.7m					
0.8m					
0.9m					
1.0m					
1.1m	Sandy Gravelly SILT	Structure-less single grain	Compact	Light Brown	None Visible
1.2m					
1.3m					
1.4m					
1.5m					
1.6m					

1.7m					
1.8m					
1.9m					
2.0m					
2.1m	Sandy GRAVEL	Granular	Loose	Greyish Brown	None Visible
2.2m					
2.3m	----------BASE OF TRIAL HOLE----------				

Table 4.5 Particle Size Analysis of soil samples from Site A

Depth of Sample below G.L.	% Gravel	% Sand	% Silt	% Clay
1.0m	19	28	33	20
1.5m	23	18	36	23
2.0m	18	31	36	15
2.1m	40	38	15	7

Two T-test holes were excavated either side of the percolation area at depths of 0.55 m and 0.65 m, taking into account the slope of the site. Both holes revealed very similar percolation characteristics, yielding an average T-value of 3.7, as shown in Table 4.6. The equivalent field saturated hydraulic conductivity, k_{fs}, was calculated as 1.27.

Table 4.6 T-test results from Site A

	Test Hole No. 1			Test Hole No. 2		
Fill No.	**Start Time (300mm)**	**Finish Time (200mm)**	**Δt (mins.)**	**Start Time (300mm)**	**Finish Time (200mm)**	**Δt (mins.)**
1	09:59	10:11	12	11:40	11:51	11
2	10:12	10:26	14	11:52	12:06	14
3	10:27	10:45	18	12:07	12:27	20
Average Δt (minutes)			14.7	Average Δt (minutes)		15
Average $\Delta t/4 = t_1$ (minutes)			3.7	Average $\Delta t/4 = t_2$ (minutes)		3.8
T-value = (t1+t2)/2 = 3.7 (minutes/25mm)						



Figure 4.6 Photograph of T-test hole 1 at Site A

For the duration of the project there were six people resident at Site A; a husband and wife, and their four sons. All the children were students at primary and secondary schools, generally leaving the house between 08:00 and 09:00 and returning home between 16:00 and 17:00, Monday to Friday. The father owned and run an equestrian centre locally with operating hours of 09:00 – 17:00. However, on a number of occasions he would work from home. The mother worked part-time two days a week, generally leaving the house between 09:30 and 10:00 for work, returning between 16:30 and 17:00. A housekeeper also called twice a week throughout the research period, arriving early morning and departing early afternoon.

4.4.2 Site B: Redcross, Co. Wicklow

There was an existing conventional septic tank system on Site B, which had been installed when the house was built in 1990. The STE was being discharged to a single land drain pipe which was buried and channeled parallel to the slope of the garden. It was found to be blocked up when excavated in advance of the research project.

A full on-site assessment according to EPA guidelines (EPA, 2000) for this site is also given in Appendix A. In the desk study carried out, subsoil mapping from the Teagasc/GSI database revealed Redcross to be in a region predominantly covered by till derived chiefly from Lower Palaeozoic rock (Figure 4.8). An alluvium plane lies

immediately north along the path of the Redcross river flowing through the village. Bedrock is comprised of Ordivician metasediments (Figure 4.9) while the aquifer has been classified as locally important (Ll) (Figure 4.10).

As was the case with Site A, a 2.1 m deep trial hole was excavated to examine the subsoil profile and characteristics, and the results obtained used to complete the required site characterisation form (Appendix A). On inspection of the trial hole three distinct layers were identified and classified accordingly (Table 4.7).

BS5930 analysis revealed the subsoil to be sandy GRAVEL from 0.7 to 2.0 m which was overlain by an indicatively less permeable 0.2 m sandy SILT layer. Particle size analysis was also carried out on four subsoil samples at depths of 0.5, 1.0, 1.5 and 2.0 m (Table 4.8). Results corroborated the BS5930 findings with low fines content at 0.5 m decreasing continuously with depth, with gravel the major soil component.

Figure 4.7 : Site B (Redcross) - Aerial View





Legend

Scale: 1:5,892

Map center: 324189, 183683

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Snapshot Date: 10-Nov-2008

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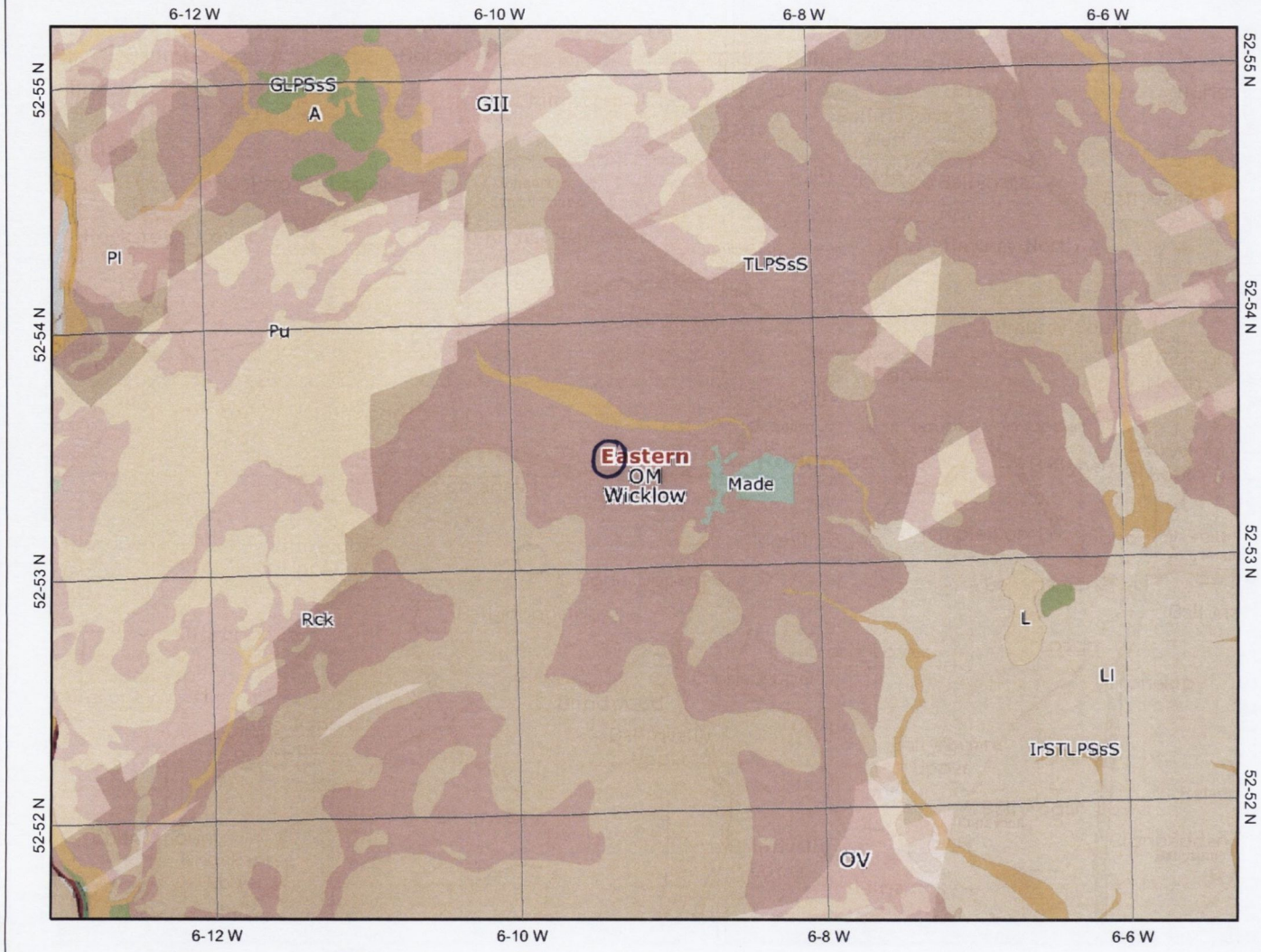
Figure 4.8 : Site B (Redcross) - Subsoil Map





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

Eastern RBD Subsoils

- Alluvium
- Beach sands and gravels
- Bedrock outcrop and subcrop
- Esker sands and gravels
- Glaciofluvial sands and gravels
- Irish Sea till
- Lake sediments
- Made ground
- Marine/estuarine silts and clays
- Marsh
- Peat
- Scree
- Till derived chiefly from Cambrian sandstones and shales

Scale: 1:47,135

Map center: 324356, 183685

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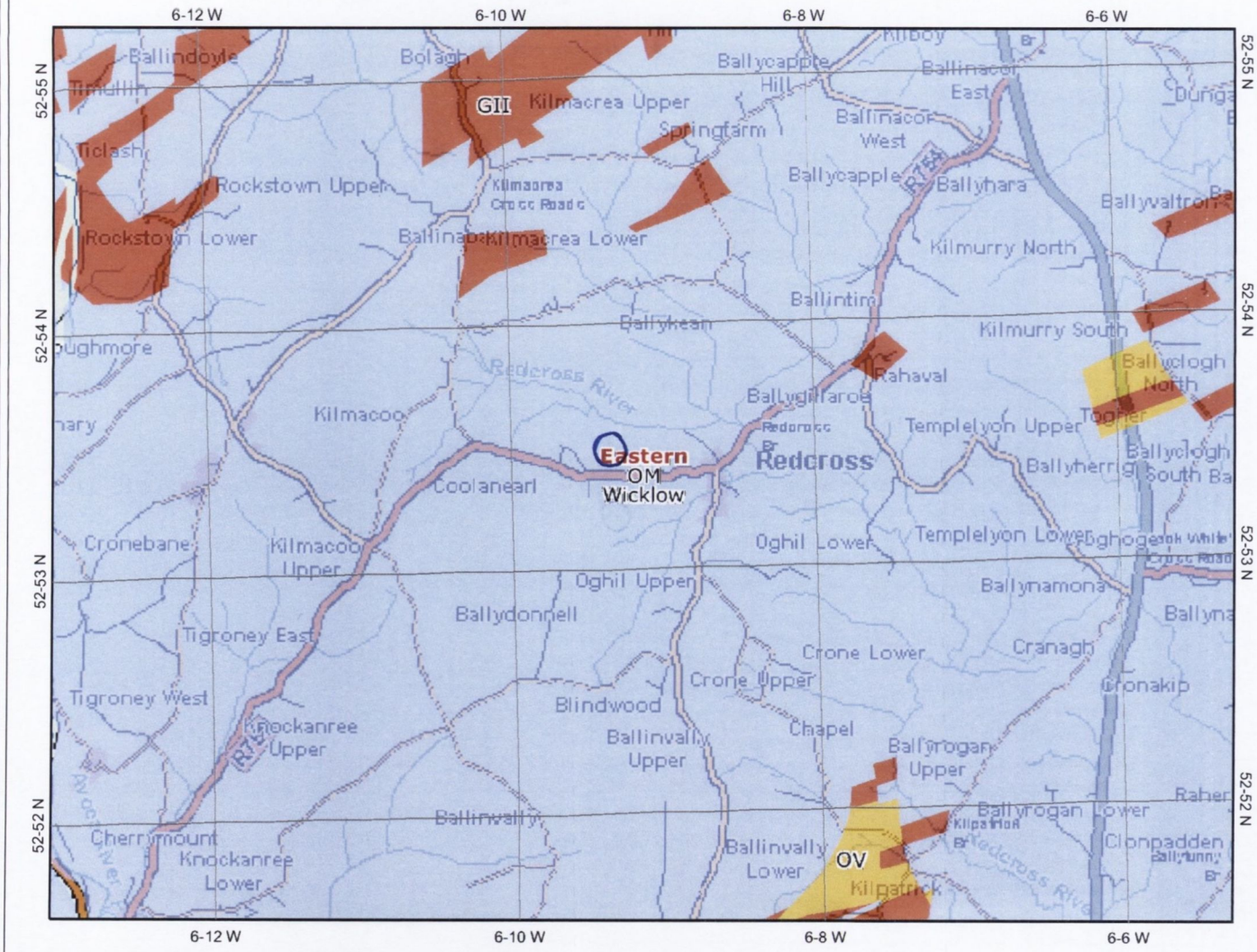
Snapshot Date: 10-Nov-2008

Figure 4.9 : Site B (Redcross) - 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
- 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

Scale: 1:47,135

Map center: 324356, 183685

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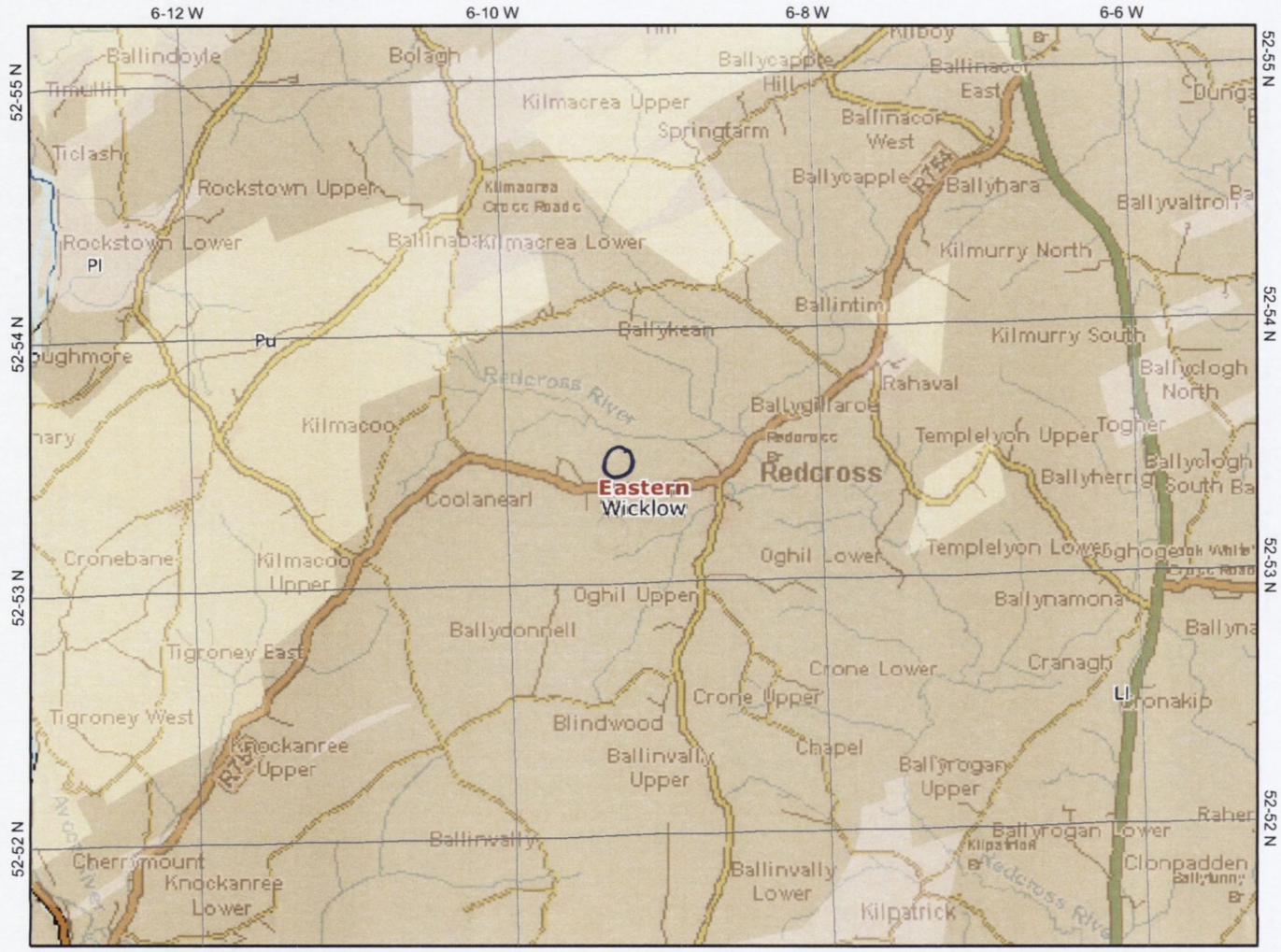
Figure 4.10 : Site B (Redcross) - Aquifer Map



Map center: 324356, 183685



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

Scale: 1:47,135

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Snapshot Date: 10-Nov-2008

Table 4.7 Characterisation of soil profile at Site B

Depth	Soil/Subsoil Texture & Classification	Soil Structure	Density	Colour	Preferential Flowpaths
0.1m	Topsoil CLAY	Crumb	Uncompact	Brown	None Visible
0.2m					
0.3m					
0.4m					
0.5m	Sandy SILT	Structure-less single grain	Loose	Golden Brown	None Visible
0.6m					
0.7m					
0.8m	Sandy GRAVEL	Granular	Loose	Brown	None Visible
0.9m					
1.0m					
1.1m					
1.2m					
1.3m					
1.4m					
1.5m					
1.6m					
1.7m					
1.8m					
1.9m					
2.0m					
2.1m	----------BASE OF TRIAL HOLE----------				

Table 4.8 Particle Size Analysis of soil samples from Site B

Depth of Sample below G.L.	% Gravel	% Sand	% Silt	% Clay
0.5m	59	19	17	5
1.0m	45	34	10	11
1.5m	62	27	7	4
2.0m	57	35	6	2

Two T-tests were carried out on either side of the proposed percolation area at a depth of 0.55 m to give an average T-value of 4.5, as shown in Table 4.9. Both holes revealed rapid percolation rates as expected from the SILT to GRAVEL subsoil description at these depths, although there was some variation between the two tests, which might be expected in such a heterogeneous subsoil matrix. The equivalent field saturated hydraulic conductivity, k_{fs}, was calculated as 0.93.

Table 4.9 T-test results from Site B

	Test Hole No. 1			Test Hole No. 2		
Fill No.	**Start Time (300mm)**	**Finish Time (200mm)**	**Δt (mins.)**	**Start Time (300mm)**	**Finish Time (200mm)**	**Δt (mins)**
1	11:49	11:56	7	12:38	12:56	18
2	11:56	12:04	8	13:01	13:31	30
3	12:05	12:14	9	13:34	14:09	35
Average Δt (minutes)			8	Average Δt (minutes)		27.7
Average $\Delta t/4 = t_1$ (minutes)			2	Average $\Delta t/4 = t_2$ (minutes)		6.9
T-value = (t1+t2)/2 = 4.5 (minutes/25mm)						

There were three people resident at Site B; a husband and wife, and her elderly mother, who lived in a separate part of the house with her own separate kitchen and toilet facilities. The husband worked daily in Dublin, leaving home at 08:00 and returning between 17:00 and 18:00. The wife worked locally four days a week between 09:00 and 17:00, returning home for lunch between 13:00 and 14:00. The wife's mother was housebound throughout the duration of the project due to her elderly age.

5. SITE CONSTRUCTION, INTRUMENTATION AND ANALYSIS METHODOLOGY

5.1 Introduction

In being one of the primary objectives of the research project, the attenuation capacity of undisturbed freely draining subsoil was examined on Sites A and B in treating both septic tank and secondary effluent. Similarly, the performance efficiency of horizontal SSF reed beds in an Irish climate was carried out under both septic tank (Site A) and secondary (Site B) effluent loading conditions.

The on-site wastewater treatment systems were newly constructed on both sites at the beginning of the project and built in full accordance with EPA specifications (EPA, 2000). It is a recurring practice of some builders in Ireland to illegally connect the household's roof water into the wastewater treatment system which contravenes EPA regulations (EPA, 2000). As such, it was ensured, through diversion works on each site, that all roof water from rainfall was separated from the domestic wastewater and prevented from entering the treatment system. Upon completion of the installation works, new reconnecting pipework was diverted from the existing on-site treatment system to the newly installed system. As the project centered on the collection and analysis of on-site wastewater samples, it was of fundamental importance that the installation of instrumentation for measuring such parameters was both accurate and successful. Automatic water samplers were installed downstream of the septic tank, packaged treatment systems and reed bed to obtain a profile of the effluent entering the percolation trenches whilst suction lysimeters were installed at strategic positions along the length of the percolation trenches to obtain soil moisture samples for analysis of some of the domestic wastewaters' key constituents of concern. A number of zero-tension gravity-fed samplers were installed in tandem with their suction-based counterparts for cross-checking both sampling techniques. Tensiometers were also installed along the trenches to monitor the soil moisture tension below the percolation area. Installation of the lysimeter and tensiometer instrumentation was carried out by a combination of hand and mechanical augurs, together with a compact hammer drill rig. Tipping bucket devices were attached to the outlets of the distribution box on both sites

to measure and assess the distribution of gravity-fed flow entering the percolation trenches. Finally, in order to measure the meteorological effects (evapotranspiration and precipitation levels) on the reed bed and percolation area, a weather station and rain gauge were mounted on both sites.

5.2 Site Layout

Site A, serving 6 no. residents, received STE which was gravity-fed and evenly split two-ways via a distribution device to a set of percolation trenches and an on-site constructed horizontal SSF reed bed (Figure 5.1(a)). The effluent from the reed bed (RBE) was thereafter discharged to a set of percolation trenches to provide further treatment in the underlying subsoil. In essence, the site was thus regarded, and ultimately analysed, as two separate treatment systems:

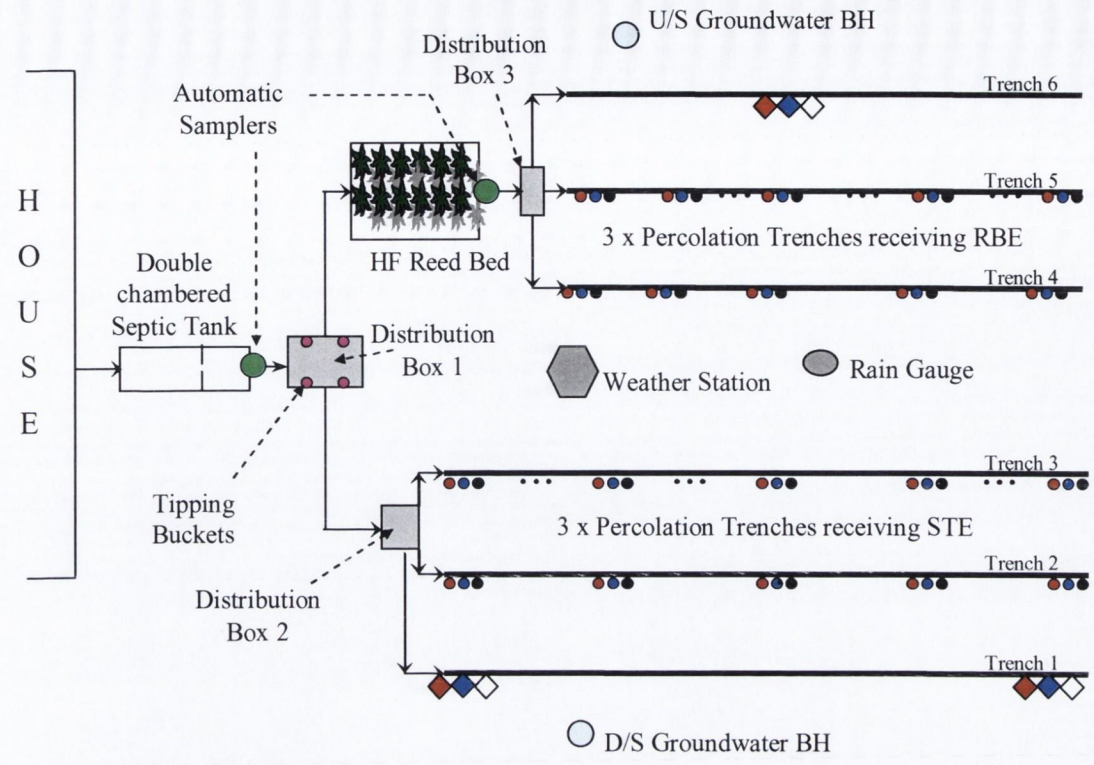
System I: A conventional septic tank system where the percolation area receives STE (half the total hydraulic load)

System II: A septic tank and horizontal subsurface flow reed bed providing primary and a secondary treated effluent, respectively, before discharge of the RBE to a percolation area for polishing (half the total hydraulic load)

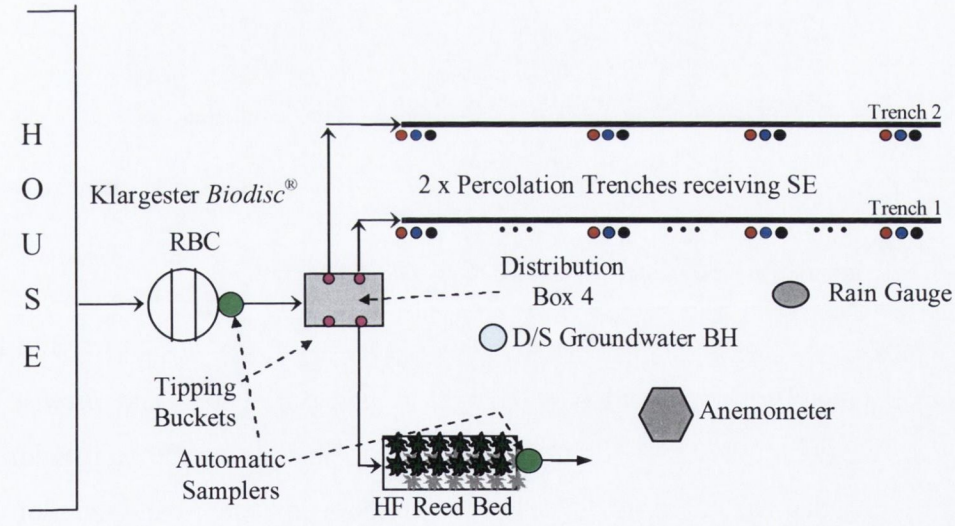
Site B, serving 3 no. residents, received SE from a Klargester *Biodisc*® RBC treatment system with half the gravity-fed flow split to percolation trenches and the other half to a small on-site constructed horizontal SSF for tertiary treatment (Figure 5.1(b)). The site was therefore also regarded and ultimately analysed as two separate treatment systems:

System III: A rotating biological contactor proprietary plant providing secondary treated effluent before subsequent polishing in a percolation area (half the total hydraulic load)

System IV: A rotating biological contactor proprietary plant providing secondary treated effluent before subsequent polishing in a horizontal subsurface flow reed bed (half the total hydraulic load)



(a)



(b)

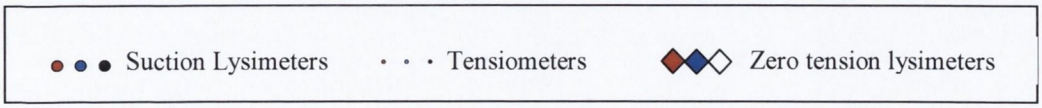


Figure 5.1 Construction Plan and Instrumentation Layout of **(a)** Site A (Kilrainy) and **(b)** Site B (Redcross)

5.3 Proprietary Treatment Systems

5.3.1 Septic Tank

A prefabricated two-chambered, reinforced-concrete septic tank (Carlow Precast) with adequate volume (3785 L) was installed on Site A (Figure 5.2). This is in line with EPA specifications (EPA, 2000) and provides a minimum retention time of 3.5 days based on a national daily design hydraulic loading of 180 L c^{-1} d^{-1} (EPA, 2000).



Figure 5.2 Installation of double chambered septic tank on Site A

5.3.2 Rotating Biological Contactor (RBC) - *Biodisc*®

The packaged plant secondary treatment system chosen for installation on Site B was the *Biodisc*® system manufactured by Klargester Environmental. The *Biodisc*® is a rotating biological contactor (RBC) plant which relies on the continuous rotation of its discs for supporting the micro organisms responsible for the aerobic degradation of the wastewaters' constituents. Wastewater from the house first discharges into a designated primary settlement zone [Figure 5.3 (a)] in the plant where solids are settled out and retained as sludge. Partially clarified liquor containing fine suspended solids then flows upwards into the first stage biozone [Figure 5.3 (b)] for stabilisation by the fixed film micro organisms on the rotating discs. Any biomass solids from this stage can settle in the primary settlement zone beneath with the remaining liquor transferred to the second stage biozone [Figure 5.3 (c)] for further treatment. It is in this second biozone where nitrification occurs. The effluent then passes to the final clarifier [Figure 5.3 (d)] where

any solids remaining settle out as humus sludge and the supernatant is discharged at the outlet. The plants' biological processes are carried out by both aerobic heterotrophic and nitrifying bacteria, resulting in a nitrified effluent with a greatly reduced carbonaceous element.

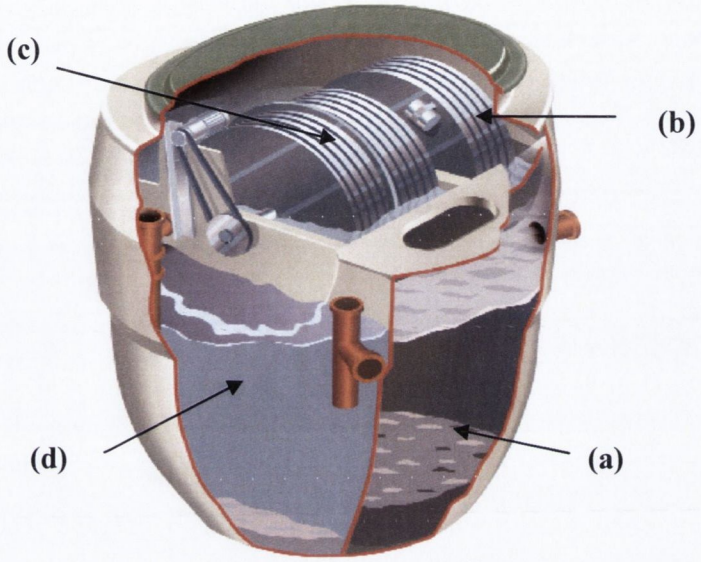


Figure 5.3 Sectional diagram of Klargester *Biodisc*® Rotating Biological Contactor

To avoid any potential long-term settlement of the treatment unit in the ground, dry cement was secured around its base and sides prior to backfill of the excavated soil. A collection sump, to act as a sampling point, was installed immediately downstream of the *Biodisc*® system, after which the effluent flowed by gravity to the distribution box.

5.4 Construction of Percolation Trenches

5.4.1 Design Criteria

As outlined in Section 5.2, both sites required the construction of parallel percolation trenches for subsurface disposal of the partially treated effluent. Under EPA guidelines (2000), the length of percolation trench is calculated as a function of both the number of persons for which the house is designed and a suitable hydraulic loading rate. The hydraulic loading through the trench base and sidewalls of the percolation trench is very much controlled by the biomat on the floor and sides of the trench rather than by the

subsoil itself in the case of all suitable subsoils. A LTAR of 20 L m^{-2} d^{-1} is recommended for STE being discharged into a percolation area to take into account the effect of the biomat. On Site A, the area for the percolation trenches receiving STE (*System I*) was sized on a 3-person hydraulic load since the total flow from the household was split equally into two parallel systems following septic tank treatment. With a daily design hydraulic load per capita of 180 L, this yielded an invert area of percolation trench of 27 m^2. The width of the invert of each percolation trench was set at 450 mm resulting in an overall required length of trench of 60 m (3 x 20 m lengths). In the case of the subsoil being used as a polishing filter (i.e. receiving secondary treated effluent) a LTAR of 50 L m^{-2} d^{-1} is recommended for the discharge of SE into subsoil with a T-value of between 1 and 20. For the purposes of this project, a precautionary LTAR of 25 L m^{-2} d^{-1} was adopted for sizing the trenches in case the development of the biomat was to be greater than anticipated. In the case of Site A, this yielded a total required trench length of 48 m (3 x 16 m lengths) for the percolation trenches receiving effluent from the secondary treatment reed bed (*System II*). This is again based on a 3-person hydraulic load. Similarly, on Site B a total length of 32 m (2 x 16 m lengths) was required for the percolation trenches receiving SE from the *Biodisc*®, based on a minimum design 2-person hydraulic load and LTAR of 25 L m^{-2} d^{-1}.

The area required for the percolation area was marked out and spot levels taken along the ground surface (Table 5.1). The highest point on the percolation area - ground level above the start of Trench 6 - was taken as datum. Careful consideration had to be given when choosing the most appropriate percolation area location, in terms of the topography of the land, so that a sufficient amount of head be preserved for (i) the installation of flow measuring devices at the outlet of distribution device 1 upstream of the trenches receiving STE and (ii) the installation of the horizontal SSF and aforementioned flow measuring devices, upstream of the trenches receiving RBE.

While it is recommended that the invert of the percolation trench should be 800 mm below ground level along its full length this is often unattainable due to a site's topography. On sites where a significant slope on the proposed percolation area is evident, a deeper excavation may be required at the start for example, or at the end, in order to achieve a trench invert depth of 800 mm throughout. Such large discrepancies

in invert depth along the trench ultimately make it more difficult for the sampling instrumentation to be installed to their required depth. The depth at which the T-test was carried out and the depth to which the trial hole was excavated must also be considered. Even assuming that the results obtained from the on-site assessment are representative of the layers in which they were performed, and that these layers are isotropic and homogeneous, it is clear that they may not be representative of the subsoil at the invert of the trenches should the trenches be excavated to a greater depth. On Site A, despite a significant slope (approx. 1:6) being measured perpendicular to the proposed line of the percolation trenches, ground levels at the proposed front and back of the trenches were markedly similar as illustrated in Table 5.1. As such, it was recognised that the invert level of each percolation trench could be kept relatively uniform and constant throughout its full length.

Table 5.1 Levels (m) taken at ground level along the length of proposed percolation trenches on Site A (relative to ground level at start of Trench 6)

Distance along trench (m)	**Trench Number**					
	1	2	3	4	5	6
0	-1.120	-0.990	-0.610	-0.415	-0.200	0.000
10	-1.184	-1.000	-0.693	-0.444	-0.231	0.055
20	-1.235	-1.025	-0.745	-0.500	-0.255	0.000

Nevertheless, given the level of importance attached to the depth and characteristics of the subsoil below the base of the percolation trench for effluent treatment, it was decided to design the trenches so that the recommended EPA (2000) trench invert depth of 800 mm was achieved at the midpoint of each trench – 10 m for the trenches receiving STE; 8 m for the trenches receiving RBE. The topography of Site B comprised a gentler slope perpendicular to the proposed trench markings but had an almost flat gradient running parallel to the trenches. A constant invert depth of 800 mm was therefore maintained along the full length of both trenches too (Table 5.2).

Table 5.2 Depth (m) of trench inverts on Site A below ground level at 0 and 20 m

Distance along trench (m)	Trench Number					
	1	2	3	4	5	6
0	0.814	0.860	0.833	0.788	0.791	0.800
20	0.799	0.825	0.798	0.784	0.816	0.800

Whilst flow measuring devices were to be installed at the outlets of distribution boxes 1 and 4, it was necessary to connect pipework from distribution boxes 2 and 3 (Figure 5.1(a)) to the percolation trenches at a requisite slope of 1 in 200 (EPA, 2000). Given that the distribution boxes currently available in Ireland have the provision of only four or six outlets, and with the former option chosen, it was necessary to close off one of the outlets in both boxes 2 and 3 to promote a three-way split in tandem with the number of subsequent percolation trenches (Figures 5.4, 5.5 and 5.6).



Figure 5.4 Site A distribution box 2 (concrete box design with V-notch weirs)

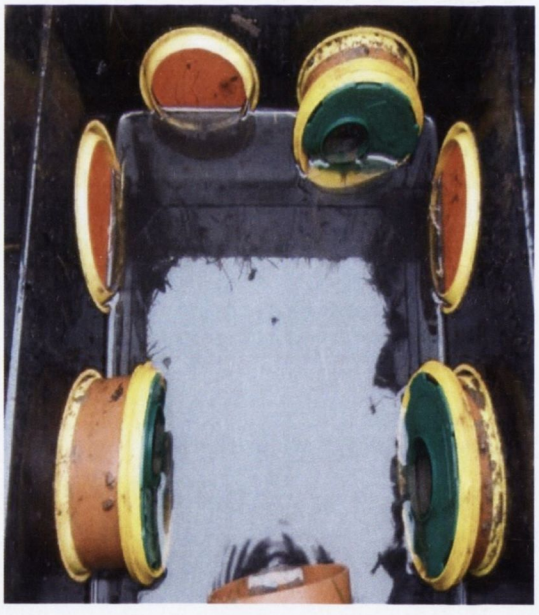


Figure 5.5 Site A distribution box 3 (plastic stilling box design with circular weirs)

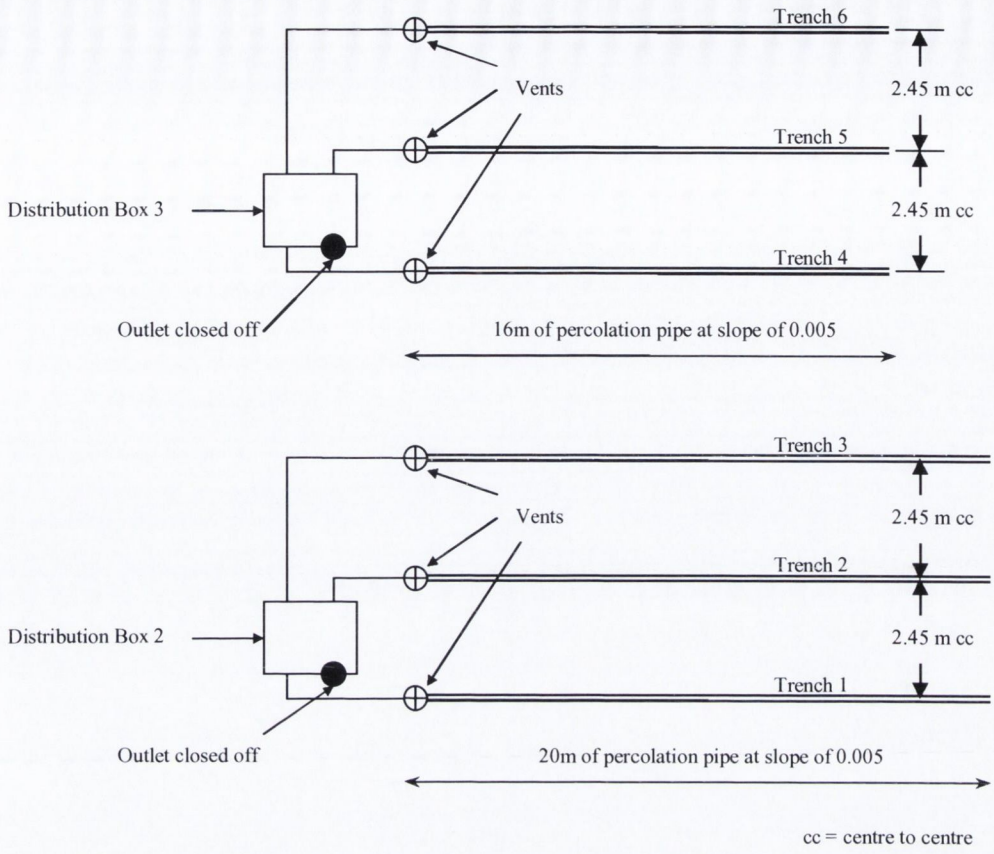


Figure 5.6 Plan of percolation area on Site A (specifications as per EPA (2000)

Additional design specifications, in accordance with EPA (2000), were slightly altered to include:

1) the positioning of the vents on each percolation trench at the front as opposed to the back end to promote and maximize the diffusion of oxygen into those areas predicted to be receiving most effluent
2) the non-connection of the percolation trench pipework given that each trench was to be treated as a separate entity for research purposes

5.4.2 Trench Construction

The construction of the percolation trenches involved a number of stages to ensure full compliance with EPA (2000) guidelines. All materials (see Table 5.3) for both sites were sourced locally and delivered on site upon instruction. Prior to excavation, the location of the trenches on each site had been marked on the ground surface to aid the JCB operator (Figure 5.7 (a)). Trench 6 was excavated first on the site, as shown in Figure 5.7 (b). The soil was left outside the percolation area and later used to backfill

the last trench excavated. The soil from the excavation of subsequent trenches was used to backfill the previously excavated trench.

Table 5.3 Material required for the construction of percolation area consisting of 6 no. trenches of total length 108 m on Site A

Description	*Approximate Quantity*
Distribution Device (Box, Flow splitter)	2
20 – 30 mm washed gravel	25 m^3 (42.05 t)
110 mm (4") percolation pipe	114 m (in 6 m lengths)
110 mm (4") sewer pipe	24 m (in 6 m lengths)
110 mm (4") sewer 90° swept bend	6
110 mm (4") sewer T branch	6
110 mm (4") sewer collar	6
110 mm (4") sewer plain stopper	6
110 mm (4") soil pipe cowl	6
Geotextile	48.6 m^2

Whilst excavating, levels were taken at the trench base to ensure the correct invert was achieved along its length. Following this, an initial layer of washed gravel of 250 mm thickness was placed into the trenches to act as both a distribution layer and filter below the percolation pipe. At this stage, guide tubes were also inserted to allow for the future installation of the sampling instrumentation (Figure 5.7 (c); Section 5.7.1). After placement of the percolation pipe on the first gravel layer, a second layer of gravel, again of 250 mm thickness, was added to protect and cover the pipe. Levels were taken at the top of the first gravel layer and at the soffit of the percolation pipe to ensure that a necessary gradient of 0.005 was being achieved to promote even distribution of the effluent. Prior to backfilling, a geotextile (Terram® 1 000) was placed over the second gravel layer to prevent fines from being washed into the distribution gravel and causing clogging (Figure 5.7 (d)). On completion of the percolation trenches the distribution box was installed and leveled and a trench excavated on both sides to allow for installation of flow measurement instrumentation (on distribution devices 1 and 4) and connection with the percolation pipes. The connecting pipework was surrounded by gravel and backfilled with excavated soil. It was ensured that the trench containing this

connecting pipework was dug to a depth not greater than to the invert of the percolation pipes to avoid the potential creation of preferential flowpaths, which would facilitate the free movement of effluent from the distribution gravel. On completion of the percolation areas, grass-seed was sown on both sites to achieve representative evapotranspiration rates.



(a)



(b)



(c)



(d)

Figure 5.7 Construction of percolation area:

(a) Marking of trenches

(b) Initial excavation of outside trench

(c) Placement of percolation pipe on first layer of gravel plus insertion of guide tubes along the trench

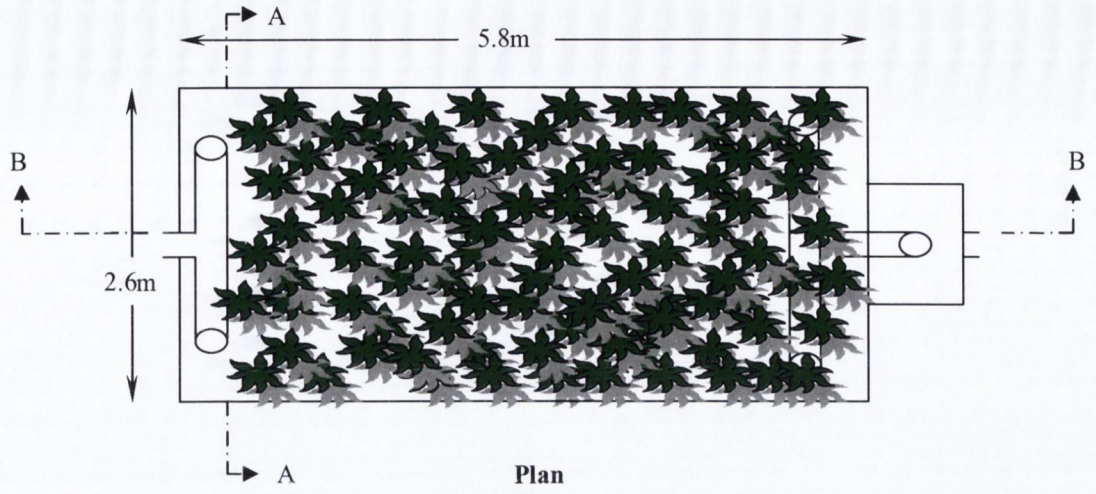
(d) Geotextile in place over percolation pipe and second gravel layer prior to backfilling with excavated soil

5.5 Construction of Reed Beds

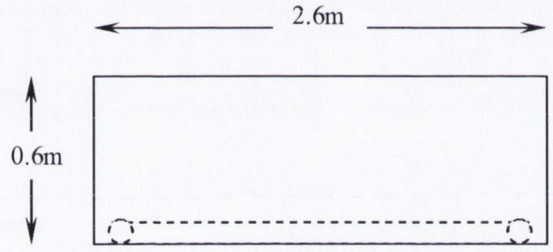
5.5.1 Design Criteria

As detailed earlier in Section 3.4, the current design approach for horizontal SSF reed beds is based upon first-order kinetics assuming ideal plug flow behaviour which has been widely adopted throughout Europe and included in the *European Design and Operations Guidelines for Reed Bed Treatment Systems* (Cooper, 1990). As such, the areal sizing of a horizontal SSF bed providing secondary treatment of domestic wastewater has been determined through use of Eqn. 3.4, yielding a surface area of 5 m^2 PE^{-1}. This assumes an average daily wastewater generation per capita of 180 L d^{-1} and a k_{BOD_5} value of 0.1 m d^{-1}. Applying these constraints to the proposed horizontal SSF bed on Site A resulted in a total design surface area of 15 m^2 (5 m^2 x 3 PE) since it was to treat half the total 6-person hydraulic load. Horizontal SSF reed bed design is based on a sizing of ~ 1m^2 PE^{-1} when providing tertiary treatment of domestic wastewater (Cooper *et al.*, 1996). With such a small footprint it is recommended that the minimum area provided be based on a serving population of 4 people. As such an area of 4 m^2 was designated for the tertiary reed bed on Site B.

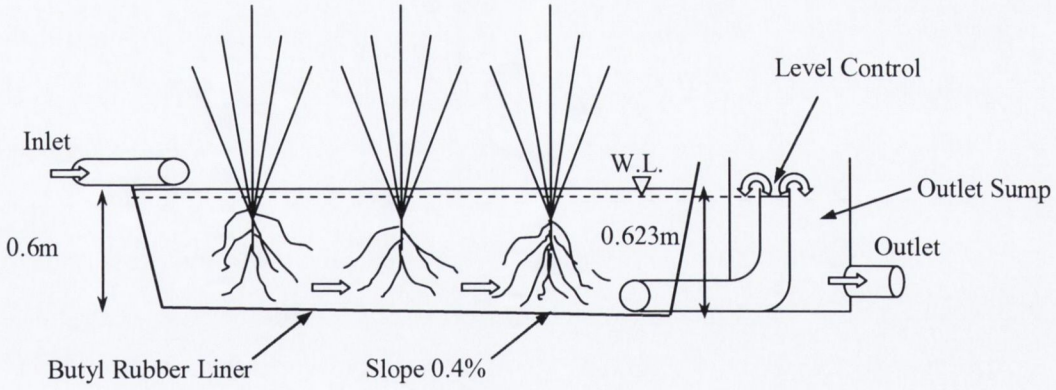
Further dimensions required in the design of the two horizontal SSFs were the beds' length and width. To achieve this, the cross-sectional area at the inlet of the bed was calculated using Darcy's Law (Eqn. 3.8). Using a recommended hydraulic conductivity value of 1 x 10^{-3} m s^{-1} and suitable base slope of 0.004 (0.4%), a cross-sectional area of 1.56 m^2 was achieved for the reed bed on Site A. Given WRc guideline recommendations (Cooper, 1990) of a 0.6 m bed depth, a width of 2.6 m was determined across the bed. The subsequent length of bed could then be calculated, yielding a value of 5.8 m. This gave an aspect ratio (L:B) of just over 2:1 which is adequate for such a small-scale design. The overall dimensions for the secondary treatment reed bed on Site A were thus 5.8 x 2.6 x 0.6 m (L x B x H). A similar procedure was carried out for the tertiary reed bed on Site B which produced dimensions of 4.0 x 1.0 x 0.6 m with a base slope of 0.01 (1%).



Plan



Section A-A



Section B-B

Figure 5.8 Plan and cross section cuts from the reed bed design on Site A

5.5.2 Reed Bed Construction

Construction of the horizontal SSFs on both sites involved a number of stages which all required much attention to detail. Prior to excavation of the soil, survey levels were taken upstream of the proposed bed location to ensure sufficient head was maintained to

the distribution box. In the case of Site A, levels were also recorded downstream of the bed to facilitate gravity flow of the effluent to the subsequent percolation trenches. Additional levels were also taken at the base of the proposed reed bed during excavation of the soil to ensure the necessary slope was being achieved to promote lateral flow of wastewater to the outlet.

The reed beds were sealed with a single sheet of impervious butyl rubber liner (Advanced Butyl Systems Ltd., Portarlington) of 1.2 mm thickness which spanned both the side walls and base (Figure 5.9 (a)). Two holes were then carefully punctured in the liner at the front and end of the reed bed to insert the 110 mm diameter inlet and outlet PVC pipework. The former consisted of a tee-splitter and dual entry configuration (Figure 5.9 (b)) which would again promote hydraulic distribution of the incoming wastewater in the bed. While the free discharge entry points on Site A were laterally placed, it was decided to use V-notch riser pipe entries on Site B instead, given that deposition of solids from the *Biodisc*® effluent at the base of the riser pipe would be very low. The outlet configuration consisted of a perforated pipe placed at the base and spanning the width of the bed (Figure 5.9 (c)). The partially treated effluent in this submerged pipe would then be discharged via a standpipe in a separate outlet sump (Figure 5.9 (d)). The discharge level on this standpipe was set to control the level of wastewater in the reed bed at a depth of 100 mm below the proposed top surface of the bed. Washed pea gravel of 5 - 15 mm diameter was then poured into the bed and filled to a depth of 0.6 m. At the inlet and outlet zones, 15 - 30 mm gravel was spread locally to reduce the threat of clogging and improve effluent distribution (Figure 5.9 (f)). A selection of wetland plants (Figure 5.9 (g)) were chosen for planting in blocks of 4 per m^2 in both reed beds. *Phragmites australis* were grown on Site A (Figure 5.9 (i)) while a mixture of typha and yellow iris were planted on Site B (Figure 5.9 (j)).



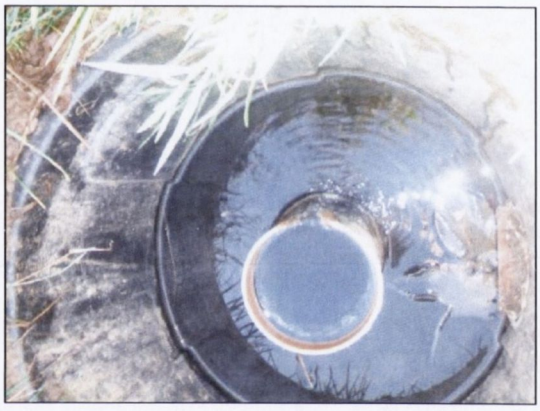
(a)



(b)



(c)



(d)



(e)



(f)



(g)



(h)



(i)



(j)

Figure 5.9 Construction of reed beds

(a) Insertion of butyl rubber liner

(b) Inlet pipe configuration

(c) Perforated submerged outlet collection pipe

(d) Discharge outlet stand-pipe

(e) Backfilling of reed bed with 5 - 15 15 mm washed pea gravel media

(f) 15 - 30 mm washed gravel around inlet and outlet configuration

(g) Selection of wetland plants (*Phragmites australis*, typha, yellow iris)

(h) Block planting of *Phragmites australis* (4 per m^2)

(i) Site A reed bed with *Phragmites australis*

(j) Site B reed bed with typha

5.6 Monitoring of Percolation Trench Influent

5.6.1 Flow Measurement

The measurement of overall wastewater production and comparison of different flow rates split at distribution boxes 1 (Site A) and 4 (Site B) under normal operational conditions was achieved by placing a tipping bucket flow-gauge (Model 6506H-Unidata, Australia) underneath each of the four outlets (Figure 5.10). The volume of effluent collected by each bucket per tip was calibrated and set to 125 mL. Each tip from all four gauges was recorded onto a *Starlog* data logger which was downloaded at least once per week. The flow rate into each distribution outlet was then calculated on the basis of number of tips for each tipping bucket and comparisons made between the four buckets installed at each site.



Figure 5.10 Tipping bucket flow-gauge instrumentation in place on Site B

A detailed analysis of six different types of gravity distribution devices, designed to split on-site wastewater effluent equally between the percolation trenches, was being run in parallel as a subset of the research project (see Patel *et al.*, 2008). Monitoring of each device was carried out both in the university laboratory under clean water conditions and also on Sites A and B, receiving septic tank and secondary treated effluent respectively, under genuine loading conditions. Initially, at each site a V-notch distribution box (Figure 5.11) was installed to distribute the incoming gravity flow

effluent evenly in four directions. These were then replaced by T-splitters (with and without baffles) (Figure 5.12 (b) and (c)) and a stilling chamber distribution box (Figure 5.13) on Site A and B respectively after a six month period (May to October 2006) for another six months (November 2006 to April 2007). These devices were then switched between sites and the order of splitters changed from August 2007 to February 2008. Finally, optimized systems were trialed on both sites for the final 5 months (see Table 5.4) using a modified stilling chamber design on Site A and a prototype of a new tipping bucket design (Figure 5.14) installed on Site B.

Table 5.4 Monitoring schedule for on-site distribution device trials

Date	Site A (septic tank effluent)	Site B (secondary effluent)
Mar '06 – Nov '06	V-notch modified box	V-notch modified box
Nov '06 – July '07	2 x T split (with baffles) & 1 x T split	Stilling chamber
Aug '07 – Feb '08	Stilling chamber	2 x T split & 1 x T split (with baffles)
Feb '08 – June '08	Stilling chamber with modified V-notch weirs	Tipping bucket device

Particular attention was taken to ensure that the distribution devices were installed exactly level. The level was checked throughout the trial period on each subsequent visit to ensure it did not change due to settlement or disturbance. It was decided to clean the weirs at the end of every month-long trial period to standardise comparisons between the different devices.

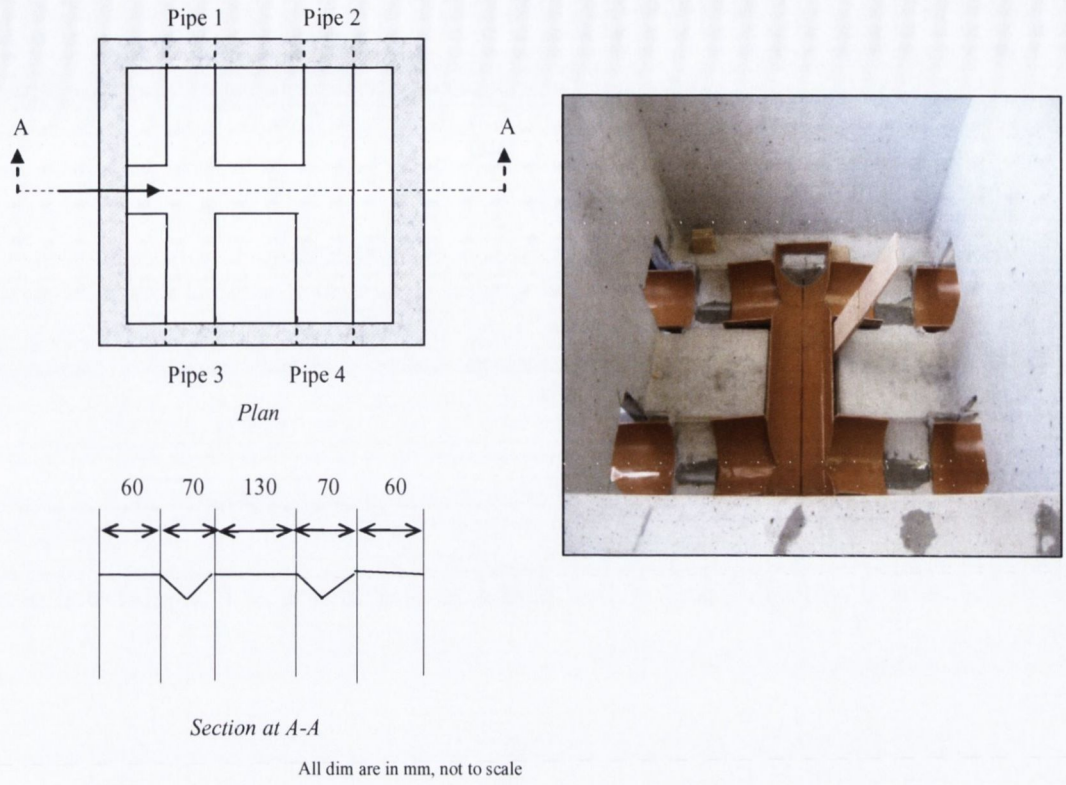
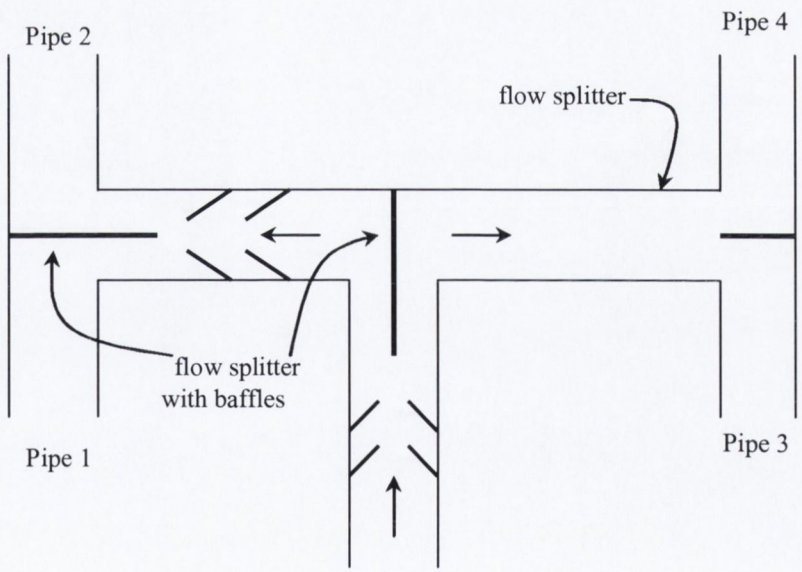
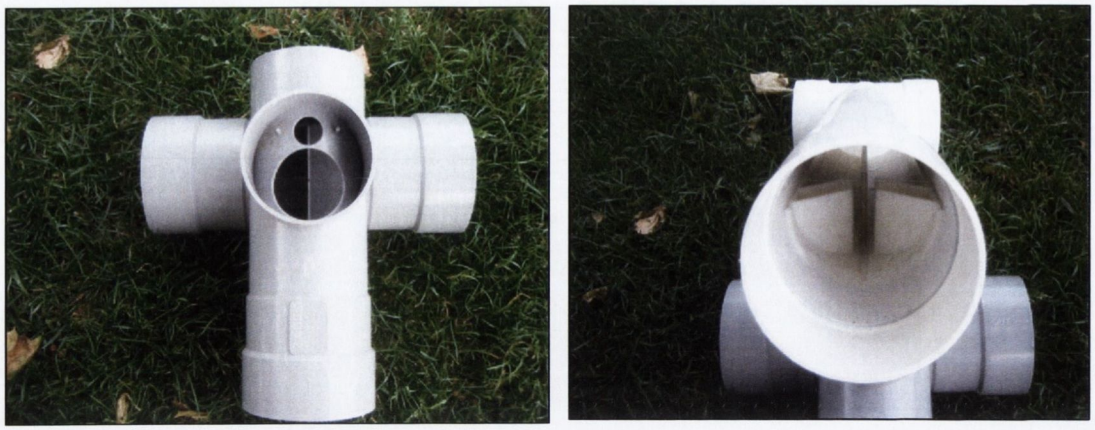


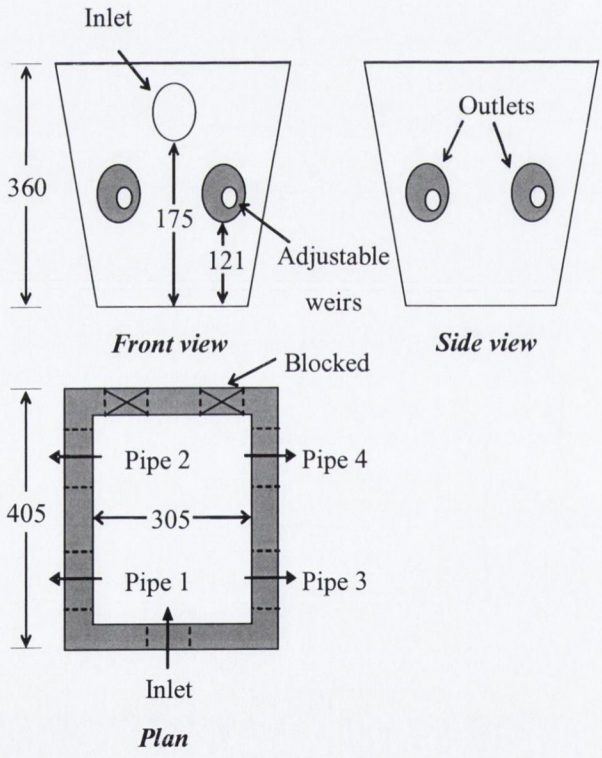
Figure 5.11 V-notch distribution box: **(a)** dimensions (mm) and **(b)** photograph





(b) **(c)**

Fig. 5.12 Flow Splitter without baffle (Zabel Manufacturers) and with baffle (Terra Firma Consultants): **(a)** schematic, **(b)** and **(c)** photographs of each configuration



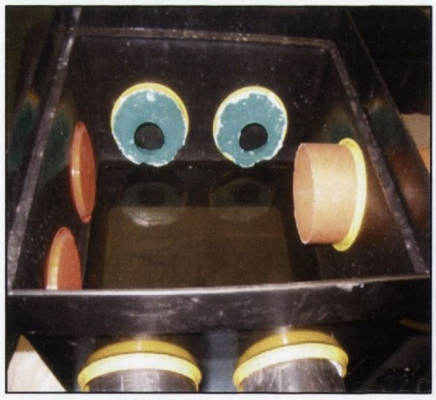


Fig. 5.13 Stilling chamber distribution box: **(a)** dimensions (mm) and **(b)** photograph

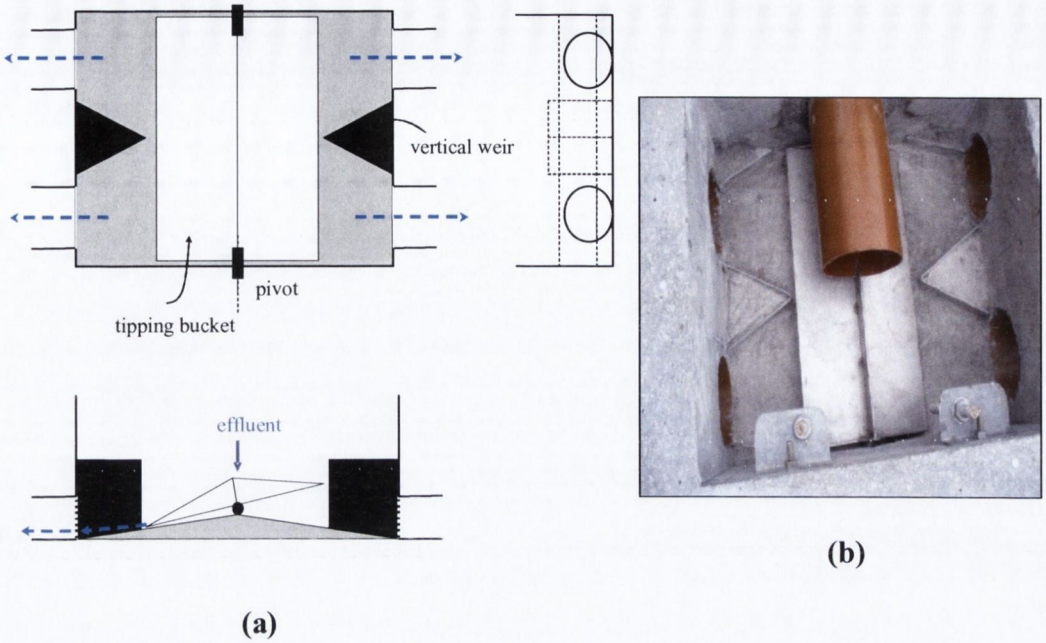


Figure 5.14 Tipping bucket distribution box design: **(a)** schematic and **(b)** photograph of design installed on Site B

5.6.2 Septic Tank and Secondary Effluent Sampling

In order to carry out composite sampling on the septic tank, *Biodisc*® and reed beds, Isco sequential portable samplers 3 700 (Figure 5.15) and 6 712, and Buhler Montec *xian 1 000* automatic samplers were installed on both sites. This enabled the changes in effluent quality across each system to be assessed. Sampling of the crude wastewater coming directly from the households was not carried out as it was thought results achieved would be poorly representative in terms of quality and quantity given the sporadic nature of flows received from a household.

During the course of the project the samplers were programmed to take samples every 3 hours over the 24-hour period preceding lysimeter sampling, thus providing a diurnal profile of the wastewater entering the reed bed/percolation trenches. The eight samples were then mixed to provide a representative composite sample. To investigate any potentially large variability in the diurnal profile of the wastewaters' constituents, intensive diurnal trials were carried out on the STE, *Biodisc*® and reed bed effluents from Sites A and B (see Appendix D).



Figure 5.15 Isco sequential portable sampler 3 700 and sample collection bottles

Table 4.4 reveals very little variance in all parameters in the STE on Site A over a 48-hour cycle. This is presumably due to the relatively long hydraulic retention time (HRT) in the tank (a median of 5.9 days) and its resultant high buffering capacity. This demonstrated that the 24-hour composite samples could be used with confidence as representative of septic tank effluent quality.

Table 5.5 Chemical (mg L^{-1}) and bacteriological (MPN 100 mL^{-1}) results from 2 x 24-hour diurnal trials (24/07/07 – 26/07/07) on constituent quality from the STE on Site A (*Note: Sample values found below the lowest detectable limit (e.g. < 0.1 mg L^{-1}) were deemed negligible and included as zero values for calculations*)

Date	Time	COD (nf)	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
24/07/2007	11:00	599	73	0.3	0.2	19.2	4.84E+07	1.22E+06
	14:00	629	75.5	1.8	0.22	18.5	5.36E+07	1.29E+06
	17:00	508	73	0.1	0.21	15.6	1.55E+07	1.20E+06
	20:00	642	78	<0.1	0.21	17.2	2.42E+07	1.08E+06
	23:00	721	74	0.3	0.23	15.05	2.42E+07	1.12E+06
25/07/2007	02:00	995	75.5	0.4	0.2	14.6	2.42E+07	9.89E+05
	05:00	748	74	0.5	0.19	15.4	9.65E+07	1.42E+06
	08:00	514	79.5	0.7	0.3	16.1	7.88E+07	1.15E+06
	11:00	526	67.5	2	0.21	16.95	3.69E+07	1.35E+06

Mean		**654**	**74.4**	**0.7**	**0.22**	**16.5**	**3.79E+07**	**1.20E+06**
Std. Deviation		**154**	**3.4**	**0.7**	**0.03**	**1.6**	**2.76E+07**	**1.36E+05**
CV		**0.24**	**0.05**	**1.0**	**0.14**	**0.1**	**0.73**	**0.11**

nf = non-filtered

Date	Time	COD (nf)	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
25/07/2007	**14:00**	435	88.5	<0.1	0.25	11.5	2.61E+07	1.60E+06
	17:00	444	85	<0.1	0.21	12.4	3.45E+07	1.46E+06
	20:00	351	98.5	<0.1	0.2	15	2.76E+07	1.21E+06
	23:00	386	99	<0.1	0.26	15.5	1.72E+07	1.10E+06
26/07/2007	**02:00**	416	95	<0.1	0.38	15.15	2.05E+07	1.60E+06
	05:00	516	106	<0.1	0.29	17.65	2.49E+07	1.87E+06
	08:00	483	111	<0.1	0.28	16	4.11E+07	1.34E+06
	11:00	583	93.5	<0.1	0.27	17.45	2.76E+07	1.34E+06
Mean		**452**	**97.1**	**<0.1**	**0.27**	**15.1**	**2.66E+07**	**1.42E+06**
Std. Deviation		**74**	**8.6**	**0.0**	**0.06**	**2.2**	**7.54E+06**	**2.46E+05**
CV		**0.16**	**0.09**	**0.0**	**0.22**	**0.15**	**0.28**	**0.17**

nf = non-filtered
CV = coefficient of variation (= std. deviation ÷ mean)

Each composite sample was then collected in a sterilised 1 L glass sample bottle for analysis in the university laboratory. On Site A, samples collected were marked CLX and CLZ for the septic tank outlet and reed bed outlet, respectively. Three further sampling points were also installed at the middle of the reed bed (left - CLY_L, centre - CLY_M and right - CLY_R) half way during the monitoring for more comprehensive data analysis. Similarly, samples from Site B were marked RCX and RCZ for the *Biodisc*® and reed bed outlet, respectively. A singular sample point was placed in the middle of this bed, marked RCY (see Appendix D).

5.7 Percolation Trench Monitoring

5.7.1 Suction Lysimeter Installation and Sampling

One of the most fundamental but equally challenging aspects of the project was the successful installation of sampling instrumentation in the subsoil along the length of the

percolation trenches. 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 under the percolation area. By placing such instrumentation at strategic positions directly below or immediately adjacent to the trenches, a detailed three-dimensional profile of the wastewaters' chemical and bacteriological constituents, coupled with its hydraulic behaviour, could be determined.

Soilmoisture Equipment Corporation Model 1 900 suction lysimeters (which will be referred to from this point onwards as lysimeters) of three different lengths, 1.3 m (red), 1.6 m (blue) and 1.9 m (black), 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 Santoprene 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.

To facilitate the installation of the lysimeters below the trench, 50 mm diameter PVC guide tubes approximately 1 m in length had been inserted into Trenches 2, 3, 4 and 5 on Site A (Figure 5.6) during construction. These guide tubes were placed in groups of three at 5 m intervals in both sets of the sites' percolation trenches (Figure 5.7 (d) and (e)). However, given that a reduced biomat spread was predicted on the percolation trenches receiving RBE owing to the additional secondary treatment provided, an additional set of guide tubes were installed 2.5 m along trenches 4 and 5. A combination auger of 45 mm diameter (Figure 5.16) was then inserted through the guide tube and 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. If a hole could be bored (despite encountering the particularly unfavorable subsoil conditions of Site A), 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 through the guide tube and pushed down to the base of the hole to ensure it fitted.



Figure 5.16 Percolation trench monitoring instrumentation and equipment required for its installation. From left of photograph: 2.0 m tensiometer, 1.6 m lysimeter, steel reinforcing bar, gouge augur, combination augur, screw auger, auger extension bar, auger handle and stilson wrenches

To maximize contact between the porous cup and the soil matrix, the guide holes were partially backfilled with a soil slurry produced by mixing excavated soil, from which any gravel had been removed, with water. The lysimeter was then inserted through the guide tube and pushed into the slurry until the base of the hole was reached. A conical trench was then dug around the guide tube where additional slurry was poured. The void between the guide tube and lysimeter was also filled with slurry after which the guide tube was extracted. A bentonite slurry, consisting of bentonite powder, soil and water, was then mixed and poured into the void between the lysimeter and the subsoil and tamped to ensure a good seal for the top metre of the lysimeter. All these installation stages are illustrated in Figure 5.17.

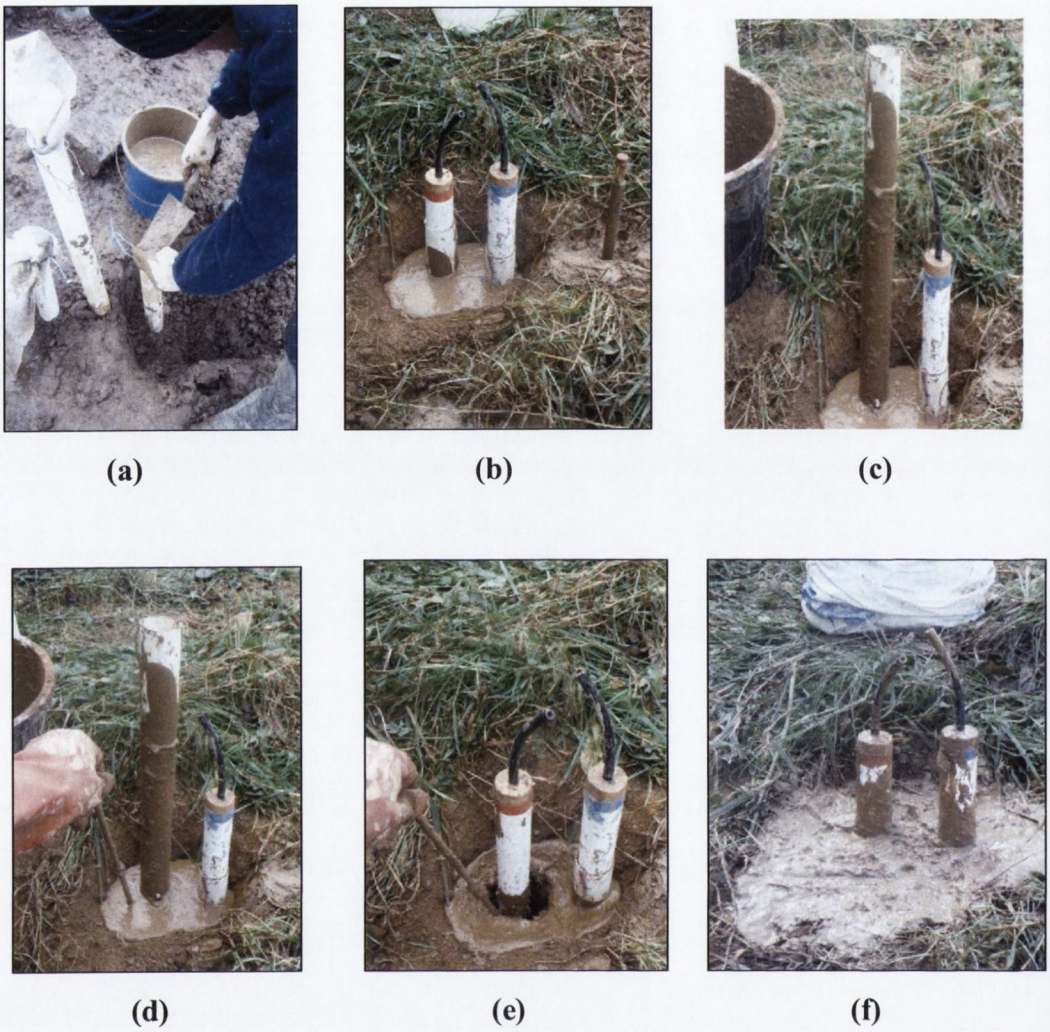
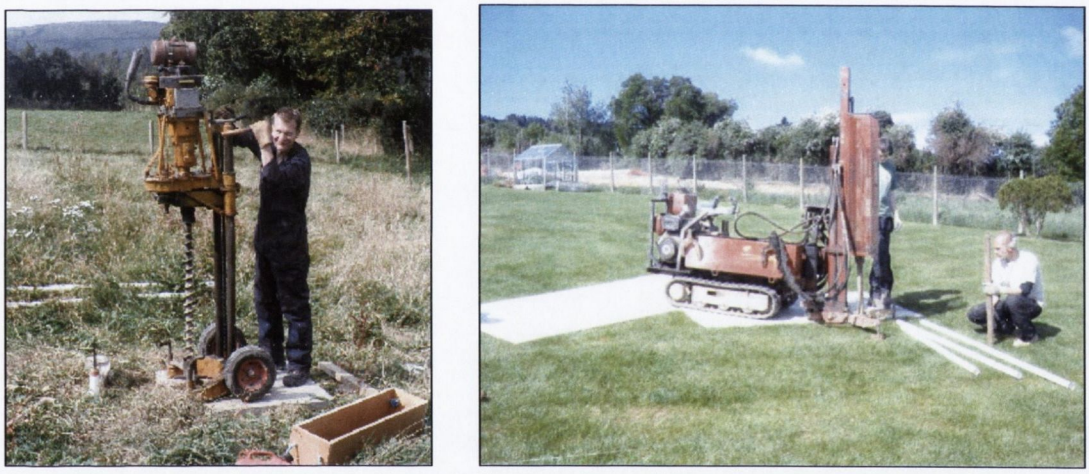


Figure 5.17 Stages of lysimeter installation **(a)** – **(f)**

Unfortunately, due to the unsorted mixture of gravel, pebbles and cobbles in the limestone till of Site A it was not possible to install all the lysimeters using the guide tubes and hand auger. Only 11 of the total 60 lysimeters to be installed were carried out using this procedure. A mechanical auger (Minute Man) was therefore used as an alternative (Figure 5.18 (a)). Given its larger auger diameter size of 65 mm, the guide tubes were declared redundant and lysimeter holes were bored directly adjacent to, rather than in, the percolation trenches. This yielded limited success, despite best efforts, on Site A with a further 12 lysimeters installed. The installation process on Site B differed from that on Site A by virtue that no guide tubes were installed during initial trench excavation owing to the extremely gravelly nature of the subsoil; it was thought that none of the hand augurs would be able to penetrate down to the requisite lysimeter

hole depth. Subsequent application of the Minute Man proved unsuccessful too with zero lysimeters installed.

As a remedy to this problem, a hammer rig (Figure 5.18 (b)), of diameter 90 mm, was successfully used on both sites with the remaining 37 lysimeters inserted in Site A and the full complement of 24 installed on Site B. Similar to the Minute Man, lysimeter holes were bored directly adjacent to the percolation trenches. Particular care was taken to backfilling the base of each lysimeter hole and void between the lysimeter and subsoil with soil and bentonite slurries. The successful operation of the hammer rig enabled all identically coloured lysimeters to be installed at similar depths below the percolation trench inverts.



(a) **(b)**

Figure 5.18 Installation of lysimeters by **(a)** Minute Man mechanical auger and **(b)** compact hammer drill rig

The sampling of all soil moisture and composite samples involved two days of site work:

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

On the morning preceding sample collection (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 bars) which helps ensure the soil moisture

solution is pulled horizontally from the vadose zone and the local soil doesn't dry out causing discontinuity in the sample. While a potential gradient is required to draw 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 forces between the moisture and the soil matrix, being extracted. Once the vacuum was created by the application of the requisite pressure through the lysimeter's neoprene tubing, the latter was clamped with a plastic ring to maintain suction. The following morning (Day 2), after approximately 24 hours under suction, the lysimeter clamps were released and the samples were ready for extraction. 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. 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 pre-labeled sample bottles (Figure 5.19). After each lysimeter, the conical flask and extraction tube were rinsed with sterilised water to minimise sample contamination. Sampling was also sequenced to extract samples from the black labeled lysimeters first, followed by their blue and red labeled 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.

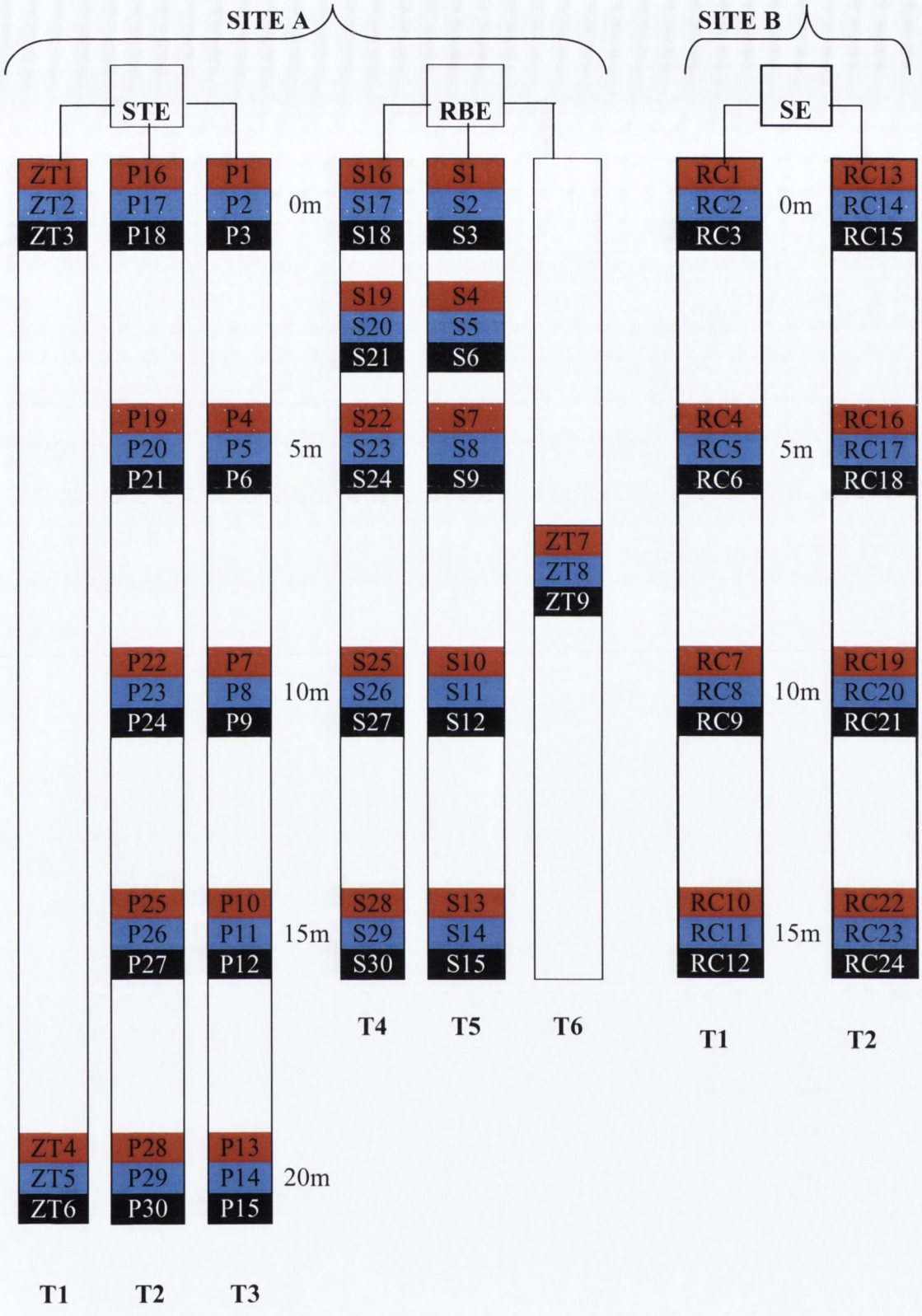


Figure 5.19 Labelling sequence for lysimeter and zero tension samples on Site A and Site B

5.7.2 Zero Tension Sampler Installation and Sampling

As an alternative sampling technique, it was decided to employ zero tension samplers in tandem with the installed suction lysimeters for sample collection. These samplers, operating at ambient pressure, would offer an interesting cross-check on the suction lysimeters to determine how representative both the chemical and bacteriological results from the lysimeter samples actually are of the percolating effluent. To this end a design for the zero tension samplers was agreed and eighteen of them manufactured in-house. Each sampler comprised a 1.85 m long stainless steel hollow tube of 50 mm OD with a pointed tip at one end (Figure 5.20). A 1 m long grid of slot openings was then cut into each tube and bordered either side by two 1 100 mm long x 20 mm wide x 3 mm thick steel fins which were welded onto the tube of each sampler at 45 ° angles. This would increase the local catchment area of percolating effluent entering the slots in each sampler. A 52 mm ID removable plastic sleeve was then prepared for casing the sampler and fitting tightly over the slotted grid between the fins. It was intended the inclusion of both the fins and plastic sleeve would negate the threat of smearing on the face of the slotted grid by the overlying soil during installation.



Figure 5.20 Stainless steel zero-tension samplers and plastic sleeve

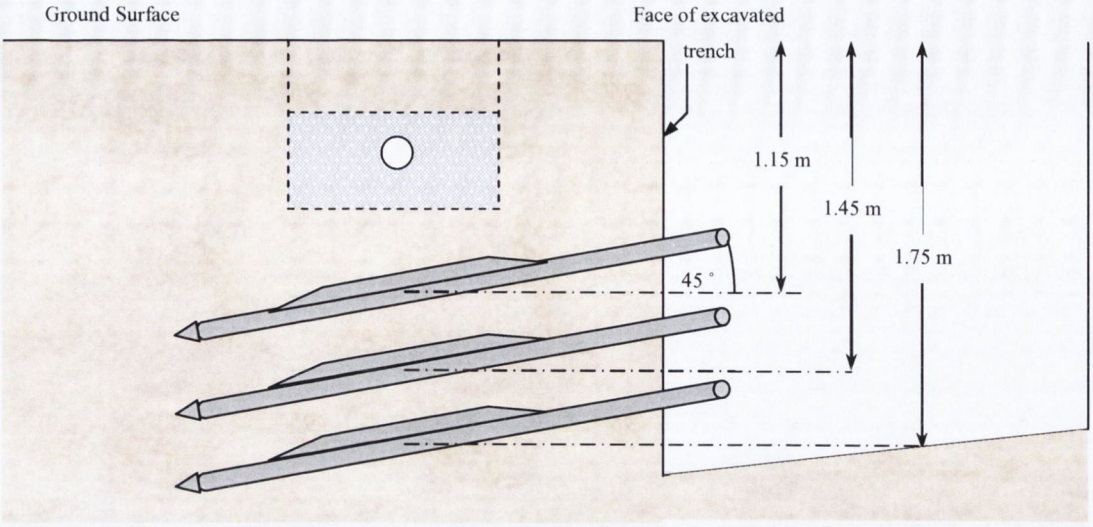


Figure 5.21 Positioning of zero tension samplers.

With regard to installation, a line was firstly marked 0.5 m from the side of the percolation trench. A new trench approximately 1 m wide and 2 m deep was then excavated perpendicular to the percolation trench from this point. With the aid of the combination auger, holes were then cored at an angle of 45° in the walls of the trench to vertical depths of 1.15, 1.45 and 1.75 m (i.e. the same average depths as the respective suction lysimeters) (Figure 5.21). The screw auger was then inserted in the cored hole and its surface scoured to minimise any potential glazing the combination auger may have caused to the soil (Figures 5.22 (a)). A natural soil surface in contact with the slotted grid was essential to maximise infiltration. Each sampler with covering sleeve was then positioned with the slotted section facing the ground surface and pushed through a cored hole using the back-bucket of a mechanical excavator (Figures 5.22 (b) and (c)). A line had been drawn on each sleeve to indicate when the sampler was in place. The sleeve was then pulled out by hand ensuring that the sampler did not simultaneously twist and that the slotted grid remained facing in the same direction. A 6.4 mm extraction tube was then inserted to the end of each tube and duly fed through a rubber cap which closed off the other end (Figure 5.22 (e)). Casing was provided for protection in guiding the extraction tube to the ground surface.



(a)



(b)



(c)



(d)



(e)

Figure 5.22 Stages of zero tension sampler installation (a) – (e)

Sampling procedures for the zero tension samplers followed along similar lines to the suction lysimeters. Instead of creating any vacuum in the samplers on Day 1 though, they were purged by discarding any residing solution in the tube and thus ensuring the extracted sample on Day 2 was fresh and representative of a composite 24 hour sample. Of the eighteen zero tension samplers manufactured, nine were successfully installed on Site A with the remaining hindered through difficulties in coring the installation holes owing to the heterogeneity of the subsoil. Six were positioned on Trench 1 (three at the front and three at the back) and three installed in the middle of Trench 6 (Figure 5.19). However, during the course of the field studies, despite aspirations that each of the samplers would obtain soil moisture volumes for analysis, only the front three samplers on trench 1 operated with success. It was assumed that the slotted grid had been smeared by the overlying soil for the remaining – most probably during the installation process upon removal of the plastic sleeve. No zero tension samplers were installed on Site B.

5.7.3 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. A tensiometer itself consists of a water-filled tube closed at the bottom with a porous ceramic cup and at the top with an airtight seal (Figure 5.16). They work by producing hydraulic continuity across the ceramic cup. Under unsaturated 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, nine Soil Measurement Systems tensiometers, consisting of a 21.5 mm OD plastic tube with a 22.2 mm OD porous ceramic cup attached, were

installed on the percolation areas of Sites A and B. A set of three tensiometers were positioned at distances of 2.5, 7.5 and 15 m along one of the trenches in each percolation area. Each trio comprised tensiometers 1.0 m (red), 1.5 m (blue) and 2.0 m (black) in length. Installation involved solely the use of a gouge augur of 30 mm diameter (Figure 5.16) for coring purposes after which the steps for inserting the tensiometers proceeded along the same lines as lysimeter installation. All tensiometers were therefore located directly adjacent to the percolation trenches. Once installed the tensiometers were filled to within 12.5 mm of the top with de-aerated de-ionised water (Figure 5.23). A septum stopper, which allows measurement of the vacuum within the top of the tensiometer while maintaining an airtight seal, was then inserted on the top of each tensiometer. As UV light degrades the septum stoppers it was important that they were covered to protect them from exposure to the sunlight. In some cases the stoppers were replaced if damaged.

The vacuum created in the tensiometer was measured, in mbar, using a tensimeter, which consists of a pressure transducer and attached needle that is inserted through the septum stopper (Figure 5.24). As the tensimeter measures the vacuum, the height of the column of water in the tensiometer must be subtracted from the transducer reading to give the actual soil moisture tension. During sustained dry periods with continuous unsaturated conditions, water levels in the tensiometers may drop and as such it is necessary for them to be refilled with de-aerated de-ionised water.



Figure 5.23 Addition of de-aerated deionised water to tensiometers



Figure 5.24 Tensimeter recording soil moisture tension

5.7.4 Reed Bed Instrumentation

For greater assessment of the change in effluent quality across the reed beds on both Sites A and B, sample points were installed at the mid centre positions of each bed, with additional points on the right, centre and left centre positions of Site A reed bed. This was carried out to determine whether there were any occurrences of hydraulic channeling (short-circuiting) in the beds which would compromise the level of treatment achieved during the process with respect to the intended design.

Each collection sampler comprised a 50 mm PVC tube of height 0.65 m which was extensively perforated and closed at one end with a rubber bung. The sampler was gently eased through the gravel bed (closed end first) until the base was reached. Extraction of the point samples followed along the same lines as the lysimeters using the same aforementioned extraction kit.

5.8 Meteorology Instrumentation

In order to assess the meteorological effects (evapotranspiration and precipitation levels) on the percolation areas and reed beds, appropriate data from weather stations and rain gauges were required. Due to the project's financial restrictions it was not possible to erect full weather stations on both sites. As such, it was agreed to install a Campbell Scientific weather station on Site A (Figure 5.25) given it was the largest in terms of physical size and volume of data for collection. Parameters recorded from the instrument were temperature, relative humidity, wind speed, wind direction, solar radiation and net radiation. An anemometer was erected on Site B to measure wind speed and wind direction, two of the more influential parameters in evapotranspiration measurement. All other parameters were acquired from the weather station on Site A.

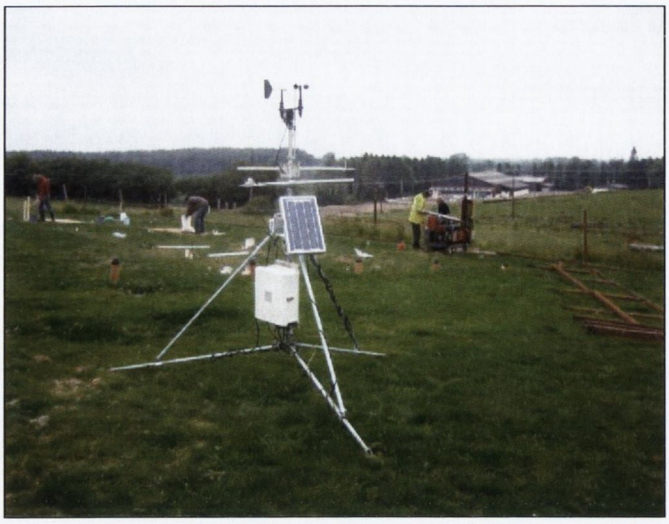


Figure 5.25 Installation of weather station on Site A

In order to record precipitation levels, a Casella® tipping bucket rain was installed on both sites which consisted of a datalogger with attached tipping bucket. The precipitation was directed into one side of the tipping bucket via the funnel shaped rain gauge cover. Each 0.2 mm of precipitation caused the tipping bucket to tip and each tipping event was recorded by the datalogger. In general, when siting a rain gauge consideration must be given to the effects of shading from surrounding obstacles. A general rule of thumb is that no object should be closer than four times its height to the rain gauge so as not to impede collection. However, with respect to this project these guidelines could be ignored as it was the precipitation falling on the percolation area and reed bed rather than the areal precipitation that was of interest. The rain gauge was therefore located in an appropriate position between both target areas on each site. A 450 mm square concrete slab provided a steady base upon which the rain gauge was secured and leveled with the aid of the attached spirit level. The rain gauge funnel and inlet mesh were cleaned and the recorded data downloaded upon regular visits to both sites. In addition, a clean plastic container was located beside, and anchored to, the rain gauge to prevent its disturbance. Rainfall samples were collected in this container for Cl analysis. All meteorological data, including evapotranspiration and rainfall measurements, from the three sites can be viewed in Appendix F.

5.9 Analysis Methodology

5.9.1 Soil Moisture Sample Collection

Given that the greatest volume of effluent (100 mL) was required for zero dilution bacteriological analysis, soil moisture samples were firstly transferred directly on site from the 1 L conical flask to disposable Colilert®-18 (Section 5.9.3) 120 mL sterile vessels containing sodium thiosulphate. All remaining sample volume from the soil moisture lysimeters were collected in 300 mL plastic sample bottles for chemical analysis. If less than 100 mL volume was extracted from the lysimeters the whole sample was transferred to the 300 mL sample bottles and later divided up in the laboratory to carry out appropriate dilutions for bacteriological analysis. All 300 mL bottles were sterilised prior to each sampling event. Samples for phage analysis were collected in 30 mL Sterilin polystyrene containers. After all sample bottles were capped, they were stored in a cooler box and transported directly to the Environmental Engineering Laboratory in TCD for analysis.

5.9.2 Chemical Analysis

Throughout the duration of the field studies, all septic tank, *Biodisc*®, reed bed and soil moisture samples were 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. On those samples where Biochemical Oxygen Demand (BOD_5) was required, it was determined as per APHA (1998) by measuring the dissolved oxygen content of a sample before and after a 5-day incubation period. Samples were diluted at three different ratios with BOD buffer. Initial and five day dissolved oxygen (DO) levels of a BOD_5 blank (sample bottle containing only BOD buffer) and all three replicates of each sample were taken using a Eutech Cyberscan DO 5 000 bench meter. The BOD_5 of a particular sample was then determined using Eqn. 5.3:

$$BOD_5 = (\text{initial DO reading} - \text{5 day DO reading}) \times \text{sample dilution} \quad \text{(Eqn. 5.3)}$$

Septic tank, *Biodisc*®, reed bed and a number of soil moisture samples were also analysed for total nitrogen (TN) using a Hach Lange LT200 thermostat and spectrophotometer DR2800. Concentrations of organic nitrogen (org-N) and total kjeldahl nitrogen (TKN) wastewater samples could then be deduced using TN, NH_4-N, NO_2-N and and NO_3-N concentration results derived from laboratory analysis. Eqn. 5.4 was used to determine the inorganic-N concentrations while Eqn. 5.5 was used to determine the org-N concentrations. TKN concentrations were then calculated through use of Eqn. 5.6.

$$Inorganic\text{-}N = NO_2\text{-}N + NO_3\text{-}N + NH_4\text{-}N \quad \text{(Eqn. 5.4)}$$

$$Organic\text{-}N = TN - (NO_2\text{-}N + NO_3\text{-}N + NH_4\text{-}N) \quad \text{(Eqn. 5.5)}$$

$$TKN = Organic\text{-}N + NH_4\text{-}N \quad \text{(Eqn. 5.6)}$$

Total suspended solids (TSS) of a particular wastewater sample was determined according to APHA (1998) by filtering between 100 and 500 mL of a shaken wastewater sample with a pre-dried and weighted 0.8 μm glass fibre filter paper. After the completion of the filtration, filter paper was dried in a 105 °C oven for 1 hour, allowed to cool in a desiccator, and weighed again. The cycle of drying, cooling and weighing was repeated until weight change was less than 4% of the previous weighing or 5 mg, whichever was less. TSS concentration of the sample was then determined using Eqn. 5.7:

$$TSS = [(W2 - W1) \times 1{,}000] / V \quad \text{(Eqn. 5.7)}$$

where, TSS = Total Suspended Solids (mg L^{-1})

$W1$ = weight of pre-dried filter paper (mg)

$W2$ = weight of filter paper after filtration (mg)

V = volume of wastewater filtered (mL)

If parameter concentrations were outside the detectable range for a specific reagent the samples were diluted with a known volume of distilled water. However, it is important to note that where a sample was diluted, an error in the analysis would be

multiplied by the size of the dilution step in the reported concentration. For example, if a 1 : 10 dilution was used this would mean that a small error in the analysis would result in a tenfold increase in the error in the reported concentration. To minimise such error, replicate samples were taken for each wastewater sample requiring a dilution. Those samples with recorded values below the parameter's lowest detection limit were deemed negligible and assigned zero-values in calculations.

The assessment of the reed beds in terms of the range of wastewater parameters is based on three performance indicators: (a) effluent concentration (mg L^{-1} or MPN 100 mL^{-1}), (b) load removal efficiency (%) where load is in g d^{-1} and (c) surface load removal where surface load is in g m^{-2} d^{-1}. Each indicator has its own strengths and weaknesses. Effluent concentration is important where a regulatory standard has to be met but is strongly influenced by influent concentration as well as by system performance. Reed bed load removal efficiency (%) was calculated for all tested pollutants using the following Eqn. 5.8:

$$\textit{Load Removal Efficiency} = 100(PL_i - PL_o) / PL_i \qquad \text{(Eqn. 5.8)}$$

where, PL_i = Average pollutant load of influent (g d^{-1})

PL_o = Average pollutant load of effluent (g d^{-1})

Percentage load removal has the advantage of being somewhat independent of influent concentration for a given residence time and of being a widely accepted indicator.

Surface load removal (g m^{-2} d^{-1}) was calculated for all reed beds using the following Eqn. 5.9:

$$\textit{Surface Load Removal} = (SL_i - SL_o) / SL_i \qquad \text{(Eqn. 5.9)}$$

where, SL_i = Average surface load of influent (g m^{-2} d^{-1})

SL_o = Average surface load of effluent (g m^{-2} d^{-1})

As such, surface load removal indicates the actual rate of removal of pollutant mass per unit area and is a very relevant performance indicator where space is limited. It has the disadvantage, however, of being strongly influenced by the influent concentration, as more concentrated effluents show higher areal removal rates in any given system.

Bromide (Br^-) and Rhodamine WT (RWT) were used as tracers in the analysis of the subsoil and reed beds respectively. With its negative charge, bromide, used in the test as KBr in an aqueous solution, is likened to Cl in that it serves as a conservative tracer representative of the water movement through soil, though some diffusion from mobile to immobile water may occur. It has been used to investigate water and contaminant transport in many agricultural and environmental research scenarios (Smith and Davis, 1974; Harvey and George, 1988; Jabro *et al.*, 1994; Kessavalou *et al.*, 1996; Schuh *et al.*, 1997; Kelly and Pomes, 1998; Woessner *et al.*, 2001; Chu *et al.*, 2003; Lin *et al.*, 2003; Van Cuyk *et al.*, 2005). Analysis of bromide in the soil moisture samples during the tracer tests (Section 6.36) was carried out using a Dionex ICS-1500 Ion Chromatography System with an AS40 Automated Sampler. The column used was an Ion Pac AS14A 4 x 250 mm analytical column electrolytic suppression using an ASRS UltraII 4 mm suppressor. All reagents were AnalaR grade and the deionised water was 18 MOhm-cm, Type 1 water. The eluant was 8.0 mM Sodium Carbonate, 1.0 mM sodium bicarbonate used at a flow rate of 1 mL min^{-1}. Standards were made from certified stocks and an independent QC was run alongside samples (every 10).

RWT is a non-conservative tracer used in this study for the determination of actual hydraulic retention times in the reed beds. It is a florescent dye commonly used in surface and groundwater tracer studies because of its relatively low cost, strong fluorescence, high diffusivity, and benign character in the environment (Kilpatrick and Wilson, 1989). RWT itself is a large organic molecule with positive and negative ionic functional groups. These ionic groups increase the water solubility (180 g L^{-1}, Gaspar, 1987), allowing for quick and complete dissolution into water. As such RWT is often used as a surrogate for organic chemicals in surface water, domestic and municipal wastewater (Van Cuyk *et al.*, 2005) and groundwater studies. Active measurement of the RWT in the reed bed effluent was enabled by connecting a

calibrated Cyclops-7® submersible fluorometer (Turner Designs Inc.) to the datalogger and power outlet of the meteorological station on both sites and inserting the fluorometer in the level control standpipe in the outlet sump.

Volatile fatty acid (VFA) analysis was carried out on two separate septic tank effluent samples from Site A. The samples were sent to CAL Laboratories, Dun Laoghaire, Dublin, where analysis of a suite comprised the following VFA constituents: ethanol, propanol, acetic acid, propionic acid, isobutyric acid, n-butyric acid, isovaleric acid, n-valeric acid, INT-4 methyl valeric acid, heptanoic acid and hexanoic acid.

In recent years there has been heightened interest in a number of compounds that interfere with the normal action of the endocrine system, collectively known as endocrine disrupting chemicals, or EDCs. An endocrine disrupter is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub)populations (Damstra *et al.*, 2002). The majority of EDCs associated with domestic wastewater can be grouped into the following generic categories: steroid compounds, surfactants and organic oxygen compounds. Other groups of EDCs, including pesticides and polyaromatic hydrocarbons, are not generally found in significant concentrations in domestic effluent. Natural steroid oestrogens usually found in domestic effluent in significant quantities include oestrone, 17β-oestradiol, synthetic ethynyloestradiol (a component of the contraceptive pill and hormone replacement therapy) and oestriol. The main *organic oxygen* compound of concern in domestic sewage effluent is bisphenol A, which is generated from the production of polycarbonate and epoxy resins and certain phthalates, which are involved in the manufacture of PVC and other resins. These plastics are used in food packaging, tooth fillings, dental materials (and other domestic products) and can leach into the product thereby finding their way into the sewage effluent. Finally, caffeine was analysed to ascertain whether it can be used as a reliable indicator of domestic wastewater effluent as it is present in most wastewater effluents (Seiler *et al.*, 1999; Swartz *et al.*, 2006).

Samples for EDC analysis were collected in two 1 L glass jars, one containing preservative for the oestrogen analysis, the other unpreserved sample for bisphenol A and caffeine analysis. The samples were then sent to Severn Trent Ltd. (STL)

laboratories in Coventry, UK for analysis. Six EDCs were targeted for analysis based on their previously documented existence in domestic wastewater, variety in terms of source and also their likely persistence through the unit treatment processes and thus levels in the effluent:

- Natural steroid oestrogens - oestrone, 17β-oestradiol, ethynyloestradiol, oestriol
- Organic oxygen compound - bisphenol A
- Consumer product chemical - caffeine

The methods used by CAL and STL for VFA and EDC analysis respectively are contained in Appendix B.

In order to study the relative importance of the various nitrogen pathways and removal mechanisms both in the reed beds and subsoil, the influent to these systems were spiked with labeled ammonium chloride ($^{15}NH_4Cl$). The resulting levels of the nitrogen isotope (^{15}N) in both the suspended organic fraction and in solution (ammonium and nitrate) were then analysed by continuous flow-isotope ratio mass spectrometry (Thermo Delta^{plus} CF-IRMS) in the Department of Geology, TCD, to determine $^{15}N/\ ^{14}N$ ratios. The suspended fraction was obtained by filtration of the sample through glass fibre filter paper (Whatman GF/C). Both the filter paper and filtrate were then placed on separate evaporation dishes and placed in an oven at 55 °C for 24 hours. The residue from the glass evaporation dish (the solute) was then scraped off into a sample container before being sent for isotope analysis along with the dried suspended fraction on the filter paper

In order to study the importance of the macrophytes in the reed beds with respect to phosphorus removal, representative samples of the reeds in Site A (*Phragmites australis*) and Site B (*Typha laitfolia* and *Iris pseudacorus*) were dug up at the end of the third season. All reeds (stems and roots) were thoroughly washed in distilled water to remove any sediment or biofilm which may have compromised the sample. Each reed was then cut into two halves, stem and roots, labelled and placed into an oven for

3 days at 105 °C to dry out. Once dry the respective biomass samples were then weighed. Each sample was then ground down to a fine dust using a mill.

The samples were then ready for phosphorus extraction. This was carried out using an acid digestion method as per the Standard Methods (APHA, 1998). 0.5 g of sample was added to 10 mL of nitric acid and 2 mL of sulphuric acid. The mixture was placed on a boiling bath until the volume reduced to around 2 mL. The solution was then made up to 20 mL with distilled water. The concentrations were subsequently measured in a Varian ICP (Inductively Coupled Plasma) machine following calibration against standards over 0.5 to 100 mg L^{-1} range.

5.9.3 Bacteriological Analysis

All aforementioned samples tested for chemical analysis were also tested for the presence of pathogenic bacteria. Total Coliforms (TC) and *E. coli* are two common indicator organisms of faecal contamination which denote the possible presence of enteric bacteria. Their presence in the designated samples was detected using the Idexx Colilert®-18 test (Appendix B). Colilert®-18, with its patented Defined Substrate Technology® (DST®), is the only US EPA approved 18 hour test and is currently used for water quality analysis in over 90% of all US State laboratories. It boasts superior 95% confidence limits than 5- or 10-tube Most Probable Number (MPN) and 95% confidence limits better than or comparable to membrane filtration (MF) techniques. DST® uses two nutrient-indicators, ONPG and MUG, as the major sources of carbon in this test and can be metabolised by the coliform enzyme β-galactosidase and the *E. coli* enzyme β-glucuronidase, respectively. As coliforms then grow in Colilert®-18, they use β-galactosidase to metabolise ONPG and change it from colourless to yellow. *E. coli* use β-glucuronidase to metabolise MUG and create fluorescence. Enumeration of TC and *E. coli* was carried out using Idexx Quanti-Tray®/2000, a semi-automated quantification method based on the Standard Methods Most Probable Number (MPN) model. As each tray provides a maximum count of only 2 419 MPN 100 mL^{-1}, serial dilutions using sterilised water were prepared in the laboratory for the septic tank, *Biodisc*® and reed bed samples together with a number of soil moisture samples. In the case of the latter, dilution was sometimes a prerequisite on those occasions where the total volume of sample extracted from the lysimeters was less than the necessary 100 mL. In such cases, minimum counts for TC

and more pertinently *E. coli* increased relative to the dilution factor. This is displayed in the results in Appendix D where lowest detection limits for *E. coli* vary depending on the extent of dilution.

In the case of coliform analysis, log-unit load removal (where each log represents a decrease of one order of magnitude in pollutant load) is the most commonly used performance indicator and is adopted in both the subsoil and reed bed analysis.

5.9.4 Bacteriophage Analysis

Three bacteriophages, MS2, ΦX174 and PR772, were used in tracer studies on the subsoil and reed beds as surrogates for human enteric viruses. 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 2.5.2. 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). 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 15 g of agar per litre. The host bacteria was grown in TSB in a conical flask and placed in a 37°C orbital shaker until mid-log phase (OD_{600nm} = 0.5) was reached. Top agar consisting of Trypticase soy broth containing (per litre) 7 g of agar and 1 mL of 1 M $CaCl_2$ was melted in a steamer after which 3.5 mL were aliquotted into a series of sterile culture tubes (1 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 100 μL 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 (50 μL) 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 and Misera, 1938) with each plate split into four quarters. Duplicates were carried out for each dilution and the average count reported. Only the dilutions that resulted in 10 - 300 plaques per quarter were counted. Calculation of the quantity of phage present in the sample was then deduced from the equation:

$$\textit{Phage Quantity (PFU mL}^{-1}\textit{)} = \textit{(No. of plaques on plate) x (dilution factor) x 20} \qquad \text{(Eqn. 5.10)}$$

Using this method the minimum phage detection limit was 10 PFU mL^{-1} and as such, any non-contaminated sample was reported as < 10 PFU mL^{-1} or < 1 log-unit.

Bacteriophage stocks were propogated by preparing plates with the soft agar/host overlay just described, and covering the surface with approximately 0.5 mL 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 1 000 rpm for 25 minutes to sediment the cellular debris and agar. The supernatant was conserved and passed through a 0.22 μm Millipore filter and the filtrate stored at 4 °C.

5.9.5 Sample Analysis Quality Control

In order to assess the accuracy of sample analysis in the TCD laboratory quality control measures were carried out. Two sets of samples, nine in the first batch (Site A), eight in the second (Site B), were sent to CAL Ltd., an accredited laboratory in Dun Laoghaire, Dublin. Samples analysed ranged from low to high strength representing a broad spectrum of parameter concentrations. The chemical and bacteriological results obtained from the samples analysed by CAL (methods contained in Appendix B) were compared against those obtained in the TCD laboratory. Statistical analysis was carried out based on the R^2 (coefficient of determination) value and the slope of the regression line. As shown in Figure 5.26, an

excellent correlation (R^2 ~ 97%; Slope = 0.94) was found between the two sets of data in the analysis of all chemical parameters. This is due to the close linear relationship found between the two sets of data for a number of individual parameters; TCD laboratory analysis for COD, BOD, NO_3-N, TN, PO_4-P, Cl and TSS were markedly similar to results from CAL analysis for the same parameters (Table 5.6).

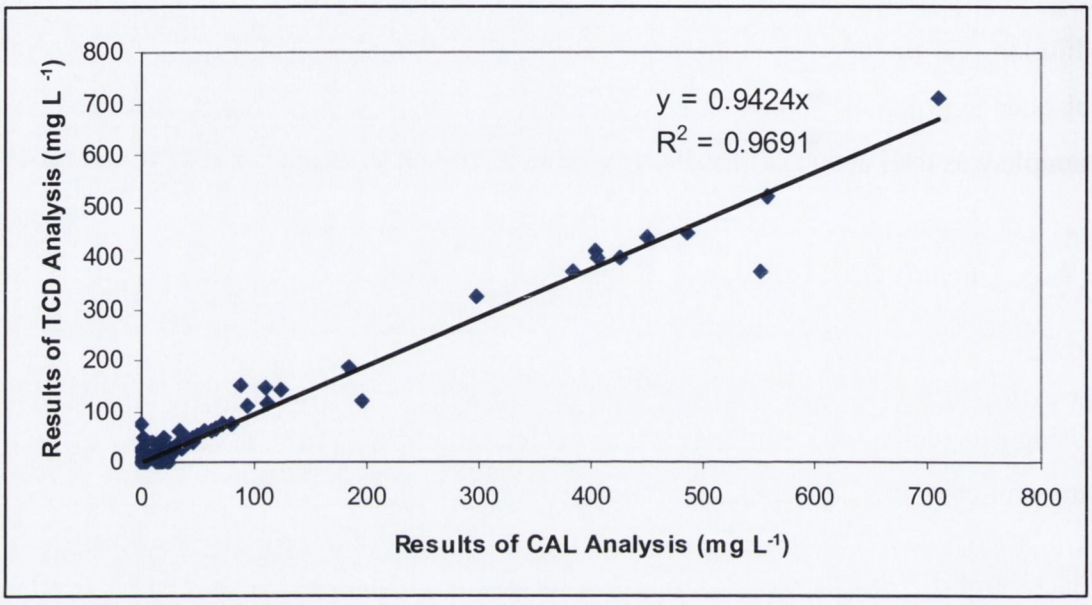


Figure 5.26 Graph of TCD results against CAL results for all chemical parameters (COD, BOD_5, NO_3-N, NO_2-N, NH_4-N, TN, PO_4-P, Cl, TSS)

Table 5.6 Regression statistics from comparison of CAL results (x-axis) with results obtained in the TCD laboratory (y-axis)

Parameter	R^2	Slope
COD	0.98	0.98
BOD	0.99	1.02
NO_3-N	0.92	0.91
NO_2-N	0.60	0.02
NH_4-N	0.85	1.22
TN	0.98	1.06
PO_4-P	0.81	1.29
Cl	0.94	0.92
TSS	0.88	0.97

While NH_4-N results (R^2 = 0.85; Slope = 1.22) may not have been as accurate between both sets of analysis as many other parameters, it was worth noting that the correlation improved (R^2 = 0.95; Slope = 0.83) when only those samples with significant concentrations (e.g. from Septic Tank, *Biodisc*® and reed beds) were included in the analysis. Of additional note is the reduced slope (<1), indicating that TCD analysis results were more conservative than the corresponding CAL results for this parameter using the revised sets of data. NO_2-N results showed a surprisingly poor correlation between both sets of analysis. However, given that this parameter plays a minor role throughout the course of the analysis with such negligible values recorded, the effect on the overall correlation of all parameters proved minimal.

Comparison of *E. coli* results between TCD and CAL analysis showed a varying degree of correlation. All soil moisture samples showed equally negligible *E. coli* concentrations (< 1 MPN 100 mL^{-1}) for both sets of analysis although CAL results for highly contaminated samples (septic tank, *Biodisc*® and reed beds) were significantly lower than TCD results, varying between 1 and 3 log-unit difference. However, given the conservative nature of the TCD results coupled with their greater similarity to equivalent literature data, such discrepancies were not deemed highly significant.

6. ON-SITE LOADINGS

6.1 Introduction

On Site A, a successful site assessment was completed on 29th July, 2005. The installation of the septic tank and the construction of the reed bed and percolation area were duly completed and on-site effluent flows started to be discharged into the system on 26th October, 2005. Diversion works were then required to separate the domestic wastewater effluent from the roof runoff, which was diverted to a soakaway. The installation of sampling equipment commenced on 26th October, during construction of the treatment system, but the full set of suction lysimeters were not installed at their appropriate depths in the percolation area until 26th June, 2006. This was due in part to adverse weather conditions but primarily because of the aforementioned difficulties during the installation of the full set of suction lysimeters with the aid of both the hand augurs and Minute Man. Despite this, sampling began on the septic tank, reed bed and available lysimeters on the percolation area on 10th April, 2006 and continued until 13th June, 2008 resulting in a 32-month operational period and 26-month monitoring period. The installed septic tank provided consistent effluent quality over this period with minimal maintenance demands.

A successful site assessment was completed for Site B on 9th September, 2005. The installation of the *Biodisc*® filter and construction of the reed bed and percolation area on Site B was completed on 8th October, 2005 and on-site effluent flows started to be discharged into the system on the same date. Minor diversion of a roof runoff drain was subsequently carried out to ensure domestic wastewater alone was being discharged to the treatment system. As on Site A, problems with suction lysimeter installation resulted in delays to work completion. Full installation of instrumentation was eventually achieved on 31st May, 2006. Sampling began on the *Biodisc*® filter and reed bed on 9th May followed by the percolation area on 4th July. The last set of samples was taken on 25th June, 2008 resulting in an average 24-month monitoring period, although the system had been operational for 32 months. The *Biodisc*® filter operated continuously from startup. As will be highlighted, biological processes in the filter were compromised from the period November 2006 to May 2007 due to an unsolicited layer

of biomass forming in the final settlement section of the unit. No maintenance was carried out until the 5th June, 2008 when the *Biodisc*® was desludged after more than two and a half years in operation.

For each of the two selected Sites, A and B, the hydraulic and pollutant loadings from the respective septic tank and *Biodisc*® filters are measured and assessed. Given the length in time of monitoring, a large dataset of effluent quality parameters has been accrued. It is important to note that given the absence of raw influent quality data, reporting on the performance efficiency across each treatment system in terms of percentage removal is not possible. As such, each system is analysed based purely on its effluent quality over time and moreover as a means of determining the source chemical and bacteriological concentrations and loadings prior to subsequent treatment.

6.2 Site A – Analysis of Septic Tank Effluent

6.2.1 Hydraulic Loading

As outlined in Section 5.6.1, the accurate measurement of flow rates from proprietary treatment systems (septic tank and *Biodisc*®) was achieved by placing 4 tipping bucket flow-gauges underneath each of the four distribution device outlets. On Site A, monitoring of the STE flow was carried out from 1st March 2006 to 12th June 2008 inclusive (Appendix C). Apart from a few brief periods where data had been lost as a result of either the data storage capacity of the datalogger being reached or the battery exhausting, a continuous record of flow to both the percolation area and reed bed was acquired.

The flow distribution characteristics of the STE at Site A arriving at the distribution box over parallel twelve-month periods are shown in Figures 6.1 (a) and (b) respectively. The mean flow rate with respect to frequency and total volume was determined by the method of moments (Bedient and Huber, 1992).

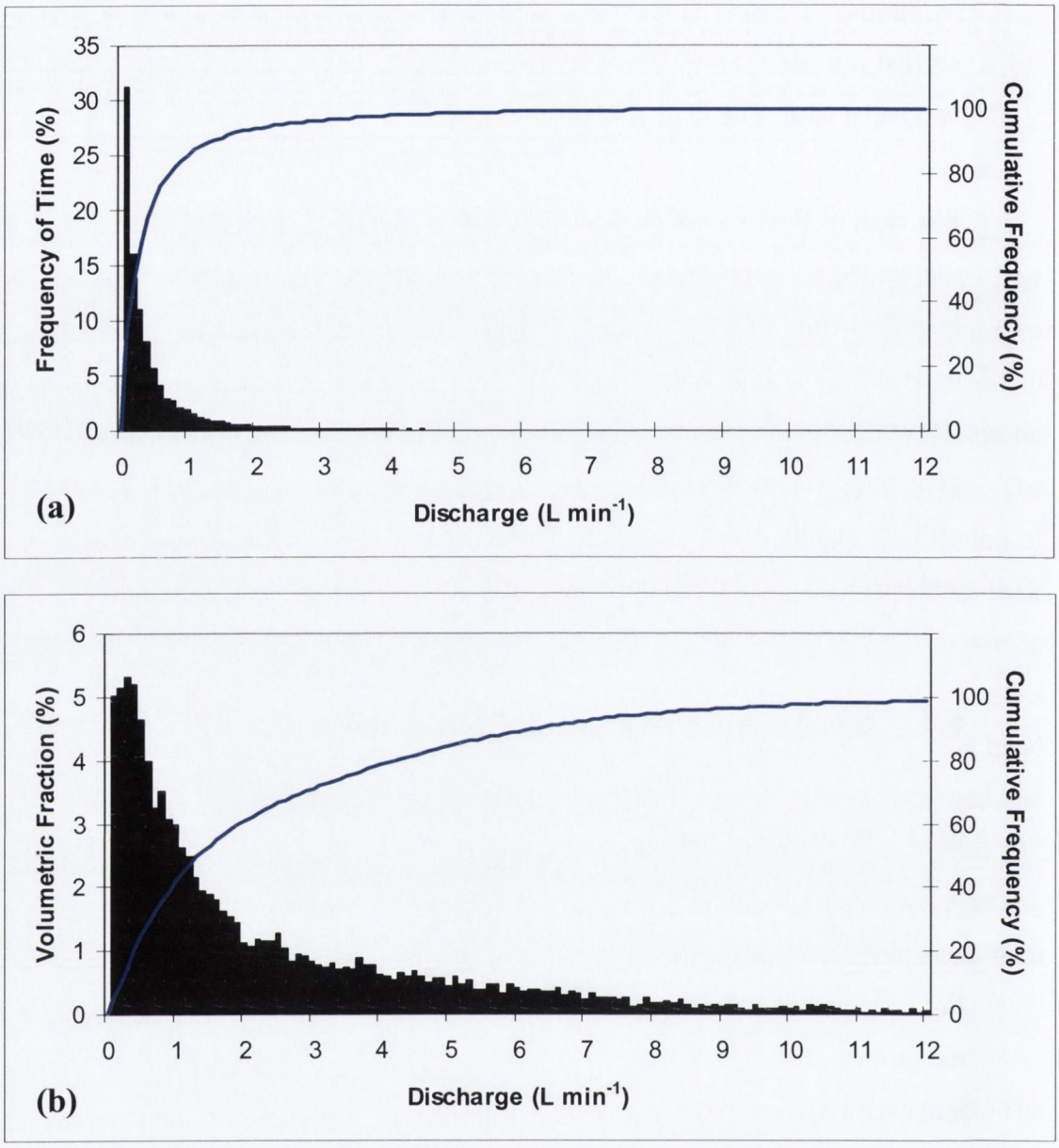


Figure 6.1 Flow distribution at Site A; **(a)** frequency of time, **(b)** volumetric fraction

The statistics reveal that the most common flow rates experienced at the distribution device at Site A (> 85% of the time) was between 0.1 – 1 L min^{-1} across the sampling period (mean = 0.62 L min^{-1}). The volumetric mean flow observed for this period was 2.49 L min^{-1}. Figure 6.1 (a) also shows that for almost 50% of the time the flow rate was less than 0.3 L min^{-1} indicating that the STE flow that needed to be evenly distributed between the percolation trenches and reed bed was most often in the form of intermittent, small volume pulses. This is important to consider for the design of any potential gravity fed distribution device, especially for optimal performance at lower

flow rates. Equally, Figure 6.1 (b) shows that 50% of the effluent volume was discharged at flows less than 1.4 L min^{-1}.

A graph of the total daily on-site flow rates at the distribution box is plotted (Figure 6.2) which shows that the daily flow rates remained relatively constant over the research period with the exception of some intermittent high loading. This high loading most likely occurred as a result of an increased number of visitors to the house over a short period of time (i.e. party or other event). The mean flow measured on Site A was 716.3 L d^{-1} [Std. dev. = 398.9], calculated by cumulating the number of tips (each representing a volume of 125 mL) from each bucket 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 119.4 litres per capita per day (L c^{-1} d^{-1}) [median value = 106.8 L c^{-1} d^{-1}], as shown on Figure 6.3. As such, the assumption of 180 L c^{-1} d^{-1} in the Irish EPA guidelines (EPA, 2000) appears to grossly over-predict the mean wastewater production in such one-off dwellings with typical sized family units.

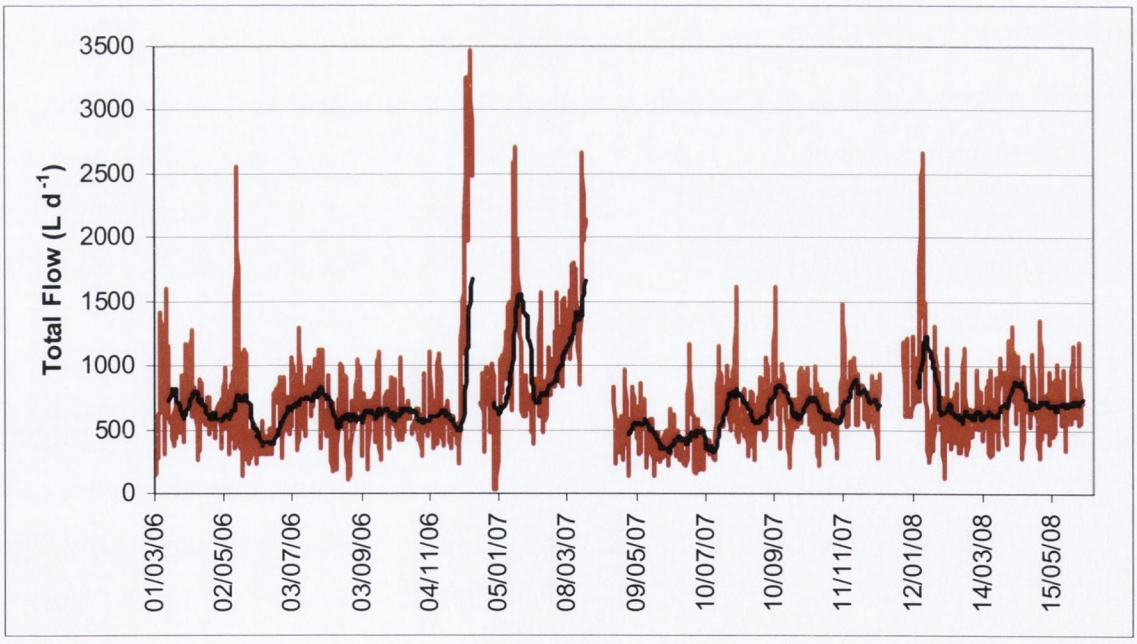


Figure 6.2 Daily flows to Site A (with 2 week moving average trend line)

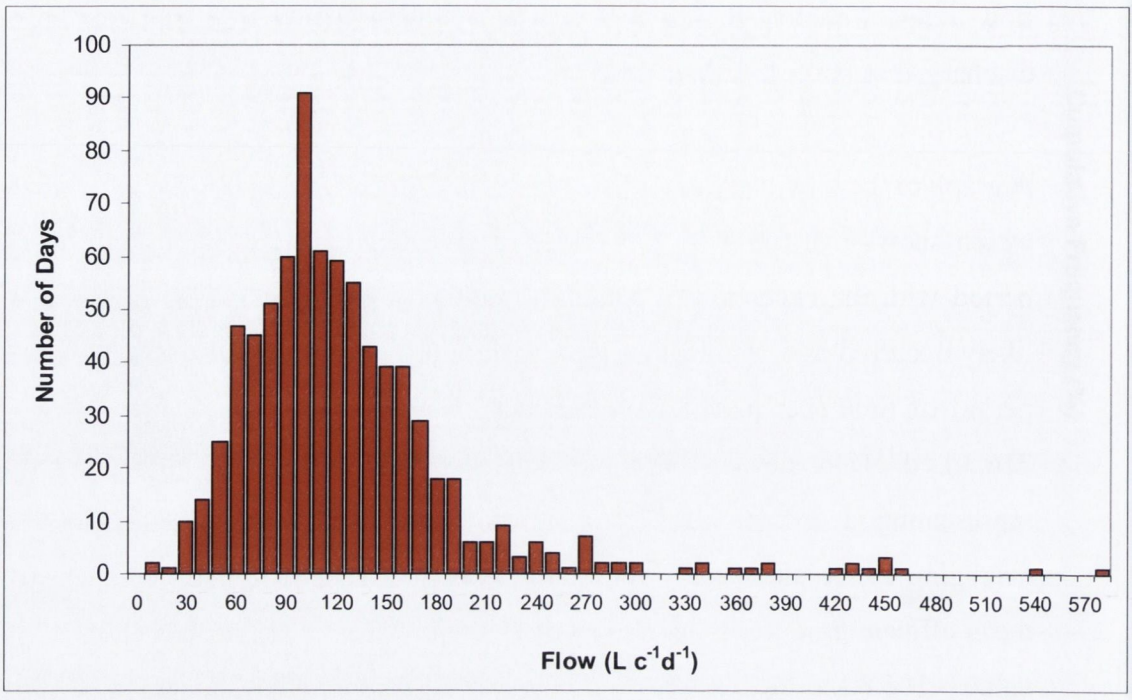


Figure 6.3 Frequency distribution of daily effluent production per capita on Site A

However, design of the percolation area must account for the maximum projected hydraulic load and there were occasional days (10.7% of the monitoring period) when the wastewater flow rates matched or exceeded 180 L c^{-1} d^{-1}. On the other hand, one suspects that the living arrangements of the family may not be representative of the decentralised population given the regularity with which the husband worked in the house and the employment of a part-time housekeeper. In the current climate it is not unusual for both of a cohabiting couple to work outside the home. In view of this, it is possible that these measured flows are greater than average.

Further statistics reveal that the mean split of the total on-site effluent discharging to the trenches and to the reed bed was 54% to 46%, respectively, over the course of the trial period. With regard to hydraulic retention times in the septic tank, daily figures, as calculated by dividing the daily flows by the tank volume, are plotted in Figure 6.4. The large variation in data as illustrated by a significant number of spikes in the plot is corroborated by the long tail on the normal distribution curve (Figure 6.5). The mean HRT from this data of 7.0 days is somewhat affected by intermittent daily low flows which act to skew the data. An alternative approach is to ascertain the mean HRT by dividing the mean daily flow over the duration of the monitoring by the tank volume (5.3 days). Given the drawbacks of both mean calculations, it was thought the most

representative value to be used for further calculations be the median of the daily HRTs, which yields a figure of 5.9 days.

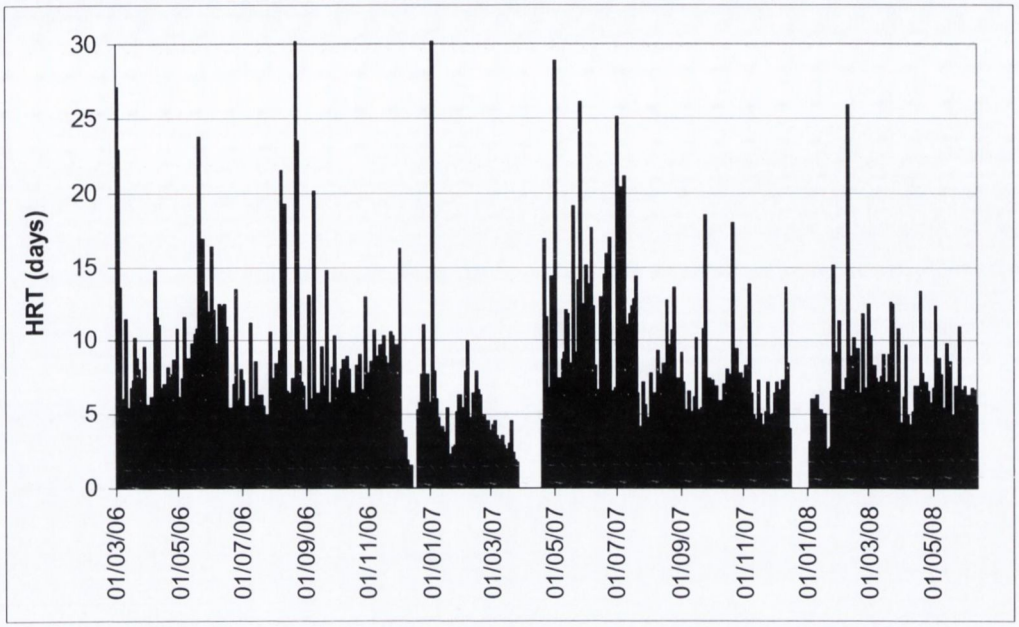


Figure 6.4 Daily nominal hydraulic retention times for septic tank on Site A

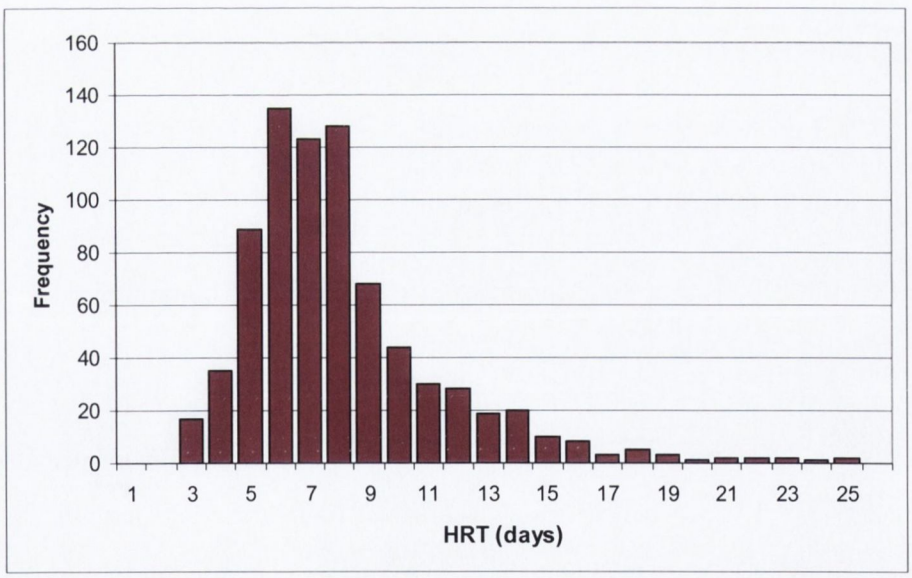


Figure 6.5 Frequency distribution of hydraulic retention times for septic tank on Site A

In order to confirm the success of the roof and driveway runoff diversion work that was initially carried out prior to sampling, a graph of correlation between daily rainfall and flows on Site A (Figure 6.6) was plotted. In showing no particular correlation it is clear that the wastewater treatment system is treating only the quantity and quality of household wastewater, as desired and specified in EPA regulations (EPA, 2000).

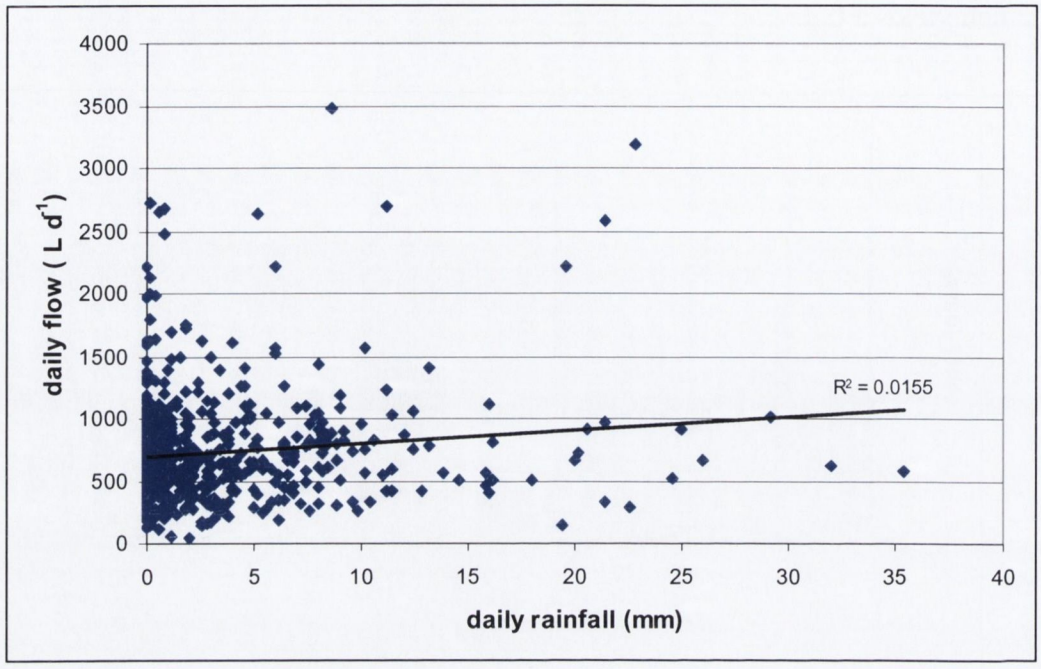


Figure 6.6 Correlation of daily rainfall and on-site effluent flows at Site A

6.2.2 Pollutant Loading

Chemical and Bacteriological Analysis

Appendix D contains the results of both the chemical and bacteriological analysis carried out on all samples taken from Site A. Table 6.1 summarises the set of chemical results relating to the STE in terms of concentrations and loading rates while Table 6.2 presents the STE's bacteriological results. The coefficient of variation (CV), also known as the relative standard deviation (RSD), is a normalised measure of dispersion of a probability distribution and is useful for comparing datasets with hugely different mean values (Mac Berthouex and Brown, 2002). In all cases, the dispersion in the distribution for each of the STE's constituents has resulted in the CV to be consistently less than 1, indicating low variance throughout.

Table 6.1 Summary of chemical and TSS analysis of STE on Site A

Pollutant	n	Range ($mg\ L^{-1}$)	Mean Concentration (±sd)	CV	Mean Load [a] ($g\ d^{-1}$)
COD	20	278 – 941	**547** (±186)	0.34	**391**
BOD_5	4	108.8 – 260	**185** (±62)	0.33	**132**
NH_4-N	22	10.5 – 112	**75.0** (±25)	0.33	**53.7**
NO_2-N	18	0.08 – 0.43	**0.22** (±0.09)	0.40	**0.16**
NO_3-N	23	0.2 – 2.4	**0.8** (±0.6)	0.77	**0.8**
TN	18	51.7 – 148	**107** (±26)	0.24	**76.7**
PO_4-P	20	5.5 – 37.4	**16.6** (±10.8)	0.65	**11.9**
Cl	20	50 – 960	**366** (±297)	0.81	**262**
TSS	7	84 – 377	**155** (±101)	0.66	**111**

[a] based on mean total daily flow of 716.3 L day^{-1}; n = number of samples; sd = standard deviation; CV = coefficient of variation;

Table 6.2 Summary of bacteriological analysis of STE on Site A

Pollutant	N	Range ($MPN\ 100mL^{-1}$)	Geometric Mean ($MPN\ 100mL^{-1}$)	CV [a]
Total Coliforms	20	$6.84 \times 10^5 – 5.17 \times 10^8$	1.28×10^7	0.11
E. coli	19	$4.45 \times 10^4 – 3.55 \times 10^7$	7.44×10^5	0.14

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

While concentrations of organics in the form of COD are slightly above typical influent concentrations outlined in EPA (2000), summarized in Table 6.3, nitrogen levels in the form of NH_4-N are particularly high. CEN 12566 is a seven-part series of European standards on small wastewater treatment systems being prepared by the European Standards Committee (CEN 2005a, b, c). PrEN 12566: Part 6 (CEN, 2005c), specifies the influent characteristics required for testing prefabricated secondary treatment units receiving STE. Hence, this specified influent range (shown below in Table 6.4) may be compared with the project's STE data. Immediate observations indicate that the measured STE quality is on the high side (i.e. highly concentrated) in terms of organics

and nutrients and in the case of TKN and PO_4-P just above the range of effluent quality required by CEN 12566. A mean BOD_5:COD ratio of 1:3 was determined over the length of the monitoring period, which is less than EPA (2000) estimates but falls within STE quality required by CEN 12566.

Table 6.3 Characteristics of domestic wastewater from a single house (EPA, 2000)

Parameter	Mean Concentration (mg L^{-1})
COD (mg L^{-1})	400
BOD_5 (mg L^{-1})	300
Total Solids (mg L^{-1})	200
Total N (mg L^{-1})	50
Total P (mg L^{-1})	10
Total Coliforms (MPN 100mL^{-1})	$10^7 - 10^8$

Table 6.4 Influent quality required by CEN 12566 for secondary treatment plant tests

Parameter	Range in Concentration (mg L^{-1})
COD	200 – 700
BOD_5	100 – 350
SS	40 – 200
NH_4-N	22 – 80
TKN	25 – 100
Total-P	4 – 20
PO_4-P	2 – 15

Variations in COD concentration over the monitoring period ranged between a low of 278 mg L^{-1} recorded on 2/02/07 and a high of 941 mg L^{-1} on 19/04/07. There was little corresponding change in the daily routine, in terms of water usage, on these two dates. A high total daily flow of 1 993.7 L d^{-1} on the sampling date 23/01/07 may suggest partial dilution being responsible for the lower than average COD concentration measured (412 mg L^{-1}) on that date. However, analysis of effluent flow rate versus STE quality shows a very poor negative correlation between the flows and concentrations of COD (Spearman r = -0.2; p = 0.387), NH_4-N (Spearman r = -0.1; p = 0.668) and PO_4-P

(Spearman r = -0.24; p = 0.319), respectively. This was the case when both the measured flow on the day of sampling and the mean of the daily flows across the calculated nominal hydraulic retention time for each individual sample were adopted in the analysis. Seasonal air temperatures show a similar transient trend to concentrations over the monitoring period. This pattern for COD, shown in Figure 6.7, suggests that, in the main, during the months where cooler temperatures were experienced, COD concentrations dipped whereas an increase in levels was recorded during the warmer summer months. This may be attributed to the increased biological degradation of soluble organics in the tank's anaerobic environment under warmer temperatures, resulting in elevated COD levels being leached out in the STE.

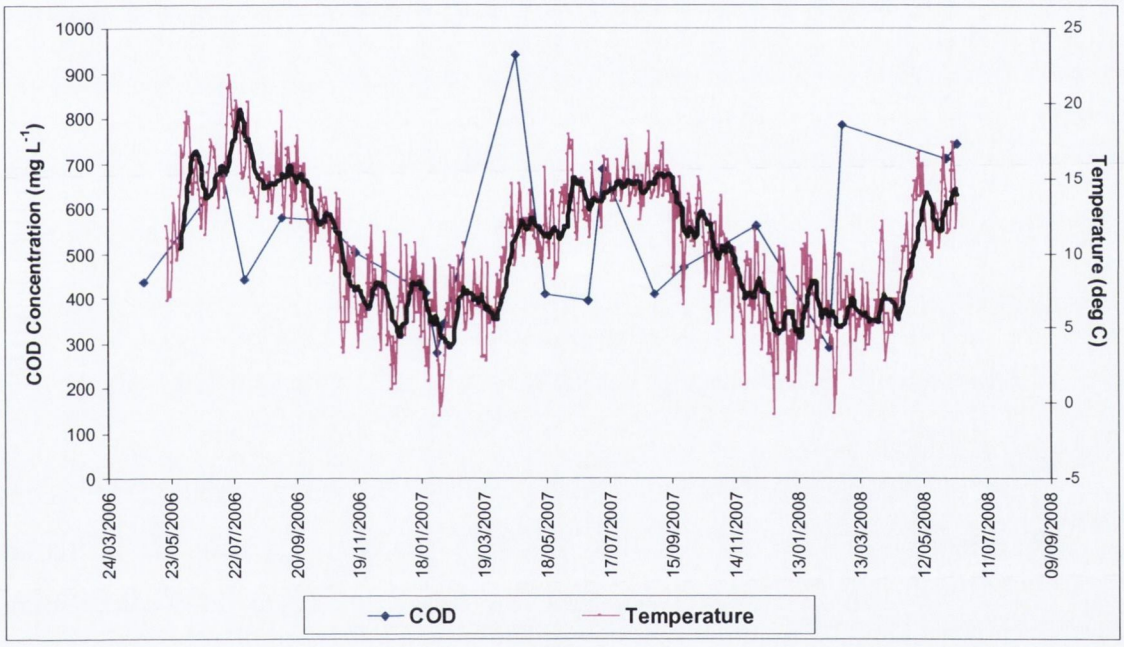


Figure 6.7 Time series comparison of COD concentrations from the STE and mean daily air temperatures (with 2 week moving average trend line) on Site A

Retention times for each septic tank sample date were calculated by back-cumulating recorded daily outflows from 12 midday on each sampling date (approximate time of sample extraction) until the volume of the tank was reached. Comparison of the effluent COD concentrations on particular sampling dates with their corresponding nominal HRTs in the septic tank, which ranged from 2.0 to 11.4 days, showed a very weak relationship (Figure 6.8). One may have assumed a much greater negative correlation in this case based on the supposition that effluent COD concentrations should decrease if

the decomposing solids in the tank are solubilising at a more or less constant rate. However, the absence of raw input data for quantifying the removal efficiency together with the highly variable composition of raw domestic sewage and its sporadic discharges to the septic tank questions the validity of such a comparison. On the other hand maybe this lack of correlation indicates that the COD removal from solubilisation is relatively insignificant to the actual COD concentration in the effluent (i.e. most of the COD is passing straight through the tank without significant breakdown).

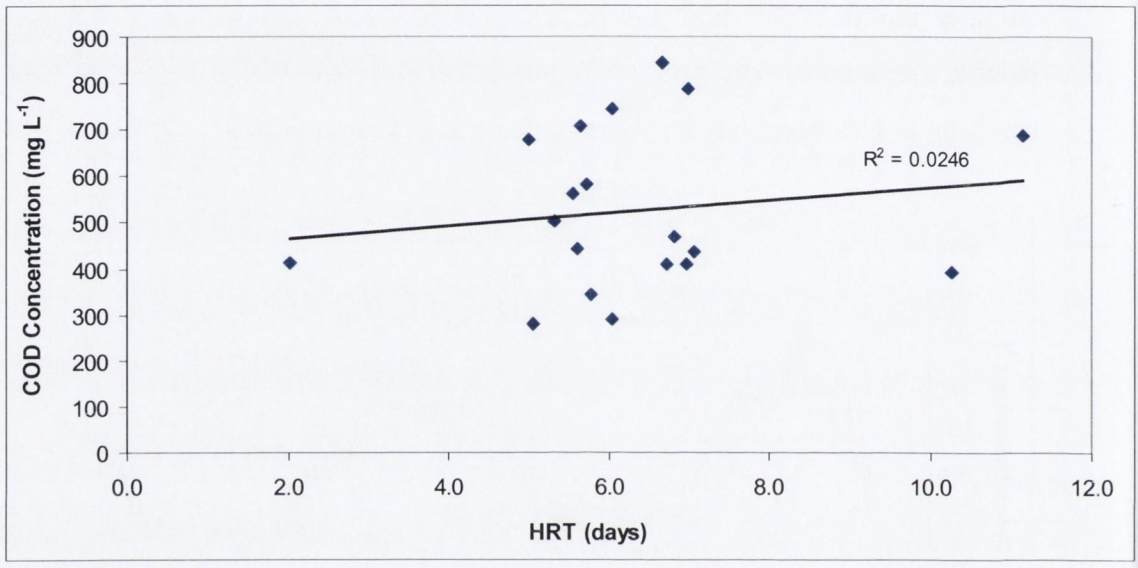


Figure 6.8 Septic tank effluent COD (mg L^{-1}) quality versus HRT (days)

As expected, the anaerobic environment of the septic tank has facilitated the conversion of the majority of organic nitrogen (org-N), in the form of protein-rich matter and urea, to its inorganic ammonium (NH_4-N) form. This is largely due to decomposition of the wastewater's soluble organic matter (containing nutrients) by facultative and obligate anaerobic heterotrophs. As inorganic nitrogen is more likely to exist in its reduced (NH_4-N) or oxidised (NO_3-N) form in the subsoil, NO_2-N concentrations were measured to enable calculation of total inorganic nitrogen according to Eqn. 5.4. The measurement of Total Nitrogen (TN) was carried out to enable calculation of Total Kjeldahl Nitrogen (TKN) according to Eqn 5.6, and thus ascertain the fraction of nitrogen in the STE in its organic form.

With a high level of ammonification occurring in the septic tank and negligible NO_3-N and NO_2-N concentrations, NH_4-N accounted for over 98% of the total inorganic N in the effluent. As a result, mean TKN and TN values were very similar with the former

fractionally lower at 106.1 mg L^{-1} (Table 5.5). The NH_4-N : TKN ratio, used to determine the fraction of organic and inorganic nitrogen in the discharging effluent, was found to be 0.71 (i.e. org-N formed 29% of the STE total-N). This compares favorably with literature findings where it is suggested between 70 to 85% of N in STE is in its inorganic form (Kirkland, 2001).

Table 6.5 Breakdown in nitrogen in the STE on Site A

Parameter	Mean Concentration (mg L^{-1})	Ratio
Total Inorganic-N	76.1	-
Total Organic-N	31.1	-
Total Kjeldahl Nitrogen (TKN)	106.1	-
NH_4:TKN	-	0.71

A similar trend with daily air temperatures was also witnessed for NH_4-N and PO_4-P with increased constituent concentrations in the effluent during warmer periods of the monitoring (Figures 6.9 and 6.10). The NH_4-N values of 0.11 mg L^{-1} and 0.1 mg L^{-1} measured on the first two sampling dates of 10/04/06 and 27/04/06 respectively were deemed egregious and omitted from further calculations. This assumption is based on the fact that corresponding NO_3-N and NO_2-N concentrations were low, as expected, ruling out the possibility that potential nitrification may have occurred. It is possible that these rogue NH_4-N values arose due to analytical error at the outset of the testing regime due to accidental failure in calibrating the spectrophotometer.

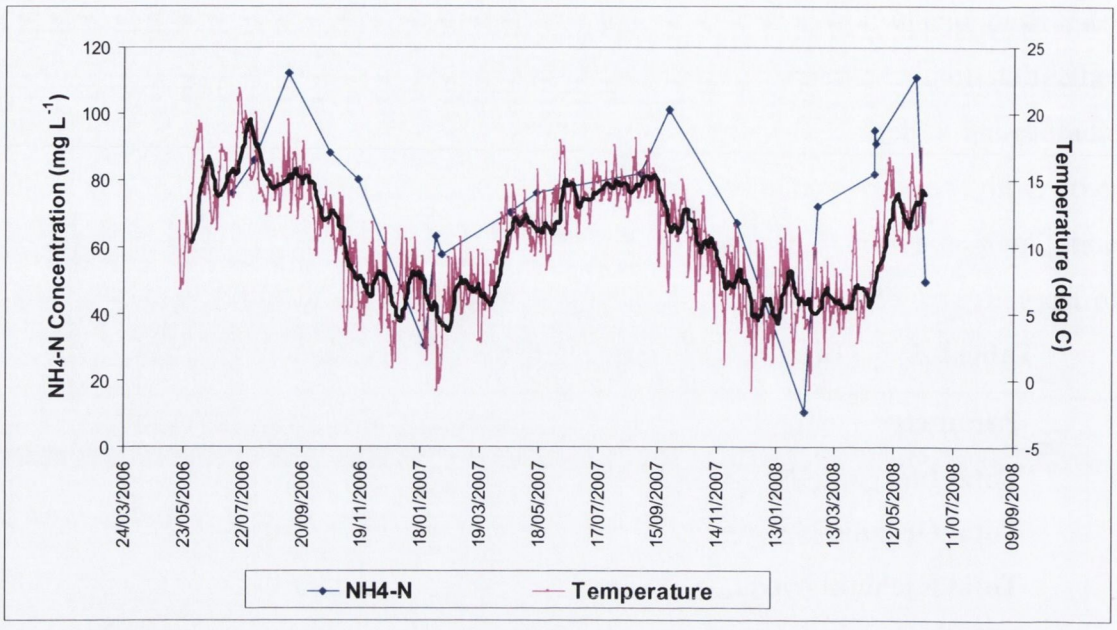


Figure 6.9 Time series comparison of NH_4-N concentrations from the STE and mean daily air temperatures (with 2 week moving average trend line) on Site A

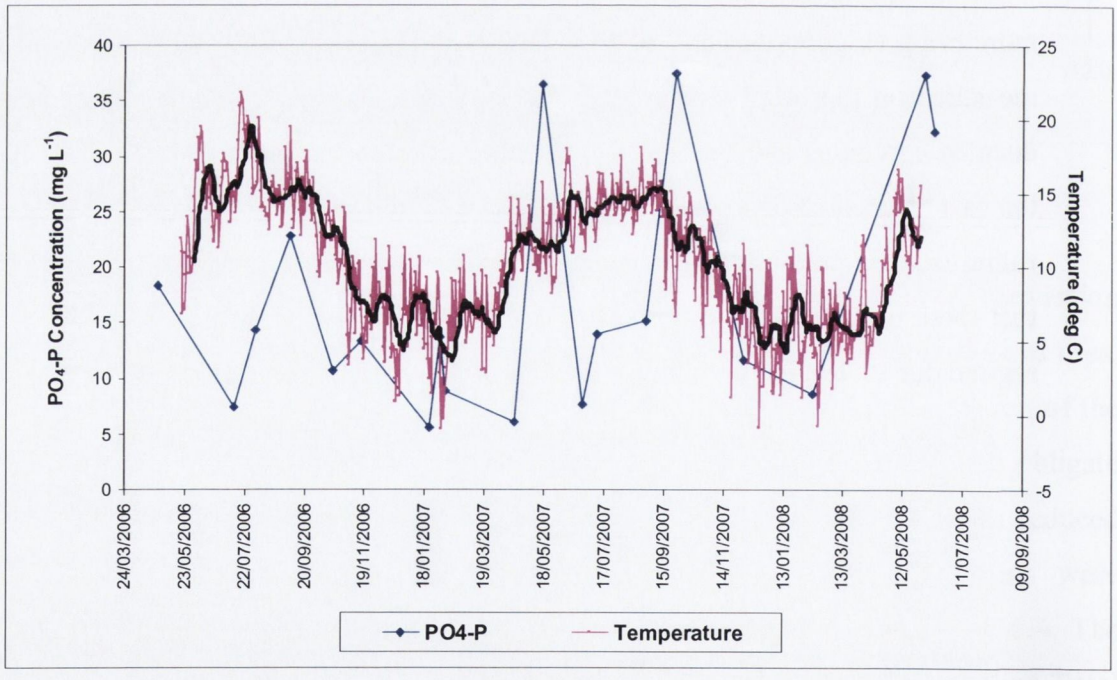


Figure 6.10 Time series comparison of PO_4-P concentrations from the STE and mean daily temperatures (with 2 week moving average trend line) on Site A

A mean TSS concentration of 155 mg L^{-1} in the STE compares favourably with similar research carried out in Ireland on two sites by Henry (1990) who recorded suspended solids concentrations at 160 and 198 mg L^{-1}, respectively. This figure almost doubles the

suggested 80 mg L^{-1} suspended solids reported by other sources (Patterson *et al.*, 1971; Goldstein and Wenk, 1972; EPA, 2000).

To assess the bacteriological quality of the domestic wastewater from the proprietary treatment systems, two indicator organism species, total coliforms (TC) and *E. coli*, were chosen for analysis. While TC bacteria are indicator organisms of faecal contamination and possible presence of pathogens, it is widely accepted that the group is diverse and that some genera also exist as indigenous inhabitants in water and soil (growing and reproducing on organic matter), which have not been impacted by faecal pollution (Viessmann & Hammer, 1993; Stevens *et al.*, 2003). As such, despite its continued widespread use as a bacterial indicator, doubts persist surrounding the suitability and accuracy level of TC in representing faecal contamination. However, given that *E. coli* has been found to make up over 90% of TC in human faeces (Dufour, 1977) it provides a useful guide in assessing the bacteriological quality of domestic wastewater and thus results are included in the analysis.

Removal of bacterial pathogens in a septic tank is known to be limiting given its intrinsic function as a sedimentation unit for solids removal. Total coliform and *E. coli* counts were found at consistently high levels in the STE (Figure 6.11). The geometric mean values measured for total coliforms (1.28×10^7 MPN $100mL^{-1}$) and *E. coli* (7.44×10^5 MPN $100mL^{-1}$) are very much in line with literature findings with a number of sources reporting mean population densities in the STE of between 10^6 and 10^8 MPN 100 mL^{-1} for total coliforms and between 10^5 and 10^7 MPN $100mL^{-1}$ for faecal coliforms (Ziebell *et al.*, 1974; Scherer and Mitchell, 1982; Canter and Knox, 1985; EPA, 2000). The resultant effluent therefore contains high levels of bacterial contamination and requires subsequent purification prior to safe groundwater discharge. Like COD, a linear correlation plot of *E. coli* levels against nHRTs shows very little apparent influence of the latter on the kinetics.

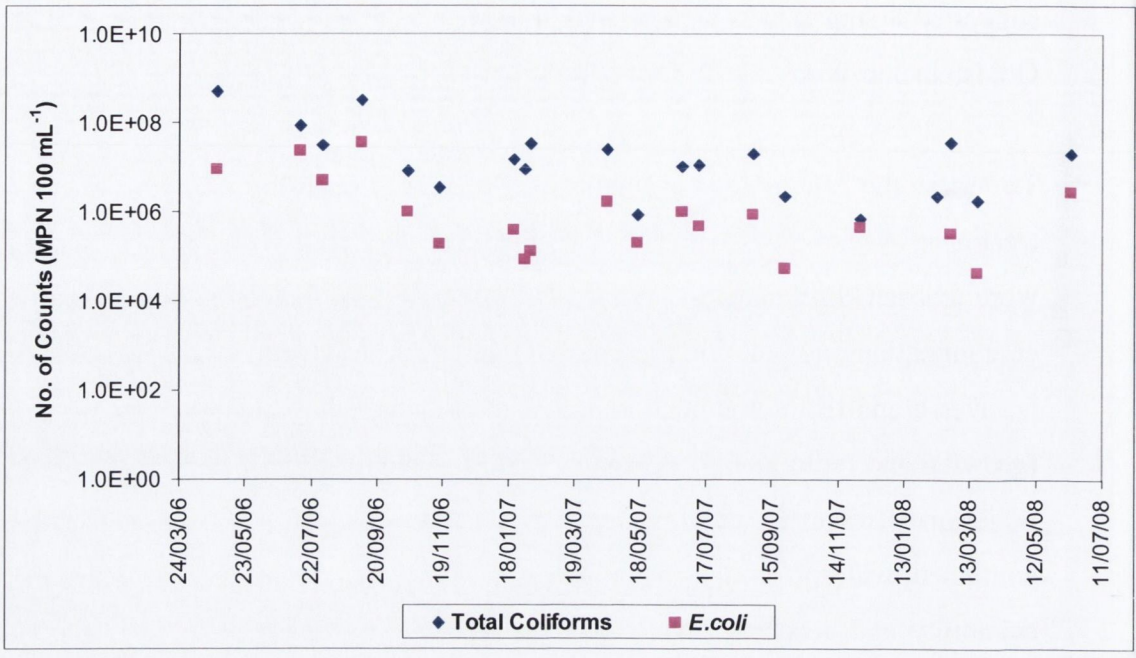


Figure 6.11 Time series plot of bacteriological constituents in STE on Site A

Volatile Fatty Acids (VFAs)

The production of VFAs was analysed under the prevailing anaerobic conditions in the septic tank on two separate dates and summarized in Table 6.6. Acetic acid was the dominant VFA detected on both sampling dates, accounting for, on average, 85% of the total VFAs in the STE. This could be a by-product of the metabolic activity of acidogenic bacteria in the anaerobic processes but also of the non-methanogenic sulphate reducing bacteria (SRBs) (e.g. *Desulfovibrio desulfuricans*). Other VFAs detected include isobutyric, propionic, isovaleric, methyl valeric and hexanoic acid. Narkis *et al.* (1980) reported a similar spectrum of volatile organic acids for raw wastewater. On average, the VFAs form 15% to 17% of the COD concentration.

Previous studies on anaerobic reactors (Carlsson *et al.*, 1996) have shown a linear relationship between VFA concentrations and phosphorus release and so the VFA concentrations in the effluent can be compared against the mean phosphate concentration in the STE of 16.6 mg L^{-1}. Several more VFA samples would be needed, however, in order to study this relationship but the data does provide an interesting baseline.

Table 6.6 Summary of VFA results from STE on Site A

Parameter	Date	
	30/08/2007	**03/06/2008**
COD (mg L^{-1})	735	710
BOD (mg L^{-1})	260	183
Ethanol (ppm)	<0.1	<0.1
Propanol (ppm)	<0.1	<0.1
Acetic Acid (ppm)	92.71	107.08
Propionic Acid (ppm)	8.46	<0.1
Isobutyric Acid (ppm)	2.26	3.95
n Butyric Acid (ppm)	<0.1	<0.1
Isovaleric Acid (ppm)	2.95	4.96
n Valeric Acid (ppm)	<0.1	<0.1
INT-4 methyl Valeric Acid (ppm)	1.00	-
Hexanoic Acid (ppm)	1.97	2.93
Heptanoic Acid (ppm)	<0.1	5.44

6.3 Site B – Analysis of Biodisc® RBC Effluent

6.3.1 Hydraulic Loading

A graph of the total daily on-site flow rates leaving the *Biodisc®* system and measured at the distribution box on Site B is presented in Figure 6.12. As on Site A, the trend shows the daily flow rates to have remained relatively constant over the monitoring period with a mean value of 268.8 L d^{-1} [Std. dev. = 159.2]. This equates to a mean effluent production per person of 89.6 L c^{-1} d^{-1} [median value = 82.3 L c^{-1} d^{-1}] as shown in Figure 6.13. With only 4.3% of the recorded flows found to match or exceed the design daily hydraulic loading of 180 L c^{-1} d^{-1} it is clear that for the vast majority of flows the percolation area has been over-designed hydraulically.

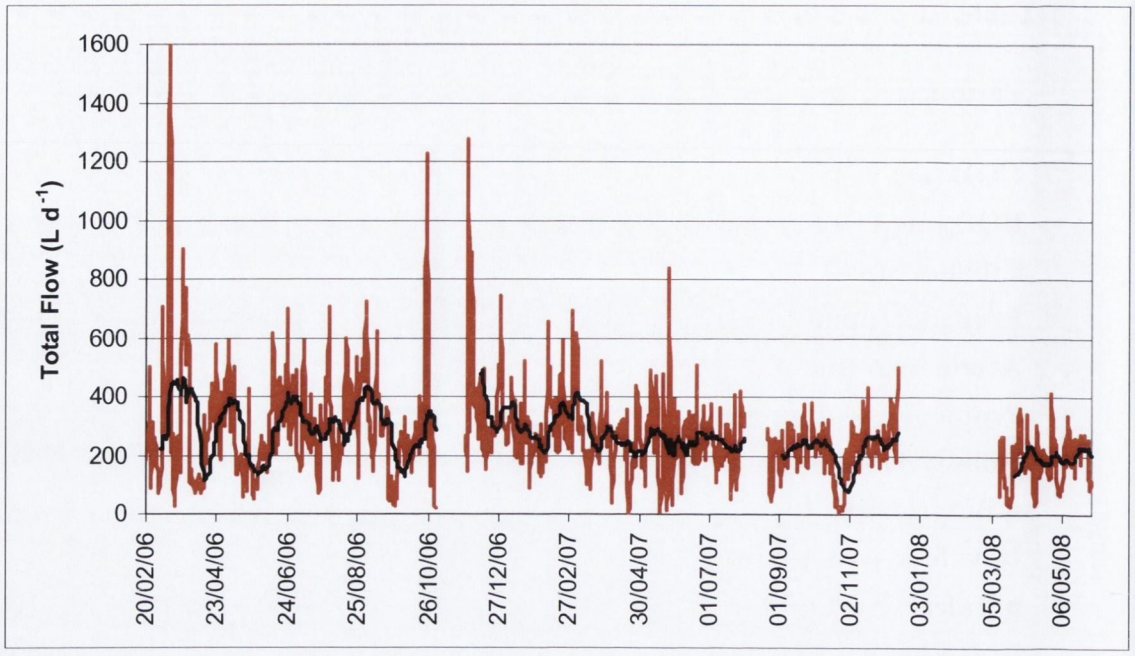


Figure 6.12 Daily flows to Site B (with 2 week moving average trend line)

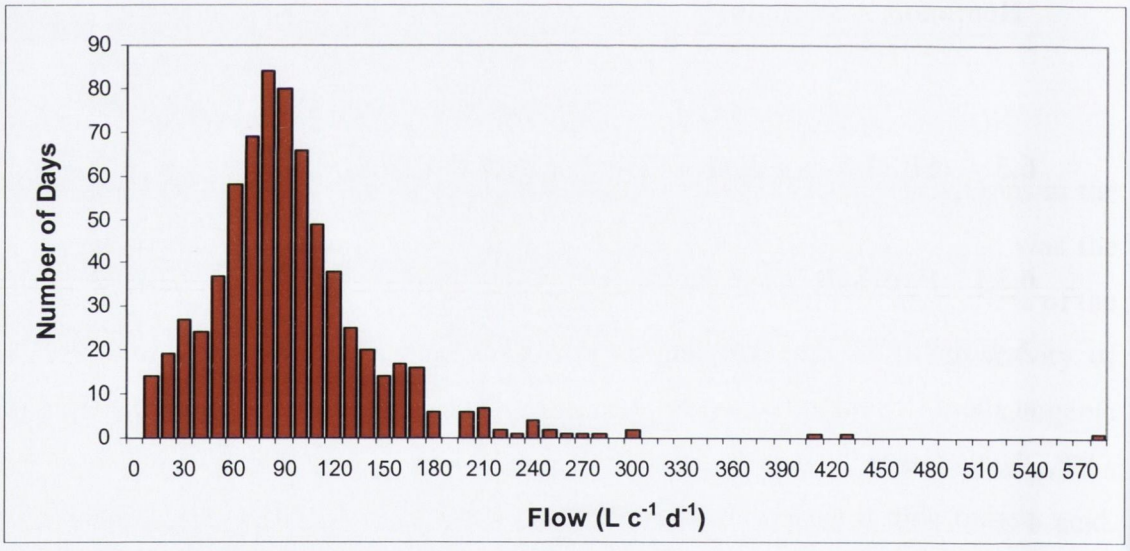


Figure 6.13 Frequency distribution of daily effluent production per capita on Site B

The most common flow rates leaving the *Biodisc*® at Site B (>91% of the time) were between 0.1 – 0.5 L min^{-1} (mean = 0.3 L min^{-1}) (Figure 6.14 (a)). The flow characteristics from the secondary treatment package showed a much more constrained range of flows compared to the septic tank on Site A, due to the hydraulic regulation of effluent in the *Biodisc*® unit whereby it is transferred from the primary zone to the secondary zone upon every revolution of the media via a small container. Figure 6.14 (b) shows that 77% of the effluent volume was discharged at flows less than 0.5 L min

[1]. The mean split of the total on-site effluent discharging to the trenches and to the reed bed was 48 % to 52% respectively over the course of the trial period.

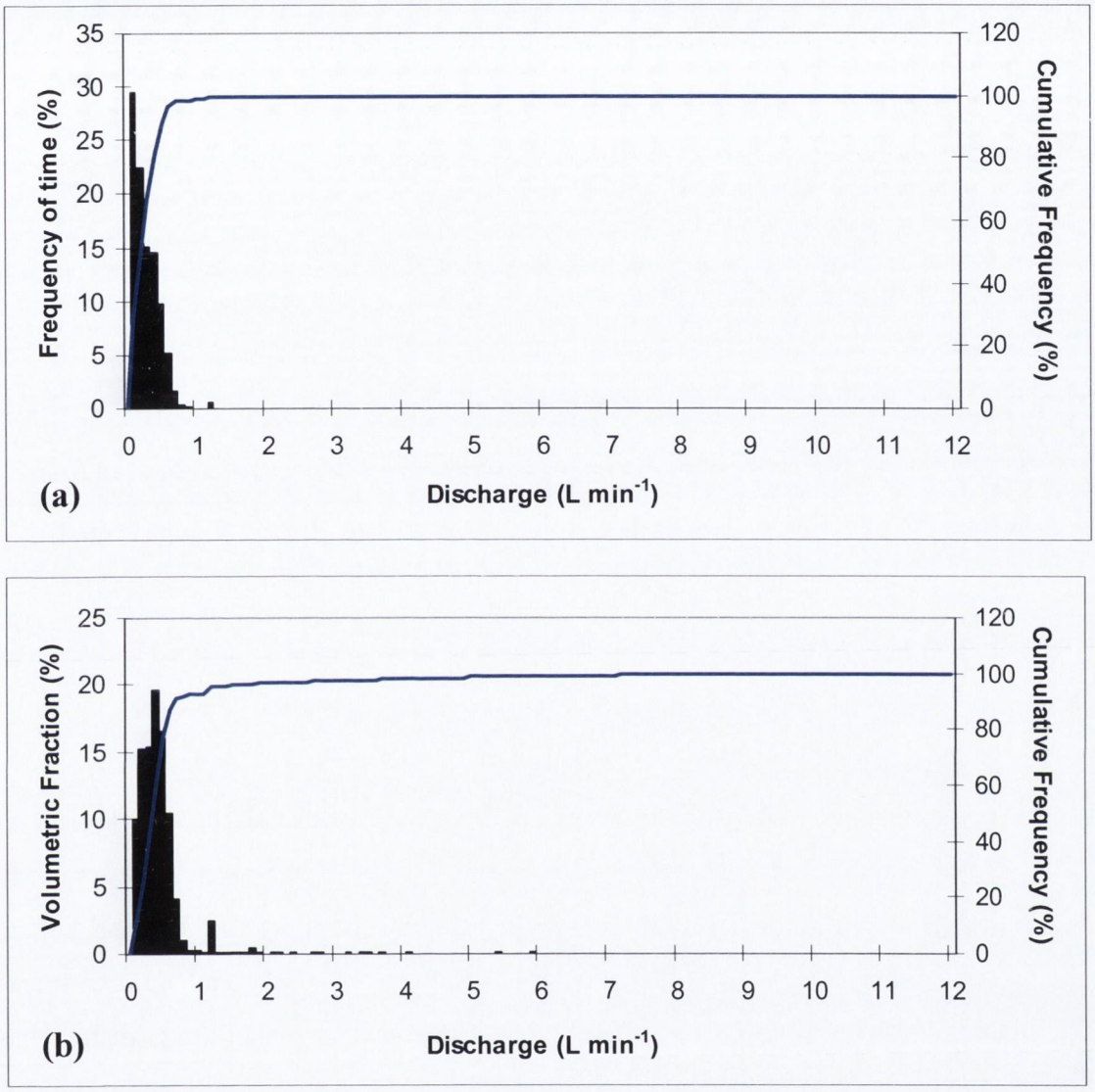


Figure 6.14 Flow distribution at Site B; **(a)** frequency of time, **(b)** volumetric fraction

As discussed previously, all rainwater, surface water and runoff associated drainage had been diverted on the site prior to monitoring in accordance with regulations (EPA, 2000). Again, a graph of correlation between daily rainfall and flows on Site B (Figure 6.15) does not show a significant correlation between the two which confirms the success of the roof diversion work carried out.

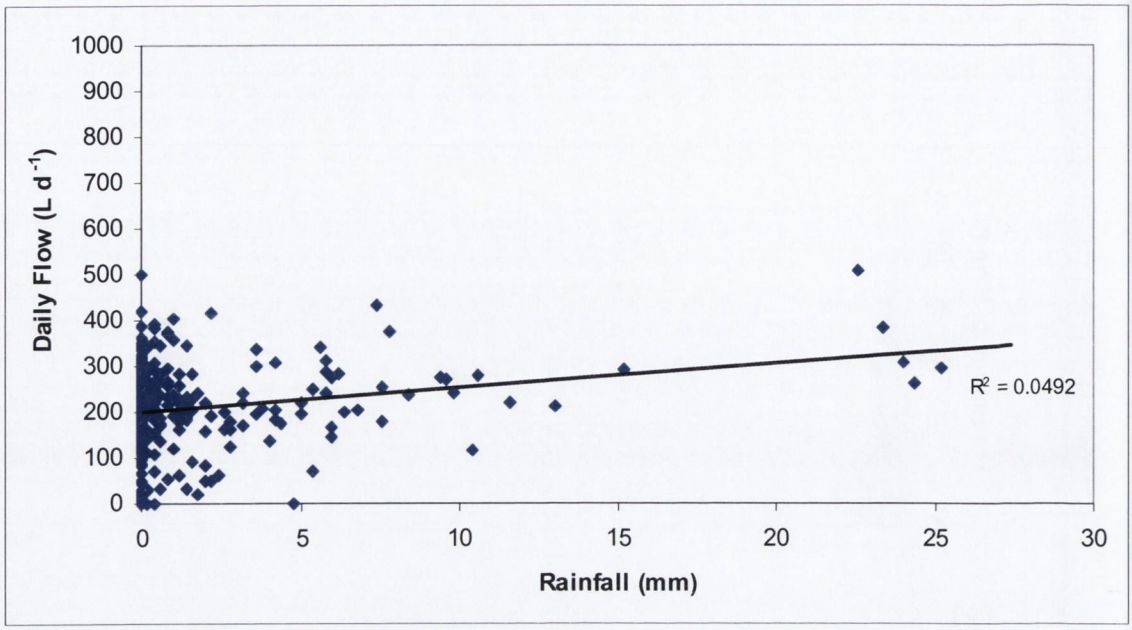


Figure 6.15 Correlation of daily rainfall and on-site effluent flows at Site B

5.3.2 Pollutant Loading

Chemical and Bacteriological Monitoring

Appendix D contains the results of both the chemical and bacteriological analysis carried out on all samples taken from Site B. Table 6.7 summarises the set of chemical results relating to the SE from the *Biodisc*® in terms of concentrations and loading rates while Table 6.8 presents the coliform results from the packaged treatment plant. Dissemination of the data indicates that degradation of organic matter has been achieved, mainly through physical, chemical and biological processes by the consistent presence of aerobic and facultative bacteria on the rotating biological contactor disks. Nitrogen data from Table 6.7 indicates partial nitrification to have occurred in the *Biodisc*® owing to the presence of nitrifying bacteria which can gain a niche in the system's second aerobic biozone where the organic loading is reduced. This is demonstrated by elevated NO_2 and NO_3 levels in the SE. High PO_4-P levels are also in line with typical secondary effluent quality.

Table 6.7 Summary of chemical and TSS analysis of SE on Site B

Pollutant	n	Range ($mg\ L^{-1}$)	Mean Concentration (±sd) ($mg\ L^{-1}$)	CV	Mean Load [a] ($g\ d^{-1}$)
COD	23	52 – 375	**199** (±85)	0.43	53
BOD_5	3	74 – 162	**101** (±53)	0.53	27
NH_4-N	23	2.22 – 88	**19.4** (±21)	1.06	5.2
NO_2-N	22	0.16 – 62	**13.9** (±23.1)	1.66	3.7
NO_3-N	23	1.2 – 93.5	**35.7** (±28.1)	0.79	9.6
TN	15	45.7 – 261	**96** (±53)	0.54	26
PO_4-P	23	9.94 – 45.4	**26.4** (±9.3)	0.35	7.1
Cl	21	45 – 180	**120** (±33)	0.27	32
TSS	8	19.5 – 88.8	**44.9** (±21)	0.47	12.1

[a] based on mean total daily flow of 268.8 L d^{-1}

Table 6.8 Summary of bacteriological analysis of SE on Site B

Parameter	n	Range (MPN $100mL^{-1}$)	Geometric Mean (MPN $100mL^{-1}$)	CV
Total Coliforms	15	$2.78 \times 10^4 – 1.12 \times 10^6$	2.88×10^5	0.10
E. coli	15	$9.10 \times 10^2 – 5.20 \times 10^5$	1.33×10^4	0.17

Further inspection of the nitrogen data was carried out given the large range of values recorded for its three inorganic constituents in Table 6.7. On those dates when TN was measured, org-N is found to comprise 23% of the TN discharging load, which although less than that recorded in the STE on Site A, would have been expected to be significantly lower. High CV values were also noted for NH_4-N and NO_2-N, exceeding a value of 1 (indicating high variance). A greater level of nitrification would normally have been expected in such a packaged treatment plant. The partial nitrification observed may be due to the high organic concentrations that are recorded in the effluent. This would indicate the presence of heterotrophic bacteria in the first stage biozone acting in competition with and hindering the work of the autotrophic nitrifying bacteria. A time series plot of NH_4-N, NO_2-N and NO_3-N (Figure 6.16) highlights the

sudden variability of the data between November 2006 and May 2007 and again in May/June 2008. Oxidation of NH_4-N to NO_2-N by the *Nitrosomonas* is prevalent accompanied by a sharp reduction in NO_3-N concentrations. With an obvious deficiency in *Nitrobacter* population during this period only partial nitrification is possible. The aforementioned build-up of humus solids on the surface of the final settlement tank around these dates has most likely hindered continuous aeration of the discharging effluent and as such has compromised the potential for a greater level of nitrification to occur.

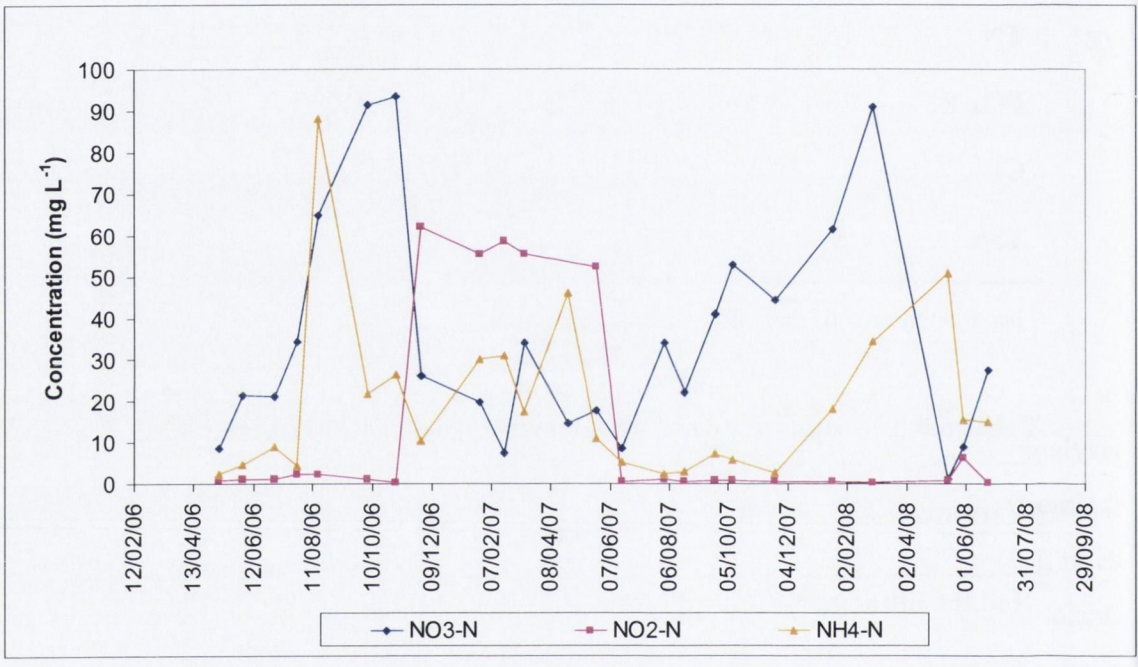


Figure 6.16 Time series plot of nitrogen concentrations from the SE on Site B

Apart from this period between November 2006 and May 2007 results show much greater levels of nitrification and lower levels of variance in the distribution. Table 6.9 shows these effects with NH_4-N, NO_2-N and NO_3-N data from 28/11/06, 26/01/06, 21/02/07, 13/03/07, 26/04/07, 24/05/07, 14/05/08 and 30/05/08 omitted from the calculations.

Table 6.9 Summary of the nitrogen results from the SE during periods of unhindered nitrification

Pollutant	n	Range ($mg\ L^{-1}$)	Mean Concentration (±sd) ($mg\ L^{-1}$)	CV	Mean Load ($g\ d^{-1}$)
NH_4-N	15	2.22 – 88	**15.6** (±21)	1.43	4.2
NO_2-N	15	0.16 – 2.34	**0.99** (±0.62)	0.63	0.27
NO_3-N	15	8.5 – 93.5	**46.0** (±29.1)	0.63	12.4

The large CV value for NH_4-N can be explained by the high concentration of TN recorded on 16/08/06. At a measurement of 261 TN mg L^{-1}, it is almost double the next largest TN concentration recorded throughout the monitoring period. The sample's corresponding NH_4-N concentration (88 NH_4-N mg L^{-1}) is over five times its mean value calculated over the length of the sampling. Accompanied by increased COD and PO_4-P concentrations on this date, the reason for such elevated organic and nutrient levels may be due to some change in the daily routine in the household. Upon closer inspection of the flows it appears no reduced loading occurred in the days preceding the sampling event. It is possible that due to warmer temperatures occurring at the time, sludge digestion may have increased in the *Biodisc*®. This creates an increased likelihood of sludge lifting in the final clarifier (and additional solids being discharged with the effluent) due to denitrification causing nitrogen bubbles to attach to the flocs.

Analysis of PO_4-P concentrations with time show little variance apart from an isolated high value measured on 3/11/06 which was deemed egregious, most likely due to analytical error in the laboratory, and consequently omitted from all calculations (Figure 6.17).

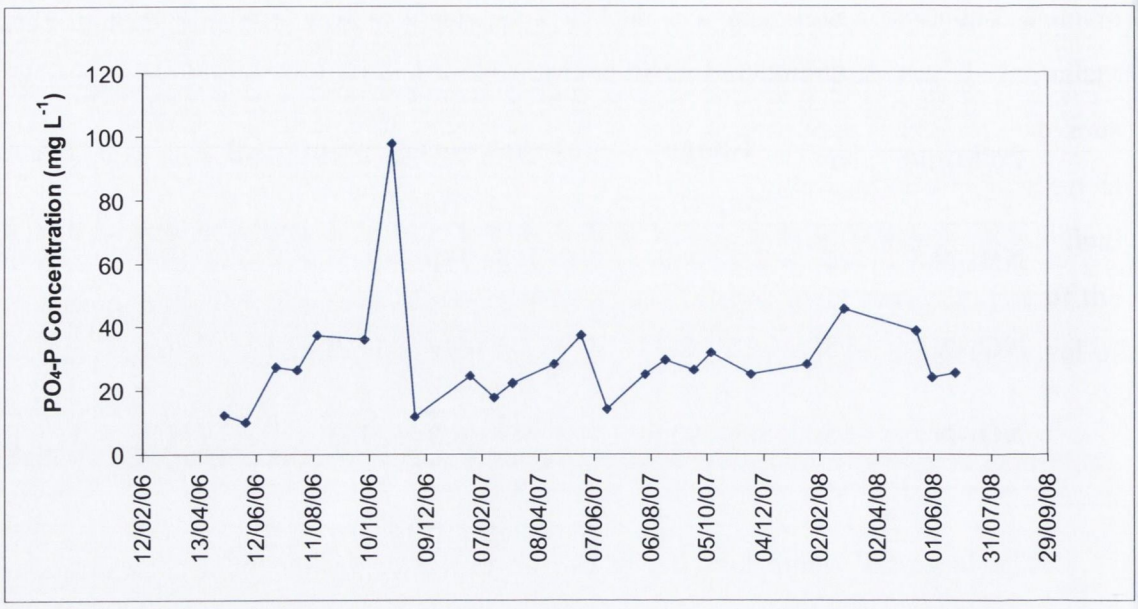


Figure 6.17 Time series plot of PO_4-P concentrations from the SE on Site B

Total coliforms and *E. coli* were detected at consistently high levels in the SE with mean values of 2.88 x 10^5 and 1.33 x 10^4 MPN 100 mL^{-1}, respectively, as shown on Figure 6.18. These values are 1.5 to 2 orders of magnitude less than the equivalent concentrations measured in the STE on Site A, but still constitute a significant risk of contamination to water resources and thus further treatment for bacterial breakdown is essential prior to groundwater discharge.

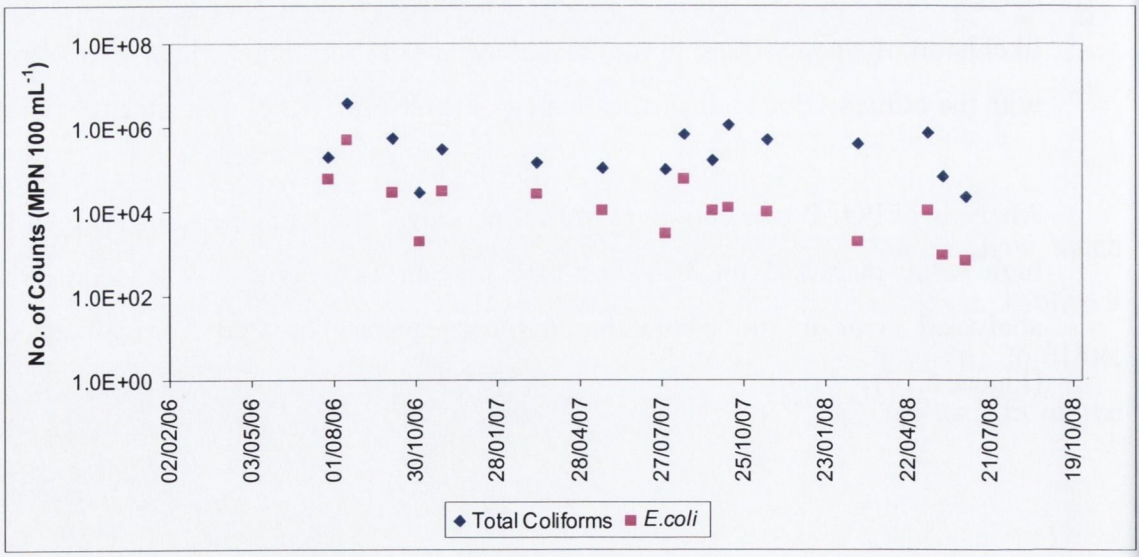


Figure 6.18 Time series plot of bacteriological constituents in the SE on Site B

7. ANALYSIS OF RESULTS FROM SUBSOIL TREATMENT SYSTEMS

7.1 Introduction

A detailed characterisation of the purification performance of freely draining unsaturated subsoil treatment from each of the three systems I, II and III (see Section 5.2) in terms of chemical, bacteriological and viral parameters, is carried out and presented. The 32-month operational period of the on-site systems provides valuable insight concerning the early performance of the vadose zone at three chosen depths in treating effluents of differing quality, while also assessing the impact of soil clogging and biozone development during effluent infiltration and percolation. The effluents generated by the septic tank, horizontal SSF reed bed and *Biodisc*® achieved different treatment efficiencies for organic matter, solids, nutrients and bacteria and so examination of the physical, chemical and biological processes affecting each in the coarse-textured subsoil is detailed.

7.2 Analysis of Flow Data

System I – Percolation Trenches Receiving STE (Site A)

While Section 6.2.1 has previously described the flow regime and characteristics from the total STE flow, it was also necessary that, given Site A was effectively divided into two systems at this point, the mean flow split to each subsequent unit treatment process (horizontal SSF reed bed and percolation trenches) was calculated. Figure 7.1 presents a graph of the daily on-site flow rates to the three percolation trenches receiving STE (System I) which represents, in effect, a 3-person hydraulic load. The mean daily flow rate over the trial period was found to be 395.4 L d^{-1} [Std. dev. = 250.3].

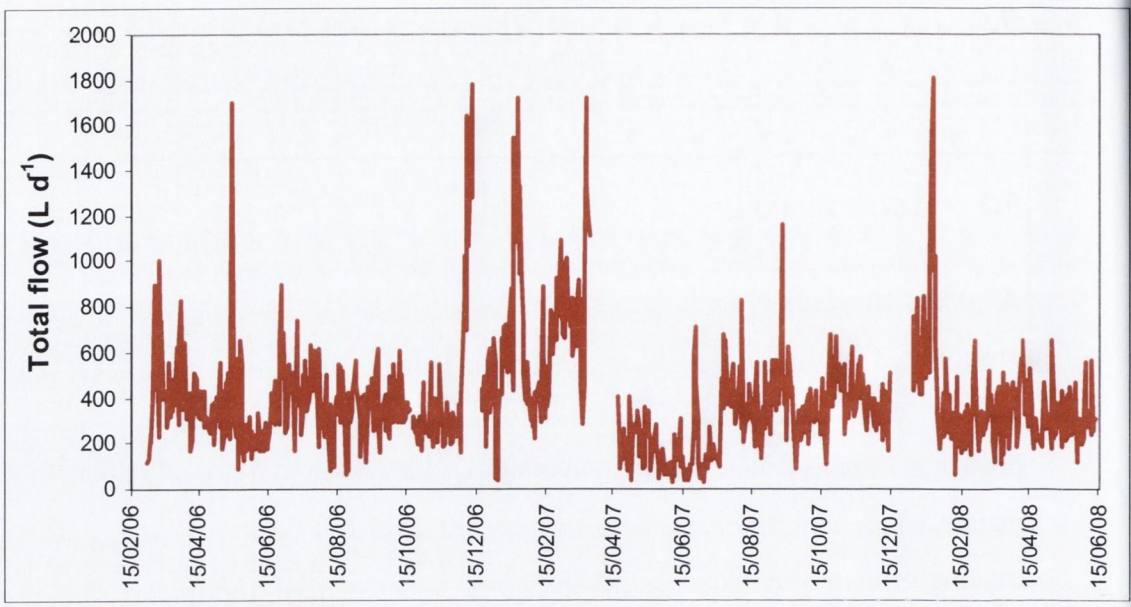


Figure 7.1 Daily flows to percolation trenches receiving STE on Site A

System II - Percolation Trenches Receiving RBE (Site A)

The flow rate to the horizontal SSF reed bed (System II) was continually measured and resulted in a mean daily flow rate over the trial period of 327.3 L d^{-1} [Std. dev. = 186.4]. Despite the frequent change of distribution device 1 on Site A, the flow split to the percolation trenches (System I) and horizontal SSF bed (System II) was therefore found to be relatively even at a ratio of 1.13 : 1. However, it is important to note that the measured flow to the horizontal SSF is not necessarily the same discharge rate which exits the reed bed system and which then flows to the three percolation trenches receiving RBE. Performing a water balance on the horizontal SSF acts to modify the outlet flow due to the addition of extra water from rainfall and the loss of water due to evapotranspiration. The calculation of this water balance is detailed in Section 8.2.1, the results of which show the mean outflow from the horizontal SSF bed to the percolation trenches to be 349.9 L d^{-1} [Std. dev. = 210.2]. The daily variation in flows out of the horizontal SSF and to the subsequent percolation trenches is shown in Figure 7.2.

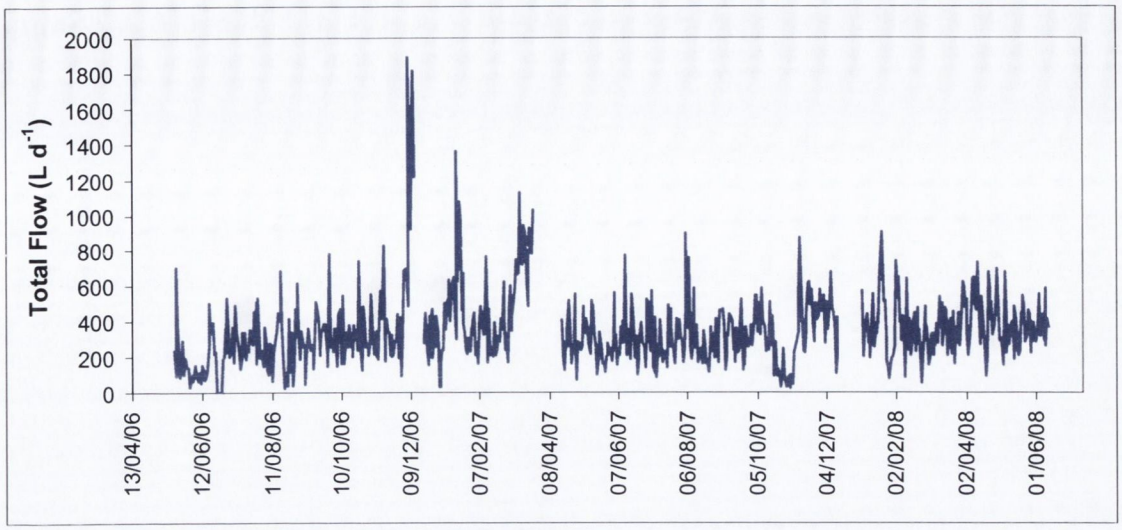


Figure 7.2 Daily flows to percolation trenches receiving RBE on Site A

System III – Percolation Trenches Receiving SE (Site B)

Following the same procedures as Site A, it was necessary to calculate the flow split from the *Biodisc®* to the percolation trenches and tertiary treatment horizontal SSF on Site B. A graph of the total daily on-site flow rates to the two percolation trenches receiving SE is shown in Figure 7.3. The mean daily flow rate over the trial period was 132.1 L d^{-1} [Std. dev. = 102.9]. Following measurement of the flows to the horizontal SSF on this site, the flow split ratio was found to be 1.09 : 1 (horizontal SSF bed : percolation trenches).

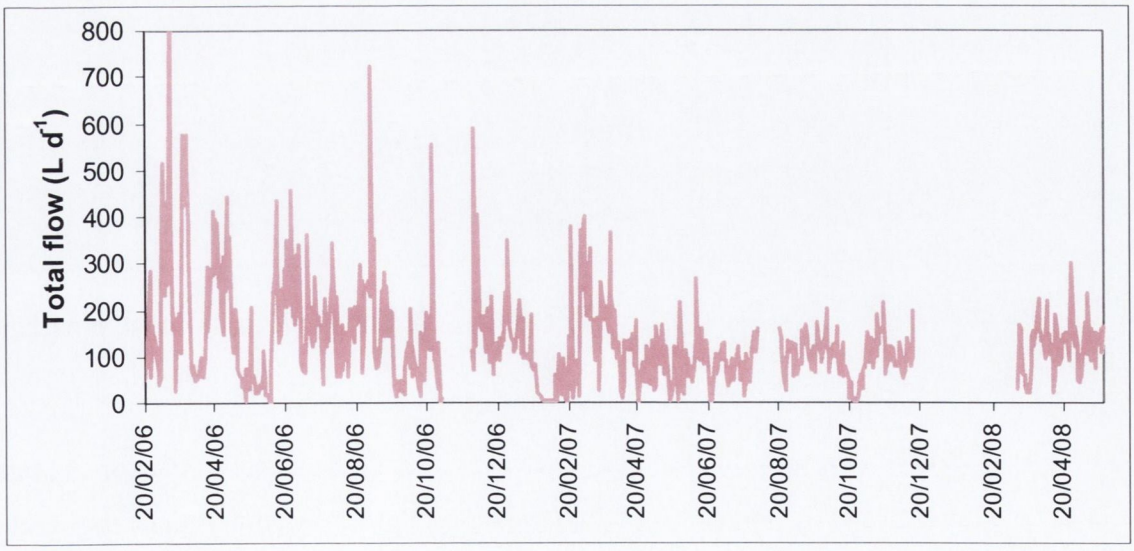


Figure 7.3 Daily flows to the percolation trenches receiving SE on Site B

7.3 Analysis and Results of STE, RBE, SE and Soil Moisture Samples

7.3.1 Method of Analysis

As explained in Section 5.7.1, the three lysimeter and tensiometer lengths (1.3 m, 1.6 m and 1.9 m) were installed below ground level leaving between 100 to 200 mm of the tube above ground level for sample extraction purposes. Assuming a mean figure of 150 mm this resulted in the creation of three nominal depths of 0.35 m (red), 0.65 m (blue) and 0.95 m (black) below the infiltrative surface (0.8 m), referred to as "depth planes" and colour coded to conform with the lysimeter and tensiometer colour code (i.e. red lysimeters/tensiometers were installed to the red depth plane (0.35 m below infiltrative surface)) – Figure 7.4.

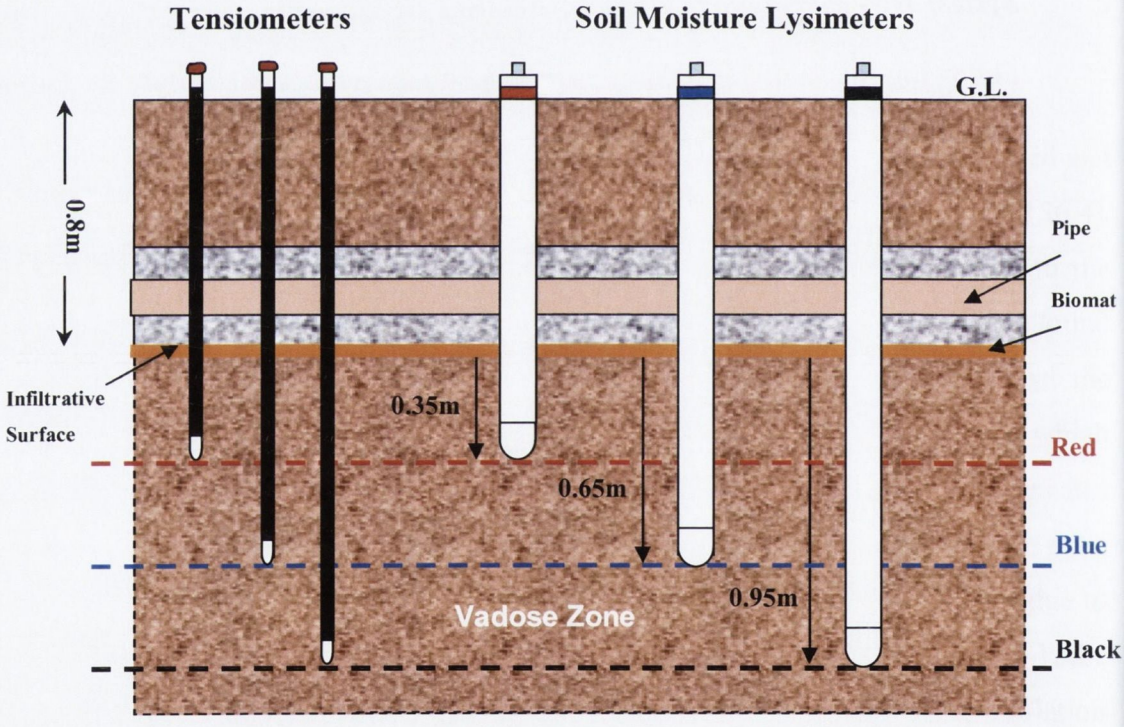


Figure 7.4 Cross-sectional cut of instrumentation layout including depth planes

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 studies to identify those areas across the percolation areas which were receiving wastewater effluent. Such analyses would help in determining the most representative method of reporting the attenuation of the percolate.

Given the percolation areas on both sites were being monitored over more than two year periods, it was of interest to assess and examine the dispersion of the effluent, if any, along each trench with time. As such, yearly analysis was carried out in which the laboratory results for Cl at the different sample positions along each trench were averaged at the same depth plane at which they were recorded. This enabled the identification of differences in loading rates between (i) the trenches and (ii) the sampling distances on the same depth plane, thus highlighting any anomalies within each plane. Similar analysis was then carried out encompassing the combined means from instrumented trenches over the duration of the sampling. From this, a conceptual model was derived for the analysis of the attenuation of the percolate according to one of the two following methods:

(i) *Planar average*: the averaging, from the instrumented trenches, of the concentrations of each parameter across all sampling positions at the 0.35, 0.65 or 0.95 m depth planes. The difference between the mean loading rates is then compared for the different depth planes.

(ii) *Depth average*: the averaging, across all instrumented trenches, of each parameter within each plane calculated at the different sample distances along the trenches and the corresponding differences in loading rates between the planes then compared at these sample distances.

As is the case with the presentation of all results of chemical, bacteriological and viral analysis of soil moisture samples, this model assumes homogeneous and isotropic subsoil properties and only takes account of matrix flow (i.e. no heterogeneous preferential flow).

System I - Percolation Trenches Receiving STE (Site A)

The attenuation of the percolate from the trenches receiving STE was carried out by analysing soil moisture samples from the zero tension samplers installed on Trench 1 and the suction lysimeters installed on Trenches 2 and 3 (see Figure 4.17). Initial analysis of the percolation trenches receiving STE involved plotting a bar chart of the yearly mean Cl concentrations of each depth plane lysimeter at each sample position along Trenches 2 and 3 (Figure 7.5). As samples were only drawn from the zero tension

samplers at the front of trench 1 and their installation was not carried out until the beginning of the second year of sampling, results obtained were only included in the analysis of the combined Cl means from the three trenches. In examining the trend, it is immediately obvious the reduction in loading between sample points P1 – P9 and sample points P10 – P15 of Trench 2. A plot of the equivalent Cl loads shows that the continuous application of STE on the front of the trench has, with the exception of two lysimeters (P1 and P7), seen loadings either remain unchanged or increase over time. It is worth noting that no sample was extracted from lysimeter P5 during the second year of sampling which had developed a crack in the porous cup, as discovered at the end of the project when the instrumentation was removed. In comparison to Trench 2, the bar chart for Trench 3 shows a more gradual reduction in Cl concentrations with length although a distinct dip in Cl loadings between the front and back of the trench is also evident, if not as clearly. Sample points P16, P17 and P18 yield continuously high Cl concentrations throughout the two years. However, determining whether effluent has spread to the 5 and 10 m sample positions (sample points P19 – P24) on Trench 3 over the two year sampling period is more ambiguous and needs further elucidation.

In order to establish if and when both sets of lysimeter trios (P19, P20, P21 and P22, P23, P24) were to be included in chemical and bacteriological analysis, the background Cl concentration was deduced by calculating the mean of all values recorded at the back of both trenches (i.e. sample points P10 – P15 and P25 – P30) over the duration of the project (Table 7.1). This is under the safe assumption that the effluent had not yet dispersed to this distance along the trenches.

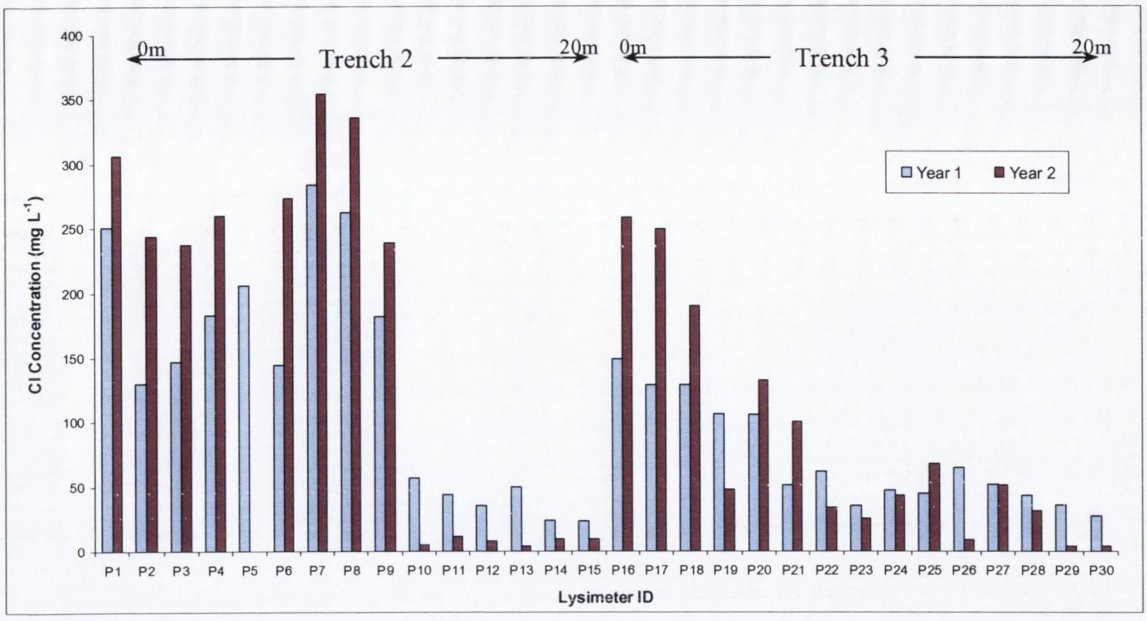


Figure 7.5 Yearly mean Cl concentrations of each depth plane lysimeter along both Trenches 2 and 3

If concentrations from each colour coded lysimeter in a trio over both years of analysis were above the calculated mean + std. dev. (= 44 mg L^{-1}) they were to be included in further calculations with the assumption that effluent had dispersed to these points. The Cl concentrations at each sample point for both years are presented in Tables 7.2 and 7.3. Relatively high mean Cl concentrations can be seen at the back of both trenches over the first year of analysis (Table 7.2) but this is primarily restricted to the first three sampling dates when concentrations measured were particularly high. Although this may be due to preceding periods of elevated STE flow which increased the hydraulic load and thus facilitated the temporary distribution of STE along a greater length of percolation trench, it is also possible that it may be due to liberation of Cl ions in the disturbed soil post-lysimeter installation. Subsequent concentrations at the back of the trenches over the remaining period of monitoring were considerably smaller and deemed to be at background levels.

The results of this hypothesis on Trench 3 suggested that all concentrations over the duration of the sampling at the 5 m sample position (P19, P20 and P21) were to be included in further calculations while measurements at the 10 m sample position (P22, P23 and P24) over the duration of the project were to be omitted.

Table 7.1 Evaluation of the background Cl concentration on Site A

Trench 2		Trench 3	
Sample Point	**Mean Concentration (mg L^{-1})**	**Mean Concentration (mg L^{-1})**	**Sample Point**
P10	31	45	**P25**
P11	36	37	**P26**
P12	24	55	**P27**
P13	32	42	**P28**
P14	17	25	**P29**
P15	26	15	**P30**
Mean	**32**		
Std dev.	**12**		

Table 7.2 Mean Cl concentrations from each sample point over year 1 of analysis

Trench 2		Trench 3	
Sample Point	**Mean Concentration (mg L^{-1})**	**Sample Point**	**Mean Concentration (mg L^{-1})**
P1	242	**P16**	159
P2	130	**P17**	140
P3	156	**P18**	129
P4	178	**P19**	124
P5	206	**P20**	109
P6	148	**P21**	58
P7	284	**P22**	75
P8	264	**P23**	35
P9	188	**P24**	54
P10	57	**P25**	52
P11	62	**P26**	65
P12	41	**P27**	58
P13	60	**P28**	56
P14	24	**P29**	46
P15	42	**P30**	27

Table 7.3 Mean Cl concentrations from each sample point over year 2 of analysis

Trench 2		Trench 3	
Sample Point	**Mean Concentration ($mg\ L^{-1}$)**	**Sample Point**	**Mean Concentration ($mg\ L^{-1}$)**
P1	309	**P16**	241
P2	264	**P17**	270
P3	307	**P18**	209
P4	260	**P19**	48
P5	-	**P20**	132
P6	273	**P21**	100
P7	354	**P22**	34
P8	336	**P23**	26
P9	239	**P24**	43
P10	5	**P25**	68
P11	11	**P26**	9
P12	8	**P27**	51
P13	4	**P28**	31
P14	10	**P29**	4
P15	10	**P30**	4

For the analysis of the combined mean Cl concentration across the trenches, given that the trio of zero tension samplers were only successfully operating at the very front of Trench 1, concentrations were combined with those at the 0 m sample positions on Trenches 2 and 3. A time-series plot of the combined mean Cl concentrations measured at all five sample positions for the three depth planes (Figure 7.6) illustrates the load reduction from the front half (0 – 10 m) to the back half (10 – 20 m) of the trenches throughout the project duration. Samples taken from all depth planes on 12/07/06 yielded erroneously high Cl concentrations as a result of the addition of hypochlorite solution to the lysimeters post-installation for sterilisation purposes. These outliers were excluded from the data accordingly. While Cl concentrations at the front of the trenches were significantly high on a continuous basis it was noted that concentrations at the 15 and 20 m sample positions were, on average, 5 times lower and regarded as negligible.

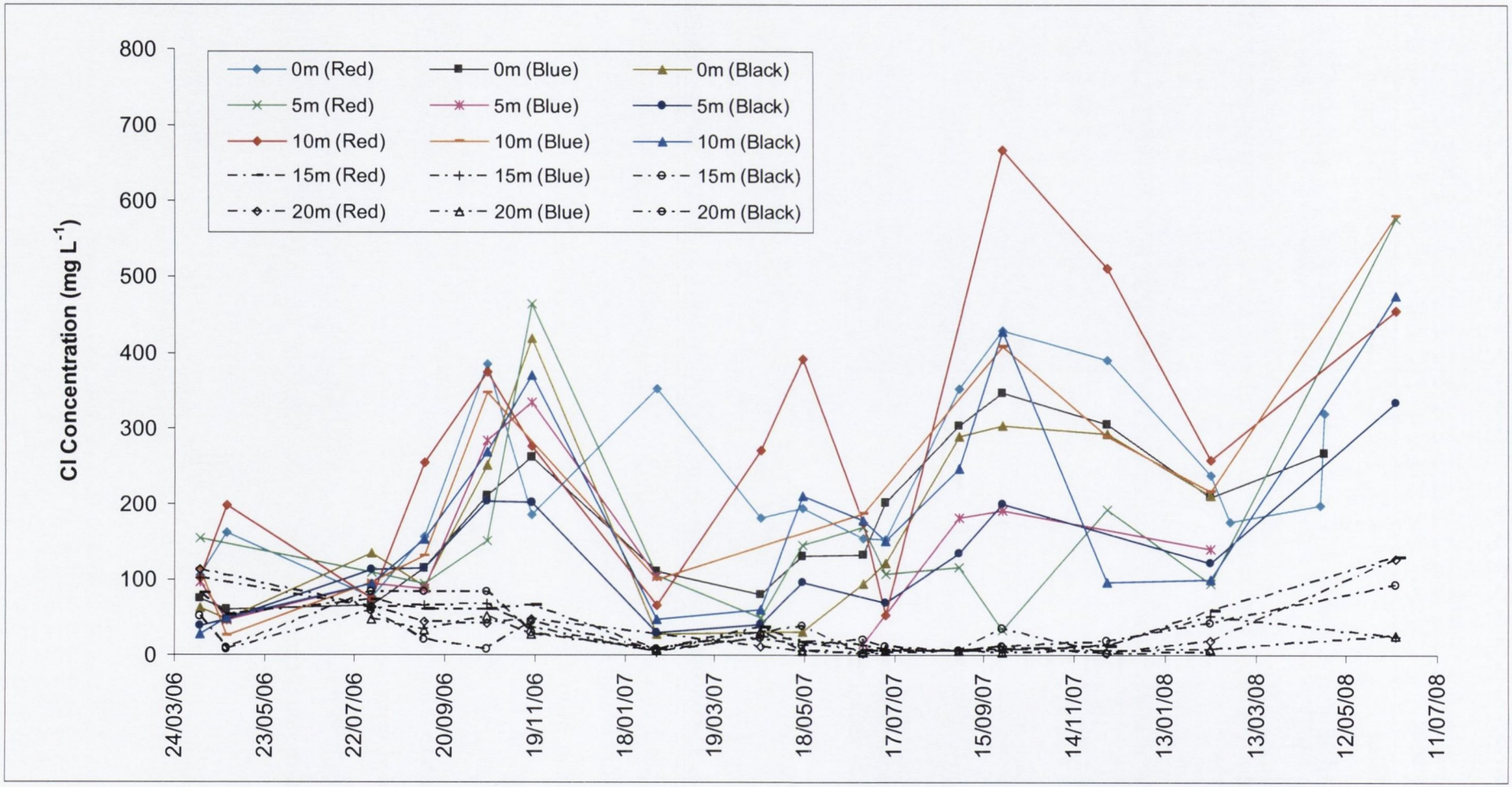


Figure 7.6 Mean Cl concentrations measured for the three depth planes at the five sample positions

This is corroborated by a further plot of the mean planar loadings at the 0, 5 and 10 m sample positions (Figure 7.7) which shows relatively little difference with depth. Any noticeable reductions may potentially be due to both the effects of physical straining on the percolating effluent and that of dilution, to be discussed in Section 7.3.3.

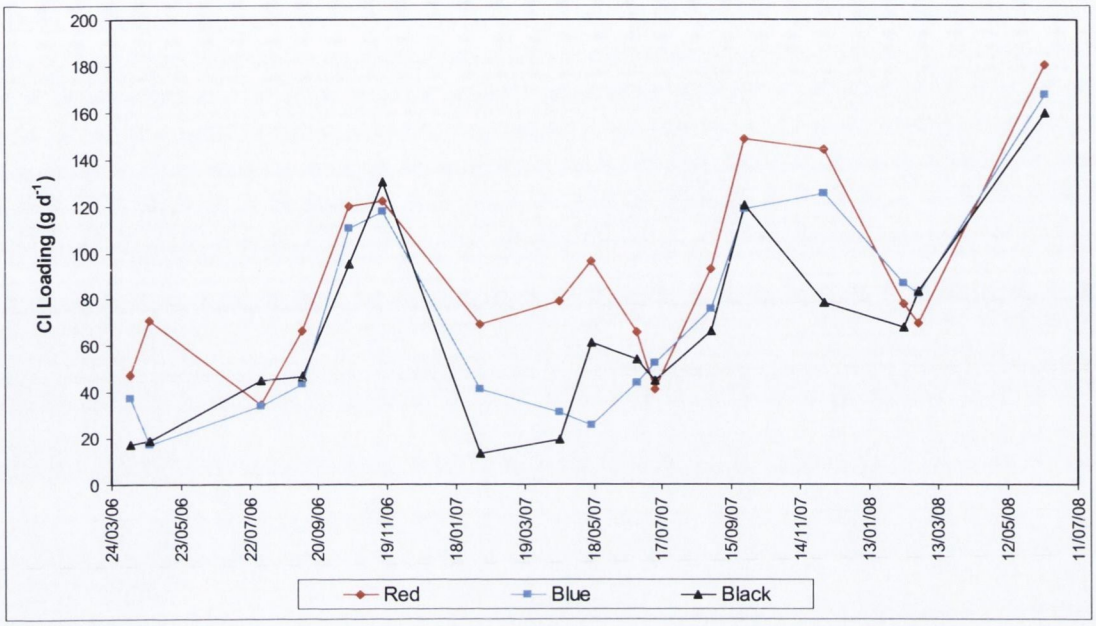


Figure 7.7 Planar mean Cl loadings across the first 10 metres of percolation trench (0, 5 and 10 m sample positions)

Overall analysis suggests that the STE has been dispersed to, and thus the biomat has spread to, between 10 and 15 m on Trench 2 and between 5 and 10 m on Trench 3. While certain variations in loadings between the depth planes can be seen at the 0, 5 and 10 m sample positions individually, the emerging pattern suggests that the *planar average* method using effluent data over the first 10 m of percolation Trench 2 and 5 m of percolation Trench 3 is the more representative way of analysing the attenuation of the percolate.

System II - Percolation Trenches Receiving RBE (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 RBE in the vadose zone. A plot of the yearly mean Cl concentrations of each depth plane lysimeter at each sample position along Trenches 4 and 5 (Figure 7.8) reveal the effluent was distributed over a 5 m length, as

represented by sample points S1 – S9 and S16 – S24. In comparison to the trenches treating STE in System I, this would suggest that, as suspected, the reduction in RBE organic load brought about by the installation of the reed bed has restricted such an extensive biomat along the infiltrative surface of both trenches, thus confining the effluent loading to between 5 and 10 m. The noticeable mean increase in Cl concentrations at the majority of sample positions across the first 5 m of trench from year 1 to year 2 highlights continuous trench loading and suggests the gradual exhaustion of precipitation sites for Cl ions at shallow depths resulting in greater vertical movement of the chemical to the blue and back depth planes. Significantly, the effluent does not seem to have dispersed more laterally from year to year with sample points S10 – S15 and S25 – S30 yielding negligible Cl concentrations throughout the duration of the monitoring. This underlines the importance of both the influent strength and subsoil permeability on biomat development (and inevitably the lifespan of the system). No sample was extracted from sample S29 at any point. Upon the lysimeter's removal at the end of the project the porous cup was found to have smashed, most probably during its installation. Curiously, no sample was drawn from S11 over year 2 and even though no damage to the lysimeter was noticed upon its removal, a small crack in the lysimeter tube, porous cup or neoprene tubing must have resulted in its recurring loss of vacuum.

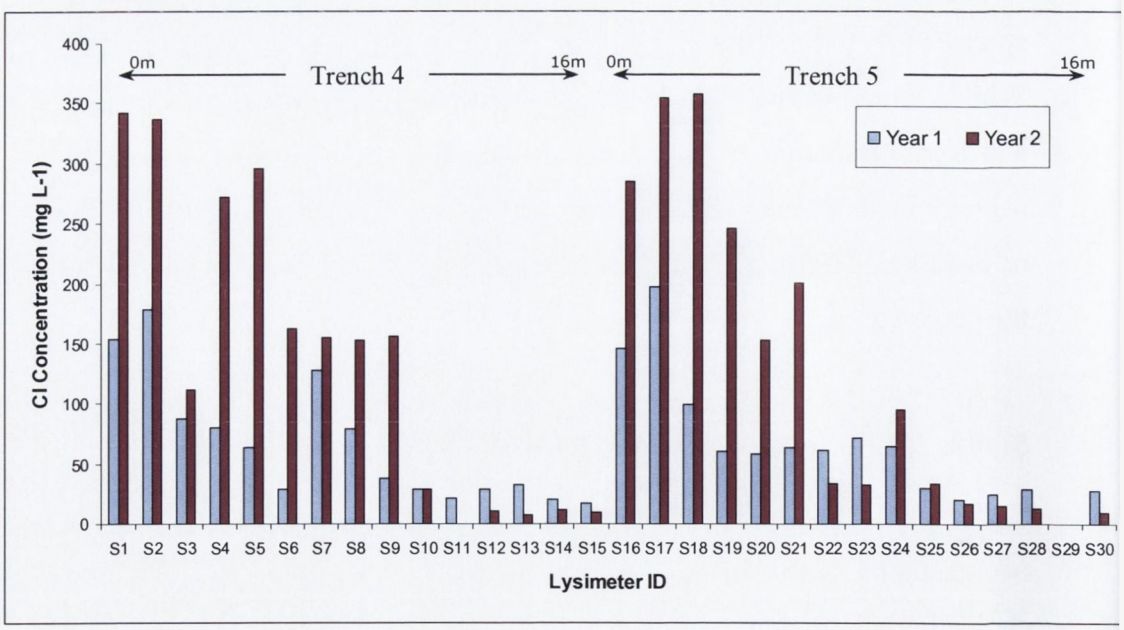


Figure 7.8 Yearly mean Cl concentrations of each depth plane lysimeter along both trenches receiving RBE

In combining the Cl results from both trenches (Table 7.4), the mean concentrations at the five sample positions on the red plane were graphed (Figure 7.9).

Table 7.4 Mean Cl concentrations measured at each sample point under percolation area treating RBE over duration of project

Sample Point	Mean Concentration (mg L^{-1})	Sample Point	Mean Concentration (mg L^{-1})
S1	232	S16	196
S2	246	S17	270
S3	94	S18	210
S4	168	S19	144
S5	162	S20	90
S6	96	S21	83
S7	142	S22	51
S8	110	S23	56
S9	102	S24	55
S10	29	S25	31
S11	21	S26	19
S12	19	S27	22
S13	18	S28	22
S14	17	S29	N/A
S15	14	S30	20

N/A = Lysimeter broken (i.e. no sample extracted)

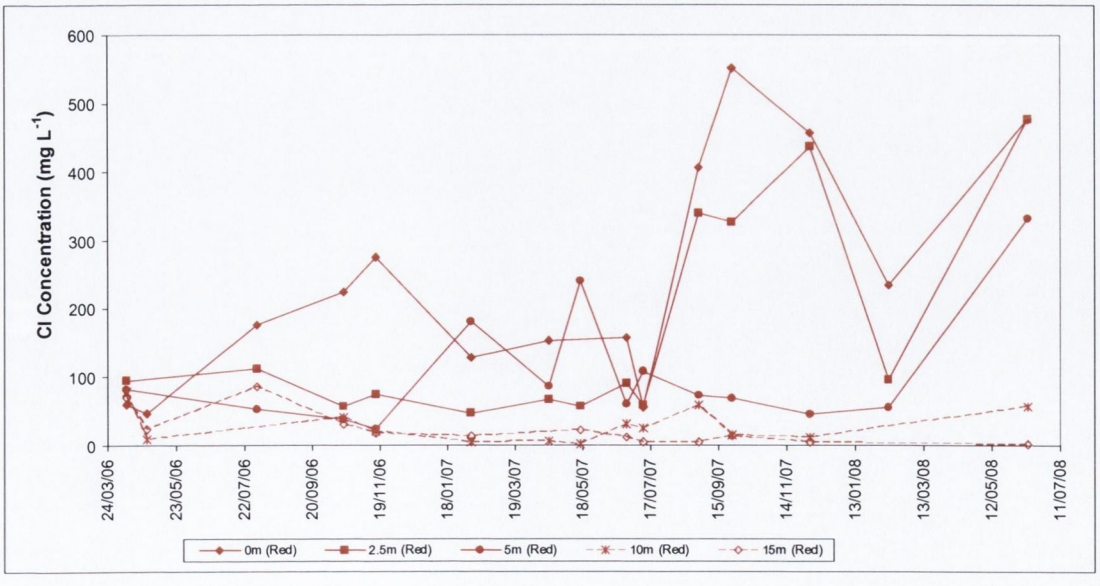


Figure 7.9 Mean Cl concentrations measured at the red depth plane at the five sample positions

A distinct reduction in effluent loading between 0 – 2.5 m sample points and 10 – 15 m sample points was immediately apparent over the duration of the project. It appears that approximately 10 months after the start of monitoring (or 16 months after operational start-up) the effluent had dispersed to the 5 m sample position with concentrations seen to pull away from background level for the first time on 8/02/07. Cl concentrations at the three sample depths from the 0 m, 2.5 m and 5 m sample positions also followed a similar pattern which was highlighted prominently when the mean concentrations measured at all sample positions were illustrated (Figure 7.10).

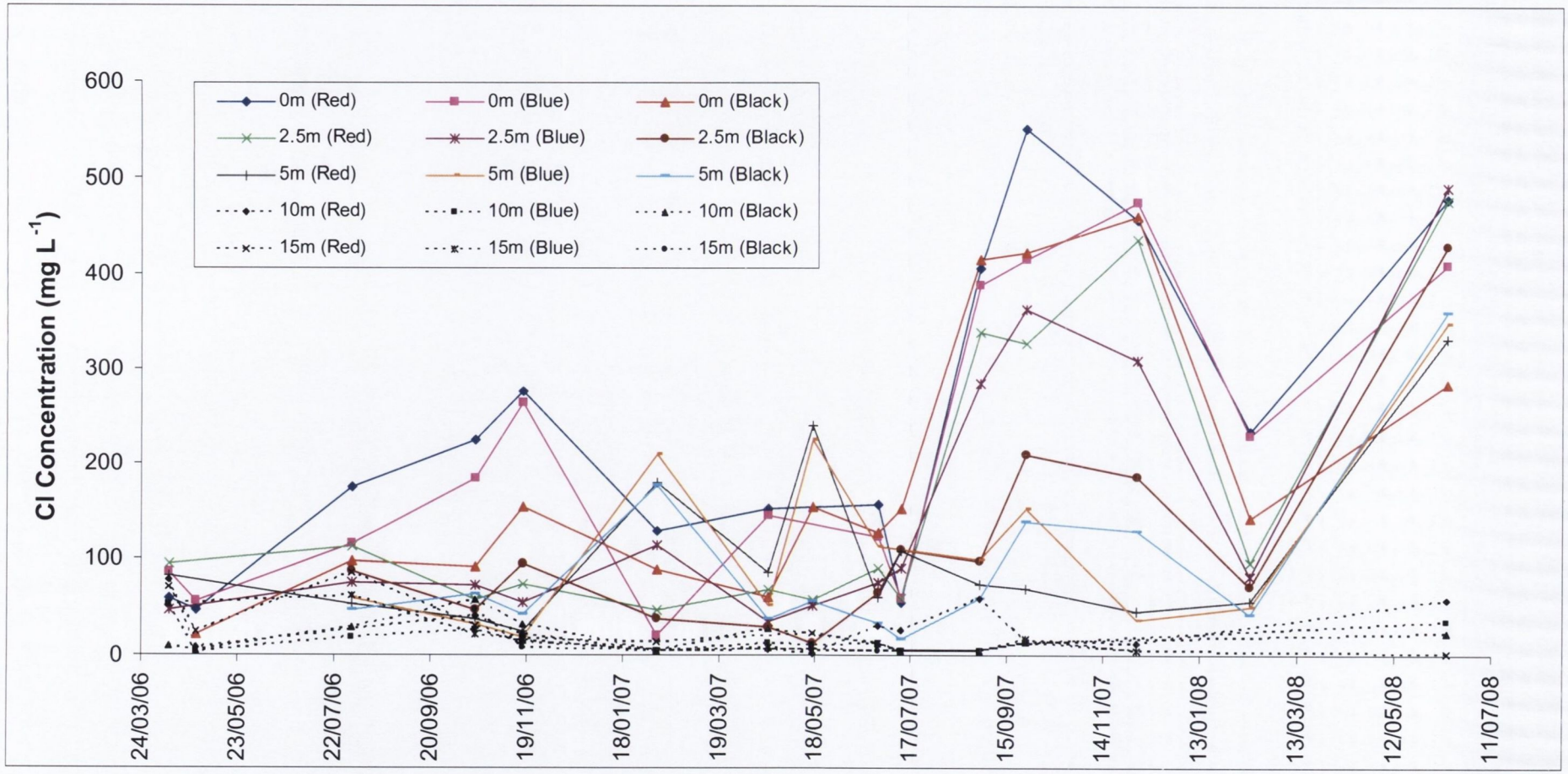


Figure 7.10 Mean Cl concentrations measured for the three depth planes at the five sample positions

Before choosing the optimal method of analysis for reporting the attenuation of the percolates' constituents, final verification was gained through the plot of the mean planar Cl loadings at the 0 m, 2.5 m and 5 m sample positions (Figure 7.11). Concentrations at the 5 m sample position were included from 8/02/07 onwards, as predicted from Figure 7.9. The mean flow from the reed bed to the trenches over the duration of the project was employed in calculations (see water balance analysis in Section 8.2.1). Given the minor difference in loadings between the sample depth planes across this length of trench, it was clear that the *planar average* method across the first 5 m of percolation trench was the most representative form of parameter analysis to proceed with.

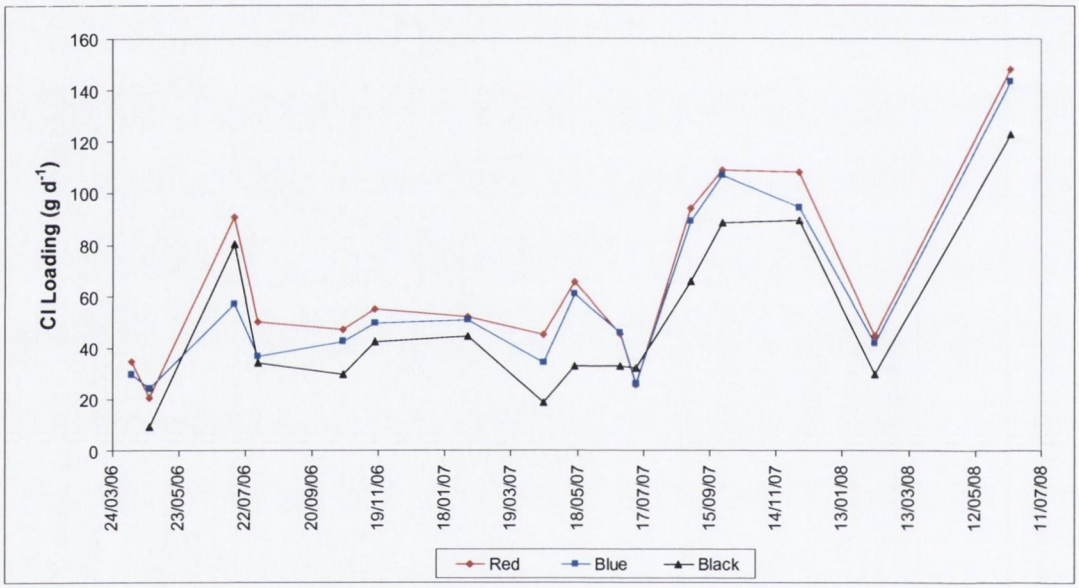


Figure 7.11 Mean readings measured for the three depth planes at the 0, 2.5 and 5 m sample positions

System III - Percolation Trenches Receiving SE (Site B)

The attenuation of the percolate in the vadose zone on Site B was carried out by analysing soil moisture samples from the lysimeters installed on Trenches 1 and 2. One of the benefits on Site B was that given the flow entering each trench was accurately measured by the tipping buckets at the distribution device outlets, parameter loadings along each trench over the two years of sampling could be determined directly. Prior to considering the hydraulic effect on the trenches, the yearly mean Cl concentrations at each depth plane sample position along both trenches were plotted (Figure 7.12). The

bar chart clearly illustrates the high concentrations of effluent at the front of both trenches each year as recorded at points RC1, RC2, RC3 and RC13, RC14 and RC15 (0 m sample position). Again, there is a visible increase in Cl concentrations at these points from year 1 to year 2 owing to the continuous accumulation of Cl ions at the three sample depths through consistent loading. In addition, the hydraulic loading to the percolation trenches is seen to significantly drop in the second year of monitoring [from 162.9 L d^{-1} (or 22.6 L m^{-2} d^{-1}) in year 1 to 116.7 L d^{-1} (or 16.2 L m^{-2} d^{-1})] in year 2 (ratio ~ 1.4 : 1) which would have had the effect of distributing more concentrated Cl loads to the trenches. The elevated Cl levels recorded at RC4 and RC5 in Year 1 were isolated events suspected to be related to the infiltration of hypochlorite solution to subsoil from their respective lysimeters (for sterilization purposes). Cl concentrations at the 5 m, 10 m and 15 m sample positions are consistently low at an mean concentration of 16 mg L^{-1}, assumed to be background level.

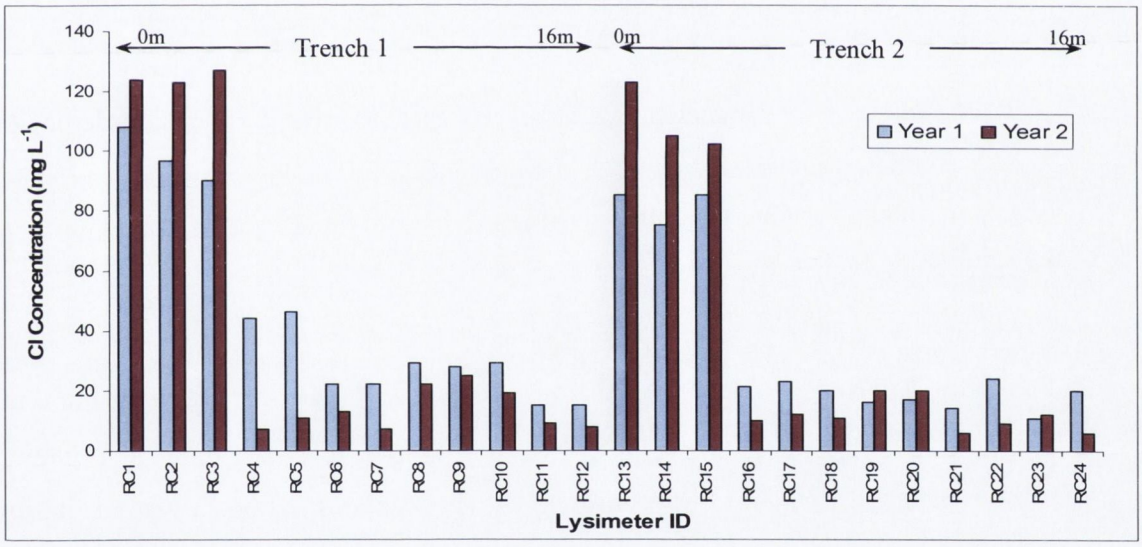


Figure 7.12 Yearly mean Cl concentrations of each depth plane lysimeter along both Trenches 1 and 2

A further plot of the combined Cl concentrations from both trenches measured on the red depth plane for each of the sample positions (Figure 7.13) shows that levels at the 0m sample position were, on average, 4 times greater than that measured at the other three sample positions. A number of samples taken from all depth planes on 04/07/06, 26/07/06 and 16/08/06 yielded erroneously high Cl concentrations as a result of the addition of hypochlorite solution to the lysimeters post-installation for sterilization purposes. These outliers were excluded from the data accordingly.

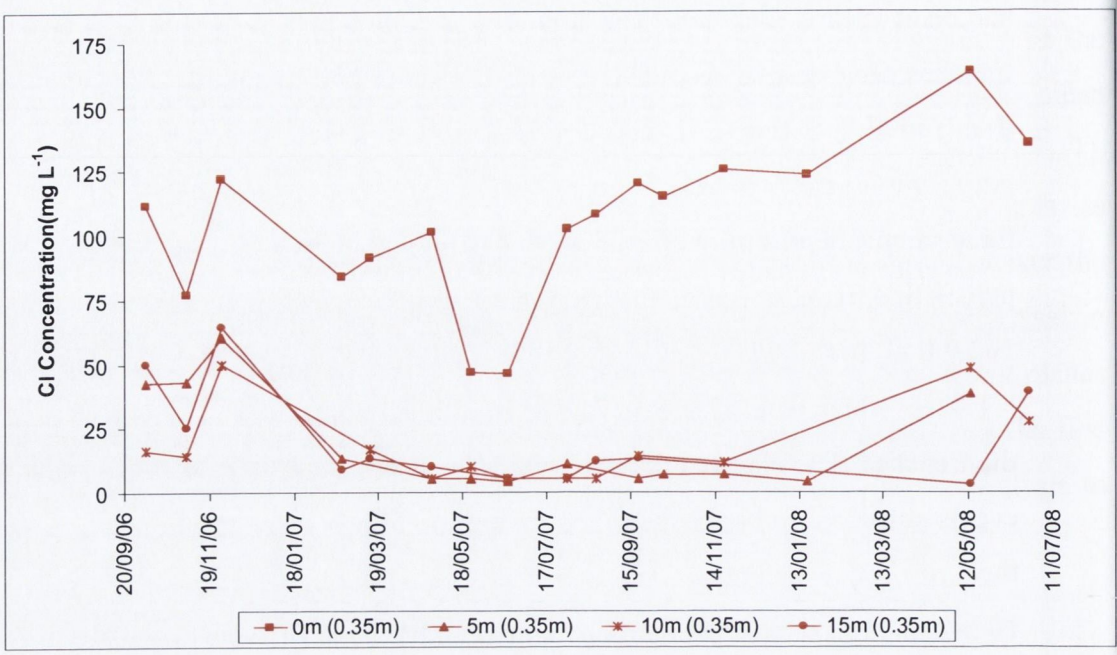


Figure 7.13 Mean Cl concentrations measured on the red depth plane at the four sample positions across both trenches

When the mean Cl concentrations for each depth plane at the 0 m sample position were then plotted, they were found to be very similar while red, blue and black depth concentrations were repeatedly negligible at the 5, 10 and 15 m sample positions (Figure 7.14 and Table 7.5).

Overall, this suggests that the SE from the *Biodisc*® was only reaching the 0 m sample position throughout the duration of the project and that the reduced organic loading brought about by the provision of the packaged treatment system inhibited the formation of a biomat and thus had prevented dispersion of the effluent along the base of the percolation trenches. Initial estimates, therefore, suggested that the SE loading was confined to less than the first 5 m of the trenches. In addition, observing the little difference in concentrations between the depth planes at the 0 m sample position suggests the influence of dilution on effluent attenuation between these planes was small (Section 7.3.3). What is clear is that over the two year duration of the project there was little progression in the distribution of the SE across the length of the trenches. In the general context, however, it was clear from Cl analysis carried out that the *depth average* method performed at the 0 m sample position was most representative in highlighting the chemical and bacteriological behaviour of the SE in the vadose zone.

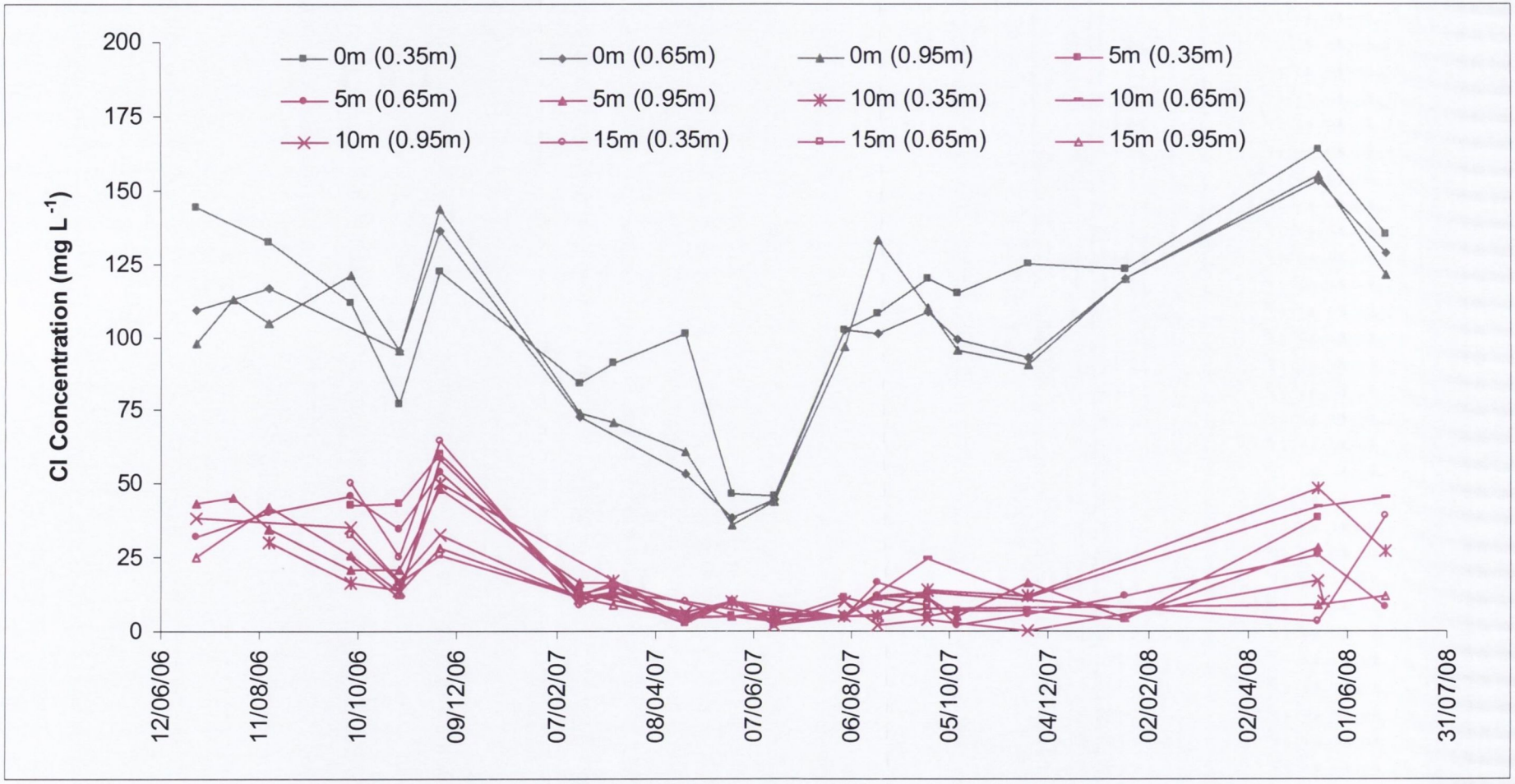


Figure 7.14 Mean Cl concentrations measured for the three depth planes at the four sample positions

Table 7.5 Mean Cl concentrations measured at each sample point on Site B over the duration of the sampling period

Lysimeter ID	Mean Concentration (mg L^{-1})	Lysimeter ID	Mean Concentration (mg L^{-1})
RC1	107	RC13	103
RC2	111	RC14	88
RC3	105	RC15	90
RC4	26	RC16	17
RC5	24	RC17	16
RC6	15	RC18	14
RC7	14	RC19	20
RC8	21	RC20	19
RC9	27	RC21	8
RC10	26	RC22	15
RC11	12	RC23	9
RC12	10	RC24	13

7.3.2 Biomat Formation

System I - Percolation Trenches Receiving STE (Site A)

As outlined in Section 7.3.1, Cl analysis of the soil moisture samples from the percolation trenches receiving STE revealed that the effluent had, on average, been distributed along the first 10 m of the trenches. This would suggest that the organic load of the STE, not having undergone a secondary treatment phase, facilitated the formation of a biomat at the infiltrative surface thereby promoting distribution along the base of the percolation trench. The consistent presence of elevated mean Cl levels along the first 10 m of trench throughout the project suggests that, at the commencement of monitoring, the biomat had already developed between the 0 and 10 m sample positions. This was due to the time lag between site commissioning, 26th October, 2005, and the commencement of monitoring, 10th April, 2006.

Through further analysis of the Cl concentrations of the soil moisture samples, it became clear, however, that the rate of effluent distribution, and thus biomat formation, differed between Trenches 2 and 3. While Cl levels on Trench 2 were consistently high along the first 10 m over the duration of the project, the 10 m sample position on

Trench 3 only received effluent on an infrequent basis. While the 0 m and 5 m sample positions received effluent constantly over the duration of the sampling period, Cl concentrations were, on average, not seen to increase at the 10 m sample position over time. This suggests that these sporadic "hits" may have been due to intermittently high hydraulic loads entering this trench as a result of possible blockages to one or both of the other V-notch weirs in the upstream distribution box. On an overall basis, however, it is possible that the reduced development of the biomat along Trench 3 is due to a smaller hydraulic load being received owing to unequal distribution of the STE between the three trenches.

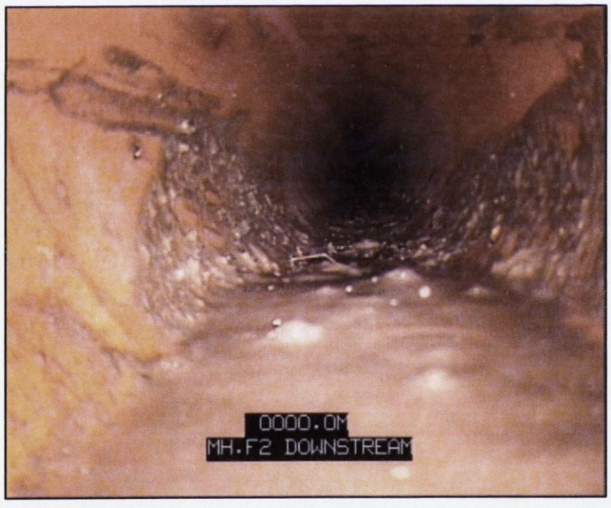
To examine further the distribution of effluent in the trenches and qualify the findings from the Cl analysis, a CCTV investigation (McAllister Bros. Ltd.) was carried out on Site A on 24/07/07 - the end of the first year of sampling. A push rod system with built-in miniature survey camera (Scanprobe) of head diameter 30 mm was used (Figure 7.15). The camera was inserted into each of the six percolation pipes on site and pushed along the total length of each pipe for continuous surveying.

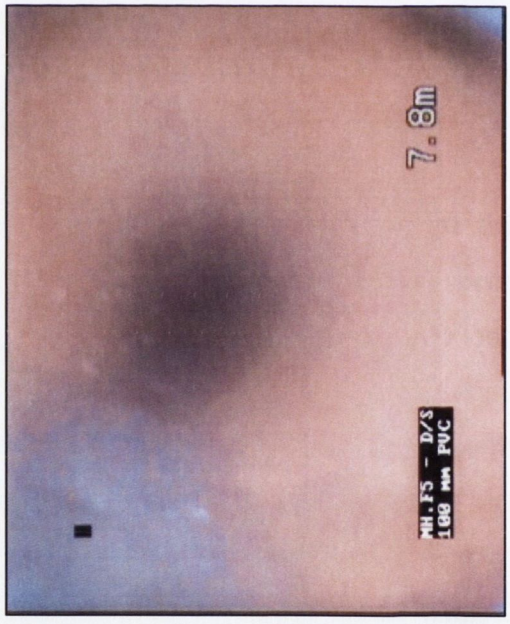


Figure 7.15 CCTV push rod camera and its insertion through the percolation pipework

From video evidence and snapshot photos taken at various distances along the length of each of the trenches (Figure 7.16), it was possible to observe if and where a coating of biofilm was present along the base of the percolation pipework. Such a coating would indicate the presence of effluent at that point and hence it would be possible to estimate

the dispersion of the effluent and subsequent development of the biomat at the infiltrative surface. Photos taken at distances of 0, 1.8, 4.6 and 7.8 m along the three percolation pipes receiving STE clearly show a significant biofilm coating along the base. In contrast, the absence of the biofilm is evident at 11.8 m suggesting no effluent had reached this position. The marked deterioration in quality of the camera shots is due to the build-up of debris during its passage. In addition, given the aforementioned difference in rate of biomat progression between Trenches 2 and 3, it was interesting to note that a snapshot taken at 9.9 m on the percolation pipe from Trench 3 (Figure 7.17) revealed no biofilm coating to be present. This supports the assertion that effluent loading on this trench had, in general, failed to reach the 10 m distance in contrast to Trench 2. All CCTV evidence from the percolation pipework, as such, corroborates with both effluent dispersion and biomat development predictions along the trenches from the Cl analysis.





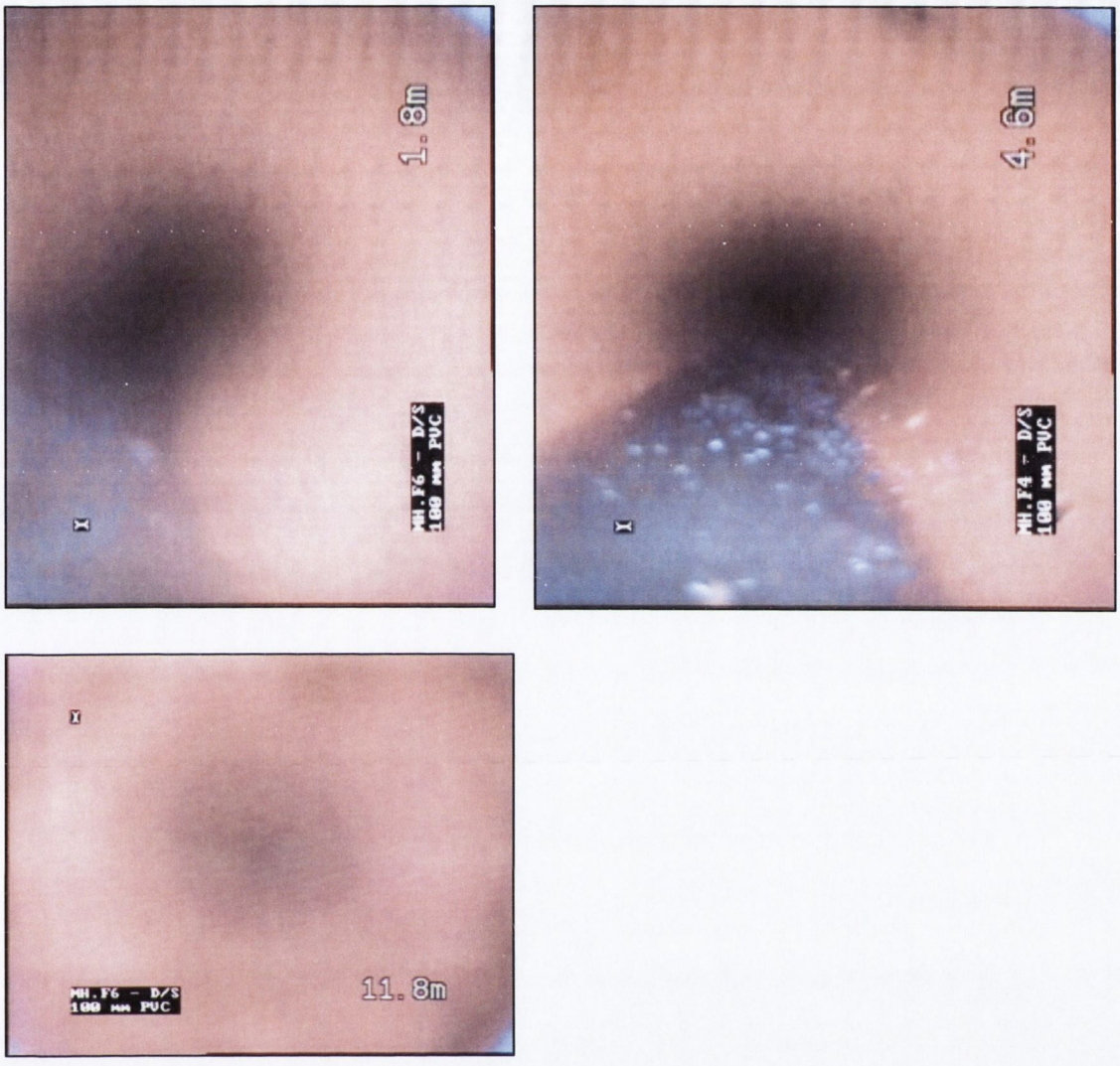


Figure 7.16 Snapshot photographs from the CCTV Investigation of the three percolation pipes (Trenches 1, 2 and 3) receiving STE at various distances along their base

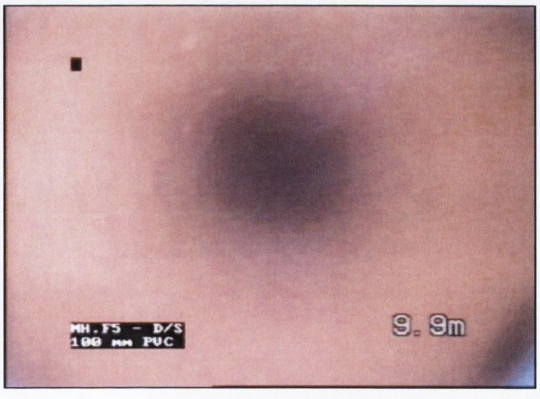


Figure 7.17 Photo of percolation pipe from Trench 3 (receiving STE) at 9.9 m showing absence of biofilm coating along the base

System II - Percolation Trenches Receiving RBE (Site A)

One of the primary benefits cited for horizontal SSF reed bed treatment is the reduction it provides in organic chemicals and suspended solids. The installation of the horizontal SSF on Site A reduced effluent TSS concentrations by an average of 77% while COD removal averaged 67% over the duration of the project (see Section 8.4.1). The subsequent loading of RBE to percolation Trenches 4, 5 and 6 resulted in a reduced dispersion of effluent compared to the trenches receiving STE owing to this removal. According to the Cl analysis, the effluent reached the 5 m sample position along the trenches by the time monitoring commenced but never progressed as far as the 10 m sample position throughout the duration of the trial period. The CCTV investigation on the percolation pipes of the three trenches on 24/07/07 supported the Cl analysis with the presence of a biofilm noted to just beyond the 5 m distance at the base of each pipe. Hence, unlike the percolation trenches receiving STE, the development of the biofilm appeared equal at the base of the percolation pipes in Trenches 4, 5 and 6, indicating a relevantly even distribution of the effluent from the upstream distribution device and hence an equal rate of biomat progression along the infiltrative surface.

System III - Percolation Trenches Receiving SE (Site B)

As for the reed bed on Site A discussed above, the installation of the *Biodisc*® RBC secondary treatment system significantly reduced the solids loading to the two percolation trenches. However, the superior standard of effluent discharged from the *Biodisc*® compared to the reed bed had a significant bearing on the difference in effluent dispersion along the trenches. Cl concentrations were consistently recorded at background level at the 5 m sample position while with a lower hydraulic load entering each trench compared to Site A, it resulted in minimal spread of the effluent beyond the 0 m sample position and little subsequent biomat development over the course of the sampling. The readings from the front tensiometers (2.5 m) would also indicate whether there was a strong influence by the dispersing effluent at this point and thus provide additional information on the proposed length of the wetted infiltrative surface.

7.3.3 Effect of Dilution on 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. As outlined in Section 5.8 and included in Appendix F, rainfall figures available for dilution at the depth planes over the duration of the project on Sites A and B were collected from on-site rain gauges while hourly Penman-Monteith reference evapotranspiration (ET_o) figures (FAO, 1998) were calculated using data from the on-site meteorological stations.

A model developed by Bartley (2004) based on the FAO Penman-Monteith method (FAO, 1998) of reference evapotranspiration (ET_o) calculation was used to determine actual evapotranspiration (AET) (Eqn. 7.1) (Appendix F). Where soil moisture deficit (SMD) was greater than 40 mm, the AET was considered to occur at a slower rate than ET_o and was therefore calculated using the Aslyng scale:

$$AET = ET_o\,(120 - SMD^*)/(120 - 40)\ mm \qquad \text{(Eqn. 7.1)}$$

where, SMD* is the accumulated soil moisture deficit at the beginning of each period and where SMD* > 40 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).

As meteorological data from Sites A and B were collected for the first time in May and July 2006 respectively, when a SMD generally exists, it was necessary to determine the SMD 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 Mullingar and Casement Aerodrome and to search back on the records to find a date

when there was no SMD. A zero SMD value was recorded on 20/01/06 and so this was chosen as the starting date from which SMDs were calculated each day up to the beginning of the meteorological results from the weather stations on the research sites. As it transpires, the SMD on Site A from the first day of data collection (19/05/06) was in fact zero too due to a prolonged period of rainfall around this time. On the other hand, a SMD of 78 mm was calculated for Site B on the first day of data collection. Using this method it was found that on Site A, for a recorded rainfall of 1 913 mm over the 25-month period 19/05/06 to 12/06/08, the total effective rainfall was 1 114 mm. Similarly on Site B, for a recorded rainfall of 1 857.6 mm for the period 03/07/06 to 12/06/08, the calculated effective rainfall was 1 167.2 mm.

System I - Percolation Trenches Receiving STE (Site A)

In analysing the effect of dilution on the attenuation of the percolate and calculating the zone of contribution around each trench, the disparity in Cl concentrations between the STE and three depth planes was examined during both dry periods, and periods of sustained effective rainfall. Figure 7.18 shows a time series plot of the Cl concentrations at the three depth planes against the effective rainfall.

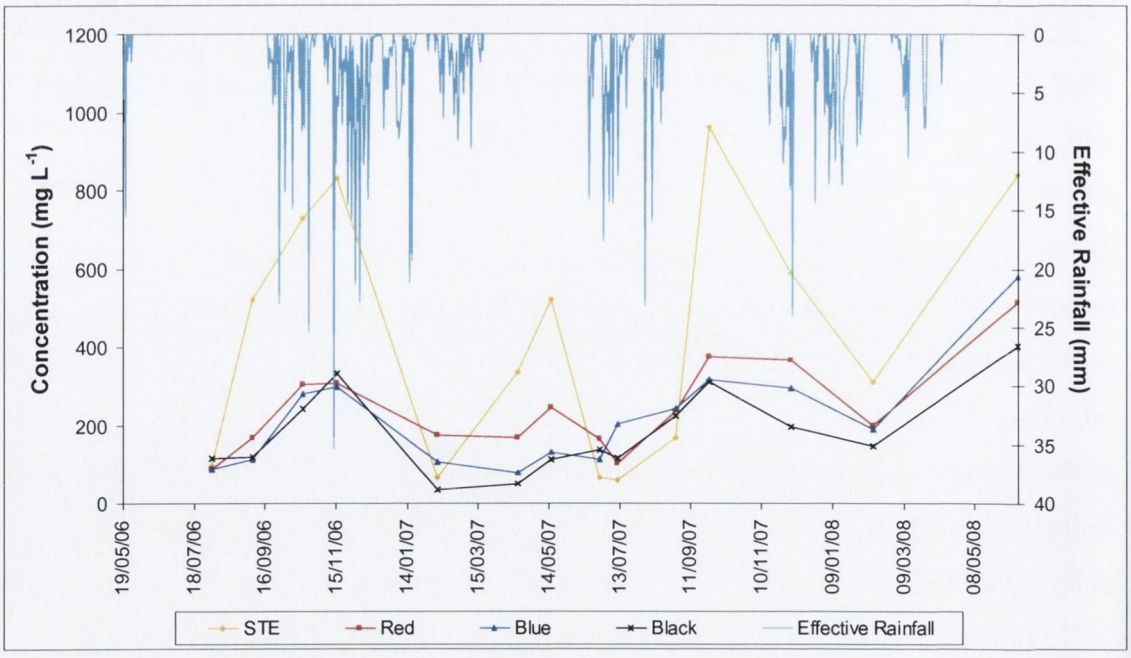


Figure 7.18 The effect of dilution by effective rainfall on Cl concentration for the trenches receiving STE

As Cl is regarded as a non-reactive chemical it is probable that the noticeable reduction

in Cl concentration between the STE and three depth planes during periods of zero effective rainfall is due to the physical straining of colloidal matter in both the biomat and underlying subsoil. Further inspection of the plots shows that there does not appear to be a significant trend indicating any additional dilution of the effluent during periods of high recharge. Nevertheless, to quantify any such contribution of recharge to effluent dilution, the reduction in Cl concentration between the STE and three depth planes was initially calculated during periods of effective rainfall (Table 7.6). As can be seen from Figure 7.18 sampling resulted in occasions where mean Cl concentrations at all depth planes were greater than those measured in the STE due to time lapse, i.e. the time taken for STE to travel from the septic tank to the lysimeters. As a result, these dates (26/06/07, 11/07/07 and 29/08/07) were excluded from further dilution calculations. It was found that, on average, a 53.1%, 58.5% and 64.7% reduction in Cl concentration was recorded during periods of effective rainfall between the STE and red, blue and black depth planes, respectively (Table 7.6).

Table 7.6 Mean percentage reduction in Cl concentrations between the STE and three depth planes during periods of sustained effective rainfall

Date	% Reduction in Cl Concentration from STE		
	Red Plane	Blue Plane	Black Plane
18/10/2006	58.4	61.6	67.0
16/11/2006	62.9	64.2	60.2
05/12/2007	38.0	60.7	67.0
Mean	**53.1**	**62.1**	**64.7**

This reduction in Cl concentration, however, is 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 7.7) 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 8.0%, 8.2% and 8.5% reductions in Cl concentration at the red, blue and black planes, respectively.

Table 7.7 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 STE		
	Red Plane	Blue Plane	Black Plane
02/08/2006	8.8	10.0	-
06/09/2006	67.7	78.8	77.1
18/04/2007	50.4	76.5	85.1
16/05/2007	53.0	74.8	78.2
27/09/2007	60.8	67.2	67.7
12/02/2008	36.5	39.4	53.4
13/06/2008	38.6	31.0	51.9
Mean	**45.1**	**53.9**	**56.3**

Having quantified the dilution factors at each depth plane a simple mass balance approach (Eqn. 7.2) was adopted to estimate the zone of contribution (A_c) of effective rainfall at each depth plane.

$$(Q_{in})(df)(C_{in}) + (ERF)(A_c) = (Q_T)(C_{out}) \qquad \text{(Eqn 7.2)}$$

where,

Q_{in} = mean flow received to the trenches on each sampling date ($m^3\ d^{-1}$)

df = dilution factor

ERF = effective rainfall (m)

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

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

C_{in} = STE concentration on each sampling date ($g\ m^{-3}$)

C_{out} = depth plane Cl concentration on each sampling date ($g\ m^{-3}$)

With a mean concentration of Cl measured in rainfall at Site A of 4.0 mg L^{-1} and using 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 19.9 m^2. Multiplying by the total effective rainfall over the sampling period of 1 114 mm equates to a total volume of effective rainfall at the red depth plane of

22.2 m^3. As determined in Section 6.3.1, effluent Cl concentrations were continually measured at the 0, 5 and 10 m sample positions on Trench 2 and at the 0 and 5 m positions on Trench 3. This was corroborated in the previously outlined CCTV investigation of the percolation pipework where photographic evidence showed a clear biofilm to a maximum distance of 11.8 m at the base of the pipe on Trenches 1 and 2, and 9.8 m at the base of the pipe on Trench 3. Assuming lengths of 11 m for Trenches 1 and 2 and 8 m for trench 3 to represent effluent distribution, or the length of the wetted infiltrative surface, and taking the trench width of 0.45 m, this equates to a zone of contribution of effective rainfall of 0.1 m on all sides of each of the trenches at the red depth plane. Similarly, calculations carried out for the blue and black planes estimated areal zones of contribution due to effective rainfall of 24.1 m^2 (equivalent to 26.8 m^3 of effective rainfall) and 33.5 m^2 (equivalent to 37.3 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. The width of the plume had thus extended to an estimated 0.17 m on all sides of each of the trenches at the blue plane and 0.3 m on all sides at the black plane (Table 7.8 and Figure 7.19).

Table 7.8 Estimated biomat length and zone of contribution of effective rainfall for percolation trenches receiving STE

Site A (STE)		**Width of plume (m) from edge of trench at depth plane**		
	Length of wetted infiltrative surface (m)	**0.35 m**	**0.65 m**	**0.95 m**
Trenches 1 & 2	11	0.1	0.17	0.3
Trench 3	8			

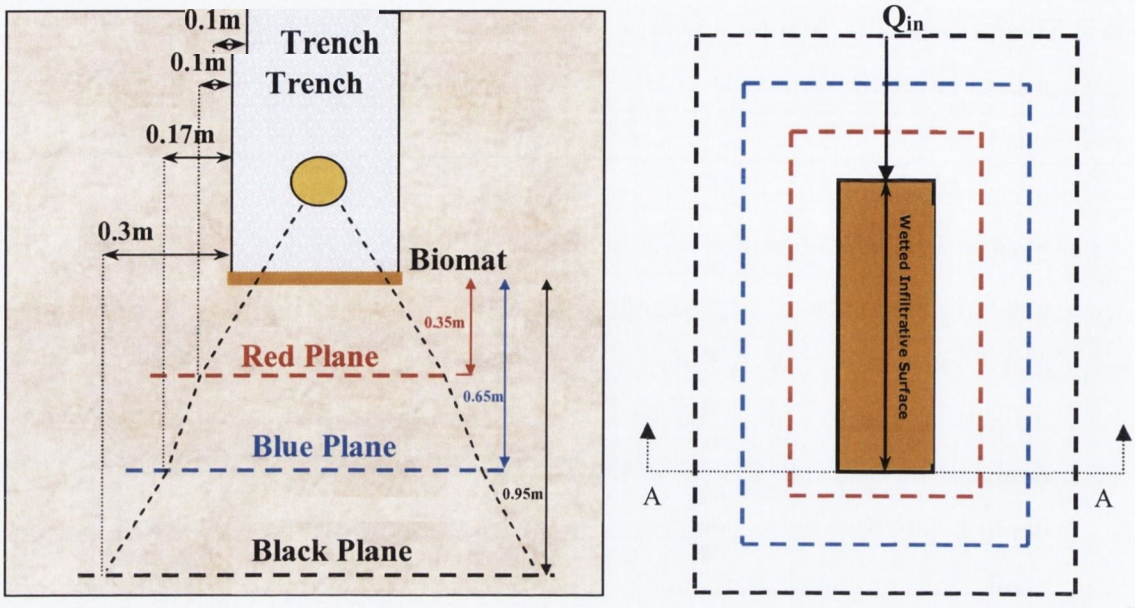


Figure 7.19 Plan and section-view of trench receiving STE, showing the estimated zone of contribution of effective rainfall at each depth plane

In order to corroborate the (i) findings on dilution effects and (ii) dispersion of the effluent, it was useful to examine the response of the tensiometers against effective rainfall at three strategic sample positions [2.5 m (front), 7.5 m (middle) and 17.5 m (back)] along the trenches. As can be seen in Figure 7.20, the tensiometers at the three depth planes at the 17.5 m sample position, where no effluent was recorded, react significantly to the variation in effective rainfall over the total sampling period. During periods of zero effective rainfall, as the soil dries, water becomes less available and the water potential becomes more negative. Vice versa, when the soil becomes more saturated during periods of effective rainfall the soil moisture tension is seen to increase. While the tensiometers at the 2.5 m sample position (Figure 7.21) show some response during high rainfall events, it can be seen that the readings are more changeable and affected to a greater extent by the percolating effluent rather than the contribution of recharge. Hence, it is clear that under the percolation trenches receiving STE it is physical, chemical and biological processes rather than dilution that are the more prominent attenuation processes operating in the vadose zone.

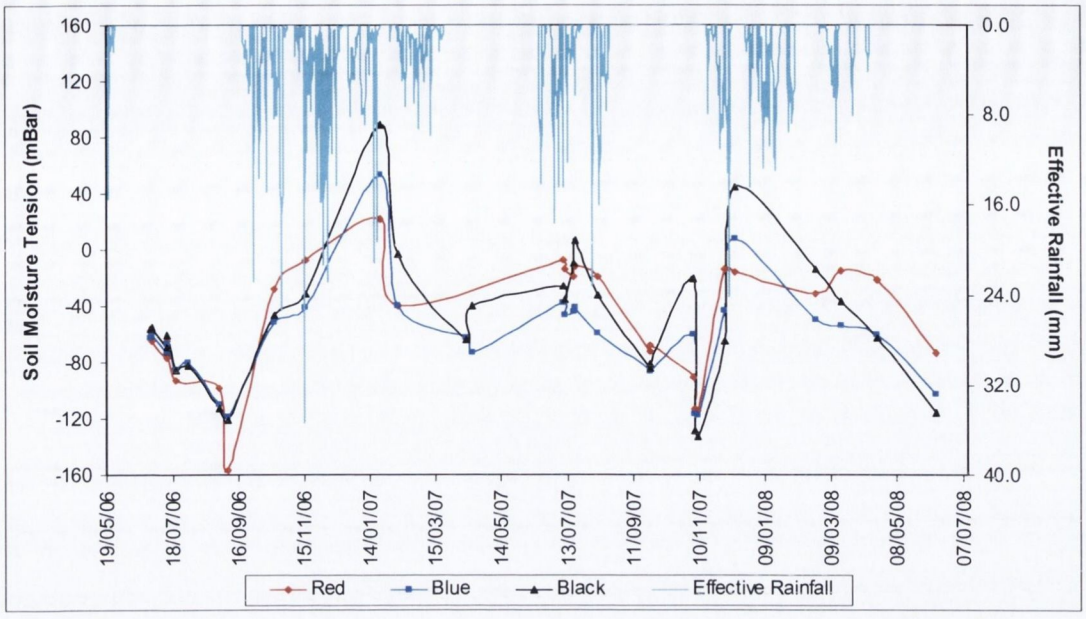


Figure 7.20 Soil moisture tension plotted against effective rainfall for the 17.5 m sample position on the percolation trenches receiving STE (Site A)

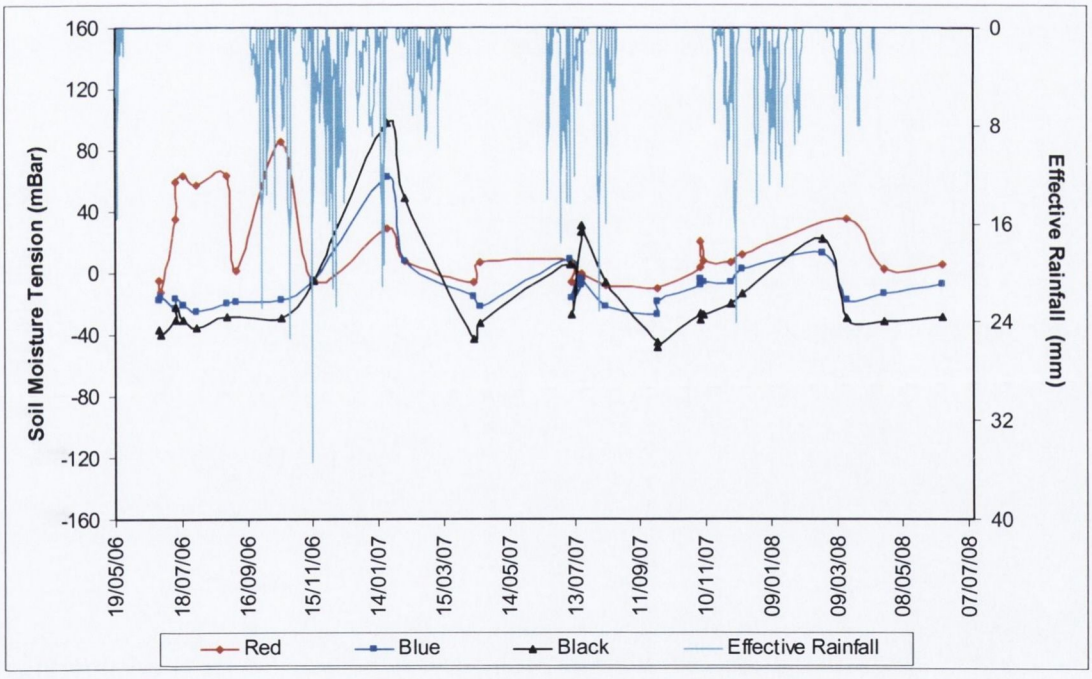


Figure 7.21 Soil moisture tension plotted against effective rainfall for the 2.5 m sample position on the percolation trenches receiving STE (Site A)

System II - Percolation Trenches Receiving RBE (Site A)

Given the fact that little reduction in Cl concentrations occurred across the horizontal SSF reed bed, the effect of dilution by recharge on the percolation trenches receiving

RBE was naturally found to be similar to that of the trenches treating STE. Again, a plot of Cl concentrations in the RBE and at the depth planes (Figure 7.22) shows a number of occasions when the latter were greater than the former due to time-lapse. As such, dates 02/08/06, 08/02/07 and 11/07/07 were omitted from further dilution calculations. During those periods hit by sustained effective rainfall, reductions in Cl concentrations of 53.7%, 56.2% and 77.8% were recorded between the RBE and red, blue and black planes (Table 7.9).

Table 7.10 presents the mean reduction in Cl concentrations between the RBE and three depth planes during periods of zero effective rainfall, as a result of assumed physical straining in the subsoil. The resultant percentage reduction in Cl concentration due exclusively to the dilution effects of recharge were found to be 8.9%, 9.2% and 15.9% at the red, blue and black planes, respectively.

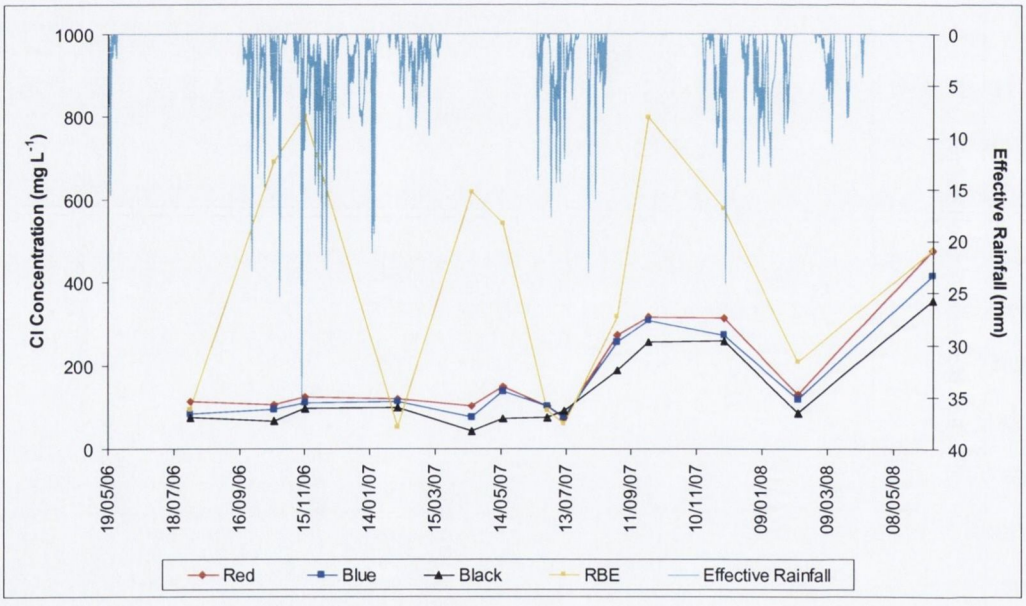


Figure 7.22 The effect of dilution by effective rainfall on Cl concentration for the trenches receiving RBE

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

Date	% Reduction in Cl Concentration from STE		
	Red Plane	Blue Plane	Black Plane
18/10/2006	84.6	86.1	90.3
16/11/2006	84.5	86.0	87.9
05/12/2007	45.8	52.6	55.2
Mean	**53.7**	**58.7**	**77.8**

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

Date	% Reduction in Cl Concentration from STE		
	Red Plane	Blue Plane	Black Plane
18/04/2007	83.5	87.5	93.2
16/05/2007	72.6	74.4	86.3
29/08/2007	13.8	18.6	39.8
27/09/2007	60.4	61.1	67.8
12/02/2008	38.5	42.6	59.2
13/06/2008	0.00	12.8	25.0
Mean	**44.8**	**49.5**	**61.9**

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 16.0 m^2. Multiplying this figure by the total effective rainfall over the sampling period of 1 114 mm equates to a total volume of effective rainfall at the red depth plane of 17.8 m^3. As noted by the Cl analysis and subsequent CCTV investigation, percolation trenches 4, 5 and 6 saw a reduced dispersion of effluent compared to the trenches receiving STE owing to the additional treatment provided by the reed bed. While significant Cl readings were only recorded to the 5m sample position on both instrumented trenches (4 and 5), the CCTV findings showed the presence of a biofilm at the base of each of the three percolation pipes to just beyond the 5 m distance. Taking a feasible figure of 6.5 m to represent the length of the wetted infiltrative surface on all three percolation trenches receiving RBE, an estimated zone of contribution of effective rainfall of 0.15 m is deduced on all sides of each of the trenches at the red depth plane. Similarly, calculations carried out for the

blue and black planes estimated areal zones of contribution due to recharge of 19.3 m^2 (equivalent to 21.5 m^3 of effective rainfall) and 21.9 m^2 (equivalent to 24.4 m^3 of effective rainfall), respectively. This equates to a 0.25 m width of plume on all sides of the trenches at the blue plane and 0.3 m on all sides at the black plane. Again the effluent plume is seen to increase with depth in the subsoil owing to natural hydrodynamic dispersion of the effluent in the course of its travel (Table 7.11).

Table 7.11 Estimated biomat length and zone of contribution of effective rainfall for percolation trenches receiving RBE

Site B (SE)		Width of plume (m) from edge of trench at depth plane		
	Length of wetted infiltrative surface (m)	0.35 m	0.65 m	0.95 m
Trenches 4, 5 & 6	6.5	0.15	0.25	0.3

With regard to the tensiometers under the percolation area treating RBE, a limited amount of data was lost when the perspex tube at the top of two tensiometers (blue and red at the 2.5 m and 7.5 m sample positions respectively) cracked during the project resulting in a loss of vacuum. This left the blue tensiometer redundant between 26/09/07 and 19/03/08 and the red tensiometer redundant between 18/10/06 and 10/07/07, after which they were both successfully replaced and normal measurement resumed. Otherwise, from the response of the tensiometers to recharge events, it appears from Figures 7.23, 7.24 and 7.25 that the soil moisture tension readings corroborate the Cl analysis in that they show that it is physical, chemical and biological processes, rather than dilution, which are the more prominent effluent attenuation processes. The tensiometers stationed at the 7.5 m and 12.5 m sample positions, where no effluent was recorded according to the Cl analysis, react to the variation in effective rainfall over the duration of the sampling period. Soil moisture tension is seen to increase during prolonged recharge events and drop off as the soil dries out during periods of zero effective rainfall. Conversely, the tensiometers installed at the 2.5 m sampling position, where the dispersion of effluent has been confirmed, appear largely uninfluenced by effective rainfall patterns. This suggests that it is the percolating

effluent that influences the change in soil moisture tension and that the contribution of dilution to effluent attenuation is small, as calculated by the Cl analysis.

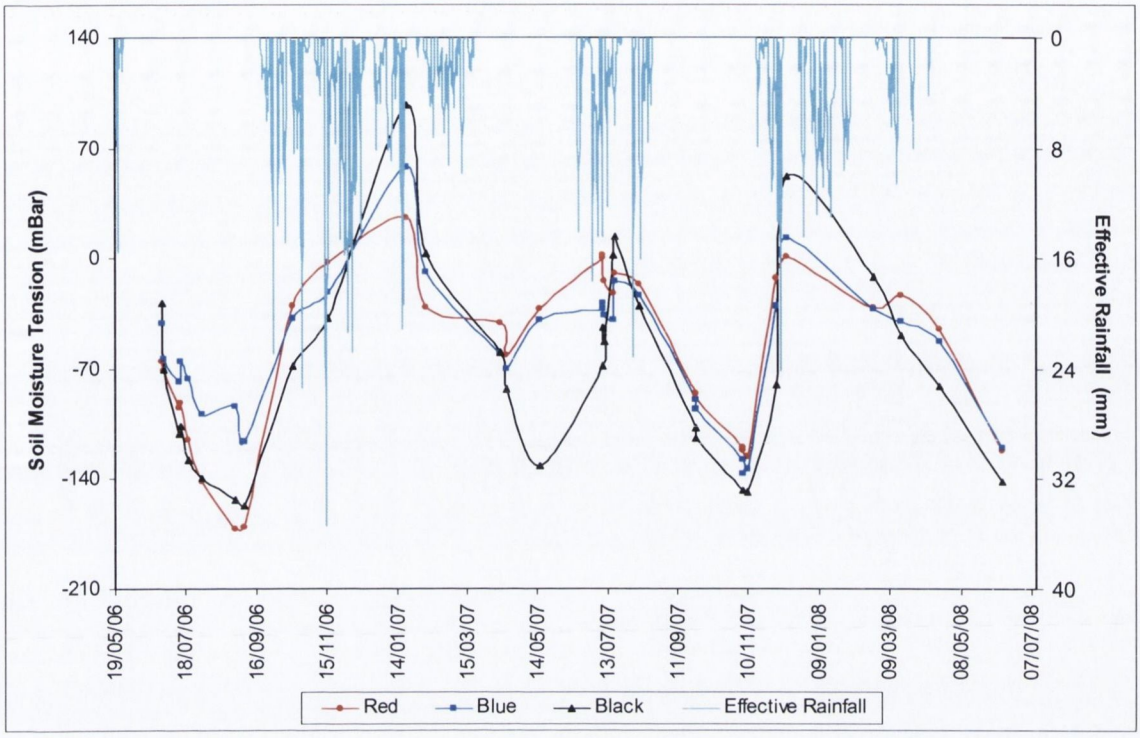


Figure 7.23 Soil moisture tension plotted against effective rainfall for the 12.5 m sample position on the percolation trenches receiving RBE (Site A)

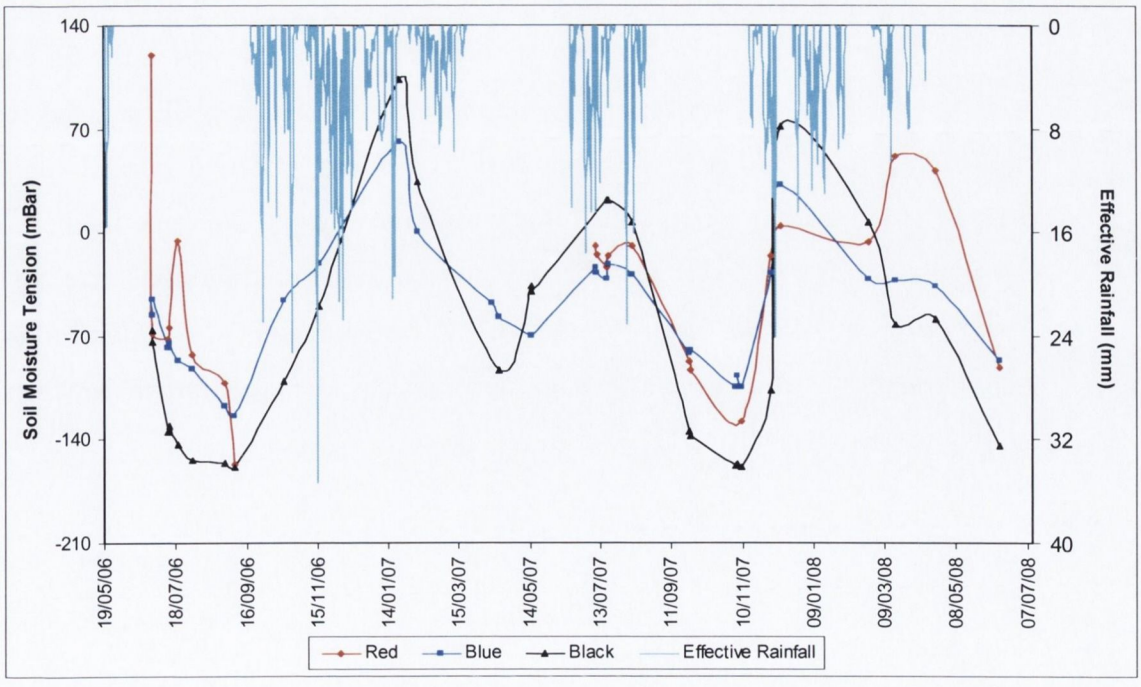


Figure 7.24 Soil moisture tension plotted against effective rainfall for the 7.5 m sample position on the percolation trenches receiving RBE (Site A)

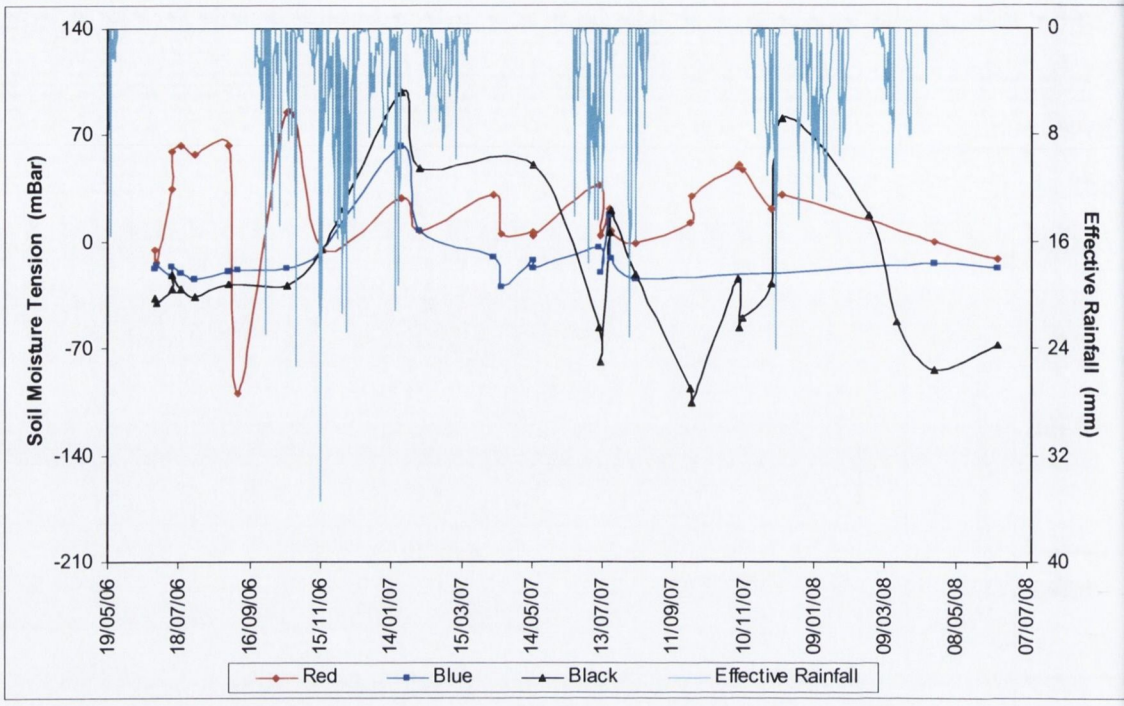


Figure 7.25 Soil moisture tension plotted against effective rainfall for the 2.5 m sample position on the percolation trenches receiving RBE (Site A)

System III: Percolation Trenches Receiving SE (Site B)

In contrast to Site A, quantification of effluent dilution within the subsoil and estimation of the associated zone of contribution proved more problematic for Site B. As can be seen from Figure 7.26 in a plot of the Cl concentrations in the SE and at the three depth planes, the reduction in Cl concentrations between SE and the red plane appear larger, oddly enough, during periods of zero effective rainfall than during periods of sustained recharge. This was corroborated using the same method outlined for Site A in defining the percentage reduction in Cl concentration due to dilution exclusively. As such, findings were thought to be anomalous, it was decided to ignore SE concentrations and instead focus on the difference in concentrations between the red depth plane and the blue and black planes below.

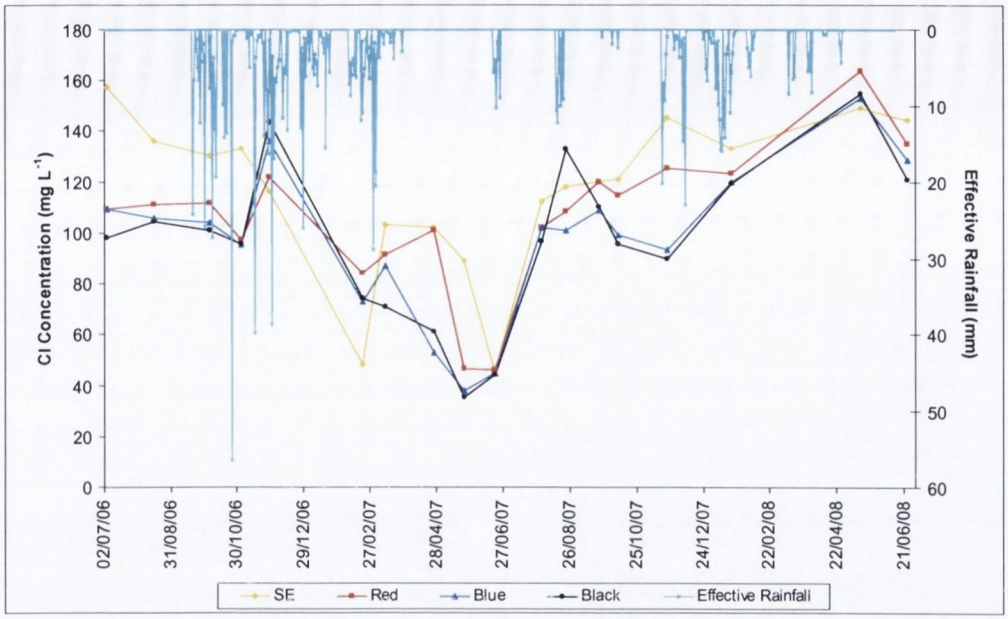


Figure 7.26 The effect of dilution by effective rainfall on Cl concentrations for the trenches receiving SE

When the Cl concentrations at the blue and black planes were examined against the red plane during periods of zero effective rainfall (Table 7.12), it was found that, on average, a 5.2% and 8.9% reduction was achieved (due to retention of colloidal matter). Following a similar calculation for periods hit by high recharge (Table 7.13), it was deduced that a net Cl reduction of 8.1% and 13.2% was recorded across the blue and black planes, respectively, owing to dilution effects only.

Table 7.12 Mean percentage reduction in Cl concentrations between the red depth plane and two other depth planes (blue and black) during periods of zero effective rainfall

Date	% Reduction in Cl Concentration from STE	
	Blue Plane	Black Plane
04/07/2006	0.0	10.1
16/08/2006	4.5	5.9
03/11/2006	2.1	1.6
01/08/2007	0.0	5.4
24/05/2007	18.3	23.7
14/05/2008	6.4	5.2
24/06/2008	4.8	10.4
Mean	**5.2**	**8.9**

Table 7.13 Mean percentage reduction in Cl concentrations between the red depth plane and two other depth planes (blue and black) during periods of effective rainfall

Date	% Reduction in Cl Concentration from STE	
	Blue Plane	Black Plane
05/10/2006	6.7	9.4
21/02/2007	13.1	11.9
13/03/2007	4.4	22.0
26/04/2007	47.5	95.4
20/06/2007	3.3	4.4
22/08/2007	6.5	-
21/09/2007	9.6	8.3
09/10/2007	13.55	16.6
21/11/2007	25.6	28.0
19/01/2008	2.4	2.9
Mean	**13.3**	**22.1**

With a mean concentration of Cl in rainfall at Site B of 4.3 mg L^{-1} and using the mean flows and concentrations recorded on each date of sampling, the areal zone of contribution of effective rainfall for the blue depth plane was estimated to be only 0.75 m^2. Given the total effective rainfall over the sampling period was calculated as 1 167.2 mm, this equates to a total volume of effective rainfall at the blue depth plane of 0.9 m^3. Equivalent calculations carried out for the black plane estimated an areal zone of contribution due to effective rainfall of 2.6 m^2 (equivalent to 3.1 m^3 of effective rainfall). As there was no way to approximate the exact length of wetted infiltrative surface, between the 0 and 5 m sample positions, over which the effluent had spread (no CCTV investigation was carried out on the percolation pipework on Site B), an estimate of 0.4 m was taken. Given the trench width of 0.45 m, this yields a zone of contribution of effective rainfall of 0.1 m and 0.35 m on all sides of each of the trenches at the blue and black depth planes, respectively (Table 7.14). As the red plane lysimeters installed on Site B at the front and directly adjacent to both percolation trenches successfully recorded the presence of effluent and assuming, as in Site A, an increased dispersion of the effluent plume with depth, an average zone of contribution of effective rainfall of 0.05 m was estimated at the red depth plane. The reduced width of the effluent plume at

the red and blue depth planes in the unsaturated subsoil on Site B, in comparison to Site A, is as predicted given the poor biomat formation owing to the reduced hydraulic and organic loading which, along with the high sand and gravel content in the subsoil, has promoted a more pronounced vertical movement of the percolate.

Table 7.14 Estimated biomat length and zone of contribution of effective rainfall for percolation trenches receiving SE

Site B (SE)		Width of plume (m) from edge of trench at depth plane		
	Length of wetted infiltrative surface (m)	0.35 m	0.65 m	0.95 m
Trenches 1 & 2	0.4	0.05	0.1	0.35

Examination of the tensiometers in the percolation area of Site B show a significant reaction to the variation in effective rainfall over the sampling period at all three sample positions [2.5m (front), 7.5m (middle) and 12.5m (back)]. Figures 7.27, 7.28 and 7.29, which present the effective rainfall and soil moisture tension records for the three sample positions, show that the tensiometer readings are substantially affected by the contribution of effective rainfall with little or no interference witnessed from the potential presence of percolating effluent. This corroborates the results from the Cl and other chemical analyses which indicate the effluent has dispersed to between the 0 and 5 m sampling position over the duration of the sampling. Given the high response of the tensiometer readings at the 2.5m sample position to the variation in effective rainfall coupled with the nominal effect of dilution on effluent attenuation, as already ascertained, it is apparent that the percolate had not yet dispersed to the 2.5m sample position by the end of the sampling period. The assumption of 0.4m for the wetted infiltrative surface, taking into account dilution effects, therefore also appears to be reasonable.

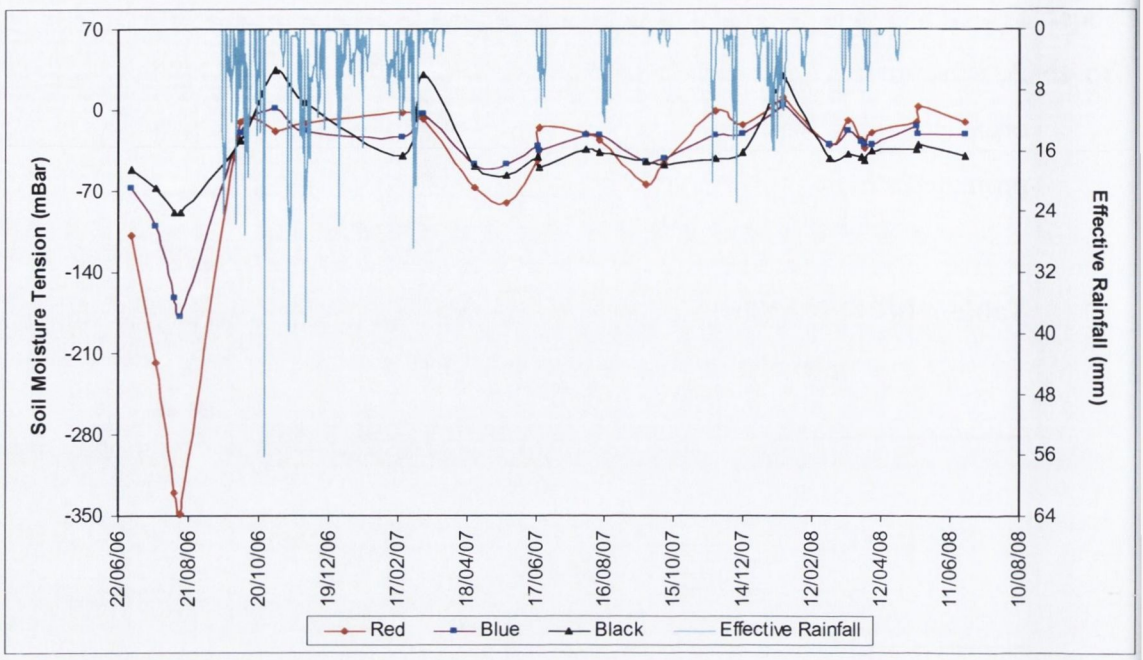


Figure 7.27 Soil moisture tension plotted against effective rainfall for the 12.5 m sample position on the percolation trenches receiving SE (Site B)

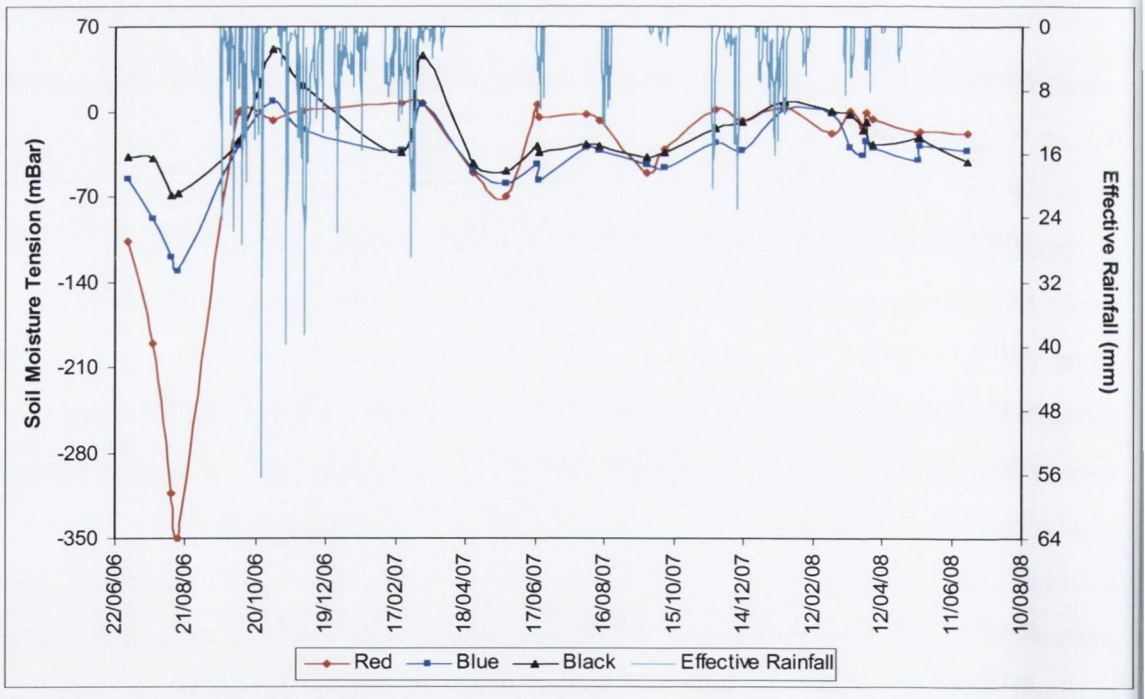


Figure 7.28 Soil moisture tension plotted against effective rainfall for the 7.5 m sample position on the percolation trenches receiving SE (Site B)

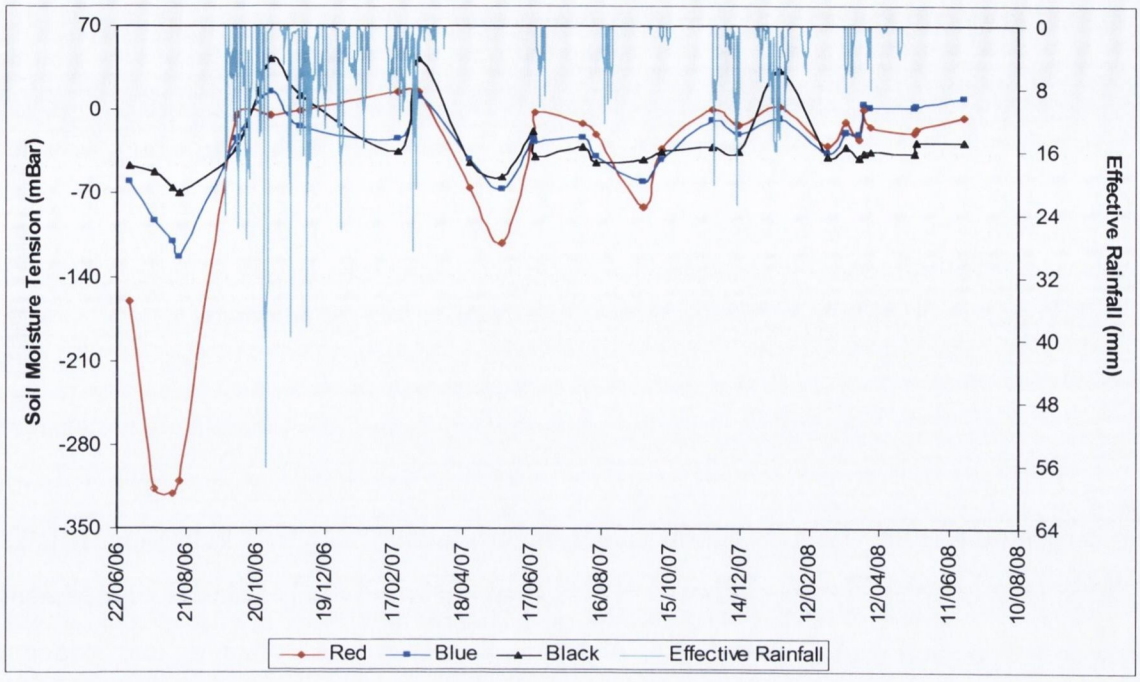


Figure 7.29 Soil moisture tension plotted against effective rainfall for the 2.5 m sample position on the percolation trenches receiving SE (Site B)

7.3.4 Results of Chemical Analysis

The results of all chemical analysis carried out on STE, RBE, SE and soil moisture samples obtained from Sites A and B are contained in Appendix D. In presenting the results of the chemical analysis, pollutant loading rates are reported in addition to parameter concentrations. The pollutant loads from the septic tank to the percolation trenches in System I (Site A) are calculated as the mean daily flow split at distribution box 1 (i.e. 395.4 L d^{-1} see Section 7.2.1) multiplied by the concentration of each STE parameter. Similarly, the mean daily outflow from the horizontal SSF reed bed in System II (Site A) (i.e. 349.9 L d^{-1} – see Section 7.2.1) enabled subsequent calculation of the RBE pollutant loads to the receiving trenches. In System III (Site B) pollutant loads from the *Biodisc*® to the percolation trenches are measured as the product of the mean daily flow split at distribution box 4 (i.e. 132.1 L d^{-1} – see Section 7.2.1) and the concentration of each SE parameter. In contrast, subsoil pollutant loads are measured as the mean daily flow received by the trenches plus any effective rainfall dilution over the zone of contribution multiplied by the mean parameter concentration across the specified depth plane for the two trenches being monitored in each system.

System I – Percolation Trenches Receiving STE (Site A)

Analysis of all the soil moisture samples from each lysimeter on the percolation trenches receiving STE did not reveal any anomalies in the results which would suggest that each sample point was representative of matrix flow. Any possibility of effluent channeling in the vicinity of a lysimeter in the subsoil would, in all likelihood, have been identified by high ammonium concentrations in the percolate.

Table 7.15 presents the results from the COD analysis, which shows that the vast majority of the organic concentration and load is reduced above the red depth plane and/or within the distribution gravel directly under the percolation pipe. It is assumed that the formation of a significant biomat at the infiltrative surface is largely responsible for the 83% removal in organic load through both physical straining and biodegradation processes.

Table 7.15 Reduction in COD load with respect to the STE, attributed to the specific treatment steps

	Mean COD Concentration ($mg\ L^{-1}$)	**Mean COD Load ($g\ d^{-1}$)**	**Cumulative COD Load Removal ($g\ d^{-1}$)**	**Net COD Load Removal (%)**
STE	545.4	216	-	-
Red Depth Plane	84.9	35.9	180.1	83
Blue Depth Plane	69.2	30.0	186	86
Black Depth Plane	68.1	29.9	186.1	86

Extensive biological activity prevails in the biomat with the resident aerobic heterotrophic bacteria dependent on organic carbonaceous material for both energy production and the formation of cell tissue. Further reduction in COD levels is shown to be limited between the red and black depth planes owing to the reduced microbial populations. When Figure 7.30 is further examined it is also clear that the attenuation performance of the subsoil is not affected by the varying organic load of the STE.

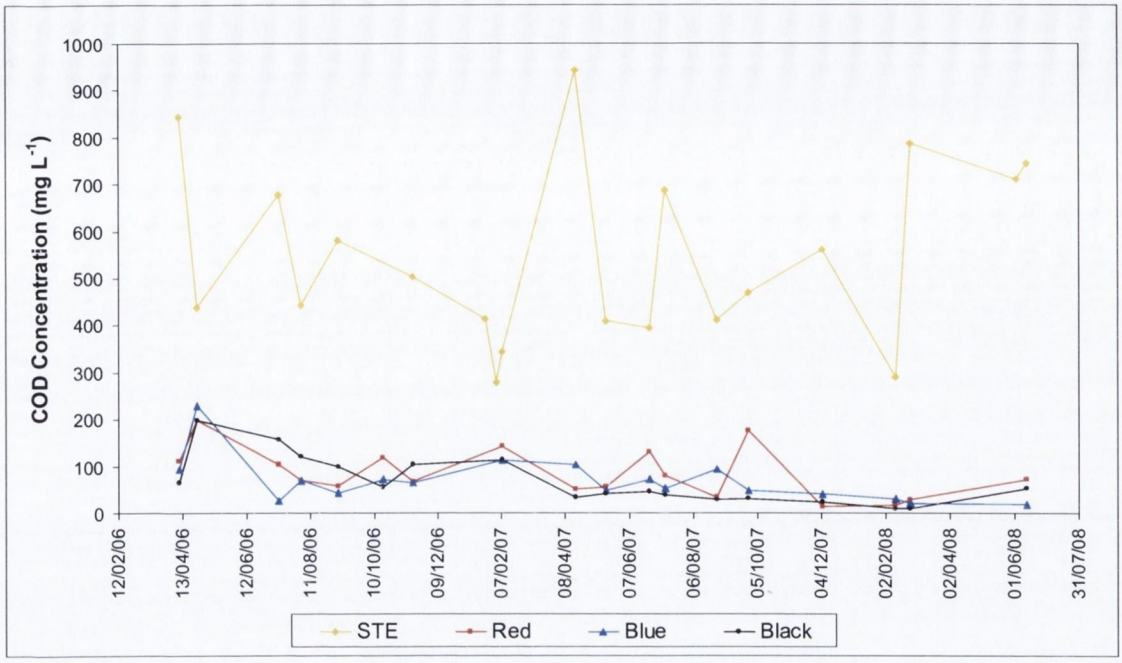


Figure 7.30 COD concentrations in STE and across the three depth planes.

Similarly, nitrogen analysis of the STE and soil moisture samples (Table 7.16) shows that the greatest reduction in total inorganic-N concentration (51%) and load (45%) occurred above the red depth plane (Figure 7.31). 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 percentage of 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. Such a process may occur above the biomat at the infiltrative surface where localised saturated conditions, giving rise to limiting O_2 levels, may have promoted partial sorption of NH_4-N by cation exchange. Nitrification of the remaining NH_4-N above the red depth plane resulted in a jump in NO_3-N from 1.4% to 68.6% of the total inorganic-N in the STE and the percolate at the red depth plane, respectively (Table 7.17). While almost half the total inorganic-N load was removed by the red depth plane, little further loss occurred between the red and black plane. In fact the percolate was still nitrifying between the red and blue plane with the remaining ammoniacal load facilitating the survival of the nitrifying bacteria. Almost complete nitrification was achieved (95.2%) by the black depth plane with minimal subsequent denitrification occurring in tandem.

Table 7.16 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	75.0	29.7	0.2	0.09	1.1	0.4	76.3	30.2
Red	10.2	4.4	1.6	0.69	25.8	11.4	37.6	16.5
Blue	4.9	2.2	0.6	0.26	31.2	14.9	36.7	17.4
Black	1.4	0.7	0.1	0.04	30.1	14.6	31.6	15.3

Table 7.17 Average breakdown 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	98.3	0.3	1.4
Red Depth Plane	27.1	4.3	68.6
Blue Depth Plane	13.4	1.6	85.0
Black Depth Plane	4.4	0.3	95.2

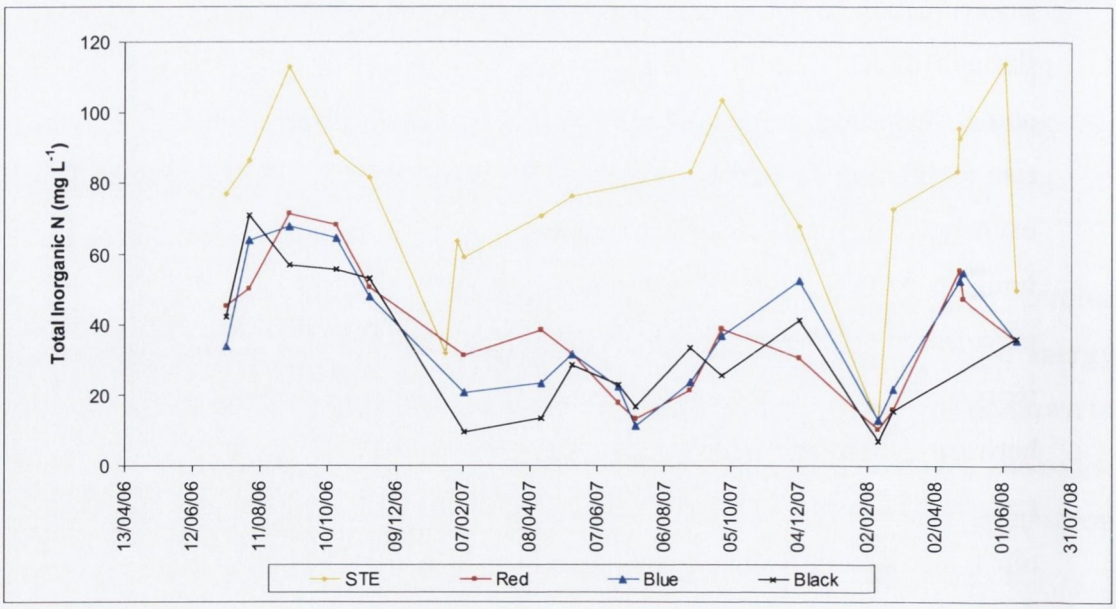


Figure 7.31 Total inorganic-N concentrations in the STE and across the three depth planes

As illustrated in Figure 7.32, the greatest increases in NO_3-N levels between the red and blue/black depth planes occurred during periods of zero effective rainfall (April – September 2006, May 2007, September – October 2007) which may be related to increased aerated conditions in the subsoil. Conversely, given the little nitrification occurring during periods of high effective rainfall and thus potentially localised saturated conditions, denitrification of nitrified NH_4-N was seen to be minimal (with the exception of 08/02/07) between the depth planes.

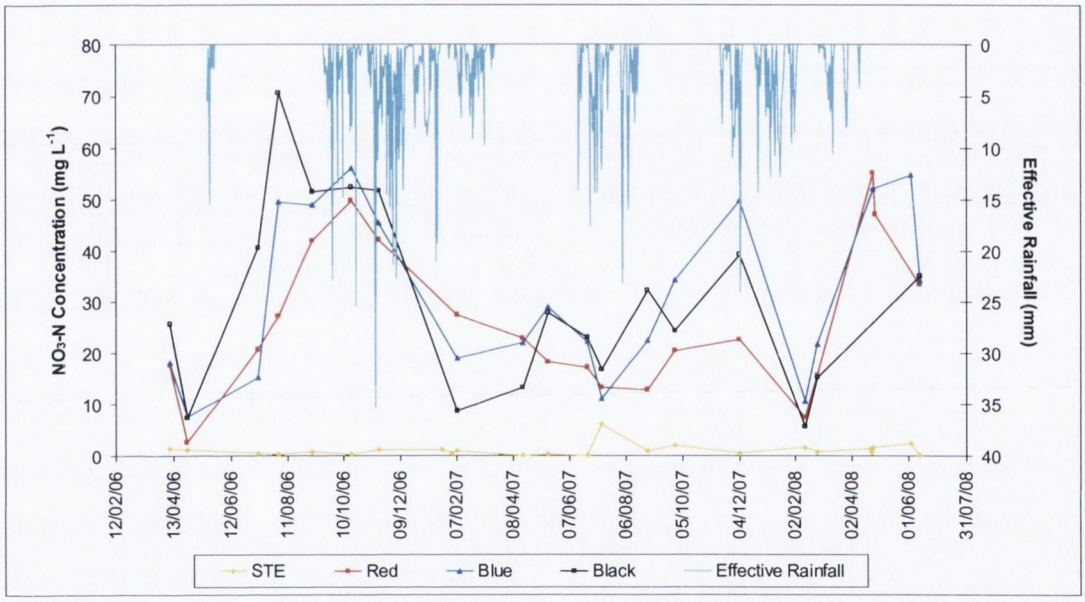


Figure 7.32 NO_3-N concentrations in the STE and across the three depth planes

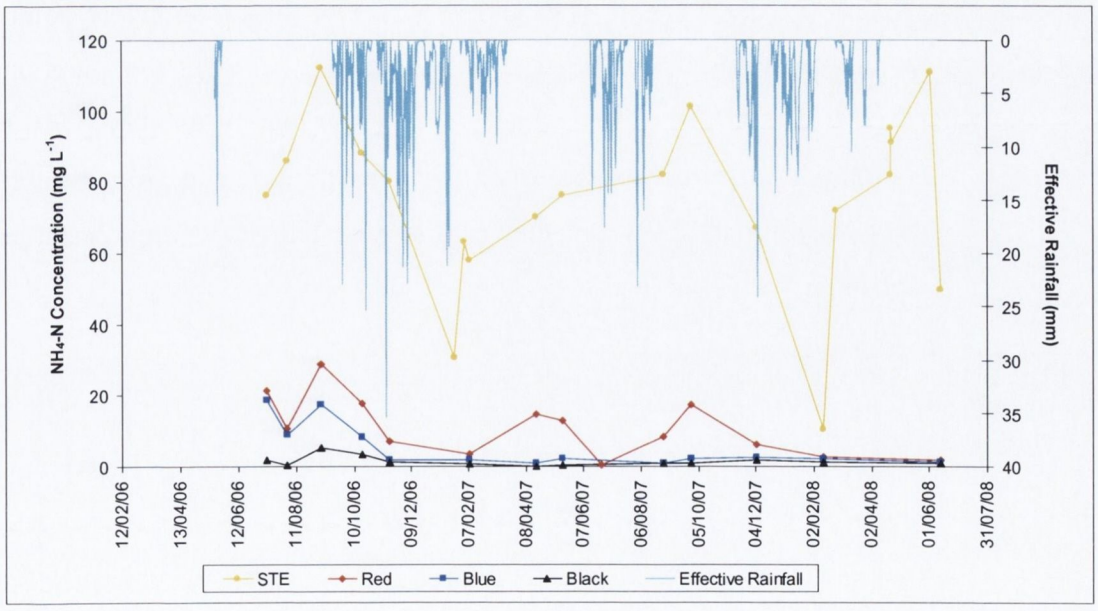


Figure 7.33 NH_4-N concentrations in the STE and across the three depth planes

This confirms that nitrification is the dominant nitrogen process in the subsoil and any

significant denitrification has been confined to the base of the percolation trench in the biomat where both denitrifying bacteria and carbon levels are in abundance. The inability of the highly permeable subsoil to denitrify and thus reduce the total inorganic-N load of the percolate on its path to groundwater is highly significant. In addition, despite the genesis of a biomat along the infiltrative surface and its ability to promote an unsaturated flow regime through providing more uniform temporal and spatial infiltration over time, the greater effluent velocity and thus reduced purification capacity in such highly permeable subsoil is most probably the key factor in the poor reduction in nitrogen loads. The resultant impact on localised groundwater quality was continuously measured by the installed groundwater boreholes upstream and downstream of the percolation area. Consistently elevated Cl concentrations were recorded at the downstream groundwater monitoring point which corresponded closely to the results at the black plane (Figure 7.34), thus confirming effluent infiltration to groundwater. Given the poor levels of denitrification achieved in the unsaturated subsoil under the percolation area, nitrate contamination originating from anthropogenic activities poses a significant risk to groundwater quality. NO_3-N concentrations were seen to rise rapidly between upstream and downstream groundwater sampling points with the latter fluctuating in a similar pattern to the black depth plane (Figure 7.35). The potential mean NO_3-N infiltrative concentration to groundwater (28.3 mg NO_3-N L^{-1}), as measured at the black depth plane, was realised in the groundwater point directly downstream with a mean 30.9 mg NO_3-N L^{-1} measured over the duration of the sampling (Table 7.18). This exceeds the drinking water quality standard of 10 mg NO_3-N L^{-1}. In addition it also reveals the effect of rainfall dilution and groundwater dilution to be almost insignificant given the similarity in recorded NO_3-N concentrations at the black plane and in the groundwater.

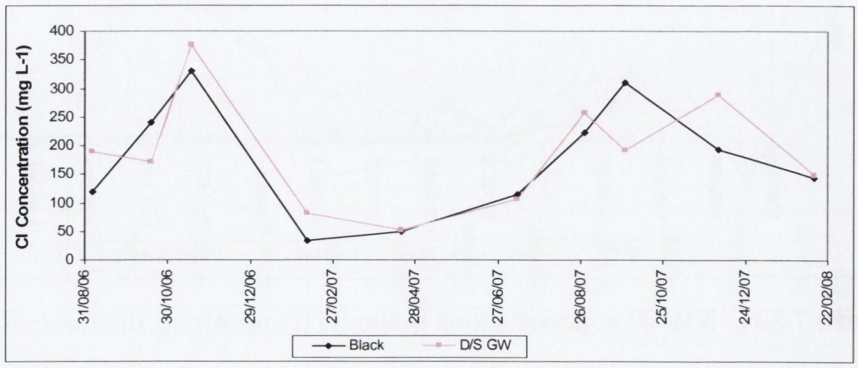


Figure 7.34 Cl concentrations at the black depth plane and groundwater monitoring point located 1 m downstream of percolation area

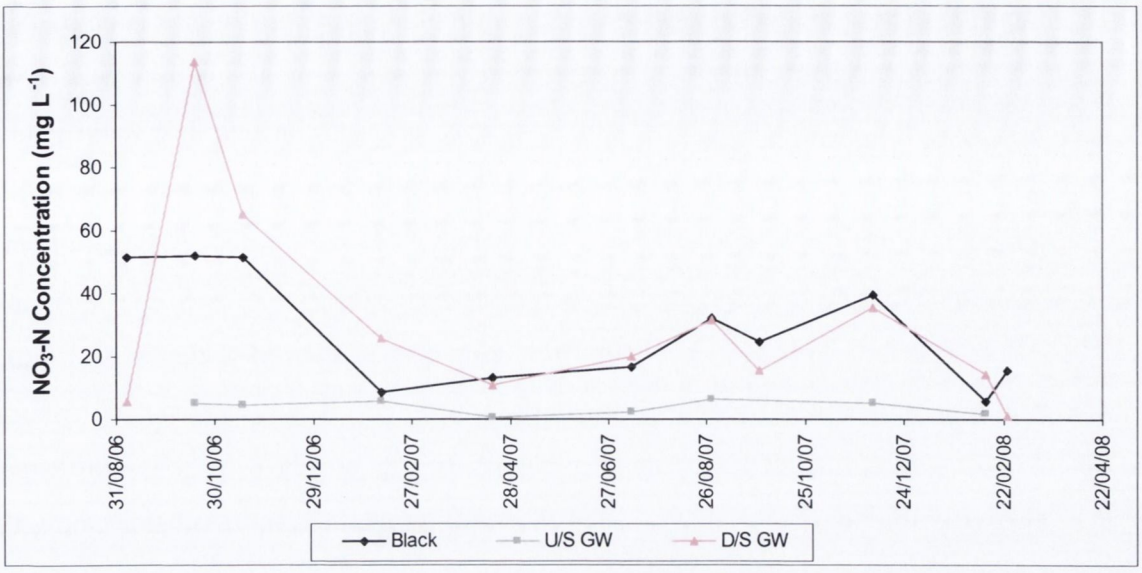


Figure 7.35 NO_3-N concentrations at the black depth plane and from groundwater samples taken upstream and downstream of the percolation area

Table 7.18 Mean NO_3-N concentrations at the groundwater monitoring points and black depth plane

	NO_3-N Concentration (mg L^{-1})		
	U/S GW	D/S GW	**Black Plane**
06/09/06	N/A	5.9	51.4
18/10/06	5.1	114	52.3
16/11/06	4.3	65	51.6
08/02/07	5.6	26	8.6
18/04/07	0.6	10.9	13.3
11/07/07	2.4	20.2	16.7
29/08/07	6.3	31.4	32.2
27/09/07	N/A	15.5	24.5
05/12/07	5.4	35.6	39.2
12/02/07	1.5	14.5	5.8
25/02/08	N/A	1.0	15.4
Mean	**3.9**	**30.9**	**28.3**

N/A = No groundwater sample yielded

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, not least its clay content, 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 and loads in the STE and at the three depth planes reveals the majority of phosphorus fixation (90%) to have occurred above the red depth plane (Table 7.19 and Figure 7.36). In examining the trial hole BS5930 tests revealed the subsoil to be a sandy gravelly SILT/CLAY between 0.4 and 1.0 m depth. Further particle size analysis taken at a depth of 1.0 m below ground level showed the subsoil to contain 20% clay which was later corroborated by X-ray diffraction (XRD) analysis in showing the presence of a minute amount of swelling illite-smectite clay. As such this would mean 0.2 m of subsoil below the base of the percolation trench/infiltrative surface containing soil particles of a larger specific surface which are more conducive to phosphorus adsorption. In retrospect, the presence of small amounts of clay directly below the base of the percolation trench may have promoted increased saturated conditions and aided in the aforementioned loss of NH_4-N by cation exchange at this depth. Further inspection of Figure 7.36 shows that the available sites for PO_4-P adsorption appear only to be reducing around the end period of monitoring, with increasing concentrations recorded at the depth planes at this time. Thus almost complete adsorption of PO_4-P (95.4%) has occurred between the infiltrative surface and the black plane over the first 30 months since system start-up after which the removal efficiency has begun to tail off. While the P-sorption capacity of fine-grained subsoils would be expected to hold for a period of 10 years at least (Jenssen, 2001), the reduced longevity of the coarse textured subsoil on Site A is becoming evident after only a quarter of this time.

Table 7.19 Reduction in PO_4-P load from the STE attributed to the specific treatment steps

	Mean Conc. ($mg\ L^{-1}$)	**Mean Load ($g\ d^{-1}$)**	**Load Removal ($g\ d^{-1}$)**	**% Load Removal**
STE	16.6	6.6	-	-
Red	1.5	0.7	5.9	89.4
Blue	1.0	0.4	0.2	93.9
Black	0.8	0.3	0.1	95.4

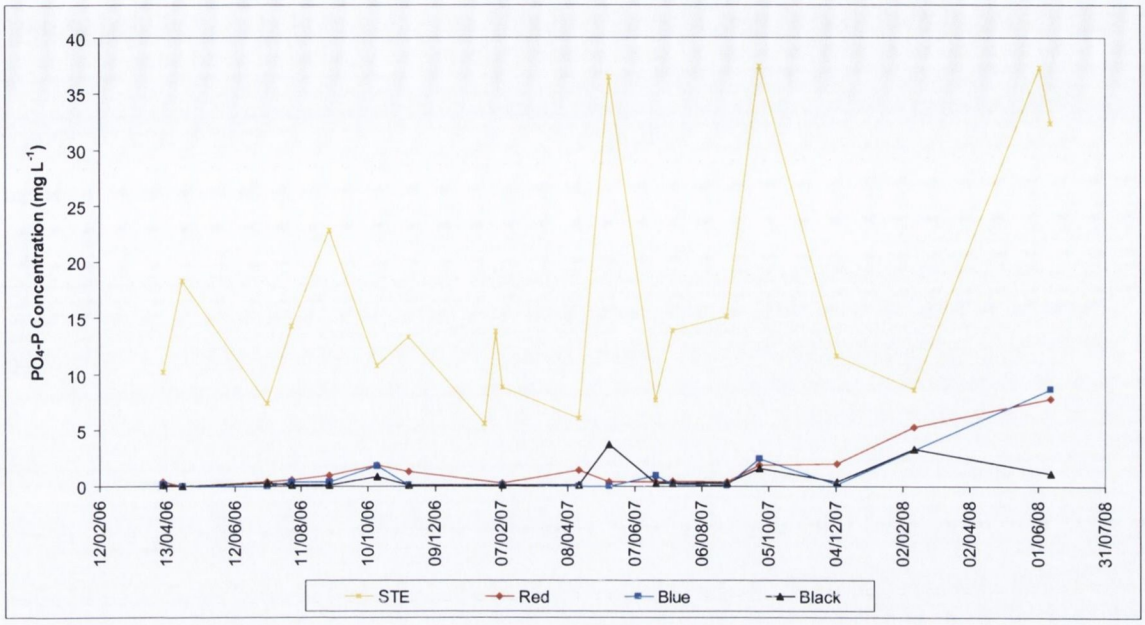


Figure 7.36 Mean PO_4-P concentrations at the three depth planes

System II - Percolation Trenches Receiving RBE (Site A)

Similar analysis is provided for the percolation trenches of System II treating RBE from the horizontal SSF. As such the attenuation capacity of the subsoil is examined at depth with respect to the inflowing RBE only. Removal efficiency between the STE and RBE is analysed in more detail in Chapter 8.

Table 7.20 shows that, as was the case under the percolation trenches receiving STE, the greatest degradation in organic material (61%) occurs above the red depth plane or within the distribution gravel. In fact, it can be seen from Figure 7.37 that, given the similarity between the COD concentrations on each plane over the duration of the sampling period, almost complete attenuation of the organic chemicals in the percolate has been achieved within the system. Levels recorded at the back of the trenches where no effluent was present were also shown to be similar to the black plane results.

Table 7.20 Reduction in COD load with respect to the RBE, attributed to the specific treatment steps

	Mean Concentration (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load Removal (%)
RBE	219.6	60.5	-	-
Red Depth Plane	56.1	23.8	36.7	61
Blue Depth Plane	56.0	23.3	37.2	61
Black Depth Plane	47.4	21.0	39.5	65

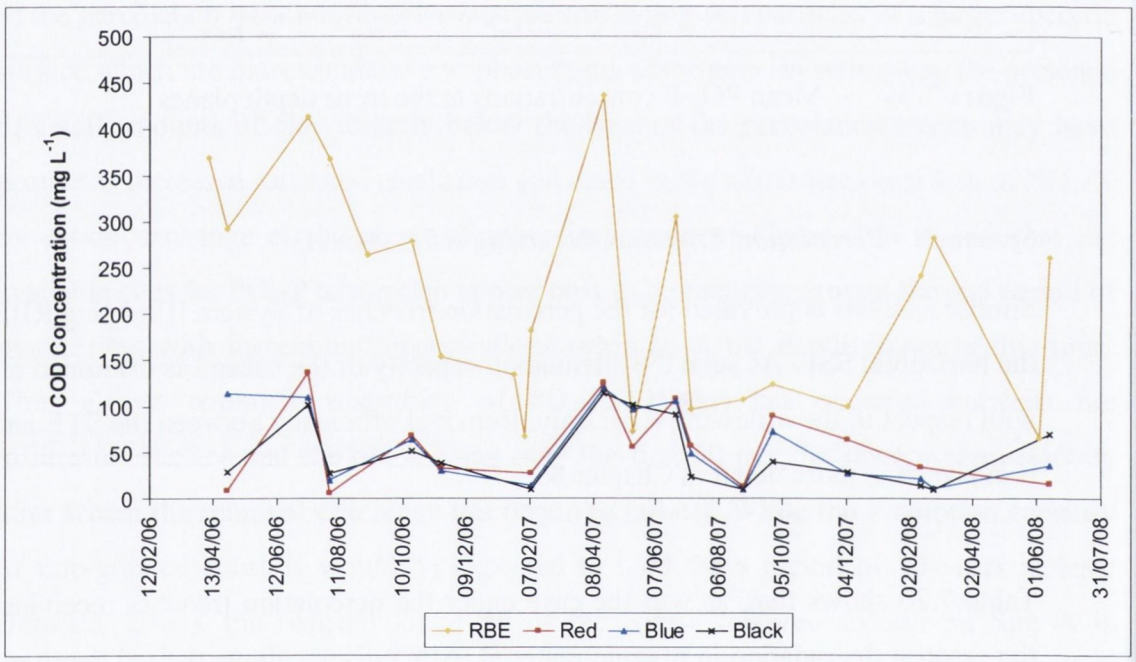


Figure 7.37 COD concentrations in RBE and across the three depth planes

This highlights the fact that despite the influent load to these trenches containing less than one third the amount of organic chemicals found in the STE load, the respective biomat properties and the underlying subsoil have sufficient capacity to degrade both wastewater strengths to comparable levels within 0.95 m of the infiltrative surface.

Analysis of the RBE shows approximately one sixth of the nitrogen load to be in its organic form despite there being favourable anaerobic conditions for mineralisation to NH_4-N available in the septic tank and reed bed. Unfortunately due to analytical constraints TN, from which the organic fraction can be deduced, was not analysed in

the soil moisture samples from this set of percolation trenches over a considerable period of time. A number of samples from the three depth planes were, however, tested for TN on a short-term basis and showed the org-N fraction to be almost zero. In any case, given the rapid conversion of NH_4-N to its solubilised form above the red depth plane in the trenches treating STE, it is thought any little org-N in the percolate was quickly mineralised in the distribution gravel of the trenches without playing any significant part in nitrogen kinetics in the subsoil.

With the vast majority (99%) of the inflowing RBE inorganic nitrogen load in NH_4-N form (Table 7.21), a combination of the aerobic environment of the distribution gravel, the abundance of thriving nitrifiers beneath the biomat, and the many chemical and biological processes within the subsoil matrix have facilitated almost complete (93%) nitrification of the percolate to NO_3-N above the red depth plane. However, like the trenches treating STE, it was found that the decrease in NH_4-N recorded across the red depth plane did not correspond to the increase in NO_3-N levels at the same depth. Again, the saturated conditions thought to be present directly below the percolation trenches may have promoted sorption of NH_4-N by cation exchange which would have the effect of removing NH_4-N directly from the percolating effluent. In examining the NO_3-N trend over time (Figure 7.39) it can be seen that the greatest instances of nitrification above the red depth plane occurred during periods of minimal effective rainfall. Interesting to note also was that any reduction in nitrogen load provided by the reed bed was nullified within the first 0.35 m of unsaturated subsoil where total inorganic-N concentrations and loads were found to be the same for both sets of percolation trenches (i.e. those receiving STE and those treating RBE). The subsequent reduction in NO_3-N and total inorganic-N concentrations between the red and black depth planes are owing to a combination of dilution and denitrification. Figures 7.39 and 7.40 highlight three sampling dates in particular which are responsible for the significant loss in nitrogen in the system (18/10/06, 18/04/07 and 27/09/07). Sustained effective rainfall recorded around 18/10/06 promoted saturated conditions in the subsoil as corroborated by the tensiometers (Figure 7.25). Coupled with sufficient carbon levels these conditions would be ideal for denitrification processes. COD concentrations on 18/04/07 and to a lesser degree on 27/09/07 were shown to be significantly greater than the mean levels recorded across the three depth planes over the duration of the project. This would act to accelerate any occurring denitrification. It is interesting to note

denitrification, sporadic though it is, occurring under these set of trenches in contrast to the trenches receiving STE (*System I*). A possible explanation for this may be in the reduced carbon loads from the reed bed on System II giving the nitrifiers a better chance of competing with the heterotrophs, thus providing greater nitrification of the percolate. The potential for greater denitrification follows on as a result.

Table 7.21 Mean concentrations and loading rates of NH_4-N, NO_2-N, NO_3-N and total inorganic-N measured in the RBE 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 ($g\ d^{-1}$)
RBE	58.0	21.1	0.1	0.02	0.4	0.14	58.5	21.3
Red	2.7	1.3	0.3	0.13	36.6	17.4	39.6	18.8
Blue	2.5	1.3	0.2	0.07	31.5	15.4	34.2	16.8
Black	1.2	0.5	0.1	0.04	26.1	13.2	27.4	13.8

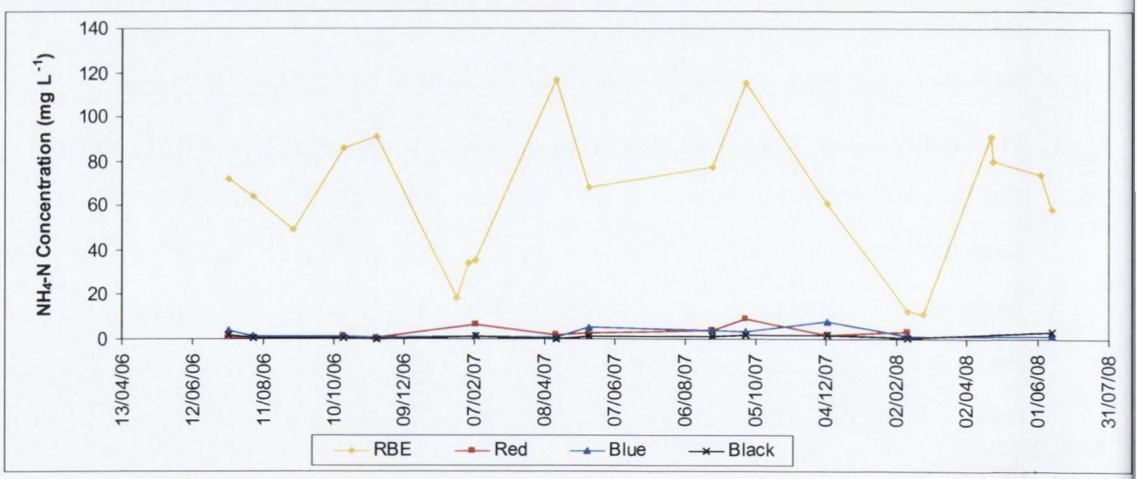


Figure 7.38 NH_4-N concentrations in the RBE and across the three depth planes

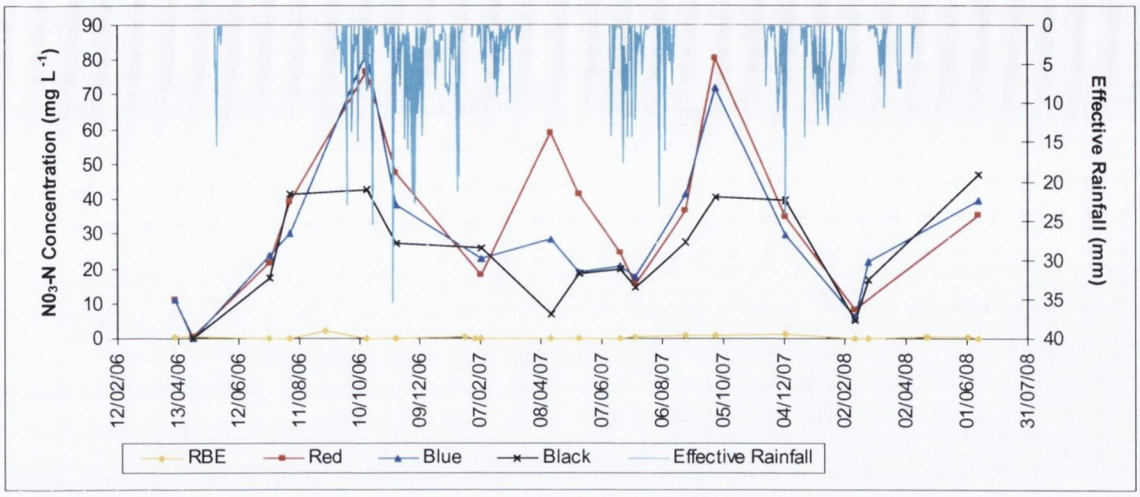


Figure 7.39 NO_3-N concentrations in the RBE and across the three depth planes

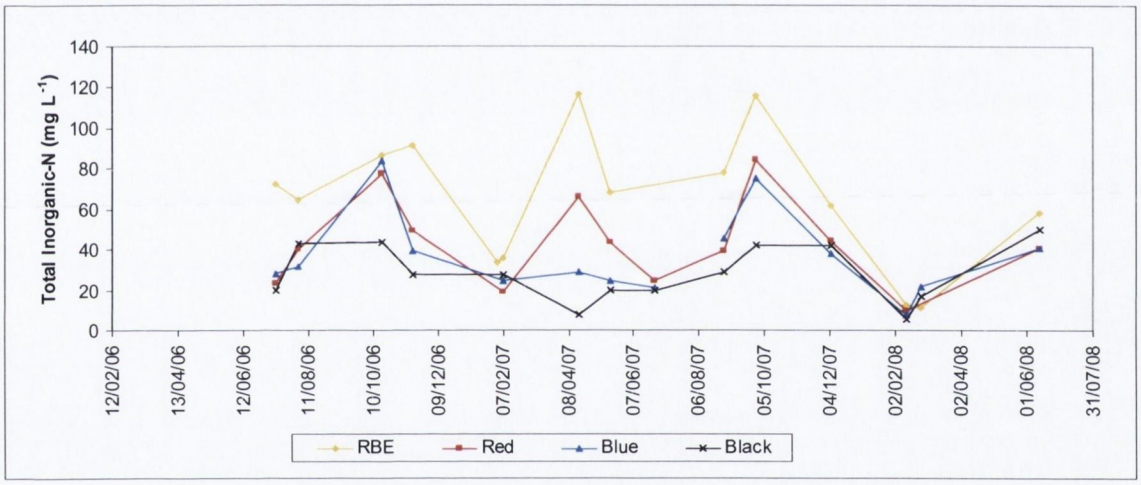


Figure 7.40 Total inorganic-N concentrations in the RBE and across the three depth planes

Removal of PO_4-P in the subsoil again is impressive with very similar planar percentage load removals to the subsoil treating STE (Table 7.22). This ties in quite nicely given the discharging RBE contains half the PO_4-P load of the STE but the resultant wetted infiltrative surface length of the RBE is half that of the STE. Again the greatest removal is seen to occur in the first 0.35 m owing to the presence of clay particles (20%) in the matrix. This supports the view that adsorption of PO_4-P to the soil is the dominant removal mechanism. Given the absence of Al, Fe and Mn, oxides, hydrous oxides or dissolved ions in the soil, as revealed by X-ray diffraction, P fixation would be confined to the high pH range. Examination of the latter shows consistently high percolate pH values ($\geq$8.0) throughout the sampling period which may therefore have contributed to the fixation. The finite capacity of the subsoil to adsorb PO_4-P is

again highlighted in Figure 7.41 with planar concentrations seen to gradually rise after 21 months of the system in operation.

Table 7.22 Reduction in PO_4-P load with respect to the RBE, attributed to the specific treatment steps

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Load Removal (g d^{-1})	% Load Removal	pH
RBE	9.6	3.5	-	-	7.4
Red	1.3	0.6	2.9	82.9	8.1
Blue	1.3	0.6	2.9	82.9	8.0
Black	1.0	0.4	3.1	88.6	8.0

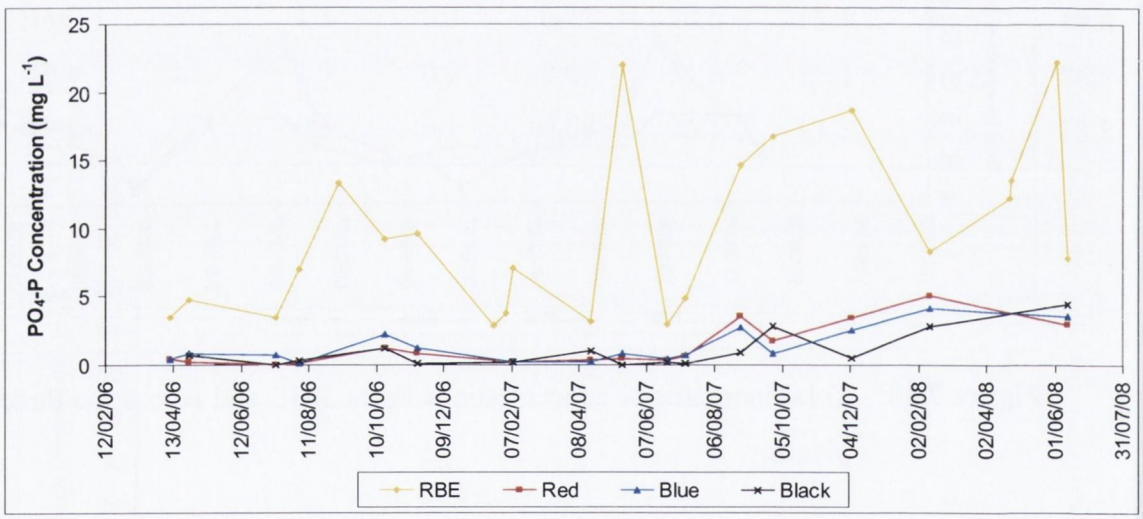


Figure 7.41 PO_4-P concentrations in the RBE and across the three depth planes

System III - Percolation Trenches Receiving SE (Site B)

As already outlined in Section 7.3.1 – 7.3.3, biomat formation under the percolation trenches on Site B had been inhibited due to the reduction in effluent solids and organic loading provided by the secondary treatment *Biodisc*® system. While breakdown in COD within the subsoil is attributed to aeration, physical straining and biological degradation, the reduced organic load of the SE has failed to significantly stimulate bacterial activity along the infiltrative surface to promote biomat formation along the entire base and side-walls of the percolation trenches. This had the effect of concentrating the effluent at the

very front of the percolation area thereby reducing the effects of other attenuation processes such as dilution, dispersion, advection and diffusion within the vadose zone. A localised hydraulic load infiltrating through a highly permeable medium may pose a particular risk to groundwater quality given its bacteriological and chemical constituents are concentrated over a smaller area thus limiting attenuation potential and possibly leading to elevated contaminant concentrations in the groundwater.

It is clear from Table 7.23 and Figure 7.42 that, despite fears attenuation processes may be affected by the absence of a significant biomat, the greatest reduction in effluent COD load and concentration occurs in the subsoil above the red depth plane or within the distribution gravel. Over two thirds (67.6%) of the SE organic load is removed by a maximum depth of 0.35 m below the infiltrative surface with only a further 11.2% reduction achieved in the subsequent 0.6 m of unsaturated subsoil before reaching the black depth plane (0.9 m). Little organic breakdown has occurred between the blue and black depth plane owing to a number of reasons; (i) oxygen deficiencies, unlikely though it is in such freely draining soil and/or (ii) low heterotroph numbers present. Most likely however is that organic levels have approached background concentrations or the mean 40 mg L^{-1} recorded represents the non-biodegradable component of the organic chemicals remaining in the percolate, thus resulting in a tail-off in removal at this depth.

Table 7.23 Reduction in COD load with respect to the SE, attributed to the specific treatment steps

	Mean Concentration (mg L^{-1})	Mean Load (g d^{-1})	Cumulative Load Removal (g d^{-1})	Net Load Removal (%)
SE	193.1	25.5	-	-
Red Depth Plane	62.9	8.6	16.9	67.6
Blue Depth Plane	41.4	5.6	19.9	78.0
Black Depth Plane	40.0	5.4	20.1	78.8

In order to evaluate whether the large removal in COD load above the red depth plane occurred mainly as a result of aerobic processes within the distribution gravel of the percolation trench or in the biomat or indeed the subsoil below the infiltrative surface,

an estimate calculation of the mass of O_2 available in the percolation trenches is worthwhile. With a gravel layer of 0.5 m thickness in each 16 m length trench this equates to a total gravel volume of 6.88 m^3 in the percolation area, or 3.44 m^3 in each trench. Assuming a porosity of 50% provides 6.88 m^3, or 8.43 kg, of air space (density of air = 1.226 kg m^{-3}). Since air is 21% O_2, this means there was 1.77 kg of oxygen available in the distribution gravel. When the volume of air contained in the percolation pipe is included this increases to 1.82 kg O_2 which is regarded as more than sufficient to maintain the concentration gradient across the biofilm and to sustain aerobic processes. The O_2 demand required in achieving this reduction between the SE and red depth plane, 130.3 mg L^{-1} d or 0.017 kg d^{-1}, is therefore thought to be present within the distribution gravel in the percolation trench. Any additional reduction in COD concentration within the subsoil would result from a combination of physical straining (filtration), sorption and biodegradation processes.

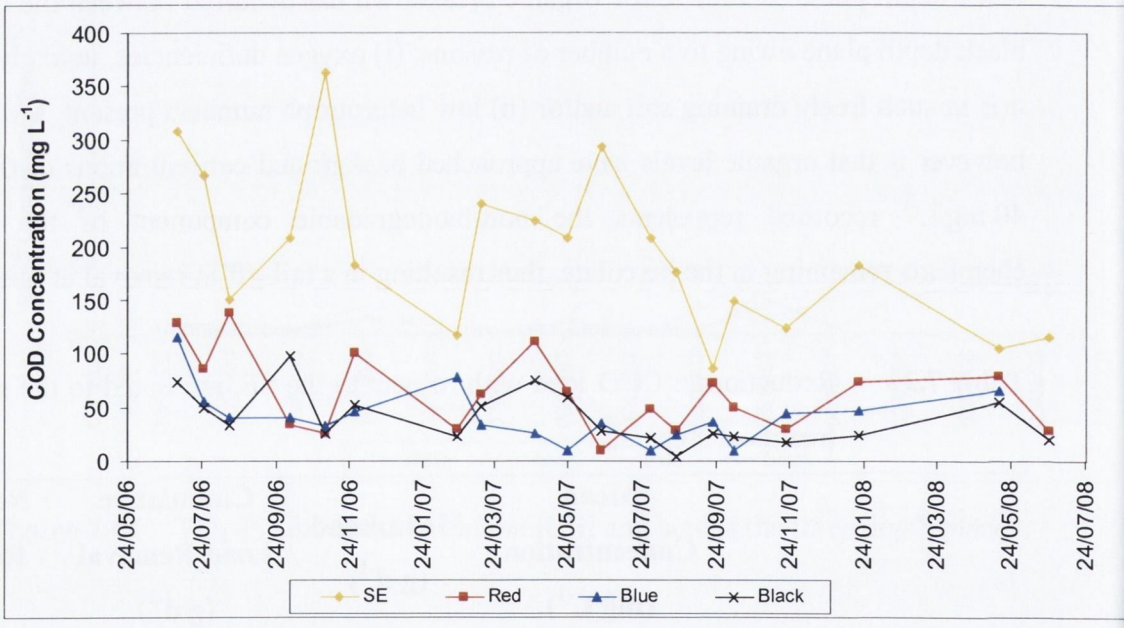


Figure 7.42 COD concentrations in SE and across the three depth planes

SE from the *Biodisc*® underwent complete nitrification within the first 0.35 m of subsoil, as shown by the conversion of the majority of NH_4-N and NO_2-N to its NO_3-N form by the red depth plane (Table 7.24 and Figures 7.44 and 7.45). As detailed in Section 6.3.2, nitrification in the first stage biozone was muted between November 2006 and May 2007 owing to excessive solids accumulation and organic loading in the system which limited the performance of the nitrifiers. As such, NO_2-N concentrations were elevated during this period (Figure 7.43). Table 7.25 displays nitrogen

concentrations and loadings when data from this period (dates 28/11/06, 26/01/06, 21/02/07, 13/03/07, 26/04/07 and 24/05/07) were omitted. Upon inspection similar nitrification rates are observed in both sets of data despite contrasting NO_2-N concentrations in the SE highlighting the capacity of the distribution gravel and underlying subsoil to oxidise all nitrogenous forms to NO_3-N.

Table 7.24 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	19.2	2.5	14.5	1.7	35.3	4.7	69.0	8.9
Red	0.8	0.1	3.8	0.6	68.1	9.2	72.7	9.9
Blue	0.4	0.1	2.2	0.3	55.0	7.4	57.6	7.8
Black	0.6	0.1	1.4	0.2	55.6	7.4	57.6	7.7

Table 7.25 Adjusted mean concentration and loading rate 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	15.6	2.1	0.9	0.1	44.9	5.9	61.4	8.1
Red	0.6	0.1	0.4	0.1	65.6	8.7	66.6	8.9
Blue	0.5	0.1	0.7	0.1	52.0	6.9	53.2	7.1
Black	0.7	0.1	0.2	0.01	52.6	7.0	53.5	7.1

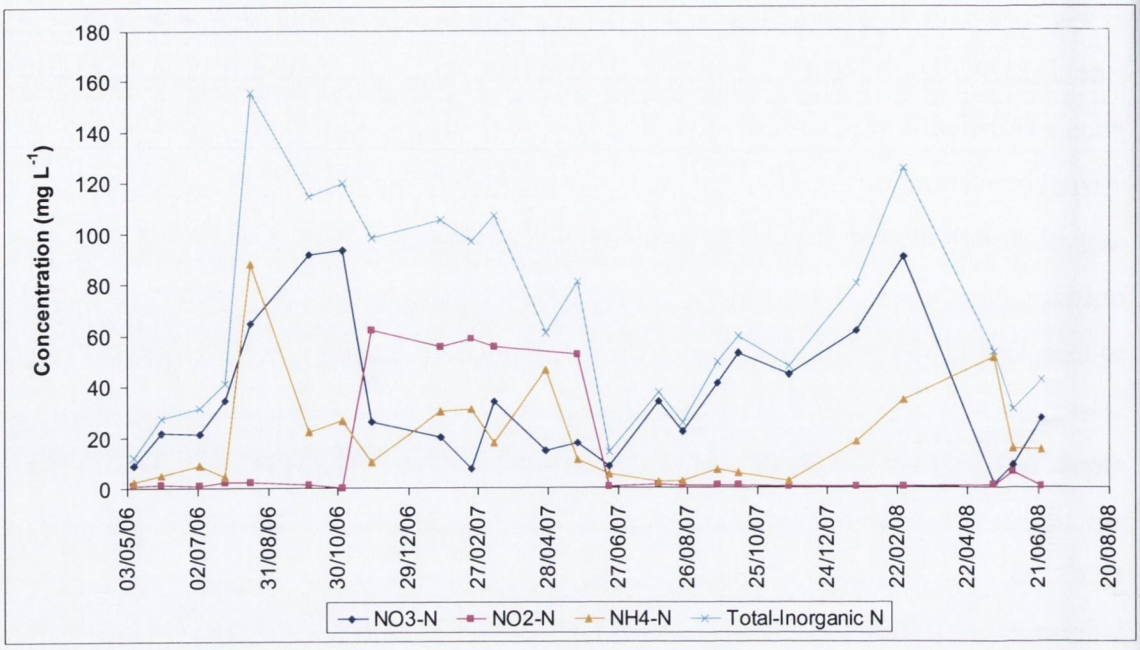


Figure 7.43 Time series plot of nitrogenous compounds in the SE on Site B including elevated NO_2-N concentrations between Nov '06 and May '07

While nitrification was dominant in the first 0.35 m of unsaturated subsoil, as reinforced by a decrease in the mean pH from 7.2 to 7.0, between the SE and red depth plane respectively (Table 7.26), there was no parallel reduction in total inorganic-N loading in the percolate over the same subsoil thickness. Furthermore, between the red and black depth planes, only a small reduction in the total inorganic-N concentration and load occurred with subsoil depth (Table 7.26 and Figure 7.46). With little NH_4-N load in the percolate, any reduction in total inorganic-N load was solely related to the slight reduction of NO_3-N to gaseous nitrogen (Table 7.26 and Figure 7.45). This was reflected by an increase in pH from 7.0 on the red and blue planes to 7.6 on the black plane, a result of the denitrification process. In examining the rise in magnitude of the pH and given that it is thought denitrification would only recover approximately half of the alkalinity used by the nitrification process, it is possible that the initial pH loss was muted by the mineralogy of the limestone-derived subsoil present. In spite of the occurrence of denitrification it is more likely, though, that dilution has played the dominant role in the N-attenuation processes. The reason for this is well founded. Facultative anaerobic heterotrophic bacteria responsible for denitrification require, not only saturated subsoil conditions, but also a supply of organic matter from which to maintain their energy and carbon for metabolism. It is clear from the COD results that the large reduction in organic load between the SE and red depth plane samples has

resulted in COD concentrations approaching background levels. With little further COD removal with depth it is likely that the organic load in the subsoil was insufficient for adequate bacterial metabolism to promote significant denitrification. In addition, the rapid infiltration of the secondary treated effluent, owing to the highly permeable soil and poor biomat development along the base and side-walls of the trenches, would have promoted and maintained unsaturated aerobic conditions unsuitable for denitrification of the percolate.

Table 7.26 The mean breakdown of total inorganic-N in SE and across the three depth planes

	% of Total inorganic-N			Mean pH
	NH_4-N	NO_2-N	NO_3-N	
SE	28.0	19.2	52.8	7.2
Red Depth Plane	1.1	6.0	92.9	7.0
Blue Depth Plane	1.3	3.8	94.9	7.0
Black Depth Plane	1.3	2.6	96.1	7.6

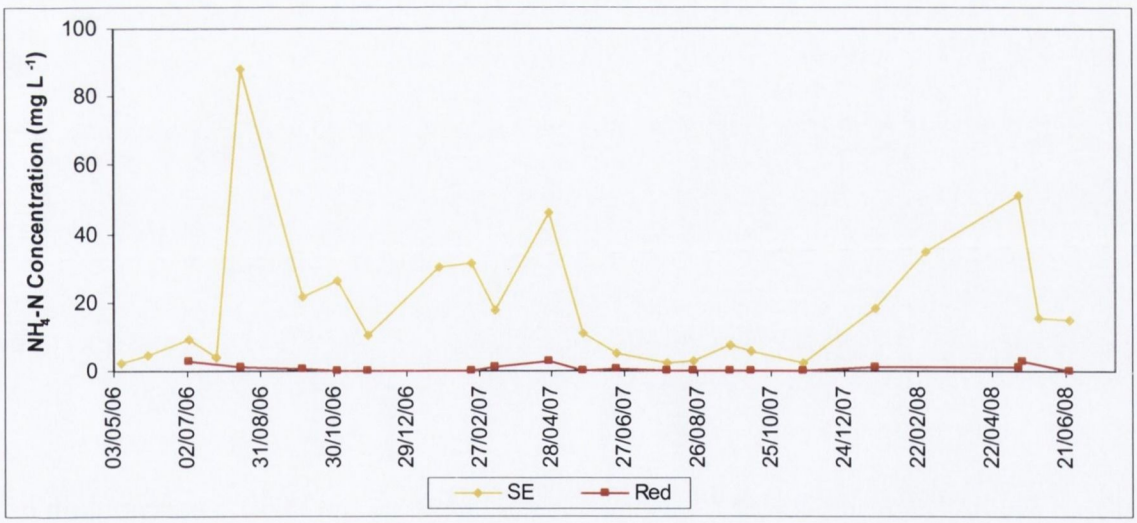


Figure 7.44 Reduction in NH_4-N concentrations between the SE and red depth plane

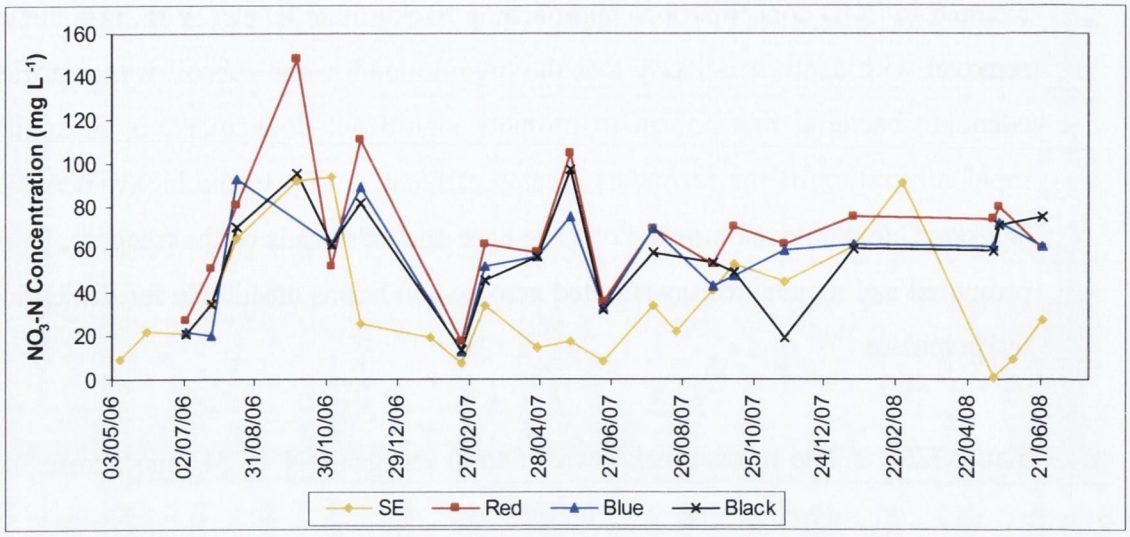


Figure 7.45 NO_3-N concentrations in the SE and across the three depth planes

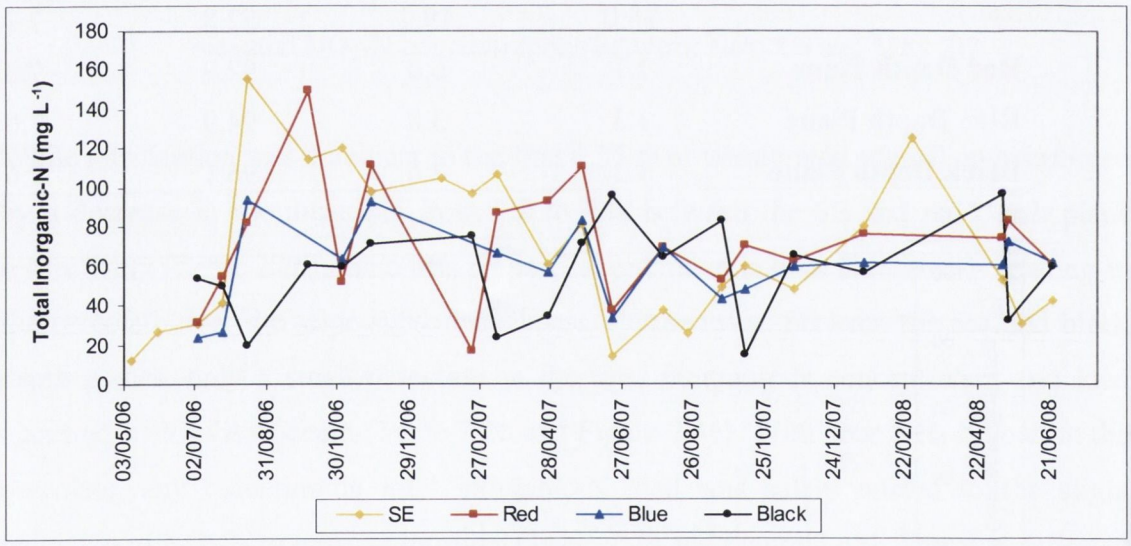


Figure 7.46 Total inorganic-N concentrations in the SE and across the three depth planes

As discussed in Section 5.3.2, the disparity between the PO_4-P concentration of the SE on 03/11/06 and the samples analysed on other dates resulted in it being passed off as egregious and excluded from further analysis. Otherwise, as was the case with COD degradation it can be seen from Table 7.27 and Figure 7.47 that the greatest reduction in effluent PO_4-P load occurred above the red depth plane. BS5930 (British Standards Institute, 1981) classification of the subsoil shows it to be a sandy GRAVEL at 1.0 m depth with an overlying thickness of sandy SILT between 0.4 m and 0.7 m below ground level. Further inspection of the particle size analysis taken at 1.0 m depth, while

showing predominant sand and gravel mix in its composition, reveals the subsoil to contain 10.8% clay. These fines may be partially responsible for sorption of the phosphate ions. Moreover, it is noted from the particle size analysis taken at 1.5 and 2.0 m below ground level that clay content reduces with depth mirroring the reduction in phosphorous loads between the red, blue and black planes. XRD analysis revealed little in way of explaining PO_4-P reduction with the subsoil devoid of calcite or any Al, Fe and Mn oxides. Mineral composition was confined to quartz, feldspars, orthoclase, chlorite and mica, none of which are associated with precipitation of phosphate ions.

Table 7.27 Reduction in PO_4-P load with respect to SE, attributed to the specific treatment steps

	Mean Conc. (mg L^{-1})	Mean Load (g d^{-1})	Load Removal (g d^{-1})	% Load Removal	Mean pH
SE	26.4	3.5	-	-	7.2
Red	3.0	0.4	3.1	88.2	7.0
Blue	0.7	0.1	3.4	97.1	7.0
Black	1.0	0.1	3.4	97.1	7.6

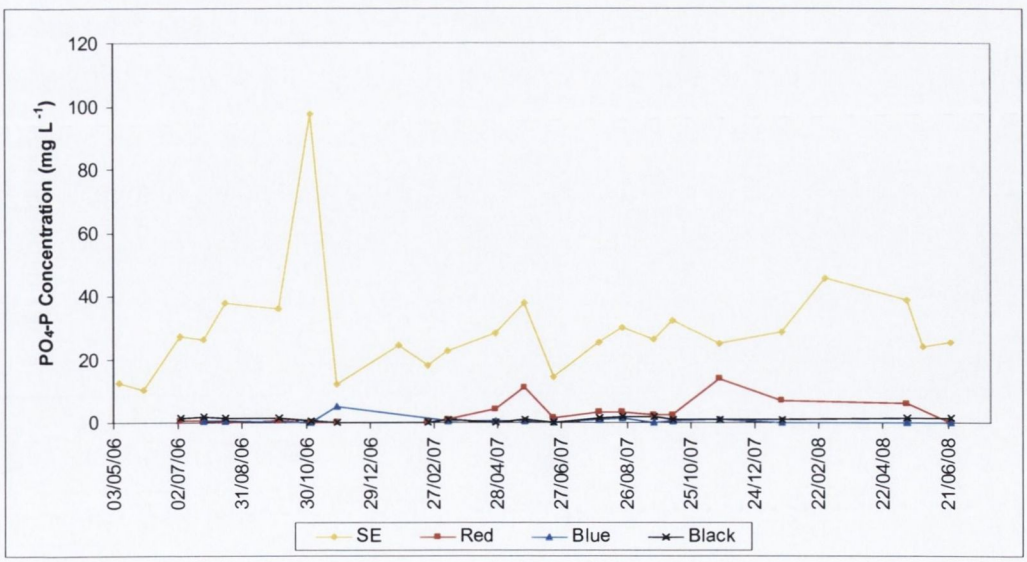


Figure 7.47 PO_4-P concentrations in SE and across the three depth planes

7.3.5 Results of Bacteriological Analysis

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) or concentrations were too high for analysis. In such cases the minimum detection level of the bacterial concentrations was affected and therefore expressed in the form < 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 D.

System I - Percolation Trenches Receiving STE (Site A)

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 biomat and 0.35 m thickness of underlying unsaturated subsoil has provided 4 log-unit removal in TC (equivalent to a 99.99% reduction) by the red depth plane (Table 7.28). The clogged interstitial pore spaces of the biomat have prevented significant transport of bacteria through physical straining. Additional removal may have occurred in the 0.2 m of subsoil below the infiltrative surface. The very small size of the smectite-clay particles present in this subsoil thickness (as revealed by x-ray diffraction), their generally platy shapes, and the occurrence of a large surface area per given volume make them ideal as adsorption sites for bacteria, along with other pathogenic organisms.

Table 7.28 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	20	$6.84 \times 10^5 - 5.17 \times 10^8$	1.28×10^7	-
Red	59	$2 \times 10^1 - 3.48 \times 10^5$	1.34×10^3	**4.0**
Blue	44	$3.1 \times 10^0 - 2.89 \times 10^4$	8.44×10^2	**4.2**
Black	49	$1 \times 10^1 - 3.4 \times 10^4$	7.13×10^2	**4.3**

Similar to COD, total inorganic-N and PO_4-P, further reduction in TC concentrations is minimal between the red and black depth planes. This may be due to a combination of (i) the larger pore spaces in the sandy gravelly SILT matrix present between the planes, as classified by BS5930, facilitating the migration of coliforms, (ii) the reduced effluent residence time in the unsaturated subsoil owing to the high permeability of the percolating medium and (iii) the presence of coliforms that naturally inhabit the soil obscuring the identification of those exclusively of faecal pollution.

Table 7.29 presents the results of sample analysis for *E. coli* which show that, allowing for the factor of safety introduced due to the sample dilutions, almost complete removal of enteric bacteria is achieved within the system. However, isolated incidences of faecal contamination were encountered with depth. The elevated *E. coli* concentrations at P1 (23.1 MPN 100 mL^{-1}), P13 (189 MPN 100 mL^{-1}) and P14 (23.8 MPN 100 mL^{-1}) on 16/05/07 and at P1 (3.1 MPN 100 mL^{-1}), P2 (146 MPN 100 mL^{-1}), P3 (20 MPN 100 mL^{-1}) and P4 (295 MPN 100 mL^{-1}) on 5/12/07 may be largely as a result of reversible adsorption (desorption) of the enteric bacteria from the aforementioned clay particles at shallow depths. Meteorology data showed high levels of rainfall occurring around these two sampling dates which may have initiated this process. Given denitrification of nitrified NH_4-N failed to occur on these dates it is assumed that the increase in hydraulic load as a result of the contribution of effective rainfall didn't result in significant saturated conditions in the subsoil that if present, may have facilitated the recorded transport of bacteria. This is corroborated by the response of the tensiometers on these dates (Figure 7.21) which do not indicate the prevalence of saturated conditions in the subsoil.

Table 7.29 Mean concentrations of *E. coli* across the three depth planes

	No. of Samples	**No. of Samples with Concentration (MPN 100 mL^{-1})**			
		< 10	**10 – 100**	**101 – 1 000**	**> 1 000**
Red	59	53	4	2	0
Blue	44	37	3	4	0
Black	49	43	6	0	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 sporadic migration of the pathogen to the black plane, 0.95 m below the infiltrative surface, is a concern and emphasises the negative influence of highly permeable subsoil in facilitating pathogenic transport to groundwater.

System II - Percolation Trenches Receiving RBE (Site A)

In undergoing additional secondary treatment in the horizontal SSF bed, TC concentrations in the domestic wastewater were reduced by two orders of magnitude with a geometric mean count of 2×10^5 MPN 100 mL^{-1} discharged to the subsoil for polishing. Despite the reduced influent load, however, removal efficiency above the red depth plane (2.0 log-unit) is shown to be inferior to that recorded in the subsoil treating STE (*System I*) (Table 7.30). This indicates that the biomat is primarily responsible for the retention of the bacteriological constituents. With reduced solids and organic loading in the RBE culminating in a shorter thinner biomat zone at the base of the percolation trenches, the potential for pathogen breakthrough is much greater. Again adsorption of TC to the soil particles beneath the infiltrative surface has been shown to be poor with only a 0.2 log-unit (30%) removal between the red and black depth planes. This has resulted in high coliform infiltration (mean = 1 580 MPN 100 mL^{-1}) to a depth of almost 1.0 m below the base of the percolation trenches.

Table 7.30 Reduction in mean total coliform concentrations from RBE to three depth planes

	No. of Samples	Range (MPN 100 mL^{-1})	Geometric Mean (MPN 100 mL^{-1})	Log-unit removal
RBE	17	$2.48 \times 10^4 - 2.61 \times 10^6$	2.07×10^5	-
Red	54	$7.06 \times 10^1 - 2.42 \times 10^5$	2.26×10^3	**2.0**
Blue	71	$7.4 \times 10^0 - 9.80 \times 10^4$	1.61×10^3	**2.2**
Black	61	$<1 - 2.0 \times 10^4$	1.58×10^3	**2.2**

Analysis of the *E. coli* data measured at the three depth planes shows 90% (Table 7.31) of the soil moisture samples to contain < 10 MPN 100 mL^{-1}. Of the 186 samples collected, there were 18, however, from which significant enteric bacteria were recovered. While this may suggest the occurrence of only isolated incidences of

bacterial migration with depth, there were 2 occasions on the black depth plane when concentrations detected were greater than 100 MPN 100 mL^{-1} and moreover a further 2 samples where recovery was greater than 1 000 MPN 100 mL^{-1}. Such incidences again appear to coincide during periods of increased hydraulic load to the percolation area owing to the addition of effective rainfall to the subsoil. Nevertheless, these events highlight the fact that despite the reduced bacterial count in the influent to these trenches, as provided by the horizontal SSF reed bed, episodical faecal contamination at the black depth plane has been shown to be more frequent than that measured at the corresponding depth in the subsoil treating STE. As such, it is clear that it is the biological processes in the biomat, and not the influent strength, that plays the dominant role in coliform retention.

Table 7.31 Mean concentrations of *E. coli* across the three depth planes

	No. of Samples	**No. of Samples with Concentration (MPN 100 mL^{-1})**			
		< 10	**10 – 100**	**101 – 1 000**	**> 1 000**
Red	54	48	6	0	0
Blue	71	67	3	1	0
Black	61	53	4	2	2

The installation of a groundwater borehole immediately downstream of both percolation areas (i.e. the trenches receiving STE and the trenches receiving RBE) enabled continuous monitoring of the bacteriological impact of the entire system on local groundwater quality. An upstream groundwater monitoring point was also bored to measure background faecal bacteria levels non-related to anthropogenic activities. Comparison measures were thus in place for downstream *E. coli* levels. As evidenced in Table 7.32, significant *E. coli* contamination in the groundwater was found in all but two of the eleven samples obtained throughout the duration of the project. This regularity in *E. coli* detection in downstream groundwater samples highlights the present bacteriological risk posed by such permeable subsoil treatment systems on underlying aquifers.

Table 7.32 *E. coli* concentrations measured at the groundwater monitoring boreholes upstream and downstream of the percolation area

Sample Point	*E.coli* Concentration (MPN 100mL $^{-1}$)										
	06/09/06	18/10/06	16/11/06	23/01/07	08/02/07	18/04/07	11/07/07	29/08/07	27/09/07	05/12/07	25/02/08
U/S GW	N/A	<10	2	N/A	1	<1	3	2	<10	<10	<10
D/S GW	<1	30	31	360	100.5	36.8	228.2	90	131	<1	131

N/A = No groundwater sample obtained

System III - Percolation Trenches Receiving SE (Site B)

The installation of the *Biodisc*® packaged treatment system has greatly reduced bacterial loading on the percolation area with concentrations of TC and *E. coli* in the SE of the same order of magnitude to that contained in the RBE on Site A. In allowing for the factor of safety introduced due to the sample dilutions, it is clear from Table 7.33 that almost complete enteric bacterial removal is achieved within the system. Moreover, in parallel to COD and PO_4-P findings, it is the first 0.35 m of subsoil that appears responsible for the majority of bacterial adsorption over the sampling period. Nevertheless, there does again appear some evidence of faecal contamination with depth as recorded on a number of sampling events. The reasons for this may be twofold. It is likely the high sand content of the coarse textured subsoil in the vadose zone, as revealed by the particle size analysis, has played an instrumental role in facilitating the undisturbed movement of bacteria through the subsoil. In addition, the poor biomat development, the presence of which would improve filtration of the percolate, would also have the effect of increasing the infiltration rate or hydraulic load per unit area, thus compromising treatment capacity.

Table 7.33 Mean concentrations of *E. coli* across the three depth planes

	No. of Samples	No. of Samples with Concentration (MPN 100 mL^{-1})			
		< 10	10 – 100	101 – 1 000	> 1 000
Red	33	28	4	0	1
Blue	29	25	4	0	0
Black	31	27	3	1	0

The elevated *E. coli* contamination (1 624 MPN 100 mL^{-1}) recorded at lysimeter RC1 (red depth plane) on Trench 1 on 01/08/07 was an isolated incident. In trying to interpret such an occurrence, it was noted that the split in the effluent from the distribution device was particularly poor on this date with a hydraulic loading of 123 L discharged to Trench 1; approximately twice the mean flow recorded on this trench over the duration of the project and over three times the flow received on Trench 2 on this date. With nitrification clearly occurring at depth on this date along with the contribution of effective rainfall being zero around this period it would suggest unsaturated conditions were dominant in the subsoil. However, the absence of an established biomat coupled with such high infiltration of effluent over a short length of the trench has the effect of reducing effluent residence time in the vadose zone and thus increasing the possibility of bacterial migration episodically. It was noted that at the corresponding lysimeter (RC13) on Trench 2 on this date, where the receiving flow was much smaller, no faecal coliform contamination was recorded at any of the three depth planes. This may emphasise the influence of flow conditions on bacterial transport.

The isolated incident of high *E. coli* contamination (259 MPN 100mL^{-1}) recorded at lysimeter RC3 (black depth plane) on 22/08/07 may be due to desorption of bacteria from the soil particles given the high level of rainfall (27 mm) experienced in the five days leading up to this sampling date. In addition, bacterial counts appear to increase with depth suggesting greater movement of the pathogen as the soil becomes increasingly saturated.

Only two downstream groundwater samples were extracted through the duration of the project due to a drop in the water table level. The sample obtained on 28/11/06 yielded an *E. coli* concentration of 2 MPN 100 mL^{-1} with the sample from RC15 (black depth)

containing 31 MPN 100 mL^{-1} on the same date. No *E. coli* was evident in the groundwater on the 13/03/07.

Analysis of TC showed a marked reduction in concentrations between the SE and red depth plane with a 2.2 log-unit removal. Further treatment with depth was markedly reduced (Table 7.34) with the mean TC concentration at the potential point of discharge to groundwater (black depth plane) measured at 865 MPN 100 mL^{-1}, the majority of which are most likely naturally occurring coliforms in the subsoil.

Table 7.34 Reduction in mean total coliform concentrations with respect to the SE at the three depth planes

	No. of Samples	Range (MPN 100 mL^{-1})	Mean (MPN 100 mL^{-1})	Log-unit removal
SE	16	$2.24 \times 10^4 - 1.12 \times 10^6$	2.45×10^5	-
Red	33	$2.49 \times 10^1 - 1.98 \times 10^5$	1.73×10^3	**2.2**
Blue	29	$5.20 \times 10^1 - 9.21 \times 10^4$	1.60×10^3	**2.2**
Black	31	$< 1 - 2.42 \times 10^5$	8.65×10^2	**2.5**

7.3.6 Results of Bacteriophage and Bromide Experiments

To investigate the fate and transport of enteric viral pathogens in the subsurface environment of the percolation area, a multivirus injection experiment was conducted using a selection of bacteriophages on trenches 1 and 2 (receiving STE) on Site A and the two percolation trenches on Site B (receiving SE from the *Biodisc*®). Three phages (MS2, ΦX174 and PR772) 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 2.5.4. 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 injection solution for the short-term trial to act as a conservative tracer which would provide validation of the reported Cl analysis as well as indicating potential breakthrough time of the phages. The trial itself was quite limited in nature in that the

primary objective was to merely ascertain if phage was being recorded at the three target depth planes (red, blue and black) and, if so, at what concentrations and removal rates. It was recognised that given the permeability of the percolating medium on both sites, any initial breakthrough was likely to be swift. As such the trials were restricted to the estimated time of effluent travel to the greatest sample depth plane below the infiltrative surface.

In order to ascertain the approximate travel time for the effluent to infiltrate and percolate to each of the three target depth planes the following relationship was applied:

$$T_{dp} = \frac{A_{is} d \rho}{Q} \qquad \text{Eqn. 7.3}$$

where, T_{dp} = travel time required for effluent to reach the target depth plane (days)

d = depth to plane of interest (red = 1.15 m, blue = 1.45 m, black = 1.75 m from G.L)

A_{is} = infiltrative surface area (m^2)

ρ = effective porosity (v/v)

Q = mean daily flow ($m^3\ d^{-1}$)

This relationship assumes uniform application and infiltration by plug flow under unsaturated conditions with no hydrodynamic dispersion or heterogeneous preferential flow. Thus it is a first approximation of travel times. For Site A, A_{is} was determined by the product of the estimated biomat length, taken as the mean across trenches 2 and 3 found in Section 7.3.2 (9.5 m), and the percolation trench width (0.45 m). The mean daily flow rate to the trenches up until the date of the trial was 0.397 $m^3\ d^{-1}$ while ρ was estimated at 0.20 v/v. For these conditions the estimated time required for the STE to percolate to between the red and black depth plane was between 2 and 4 days. The infiltrative surface on Site B, at 0.16 m^2, was found to be significantly less than that of Site A owing to the reduced biomat length (0.35 m). The effective porosity, ρ, was again estimated to be 0.20 v/v while the mean daily flow rate up to the date of the trial was 0.131 $m^3\ d^{-1}$. From Eqn. 7.3 this yielded approximate travel times to both the red and black planes of under 1 day.

With prior knowledge of the expected effluent travel times the lysimeters (and zero tension samplers in the case of Site A) shown, through Cl analysis, to be within the zone of effluent contribution were primed in readiness for daily soil moisture collection. In each experiment, 10 L of distilled water containing concentrated stocks of MS2, ΦX174, PR772 and potassium bromide (KBr) were intermittently fed over a five hour period to each percolation trench via the open vent pipe. The active effluent flows from the septic tank (Site A) and *Biodisc*® (Site B) to the trenches were simultaneously recorded, via tipping bucket measurement, to account for additional dilution of the injected solution. Soil moisture samples were collected on three consecutive days as per protocols outlined in Section 5.9.1, and returned to the laboratory for immediate viral and bromide analyses (Sections 5.9.3 and 5.9.4 respectively).

7.3.6.1 Site A: Percolation Trenches Receiving STE

Phages MS2, ΦX174 and PR772 were injected into Trenches 1 and 2 on Site A to examine their fate and transport in the vadose zone. Soil moisture samples were collected from zero-tension samplers ZT1 – ZT3 on trench 1 and from lysimeters ST16 – ST24 on trench 2. The phages were spiked into each percolation pipe at concentrations of 7.8×10^4 PFU mL^{-1}, 9.2×10^4 PFU mL^{-1} and 9.8×10^6 PFU mL^{-1}, respectively. Over the 5-hour duration of injection, a total of 19.2 L of STE flow was discharged to trenches 1, 2 and 3. Given that the phage was only injected in trenches 1 and 2 and assuming an even hydraulic split between the three trenches, a total of 12.8 L (two thirds of the total flow) passed through these trenches. Accounting for dilution this reduced mean input phage concentrations over the 5-hour period for both trenches to 5.6×10^3 PFU mL^{-1} (MS2), 2.5×10^3 PFU mL^{-1} (ΦX174) and 7.2×10^5 PFU mL^{-1} (PR772). The daily adjusted flows to trenches 1 and 2 recorded over the four day trial were 174.7 L d^{-1}, 162.1 L d^{-1}, 204.2 L d^{-1} and 131.7 L d^{-1}, respectively. This equates to a mean daily flow over the trial of 168.2 L d^{-1} or an equivalent HLR over the wetted infiltrative surface area of 19.7 mm d^{-1}. There was also zero rainfall recorded on the site over the duration of the trial.

Results from the injection trial on Site A, including bromide and respective phage breakthrough at the three depth planes within the zone of effluent contribution, are detailed in Tables 7.36 – 7.41. Inspection of the bromide results shows the effluent to

have percolated to the blue depth plane (0.65 m below infiltrative surface) along the first 5 m of trench 2 within 2 days. In contrast, samples from the zero tension samplers on trench 1 showed concentrations of bromide at the red depth plane (0.35 m below infiltrative surface) only within 2 days. The interaction of hydraulic and purification processes during subsoil treatment over the operational period of the percolation area has obviously resulted in the genesis of clogging zones which are variable in thickness and porosity; this, as such, has influenced variations in the time of travel of the bromide tracer from the point of application to the individual sampling points on the same depth plane. Percolate retention times in the soil beneath the percolation trenches under examination is constantly varying owing to differing infiltration rates.

Breakthrough of bromide to the black depth plane (0.95 m below infiltrative surface) was detected on trench 2 on day 3 at the 0 m and 5 m sample positions. No bromide was detected at the 10 m sample position over the duration of the trial. On trench 1, the effluent had percolated to the blue plane by day 3 but further travel time to the black plane sampler (ZT3) was left inconclusive due to the failure in drawing any soil moisture sample from it during the trial.

Figure 7.48 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 (as a percentage of the total input) in Table 7.35. Phage values considered were only those seen to coincide with incidences of bromide evidence at that point. Before considering respective phage removal rates it is important to note that the input concentration of PR722 (10^5) was 2 orders of magnitude greater than that of MS2 and ΦX174 (both 10^3). Greatest removal in the initial 0.35 m below the infiltrative surface was achieved by phage MS2 at 85% (0.8 log-unit), followed by PR772 (0.4 log-unit ~ 56%) and ΦX174 (0.06 log-unit ~ 12%). With the majority of the former now retained at this depth, the most significant removal of PR772 and ΦX174 occurred between the red and blue depth planes with a further 44% and 85% of the phages attenuated, respectively. By the time the percolate had reached the black depth plane on day 3 (as evidenced by bromide detection) all three phages had been reduced to their minimum detection limit of < 10 PFU mL^{-1}. This equates to an overall percentage removal of $> 99.8\%$ (MS2), $> 99.6\%$ (ΦX174) and $> 99.99\%$ (PR772)

between the infiltrative surface and black depth plane. Averaging the results from the three phages produces a mean phage removal of at least 3 log-units (99.9%) over this distance. Hence, in short, complete removal of the three phages was achieved over an unsaturated subsoil depth of 0.95 m on Site A.

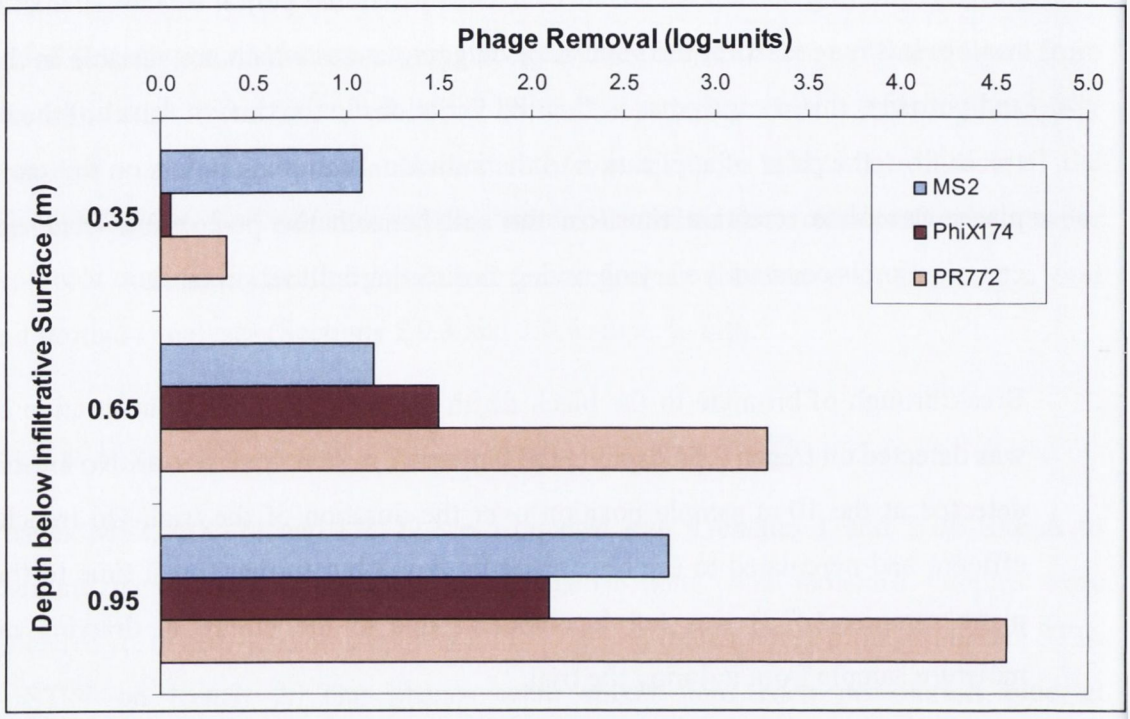


Figure 7.48 Phage log-unit removal recorded at each depth plane (0.35 m, 0.65 m, 0.95 m) at all sample positions over the duration of trial

Table 7.35 Maximum percentage phage recorded at each depth plane in the zone of effluent contribution and mean planar phage removal (log-units) over 4-day trial (mean HLR = 19.7 mm d^{-1})

	Maximum % Phage Recorded Across Depth Plane			
Depth below infiltrative surface (m)	**MS2**	**ΦX174**	**PR772**	**Mean phage log-unit removal**
0	100	100	100	-
0.35	15.0	88.0	44.44	0.43
0.65	2.5	3.2	0.05	1.97
0.95	< 0.2	< 0.4	< 0.001	> 3.03

The controlling factors and mechanisms surrounding the mobility of viral pathogens in the subsurface environment have been previously discussed in Section 2.5.2. From perusal of literature studies it is clear that there is high variability in virus retention and transport through different soils and aquifer materials, depending on their properties (clay fraction, metal oxides, organic matter content, temperature, pH) and the degree of water saturation (saturated or unsaturated). With regard to the latter, it seems plausible that in the unsaturated conditions under investigation in the test sites, viruses would move through the soil in thinner films of water and be drawn nearer to the soil particles than during saturated flow. This would increase the potential for virus adsorption and thereby decrease the virus penetration depth. A very important element in maintaining unsaturated conditions is the biomat which controls the infiltration rate. As well as performing this crucial hydraulic function on the subsoil treatment system, the biomat's purification capacity for viral attenuation is thought to be high. Strangely enough, this has often been overlooked and not incorporated in the many transport models (Corapcioglu and Haridas, 1984; Sim and Chrysikopoulos, 1999; Anders and Chrysikopoulos, 2005) for viral pathogens in the subsurface environment. As such it is thought a sizeable fraction of the removal and retardation of the phages observed above the red depth plane on Site A may be attributed to the development of the active biomat. Van Cuyk *et al.* (2004) found increased virus concentration directly below the infiltrative surface at field test sites, suggesting a more biogeochemically active zone for virus survival. The development of the biomat is, of course, closely related to the organic matter content in the receiving effluent. In a review by Schijven and Hassanizadeh (2000), the researchers pointed out that effects of organic matter are probably responsible for the considerable uncertainties associated with predicting virus removal and transport in porous media. The presence of organic matter has been shown to reduce virus attachment and thus facilitate virus transport by providing additional negative charges, covering positively charged sites, or competing with viruses for attachment sites (Zhuang and Jin, 2003), i.e. organic matter is negatively charged and hydrophilic blocking of virus sorption sites and increase of virus-medium electrostatic repulsion arising from modification of the sand and virus surface by organic matter are probably responsible for the facilitated transport. Organic matter content was determined at the three depth planes by the loss on ignition method (BS 1377:Part 3) and showed 3.7% to be present at 0.35 m below the infiltrative surface. It is thought the high concentrations of ΦX174, in particular, and PR772 (similar in diametric size and

IEP to the rotaviruses) detected at the red depth plane may therefore be largely due to the significant presence of organic matter inhibiting virus sorption by blocking or impeding the pathways to sorption sites. Sobsey *et al.* (1980) and Moore *et al.* (1981) found that organic soil materials were comparatively poor sorbents for poliovirus, an enteric virus which Jin *et al.* (1997) has shown exhibits similar attachment behaviour to phage ΦX174 due to their identical IEP values (6.6). The greater retention of phage MS2 (a useful surrogate for poliovirus, coxsackievirus and norovirus) above the red depth plane with respect to the other phages tested may be due to a number of factors. In one way the behaviour of this phage is surprising given its low IEP value of 3.5 – 3.9; the IEP has been shown to be an indicator of the degree of viral sorption to soils and other surfaces, with the lower the value compared to the soil pH (typically neutral) suggesting a less likelihood of sorption. The presence of the AWI under unsaturated conditions has been suggested by more and more researchers as the dominant removal mechanism responsible for the increased removal of colloidal particles, including viruses, in unsaturated systems (Powelson and Mills, 1996; Jin *et al.*, 2000). Powelson *et al.* (1990) have shown MS2, in particular, to be strongly influenced by this and ultimately inactivated at the AWI. Given the disparity in recorded concentrations between MS2 and the other two phages in this trial, it is suggested that the interaction of MS2 with the AWI may have played a significant early role in phage inactivation between the infiltrative surface and the red depth plane. ΦX174, unlike MS2, has been shown not to undergo any inactivation at the AWI as it has been found to be extremely hydrophilic and is thus resistant to forces at the hydrophobic AWI (Thompson *et al.*, 1998). The multi-log removal of all three phages between the red and black planes is most likely due to viral adsorption to the soil matrix, which, although dominated by sand and gravel, contains 15 – 30% clay fraction. The reduction in organic matter content with depth has also facilitated a greater number of sorption sites for phage adhesion.

Comparison of the phage results from the suction lysimeters and zero-tension samplers showed them to be markedly similar with the same of order of magnitude of each phage recorded by both at the different sample points. This validates the earlier chemical analysis by confirming the absence of any preferential flow in the vicinity of the lysimeters while endorsing both sampling techniques as accurate forms of phage measurement.

Table 7.36 Bacteriophage ***MS2*** removal from percolate at three depth planes and breakthrough of bromide (√= Yes; x = No) 2 days after injection (Site A).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
1+2	**0 m**	**INPUT**	5.6×10^3			**INPUT**	5.6×10^3		
1+2	**0.35 m**	**ZT1**	7.4×10^2	0.9	√	**ST16**	4.6×10^2	1.1	√
1+2	**0.65 m**	**ZT2**	<10	>2.4	x	**ST17**	40	2.1	√
1+2	**0.95 m**	**ZT3**	N/A	N/A	N/A	**ST18**	<10	>2.4	x
1+2	**0.35 m**					**ST19**	2.2×10^2	1.4	√
1+2	**0.65 m**					**ST20**	<10	>2.4	√
1+2	**0.95 m**					**ST21**	<10	>2.4	x
1+2	**0.35 m**					**ST22**	<10	>2.4	x
1+2	**0.65 m**					**ST23**	<10	>2.4	x
1+2	**0.95 m**					**ST24**	<10	>2.4	x

N/A = No sample obtained from lysimeter

Table 7.37 Bacteriophage ***MS2*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 3 days after injection (Site A).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
3	**0 m**	**INPUT**	5.6×10^3			**INPUT**	5.6×10^3		
3	**0.35 m**	**ZT1**	1.8×10^2	1.5	√	**ST16**	8.4×10^2	0.8	√
3	**0.65 m**	**ZT2**	20	2.4	x	**ST17**	1×10^2	1.7	√
3	**0.95 m**	**ZT3**	N/A	N/A	N/A	**ST18**	<10	>2.4	√
3	**0.35 m**					**ST19**	5.4×10^2	N/A	√
3	**0.65 m**					**ST20**	1.4×10^2	N/A	√
3	**0.95 m**					**ST21**	<10	>2.4	√
3	**0.35 m**					**ST22**	<10	>2.4	x
3	**0.65 m**					**ST23**	<10	>2.4	x
3	**0.95 m**					**ST24**	N/A	N/A	N/A

N/A = No sample obtained from lysimeter

Table 7.38 Bacteriophage ***ΦX174*** removal from percolate at three depth planes and breakthrough of bromide (√= Yes; x = No) 2 days after injection (Site A).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
1+2	**0 m**	**INPUT**	2.5×10^3			**INPUT**	2.5×10^3		
1+2	**0.35 m**	**ZT1**	2.2×10^3	0.06	√	**ST16**	1.1×10^3	0.4	√
1+2	**0.65 m**	**ZT2**	<10	>2.1	x	**ST17**	80	1.5	√
1+2	**0.95 m**	**ZT3**	N/A	N/A	N/A	**ST18**	<10	>2.1	x
1+2	**0.35 m**					**ST19**	<10	>2.1	√
1+2	**0.65 m**					**ST20**	<10	>2.1	√
1+2	**0.95 m**					**ST21**	<10	>2.1	x
1+2	**0.35 m**					**ST22**	<10	>2.4	x
1+2	**0.65 m**					**ST23**	<10	>2.4	x
1+2	**0.95 m**					**ST24**	<10	>2.4	x

N/A = No sample obtained from lysimeter

Table 7.39 Bacteriophage ***ΦX174*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 3 days after injection (Site A).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
3	**0 m**	**INPUT**	2.5×10^3			**INPUT**	2.5×10^3		
3	**0.35 m**	**ZT1**	1.8×10^3	0.14	√	**ST16**	7.4×10^2	0.5	√
3	**0.65 m**	**ZT2**	<10	>2.1	x	**ST17**	80	1.5	√
3	**0.95 m**	**ZT3**	N/A	N/A	N/A	**ST18**	20	2.1	√
3	**0.35 m**					**ST19**	80		√
3	**0.65 m**					**ST20**	<10	>2.1	√
3	**0.95 m**					**ST21**	<10	>2.1	√
3	**0.35 m**					**ST22**	<10	>2.4	x
3	**0.65 m**					**ST23**	<10	>2.4	x
3	**0.95 m**					**ST24**	N/A	N/A	N/A

N/A = No sample obtained from lysimeter

Table 7.40 Bacteriophage ***PR772*** removal from percolate at three depth planes and breakthrough of bromide (√= Yes; x = No) 2 days after injection (Site A).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
1+2	**0 m**	**INPUT**	7.2×10^5			**INPUT**	7.2×10^5		
1+2	**0.35 m**	**ZT1**	3.2×10^5	0.4	√	**ST16**	3.4×10^3	2.3	√
1+2	**0.65 m**	**ZT2**	<10	>4.6	x	**ST17**	<10	>4.6	√
1+2	**0.95 m**	**ZT3**	N/A	N/A	N/A	**ST18**	<10	>4.6	x
1+2	**0.35 m**					**ST19**	<10	>4.6	√
1+2	**0.65 m**					**ST20**	<10	>4.6	√
1+2	**0.95 m**					**ST21**	<10	>4.6	x
1+2	**0.35 m**					**ST22**	<10	>2.4	x
1+2	**0.65 m**					**ST23**	<10	>2.4	x
1+2	**0.95 m**					**ST24**	<10	>2.4	x

N/A = No sample obtained from lysimeter

Table 7.41 Bacteriophage ***PR772*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 3 days after injection (Site A).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
3	**0 m**	**INPUT**	7.2×10^5			**INPUT**	7.2×10^5		
3	**0.35 m**	**ZT1**	4.9×10^4	1.2	√	**ST16**	6.8×10^3	2.0	√
3	**0.65 m**	**ZT2**	3.8×10^2	3.3	x	**ST17**	1.6×10^2	3.7	√
3	**0.95 m**	**ZT3**	N/A	N/A	N/A	**ST18**	20	4.6	√
3	**0.35 m**					**ST19**	1.2×10^3	2.8	√
3	**0.65 m**					**ST20**	80	4.0	√
3	**0.95 m**					**ST21**	<10	>4.6	√
3	**0.35 m**					**ST22**	<10	>2.4	x
3	**0.65 m**					**ST23**	<10	>2.4	x
3	**0.95 m**					**ST24**	N/A	N/A	N/A

N/A = No sample obtained from lysimeter

7.3.6.2 Site B: Percolation Trenches Receiving SE

A phage tracer experiment, identical to that on Site A, was carried out on the percolation trenches receiving SE from the *Biodisc*®. Soil moisture samples were collected from lysimeters RC1 – RC6 on trench 1 and RC13 – RC18 on trench 2. Although chemical analysis suggests the effluent to have only been present at the very front of the trenches (< 0.35 m, i.e. the first set of lysimeters), samples from the second set of lysimeters were also collected and analysed as a precautionary measure. MS2, ΦX174 and PR772 were spiked into each percolation pipe at concentrations of 1.6 x 10^4 PFU mL^{-1}, 5.8 x 10^4 PFU mL^{-1} and 2.8 x 10^6 PFU mL^{-1}, respectively. Over the five hour duration of injection, a total of 12.95 L of SE flow was fed to both percolation trenches. Accounting for dilution this reduced mean input phage concentrations for both trenches to 9.7 x 10^3 PFU mL^{-1} (MS2), 3.5 x 10^4 PFU mL^{-1} (ΦX174) and 1.7 x 10^6 PFU mL^{-1} (PR772). The daily flows to both trenches over the three day trial were measured at 130.7 L d^{-1}, 72.7 L d^{-1} and 150.3 L d^{-1}, respectively. This equates to a mean daily flow over the trial of 117.9 L d^{-1} or an equivalent HLR over the infiltrative surface area of 749 mm d^{-1}. The calculations take into account the extra dilution resulting from 0.4 mm of rainfall recorded on day 3 of the trial.

Tables 7.43 – 7.51 list the breakthrough times (days) for bromide at each of the sample positions along with the corresponding concentrations of each phage over the 3 days of the trial. Examining the bromide from the soil moisture samples at the front of the trenches highlights the rapid travel time of the percolating effluent. All three depth planes are seen to be receiving effluent after 1 day of the trial. This is owing to a combination of the poor biomat spread, the resulting high HLR (almost 20 times that of Site A) and the highly permeable sandy GRAVEL. Bromide continued to be detected at all three depths at the front of the trenches over the 3 day trial. Minute concentrations (< 1.0 mg L^{-1}) of the chemical tracer were recorded at RC6 and RC4 on days 2 and 3, respectively. However given that no phage was detected at these sample positions (and moreover at the second set of lysimeters) coupled with the difference in magnitude of recorded bromide concentrations compared to the front set of lysimeters, it was felt that analytical error may have been responsible for the readings and, as such, the data was deemed egregious.

Minimum removal rates of the three phages across the three depth planes over the duration of the trial are plotted in Figure 7.50 while Table 7.42 expresses the results further in terms of percentage phage remaining at each plane. Again, phage values considered were only those seen to coincide with incidences of bromide evidence at that point. PR772 was injected into the trenches 2-orders of magnitude greater than ΦX174 and 3-orders of magnitude greater than MS2. Initial removal of all three phages over the first 0.35 m were found to be similar at rates of 1.1 log-unit (92%), 1.5 log-unit (97%) and 0.8 log-unit (86%) for MS2, ΦX174 and PR772, respectively. Subsequent attenuation of the phages over the remaining 0.6 m resulted in all three achieving greater than 99.5% removal with ΦX174 marginally the most efficient at 99.9%. Averaging the results from the three phages produces a mean phage removal of at least 3.5 log-units between the infiltrative surface and the black depth plane. While the majority of phage concentrations recorded at the critical black depth plane were below the limit of detection (< 10 PFU mL^{-1}), MS2 was detected at a concentration of 50 PFU mL^{-1} at RC15 on day 1 while PR772, at 30 PFU mL^{-1}, was picked up at the same sample point a day later. With chemical analysis appearing to rule out any preferential flow in the vicinity of RC15, phage detection at this depth over such a short-term trial highlights a very real risk of viral contamination in the underlying aquifer.

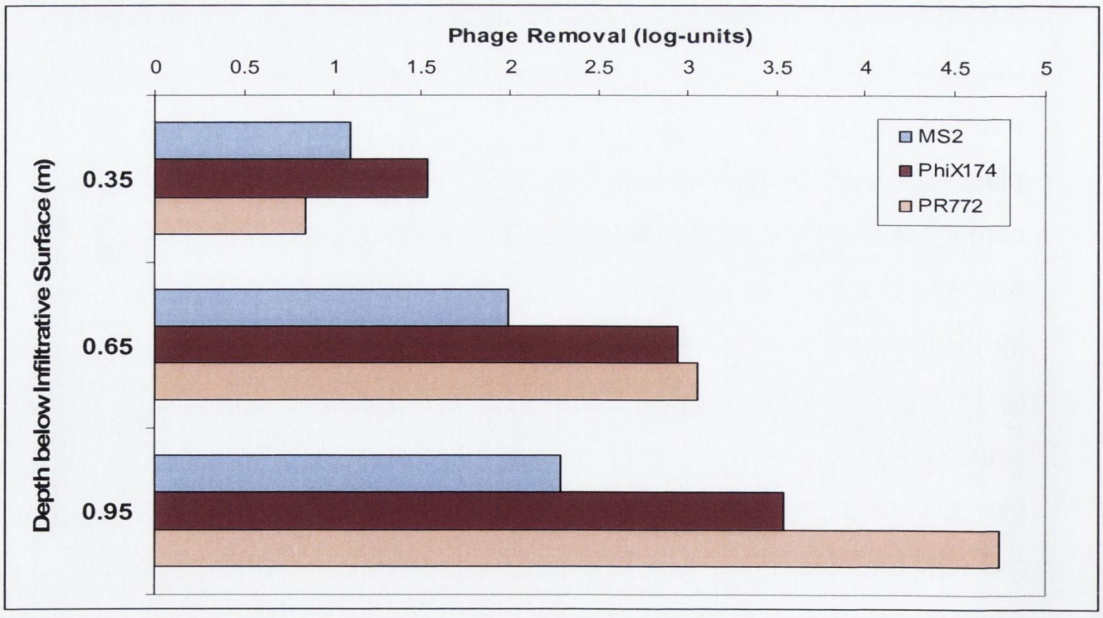


Figure 7.50 Phage log-unit removal recorded at each depth plane (0.35 m, 0.65 m, 0.95 m) at all sample positions over the duration of trial

Table 7.42 Maximum percentage phage recorded at each depth plane in the zone of effluent contribution and mean planar phage removal (log-units) over 4-day trial (mean HLR = 749 mm d^{-1})

Depth below infiltrative surface (m)	Maximum % Phage Recorded Across Depth Plane			Mean phage log-unit removal
	MS2	ΦX174	PR772	
0	100	100	100	-
0.35	8.7	2.9	14.2	1.15
0.65	1.0	0.1	4.3	2.66
0.95	0.005	0.001	0.002	3.53

The removal efficiency of MS2, ΦX174 and PR772 are shown to be more similar in the subsoil environment of Site B than in that of Site A. In addition, all three phages exhibited greater removal at the red depth plane over the trial than the corresponding plane on Site A. Three distinct differences existed, however, between the conditions on both sites which are paramount to explaining the differences in phage transport. Firstly, the quality of the applied effluent was highly contrasting, with the STE on Site A typically containing an organic (COD) load nine times that of the SE on Site B. Added to that is the disparity in HLRs on both sites with Site B treating a flow per unit surface area that is ~ 37 times greater than that of Site A. As such the hydraulic and organic loading regimes, which are a key element of the subsoil purification processes, are highly contrasting for both sites. The greatest phage removal detected at the red depth plane was that of the hydrophylic ΦX174 (97.1%) which is probably a reflection of its IEP - being the largest of the three phages and sitting just under the pH of the percolating medium. On Site A it was felt that interference from organic matter affected the capacity for viral sorption to the soil particles and thus facilitated increased vertical transport of the phages. Given the low organic matter content measured at the red depth plane at 0.9% on Site B it is clear that this interaction was minimal, if at all. Removal of all three appeared quite uniform with depth indicating consistent adsorption to the soil particles under unsaturated conditions. Van Cuyk *et al.* (2007) demonstrated that with a

higher HLR (250 mm d^{-1} as opposed to 50 mm d^{-1}) greater removal of MS2 and PRD-1 was achieved at the infiltrative surface. It is plausible therefore that the same effect may have occurred in this study.

Given the limited scope of this study with respect to viral removal, it is clear that more comprehensive and long-term research to include, for example, the impact of other environmental factors such as rainfall on the elution or desorption of viruses from soil, are needed to further investigate the hydrogeologic formations affecting groundwater vulnerability to viral contamination and the physical and chemical properties governing viral fate and transport in the vadose zone.

Table 7.43 Bacteriophage ***MS2*** removal from percolate at three depth planes and breakthrough of bromide (√= Yes; x = No) 1 day after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
1	**0 m**	**INPUT**	9.7×10^3			**INPUT**	9.7×10^3		
1	**0.35 m**	**RC1**	7.8×10^2	1.1	√	**RC13**	1.8×10^2	1.7	√
1	**0.65 m**	**RC2**	20	2.7	√	**RC14**	N/A	N/A	√
1	**0.95 m**	**RC3**	<10	>2.7	√	**RC15**	50	2.3	√
1	**0.35 m**	**RC4**	N/A	N/A	N/A	**RC16**	N/A	N/A	N/A
1	**0.65 m**	**RC5**	<10	x	x	**RC17**	N/A	N/A	N/A
1	**0.95 m**	**RC6**	<10	x	x	**RC18**	<10	x	x

N/A = No sample obtained from lysimeter

Table 7.44 Bacteriophage ***MS2*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 2 days after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
2	**0 m**	**INPUT**	9.7×10^3			**INPUT**	9.7×10^3		
2	**0.35 m**	**RC1**	8.4×10^2	1.1	√	**RC13**	1.2 x 102	1.9	√
2	**0.65 m**	**RC2**	1×10^2	2.0	√	**RC14**	<10	>2.7	√
2	**0.95 m**	**RC3**	<10	>2.7	√	**RC15**	<10	>2.7	√
2	**0.35 m**	**RC4**	N/A	N/A	N/A	**RC16**	<10	>2.7	x
2	**0.65 m**	**RC5**	N/A	N/A	N/A	**RC17**	N/A	N/A	N/A
2	**0.95 m**	**RC6**	<10	>2.7	x	**RC18**	N/A	N/A	N/A

N/A = No sample obtained from lysimeter

Table 7.45 Bacteriophage ***MS2*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 3 days after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
3	**0 m**	**INPUT**	9.7×10^3			**INPUT**	9.7×10^3		
3	**0.35 m**	**RC1**	<10	>2.7	√	**RC13**	<10	>2.7	√
3	**0.65 m**	**RC2**	<10	>2.7	√	**RC14**	<10	>2.7	x
3	**0.95 m**	**RC3**	<10	>2.7	√	**RC15**	<10	>2.7	√
3	**0.35 m**	**RC4**	<10	>2.7	x	**RC16**	<10	>2.7	x
3	**0.65 m**	**RC5**	<10	>2.7	x	**RC17**	<10	>2.7	x
3	**0.95 m**	**RC6**	<10	>2.7	x	**RC18**	<10	>2.7	x

N/A = No sample obtained from lysimeter

Table 7.46 Bacteriophage ***ΦX174*** removal from percolate at three depth planes and breakthrough of bromide (√= Yes; x = No) 1 day after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
1	**0 m**	**INPUT**	3.5×10^4			**INPUT**	3.5×10^4		
1	**0.35 m**	**RC1**	6.4×10^2	1.7	√	**RC13**	1.0×10^3	1.5	√
1	**0.65 m**	**RC2**	<10	>3.2	√	**RC14**	N/A	N/A	√
1	**0.95 m**	**RC3**	<10	>3.2	√	**RC15**	<10	>3.2	√
1	**0.35 m**	**RC4**	N/A	N/A	N/A	**RC16**	N/A	N/A	N/A
1	**0.65 m**	**RC5**	<10	x	x	**RC17**	N/A	N/A	N/A
1	**0.95 m**	**RC6**	<10	x	x	**RC18**	<10	x	x

N/A = No sample obtained from lysimeter

Table 7.47 Bacteriophage ***ΦX174*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 2 days after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
2	**0 m**	**INPUT**	3.5×10^4			**INPUT**	3.5×10^4		
2	**0.35 m**	**RC1**	2.6×10^2	2.1	√	**RC13**	9.8 x 102	1.6	√
2	**0.65 m**	**RC2**	40	2.9	√	**RC14**	<10	>3.2	√
2	**0.95 m**	**RC3**	<10	>3.2	√	**RC15**	<10	>3.2	√
2	**0.35 m**	**RC4**	N/A	N/A	N/A	**RC16**	<10	>3.2	x
2	**0.65 m**	**RC5**	N/A	N/A	N/A	**RC17**	N/A	N/A	N/A
2	**0.95 m**	**RC6**	<10	>3.2	x	**RC18**	N/A	N/A	N/A

N/A = No sample obtained from lysimeter

Table 7.48 Bacteriophage ***ΦX174*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 3 days after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
3	**0 m**	**INPUT**	3.5×10^4			**INPUT**	3.5×10^4		
3	**0.35 m**	**RC1**	<10	>3.2	√	**RC13**	<10	>3.2	√
3	**0.65 m**	**RC2**	<10	>3.2	√	**RC14**	<10	>3.2	x
3	**0.95 m**	**RC3**	<10	>3.2	√	**RC15**	<10	>3.2	√
3	**0.35 m**	**RC4**	<10	>3.2	x	**RC16**	<10	>3.2	x
3	**0.65 m**	**RC5**	<10	>3.2	x	**RC17**	<10	>3.2	x
3	**0.95 m**	**RC6**	<10	>3.2	x	**RC18**	<10	>3.2	x

N/A = No sample obtained from lysimeter

Table 7.49 Bacteriophage ***PR772*** removal from percolate at three depth planes and breakthrough of bromide (√= Yes; x = No) 1 day after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
1	**0 m**	**INPUT**	1.7×10^6			**INPUT**	1.7×10^6		
1	**0.35 m**	**RC1**	1.7×10^5	1.0	√	**RC13**	2.4×10^5	0.9	√
1	**0.65 m**	**RC2**	<10	>4.9	√	**RC14**	N/A	N/A	√
1	**0.95 m**	**RC3**	<10	>4.9	√	**RC15**	<10	>4.9	√
1	**0.35 m**	**RC4**	N/A	N/A	N/A	**RC16**	N/A	N/A	N/A
1	**0.65 m**	**RC5**	<10	x	x	**RC17**	N/A	N/A	N/A
1	**0.95 m**	**RC6**	<10	x	x	**RC18**	<10	x	x

N/A = No sample obtained from lysimeter

Table 7.50 Bacteriophage ***PR772*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 2 days after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
2	**0 m**	**INPUT**	1.7×10^6			**INPUT**	1.7×10^6		
2	**0.35 m**	**RC1**	2.2×10^5	0.9	√	**RC13**	2.3×10^5	0.9	√
2	**0.65 m**	**RC2**	1.5×10^3	3.0	√	**RC14**	4.2×10^2	3.6	√
2	**0.95 m**	**RC3**	20	4.9	√	**RC15**	30	4.8	√
2	**0.35 m**	**RC4**	N/A	N/A	N/A	**RC16**	<10	>4.9	x
2	**0.65 m**	**RC5**	N/A	N/A	N/A	**RC17**	N/A	N/A	N/A
2	**0.95 m**	**RC6**	<10	>4.9	x	**RC18**	N/A	N/A	N/A

N/A = No sample obtained from lysimeter

Table 7.51 Bacteriophage ***PR772*** removal from percolate at three depth planes and detection of bromide (√= Yes; x = No) 3 days after injection (Site B).

		Percolation Trench 1				Percolation Trench 2			
Day	**Depth**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**	**Sample Point**	**PFU mL^{-1}**	**Total log_{10} Removal (from input)**	**Bromide**
3	**0 m**	**INPUT**	1.7×10^6			**INPUT**	1.7×10^6		
3	**0.35 m**	**RC1**	5.2×10^4	1.5	√	**RC13**	1.9×10^5	1.0	√
3	**0.65 m**	**RC2**	<10	>4.9	√	**RC14**	<10	>4.9	x
3	**0.95 m**	**RC3**	<10	>4.9	√	**RC15**	<10	>4.9	√
3	**0.35 m**	**RC4**	<10	>4.9	x	**RC16**	<10	>4.9	x
3	**0.65 m**	**RC5**	<10	>4.9	x	**RC17**	<10	>4.9	x
3	**0.95 m**	**RC6**	<10	>4.9	x	**RC18**	<10	>4.9	x

N/A = No sample obtained from lysimeter

7.3.7 Fate of Endocrine Disrupting Chemicals in Subsoil Treatment Systems

In order to provide an insight into the effectiveness of both on-site systems and in-situ subsoils with respect to the removal of certain endocrine disrupting chemicals (oestrogens and bisphenol A) and caffeine, two sets of effluent samples were taken from both sites towards the end of site monitoring in February and April, 2008. At this stage of the project the percolation areas had been fully characterised in terms of effluent distribution and the reed beds had been established for over two years. As such, effluent samples from the septic tank, *Biodisc*® and reed beds were taken, as well as subsoil samples, at different depths from suction lysimeters where the effluent was known to be percolating. It should be noted that the limits of detection were much finer compared to a previous study on EDCs for on-site systems in Ireland (O'Súilleabháin *et al.*, 2008); the LOD for the oestrogens were 0.05 ng L^{-1}, compared to only 2 μg L^{-1} in said study, for example. With the exception of oestrone, most other oestrogens have been detected, if detected at all, in the range < 10 ng L^{-1} in the subsoil (Mansell and Drewes, 2004; Snyder *et al.*, 2004). It has been postulated that caffeine could be used as a conservative indicator for on-site effluent contamination and so its fate was also studied in this project. The results from this sample analysis are shown in Table 7.52. It should be noted that any comparison between STE and RBE concentrations must be viewed with caution, however, as the time-lag owing to the residence time of the reed bed is not taken into account. Similarly, travel times from the proprietary systems to the depth planes will vary depending on infiltration rate and other hydrodynamic properties and as such comparative planar reductions are treated with caution. A much longer and more frequent sampling study would be required to gain a full picture of the process.

The concentrations of oestrogens discharged in the STE compare reasonably to results published in other studies: for example, a study on septic tank effluents in Cape Cod measured oestrone in the range 49 to 74 ng L^{-1} and 17β-oestradiol values of 16 to 19 ng L^{-1} (Rudel *et al.*, 1998; Swartz *et al.*, 2006). Equally, the same research found concentrations of bisphenol A in the septic tank effluent as high as 1 μg L^{-1}, which correlates well with the data here. In contrast, Staples *et al.* (1998) have shown bisphenol A to be easily removed in aerobic secondary treatment processes with Cordy *et al.* (2004) measuring concentrations of the compound in SE in laboratory studies in the range 110 to 180 ng L^{-1}. These reported levels are, however, almost six times lower

than the bisphenol A concentration recorded in the SE from the *Biodisc*® on Site B. In this circumstance, given the absence of influent data, it is difficult to quantify the efficiency of the packaged treatment system with respect to bisphenol A removal other than to highlight the potentially greater discharge levels from such systems than what has been previously reported. The concentration of caffeine from the septic tank (320 $\mu g\ L^{-1}$) again appears larger than findings from other studies - caffeine levels in septic tanks in Wisconsin (Wilcox *et al.*, 2009) measured levels of caffeine levels 1 to 100 $\mu g\ L^{-1}$ while septic tank systems in North Carolina showed caffeine levels of 5 to 88 $\mu g\ L^{-1}$ (Chew and Weinberg, 2007). Levels found in the SE (620 $ng\ L^{-1}$) from the *Biodisc*® compare favourably to the Wisconsin study (Wilcox *et al.*, 2009) where caffeine levels in secondary treated effluent were detected in the range 50 to 900 $ng\ L^{-1}$. It should be noted that the caffeine in wastewater is due to unconsumed and waste caffeine related product sent directly to the treatment systems (un-drunk coffee and grounds etc.). The human body acts to efficiently metabolise caffeine leaving only very low concentrations in urine.

Several studies have indicated that both biodegradation and sorption are important in the removal of EDCs in wastewater treatment plants and suggested that oestrone is the most persistent steroid oestrogen in the final effluent being the most resistant to decomposition in wastewater treatment processes (Ternes *et al.* 1999; D'Ascenzo *et al.*, 2002). This appears true for the anaerobic based systems on Site A (septic tank and horizontal SSF) where oestrone concentrations are significantly greater than the other range of oestrogens. However, the evidence from these trials would seem to indicate that oestriol is more persistent than oestrone in the effluent from the aerobic secondary treatment unit on Site B. Oestrone, in turn, does seem more persistent than 17β-oestradiol to secondary treatment plant processes.

Once percolating though the unsaturated subsoil, the lipophilic properties of oestrogens mean that they would be expected to sorb onto the soil particulates. Equally, they could undergo further aerobic microbiological and chemical degradation. This is indeed what has been found in the subsoil of both sites with all oestrogens degrading with depth to very low values, with the exception of oestriol which again seems to be more persistent, especially in the case of the subsoil on Site B. This may be due to it having an octanol/water coefficient lower than that of both oestrone and 17β –oestradiol (Lai *et*

al., 2000), making it less susceptible to adsorption to soil particles or indeed organic materials. In addition, the absence of a biomat on the percolation trenches receiving SE on Site B (System III) has more than likely increased infiltration rates which, combined with the highly permeable sandy GRAVEL in the vadose zone, has compromised EDC removal efficiency.

An interesting result from the data shows the apparent slow degradation of oestrone between the infiltrative surface and the red depth plane, particularly under the trenches treating STE, when compared to 17β-oestradiol. Oestradiol can be biotransformed to oestrone under both aerobic and anaerobic conditions and so this apparent lag is perhaps evidence that the 17β-oestradiol is being biodegraded (into oestrone) over the first 0.35 m of subsoil. It is likely that the oestrone is also being degraded over the first 0.35 m but the addition of the biodegradation product from the breakdown of 17β-oestradiol results in no apparent net reduction. However, once all the oestradiol has been transformed by the red plane, the oestrone is then significantly degraded over the next 0.6 m of subsoil from the red to the black plane. 17α-ethynyloestradiol, a component of the contraceptive pill and hormone replacement therapy, was shown to be present in small quantities in the proprietary treatment systems of Sites A and B but reduced to below detection limits in the subsoil. This is despite previous studies having reported that the oestrogen displays a much slower degradation half-life than the natural oestrogens (Ying *et al.* 2003). It should be noted that there was little or no degradation of oestrogens under anaerobic conditions in the reed beds.

The organic oxygen compounds, phthalates and bisphenol A, have been shown to be easily removed in aerobic secondary treatment processes (Staples *et al.* 1998) and so would not be expected to be persistent in the on-site treatment environment as they would be subject to biodegradation and adsorption to suspended solids and sediments.

Table 7.52 Reduction in Endocrine Disrupting Chemicals and caffeine

	Oestrone (ng L^{-1})	17β-Oestradiol (ng L^{-1})	Ethynyl-oestradiol (ng L^{-1})	Oestriol (ng L^{-1})	Bisphenol A (ng L^{-1})	Caffeine (ng L^{-1})
	---------- *Site A* ----------					
STE	21.4	14.4	0.11	13.5	660	3.2×10^5
Red	21.8	1.94	0.13	2.4	159	177
Black	0.49	0.12	<0.05	<0.5	302	80
RBE	33.9	15.2	0.05	19.2	701	2.2×10^4
Red	6.62	1.7	<0.05	-	543	256
Black	0.29	<0.05	<0.05	2.3	137	154
D/S GW	0.6	0.13	<0.05	<0.5	1.7×10^4	<10
	---------- *Site B* ----------					
SE	4.24	0.44	0.07	12.9	683	620
Red	2.18	0.14	<0.05	11.3	134	23
Blue	0.83	<0.05	0.06	10.2	145	<10
D/S GW	<0.05	<0.05	<0.05	9.1	201	<10

This, however, is not strongly supported by the data. Degradation of bisphenol A is evident with depth through the subsoil in all trenches, but only in the region of 50% underneath the septic tank effluent trenches (System I). There are also still relatively significant concentrations in the downstream groundwater point on Site B. The downstream groundwater point on Site A showed an extremely high value for bisphenol A of 17 $\mu g\ L^{-1}$ which is much higher than the values from the septic tank. It is not known why this value was so high but may have been due to some previous localised pollution on the field (for example, spilt paint) which has been used as a steeple-chase course for horses. Alternatively, it may be evidence of a previous high loading event from the wastewater systems which has cleared the septic tank and subsoil perhaps. This is felt to be unlikely as very similar concentrations were recorded on both

sampling events which were 3 months apart.

Contrary to previous reports (Seiler *et al.*, 1999) it appears that there is a considerable removal of caffeine in the subsoil beneath all the trenches. Caffeine was still at measurable concentrations in the subsoil but there was no evidence in the groundwater on either site. This correlates with evidence that had been forwarded suggesting the removal of caffeine was in aerobic subsoil conditions as opposed to saturated conditions (Swartz *et al.*, 2006). This is confirmed by the comparison of STE and reed bed effluent which shows that there appears to be very little degradation of caffeine in the anaerobic environment of the reed bed. There is evidence that secondary treatment has reduced the concentrations when comparing Site A and Site B effluent. The use of caffeine as a conservative indicator of on-site treatment effluent is therefore somewhat questionable based on this study, as it appears to degrade significantly in a typical on-site environment comprising minimum 0.95 m of unsaturated subsoil. However, alternatively caffeine could be viewed as a representative tracer for some of the other contaminants of interest (COD and bacteria, for example) as their removal characteristics seem to mimic these pollutants with depth.

8. ANALYSIS OF RESULTS FROM HORIZONTAL SSF REED BED TREATMENT SYSTEMS

8.1 Introduction

An assessment of the performance of the horizontal SSF reed beds, both for the treatment of primary effluent on Site A and secondary effluent on Site B, over a sampling period of two years is presented in this chapter. Appendix D contains all chemical, bacteriological and viral results from both reed bed systems.

For stringent analysis of the reed beds, water loss and gain through evapotranspirative fluxes and rainfall were measured through accurate water balance studies. Actual hydraulic retention times were measured through Rhodamine WT (RWT) tracer trials to compare with nominal hydraulic retention times (nHRT). Retention times for each sample date were calculated by back-cumulating recorded daily inflows from noon on each sampling date (approximate time of sample extraction) until the porous volume of the reed bed, in question, was reached. The temporal variation in organic chemicals (COD, TSS), nutrients (TN, NH_4-N and PO_4-P) and bacteriological concentrations in the influent and effluent of the reed beds are presented, along with relevant correlation analysis, using MS Excel and the statistical programme Minitab® 15.1.1, of the various wastewater parameters including hydraulic loading, retention times and rate constants. Spearman-Rank correlation analysis was selected, with datasets equal to or below the significance level of $p = 0.05$ considered to be significantly correlated.

8.2 Analysis of Water Balance

As previously outlined in Section 3.6.1, meteorological effects can have a significant additional impact on treatment performance. Wastewater flows can combine with seasonally variable rain, evaporation and transpiration rates and have a considerable effect on the water budget of a wetland system and thus on the mass balance of elements entering and leaving the wetland system. Given the absence of continuous outflow data from the reed beds, daily water balances were carried out, taking into account the accurate incoming flows measured by the tipping buckets, measured crop coefficients and the relevant meteorological variables.

System II – Secondary Treatment Reed Bed (Site A)

In order to carry out a successful water balance study of the secondary treatment horizontal SSF bed and obtain outflow data, crop coefficients needed to be determined to calculate ET_{reed} in accordance with Eqn. 3.10. A short trial was devised which involved draining the outlet sump of the reed bed using a calibrated bucket and measuring the time it took for the effluent to refill just before reaching the discharge point of the outlet pipe. This volume of effluent in the outlet sump was measured and together with recorded inflow and evapotranspiration data over this trial period, K_c was calculated. On Site A two such trials were carried out in late May and mid-June, 2008, when macrophyte height and leaf surface area were deemed to be progressing and at their maximum level, respectively. The first trial (30/05/08) yielded a K_c value of 1.15 while the second trial (10/06/08) saw K_c increase slightly to 1.27. A mean value of 1.21 was therefore taken for K_c over the summer months (June-August). A value of 0.1 was assumed for the winter season (December-February) as effects from evapotranspiration were negligible at this time. Coefficient values over the intervening months were determined by interpolation with the factor gradually increasing towards summertime and reducing as winter closed in (Table 8.1). Figures 8.1 and 8.2 show the daily and monthly mean evapotranspiration rates for the reference surface and the reed bed having applied the crop coefficients.

Table 8.1 Monthly variations in crop coefficient (K_c) applied to secondary treatment horizontal SSF reed bed (Site A)

Month	**K_c**	**Month**	**K_c**
January	0.1	*July*	1.21
February	0.1	*August*	1.21
March	0.3	*September*	0.9
April	0.6	*October*	0.6
May	0.9	*November*	0.3
June	1.21	*December*	0.1

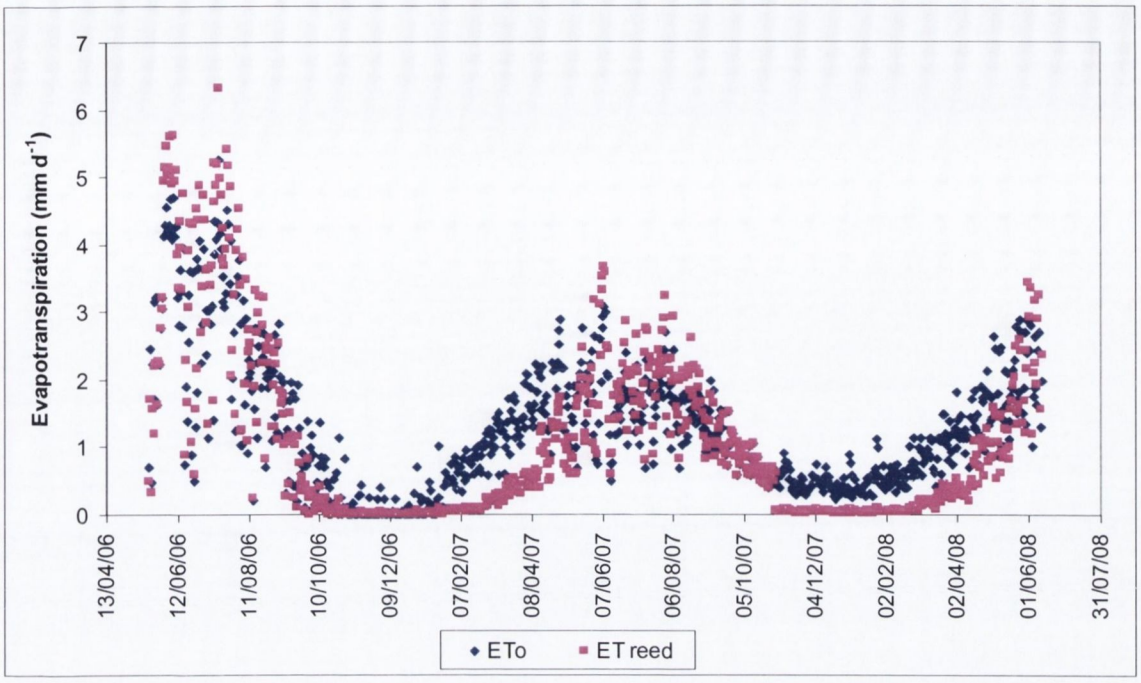


Figure 8.1 Daily Penman-Monteith reference evapotranspiration rates (ET_o) and reed bed evapotranspiration rates ($ET_{reed} = K_c ET_o$) for Site A reed bed

Mean ET_{reed} was measured at 1.06 mm d^{-1} over the duration of the sampling period with rates ranging from 0 mm d^{-1} to 6.31 mm d^{-1}. The effects of seasonality are clear with summer ET_{reed} rates averaging 2.68 mm d^{-1} in contrast to 0.04 mm d^{-1} across cooler winter months. ET_{reed} values decreased from 1.26 mm d^{-1} in Year 1 to 0.82 mm d^{-1} in Year 2 owing primarily to a cooler summer in the second year, when mean temperatures dropped from 15.1 °C to 13.5 °C. Total rainfall measured over the two year sampling period on Site A was found to be 1 912.6 mm (Year 1: 976.6 mm; Year 2: 936.0 mm).

The results from the daily water balance are included in Appendix F. In incorporating the correct crop coefficient, the mean flow from the reed bed to the percolation trenches was found to be 349.9 L d^{-1} [Std. dev. = 210.2], slightly greater than the mean flow to the reed bed of 327.3 L d^{-1} [Std. dev. = 186.4]. The daily variations in flow into and out of the reed bed are shown in Figure 8.3. As can be seen the bed did not make a significant difference to the flows going to the percolation trenches, acting to increase flows by 6.4%, on average, in winter and by 0.5% in summer.

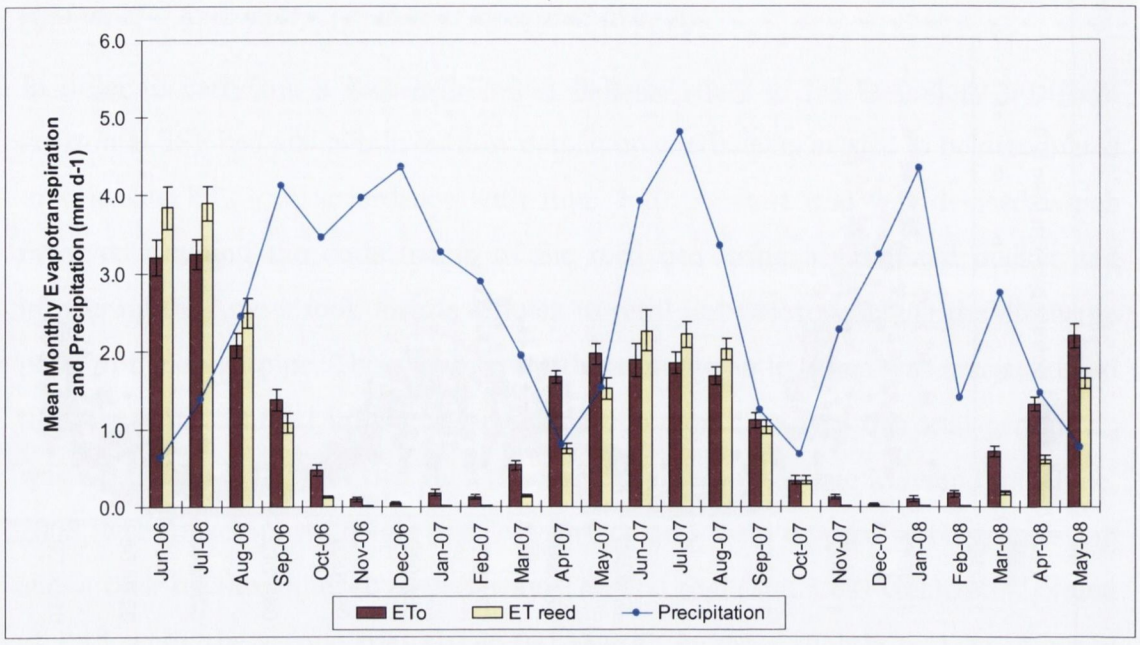


Figure 8.2 Mean monthly Penman-Monteith reference evapotranspiration (ET_o), reed bed evapotranspiration (ET_{reed}) and precipitation rates (mm d^{-1}) for Site A reed bed. Error bars represent +/- one standard error of the mean

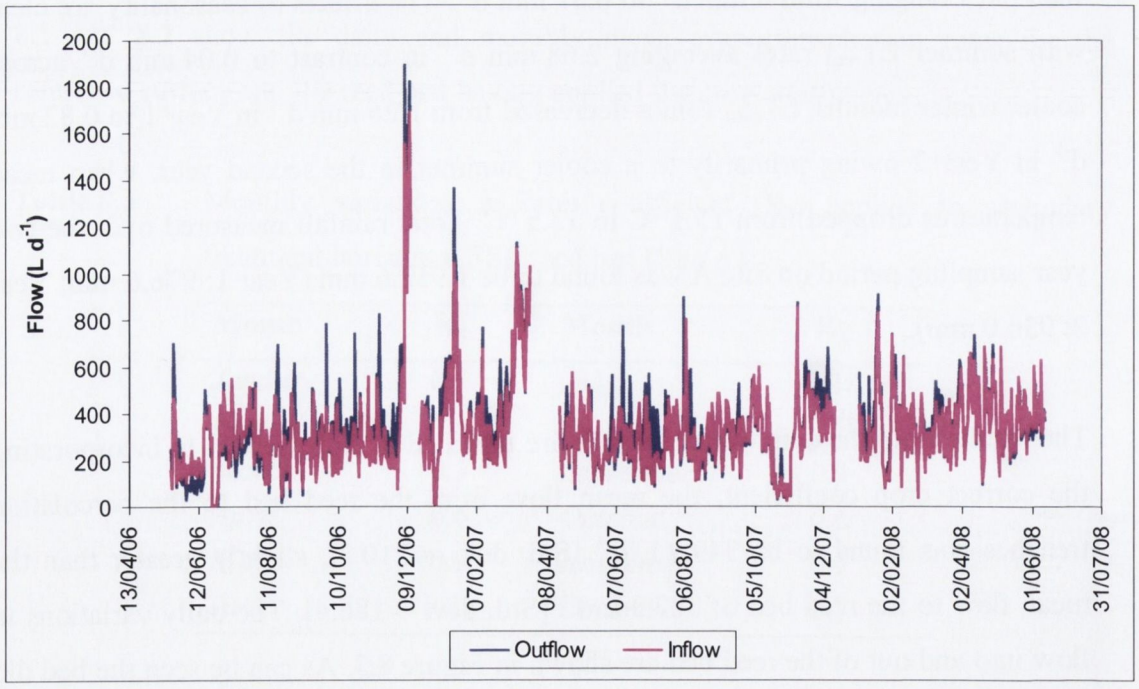


Figure 8.3 Inflow and outflow from Site A reed bed over the duration of sampling

Converting the mean inflow to the reed bed (327.3 L d^{-1}) to a hydraulic loading rate

(HLR) yields a value of 21.8 mm d^{-1}. Examining summer evapotranspiration rates, the mean ET_{reed} of 2.68 mm d^{-1}, based on a maximum K_c value of 1.21, equates to 12.7% of the reed bed's hydraulic loading. This is reduced during the cooler winter months with the mean ET_{reed} rate (0.04 mm d^{-1}), based on a minimum K_c value of 0.1, comprising a mere 0.2% of the HLR.

System IV – Tertiary Treatment Reed Bed (Site B)

Similar crop coefficient trials were carried out on the tertiary treatment horizontal SSF bed on Site B in late March and May, 2008, with measurement of a specific volume of outflow in the outlet sump over a period of time. Of the two trials carried out, the K_c value was found to have increased from 0.58 (26/03/08) in the first to an assumed maximum of 0.7 in the second (16/05/08). These values are less than the equivalent trial value on Site A and can be explained by the reduced evaporative surface area per unit flow for the reed bed on Site B. Since there was a gap of just under two months between the two trials, a period when the macrophytes were still emerging, it was decided to apply the K_c value of 0.7 for the summer months. As on Site A, a K_c value of 0.1 was assumed in winter due to little evapotranspiration occurring and interpolation applied between the two seasons (Table 8.2). Figures 8.4 and 8.5 illustrate the daily and monthly mean evapotranspiration rates for the reference surface and the reed bed having applied the crop coefficients.

Table 8.2 Monthly variations in crop coefficient (K_c) applied to tertiary treatment horizontal SSF reed bed (Site B)

Month	K_c	Month	K_c
January	0.1	*July*	0.7
February	0.1	*August*	0.7
March	0.2	*September*	0.5
April	0.3	*October*	0.3
May	0.5	*November*	0.2
June	0.7	*December*	0.1

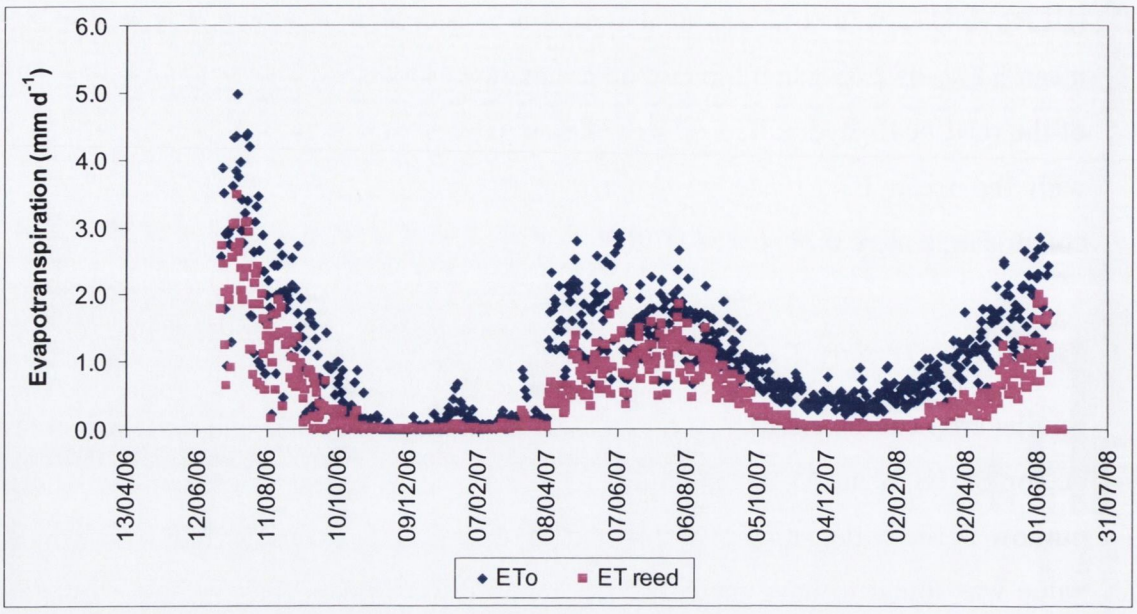


Figure 8.4 Daily Penman-Monteith reference evapotranspiration rates (ET_o) and reed bed evapotranspiration rates ($ET_{reed} = K_c ET_o$) for Site B reed bed.

Mean ET_{reed} was measured at 0.51 mm d^{-1} over the duration of the sampling period with rates ranging from 0.01 mm d^{-1} to 3.48 mm d^{-1}. As on Site A, the effects of seasonality are clear with summer ET_{reed} rates averaging 1.37 mm d^{-1} in contrast to 0.03 mm d^{-1} across cooler winter months. Temperatures dropped almost 2 °C from summer 2006 to summer 2007 (dates taken from 3rd July – 31st August each year as weather station was installed on 03/07/06) and, in accordance, summer ET_{reed} values decreased from 1.75 mm d^{-1} in Year 1 to 1.12 mm d^{-1} in Year 2. Total rainfall measured over the two year sampling period on Site A was found to be 1 858.6 mm (Year 1: 1 162.4 mm; Year 2: 696.2 mm).

The results from the daily water balance are included in Appendix A. In incorporating the seasonal crop coefficients, the mean outflow from the reed bed was found to be 149.2 L d^{-1} [Std. dev. = 92.7], slightly greater than the mean flow to the reed bed of 136.9 L d^{-1} [Std. dev. = 103.9]. The daily variations in flow into and out of the reed bed are shown in Figure 8.6. As can be seen again the reed bed did not make a significant difference to the flows going to the percolation trenches, acting to increase flows by 7.2%, on average, in winter and by 1.7% in summer.

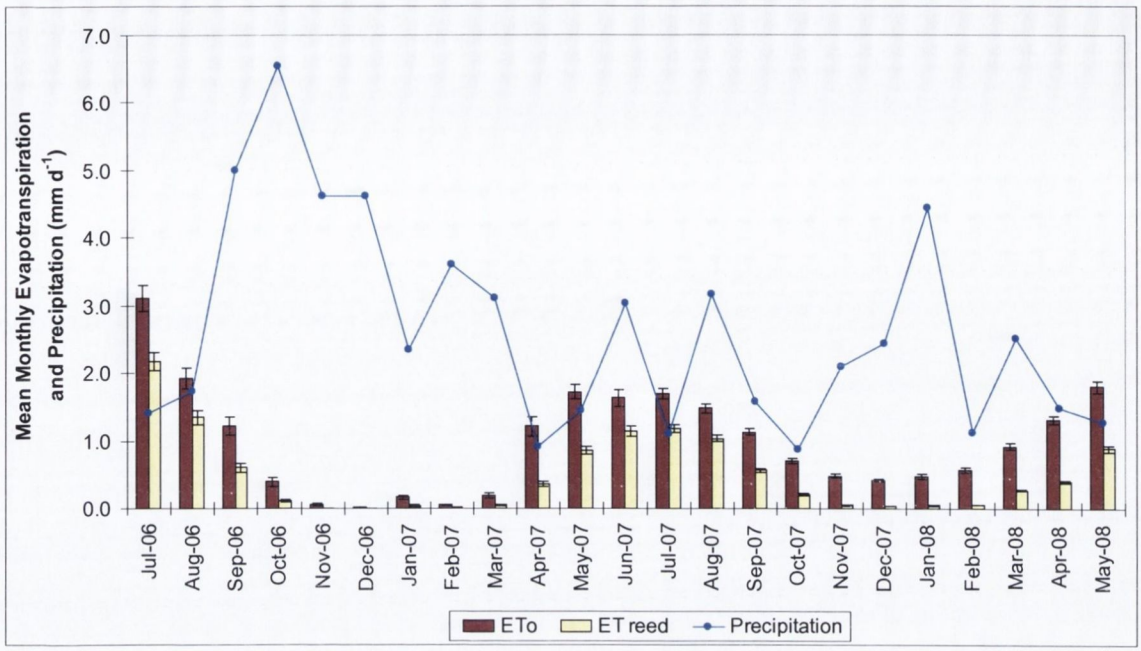


Figure 8.5 Mean monthly Penman-Monteith reference evapotranspiration (ET_o), reed bed evapotranspiration (ET_{reed}) and precipitation rates (mm d^{-1}) for Site B reed bed. Error bars represent +/- one standard error of the mean

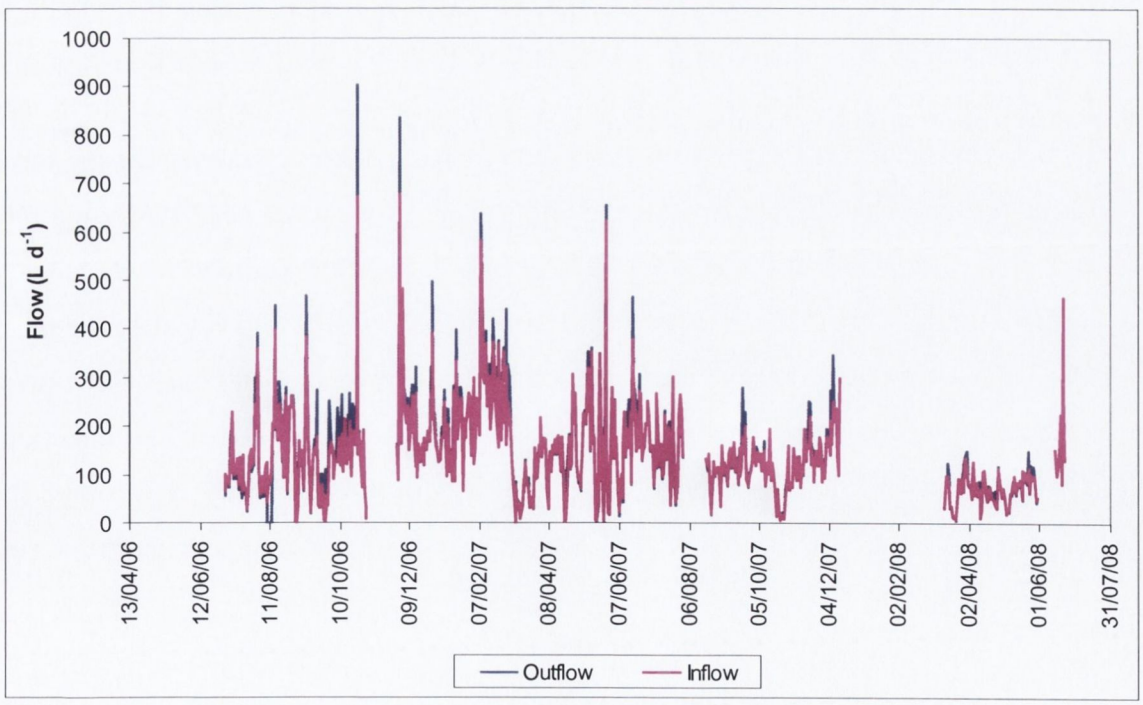


Figure 8.6 Inflow and outflow from Site B reed bed over the duration of sampling

Converting the mean inflow to the reed bed (136.9 L d^{-1}) to a hydraulic loading rate

(HLR) yields a value of 34.2 mm d^{-1}. Examining summer evapotranspiration rates, the mean ET_{reed} of 1.37 mm d^{-1}, based on a maximum K_c value of 0.7, equates to 4% of the reed bed's hydraulic loading. This is reduced to negligible during the winter months.

8.3 Analysis of Residence Time Distributions and Hydraulic Loadings

In order to ascertain the water flow patterns or hydraulic residence times of the reed beds, chemical tracer experiments were carried out using RWT. Two trials were performed on Site A; the first at the end of the first year of sampling (19/07/07) and the second during the final phase of sampling (22/04/08). A single trial was carried out at Site B on 26/03/08. The experiment was set up by connecting the calibrated fluorometer to the meteorological station and arranging for the datalogger to receive a voltage pulse, equivalent to a certain RWT concentration, every 10 minutes. The fluorometer was then securely positioned in the standpipe of the outlet sump.

RWT is supplied as a 20% w/v solution; for each trial 1.0 g of RWT was made up to 1 L with sterile deionised water to give a final tracer concentration of 200 mg L^{-1}. The RWT was stored in the dark at 4 (±1) °C for no more than seven days prior to use. Figures 8.7 (a), 8.8 (a) and 8.9 (a) show the RWT breakthrough curves for the three tracer trials. As the output from the fluorometer was given in mV, it was initially converted to concentrations (mg L^{-1}) taking into account background levels already present in the bed before a standard arithmetic method was used to calculate the mass of each RWT injection recovered from each trial having quantified hourly flow rates. This value was then expressed as a percentage of the mass of the original injection. The fraction of RWT recovered from each trial is illustrated in Figures 8.7 (b), 8.8 (b) and 8.9 (b). The respective breakthrough times, i.e. HRTs, and percentage recoveries are summarised in Table 8.3.

Results indicate very similar actual HRTs for the two trials carried out on Site A (6.38 and 6.67 days respectively). Nominal retention times were calculated across each trial using mean inflow and outflow data over that period and applying the data to Eqn 3.12 [$nHRT = V\rho/(Q_{in} + Q_{out})/2)$]. For the first RWT trial a nHRT of 7.61 days was

deduced, slightly above the actual figure while for the second trial a nHRT of 6.5 days was found, comparing favourably to the actual HRT of 6.67 days. While the disparity in trial 1 retention times may be attributed to a potential dead zone volume (~ 20%) in the bed, it is more likely that, given the results of the second trial, certain voids in the bed may have initially filled up with organic matter and biofilm of which were not taken into account in the porosity (ρ) figure adopted for calculation. As the bed then matured with time the increasing organic load may have spread more evenly across the inlet configuration in particular, promoting more even hydraulic flow distribution along the length of the bed. The decrease in percentage recovery of the RWT in the reed bed effluent between trial 1 and trial 2 (48% to 25%) points to this extra build up of organic material in the bed over the intervening 9-month period between the trials, as poor recovery of RWT has already been associated with irreversible adsorption to the abundant organic matter in wetlands (Smart and Laidlaw, 1977). Wetlands contain a high density and diversity of microbes that may also have contributed to dye loss via biodegradation. The peak breakthrough of the tracer response curve on Site B reed bed was 5.0 days, almost identical to the calculated nHRT of 4.9 days thus discounting any potential channelling or dead zones present in this wetland. Also, due to time constraints the tracer trial was cut just short from the end, i.e. RWT concentrations were still above background levels. As such the tracer curve is marginally incomplete while the reported recovery rate is slightly conservative. Despite this the RWT recovery is seen to be distinctly greater from Site B reed bed at 68% owing to the reduced level of organic compounds in the receiving secondary effluent. It is predicted that levels would have risen to between 75 and 80% had the trial continued for a further projected 48 – 72 hours. However, as tracer recoveries of anything more than 80% are considered an indication of an acceptable tracer experiment, when using a conservative tracer (Keller and Bays, 2002), it was desirable to examine the potential of a number of bacteriophages as biotracers suited to the quantitive description of water transit and dispersion within horizontal SSF reed beds. Multivirius injection experiments were therefore also carried out on both reed beds, the results (including recovery rate determinations) of which are included in Section 8.5.

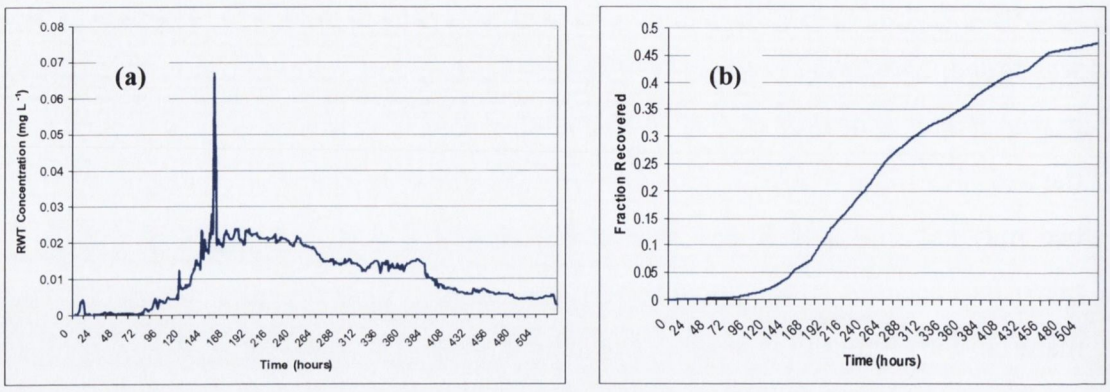


Figure 8.7 RWT **(a)** tracer response curve and **(b)** fraction recovery for Site A Reed Bed (Trial 1: 19/07/07 – 09/08/07)

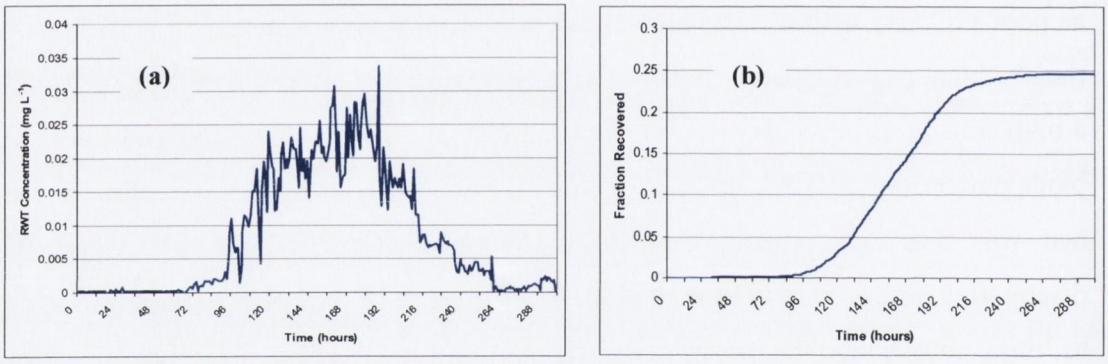


Figure 8.8 RWT **(a)** tracer response curve and **(b)** fraction recovery for Site A Reed Bed (Trial 2: 22/04/08 – 04/05/08)

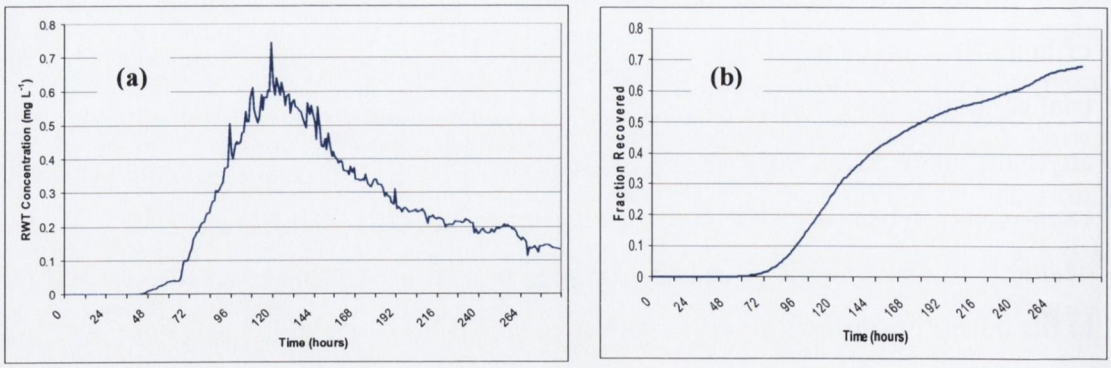


Figure 8.9 RWT **(a)** tracer response curve and **(b)** fraction recovery for Site B Reed Bed trial (26/03/08 – 08/04/08)

Table 8.3 RWT peak breakthrough time and percentage recovery

		Actual HRT (days)	nHRT (days)	% of RWT Recovered
Site A	*Trial 1*	6.38	7.6	48
	Trial 2	6.67	6.5	25
Site B	*Trial 1*	5.0	4.9	68

A summary of the design characteristics of the reed beds from Sites A and B coupled with their associated mean loading parameters is provided in Tables 8.4 and 8.5, respectively. Porosity of the pea gravel on Site A reed bed was measured at 34.6% while it was found to be 35.3% on the bed on Site B. Along with the obvious distinction in treatment level of the wastewater being purified by each reed bed the other greatest disparity is in the HLR, with Site B reed bed receiving, on average, nearly twice the daily flow per unit surface area compared to that of Site A reed bed. In comparing the respective HLRs to design values recommended in EPA (2000), it can be seen that both the secondary and tertiary treatment reed beds are significantly over-designed owing to the lower than anticipated on-site hydraulic loads previously discussed in Chapter 6. As such, in theory the additional residence time provided by the reduced HLRs should provide a greater treatment per unit surface area.

Table 8.4 Site A secondary treatment reed bed characteristics and hydraulic parameters

Influent Type	Plant Species	Dimensions, l x b x h (m)	Area (m^2)	Mean Inflow ($L\ d^{-1}$)	Mean HLR ($mm\ d^{-1}$)	EPA (2000) Design HLR ($mm\ d^{-1}$)
STE	*Phragmites Australis*	5.8 x 2.6 x 0.6	15	327.3	21.8	36

Table 8.5 Site B tertiary treatment reed bed characteristics and hydraulic parameters

Influent Type	Plant Species	Dimensions, l x b x h (m)	Area (m^2)	Mean Inflow ($L\ d^{-1}$)	Mean HLR ($mm\ d^{-1}$)	EPA (2000) Design HLR ($mm\ d^{-1}$)
SE	*Iris* & *Typha*	4.0 x 1.0 x 0.6	4	136.9	34.2	90

8.4 Results of Chemical and Bacteriological Analysis

System II - Secondary Treatment Reed Bed (Site A)

A summary of the treatment performance of the reed bed on Site A, installed to provide secondary treatment of STE, is shown in Table 8.6. Mean influent and effluent concentrations of pollutants and standard deviations over the total sampling period are provided. Surface load removal rates are calculated for each pollutant as per Eqn. 5.8. Likewise, the percentage load removal is calculated for every sample date according to Eqn. 5.9 and expressed as the mean of these values.

Immediate inspection of the results shows similar levels of reduction in COD and BOD_5. High removal efficiencies were also experienced for TSS, Total Coliforms and *E. coli*. With regards to nutrient removal the horizontal SSF reed bed has been shown to be limiting with little nitrification and subsequent denitrification along with poor PO_4-P fixation capacity confirming the need for further nutrient treatment provision prior to groundwater discharge.

As previously outlined in Section 3.5.1, anaerobic metabolism is believed to be the primary mechanism for the removal of organic chemicals in horizontal SSF reed beds, with some aerobic metabolism prevalent near roots and at the base of the bed (USEPA, 1993). Uptake of organic matter by the *Phragmites australis* is thought to be negligible compared to biological degradation. The organic matter removal efficiency in the bed, in the form of COD and BOD_5, is equally impressive with the slightly higher removal rate of the latter (68.3% as opposed to 66.8%) due to presence of non or low-biodegradable pollutants.

Table 8.6 Summary of Chemical and Bacteriological Analysis of Site A Reed Bed

Pollutant	Variable	Site A Reed Bed
COD	**Influent Conc. (±sd) (mg L^{-1})**	547 (±186)
	Effluent Conc. (±sd) (mg L^{-1})	220 (±120)
	Surface Load Removal (g m^{-2} d^{-1})	8.1
	% Load Removal	**66.8**
BOD_5	**Influent Conc. (±sd) (mg L^{-1})**	160 (±44)
	Effluent Conc. (±sd) (mg L^{-1})	48 (±37)
	Surface Load Removal (g m^{-2} d^{-1})	2.7
	% Load Removal	**68.3**
TN	**Influent Conc. (±sd) (mg L^{-1})**	107 (±26)
	Effluent Conc. (±sd) (mg L^{-1})	78 (±23)
	Surface Load Removal (g m^{-2} d^{-1})	0.8
	% Load Removal	**29.4**
PO_4-P	**Influent Conc. (±sd) (mg L^{-1})**	16.6 (±10.8)
	Effluent Conc. (±sd) (mg L^{-1})	8.8 (±6.0)
	Surface Load Removal (g m^{-2} d^{-1})	0.2
	% Load Removal	**43.1**
TSS	**Influent Conc. (±sd) (mg L^{-1})**	155 (±101)
	Effluent Conc. (±sd) (mg L^{-1})	41 (±23)
	Surface Load Removal (g m^{-2} d^{-1})	2.3
	% Load Removal	**77.0**
Total Coliforms	**Influent Conc. (±sd) (MPN 100 mL^{-1})**	1.28×10^7
	Effluent Conc. (±sd) (MPN 100 mL^{-1})	2.07×10^5
	Log-unit Reduction	**1.8**
E. coli	**Influent Conc. (±sd) (MPN 100 mL^{-1})**	7.44×10^5
	Effluent Conc. (±sd) (MPN 100 mL^{-1})	2.80×10^4
	Log-unit Reduction	**1.4**

The pattern of effluent COD concentrations, shown in Figure 8.10, appears to be consistent with influent concentrations. As detailed in Section 3.6.2, studies carried out in Mediterranean and sub-tropical climates have shown that seasonal effects play a significant role in organic removal in horizontal SSF reed beds while the

performance of these systems tend to improve over time, not least in the first three years of operation (Solano *et al.*, 2004; Headley and Davison, 1999).

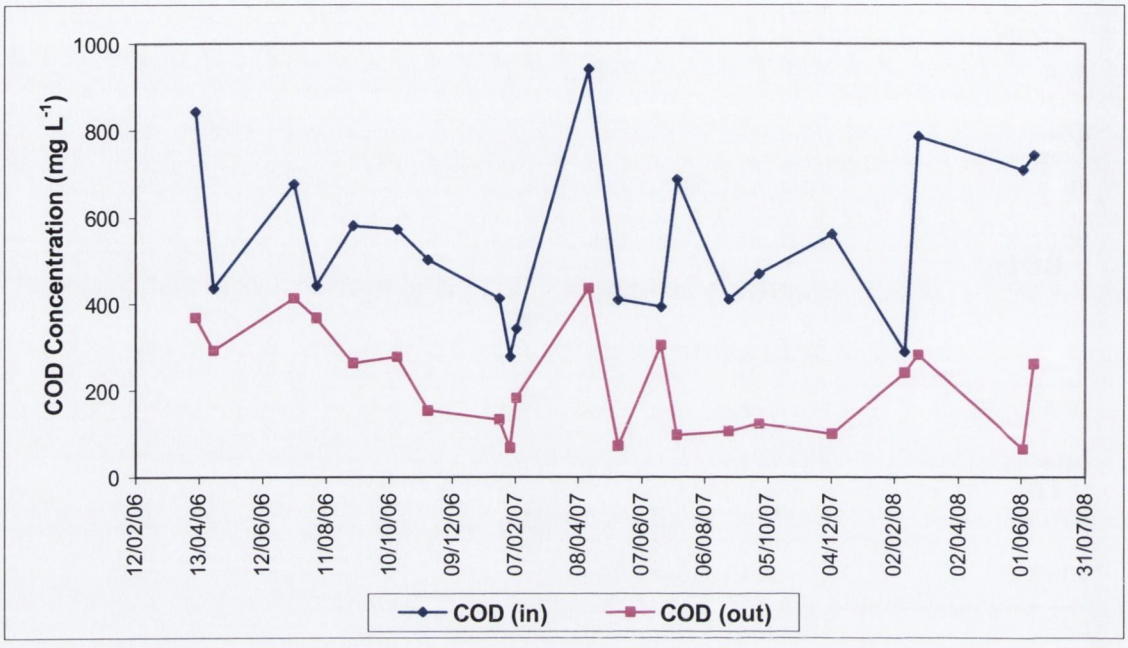


Figure 8.10 Temporal variation of influent and effluent COD (mg L^{-1}) in Site A reed bed

The seasonal and temporal variation in COD load removal over Site A reed bed throughout the duration of the project is presented in Table 8.7. The steady increase in treatment performance of the bed over time with respect to organic matter is evident with a mean 75% COD load removal in its third summer since operation drawing comparisons to overseas studies. This trend can be recognised in Figure 8.10 where, with the exception of the poor COD removal achieved on 12/02/08, a clear improvement in bed performance can be seen between the first and second year of operation. This presumably is as a result of the bed undergoing an adaptation period, with increasing biofilm on the bed's media over time responsible for extracting and digesting organic compounds. On a seasonal basis, there appears as yet to be no additional degradation of organic chemicals in summer suggesting that, in a temperate climate like that of Ireland, temperature does not play a major role in the kinetics of the system, at least during its early years of operation.

Table 8.7 Seasonal COD load removal (%) on Site A reed bed

COD Load Removal (± sd) (%)				
Year 1		Year 2		Year 3
Summer	Winter	Summer	Winter	Summer
50 (± 8)	62 (± 20)	68 (± 25)	69 (± 21)	75 (± 12)

[a] Summer months comprise sampling dates from May – September
[b] Winter months comprise sampling dates from October - April

Through linear regression and Spearman-Rank correlation analysis, a significant positive correlation ($p < 0.05$) between the influent and effluent COD concentrations (Spearman $r = 0.36$; $p = 0.04$) was found. This is illustrated in Figure 8.11, with the slope of the curve (0.29) very similar to that found for BOD_5 in Kadlec and Knight (1996) – see Table 4.5. A stronger correlation exists between the respective loadings (Spearman $r = 0.49$; $p = 0.003$). This is corroborated by the strong positive correlation between the surface loading of COD on the reed bed and the surface load removal achieved (Spearman $r = 0.86$; $p = 0.000$), shown in Fig. 8.12. One must be cautious with this finding, however, as it implies that the organic load is applied uniformly over the entire surface area of the system, when in reality it is thought that much of the input solids and organic chemicals are removed rapidly near the front end of the reed bed (i.e. the actual organic loading on this zone is much higher than on the rest of the bed).

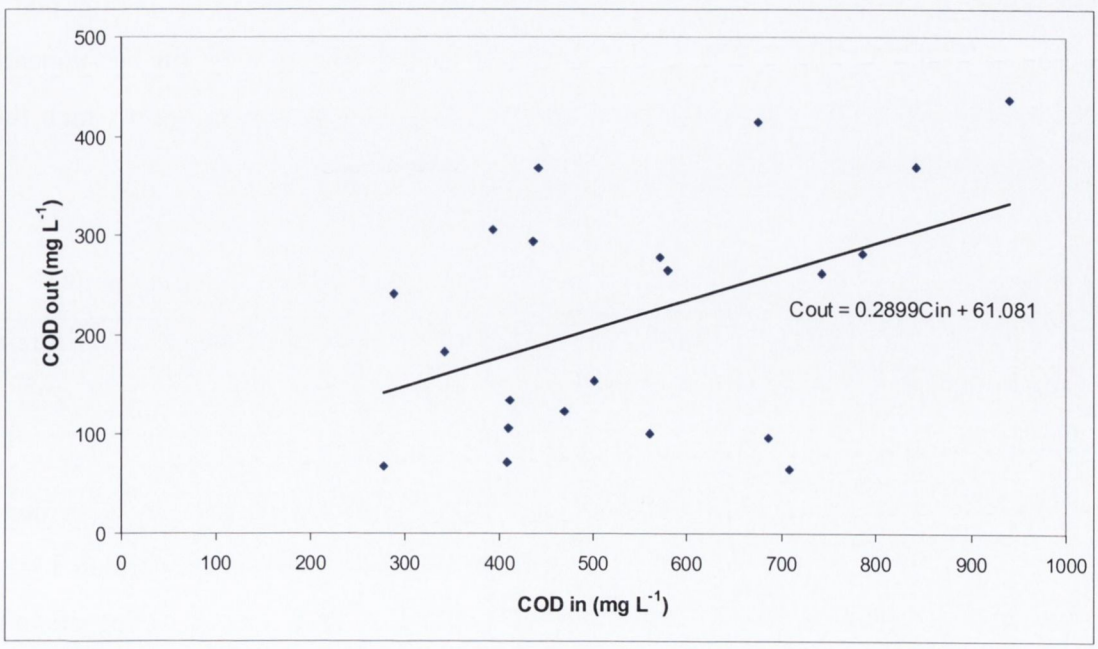


Figure 8.11 Relationship between influent and effluent COD concentrations

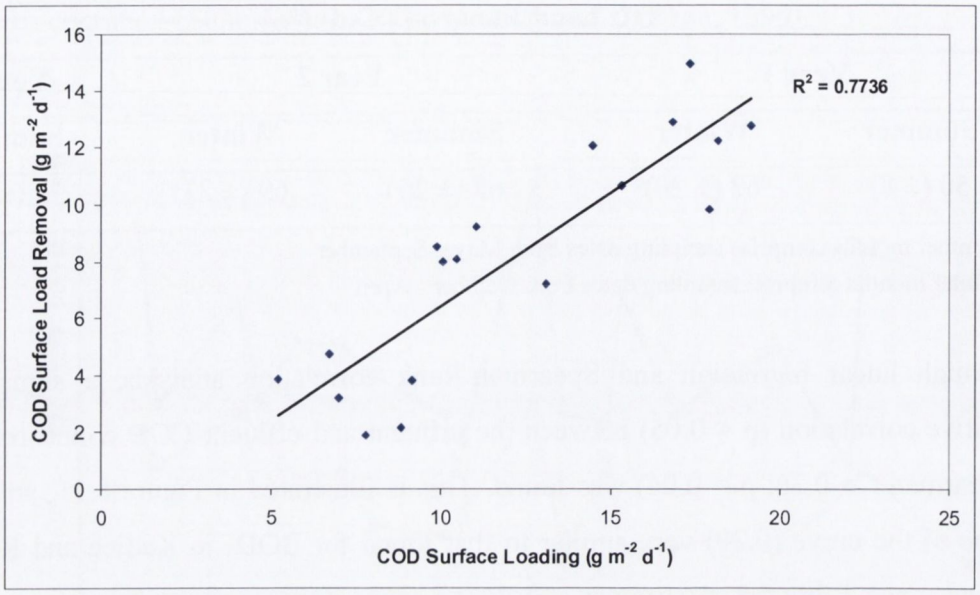


Figure 8.12 Relationship between COD surface loading and surface load removal rate

To further investigate this assertion, COD analysis was carried out on samples taken from the collection points at the middle of the reed bed (left, centre and right). Results are tabulated in Table 8.8 and interestingly reinforce the view that the majority, if not all the organic removal has been carried out in the first 7.5 m stretch of the bed. Seasonal COD patterns at the centre points also follow the same trend as the effluent sample point. In addition, removal rates were found to be uniform across the bed's width emphasizing the even hydraulic distribution achieved. As such, the bed appears to be oversized with respect to organic removal, the main parameter upon which the system is initially designed.

Table 8.8 Mean COD concentrations recorded at all reed bed sampling points

	Influent	Left Centre	Centre	Right Centre	Effluent
COD (mg L^{-1})	547	191	217	198	220

Analysis of hydraulic parameters show that little significant correlation is evident between the range of nHRTs and COD percentage load removals (Spearman r = -0.005; p = 0.75) and range of HLRs and COD percentage load removals (Spearman r = -0.185; p = 0.96).

First order rate constants, according to Eqn. 3.2, were calculated for each analysed wastewater parameter by way of integration. This involved plotting $-\ln(C_{out}/C_{in})$ against HRT. The reaction rate constant (k) is the resulting slope of the line-of-best-fit through this plot. A reasonable assumption was made that all background parameter concentrations were negligible and excluded from the kinetics.

A plot to investigate the value of k_{COD} over the duration of the monitoring yielded a value of 0.05 (Figure 8.13), slightly lower than the value of 0.1 for k_{BOD} adopted by Cooper *et al.* (1996) in WRc guidelines for secondary treatment horizontal SSF reed beds. Correlation analysis, however, show there to be no statistical significance in the observed data (Spearman = 0.04, p = 0.94).

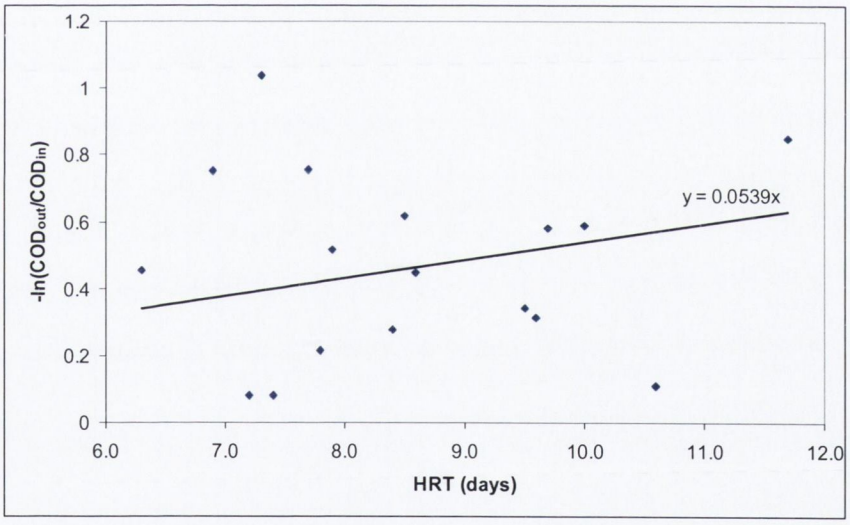


Figure 8.13 Plot of $-\ln(C_{out}/C_{in})$ versus HRT for COD

In assessing the variability in the kinetic process over time (Figure 8.14) it is interesting to note that whilst a positive but relatively loose relationship exists between k and the total reed bed age (Spearman r = 0.35, p = 0.13), a much stronger linear correlation occurs over the first 6 months of operation (Spearman r = 0.89, p = 0.017).

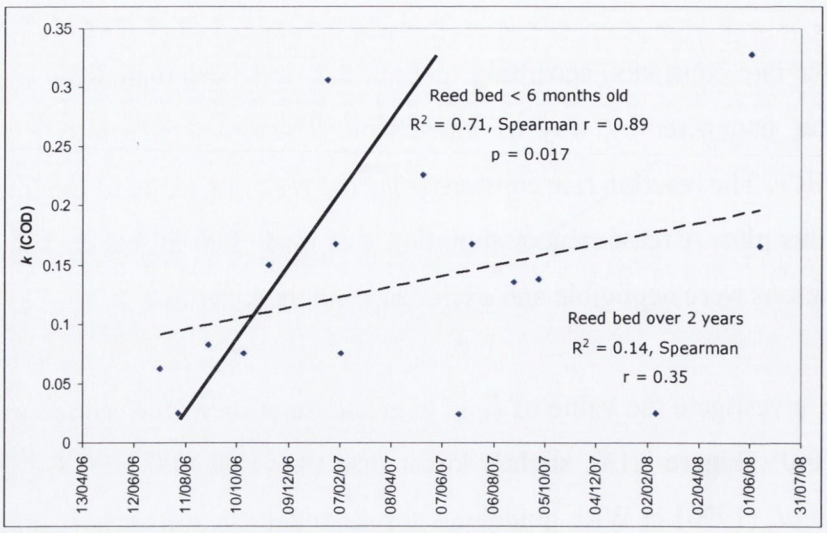


Figure 8.14 Plot of COD first order rate constant (k_{COD}) against reed bed age

This suggests that the bed has undergone an initial adaptation period before the performance has begun to level out with a greater spread in removal efficiencies.

The vast majority of suspended solids removal in horizontal SSF beds occurs at the inlet or within the first metre of the bed as a result of particle adhesion to both the gravel and associated biofilms. As a result, TSS is not commonly used as a criterion for wetland design. However, percentage load removal is reported and found, as expected, to be high at 77.1%, with little seasonal variation (Figure 8.15).

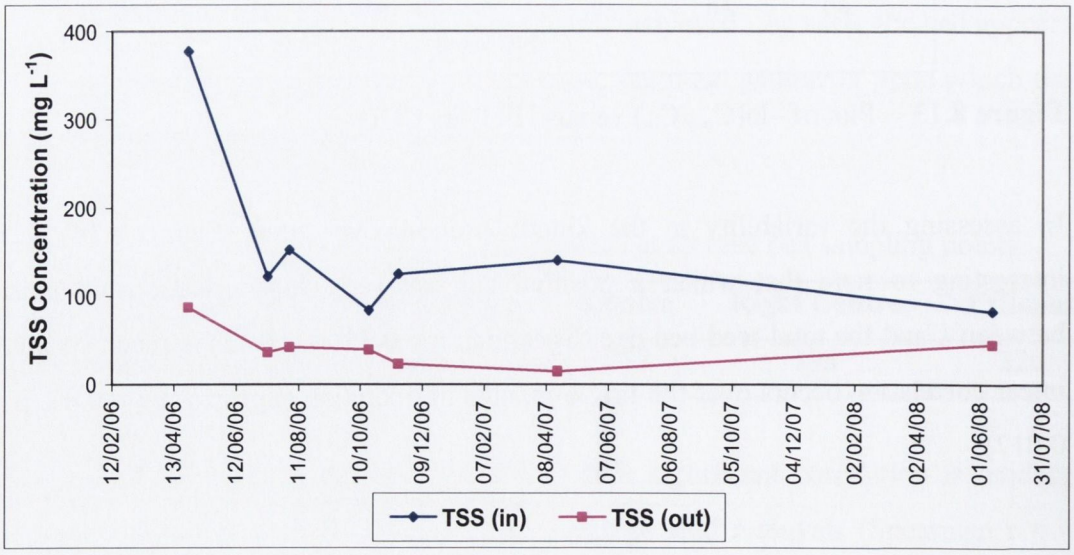


Figure 8.15 Temporal variation of influent and effluent TSS (mg L^{-1}) in Site A reed bed

The efficient removal of nitrogen is dependent on a series of transformations, namely, mineralisation of org-N to NH_4-N, nitrification of NH_4-N to NO_3-N followed by denitrification of NO_3-N to nitrous oxides and di-nitrogen oxide and finally nitrogen gas. The rate of these processes is very much dependent on both the composition of the influent and the prevailing conditions of the bed itself. Table 8.9 displays mean nitrogen species loadings at the inlet (i.e. composition of the STE) and outlet of the reed bed over the duration of the sampling. Figure 8.16 shows org-N, NH_4-N and NO_x-N loads at the inlet and outlet, with the total height of each bar representing the mean TN load. As expected, NH_4-N accounts for the highest percentage contribution to TN concentrations at both sample points although the efficiency of N-removal in the bed appears to be limited by slow rates of (i) mineralisation, with only an apparent net 50% conversion of the org-N fraction to NH_4-N and (ii) nitrification to NO_3-N, owing to the predominant anoxic environment of the bed. In examining concentrations, the NH_4-N : TKN ratio was seen to increase to 0.87 (i.e. org-N formed 13% of the reed bed TN) in the discharging reed bed effluent compared to 0.71 in the STE (see Section 6.2.2).

Table 8.9 Mean influent and effluent nitrogen loads from Site A reed bed over duration of sampling

	TN	**org-N**	**NH_4-N**	**TKN**	**No_x-N**
Influent (g d^{-1})	38.6	10.1	27.5	37.3	1.0
Effluent (g d^{-1})	27.3	4.7	21.1	26.9	1.5

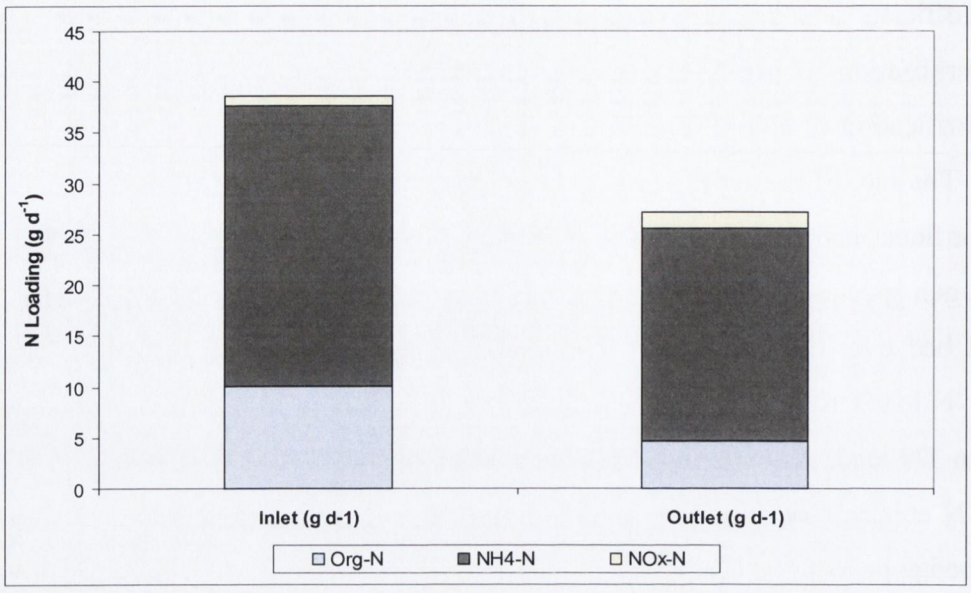


Figure 8.16 Mean nitrogen species loading in Site A reed bed

Under anoxic conditions, NH_4-N is stable and may be adsorbed by the substrate or used by plants and micro organisms (Sikora *et al.*, 1995). While little or no nitrification has been recorded in the results, it is possible that localised nitrification of NH_4-N may have occurred in micro zones adjacent to the roots and rhizomes in the bed. Oxygen diffusion is thought to be greatest through the macrophytes' roots. Any NO_3-N fraction may have then denitrified along its passage to the outlet as a result of the bed's prevailing anoxic conditions. Anammox of NH_4-N and NO_2-N directly to nitrogen gas may be another potential mechanism of removal.

TN and NH_4-N concentrations in the influent exhibit a similar temporal variation (Figure 8.17) ranging from 52 to 148 mg L^{-1} and 11 to 112 mg L^{-1} respectively. In the effluent, concentrations of both show the same temporal changes. NH_4-N concentrations are shown to sometimes exceed that in the entrance of the system, i.e. negative removal, which is thought to be as a result of the complexities attached to nitrogen detention times in wetlands. Continuous plant litter decomposition and mineralisation processes in the reed bed are converting stored org-N to NH_4-N indefinitely, creating a spiralling effect, as will be duly discussed.

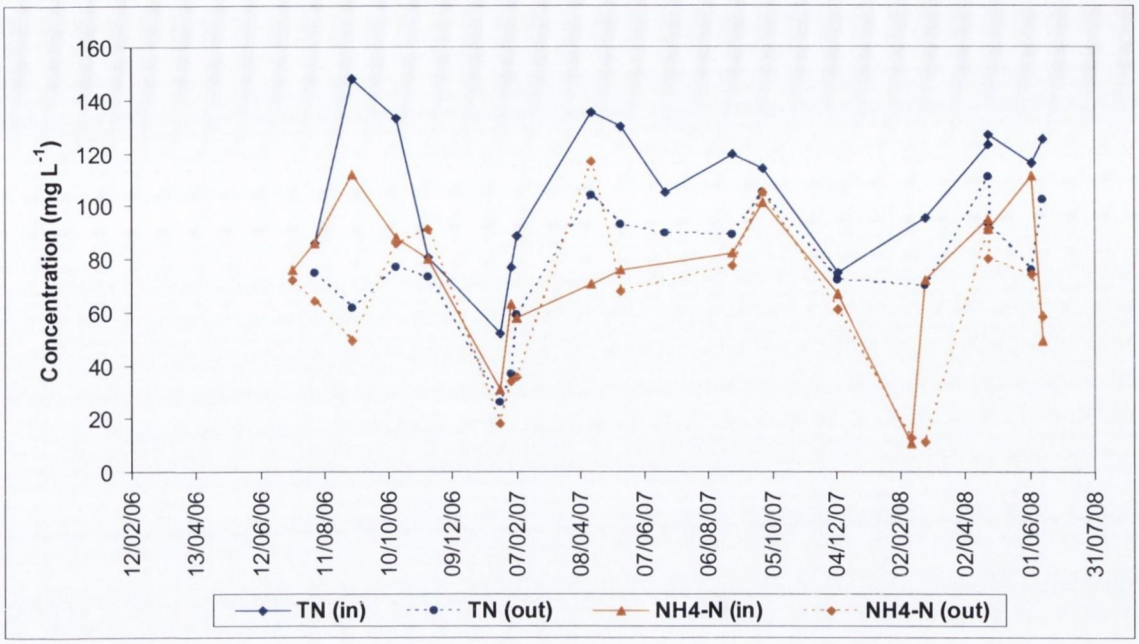


Figure 8.17 Temporal variation of influent and effluent TN and NH_4-N (mg L^{-1}) in Site A reed bed

While no discernible pattern can be observed from Table 8.9 with regard to seasonal removal it can be observed that removals were at their highest during the first year of reed bed operation. If TN loss through localised nitrification and subsequent denitrification is assumed, the lower removals obtained during the second year may be due to oxygen deficient areas occurring in the root-zone system. These areas are probably due to an excessive sedimentation of solids caused by continuous loading of the influents' organic compounds.

Table 8.9 Seasonal TN Load Removal (%) on Site A reed bed.

TN Load Removal (± sd) (%)				
Year 1		Year 2		Year 3
Summer [a]	Winter [b]	Summer	Winter	Summer
50 (± 4)	42 (± 22)	19 (± 8)	39 (± 18)	11 (± 22)

[a] Summer months comprise sampling dates from May - September
[b] Winter months comprise sampling dates from October - April

In examining NH_4-N and TN input-output data, correlation analysis reveals a strong positive relationship between influent and effluent concentrations. Figure 8.18 presents NH_4-N input versus output data with any points above the broken line

representing those dates when there was a net production of NH_4-N as the wastewater passed through the bed. The overall data, however, was statistically significant with Spearman r = 0.58 and p = 0.005. The correlation between input and output TN concentrations was again shown to be statistically significant with Spearman r = 0.58 and p = 0.002.

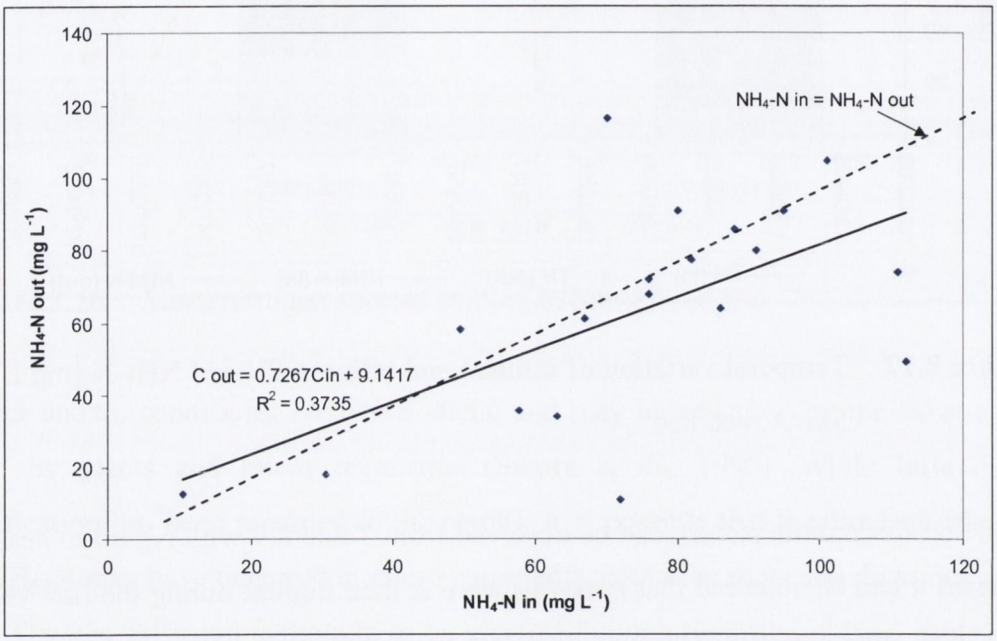


Figure 8.18 Relationship between influent and effluent NH_4-N concentrations

Unlike NH_4-N, removal of TN in the reed bed is shown to be positive throughout the duration of the study owing to the consistent mineralisation of org-N to NH_4-N. Hammer and Knight (1992) have shown that the effluent NH_4-N for horizontal SSF systems is related to the surface loading of TKN (or TN) on the system. There is a missing element to this approach, however, in that the residue from decomposition of plant matter in the bed is not taken into account given that the TKN loading is only a measure of nitrogen in the entering wastewater. Nevertheless a comparison of both is plotted in Figure 8.19 which shows a relatively strong linear relationship as shown by the value of the coefficient of correlation. Spearman rank statistics reveal a high level of significance with r = 0.5 and p = 0.011. This suggests that aside from the additional internal conversion of stored org-N to NH_4-N (a process with a turnover rate of between months and years) there was consistent mineralisation of influent org-N to NH_4-N across the reed bed.

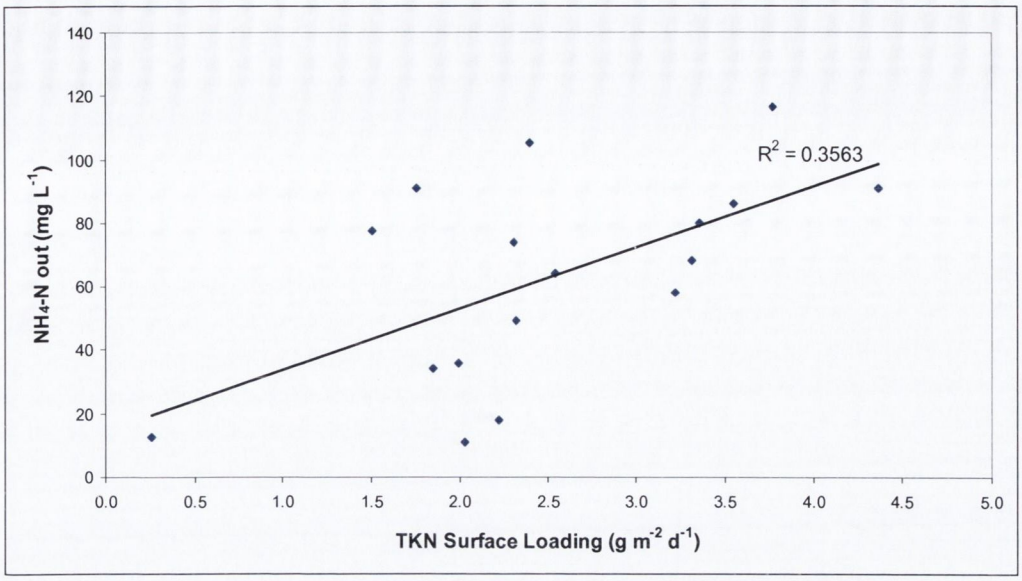


Figure 8.19 Relationship between TKN surface loading (g m^{-2} d^{-1}) and effluent NH_4-N concentrations (mg L^{-1})

In order to determine the rate constant for TN, a graph of HRT against $-\ln(C_{out}/C_{in})$ is plotted (Figure 8.20). Linear correlation shows the relationship between the two variables to be insignificant (Spearman r = 0.24; p = 0.264), indicating that in terms of first-order removal kinetics, increased HRTs (< 12 days) and subsequent reduced HLRs have a minimal effect on treatment performance. This is understandable given the complexities in nitrogen detention times outlined previously in Section 3.5.3. The slope of the best-fit-line, however, is equivalent to a k_{TN} value of 0.04 which is very close to the 0.07 quoted by Kadlec and Knight (1996).

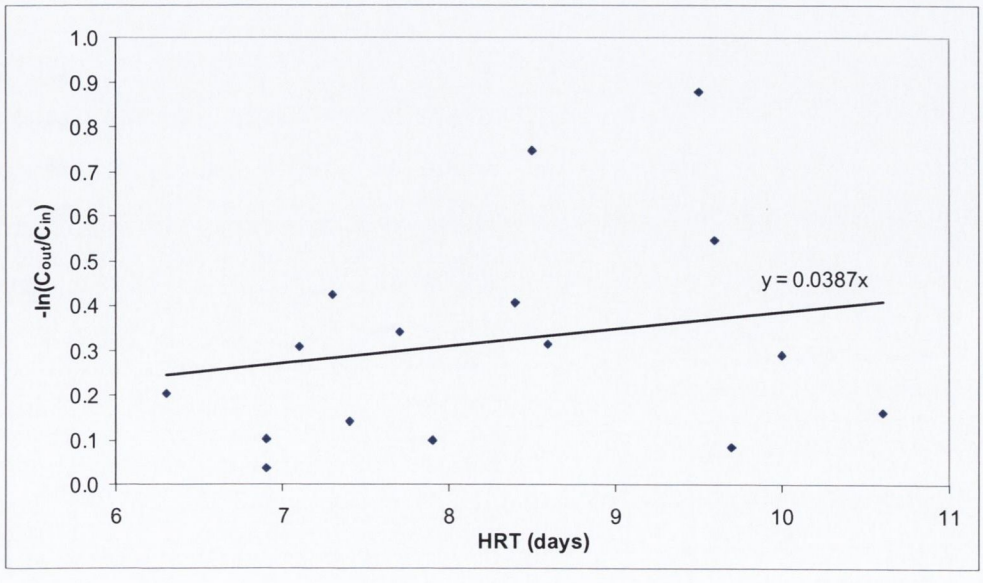


Figure 8.20 Plot of $-\ln(C_{out}/C_{in})$ versus HRT for TN

Correlation analysis found a slight reduction in reaction rates over time although the linear relationship was weak. This trend, illustrated in Figure 8.21, corroborates the earlier findings on temporal TN removal which shows the removal efficiency of the bed to be slowly declining over the first three years of operation.

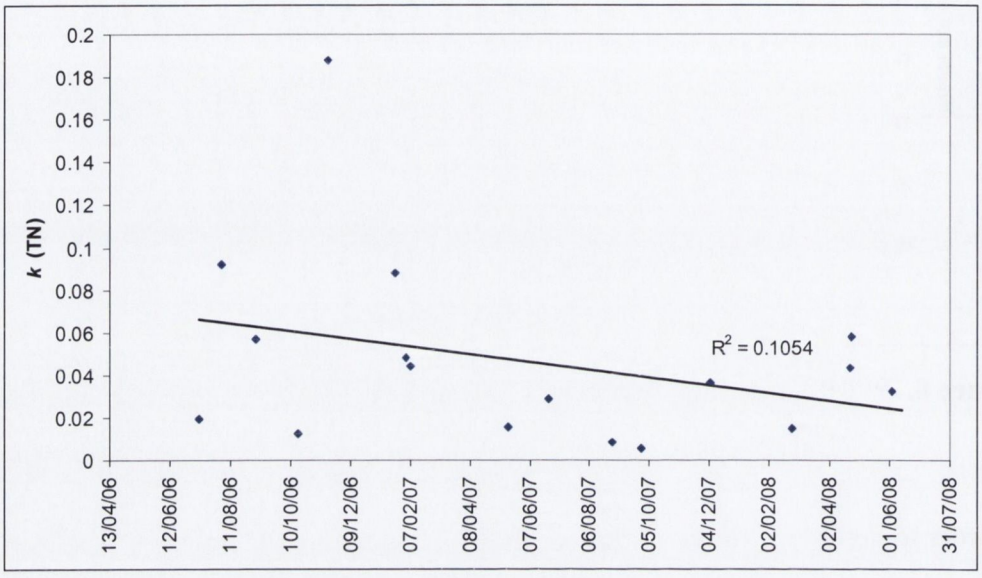


Figure 8.21 Plot of TN first order rate constant (k_{TN}) against reed bed age

^{15}N-Isotope Study

To further investigate and gain more understanding of the various mechanisms and pathways by which nitrogen is transformed and removed in the reed bed, a ^{15}N stable isotope tracer study was carried out with $^{15}NH_4$-N as the designated isotope used to provide an estimate of the nitrogen residence time.

The trials on each reed bed used pulse inputs of $^{15}NH_4$-N stable isotope to provide an estimate of N residence time in the subsurface-flow wetlands. The aim of the study was to gain more understanding of the various mechanisms and pathways by which nitrogen is transformed and removed in these reed beds using this isotope tracing technique which has been used in several studies on constructed wetlands and also the effects of organic fertilizers on soil (Cliff *et al.*, 2002; Powell *et al.*, 2004; Kadlec *et al.*, 2005; Camargo and Mara, 2007).

The influent and effluent samples for the reed beds were analysed for $^{15}N/^{14}N$ ratios which are reported in terms of the reference value of the average abundance of ^{15}N in air which is isotopically constant and designated as 0 ‰. Nitrogen isotope ratios are

generally reported in per mil (‰); a positive value indicates that sample has a higher proportion of ^{15}N compared to air, a negative value indicating a lower enrichment of ^{15}N compared to air.

The reed bed influent was spiked with 1.5 g of $^{15}NH_4Cl$ (98% ^{15}N, Cambridge Isotope Laboratories) on 22nd April 2008. One effluent sample per day (as a 24-hour composite) was taken for a period of 40 days which was over 6 times the hydraulic retention time of the bed. The effluent samples were analysed for different concentrations of nitrogen (NH_4-N, NO_3-N, NO_2-N and org-N) and the sample partitioned into organic suspended (org-N) and dissolved (NH_4-N and NO_x-N) for analysis of $^{15}N/^{14}N$ ratio. In the reed bed effluent on Site A, the dissolved fraction is almost totally in ammonium-N form as there is partially zero nitrite and nitrate concentrations. *Note: the small concentrations that were measured probably happened in the time between sampling and analysis in the aerated sample bottle.*

The background values of $\delta^{15}N$ values for septic tank and reed bed effluent yield some interesting information (Table 8.10). Physical and biogeochemical processes are accompanied by kinetic and equilibrium isotopic fractionations which lead to nitrogen compounds having different isotopic ratios (Karr *et al.*, 2001). The $\delta^{15}N$ values in the septic tank in both organic and ammonium forms are slightly enhanced with respect to the reference, as expected from waste products (Kendall and McDonnell, 1998). The reed bed effluent background concentrations show that the reed bed acts to slightly reduce the ammonium $\delta^{15}N$ values and fairly significantly reduce the org-N. The reduction in the suspended org-N is due to the biologically mediated reactions in the reed bed (principally assimilation and denitrification) which commonly result in increases in the $\delta^{15}N$ values of the substrate (i.e. the ammonium) and decreases in the $\delta^{15}N$ values of the product (the suspended organic fraction) (Kendall and McDonnell, 1998). The fact that the NH_4-N is not naturally enriched with respect to $\delta^{15}N$ values might indicate that most of the influent NH_4-N from the septic tank is passing straight through the reed bed without being taken up in any biologically mediated reactions. The context against which this is set is the overall nitrogen removal statistics from the wetland of 22% during the trial and the fact that influent is 24% org-N whereas 85% of the effluent was in NH_4-N form.

Table 8.10 $\delta^{15}N$ values (‰) for background septic tank and reed bed effluent

	Septic tank effluent	Reed bed effluent
NH_4-N	4.86	3.38
org-N	2.48	-3.55

The results of the $^{15}NH_4Cl$ tracer study are plotted in Figure 8.22 against the parallel results from the RWT tracer study which indicates the hydraulic retention time. The peak in the ammonium can be seen to come through exactly the same time as the RWT peak in about 6.5 days. This confirms what was suspected above that a high proportion of the NH_4-N from the septic tank is passing straight through the reed bed without taking part in any biogeochemical processes. On average, the ammonium loads have been reduced by 14%. However, there is a lag and then a distinct rise in the $\delta^{15}N$ values for the suspended org-N fraction (with a peak at around 10 days) which shows that some of the NH_4-N has been biologically assimilated into org-N (biomass or plants). There is a slight tail on the ammonium trace after the RWT trace has decayed sharply away which may be indicative of the ammonium that has been taken onto organic form and then released again as soluble ammonium – an example of so-called nitrogen "spiralling" (Kadlec *et al.*, 2005).

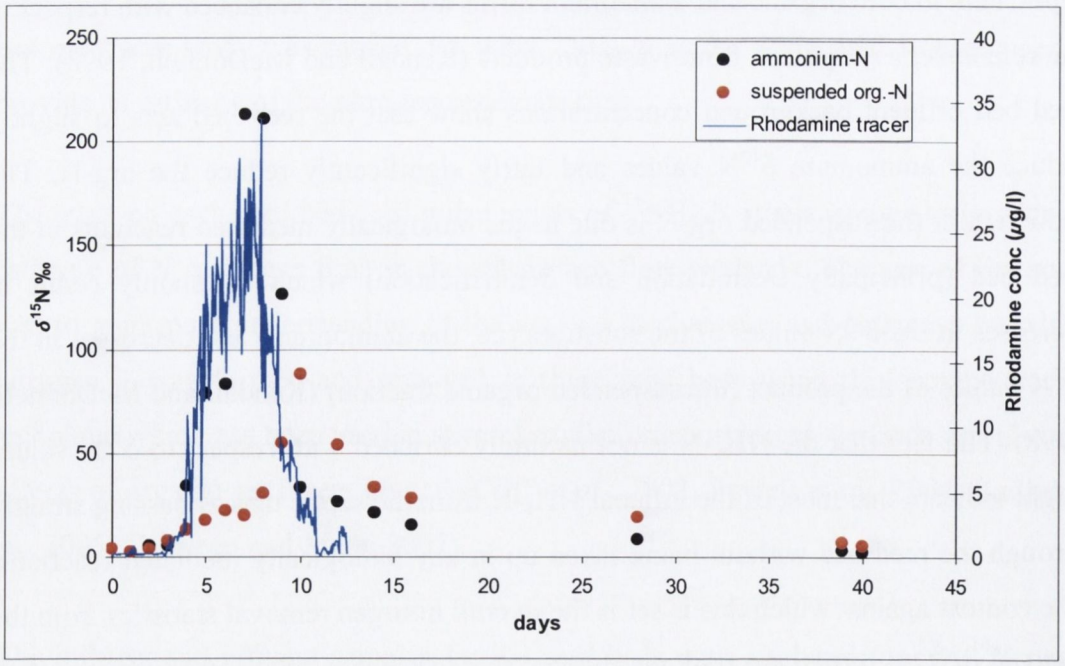


Figure 8.22 ^{15}N values for reed bed effluent nitrogen fractions and RWT tracer (Site A)

When the cumulative mass of ^{15}N above the background is computed it can be seen (Figure 8.23) that approximately 35% of the spiked ^{15}N has passed straight through the reed bed. From this point on (i.e. after the hydraulic retention time from the time of tracer addition) there is a gradual rise in the recovery which indicates that the original ^{15}N in ammoniacal form is passing through different states in org-N. After 50 days only 44% of the spiked ^{15}N has been recovered which suggests the other has been taken up by the plants (as it was at the beginning of the growth season) or lost by other means (denitrification etc).

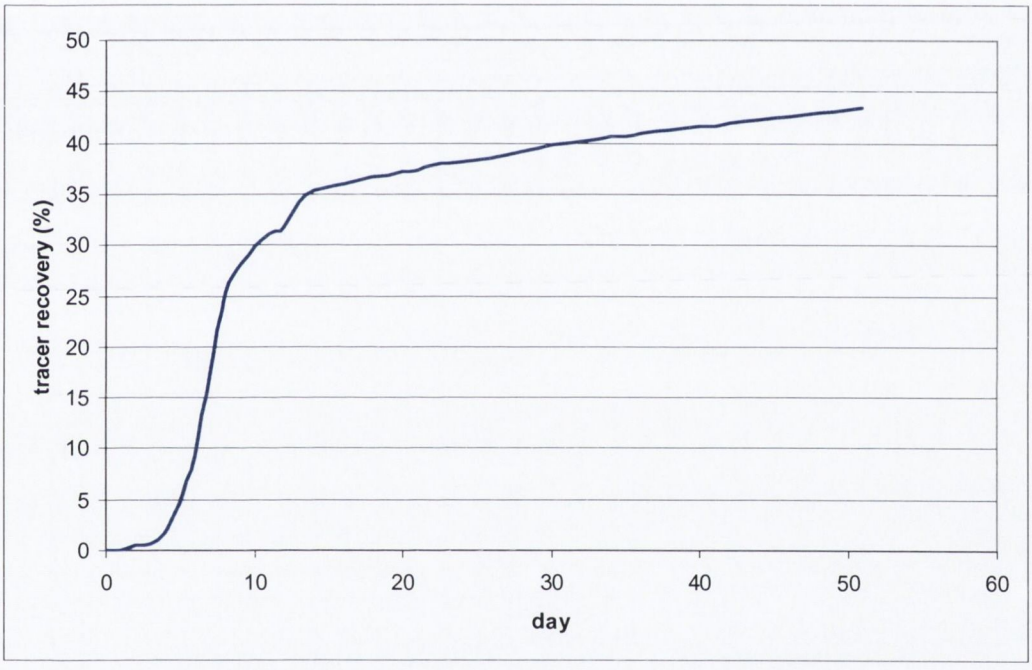


Figure 8.23 ^{15}N tracer recovery during the trial

Removal of phosphorus, in its soluble PO_4-P form, is found to be, on average, 45.1% which is surprisingly higher than TN removal, at 29.4%. Horizontal SSF type beds are generally thought to have a greater potential to remove nitrogen than phosphorus (Vymazal *et al.*, 1998) as the former can be converted to nitrogen gas and be emitted to the atmosphere as a consequence of coupled nitrification-denitrification processes as well as other possible aforementioned removal mechanisms. The only sustainable removal mechanism for phosphorus is plant uptake and subsequent harvesting. However, the amount of phosphorus that can be removed by harvesting the plants usually constitutes only a small fraction of the amount of phosphorus loaded into the reed bed with sewage (Brix, 1994). Phosphorus may also be mobilised by micro

organisms as well as being bound to the media of the reed bed mainly as a consequence of adsorption and precipitation reactions with calcium (Ca), aluminium (Al) and iron (Fe) in the gravel media. Given that the pea gravel media used in the reed beds of Sites A and B is devoid of suitable minerals for precipitation, it is thought plant uptake, adsorption and microbial immobilisation are the three principal mechanisms of PO_4-P removal in these beds.

Examination of temporal variations in PO_4-P (Figure 8.24) shows the effluent concentrations to follow the same pattern as the influent values. Assuming adsorption is partially responsible for PO_4-P fixation, it appears that adhesion sites are still readily available despite increased mean P-loadings to the bed between May 2007 and June 2008. As for NH_4-N, when examining PO_4-P loads it was clear that on a number of sampling dates a net production of phosphorus was produced. Whilst this may be attributed to lag in the system, negative removal of the contaminant is most likely due to litter decomposition and phosphorus release back to the system.

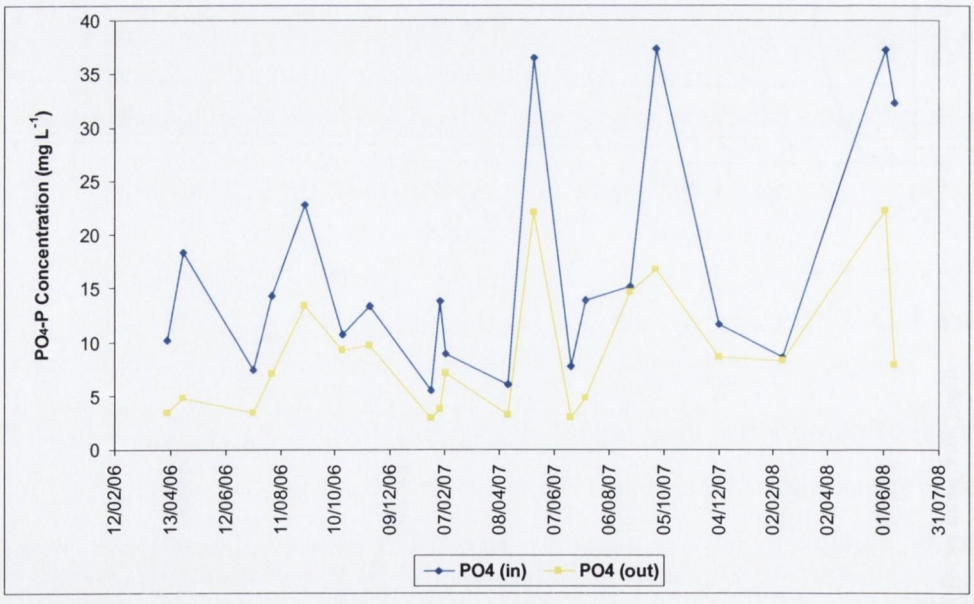


Figure 8.24 Temporal variation of influent and effluent PO_4 (mg L^{-1}) in Site A reed bed

Removal in PO_4-P over time follows a similar trend to TN in that the performance efficiency of the bed appears to drop after year 1 and stabilise over the next 18 months. This is further broken down in Table 8.11 where apart from the first year of

reed bed operation, removal rates are seen to remain relatively stable over both the growing and dormant seasons. This may in some way highlight the little phosphorus being taken up in the macrophytes which could otherwise have seen noticeably greater P-removal during the summer months. This is further substantiated in a quantitative study on phosphorus uptake, detailed later.

Table 8.11 Seasonal PO_4-P Load Removal (%) on Site A reed bed

PO_4-P Load Removal (± sd) (%)				
Year 1		**Year 2**		**Year 3**
Summer [a]	**Winter** [b]	**Summer**	**Winter**	**Summer**
61 (± 20)	43 (± 29)	43 (± 29)	40 (± 4)	35 (± 6)

[a] Summer months comprise sampling dates from May - September
[b] Winter months comprise sampling dates from October - April

Figure 8.25 presents PO_4-P influent against effluent concentrations with the plotted data showing the strongest linear correlation of all the wastewater's chemical constituents (Spearman r = 0.76; p = 0.0001). Analysis of the equivalent input-output PO_4-P loads shows a similarly strong correlation.

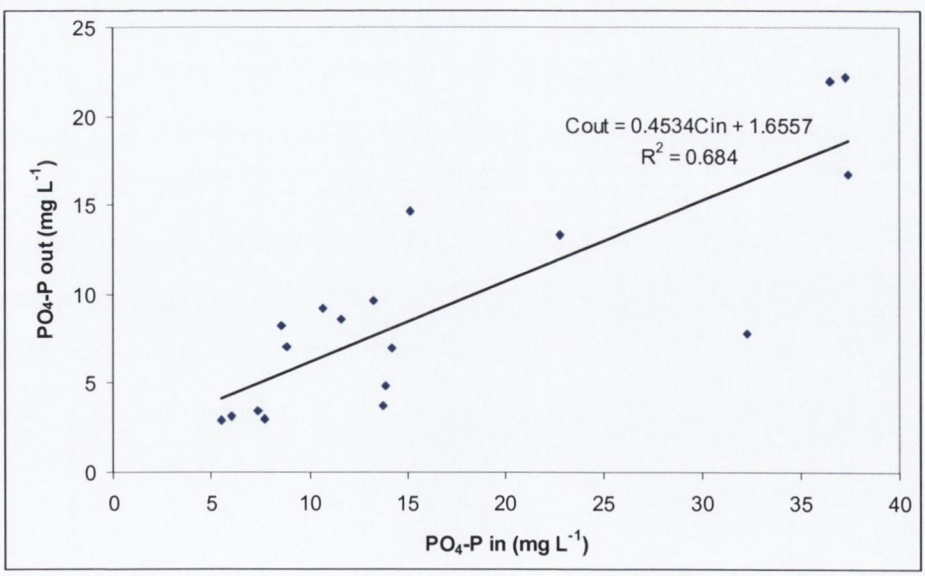


Figure 8.25 Relationship between influent and effluent PO_4-P concentrations

In assuming sorption to the filtration medium is one of the predominant mechanisms for removal of PO_4-P in reed beds, notwithstanding its limited capacity given the dearth of such minerals as Fe, Ca or Al, the full use of the bed for treatment is

essential to maximise the surface area for adsorption purposes. A subsequent plot to examine the relationship between PO_4-P surface loading and removal per m^2 (Figure 8.26) produces a strong linear correlation (Spearman r = 0.77; p = 0.0001) suggesting consistent removal of P throughout the bed area and plentiful adsorption sites availability after two and a half years of monitoring.

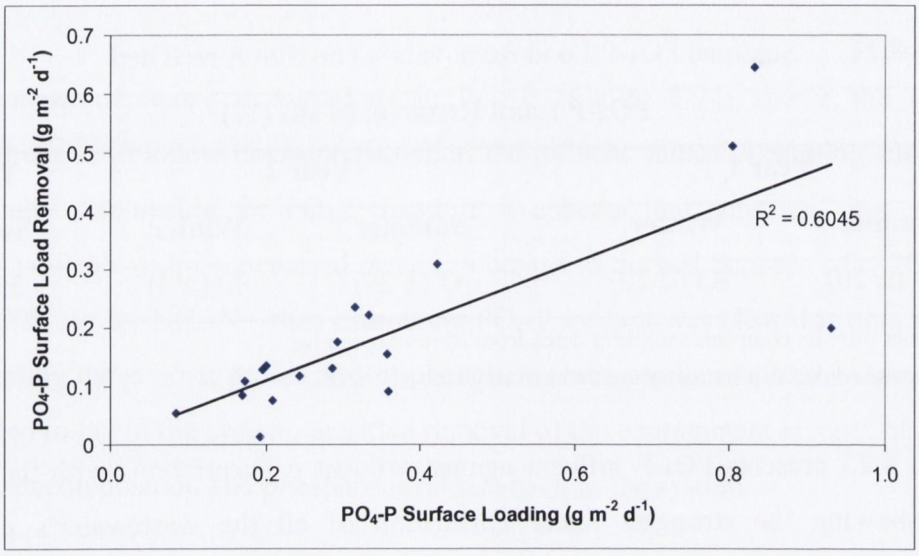


Figure 8.26 Relationship between PO_4-P surface loading and surface load removal rate

Further assessment of the kinetics of the reed bed in terms of P-removal shows the first-order reaction rate, k_P, as represented by the slope of the best-fit-line in Figure 8.27, to be negligible. Thus, the effect of variations in retention time appears to be negligible on P-removal efficiency. On a long-term basis, there appears to be little suggestion of first-order removal kinetics accurately representing the retention of P in the reed bed (Figure 8.28), with the poor correlation confirming the finding that performance efficiency hasn't improved over the two and a half year monitoring period.

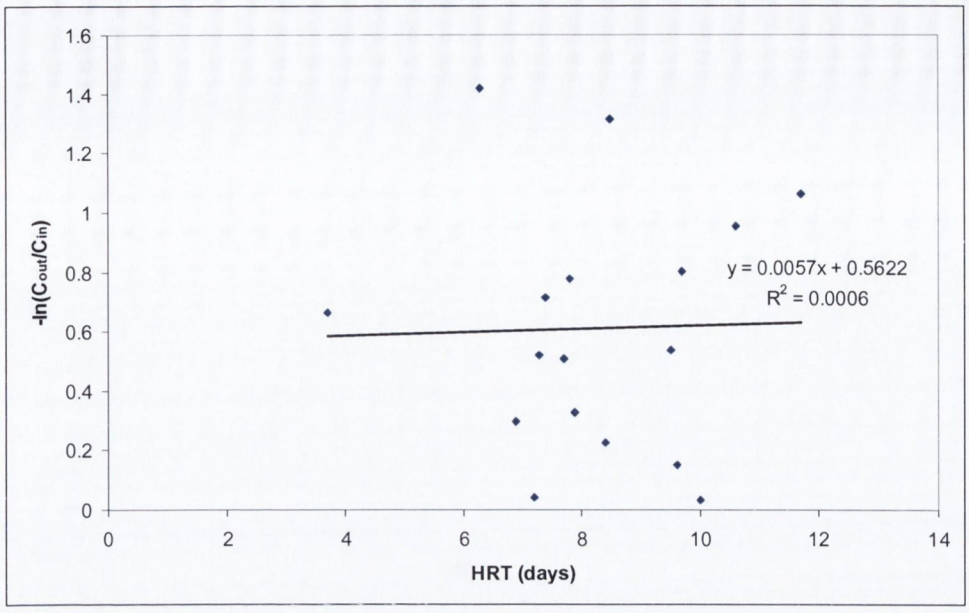


Figure 8.27 Plot of $-\ln(C_{out}/C_{in})$ versus HRT for PO_4-P

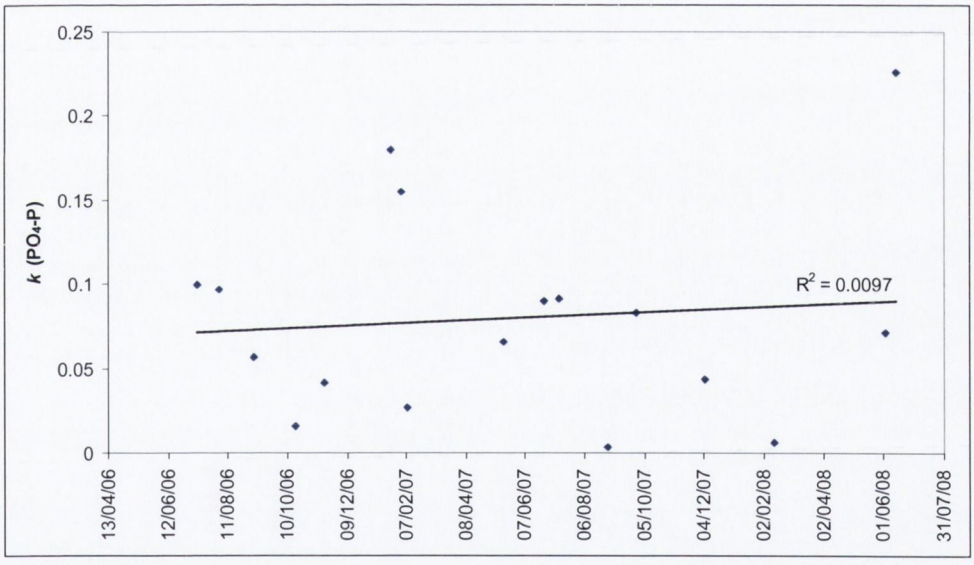


Figure 8.28 Plot of PO_4-P first order rate constant (k_P) against reed bed age

Quantification of Phosphorus Uptake by Reeds

In order to quantify the level of P-uptake from the macrophyte plants in the reed bed, a study was carried out at the end of its third year of operation at the height of the growing season. Samples of reeds were taken from the unharvested bed while they were at their maximum growth (25th September 2008), as shown in Figure 8.29.



Figure 8.29 Site A reed bed on 25th September 2008

A total of 9 *Phragmites australis* plants were dug up from the gravel using a trowel. Care was taken to ensure that all the root material was removed with each respective plant. It was decided to take 3 reeds from the front third of the reed bed, 3 from the middle third and 3 from the back third to ensure representative samples across the reed bed, as shown in Figure 8.30. The density of reed growth was measured in each section using a 1 m x 1 m quadrant.

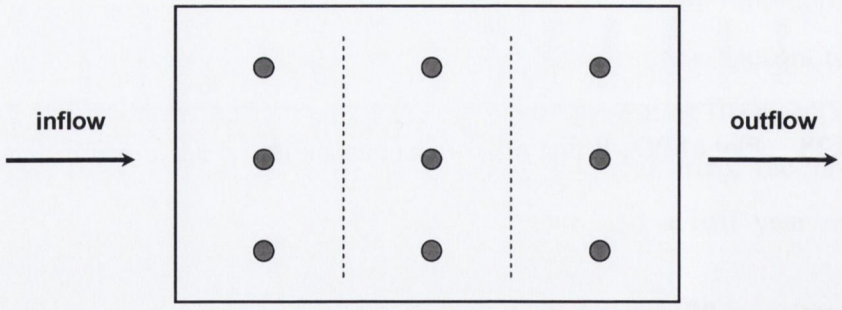


Figure 8.30 Positions of reeds sampled on Site A

The concentration of phosphorus in the samples of the reeds (stems and roots) was then determined using the analytical techniques detailed in Section 5.9.2.

The results from the analyses of the *Phragmites australis* samples on Site A are summarised in Table 8.12. Firstly, the density of the reeds is seen to vary depending on bed location with numbers significantly reduced in the back third compared to the front and middle. This may in some part be due to reduced nutrient concentrations at this location in the bed. Overall, the concentration of P in the biomass of both roots and stems was found to be similar although there appears a pattern of higher P in the stems at the front of the bed (compared to the roots), a trend which seems to reverse towards the back with the roots showing more elevated levels of P.

Table 8.12 Phosphorus mass in stems and roots of *Phragmites australis* on Site A

	Front	**Middle**	**Back**
Reed density (m^{-2})	312	367	202
Avg. P conc. in stems (mg P g^{-1}dry matter)	2.21	1.41	1.47
Avg. P conc. in roots (mg P g^{-1}dry matter)	1.72	1.63	2.32
Total stem P mass (g)	64.4	75.2	28.4
Total root P mass (g)	20.4	36.7	25.1
	Total P mass in stems (g)		**168.1**
	Total P mass in roots (g)		**82.2**

Results as such show that at the end of the third year of operation approximately 250 g of phosphorus was present in the biomass with approximately two thirds associated with the stems. The total phosphorus removed since the beginning of operation of this secondary treatment bed as measured by the effluent samples, flow to the reed bed and taking into account the effects of rainfall and evapotranspiration was found to be 2.50 kg over the 1 063 days of operation. Hence, the phosphorus in the living roots and stems accounts for 10% of the mass of phosphorus. It must be acknowledged that the reed growth of the previous 2 years had decayed and were sitting on the surface of the bed as shown in Figure 8.31. However even if the same mass of living stems is assumed for the previous 2 years (which is very conservative as the growth of reeds was much less plentiful in previous years) then the phosphorus

associated with the reeds (roots plus 3 years of stem growth) accounts for 23% of the total load removed.



Figure 8.31 Surface of Site A reed bed showing stem and leaf remains from previous years' growth

It is often maintained that the reeds on such reed bed treatment systems should be harvested at the end of each growing season as a method to control phosphorus build up in the beds. These results show that if the annual above ground stem matter was completely removed it would account for only 19.6% of the total phosphorus removal in the bed (or 8.4% of the annual total P-load to the reed bed).

It has been shown that the concentrations of coliform bacteria in wastewaters have diurnal fluctuations so that for any given wetland system, the highest concentrations in the influent do not necessarily coincide with the highest numbers in the effluent (Cooper *et al.*, 1996; Green *et al.*, 1997). However, during the present study, for logistical reasons, it was necessary to sample the influent (STE) and effluent (RBE) from the reed beds on both sites at the same time. Therefore the removal rates shown here (expressed in terms of concentrations) may not accurately reflect the actual removal rates.

Initial analysis of the temporal log-removal rates (Figure 8.32) shows both indicator organisms to follow the same pattern throughout the course of the monitoring with little seasonal or annual variation evident.

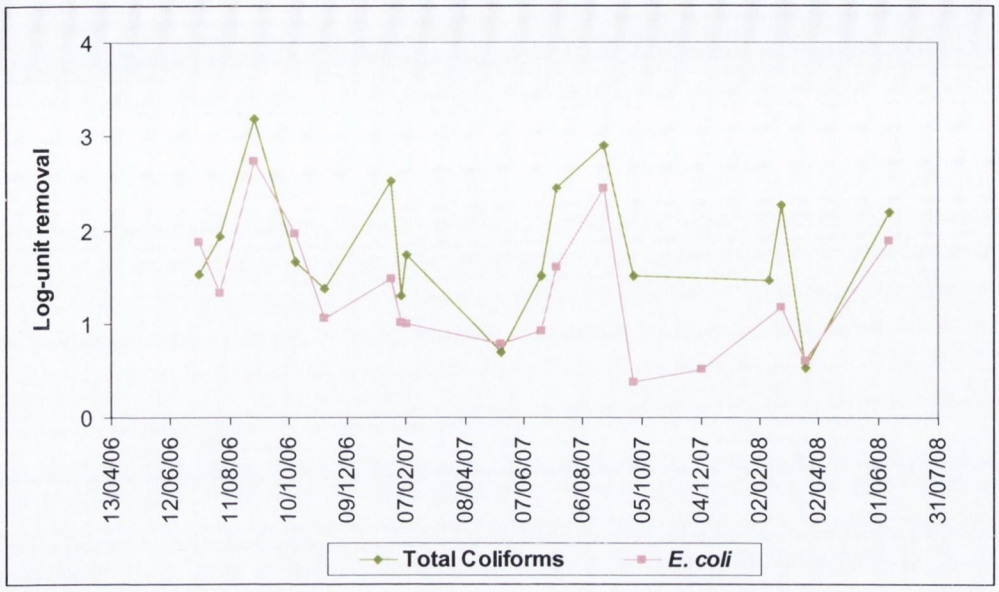


Figure 8.32 Log-unit removal of Total Coliforms and *E. coli* in Site A reed bed

Mean removal rates in TC and *E. coli* are found to be similar at 1.8 (98.5%) and 1.4 log-unit (96%), respectively. Despite such high removal, it is clear that with coliforms ranging $3 \times 10^3 - 2 \times 10^6$ MPN 100 mL^{-1} still remaining in the discharging effluent, further bacteriological treatment of the effluent is a prerequisite prior to groundwater infiltration.

Figure 8.33 plots the mean TC and *E. coli* concentration in the influent, effluent and across the middle (left, rights and centre) of the reed bed over the duration of the monitoring. Both coliform species show the same trend, with a much greater decrease in concentration in the first half of the bed. On average, TC removal was of 1.1 – 1.5 orders of magnitude in the first half with only a further 0.3 – 0.7 log-unit reduction in the second half. *E. coli* removal showed a similar trend. With respect to sampling at the centre of the bed, removal rates have shown to be similar across the width of the system at this location indicating efficient hydraulic distribution. Overall there was an exponential decrease in the concentration of both coliform species with distance along the bed (TC: $r^2 = 0.986$ (left), 0.947 (centre), 0.862 (right); *E. coli*: $r^2 = 0.997$ (left), 0.977 (centre), 0.976 (right)). This pattern mirrors previous studies (Williams *et al.*, 1995; Decamp and Warren, 1999) which have shown faecal bacteria inactivation throughout the length of the beds to be simply exponential.

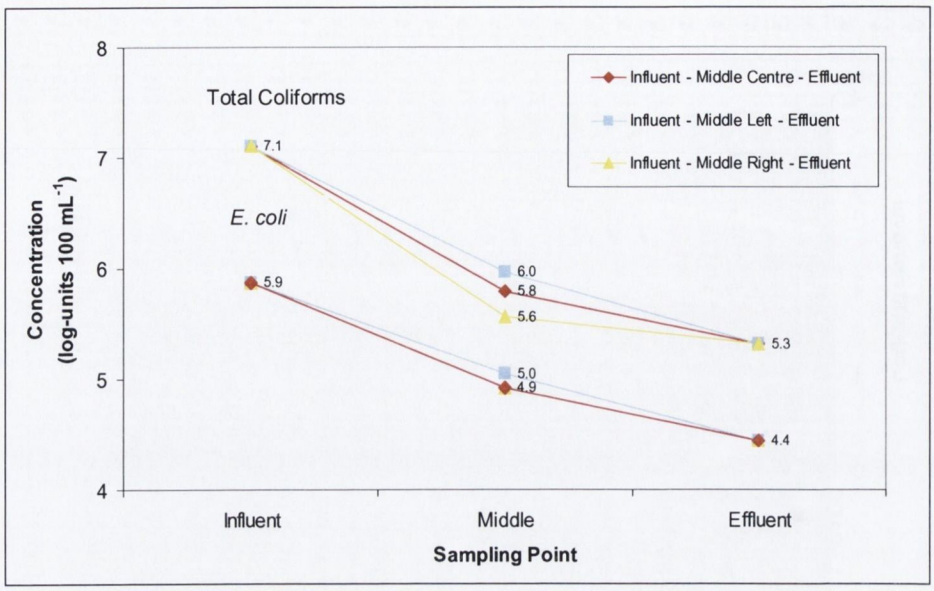


Figure 8.33 Mean TC and *E. coli* concentration in the influent and effluent and across the middle (left, right and centre) of Site A reed bed over the duration of the monitoring

Correlation analysis found a positive but non-statistically significant relationship when plotting removal rates of TC and *E. coli* against HRT (TC: Spearman r = 0.4; p = 0.25; *E. coli*: Spearman r = 0.1; p = 0.76). It must be outlined that this hypothesis is based on the range of retention times accurately calculated for each sampling date and included in the plots (Figure 8.34), i.e. 6 to 12 days. A greater correlation may be found for retention times outside of this range. In terms of the system design assumption of first-order kinetics, the loose linear correlation generates a k value of 0.48 for TC and 0.36 for *E. coli*. In comparison, Kadlec and Knight (1996) predicted a k-value of 0.36 in horizontal SSF beds for faecal coliform removal.

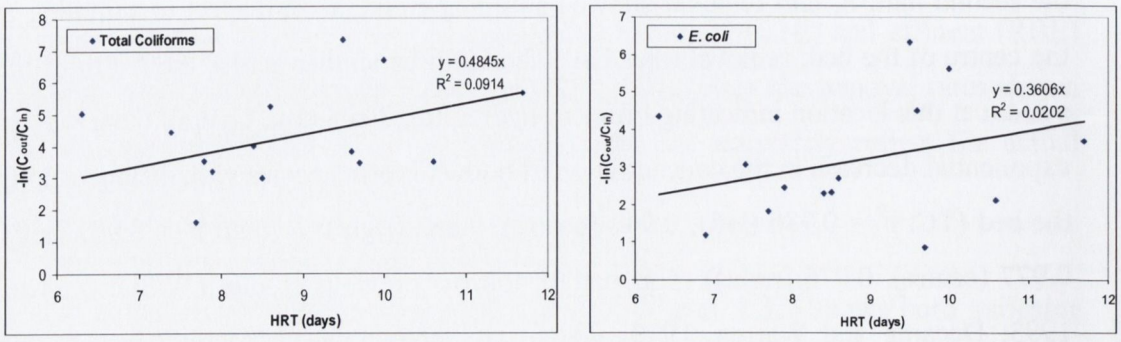


Figure 8.34 Plots of $-\ln(C_{out}/C_{in})$ versus HRT for both TC and *E. coli* (slope of the line-of-best-fit is equal to k, the first-order decay rate constant)

Plots of TC and *E. coli* removal against individual HLRs (Figure 8.35) again show a poor statistical relationship (TC: Spearman r = -0.37; p = 0.18; *E. coli*: Spearman r = -0.13; p = 0.38) but do predict a slight drop in removal efficiency with increasing hydraulic loading as would be expected.

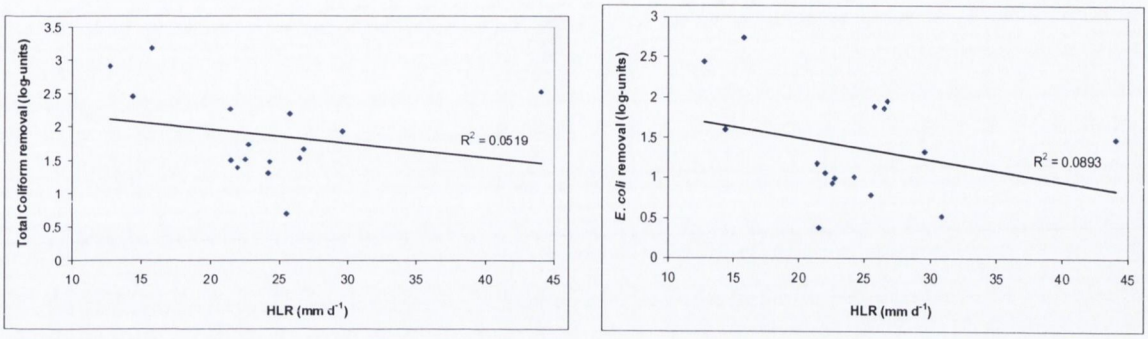


Figure 8.35 Plots of TC and *E. coli* removal (log-units) against HLR

System IV - Tertiary Treatment Reed Bed (Site B)

A summary of the treatment performance of the reed bed on Site B, installed to provide polishing of the secondary effluent from the *Biodisc*® filter, is shown in Table 8.13.

Organic matter removal efficiency, in the form of COD, is slightly lower than that achieved across the secondary treatment bed on Site A at 54.5% load removal. Again, BOD_5 removal is greater than COD although the dataset for the former is much smaller (n = 3). Time series analysis of COD concentrations shows largely similar influent and effluent patterns (Figure 8.36).

Table 8.13 Summary of chemical and bacteriological analysis of Site B reed bed

Pollutant	Variable	Site B Reed Bed
COD	**Influent Conc. (±sd) (mg L^{-1})**	193 (±88)
	Effluent Conc. (±sd) (mg L^{-1})	107 (±62)
	Surface Load Removal (g m^{-2} d^{-1})	4.4
	% Load Removal	**54.5**
BOD_5	**Influent Conc. (±sd) (mg L^{-1})**	101 (±53)
	Effluent Conc. (±sd) (mg L^{-1})	7 (±6)
	Surface Load Removal (g m^{-2} d^{-1})	2.3
	% Load Removal	**89.9**
TN	**Influent Conc. (±sd) (mg L^{-1})**	93 (±52)
	Effluent Conc. (±sd) (mg L^{-1})	64 (±26)
	Surface Load Removal (g m^{-2} d^{-1})	1.6
	% Load Removal	**40.9**
PO_4-P	**Influent Conc. (±sd) (mg L^{-1})**	26.4 (±9.1)
	Effluent Conc. (±sd) (mg L^{-1})	23.1(±10.9)
	Surface Load Removal (g m^{-2} d^{-1})	0.2
	% Load Removal	**22.2**
TSS	**Influent Conc. (±sd) (mg L^{-1})**	43 (±21)
	Effluent Conc. (±sd) (mg L^{-1})	20 (±19)
	Surface Load Removal (g m^{-2} d^{-1})	0.6
	% Load Removal	**41.4**
TC	**Influent Conc. (±sd) (MPN 100mL^{-1})**	2.45×10^5
	Effluent Conc. (±sd) (MPN 100mL^{-1})	1.32×10^4
	Log Reduction	**1.3**
E. coli	**Influent Conc. (±sd) (MPN 100mL^{-1})**	1.10×10^4
	Effluent Conc. (±sd) (MPN 100mL^{-1})	2.39×10^2
	Log Reduction	**1.7**

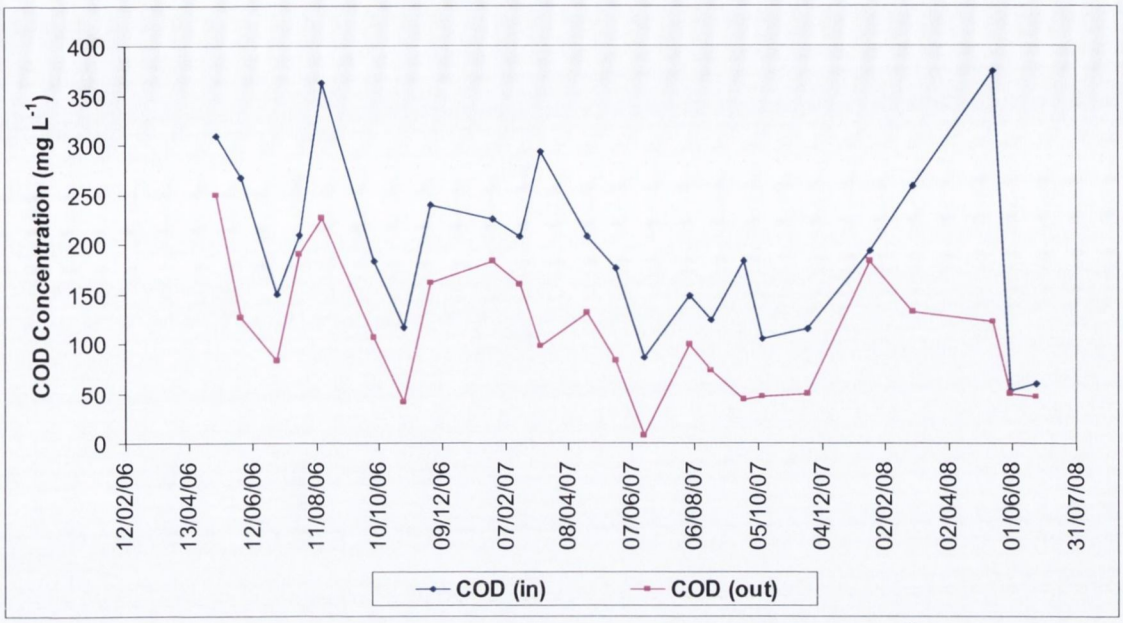


Figure 8.36 Temporal variation of influent and effluent COD (mg L^{-1}) in Site B reed bed

While analysis of COD concentrations appear to show relatively consistent removal of organic chemicals over the duration of the project, loading analysis reveals a developmental trend to the performance of the reed bed over time. As on Site A, initial treatment performance in terms of COD was very poor. On average, much greater removal was achieved in the second year of operation (Table 8.14) owing to the greater biofilm development and leaf area presence in the bed. A slight increase is also evident between winter and summer months although the performance of the bed appears to be levelling out over the final 18 months of monitoring. While the limited BOD_5 results suggest the standard of the reed bed tertiary effluent (mean BOD_5 = 7 mg L^{-1}) to be satisfactory, the more robust COD dataset suggests the discharging effluent to be still high in organic chemicals (mean COD = 107 mg L^{-1}) and unsuitable for direct discharge to surface or groundwater bodies without further purification.

Table 8.14 Seasonal COD load removal (%) on Site B reed bed

COD Load Removal (± sd) (%)				
Year 1		Year 2		Year 3
Summer [a]	Winter [b]	Summer	Winter	Summer
18 (± 4)	56 (± 25)	67 (± 19)	57 (± 17)	64 (± 12)

[a] Summer months comprise sampling dates from May – September

[b] Winter months comprise sampling dates from October - April

Like the reed bed on Site A, linear correlation analysis found a significant positive relationship between the influent and effluent COD concentrations (Spearman r = 0.78; p = 0.0001), as shown in Figure 8.37, while a similar result is found for the respective loadings (Spearman r = 0.51; p = 0.001). An increase in the surface loading of COD also significantly raised the surface load removal rate (Spearman r = 0.69; p = 0.014).

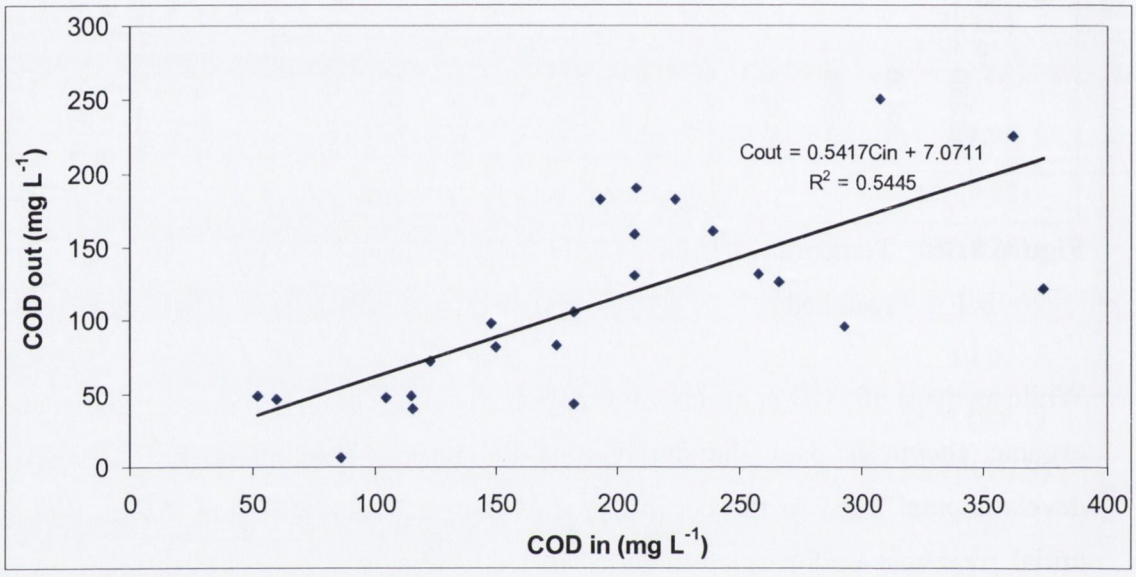


Figure 8.37 Relationship between influent and effluent COD concentrations

A first-order kinetics plot of $-\ln(C_{out}/C_{in})$ against HRT (Figure 8.38) yields a linear correlation that is positive but statistically insignificant (Spearman r = 0.137; p = 0.796). Similar to the secondary treatment reed bed on Site A, the HRT (and thus the HLR) appears not to play a defining role in the removal of organic matter. The resulting reaction rate constant, k_{COD}, is found to be 0.09, lower than the 0.31 value recommended by Cooper *et al.* (1996) in WRc guidelines for tertiary treatment horizontal SSF reed beds.

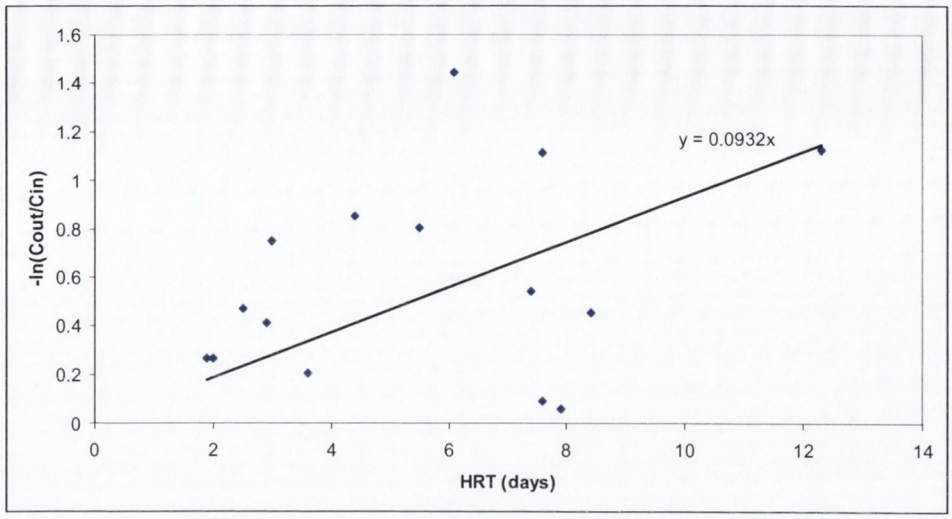


Figure 8.38 Plot of $-\ln(C_{out}/C_{in})$ versus HRT for COD

Despite TSS only yielding a removal rate of 41% much of the solids were successfully removed in the *Biodisc*® resulting in a mean reed bed effluent concentration of 20 mg L^{-1}.

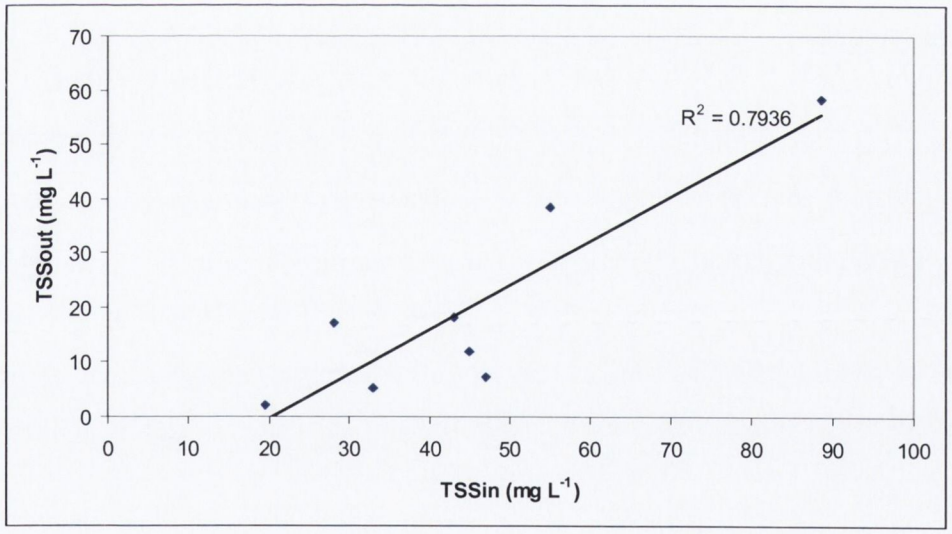


Figure 8.39 Relationship between influent and effluent TSS concentrations

The aerobic conditions of the *Biodisc*® facilitated partial nitrification of the effluent and thus increased the NO_3-N fraction to the reed bed. Competition with heterotrophic bacteria (in their quest to degrade organic matter) in the biozone, however, resulted in the failure of *Nitrobacter* to fully nitrify the effluent to NO_3-N during sustained periods of the monitoring. This resulted in occasionally high NO_2-N in the discharge (Figure 5.18). Table 8.15 details mean nitrogen species loadings at the inlet and outlet

of the reed bed over the duration of the sampling. Figure 8.40 illustrates the organic and inorganic loads at the inlet and outlet, with the mean TN load represented by the height of each of the bars. The high org-N in the reed bed influent, comprising 26% of the TN concentration, was reduced either through transitory burial in the bed's sediment or further mineralisation to NH_4-N in the anoxic environment of the bed. While some nitrification of NH_4-N to NO_3-N is possible in the isolated aerobic zones of the bed it is more likely that adsorption to sediment particles and litter is responsible for any further breakdown in NH_4-N. In summary it is evident that the oxidised forms of N (NO_3-N and NO_2-N) are being denitrified in the anoxic environment of the bed contributing to a percentage of the TN removal. NH_4-N and org-N, in contrast, are merely changing form on a cyclic basis through processes such as mineralisation, immobilisation and plant uptake.

Table 8.15 Mean influent and effluent nitrogen loads from Site B reed bed over duration of sampling

	TN	**NO_3-N**	**NO_2-N**	**NH_4-N**	**org-N**
Influent (g d^{-1})	15.6	5.1	2.4	4.0	4.1
Effluent (g d^{-1})	9.2	3.9	0.9	2.6	1.8

TN load removal (41%) was poor especially given that nutrient removal, and denitrification in particular, is a key focus in tertiary treatment systems prior to groundwater discharge. Additional consideration, however, must be given to the performance of the *Biodisc*® in this respect with its inability to mineralise all org-N to NH_4-N and fully nitrify the effluent compromising subsequent rates of denitrification in the reed bed.

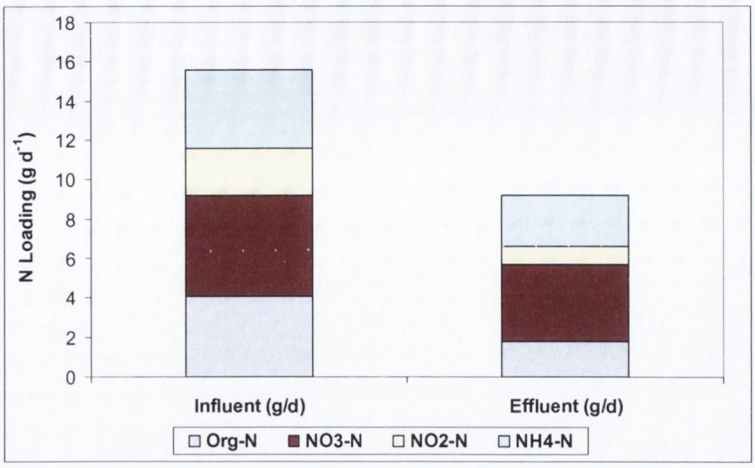


Figure 8.40 Mean nitrogen species loading in Site B reed bed

Further examination of the temporal breakdown in each of the nitrogen species provides greater insight into their fate in the system (Figures 8.41 and 8.42). It is clear that the reed bed is highly limiting with respect to N-removal given the little TN and NO_3-N reduction throughout the monitoring period. This is exemplified even during the period June – December 2007 when the influent was fully nitrified prior to reed bed treatment. A mean NO_3-N effluent concentration of 35 mg L^{-1} exceeds river discharge consent demands and is atypical of tertiary treatment standard. Moreover, the potential for intermittently high NH_4-N and NO_2-N in the reed bed discharge is real owing to the failure of the *Biodisc*® to fully nitrify on a consistent basis and the subsequent inability of the reed bed to significantly denitrify.

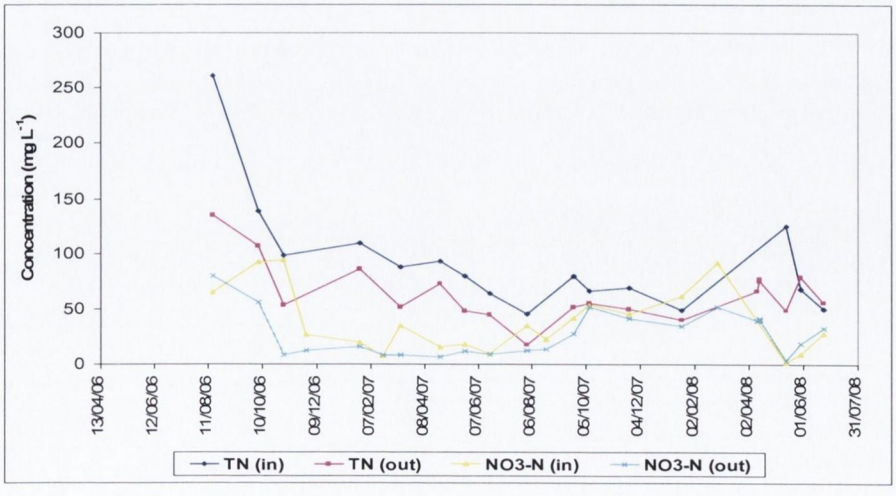


Figure 8.41 Temporal variation of influent and effluent TN and NO_3-N (mg L^{-1}) in Site B reed bed

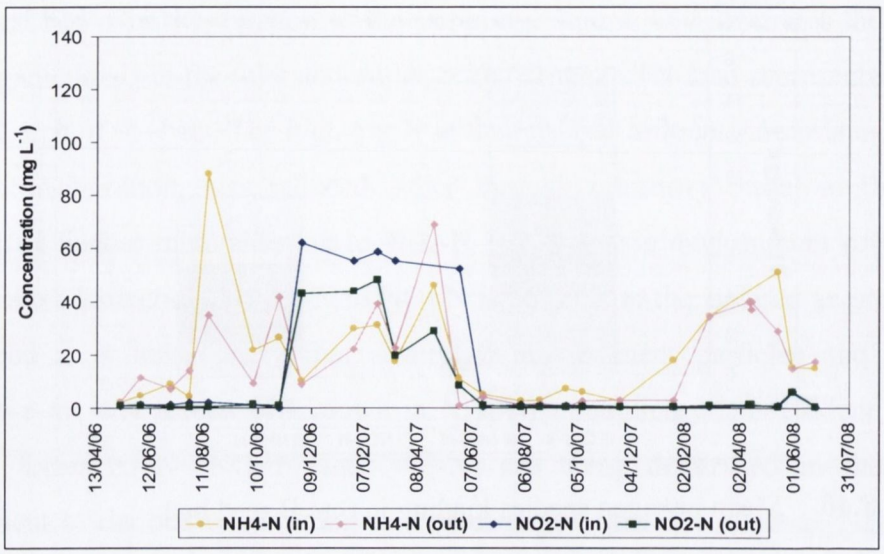


Figure 8.42 Temporal variation of influent and effluent NH_4-N and NO_2-N (mg L^{-1}) in Site B reed bed

On a seasonal basis (Table 8.16), it can be seen that rates of denitrification (on average over the monitoring period) are slightly reduced during the colder months. This is most likely due to little nitrogen assimilation occurring at this time owing to macrophyte die-back, a decrease in the release and mineralisation of org-N and consequently a reduction in nitrification and denitrification rates. The negative removal of nitrogen in the winter of Year 1 is particularly influenced by the results from sampling on 5/10/06 – a time when the macrophytes are beginning to die back. Unlike other dates, org-N was shown to increase probably due to initial plant litter decomposition and, together with low biological activity under cooler temperatures, there was little subsequent mineralisation to NH_4-N. An important observation from the TN data is the large magnitude of the standard deviations reported on a seasonal basis with regularly occurring positive and negative removals highlighting the cycling of nitrogen species throughout the bed.

Table 8.16 Seasonal TN Percentage Load Removal on Site B reed bed

TN Load Removal (± sd) (%)				
Year 1		Year 2		Year 3
Summer [a]	Winter [b]	Summer	Winter	Summer
30 (± 0)	-21 (± 157)	19 (± 66)	23 (± 34)	55 (± 13)

[a] Summer months comprise sampling dates from May – September

[b] Winter months comprise sampling dates from October – April

As on Site A, a ^{15}N isotope tracer study was carried out on the tertiary reed bed of Site B to ascertain N-detention times in the wetland and investigate any ongoing cyclic nitrogen processes and fluxes in the system. The reed bed influent was spiked with 0.35 g of $^{15}NH_4Cl$ (98% ^{15}N, Cambridge Isotope Laboratories) on 27th March 2008. Effluent samples were taken for a period of 64 days which was, in this case, over 12 times the actual hydraulic retention time of the bed. The effluent samples were again analysed for the different concentrations of nitrogen and the sample partitioned into suspended (org-N) and dissolved (NH_4-N and NO_x-N) for analysis of $^{15}N/^{14}N$ ratio. The dissolved form includes both the N in the ammonium fraction and nitrate (and nitrite) as chemical analysis has shown the wastewater being treated in the reed bed to be partially nitrified.

Examining the background $\delta^{15}N$ (‰) values for the *Biodisc*® SE and reed bed effluent (Table 8.17), shows slightly elevated forms of nitrogen in the former compared to the STE on Site A (Table 8.10). This is most likely due to ammonia volatilisation in the aerobic conditions of the package plant process which leaves an enrichment of the heavier ^{15}N isotope in the residual ammonium (part of which is subsequently transformed into nitrate) (Karr *et al.*, 2001). Equally, the elevated org-N $\delta^{15}N$ values in the SE indicate that the source for such organic fraction is from the biomass in the plant which has taken in the soluble NH_4-N from the waste, i.e. it is not ammonium molecules in the household influent passing straight through the process.

The overall nitrogen removal during the trial from the wetland was 23%. The influent was 47% organic, 15% ammonium and 37% nitrate and the effluent 44% organic, 17% ammonium and 39% nitrate (i.e. very similar proportions). There is a significant enrichment of the soluble nitrogen species (NH_4-N and NO_x-N) through the reed bed which is indicative of the process of denitrification as the lighter ^{14}N is released as gas in the process. Again, the slight elevation of the organic nitrogen $\delta^{15}N$ values in the reed bed effluent might indicate the "spiraling" of the nitrogen through the reed bed through different phases, ammonium taken up into organic, then released again as ammonium etc. (Kadlec *et al.*, 2005).

Table 8.17 $\delta^{15}N$ (‰) values for background secondary effluent and tertiary reed bed effluent

	SE	RBE
Soluble-N	5.20	20.67
org-N	8.52	11.02

The results of the $^{15}NH_4Cl$ tracer study are plotted on Figure 8.43, against the parallel results from the RWT tracer study which revealed a hydraulic retention time of 5 days during the trial. Again, as on Site A, the peak in the ammonium can be seen to come through exactly the same time as the RWT peak which indicates that a high proportion of the NH_4-N and NO_x-N from the SE was passing straight through the reed bed without taking part in any biogeochemical processes. There is a slight elevation in the soluble-N trace after the RWT peak has passed which may be due to the partial denitrification of the tracer ^{15}N which has been taken into organic form. There is evidence of a distinct gradual rise in the $\delta^{15}N$ values for the suspended org-N fraction which shows that some of the ammonium has been biologically assimilated into org-N (biomass or plants). This is much slower than the results on Site A which may be due to the fact that the trial was carried out a month earlier (in April) at the beginning of the growing season for the macrophytes.

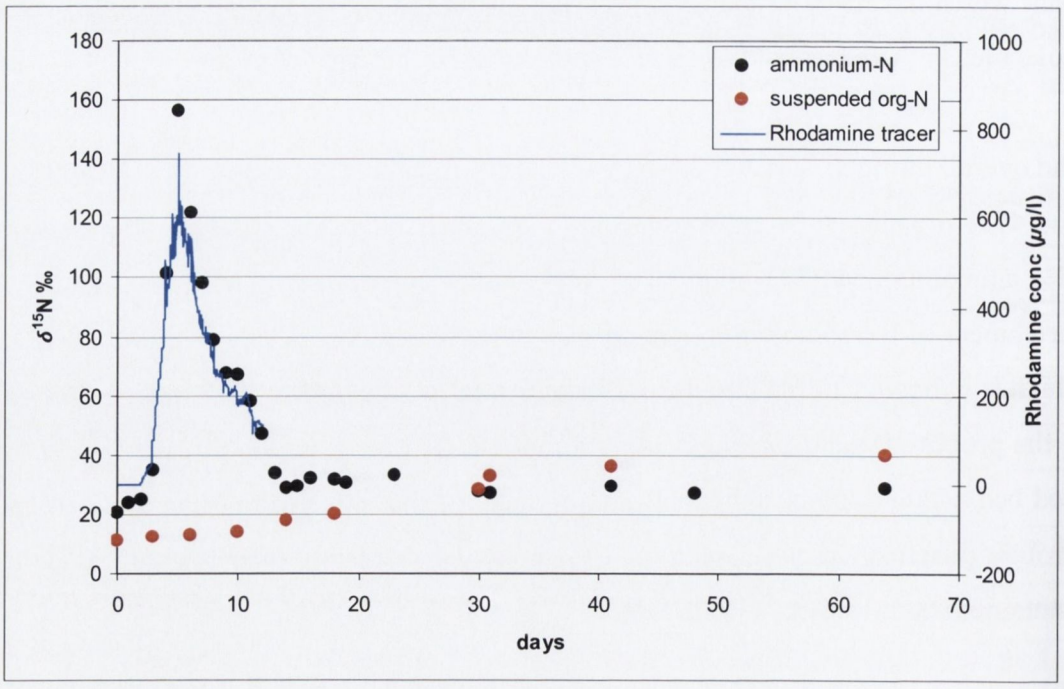


Figure 8.43 ^{15}N values for reed bed effluent nitrogen fractions and RWT tracer (Site B)

Again, when the cumulative mass of ^{15}N above the background is computed, it can be seen (Figure 8.44) that approximately 18% of the spiked ^{15}N has passed straight through the reed bed. From then on there is a gradual rise in the recovery particularly in the form of org-N. After 65 days only 28% of the spiked ^{15}N has been recovered which indicates that the other has been taken up by the plants (as it was at the beginning of the growth season) or lost by other means (denitrification etc).

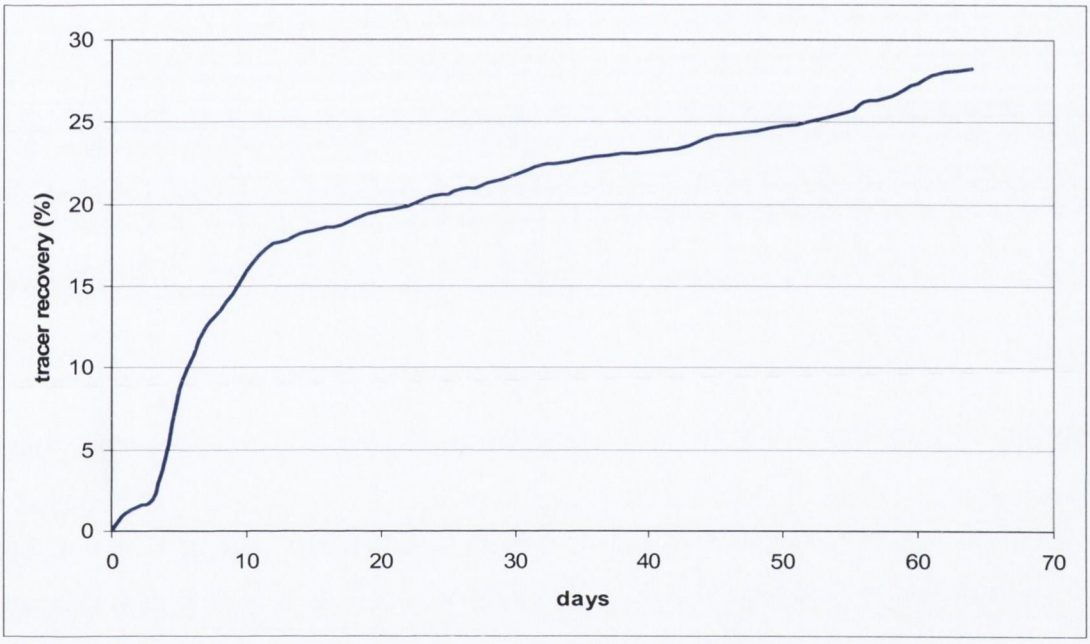


Figure 8.44 ^{15}N tracer recovery during the trial

A mean P-load removal of 22% is less than half the rate achieved by the secondary treatment reed bed on Site A owing to a combination of reduced surface area for adsorption (less than one third the size of Site A bed) and a greater mean HLR. Analysis of PO_4-P concentrations (Figure 8.45) again shows intermittent negative removal of the nutrient which, when taking loadings into account, in fact occurs on a consistent basis. This is most probably due to intermittent release of P back into the system from accumulated unharvested biomass at the bed's surface after macrophyte decay. This is explored further in the P-uptake study to follow.



Figure 8.45 Temporal variation of influent and effluent PO_4 (mg L^{-1}) in Site B reed bed

From a seasonal perspective, this is recognised more clearly in the disparity in mean removal rates between summer and winter (Table 8.18). Greater performance is achieved during the warmer months when leaf area is at its maximum for uptake, while for the first winter in operation, the bed is seen to release the stored P back into circulation leaving negative removal. After almost three years in operation, it can also be seen that the adsorption capacity of the bed media does not appear as yet to have been expended.

Table 8.18 Seasonal PO_4-P Load Removal on Site B reed bed

PO_4-P Load (± sd) Removal (%)				
Year 1		**Year 2**		**Year 3**
Summer [a]	**Winter** [b]	**Summer**	**Winter**	**Summer**
20 (± 27)	-16 (± 64)	50 (± 34)	26 (± 40)	45 (± 32)

[a] Summer months comprise sampling dates from May – September
[b] Winter months comprise sampling dates from October – April

A plot of PO_4-P influent and effluent concentrations shows there to be a positive linear correlation (Spearman r = 0.616; p = 0.007) between both.

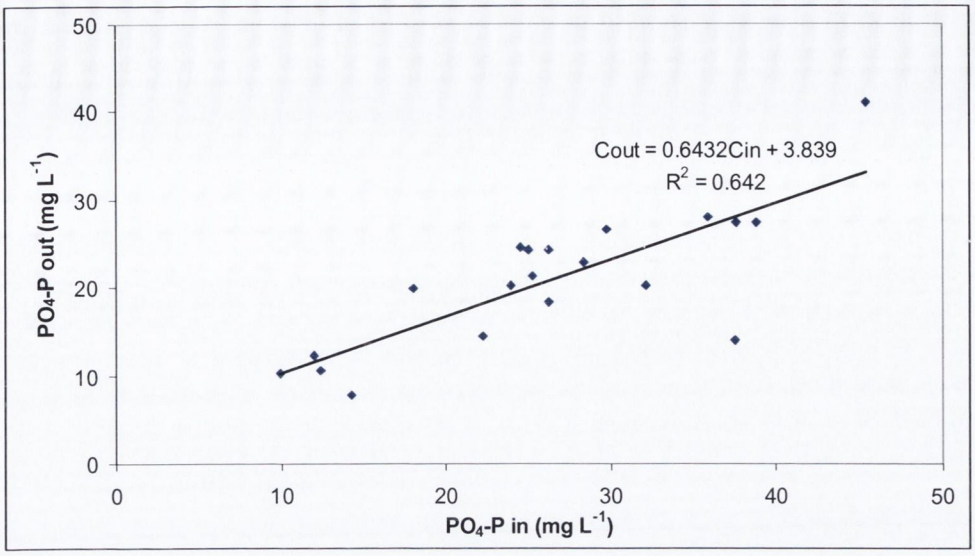


Figure 8.46 Relationship between influent and effluent PO_4-P concentrations

The first-order reaction rate constant, k_P, is shown to be negligible and very much compromised by the intermittent negative P-removal in the system.

Quantification of Phosphorus Uptake by Reeds

As on Site A, a study was also carried out to quantitatively examine the P-uptake from the macrophyte plants on Site B reed bed. Again, the reeds were at their maximum growth on the date of sampling (25th September 2008) with little visible decay, as shown in Figure 8.47. As the bed on Site B was smaller than that on Site A, it was divided in two and 3 samples of each of the two reed types (*Typha latifolia* and *Iris pseudacorus*) were taken across the width from each half. The density of reed growth was again measured in each section using a 1m x 1m quadrant.



Figure 8.47 Site B reed bed on 25th September 2008

The results from the analyses of the *Typha latifolia* and *Iris pseudacorus* reed samples on Site B are shown on Table 8.19. Calculations reveal a total phosphorus mass of 52.3 g to be present in the stems and roots of the reed beds' macrophytes.

Table 8.19 Phosphorus mass in stems and roots of *Typha* and *Iris* on Site B

	Typha latifolia		***Iris pseudacorus***	
	Front	**Back**	**Front**	**Back**
Reed density (m^{-2})	153	92	77	46
Avg. P conc. in stems (mg kg^{-1} dry matter)	1.42	0.37	1.46	1.14
Avg. Pconc. in roots (mg kg^{-1} dry matter)	2.17	1.61	1.39	1.09
Total stem P mass (g)	12.40	1.39	1.51	2.32
Total root P mass (g)	16.59	7.02	6.05	5.02
	Total P mass in stems (g)			**17.6**
	Total P-mass in roots (g)			**34.7**

The total phosphorus removed since the beginning of operation of this tertiary treatment bed as measured by the effluent samples, flow to the reed bed and taking account of the effects of rainfall and evapotranspiration, was found to be 0.167 kg over the 1 083 days of operation. Hence, the phosphorus in the living roots and stems accounts for 31% of the mass of phosphorus removed but only 1.3% of the phosphorus load. This, therefore, would be the assumed result if the reeds on such reed bed treatment systems were harvested at the end of each growing season as a method to control phosphorus build-up in the beds. If the same mass of living stems is assumed for the previous 2 years then the phosphorus associated with the reeds accounts for 52% of the total load removed but only 2.2% of the phosphorus load.

Bacteriological analysis shows mean removal in *E. coli* (1.6 log-units or 97.7%) to be slightly greater than for TC (1.3 log-units or 94.6%). Despite such high removal, it is clear that a significant number of coliforms ranging from $3 \times 10^3 - 2 \times 10^6$ MPN 100 mL^{-1} still remain in the discharging effluent. As such, with respect to coliform removal, direct discharge to surface water is not a feasible option for tertiary

treatment beds under standard secondary treatment effluent loading. In this case, further bacteriological treatment of the RBE through suitably permeable subsoil is a necessity prior to groundwater discharge.

Analysis of the temporal log-removal rates (Figure 8.48) shows both indicator organisms to follow the same pattern throughout the course of the monitoring. There does appear, however, to be a gradual increase in coliform removal over time owing to potentially increased adsorption and retention of the micro organisms to the emerging biofilms on the bed's gravel media.

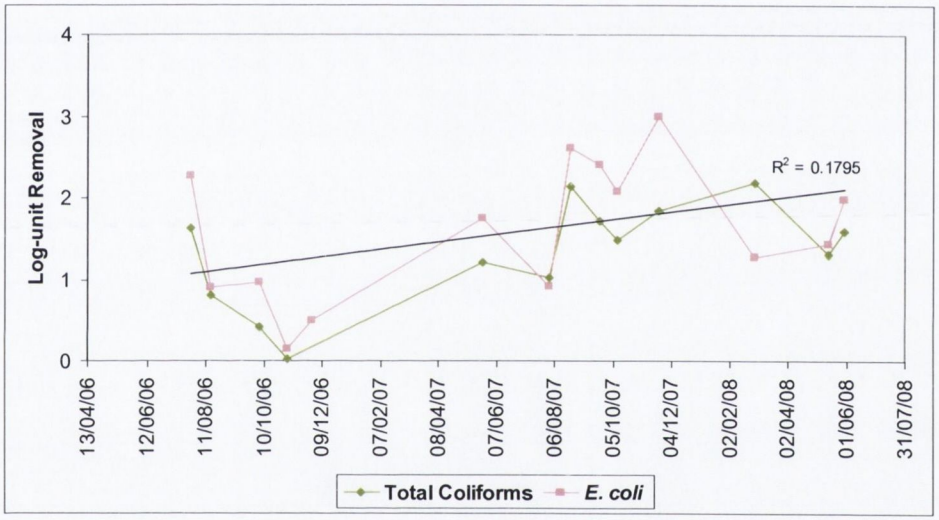


Figure 8.48 Log-unit removal of TC and *E. coli* in Site B reed bed

Figure 8.49 plots the mean TC and *E. coli* concentration in the influent, the middle of the bed and the effluent over the duration of the monitoring. Both coliform species show the same trend, with a much greater decrease in concentration in the first half of the bed. On average, *E. coli* removal was of 1.5 orders of magnitude in the first half with only a further 0.1 log-unit reduction in the second half. This pattern mirrors the findings on Site A reed bed corroborating the view that coliform removal is exponential throughout the length of the bed.

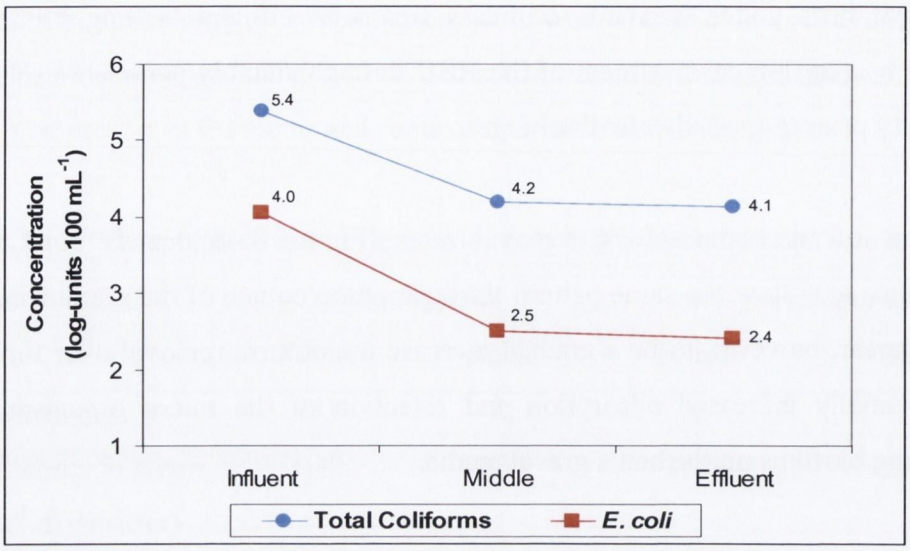


Figure 8.49 Mean TC and *E. coli* concentration in the influent, middle and effluent of Site B reed bed over the duration of the monitoring

While linear regression shows the HRT and HLR to be poorly correlated with respect to log-unit removal of both TC and *E. coli*, it is clear, in particular with TC, that greater removal is achieved at longer retention times and lower hydraulic loading rates (Figure 8.50).

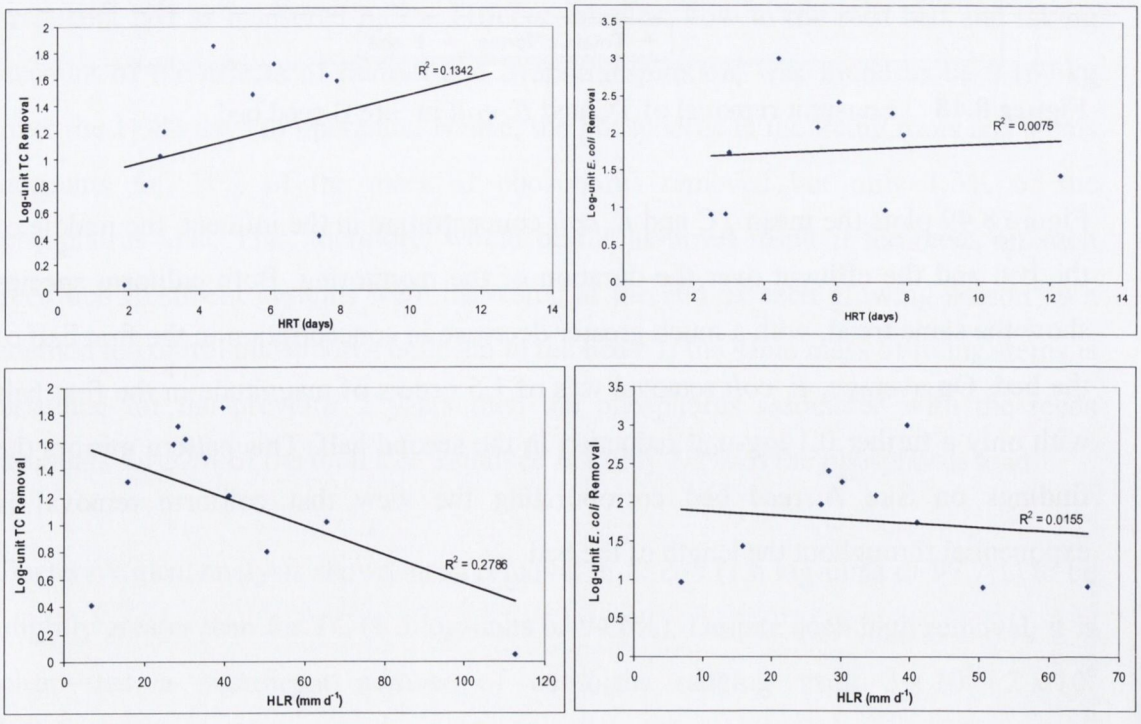


Figure 8.50 Plots of HRT and HLR against log-unit removal of TC and *E. coli*

8.5 Results of Bacteriophage Analysis

Many wetland tracer studies, carried out to ascertain the hydraulic characteristics for pollutant removal purposes, have relied on the use of the traditional hydrological tracers such as bromide, calcium, chloride, fluoride, lithium and sodium as well as the visible dyes of flourescein and rhodamine. The latter has itself been used in this study as a chemical tracer for the reed bed on Sites A and B with the results disseminated earlier in Section 8.3. Concerns, however, have been raised over the common use of some of these tracers in that they pose a potentially detrimental risk to aquatic ecosystems (Rossi, 1992). Consequently, the investigation of alternative tracers that have the potential to act as highly efficient indicators of effluent retention and offer a low environmental impact for use in wetlands is important. Biological tracers such as bacteriophages may offer that alternative. Additionally, they may be more environmentally acceptable and give a more useful indication of the dynamics of microbes in hydrological studies (Pang *et al.*, 1998).

While the assessment of each of the selected bacteriophages as suitable wetland biotracers was an important part of the investigation, it was the associated evaluation of the on-site reed beds in their ability to remove viral pathogens (through the use of phage surrogates) prior to subsurface infiltration that was also an integral part of the study. Limited information is available, to date, on the ability of on-site horizontal SSF reed beds to remove enteric viruses from domestic wastewater. This is primarily because the microbial removal characteristics of wetlands can vary, depending on factors such as adsorption, desorption and inactivation, which in turn depends on the design specifics, such as filter media characteristics and local climatic conditions. As such, this study examined the survival of the same three viral indicators employed in the subsoil study, namely ΦX174, MS2 and PR772, on both the on-site constructed reed beds of Sites A and B. All three differ in size, hydrophobicity and isoelectric point potentially affecting the level of transport through porous media.

A single trial, involving the injection of the three phages concurrently, was carried out on each reed bed; Site A: April 22nd – May 3rd, 2008 and Site B: 26th March – 7th April, 2008.

System II - Secondary Treatment Reed Bed (Site A)

Each of the three bacteriophages (ΦX174, MS2 and PR772) were injected into a 1L solution of distilled water which was in turn spiked into the bed via the dual inlet pipe configuration. Taking into account the dilution, the final titres of the three phages used in the April 2008 trial were: ΦX174 - 9.96 x 10^5 PFU mL^{-1}, MS2 - 1.76 x 10^6 PFU mL^{-1} and PR772 - 7.76 x 10^7 PFU mL^{-1}. These input concentrations are a number of magnitudes greater than mean levels of sporadically occurring F-RNA (e.g. MS2) and somatic coliphages (e.g. ΦX174, PR772, PRD-1) detected in raw sewage and STE, as reported in a number of literature studies; Zhang and Farahbakhsh (2007) found that the mean concentration of F-RNA and somatic coliphages in raw sewage was 2.9 x 10^3 PFU mL^{-1} and 1.79 x 10^3 PFU mL^{-1}, respectively. Deborde *et al.* (1998) measured similar phage concentrations in STE with a range of F-RNA coliphages varying from 7.1 to 3.4 x 10^3 PFU mL^{-1}, and from 7.7 to 3.9 x 10^3 PFU mL^{-1} for somatic coliphages. Background concentrations of the three phages in the reed bed were recorded at the start of the trial and found to be < 10 PFU mL^{-1} in all cases. Wastewater samples were collected from the bed's outlet pipe by the automated sampler every six hours (i.e. 4 samples per day) after which they were returned to the laboratory for phage assaying.

Figures 8.51 – 8.53 show the breakthrough curves for all three phages in the April 2008 trial. The mean effluent discharge over the 12 days of monitoring was recorded as 16.3 L hr^{-1} (HLR = 26.6 mm d^{-1}). Table 8.20 shows the minimum and maximum concentrations of each phage recovered at the outlet of the tracer inoculated bed. Included also is the mean concentrations recorded in the effluent over the duration of the trial. However, given the variation and sensitivity of the arithmetic mean to extreme observations, median values perhaps provide a better measure of centrality in the data sets than the mean and are therefore also provided.

The first phage to detect breakthrough of virus was PR772 after 90 hours (3.8 days) - similar to the initial RWT breakthrough, followed by ΦX174 at 108 hours (4.5 days) and MS2 at 126 hours (5.3 days). The peak breakthrough times of both ΦX174 and PR772 also coincide very closely with that of RWT at 160 hours (6.7 days). Both phages are shown to peak at times of 175 (7.3 days) and 169 hours (7.0 days),

respectively. In fact the characteristics of both the curves of ΦX174 and PR772 are very similar with an initial plateau followed by a drop off in concentrations before a swift peak is delivered. The shape of the MS2 tracer curve is not entirely different with the first (and sharpest) of two peaks breaking through after 144 hours (6.0 days), slightly before that of the other phage tracers and RWT .

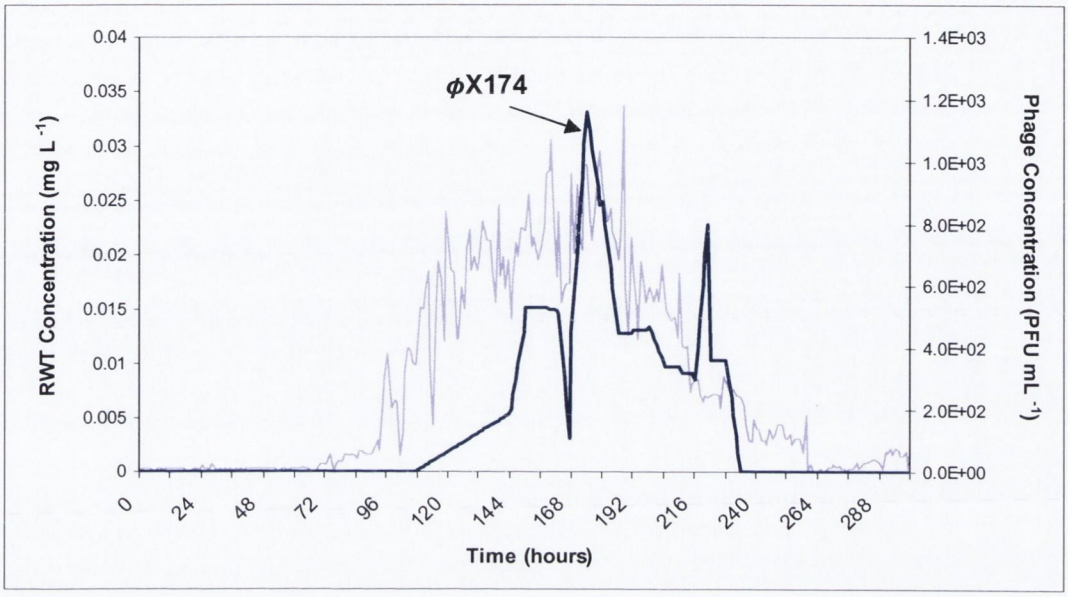


Figure 8.51 Breakthrough curve for ΦX174 on Site A reed bed (RWT curve also plotted)

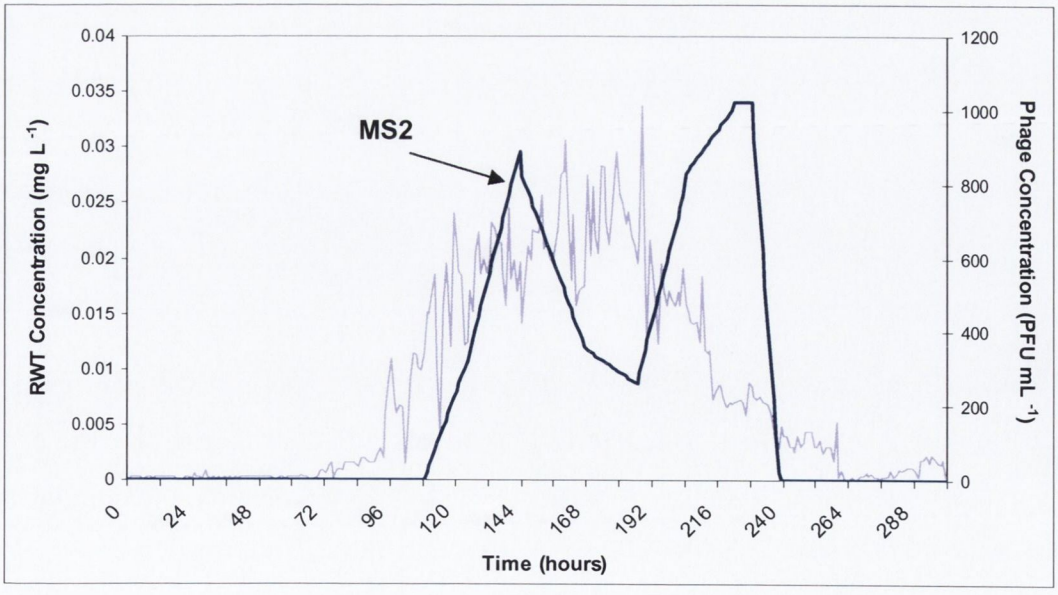


Figure 8.52 Breakthrough curve for MS2 on Site A reed bed (RWT curve also plotted)

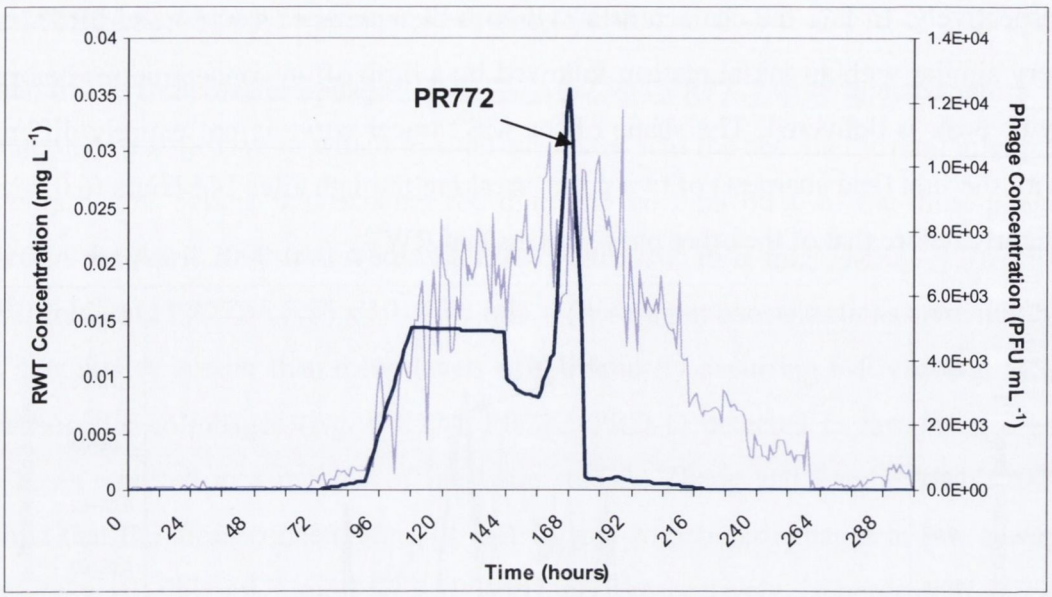


Figure 8.53 Breakthrough curve for PR772 on Site A reed bed (RWT curve also plotted)

Table 8.20 Descriptive statistics of phage tracer inoculated Site A reed bed at outflow point and time to peak (t_p) for each phage [Results expressed as PFU mL^{-1} (phages), L hr^{-1} (flow), °C (temperature) and days (t_p)]

	n	Min	Max	Mean	Median	Std. dev	t_p
ΦX174	22	<10	1.16×10^3	2.9×10^2	2.7×10^2	3.1×10^2	7.3
MS2	22	<10	1.02×10^3	3.3×10^2	2.6×10^2	4.0×10^2	6.0
PR772	22	<10	1.24×10^4	1.5×10^3	2.2×10^2	2.9×10^3	7.0
Flow	299	5.5	28.6	16.3	17.1	5.7	-
pH	22	6.4	7.9	7.4	7.4	0.4	-
Temp.	22	14.2	16.1	15.2	15.3	4.8	-

As carried out previously for RWT, a standard arithmetic method was used to calculate the fraction of each phage tracer recovered as a percentage of the titre of the original injected phage (PFU). The results including total phage numbers input and recovered are recorded in Table 8.21.

Table 8.21 Phage tracer recovery

Phage	Input (PFU)	Output (PFU)	% of Phage Recovered
ΦX174	9.96×10^{8}	9.57×10^{8}	96.0
MS2	1.76×10^{9}	1.32×10^{9}	74.8
PR772	7.76×10^{10}	8.22×10^{9}	10.6

An exceptionally high percentage recovery was noted for ΦX174 at 96.0% while almost three quarters of MS2 (74.8%) was transported through the bed. As such these two phages showed a much greater recovery than the conservative chemical tracer RWT which was found to be only 25% for the same trial (see Section 8.3). However, a very low recovery of phage PR772 (10.6%) was recorded. The explanation for such a large discrepancy in recovery between PR772 and the other two biotracers is speculative and complex.

Sorption is thought to be the most important process controlling the movement of the phages in the wetland given that the brief nature of the trial would render viral inactivation to be an unlikely event. Once again, factors contributing to the sorption of viruses to the substrate include electrostatic attraction and repulsion, van der Waals forces, covalent ionic interactions, and hydrophobic effects. Whilst the saturated nature of reed bed systems coupled with the porosity of the gravel media may indicate phage attenuation being low, other dynamics such as temperature effects and organic matter have been shown to play an instrumental role in the extent of viral sorption to porous surfaces (Bales *et al.*, 1991; Pieper *et al.*, 1997). The resistance of ΦX174 to attenuation in the reed bed draws comparisons to its behaviour in the subsoil treating STE. As previously speculated in Section 7.3.6.1, the presence of high levels of organic matter at shallow depths in the subsoil may have inhibited virus sorption by blocking or impeding the pathways to sorption sites. Similarly the level of organic matter from the STE, both dissolved and adsorbed to the bed's substrate, may have enhanced ΦX174 transport. The absence of an AWI under saturated conditions may have also encouraged greater MS2 mobility in the reed bed. The vastly increased sorption of PR772 may be related to hydrophobic factors. Hydrophobic ''attraction'' refers to the preference of non-ionic surfaces to associate with each other rather than with water. This phage's larger size would make the hydrophobic effect greater for it

than for MS2 or ΦX174. Resultant interactions between PR772 and the bed's organic matter may therefore explain the phage's increased attachment. Kinoshita *et al.* (1993) invoked hydrophobic interactions to justify increased adsorption of PRD1 (structurally and genetically very similar to PR772) to organic matter in two different geological media, aquifer sediment from Cape Cod and Borden, Ontario.

The high recoveries of the hydrophilic ΦX174 and MS2 show that the horizontal SSF reed bed has been efficient in dispersing the phages through the bed but unsuccessful in their removal to a significant level. Both phages therefore have been shown to be well suited to the quantitative description of water transit and dispersion within the reed bed and could thus be regarded as an ideal alternative to chemical tracers like RWT in secondary treatment reed bed applications.

System IV - Tertiary Treatment Reed Bed (Site B)

The final titres of the same biotracer trial carried out on the tertiary treatment reed bed on Site B were: ΦX174 - 3.5 x 10^6 PFU mL^{-1}, MS2 - 1.12 x 10^5 PFU mL^{-1} and PR772 - 4.4 x 10^6 PFU mL^{-1}. Again, background concentrations of the three phages in the reed bed were recorded at the start of the trial and found to be < 10 PFU mL^{-1} in all cases.

Figures 8.54 – 8.56 show the breakthrough curves for all three phages over the 12-day trial in March 2008. The mean effluent discharge over the 12 days of monitoring was recorded as 3.7 L hr^{-1} (HLR = 19.5 mm d^{-1}), less than that of Site A. Table 8.22 shows the maximum and minimum concentration of phages recorded at the outlet of the tracer inoculated bed over the duration of the trial along with mean and median effluent concentrations.

The initial breakthrough of each of the phages was akin to the secondary treatment reed bed on Site A with PR772 again showing first after 48 hours (2.0 days) – very similar to the initial RWT breakthrough. This was followed by ΦX174 at 72 hours (3.0 days) and MS2 at 84 hours (3.5 days). The peak breakthrough times of both ΦX174 and PR772 again, as on Site A, coincide very closely with that of RWT at 160

hours (5.0 days). However, while the descent of the PR772 curve appears to be gradual in line with the RWT trend, the ΦX174 curve is seen to take a sharp drop with vastly reduced concentrations detected thereafter. The MS2 breakthrough curve appears very similar to the RWT curve but with a phase shift of 1 – 2 days. Peaks are recorded after 6.0 days and 9.0 days.

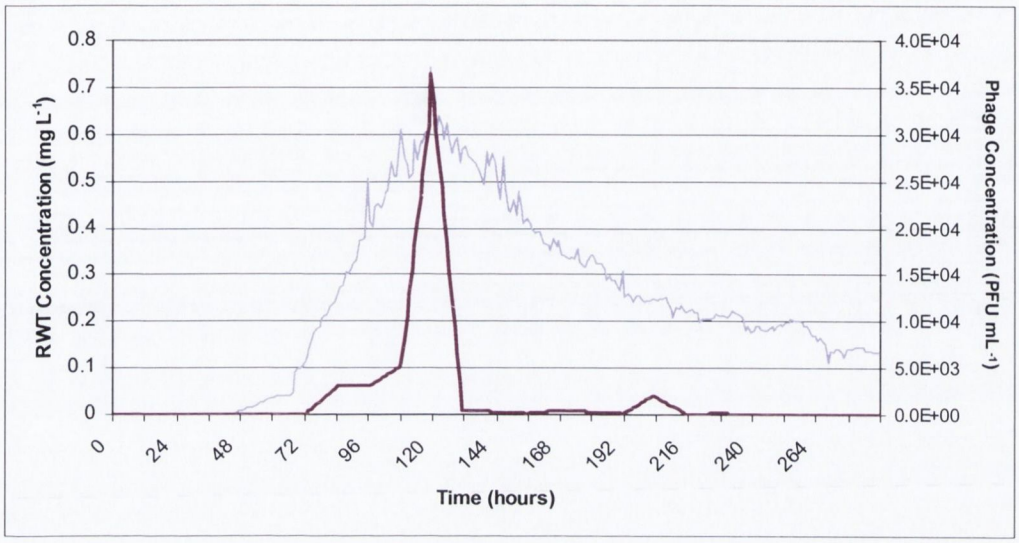


Figure 8.54 Breakthrough curve for ΦX174 on Site B reed bed (RWT curve also plotted)

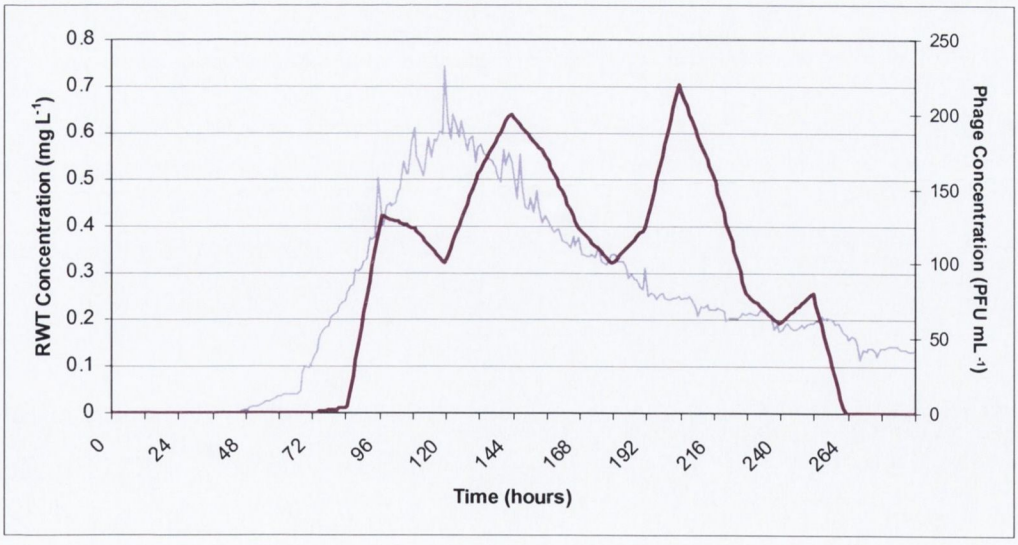


Figure 8.55 Breakthrough curve for MS2 on Site A reed bed (RWT curve also plotted)

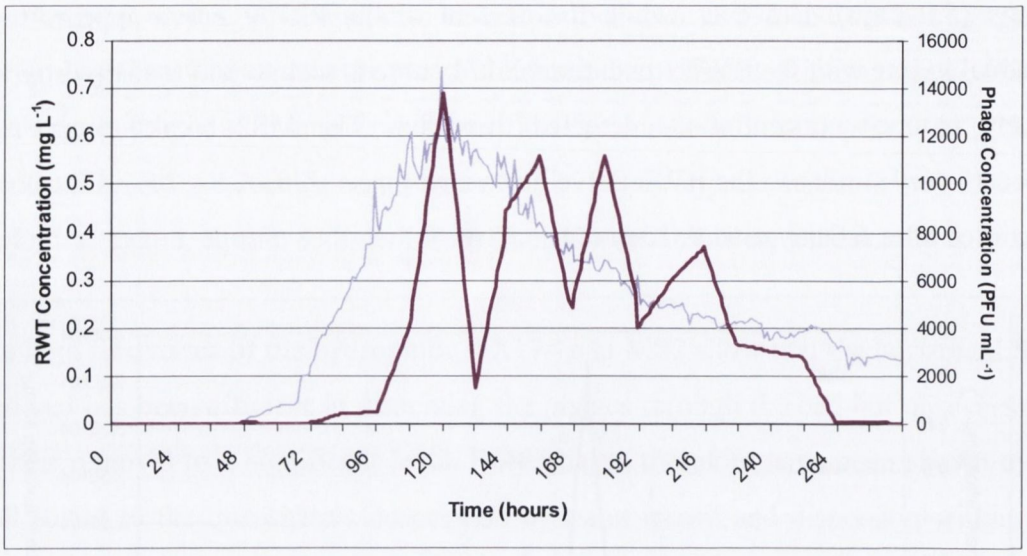


Figure 8.56 Breakthrough curve for PR772 on Site A reed bed (RWT curve also plotted)

Table 8.23 Descriptive statistics of phage tracer inoculated Site B reed bed at outflow point and time to peak (t_p) for each phage [Results expressed as PFU mL^{-1} (phages), L hr^{-1} (flow), °C (temperature) and days (t_p)]

	n	Min	Max	Mean	Median	Std. dev	t_p
ΦX174	20	< 10	3.64×10^4	2.57×10^3	1×10^2	8.1×10^3	5.0
MS2	20	< 10	2.2×10^2	1.2×10^2	1.2×10^2	6.1×10^1	6.0
PR772	20	< 10	1.38×10^4	4.38×10^3	3.3×10^2	4.3×10^3	5.0
Flow	287	2.1	5.7	3.7	3.4	1 x 102	-
pH	20	6.7	7.7	7.3	7.4	0.5	-
Temp.	20	13.6	15.8	14.9	14.9	4.2	-

Phage recovery (Table 8.24) showed some contrasting results with respect to Site A reed bed. While MS2 recovery was relatively similar for both beds, ΦX174 is seen to drop from 96.0% to 76.9% in the tertiary treatment bed. On the other hand the percentage recovery of PR772 is found to significantly increase from 10.6% to 87.5%. While little of this phage was retrieved in the reed bed on Site A where the STE being treated was high in organic chemicals, the cleaner effluent in the tertiary treatment reed bed did little to prevent significant transport of PR772 to the outlet.

Table 8.24 Phage tracer recovery

Phage	Input (PFU)	Output (PFU)	% of Phage Recovered
ΦX174	3.5×10^9	2.7×10^9	76.9
MS2	1.1×10^8	7.7×10^7	68.7
PR772	4.4×10^9	3.8×10^9	87.5

8.6 Fate of Endocrine Disrupting Chemicals in Reed Beds

Two sets of samples were taken from the reed bed on Sites A and B towards the end of the trial periods in February and April 2008 for analysis of certain Endocrine Disrupting Chemicals (oestrogens and bisphenol A) and caffeine. By this stage in the project the reed beds had matured by more than two years. Samples of influent and effluent from septic tanks, packaged plants and reed beds were taken.

There appears to be little or no degradation of oestrogens under anaerobic conditions in the reed beds (Table 8.25) which confirms previous research (Ying and Kookana, 2005). This is interesting as it points to the fact that the majority of oestrogen removal in such on-site treatment environment must be due to aerobic biodegradation and not sorption, as presumably the oestrogens would have plenty of opportunities to sorb to organic particles in the wetlands. Equally, bisphenol A has shown no significant degradation in the anaerobic environment. Finally, the caffeine analysis also reveals very little removal in the reed beds. The effect of aerobic secondary treatment on caffeine degradation can be clearly seen however, when comparing Sites A and B.

The apparent slight elevation in the concentrations of some of the parameters across the reed beds are due to the phase shift between the influent and effluent. There is an mean retention time of 5 days through the red bed on Site A for example, which means the effluent sampled was discharged into the process, on average, 5 days previously to the sampling event when influent concentrations may have been slightly more concentrated.

	Oestrone (ng L^{-1})	17β-Oestradiol (ng L^{-1})	Ethynyl-oestradiol (ng L^{-1})	Oestriol (ng L^{-1})	Bisphenol A (ng L^{-1})	Caffeine (ng L^{-1})
	---------- *Site A* ----------					
STE	21.4	14.4	0.11	13.5	660	3.2×10^5
RBE	33.9	15.2	0.05	19.2	701	2.2×10^4
	---------- *Site B* ----------					
SE	4.24	0.44	0.07	12.9	683	620
RBE	0.35	<0.05	0.32	16.0	527	1563

Table 8.26 Comparison in and removal of EDCs across the horizontal SSFs of Sites A and B

9. DISCUSSION OF RESULTS

9.1 Introduction

Groundwater in Ireland is a natural resource facing an ever-increasing risk of pollution from a number of human activities, among which include the serious threat posed by inadequately designed or dysfunctioning on-site wastewater treatment systems. Performance deficiencies can manifest themselves as mechanical, hydraulic or purification dysfunctions. The latter poses particular concerns with respect to groundwater contamination as they can be difficult to detect and mitigate. For effective treatment of on-site wastewater, such as septic tank effluent (STE), prior to groundwater recharge, infiltration and percolation through sufficiently permeable subsoil in the vadose zone is critical. The EPA's current design guidelines for single-house wastewater treatment systems in Ireland (EPA, 2000) specify a minimum 1.2 m depth of unsaturated subsoil to be present below the invert level of the percolation trench to bedrock or groundwater when treating STE. This is in line with US EPA (1980) who maintain that under unsaturated flow conditions, any STE constituents of concern can be adequately removed within 0.9 to 1.2 m of travel through soils. Where a minimum depth of 0.6 m of permeable soil is present below the infiltrative surface or can be placed over the bedrock and/or water table (i.e. shallow soils) an alternative on-site system can be developed using this soil as a polishing filter (EPA, 2000). Despite these current guidelines in place, there remains a suspicion that inadequate treatment of contaminants is being achieved in subsoils characterised as extremely permeable or porous in nature. The contaminants of particular concern include nutrients (nitrogen in particular) and pathogenic micro organisms (bacteria and viruses in particular) which are particularly sensitive to, and dependent on, site conditions. While nitrate infiltration has been found to have an adverse impact on water bodies, microbial contamination of groundwater has been heavily documented in Ireland in recent times with the EPA revealing that 36% of tested private group water schemes detected evidence of faecal contamination (EPA, 2008a). Given that 25% of all water supplies in the country are provided by groundwater, the protection of groundwater resources from contamination by domestic wastewater effluent is imperative.

Additional gaps and shortcomings exist in the current EPA manual *Treatment Systems for Single Houses* with respect to alternative treatment provided by horizontal subsurface flow reed bed systems. Currently, there is reluctance in Ireland amongst a number of local authorities to permit the use of these wetlands as stand-alone secondary treatment systems given the scarcity of reliable long-term performance data relevant to Ireland and its climate (Healy and Cawley, 2002). Any research on these systems has also been carried out using highly diluted domestic wastewaters compared to the concentrations found in domestic STE from Irish households.

Accordingly, research was carried out to examine the attenuation capacity of highly permeable subsoil on two sites in treating three different strength effluents; STE, secondary effluent (SE) provided by a rotating biological contactor (RBC) packaged treatment system (*Biodisc*®), and reed bed effluent (RBE) from a horizontal subsurface flow reed bed treatment system. Both sites had infiltration properties (measured as T-values) that fell within the specified range $1 \leq$T-value ≤ 5 and conformed to all other EPA recommendations (EPA, 2000) relating to site suitability. Monitoring took place over a two-year period in which the extent and development of the biomat, shown to be a defining factor in the retention of the effluents' constituents, was tracked on an ongoing basis. In tandem with the research carried out on the vadose zone of on-site wastewater treatment systems, the performance efficiency of horizontal subsurface flow reed beds as viable secondary and tertiary treatment options was also assessed over the same period of time.

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:

Site A — Serving Population = 6; T-value = 3.7

System I: A conventional septic tank system where the percolation area received STE (half the total hydraulic load)

System II: A septic tank and horizontal subsurface flow reed bed providing primary and a secondary treated effluent, respectively, before discharge of the RBE to a percolation area for polishing (half the total hydraulic load)

Site B — Serving Population = 3; T-value = 4.5

System III: A rotating biological contactor proprietary plant (*Biodisc*®) providing secondary treated effluent before subsequent polishing in a percolation area (half the total hydraulic load)

System IV: A rotating biological contactor proprietary plant (*Biodisc*®) providing secondary treated effluent before subsequent polishing in a horizontal subsurface flow reed bed (half the total hydraulic load)

9.2 On-Site Wastewater Production and Characteristics

9.2.1 Hydraulic Loading and Regime

The on-site wastewater production on both Sites A and B was continually measured over a 26 and 24 month period, respectively, by placing 4 tipping bucket flow-gauges underneath each of the four distribution device outlets. Each gauge was set to tip at a volume of every 125 mL of effluent, thus providing a very accurate and sensitive measure of the diurnal flow rates. The total daily on-site flow rates at the distribution box at Site A remained relatively constant over the monitoring period measured as 716.3 L d^{-1}, on average, which equates to an effluent production per person of 119.4 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 268.8 L d^{-1} which equates to a mean effluent production per person of 89.6 L c^{-1} d^{-1}.

Results from both sites reveal that the assumption of 180 L c^{-1} d^{-1} in the Irish EPA guidelines (EPA, 2000) appears to significantly over-predict the mean wastewater production in such one-off dwellings with typical sized family units. This matches data recorded in previous studies on 4 other sites continuously monitored for 12 months (O'Súilleabháin, 2004). The 180 L c^{-1} d^{-1} design figure is a value typically used for urban wastewater statistics, which include significant sewer infiltration (not applicable to on-site systems). Moreover, in large conurbations it is usual for people to live and work within the same drainage network. Hence, a full day's wastewater from each person is discharged into the same system, albeit at different points on the network. For on-site wastewater, however, a number of the residents will spend a large percentage of the day outside the septic tank "catchment" (i.e. the house) and thus some of their daily wastewater production will be directed to other systems

(catchments). This explains why the mean wastewater figures recorded on these sites are considerably lower than the guideline value.

As pollutant loading rates needed to be determined for the two separate treatment systems on each site, it was endeavoured to split the flow from the septic tank on Site A (and the *Biodisc*® on Site B) evenly at the gravity-fed distribution device. Flow distribution on Site A between the percolation area (*System I*) and the secondary treatment reed bed (*System II*) was found to be relatively even at a ratio of 1.13 : 1. This equated to a mean daily STE flow to the percolation trenches in *System I* of 395.4 L d^{-1} (based on a 3-person hydraulic load). Similar analysis on Site B again revealed an even split between the percolation trenches (*System III*) and the tertiary treatment reed bed (*System IV*) at a ratio of 1.09 : 1. This equated to a mean daily SE flow to the percolation trenches in *System III* of 132.1 L d^{-1} (based on a 1.5-person hydraulic load). On completion of a water balance on the secondary treatment reed bed of *System II* on Site A (see Section 9.4.1), the mean discharging flow to the subsequent set of percolation trenches was calculated as 349.9 L d^{-1} (based on a 3-person hydraulic load).

These flow figures are interesting in comparison to design long-term acceptance rates (LTARs) and actual hydraulic loading rates on the trenches of each of the three systems (Table 9.1). An LTAR of 20 L m^{-2} d^{-1} is recommended for STE being discharged to subsoil while this figure increases to 50 L m^{-2} d^{-1} for the discharge of SE to subsoil with a T-value of between 1 and 20 (EPA, 2000). These are used in conjunction with the daily design hydraulic load of 180 L c^{-1} d^{-1} for single-house systems to determine the required size of a percolation area. One of the key aspects of the field research carried out was to continuously monitor the spread and dispersion of the biomat at the base of the percolation trenches in each of the three systems. This was achieved by means of a combination of ongoing Cl tracer analysis, CCTV investigation studies and examining the effect of dilution (by recharge) on effluent attenuation. In all cases the biomat, once formed, was found not to develop further to any significant degree across the duration of the monitoring. On the percolation trenches treating STE (*System I*), it was estimated that 50% (or 30 m) of percolation trench had not been utilised after 32-months of system operation. On the trenches of *System II*, receiving secondary effluent from the reed bed (RBE), only 41% (or

19.5 m) of trench length was utilised over the same period of operation. Most significant, perhaps, was the little biomat development, approximated to be 1 m in total, on the percolation trenches receiving *Biodisc*® SE (*System III*) owing to both the superior standard of effluent and the high permeability of the soil medium promoting greater vertical movement of the percolate. As such, all three systems were hydraulically over-designed and construction of their percolation areas over-sized. The hydraulic loading rates experienced over the wetted (effective) lengths of trench were estimated as 29 L m^{-2} d^{-1} for *System I* treating STE, 40 L m^{-2} d^{-1} for *System II* treating RBE and a sizeable 367 L m^{-2} d^{-1} for *System III* treating SE. For *System I* the desired LTAR of 20 L m^{-2} d^{-1} could be achieved by constructing a greater number of shorter percolation trenches and installing a distribution device with more outlets so that effluent would be evenly distributed over a greater area. Whilst the design and construction of the percolation area of *System II* was based on a conservative LTAR of 25 L m^{-2} d^{-1}, the EPA recommended LTAR of 50 L m^{-2} d^{-1} for these highly permeable subsoils suggests the hydraulic design for discharge of RBE (found to be on the high side of a secondary effluent standard) to be adequate and fit nicely at this rate. The extremely high hydraulic loading rate on the trenches of *System III* suggest that in practice it is not feasible to achieve such a design LTAR by gravity flow alone. Greater regulation of effluent delivery should be required in such a case through use of a pressurised dosing system if the site conditions allow.

Table 9.1 Comparison of length of percolation trench constructed and that utilised after 32 months of system operation, based on design LTARs of 20 L m^{-2} d^{-1} for STE and 25 L m^{-2} d^{-1} for SE

System	Mean Daily Hydraulic Load (L d^{-1})	Percolation Trench Length (m)	
		Constructed	Utilised
System I	395.4	60	30
System II	349.9	48 *	19.5
System III	132.1	32 **	1

* design based on a conservative LTAR of 25 L m^{-2} d^{-1}

** while a percolation trench length of only 12 m was required (based on a LTAR of 50 L m^{-2} d^{-1} and a 1.5 person hydraulic loading), 32 m was constructed as a precautionary measure based on a minimum 4-person hydraulic load design for on-site systems (i.e. trenches were therefore designed based on the conservative LTAR of 25 L m^{-2} d^{-1} and a 2-person hydraulic load)

A more detailed examination of the recorded flow statistics revealed that the most common (> 85% of the time) flow rates experienced at the distribution device from the septic tank at Site A were between 0.1 – 1 L min^{-1} across the sampling period (mean 0.62 L min^{-1}). The volumetric mean flow observed for this period was 2.49 L min^{-1}. Almost 50% of the time the flow rate was less than 0.3 L min^{-1} indicating that the flow from the septic tank that needs to be evenly distributed between the percolation trenches was most often in the form of intermittent, small volume pulses. This information was important to consider for a parallel study carried out on distribution device design. Equally, 50% of the effluent volume was discharged at flows less than 1.4 L min^{-1}.

Similarly, the most common flow rates experienced at the distribution devices receiving secondary treated effluent from the *Biodisc*® (RBC plant) installed at Site B was between 0.1 - 0.5 L min^{-1} (mean 0.3 L min^{-1}). The volumetric mean flow observed across the sampling period was 0.57 L min^{-1}, lower, as expected, than Site A given the difference in hydraulic loading between both sites. The flow characteristics from the *Biodisc*® showed a much more constrained range of flows, as expected, due to the two-chambered design of the treatment unit whereby effluent up to a fixed maximum volume was transferred from the primary zone to the secondary zone upon every revolution of the media disk via a small container. Almost 50% of the time the flow rate was less than 0.2 L min^{-1} which indicates that the cup must have been transferring less than 100 mL per revolution given the revolution frequency of the RBC modules was 2.16 revs min^{-1}. Equally, 50% of the effluent volume was discharged at flows less than 0.4 L min^{-1} over the duration of the sampling.

9.2.2 Wastewater Characteristics – Septic Tank

In general, the effluent concentrations of most of the water quality parameters from the septic tank were relatively high when compared to the typical influent concentrations outlined in EPA (2000), particularly with regard to nitrogen levels. Equally, when comparing the data to the CEN 12566 European standards (Part 6) (CEN, 2005c) which specify the influent characteristics required for testing prefabricated small wastewater treatment systems receiving STE, it is immediately evident that the measured STE quality is on the high side (i.e. highly concentrated) in terms of organic chemicals and in the case of total-N and ortho-P, just above the range

of assumed effluent quality required. The median hydraulic retention time for the septic tank (volume of 3 785 litres) was approximately 6 days over the course of the project and it is clear that the anaerobic environment of the septic tank has facilitated the conversion of organic nitrogen (org-N), in the form of protein-rich matter and urea, to its inorganic ammonium (NH_4-N) and phosphorous to its soluble orthophosphate (PO_4-P) forms, respectively. Of the total-N (TN) in the effluent, NH_4-N formed 71% with the remaining in its org-N form. The concentration of volatile fatty acids (VFAs) was also measured which showed that, on average, they formed 15% to 17% of the overall COD effluent concentration, with acetic acid forming over 85% of the overall VFA load.

Interestingly, analysis of the flow rate with respect to the key STE constituent concentrations (COD, NH_4-N, PO_4-P and *E. coli*) showed a very poor linear correlation. There were seasonal trends in the COD and PO_4-P concentrations however, which may have been due to temperature changes, with the warmer periods in the summer promoting faster anaerobic activity in the tank and the production of soluble products. Finally, there did not appear to be any long term trend in the effluent concentrations over the sampling period, which is an interesting observation as the septic tank was not desludged from the time it was first commissioned to the end of the monitoring period, a total duration of 32 months.

The concentrations of oestrogens discharging from the septic tank compared reasonably to results published in other studies (Rudel *et al.,* 1998; Swartz *et al.*, 2006), with mean values of oestrone, 21 ng L^{-1}, and 17β-oestradiol, 14 ng L^{-1}, ethynyl-oestradiol, 0.1 ng L^{-1}, and oestriol, 13 ng L^{-1}. Equally, the concentrations of bisphenol A in the septic tank effluent were 0.66 μg L^{-1}, which also correlates well with literature review studies.

9.2.3 Wastewater Characteristics – Biodisc® RBC Package Plant

The SE from the *Biodisc*® RBC plant on Site B showed a consistently high organic concentration for secondary treated effluent and the process was only acting to partially nitrify the effluent. A greater level of nitrification would normally have been expected in a successfully functioning packaged treatment plant. The muted nitrification observed was most likely due to the high organic concentrations that were

recorded in the effluent, which would act to suppress the autotrophic nitrifying bacteria. PO_4-P concentrations in the effluent remained stable throughout the trial period with a mean value of 26 mg L^{-1}. Total coliforms (TC) and *E. coli* were detected at consistently high levels in the SE with geometric mean values of 2.9 x 10^5 and 1.3 x 10^4 MPN 100 mL^{-1}. These figures are 1.5 to 2 log units less than the equivalent concentrations measured in the STE on Site A, but still constitute a significant pollutant risk to water resources and require further treatment for bacterial breakdown prior to groundwater recharge. Finally, the sensitivity of the process to regular maintenance was evident as after approximately 18 months of operation without desludging the system, problems started to be observed with the final clarifier sludge blanket lifting. Whilst the performance of the package plant with respect to nutrient processes and removal did not significantly alter immediately following desludging, effluent COD concentrations were seen to dip sharply.

Bisphenol A concentrations recorded in the SE from the EDC study were found to be almost six times greater than reported levels in other studies. However, given the absence of influent data, it is difficult to assess the efficiency of the packaged treatment system with respect to its removal, other than to highlight its potentially greater discharge levels than what has been previously found in literature. The effect of aerobic secondary treatment on caffeine degradation can be clearly seen in the difference in levels recorded between the STE and the SE (of 3 orders of magnitude). Of the range of oestrogens tested, oestriol appears to be more persistent than oestrone during aerobic treatment. In line with other studies, the opposite was shown to be true in the anaerobic environment of the septic tank. Oestrone, in turn, was found to be more persistent than 17β-oestradiol during the secondary treatment process in the *Biodisc*® RBC.

9.3 Comparison of Subsoil Treatment Systems

The EPA currently recommends the presence of 0.6 m and 1.2 m of unsaturated subsoil below the invert of percolation trenches receiving SE and STE, respectively. It has been agreed that the former value will be adjusted to 0.9 m in the new regulatory Code of Practice document (EPA, 2008b) owing to particular concerns expressed surrounding the microbial contamination of groundwater. As such, three nominal

depth planes, 0.35 m (red), 0.65 m (blue) and 0.95 m (black), were created below the base of the percolation trench to analyse the attenuation of the percolate and its constituents throughout the vadose zone. In using suction lysimeters it must be remembered that samples were obtained from the soil matrix, which was assumed to be homogeneous and isotropic.

Chloride analysis was used to determine the distribution of the STE, RBE and SE within the percolation areas of *Systems I*, *II* and *III*, respectively. Results over the total duration of the monitoring showed each effluent type to have dispersed to different lengths along the percolation trenches owing to the discrepancy in organic materials contained in each. The highly concentrated STE was seen to disperse to the 10 m mark in *System I* trenches, while approximately 5 m of each of the trenches receiving RBE (*System II*) were utilised. The significant reduction in organic load provided by the secondary treatment of effluent in the *Biodisc*® RBC package plant resulted in the SE infiltrating directly to subsoil at the beginning of each of the *System III* trenches. Further investigation of the effluent behaviour was performed through a CCTV study of the percolation pipework and together with quantification of the effect of dilution on effluent attenuation, a more accurate biomat prediction and zone of contribution was established (Table 9.2). The increasing surface area infiltrated with depth was expected as it highlights the dispersion of the effluent plume below each percolation trench. It is important to add that the biomats at the base of each of the trenches had spread to the lengths recorded in Table 9.2 by the time monitoring of the trenches had begun (approximately 6 months following site start-up) and remained relatively constant throughout the duration of the project i.e. the effluent was not seen to have dispersed more laterally over time.

Table 9.2 Estimated biomat length and zone of contribution of effective rainfall for percolation trenches of *Systems I, II* and *III*

System ID	Influent strength	Mean COD load per trench ($g\ d^{-1}$)	Average length of biomat per trench (m)	Estimated width of plume (m) from edge of trench at depth plane		
				0.35 m	0.65 m	0.95 m
System I	STE	**216**	10	0.1	0.17	0.3
System II	RBE	**61**	6.5	0.15	0.25	0.3
System III	SE	**26**	0.4	0.05	0.1	0.35

9.3.1 Attenuation of Chemical Constituents of STE, RBE and SE

Within the percolation areas treating STE, RBE and SE, the majority of organic load degradation was seen to occur between the infiltrative surface and the red depth plane at percentage removals of between 61% and 83%. Further reduction in COD levels was shown to be limited between the red and black depth planes owing to a combination of low heterotroph populations and/or the remaining load representing the non-biodegradable component of the organic chemicals in the percolate. In addition it was noted that with respect to the subsoil treatment of *Systems I* and *II* on Site A, comparable levels of organic removal were achieved within 0.95 m of the infiltrative surface despite the influent load to *System II* trenches containing less than one third the amount of organic chemicals found in the load feeding the trenches of *System I*. Table 9.3 highlights the breakdown in COD loads across the three strategic depth planes.

Table 9.3 COD loads with subsoil depth across the percolation areas of *Systems I, II* and *III*

Sample Position	COD					
	***System I* (STE)**		***System II* (RBE)**		***System III* (SE)**	
	%	$g\ d^{-1}$	%	$g\ d^{-1}$	%	$g\ d^{-1}$
Point of Infiltration	100	216	100	60.5	100	25.5
Red (0.35 m)	16.6	35.9	39.3	23.8	33.7	8.6
Blue (0.65 m)	13.9	30.0	38.5	23.3	22.0	5.6
Black (0.95 m)	13.8	29.9	34.7	21.0	21.2	5.4

Given the disparity in wastewater volume being treated on both sites, comparison of the three subsoil treatment systems is more accurately demonstrated on a load per capita basis. Figure 9.1 illustrates this representation with respect to COD removal, showing that between 3.6 and 10 g COD c^{-1} d^{-1} were present at the key 0.65 m and 0.95 m depth planes.

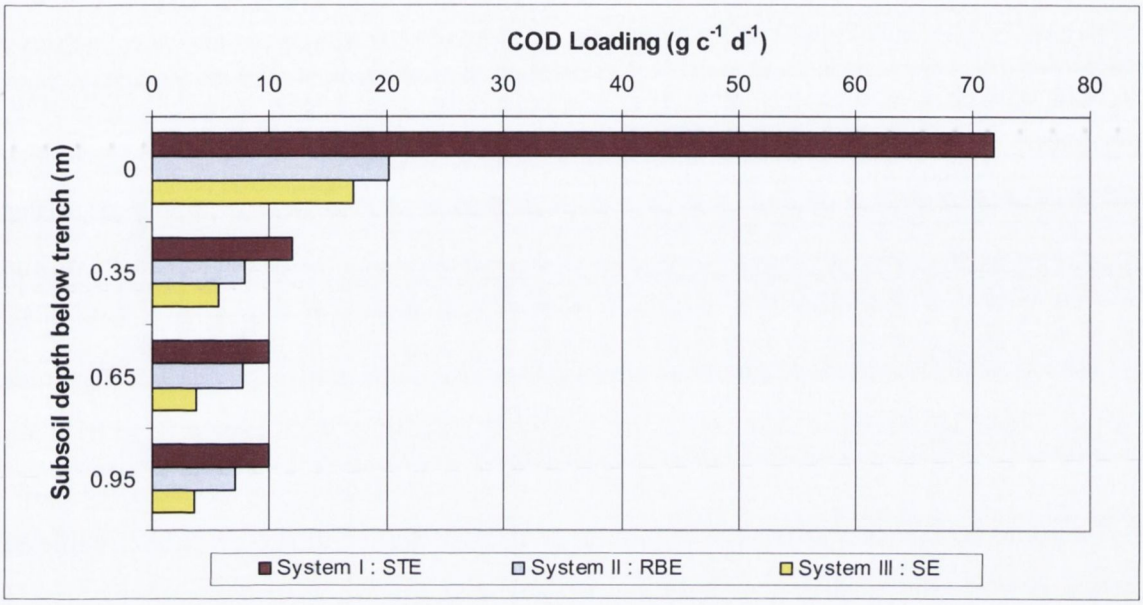


Figure 9.1 Mean COD load per capita at the designated depth planes on percolation areas of *Systems I*, *II* and *III*

A combination of the aerobic environment of the distribution gravel, the abundance of thriving nitrifiers beneath the biomat and the many chemical and biological processes within the subsoil matrix facilitated almost complete nitrification of the percolate to NO_3-N above the red depth plane on all three percolation areas. However, it was found that under the trenches of *Systems I* and *II* receiving STE and RBE, respectively, the equivalent decrease in NH_4-N recorded across the red depth plane did not correspond to the increase in NO_3-N levels at the same plane. It is postulated that localised saturated conditions directly above the developed biomat at the infiltrative surface may have promoted sorption of NH_4-N by cation exchange which would have the effect of removing NH_4-N directly from the percolate. More likely, however, was the occurrence of effluent nitrification followed by rapid denitrification in localised micro-sites where saturated conditions were prevalent. In contrast, there was no parallel NH_4-N loss contributing to total inorganic-N removal in the percolate over the same subsoil thickness under the trenches of *System III* (receiving SE) (Table

9.4). This may have been due to the absence of a sufficiently developed biomat to promote localised saturated conditions and accelerate biogeochemical processes, and/or the unavailability of a sufficient carbon load for the denitrifiers to source on. Little further denitrification occurred with depth in the trenches of *System I*, while the sporadic denitrification recorded under the trenches of *System II* may be explained by the reduced carbon loads from the secondary treatment reed bed providing the nitrifiers with a better chance of competing with the heterotrophs, thus achieving greater nitrification (and subsequent denitrification) of the percolate. Any reduction in total inorganic-N beneath the red depth plane of the trenches treating SE (*System III*) was attributed to dilution and not denitrification – a sufficient supply of organic materials at these depths was unlikely for adequate bacterial metabolism to promote significant denitrification. In summary, it appears that reduction in the organic load provided by secondary treatment inhibited the occurrence of a biomat and associated saturated zones required for sorption of NH_4-N by cation exchange and denitrification of NO_3-N. Also, rapid infiltration of SE would promote and maintain unsaturated aerobic conditions at depth, unsuitable for denitrification of the percolate, while low carbon levels at depth would deprive the bacteria of their essential source for denitrification.

Table 9.4 Total inorganic-N loads with subsoil depth across the percolation areas of *Systems I*, *II* and *III*

Sample Position	Total inorganic-N					
	***System I* (STE)**		***System II* (RBE)**		***System III* (SE)**	
	%	**g d^{-1}**	**%**	**g d^{-1}**	**%**	**g d^{-1}**
Point of Infiltration	100	30.2	100	21.3	100	8.9
Red (0.35 m)	54.6	16.5	88.3	18.8	100	9.9
Blue (0.65 m)	57.6	17.4	78.9	16.8	87.6	7.8
Black (0.95 m)	50.7	15.3	64.8	13.8	86.5	7.7

As a result, inspection of Figure 9.2 shows that the total inorganic-N load per capita recorded at the current minimum recommended depth of unsaturated subsoil; 0.6 m for RBE and SE, and 1.2 m for STE, was greater for the systems with alternative secondary treatment systems installed (i.e. reed bed on *System II* and *Biodisc*® RBC

on *System III*). These critical loads equated to 5.6 g c^{-1} d^{-1} and 5.2 g c^{-1} d^{-1} for *Systems II* and *III*, respectively, compared to 5.1 g c^{-1} d^{-1} for *System I*.

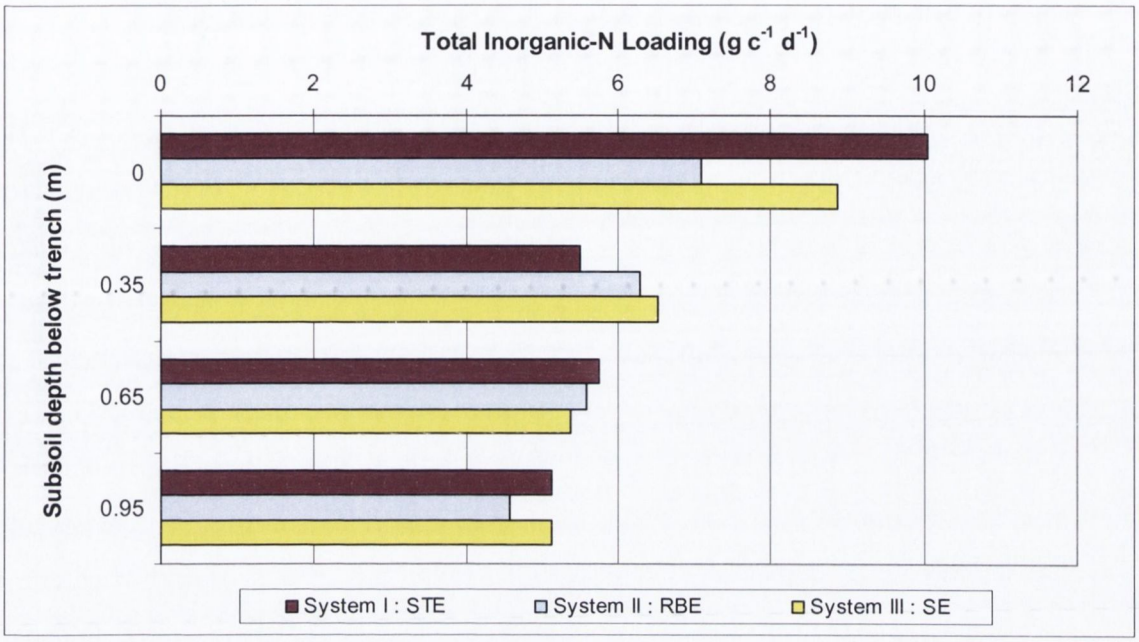


Figure 9.2 Mean total inorganic-N load per capita at the designated depth planes on percolation areas of *Systems I, II* and *III*

In assessing the loads on the back of the forthcoming increase in unsaturated subsoil depth to 0.9 m for secondary effluent in the regulatory Code of Practice document (EPA, 2008b), little difference is noted in the potential N discharge levels to groundwater with *Systems I* (STE) and *III* (SE) showing identical loads of 5.1 g c^{-1} d^{-1} despite the distinction in applied effluent quality.

The resultant impact of the treatment systems on localised groundwater quality was continuously monitored by installed groundwater boreholes upstream and downstream of the percolation areas. Consistently elevated Cl concentrations were recorded at the downstream groundwater monitoring point on Site A which corresponded closely to the results at the black plane, thus confirming effluent infiltration to groundwater. NO_3-N concentrations were also seen to rise rapidly between upstream and downstream groundwater sampling points with concentrations at the latter fluctuating in a similar pattern to the black depth plane. The potential mean NO_3-N infiltrative concentration to groundwater on Site A (28.3 mg NO_3-N L^{-1}), as measured at the black depth plane, was realised in the groundwater point directly downstream with an

mean 30.9 mg NO_3-N L^{-1} measured over the duration of the sampling. To this end, such a similarity in recorded NO_3-N concentrations between the black plane and groundwater indicated that the effect of rainfall and groundwater dilution was almost insignificant on the downstream plume.

Removal of PO_4-P from the percolate in the subsoil is typically due to a combination of soil adsorption and mineral precipitation processes. Analysis of PO_4-P loads across the three percolation areas revealed the majority of removal (83% - 89%) again occurred above the red depth plane. In the case of the systems (*I* and *II*) on Site A, 20% clay, classified as swelling illite-smectite in XRD analysis, was contained in the soil composition between the infiltrative surface and a depth of 1.0 m below G.L. (i.e. within a soil layer thickness of 0.2 m). This more than likely played a dominant role in the adsorption of PO_4-P. XRD analysis carried out on the subsoil of Site B revealed little in the way of explaining PO_4-P reduction with the subsoil devoid of calcite or any Al, Fe and Mn oxides. Mineral composition was confined to quartz, feldspars, orthoclase, chlorite and mica, none of which are associated with precipitation of phosphate ions. The small clay fraction (10.8%) was therefore assumed responsible for much of the P-adsorption above the red depth plane. In all cases almost complete adsorption of PO_4-P occurred between the infiltrative surface and the black plane as shown in Table 9.5. As such, mean daily loads per capita at the minimum recommended depth of unsaturated subsoil for the respective levels of treatment were found to be indistinguishable at ~ 0.1 g PO_4-P c^{-1} d^{-1} (Figure 9.3).

Table 9.5 PO_4-P loads with subsoil depth across the percolation areas of *Systems I*, *II* and *III*

Sample Position	PO_4-P					
	***System I* (STE)**		***System II* (RBE)**		***System III* (SE)**	
	%	**g d^{-1}**	**%**	**g d^{-1}**	**%**	**g d^{-1}**
Point of Infiltration	100	6.6	100	3.5	100	3.5
Red (0.35 m)	10.6	0.7	17.1	0.6	11.4	0.4
Blue (0.65 m)	6.1	0.4	17.1	0.6	2.9	0.1
Black (0.95 m)	4.5	0.3	11.4	0.4	2.9	0.1

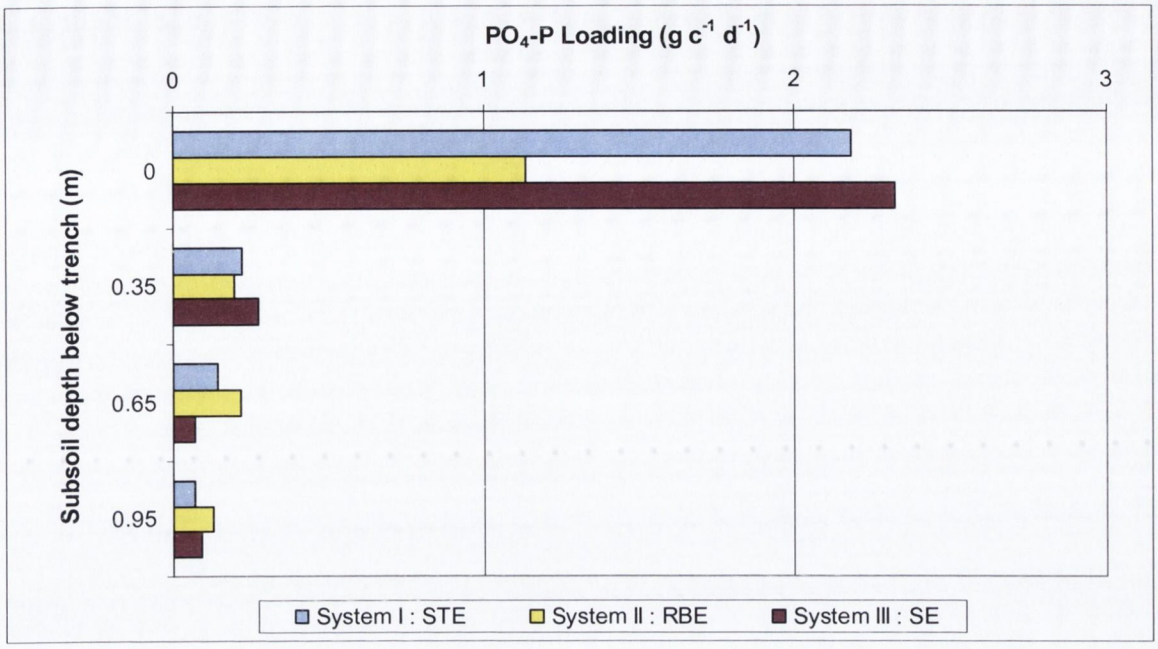


Figure 9.3 Mean PO_4-P load per capita at the designated depth planes on percolation areas of *Systems I*, *II* and *III*

In the EDC study the set of oestrogens, with the exception of oestriol, were found to break down substantially in the subsoil environment to very low levels at the black depth plane. This was expected given their propensity to sorb to soil particulates and the favorable aerobic environment for their degradation. Oestriol, in contrast, showed greater persistence in the vadose zone, especially in the percolation area of *System III* on Site B. While the hormone possesses an octanol/water coefficient lower than that of the other oestrogens which limits its ability to sorb to soil or organic particles, it is assumed the combination of a higher infiltration rate, the absence of a biomat and greater pore size of the sandy GRAVEL on Site B had a sizeable influence in permitting greater migration with depth. Another interesting observation was that of 17β-oestradiol which appears to have almost completely biodegraded and converted to oestrone above the red depth plane. However, the oestrone was then seen to significantly degrade over the next 0.65 m of subsoil from the red to the black plane, reaching negligible concentrations.

Contrary to literature studies citing high removal of the compound in aerobic treatment processes, bisphenol A was shown to resist significant degradation in the

aerobic environment of the subsoil with removal as low as 55% under the trenches treating STE in *System I.*

The use of caffeine as a conservative indicator of on-site treatment effluent was deemed questionable as it was found to degrade significantly in the aerobic subsoil environment. Alternatively, the chemical could be viewed as a representative tracer of some of the other contaminants in the percolating effluent, e.g. COD or coliforms, which show similar behavioural characteristics.

9.3.2 Attenuation of Microbiological Constituents of STE, RBE and SE

The installation of the *Biodisc*® RBC plant and the horizontal SSF reed bed greatly reduced bacterial loading on the subsequent percolation areas with mean concentrations of *E. coli* between 1.4 and 1.8 log-units (96.2 - 98.5%) smaller than that recorded in the STE. As was the case with most of the chemical constituents, the greatest reduction in bacteriological concentration in the subsoil occurred above the red depth plane on all three percolation areas. Previous research (Ziebell *et al.*, 1974; O'Súilleabháin, 2004) has shown the significance of the biomat in retaining much of the bacterial load with removal rates as high as 99.9%. Of the combined total of 146 samples taken at the red depth plane on the three percolation areas across the duration of the project, 129 samples, or 88%, yielded *E.coli* concentrations less than the limit of detection (10 MPN 100 mL^{-1}). The highest level of detection at this depth was found in the percolation area of *System III*, receiving SE, when one particular sample yielded an *E.coli* concentration of 1 624 MPN 100mL^{-1}. This was owing to a particularly high hydraulic load discharged to the trench on this date which, when combined with the absence of a biomat at the infiltrative surface of the trenches and the high sand content (i.e. larger pore size), facilitated free movement of the bacteria. This as such highlights the influence of flow conditions on bacterial transport and emphasises the risks posed by discharging effluent into permeable sand/gravel subsoils with such a high LTAR as that measured on *System III* (over the 26-month monitoring period).

Table 9.6 presents the *E.coli* results measured at the black depth plane of the three percolation areas. In evaluating the performance of the RBE and SE trenches (*Systems*

II and *III*, respectively) against the previously mentioned regulations being drafted in through the new Code of Practice document (EPA, 2008b), namely an increase in depth of unsaturated subsoil from 0.6 m to 0.9 m below the invert of percolation trenches receiving SE, twelve incidences of serious enteric bacteria migration (> 10 MPN 100 mL^{-1}) were still recorded at the black depth plane (0.95 m) on both sets of trenches. This equates to 13% of the total number of samples measured at this depth plane. Of these, two incidences of contamination exceeding 1 000 MPN 100 mL^{-1} were found on the trenches receiving RBE, where the biomat was also muted. While isolated incidences of *E. coli* contamination were measured at the black depth plane of the trenches receiving STE, frequency and, in particular, level of detection were smaller than that measured at the other percolation areas. The results as such indicate that it is the biological processes in the biomat, and not the influent strength, that plays the dominant role in coliform retention. Desorption of bacteria at depth (which initially would have migrated and sorbed to the soil particles) during periods of high rainfall was also thought to be an important mechanism of transport.

Similar conclusions to this study were drawn by O'Súilleabháin (2004) in studying a number of subsoil treatment systems with lower permeability characteristics. Analysis showed that more evidence of faecal contamination occurred at depth on the percolation area receiving SE than that receiving STE, despite the lower bacterial influent load.

Table 9.6 Concentrations of *E.coli* measured at the minimum discharge point, with respect to new Code of Practice (EPA, 2008b) proposals, for the respective levels of treatment across the three percolation areas

	Influent strength	**No. of samples**	**No. of samples at black depth plane with concentration (MPN 100 mL^{-1})**				**% of samples contaminated**
			< 10	**10-100**	**101-1 000**	**> 1 000**	
System I	STE	49	43	6	0	0	12
System II	RBE	61	53	4	2	2	13
System III	SE	31	27	3	1	0	13

This was underlined further following analysis of the groundwater monitoring point

installed downstream of the percolation areas on Site A. Significant *E. coli* contamination in the groundwater (as high as 3.6×10^2 MPN $100mL^{-1}$ in one instance) was found in all but two of the eleven samples obtained throughout the duration of the project. This regularity in *E. coli* detection highlights the bacteriological risk posed by such permeable subsoil treatment systems on underlying aquifers.

The multi-phage injection trial revealed some interesting findings regarding the ability of the subsoils on both sites to remove viral pathogens as well as highlighting different behaviour patterns of each of the phages.

On Site A, greatest removal in the initial 0.35 m below the infiltrative surface was achieved by phage MS2 at 85% (0.8 log-unit), followed by PR772 (0.4 log-unit ~ 56%) and ΦX174 (0.06 log-unit ~ 12%). It is suggested that unlike PR772 and ΦX174, the interaction of MS2 with the air-water interface (AWI) may have played a significant early role in phage inactivation between the infiltrative surface and the red depth plane. Powelson *et al.* (1990) concluded his work with a similar finding, showing MS2 to be strongly influenced and ultimately inactivated at the AWI. The more limiting removal of PR772 and ΦX174 at the red depth plane was thought to be largely due to the significant presence of organic matter in the STE biomat inhibiting virus sorption by blocking or impeding the pathways to sorption sites. The presence of organic matter has been shown by Zhuang and Jin (2003) to reduce virus attachment and thus facilitate virus transport by providing additional negative charges, covering positively charged sites, or competing with viruses for attachment sites. By the time the percolate had reached the black depth plane on day 3 of the trial (as evidenced by bromide detection) all three phages had been reduced to their minimum detection limit of < 10 PFU mL^{-1}. This equates to an overall percentage removal of $> 99.8\%$ (MS2), $> 99.6\%$ (ΦX174) and $> 99.99\%$ (PR772) between the infiltrative surface and black depth plane. The multi-log removal of all three phages therefore between the red and black planes was most likely due to viral adsorption to the soil matrix, which, although dominated by sand and gravel, contained 15 - 30% clay fraction. The reduction in organic matter content with depth may have also facilitated a greater number of sorption sites for phage adhesion.

On Site B, initial removal of all three phages over the first 0.35 m was found to be similar at rates of 1.1 log-unit (92%), 1.5 log-unit (97%) and 0.8 log-unit (86%) for MS2, ΦX174 and PR772, respectively. This level of removal at the red depth plane was therefore found to be significantly greater than that recorded on the corresponding plane on Site A. Three distinct differences existed, however, between the conditions on both sites which were paramount to explaining the differences in phage transport. Firstly, the quality of the applied effluent was highly contrasting, with the STE on Site A typically containing an organic (COD) load nine times that of the SE on Site B. Added to that was the disparity in HLRs on both sites with Site B treating a flow per unit surface area that was ~ 37 times greater than that of Site A. As such the hydraulic and organic loading regimes, which are a key element of the subsoil purification processes, were highly contrasting for both sites. While it was felt that on Site A interference from organic matter affected the capacity for viral sorption to the soil particles thus facilitating increased vertical transport of the phages, the interaction was minimal on Site B owing to the absence of any biomat or significant level of organic matter. Subsequent attenuation of the phages over the remaining 0.6m resulted in all three achieving greater than 99.5% removal with ΦX174 marginally the most efficient at 99.9%. Despite the high removal rates it was noted that MS2 was detected at a concentration of 50 PFU mL^{-1} at one of the black plane lysimeters on day 1 of the trial while PR772, at 30 PFU mL^{-1}, was picked up at the same sample point a day later. With chemical analysis appearing to rule out any preferential flow, the short-term trial at least raises the issue of potential viral contamination of groundwater from on-site wastewater treatment in highly permeable subsoils. A more detailed and comprehensive study over a longer period of time is required to further elucidate the physical and chemical properties governing viral fate and transport in the vadose zone.

Nevertheless, taking all this into account it appears the new amendment in the Code of Practice (EPA, 2008b) of increasing the unsaturated subsoil depth from 0.6 m to 0.9 m under percolation areas receiving SE, whilst being a positive step, may still underestimate bacterial and viral migration in those sites with particularly permeable subsoil conditions (i.e. high T-values). As such, from the research carried out in this project, it may be advisable that in cases where the T-value falls between 3 and 5, an unsaturated subsoil depth of 1.2 m be made compulsory to reduce the risk of

microbial contamination of groundwater. In addition, it is clear from the relationship between the T-value and the field saturated hydraulic conductivity (k_{fs}) (Eqn. 4.1) that any minor change in value of the former at the low end of the scale (i.e. $1 < T < 5$) has a significant effect on the value of the latter. For example, a change in T-value from 3 to 2 will increase the k_{fs} to a much greater extent than if the T-value was altered from 45 to 44. The risk to groundwater contamination is therefore more substantial and unpredictable when dealing with differences in T-values at the low range of the spectrum. Given that this project raises a number of key issues regarding treatment performance, most notably the levels of contamination recorded in sites with T-values of 3.7 and 4.5 only, it is suggested that the minimum acceptable subsoil T-value for approval for an on-site wastewater treatment system be raised from $T = 1$ to $T = 3$.

9.4 Comparison of Horizontal SSF Reed Bed Treatment Systems

9.4.1 Flow Characteristics & Water Balance

In order to carry out an accurate water balance across each of the horizontal SSF reed beds, seasonally varying crop coefficients (K_c) were established in order to calculate the reed bed evapotranspiration (ET_{reed}). Trials on the secondary treatment reed bed during the growth season revealed that a crop coefficient of 1.21 was a suitable value during the summer months. ET_{reed} values decreased from 1.16 mm d^{-1} in the first year of analysis to 0.87 mm d^{-1} in the second year with seasonal variations also recognised and taken into account with regards to treatment processes. Similar crop coefficient trials were carried out on the tertiary treatment horizontal SSF bed on Site B which yielded a maximum crop coefficient of 0.7 during the summer months. When compared to Site A, this lower coefficient can be explained by the reduced evaporative surface area of the bed on Site B per unit flow. As on Site A, the effects of seasonality are clear with summer ET_{reed} rates averaging 1.37 mm d^{-1} in contrast to 0.03 mm d^{-1} across cooler winter months.

The mean flow from the secondary treatment reed bed to the percolation trenches on Site A was found to be 349.9 L d^{-1}, slightly greater than the mean flow to the reed bed of 327.3 L d^{-1} over the trial period. As such, the installation of the wetland did not make a significant difference to the flows going to the percolation trenches, acting to

increase flows by 6.4%, on average, in winter and by 0.5% in summer. A similar trend was found from the tertiary treatment reed bed with the mean discharging outflow, measured at 149.2 L d^{-1}, just above the mean inflow of 136.9 L d^{-1} recorded over the monitoring period. This comprised of an increase in mean flows by 7.2% during the winter season and by 1.7% in summer.

Along with the obvious distinction in treatment level of the wastewater being purified by each reed bed (secondary and tertiary) the other greatest disparity is in the HLR, with the bed on Site B receiving, on average, nearly twice the daily flow per unit surface area compared to that of Site A reed bed. In comparing the respective HLRs to design values recommended in EPA (2000), shown in Table 9.6, it can be seen that both the secondary and tertiary treatment reed beds were significantly over-designed (with respect to the guidelines) owing to the lower than anticipated on-site hydraulic loads, as outlined in Section 9.2.1.

Table 9.6 Hydraulic loading characteristics from both horizontal SSF reed beds

Site ID	Treatment Level	Influent Type	Area (m^2)	Mean HLR (mm d^{-1})	EPA (2000) Design HLR (mm d^{-1})
Site A	Secondary	STE	15	21.8	36
Site B	Tertiary	SE	4	34.2	90

9.4.2 Hydraulic Retention Times

Tracer studies on the reed beds using the chemical Rhodamine WT (20% w/v solution) showed that the hydraulic behaviour of the systems were satisfactory with measured (actual) retention times (HRTs) comparing favorably to theoretical (nominal) retention times (nHRTs). The mean HRTs for the secondary and tertiary treatment beds were calculated as 6.8 days and 5.0 days, respectively. Recovery of RWT, however, was poor, ranging from a minimum 25% in the secondary treatment bed to 68% in the tertiary bed, which is most likely as a result of irreversible adsorption to the beds' organic matter, already documented in other similar tracer studies. Multivirus injection trials, using surrogate phages ΦX174, MS2 and PR772,

were carried out on each of the reed beds in parallel with the RWT experiment with results largely corroborating that of the chemical tracer. ΦX174, MS2 and PR772 showed peak breakthrough times of 7.3, 6.0 and 7.0 days in the secondary treatment bed, respectively. Much improved recovery was recorded for two of the phages, however, with ΦX174 showing 96% recovery and MS2 showing 74.8% recovery. This suggests that both biotracers may be better suited than the commonly used chemical tracers to the quantitive description of water transit and dispersion within horizontal SSF reed beds.

In terms of percentage recovery, bacteriophages ΦX174 (96%) and MS2 (74.8%) were found to be superior to the chemical tracer RWT (25%) and the PR772 phage (10.6%) in the reed bed treatment of STE. All three phages showed greater recovery than RWT (< 68%) at the tertiary treatment reed bed outlet in the treatment of SE, with the reduced organic content thought to play a role in greater PR772 resistance. In this respect the research has highlighted the use of a number of biological tracers as a practical, accurate and environmentally acceptable substitute to alternative chemical agents. Nevertheless it is recognised that enumeration of phage tracers is more expensive compared to traditional chemical tracer methods.

9.4.3 Pollutant Removal

Treatment provided by the secondary treatment reed bed resulted in a mean 67% reduction in COD load and 68% reduction in BOD_5 load from the applied STE. Equivalent analysis on the tertiary treatment bed showed 55% reduction in COD load and 90% reduction in BOD_5 load from the applied SE. While Mediterranean and sub-tropical climates have shown that seasonal effects play a significant role in organic removal, the temperate climate of Ireland appears not to play a major role in the kinetics of the system, at least during its early years of operation (Table 9.7). Temporal analysis of both beds since system start-up indicated, however, a gradual improvement in treatment performance over time with respect to organic matter removal. This was most likely owing to an initial adaptation period giving way to an increased level of removal efficiency as the hydraulic patterns and reed growth emerge and develop over time.

Table 9.7 Seasonal COD load removal (%) across both horizontal SSF reed beds

		COD Load Removal (± sd) (%)				
Site	**Treatment**	**Year 1**		**Year 2**		**Year 3**
ID	**Level**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
Site A	Secondary	50 (± 8)	62 (± 20)	68 (± 25)	69 (± 21)	75 (± 12)
Site B	Tertiary	18 (± 4)	56 (± 25)	67 (± 19)	57 (± 17)	64 (± 12)

While statistical analysis revealed a significantly positive linear correlation between influent and effluent COD loads for both beds, analysis of intermediate sampling points at the middle of each bed showed that the large majority of, if not all, organic decomposition had been carried out in the first half of the bed. As such, the beds were oversized with respect to organic removal, the main parameter upon which a reed bed system is usually designed.

Nitrogen removal, as expected, was found to be poor across both reed beds, with only 29% removal of TN across the secondary treatment bed on Site A and 41% removal across the tertiary treatment bed on Site B. While NH_4-N accounted for the highest percentage contribution to TN concentrations in the secondary treatment bed (owing to mineralisation processes in the anaerobic septic tank), the *Biodisc*® on Site B facilitated partial nitrification of the effluent and thus increased the NO_x-N fraction in the tertiary treatment reed bed. Removal of TN in the secondary treatment reed bed (Site A) most likely occurred as a result of localised nitrification of NH_4-N in micro zones adjacent to the roots and rhizomes of the bed which subsequently denitrified along its passage to the outlet as a result of the bed's prevailing anoxic conditions. Following a ^{15}N stable isotope tracer study on the reed bed of Site A to examine the fate and transformation(s) in nitrogen species, and in line with the results from the chemical analysis, it was deciphered that nitrogen kinetics were dominated by continuous plant litter decomposition and mineralisation processes converting stored org-N to NH_4-N indefinitely, creating a 'spiralling' effect. With a greater spread of inorganic-N constituents in the influent nitrogen load of the tertiary treatment reed bed, there was an increased potential for removal via denitrification. Nutrient

removal, and denitrification in particular, are key processes required within a tertiary treatment system prior to groundwater recharge. A combination of chemical and ^{15}N stable isotope analysis suggested, however, that only limited denitrification of the oxidised forms of N (NO_3-N and NO_2-N) was occurring in the anoxic environment of the bed contributing to a percentage of the TN removal while NH_4-N and org-N (comprising 26% of the total TN influent concentration), in contrast, were merely changing form on a cyclic basis through processes such as mineralisation, immobilisation and plant uptake.

Effluent NH_4-N concentrations were shown to sometimes exceed that recorded in the influent of each of the two reed beds, i.e. negative removal, which was thought to be as a result of the complexities attached to nitrogen detention times in wetlands. No discernible pattern was noticed with regard to seasonal removal of TN in the reed beds (Table 9.8). The performance of the secondary treatment bed appeared to show a decline since its first year of operation which may have been due to continuous accumulation of organic chemicals and solids in the root-zone culminating in oxygen deficient areas unsuitable for nitrification (and subsequently denitrification) of the effluent.

Table 9.8 Seasonal TN load removal (%) across both horizontal SSF reed beds

		TN Load Removal (± sd) (%)				
Site	**Treatment**	**Year 1**		**Year 2**		**Year 3**
ID	**Level**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
Site A	Secondary	50 (± 4)	42 (± 22)	19 (± 8)	39 (± 18)	11 (± 22)
Site B	Tertiary	30 (± 0)	-21 (± 157)	19 (± 66)	23 (± 34)	55 (± 13)

Removal of phosphorus, in its soluble PO_4-P form, in the secondary treatment bed was found to be, on average, 45.1%. This was more than double the removal achieved across the tertiary treatment bed (22%) whose poor performance may be attributed to a combination of reduced surface area for adsorption (less than one third the size of secondary treatment bed) and a greater mean HLR. Given that the pea gravel media used in both reed beds were devoid of suitable minerals for precipitation, it is thought

plant uptake, adsorption and microbial immobilisation were the three principal mechanisms of PO_4-P removal.

Seasonal breakdown of PO_4-P in the secondary treatment bed of Site A showed removal rates to remain relatively stable over both the growing and dormant months. This highlighted the little phosphorus being taken up by the macrophytes, a finding that was latter corroborated and quantified in a P-uptake study on the plants. While at their maximum growth in the third year of operation, the total phosphorus in the stems and roots of the *Phragmites australis* equated to only 10% of the total P removed over the duration of the bed's operation. In the tertiary treatment bed of Site B, more seasonal variability was recorded with intermittent negative removal found during winter periods. This was somewhat more reflected in the P-uptake study for this bed with the roots and stems of the *typha* and *iris* containing phosphorus which accounted for 31% of the overall mass removed.

Table 9.9 Seasonal PO_4-P load removal (%) across both horizontal SSF reed beds

		PO_4-P Load Removal (± sd) (%)				
Site	**Treatment**	**Year 1**		**Year 2**		**Year 3**
ID	**Level**	**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
Site A	Secondary	61 (± 20)	43 (± 29)	43 (± 29)	40 (± 4)	35 (± 6)
Site B	Tertiary	20 (± 27)	-16 (± 64)	50 (± 34)	26 (± 40)	45 (± 32)

In addition, after almost three years in operation it was observed that the P-adsorption capacity of the media on each bed had not been expended. The effluent PO_4-P concentrations from the tertiary treatment bed were still, however, extremely high at an average level of 23.1 mg L^{-1} and would require further polishing by subsoil treatment or other means prior to groundwater discharge. This is an important point given that wetlands in general are often cited as useful nutrient removal systems in situations where strict P discharge consents are required.

With regards to the fate of the selected EDCs, results showed minimal removal of oestrogens, bisphenol A and caffeine in the anaerobic environment of the reed beds. This corroborates with similar research which report aerobic degradation as the

dominant removal mechanism despite the many organic particle sites potentially available for sorption in the beds.

Bacteriological analysis of the secondary treatment reed bed showed similar mean removal rates for TC and *E. coli* at 1.8 log-units (98.5%) and 1.4 log-units (96%), respectively. Results were found to be similar in the tertiary treatment bed but showing mean removal in *E. coli* (1.6 log-units or 97.7%) to be slightly greater than for TC (1.3 log-units or 94.6%). Despite such high removal, it is clear that a significant number of coliforms ranging from 3×10^3 - 2×10^6 MPN 100 mL^{-1} were discharging from the tertiary effluent. Further analysis with the aid of intermediate sampling points confirmed that removal of coliform removal across both beds was exponential in nature with a much greater decrease in the first half of the bed lengths.

Recovery of bacteriophages ΦX174 and MS2 in both the secondary and tertiary treatment reed beds was shown to be high, as detailed in Section 9.4.2, indicating their potential suitability as viral indicators in SSF reed bed treatment systems and highlighting the poor capacity of reed beds to successfully remove viral micro organisms. Sorption is thought to be the most important process controlling the movement of the phages in the wetlands given that the brief nature of the injection trials would render viral inactivation to be an unlikely event. The increased recovery of the two phages in the secondary bed compared to the tertiary treatment bed was again most likely related to the greater organic matter content in the former, inhibiting virus sorption by blocking or impeding the pathways to sorption sites. PR772 displayed a much more contrasting trend in both reed beds with the high removal rate of the phage in the secondary treatment bed possibly owing to hydrophobic interactions with the abundant organic matter present, causing increased attachment. The larger diametric size of PR772 to the other tested phages would also have made this hydrophobic effect more pronounced.

9.5 Construction of On-Site Systems

The construction of three separate percolation areas and two horizontal SSF reed beds for the project provided an interesting exposure to the existing practice of on-site installation amongst practitioners in Ireland and also the practicality of using the EPA

guidelines (EPA, 2000). It seems to be common practice for builders to divert at least some storm water drains into the septic tank, presumably because this saves on the expense and time involved in laying extra pipework. Although this did not affect the hydraulic loading rates on the sites chosen for this project owing to diversion works carried out prior to system installation, the practice would probably be much more acute in the normal situation where builders are effectively unsupervised.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

On-Site Wastewater Production and Characteristics

(i) ***Hydraulic and Organic Loading***

- Continuous flow measurement on both sites revealed that the daily per capita wastewater generation assumption of 180 L c^{-1} d^{-1} in the Irish EPA guidelines (EPA, 2000) significantly over-predicts the average wastewater production in such one-off dwellings with typical sized family units. Therefore based on the EPA recommended hydraulic loading rates for STE and SE (EPA, 2000), it would be possible to reduce the size of the percolation areas.
- On the percolation trenches treating STE, it was estimated that 50% (or 30 m) of percolation trench had not been utilised after 32-months of system operation. On the trenches receiving secondary effluent from the reed bed (RBE), only 41% (or 19.5 m) of trench length was utilised over the same period of operation. Most significant, perhaps, was the little biomat development, approximated to be 1 m in total, on the percolation trenches receiving secondary effluent from the *Biodisc*® RBC plant. This concurred with findings from the literature which emphasised that as soil clogging is a function of the organic and solids loading from the effluent, biomat formation will be retarded or absent in subsoils receiving highly treated effluent, as the concentration of organic chemicals will be low.
- The biomat lengths for all trenches were quickly established during the first few months of receiving effluent, after which point they appeared to reach a state of equilibrium.
- The high HLR (greater than seven times the design LTAR) on the trenches receiving SE from the *Biodisc*® RBC plant, coupled with the compromise in treatment experienced in the freely draining subsoil, would indicate greater regulation of the feed (via pressurised dosing system etc.) is required in such instances.

(ii) ***Wastewater Characteristics – Proprietary Treatment Systems***

- The measured STE quality was found to be marginally worse in terms of organic chemical and nutrient level when compared to the CEN 12566 European standards (Part 6) (CEN, 2005c) which specify the influent characteristics required for testing prefabricated small wastewater treatment systems receiving STE. Similar standard STE was reported in previous research in Ireland by O'Súilleabháin (2004) suggesting Irish STE to be more concentrated than European standards.
- There appeared seasonal trends in the COD and PO_4-P concentrations from the septic tank which may have been due to temperature changes, with the warmer periods in the summer promoting faster anaerobic activity in the tank and the production of soluble products.
- Concentrations of oestrogens and bisphenol A from the septic tank were found to concur well with other literature studies. The effect of aerobic secondary treatment on caffeine degradation was clearly seen in the difference in levels recorded between the STE and the SE (of 3 orders of magnitude).

Attenuation of Domestic Wastewater Effluent in Highly Permeable Subsoil

(i) ***Attenuation of Chemical Constituents of Effluent***

- The majority of the treatment (including nitrification) of the percolating effluent took place in the distribution gravel and first 0.35 m of subsoil.
- Little denitrification was recorded with depth in the vadose zone of the three percolation areas owing to a combination of retarded biofilm development, insufficient carbon levels and high subsoil permeability.
- Total Inorganic-N load per capita recorded at the current minimum discharge points to groundwater for STE and SE (EPA, 2000) were found to be greater for the systems with alternative secondary treatment systems installed.
- NO_3-N concentrations were seen to rise rapidly between the groundwater sampling points upstream and downstream of the on-site wastewater treatment system.
- Almost complete adsorption of PO_4-P occurred between the infiltrative surface and the minimum discharge points to groundwater for STE and SE (EPA, 2000).

- The set of oestrogens, with the exception of oestriol, were found to break down substantially in the subsoil environment to minimal levels. Bisphenol A was shown to resist significant degradation in the aerobic environment of the subsoil.

(ii) ***Attenuation of Microbiological Constituents of Effluent***

- The installation of the *Biodisc*® RBC plant greatly reduced bacterial loading on the subsequent percolation area with average concentrations of *E. coli* approximately 2 log-units smaller than that recorded in the STE.
- The greatest reduction in both coliform and bacteriophage concentrations in the subsoil occurred in the first 0.35 m of subsoil on both sites.
- More evidence of faecal contamination occurred at depth on the percolation area receiving SE than that receiving STE, despite the lower bacterial influent load - 13% of samples measured for *E.coli* at a depth of 0.95 m under the percolation trenches receiving SE showed significant levels of contamination.
- All three bacteriophages were reduced to their minimum detection limit (< 99.6% removal) at a depth of 0.95 m below the percolation trenches receiving STE. Isolated incidences of MS2 and PR772 contamination were detected at the same depth under the trenches receiving SE.

Attenuation of Domestic Wastewater Effluent in Horizontal SSF Reed Beds

(i) ***Flow Characteristics and Water Balance***

- The mean flow from both reed beds was found to be only slightly greater than the mean flow to each bed.
- Both reed beds were significantly over-designed (with respect EPA guidelines) owing to the lower than anticipated on-site hydraulic loads.
- Tracer studies using Rhodamine WT and a number of bacteriophages showed that the hydraulic behaviour of both reed bed systems were satisfactory. ΦX174 and MS2 were shown to be particularly suitable wetland biotracers showing the greatest recovery levels of 96% and 75%, respectively.

(i) ***Attenuation of Chemical Constituents of Effluent***

- A 67% reduction in COD was measured across the secondary treatment reed bed with a gradual improvement in treatment performance with respect to organic matter removal noted over time.
- Unlike studies carried out in Mediterranean and sub-tropical climates, the temperate climate of Ireland appears not to play any significant role in the kinetics of reed bed treatment systems, at least during their early years of operation.
- Nitrogen kinetics in the beds were dominated by continuous plant litter decomposition and mineralisation processes converting stored org-N to NH_4-N indefinitely, creating a 'spiralling' effect.
- Limited denitrification of the oxidised forms of N was seen to occur in the anoxic environment of the tertiary treatment bed
- Phosphorus uptake by the macrophytes plants was found to be nominal when compared to the total-P removed over the duration of the beds' operation.
- Whilst the P-adsorption capacity of the reed bed media had shown no signs of exhausting after three years of operation, average discharge levels from the tertiary treatment bed were extremely high at 23 mg L^{-1}.
- Minimal removal of oestrogens, bisphenol A and caffeine occurred in the anaerobic environment of the reed beds.
- With respect to contaminant concentrations recorded at the minimum points of discharge to groundwater in the subsoils under review, no appreciable benefit appears to be gained by the installation of a secondary treatment reed bed prior to subsoil polishing when compared to the findings from the parallel conventional septic tank system under investigation

(ii) ***Attenuation of Microbiological Constituents of Effluent***

- Removal rates for TC and *E. coli* across both beds was found to be between 1.3 and 1.8 log-units (94.6% and 98.5%), respectively.

10.2 Recommendations for Further Research

- Further research should be carried out on the fate of bacteriophages in relatively fast percolating subsoil. The trials should dose the phages into the effluent over a longer period of time and also monitor for natural viruses in parallel to the tracer phages.

- Different means of distribution for secondary treated effluent should be investigated in order to spread the load over a wider area. For example, the effluent could be split between more numerous shorter trenches or pumped into a dispersed area by low pressure drip irrigation. Discharging the effluent into the root zone could also be investigated in order to reduce the nutrient loads on groundwater.

- The long term sustainability of gravity distribution devices vs pumped / drip systems in receiving both septic tank and secondary treated effluent could also be evaluated.

- Similar trials should be carried out on subsoil with very high permeability characteristics (T ~ 1) to compare against these results and define the lowest acceptable T-value for discharge of on-site effluent.

- A long-term study on hybrid reed bed systems should be carried out to assess their performance in treating on-site effluent (particularly with respect to nutrient removal).

- This study has shown the use of ^{15}N isotope to be promising in evaluating nitrogen removal mechanisms through reed beds. Longer term, more rigorous trials should be carried out on different types and configuration of reed beds (surface flow, subsurface flow and hybrid systems) to gain more understanding of these complex pathways.

- The long term phosphorus removal performance of horizontal subsurface flow reed beds should be investigated by monitoring sites for a minimum of 10 years. This will enable the degree of phosphorus storage and saturation to be realistically determined in such systems and provide invaluable information for the future maintenance and / or retrofit options in the future.

- A long term (> 10 years) instrumented site for a percolation area receiving both septic tank and secondary effluent should be set up to assess the effect of the development of the biomat over a period of years and long term pollutant removal.

- Evapotranspiration systems should also be assessed for their suitability as zero-discharge processes for areas with low permeability subsoil. The proposed specification of a lower limit to subsoil permeability (set at T = 90) has caused concern among some Local Authorities, particularly those in counties that have extensive coverage of low permeability clays, as effluent will not be allowed to discharge to ground on such sites. As surface water discharges are generally not licensed by the Local Authorities a potential solution in such areas is to use evapotranspiration systems - often termed willow treatment systems. These have received relatively little research compared to reed bed systems and there has been no published studies relating to the Irish climate.

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Appendix A

On-Site Assessment Forms, Particle Size Distribution and X-Ray Diffraction Analysis

SITE CHARACTERISATION : SITE A

1.0 GENERAL DETAILS

NAME & ADDRESS OF APPLICANT:	Vincent Loftus				
SITE LOCATION AND TOWNLAND:	Clonard, Co. Kildare				
TELEPHONE NO:	N/A	**FAX NO:**	N/A	**EMAIL:**	**N/A**
MAXIMUM NO. OF RESIDENTS:	6	**NO. OF DOUBLE BEDROOMS:**		**NO. OF SINGLE BEDROOMS:**	
PROPOSED WATER SUPPLY:	**Mains** X	**private well/borehole**		**group well/borehole**	

2.0 DESK STUDY

Soil type	Gley	**Other (specify)**	**AQUIFER CATEGORY**	**Regionally Important**	**Locally Important** Lg/H –Locally Important Sand/Gravel Aquifer	**Poor**
Is there a Groundwater Protection Scheme (Y/N):	Y		**Groundwater Protection Response: R1, R2[1], R2[2], R2[3], R2[4], R3[1], R3[2]**		R1 (Table 2.1)	
Presence of significant sites (archaeological, natural & historical):	N/A					
Past experience in the area:	Sand/Gravel Pits nearby – good indicator					

3.0 ON-SITE ASSESSMENT

3.1 Visual Assessment

LANDSCAPE POSITION:	Gently Sloping Site	**SLOPE:**	STEEP (>1:5)	SHALLOW (1:5-1:20) X	RELATIVELY FLAT (<1:20)
SURFACE FEATURES					
HOUSES:	No housing within 200m – farm approx. 300m North				
SITE BOUNDARIES:	Grazing fields for horses				
ROADS:	>100m from proposed site location				
EXISTING LAND USE:	Horse-grazing				
OUTCROPS (ROCK AND/OR SUBSOIL):	None				
SURFACE WATER PONDING:	Blockage in existing septic tank outlet pipe to soakaway – high degree of wet vegetation				
LAKES:	None				
WATERCOURSE/STREAM*:	None within 100m (River Boyne ~1km west)				
DRAINAGE DITCHES*:	Field used as a soakage pit d/s of septic tank – isolated area affected by this blockage in the system. No ditches				
WELLS*:	None				
SPRINGS*:	None				
TYPE OF VEGETATION:	Grass/Wet vegetation in vicinity of soakaway				
GROUND CONDITION:	Good firm ground				

3.2 Trial Hole

Depth of trial hole (m):	2.1m	**Date and time of**	28/07/05 10:00 hrs	**Date and time of**	29/07/05 13:00 hrs
Depth from ground surface to bedrock (m) (if present):			>2.1m		
Depth from ground surface to water table (m) (if present):			>2.1m		

	Soil/Subsoil Texture & Classification**	**Soil Structure**	**Density/ Compactness**	**Colour *****	**Preferential flowpaths**
0.1m	Topsoil CLAY			Dark Brown	None Visible
0.2m					
0.3m	Sandy Gravelly CLAY (6 threads, ~110mm ribbon, not dilatant)		Firm & Compact	Mustard Brown	None Visible
0.4m					
0.5m	Sandy Gravelly SILT/CLAY (2 threads, ~95mm ribbon, very raspy, not dilatant)		Firm & Compact	Brown	None Visible
0.6m					
0.7m					
0.8m					
0.9m					
1.0m					
1.1m	Sandy Gravelly SILT (1 thread, ~95mm ribbon, very raspy, dilatant)		Compact	Light Brown	None Visible
1.2m					
1.3m					
1.4m					
1.5m					
1.6m					
1.7m					
1.8m					
1.9m					
2.0m					
2.1m	Sandy GRAVEL		Loose	Greyish Brown	None Visible
2.2m					

Depth of water ingress:	>2.1m	**Rock type**	N/A	**Plasticity and dilatancy results:**		**Likely T value:**	<5

3.3 (a) Percolation ("T") Test for Deep Subsoils and/or Water Table

Percolation Test Hole	1	2
Depth from ground surface to top of hole (mm) (A)	550	650
Depth from ground surface to base of hole (mm) (B)	950	1050
Depth of hole (mm) [B - A]	400	400
Dimensions of hole [length x breadth (mm)]	300 x 300	300 x 300

Each hole must be pre-soaked twice before the test is carried out (from 10.00 am to 5.00 pm and from 5.00 pm to next morning)

Date of test	29/7/05	31/7/05
Date pre-soaking started	28/07/05	28/07/05
Time filled to 400 mm	9:50	11:32
Time water level at 300 mm	9:59	11:40

Percolation Test Hole No.	**1**			**2**		
Fill no.	**Start Time (at 300 mm)**	**Finish Time (at 200 mm)**	**Δt (min)**	**Start Time (at 300 mm)**	**Finish Time (at 200 mm)**	**Δt (min)**
1	9:59	10:11	12	11:40	11:51	11
2	10:12	10:26	14	11:52	12:06	14
3	10:27	10:45	18	12:07	12:27	20
Average Δt			14.67	**Average Δt**		15
Average Δt/4 = 3.67 (t_1)				**Average Δt/4 = 3.75 (t_2)**		

T value* = $(t_1 + t_2)/2$ = 3.71 **(min/25 mm)**

Result of Test : T = 3.71 (< 5)

COMMENTS: Site suitable based on T-value

SITE CHARACTERISATION FORM : SITE B

1.0 GENERAL DETAILS

NAME & ADDRESS OF APPLICANT:		Andrew & Jackie Morris			
		Redcross Village, Co. Wicklow			
SITE LOCATION AND TOWNLAND:					
TELEPHONE NO:	N/A	**FAX NO:**	N/A	**EMAIL:**	N/A
MAXIMUM NO. OF RESIDENTS:	3	**NO. OF DOUBLE BEDROOMS:**	2	**NO. OF SINGLE BEDROOMS:**	1
PROPOSED WATER SUPPLY: (tick as appropriate)		**Mains** X	**private well/borehole**	**group well/borehole**	

2.0 DESK STUDY

Soil type	**Gley**	**AQUIFER CATEGORY**	**Regionally Important**	**Locally Important** LI	**Poor**
Is there a Groundwater Protection Scheme (Y/N):	Y	**Groundwater Protection Response: R1, R2[1], R2[2], R2[3], R2[4], R3[1], R3[2]**	LI / E = R2[1] (Table 2.1)		
Presence of significant sites (archaeological, natural & historical):	N/A				
Past experience in the area:	N/A				

3.0 ON-SITE ASSESSMENT

3.1 Visual Assessment

LANDSCAPE POSITION:	Low-end of rising mountain	**SLOPE:**	STEEP (>1:5)	SHALLOW (1:5-1:20) X	RELATIVELY FLAT (<1:20)

SURFACE FEATURES	
HOUSES:	New house currently under construction <20m – expected completion late 2006/early 2007. Location is upstream of treatment system
SITE BOUNDARIES:	Grazing fields North & East of garden. New house under construction to West of garden.
ROADS:	Road to Redcross Village >30m from treatment system and upstream
EXISTING LAND USE:	Garden - Grassed
OUTCROPS (ROCK AND/OR SUBSOIL):	None
SURFACE WATER PONDING:	None
LAKES:	None
WATERCOURSE/STREAM*:	Redcross River in north-east direction of garden (>100m)
DRAINAGE DITCHES*:	None
WELLS*:	None in operation
SPRINGS*:	None
TYPE OF VEGETATION:	Grass
GROUND CONDITION:	Dry, firm ground

COMMENTS: No immediate risk posed to surface water owing to absence of any ponding in vicinity during wet weather. Obvious target at risk is groundwater. May be limited with space regarding garden size.

3.2 Trial Hole

Depth of trial hole (m):	2.1m	**Date and time of excavation:**	4/09/05 15:00 hrs	**Date and time of examination:**	9/9/05 15:00 hrs
Depth from ground surface to bedrock (m) (if present):			>2.1		
Depth from ground surface to water table (m) (if present):			>2.1		

	Soil/Subsoil Texture & Classification**	**Soil Structure**	**Density/ Compactness**	**Colour**	**Preferential flowpaths**
0.1m	Topsoil CLAY		Uncompact	Brown	None Visible
0.2m					
0.3m					
0.4m					
0.5m	Sandy SILT (6/7 threads, 90mm ribbon - quite raspy)		Loose	Golden Brown	None Visible
0.6m					
0.7m					
0.8m	Sandy GRAVEL (0 threads, 0 ribbons – very raspy) Non - cohesive layer	Granular	Loose	Brown	None Visible
0.9m					
1.0m					
1.1m					
1.2m					
1.3m					
1.4m					
1.5m					
1.6m					
1.7m					
1.8m					
1.9m					
2.0m					
2.1m					

Depth of water ingress:	N/A	**Rock type (if present):**	N/A	**Plasticity and dilatancy results:**		**Likely T value:**	**< 5**

EVALUATION: No ingress of groundwater or presence of bedrock at 2.1m depth meets requirements. Soil appears loose and homogeneous between 0.8m and 2.1m with high sand and gravel composition – indicative of freely fraining percolating medium which may pose a risk to groundwater.

3.3 (a) Percolation ("T") Test for Deep Subsoils and/or Water Table

Percolation Test Hole	1	2
Depth from ground surface to top of hole (mm) (A)	650	550
Depth from ground surface to base of hole (mm) (B)	1050	950
Depth of hole (mm) [B - A]	400	400
Dimensions of hole [length x breadth (mm)]	300 x 300	300 x 300

Each hole must be pre-soaked twice before the test is carried out (from 10.00 am to 5.00 pm and from 5.00 pm to next morning)

Date of test	2/9/05	2/9/05
Date pre-soaking started	----	----
Time filled to 400 mm	11:44	12:28
Time water level at 300 mm	11:49	12:38

Percolation Test Hole No.	1			2		
Fill no.	Start Time (at 300 mm)	Finish Time (at 200 mm)	Δt (min)	Start Time (at 300 mm)	Finish Time (at 200 mm)	Δt (min)
1	11:49	11:56	7	12:38	12:56	18
2	11:56	12:04	8	13:01	13:31	30
3	12:05	12:14	9	13:34	14:09	35
Average Δt			8	Average Δt		27.67
Average Δt/4 = 2 (t_1)				Average Δt/4 = 6.91 (t_2)		

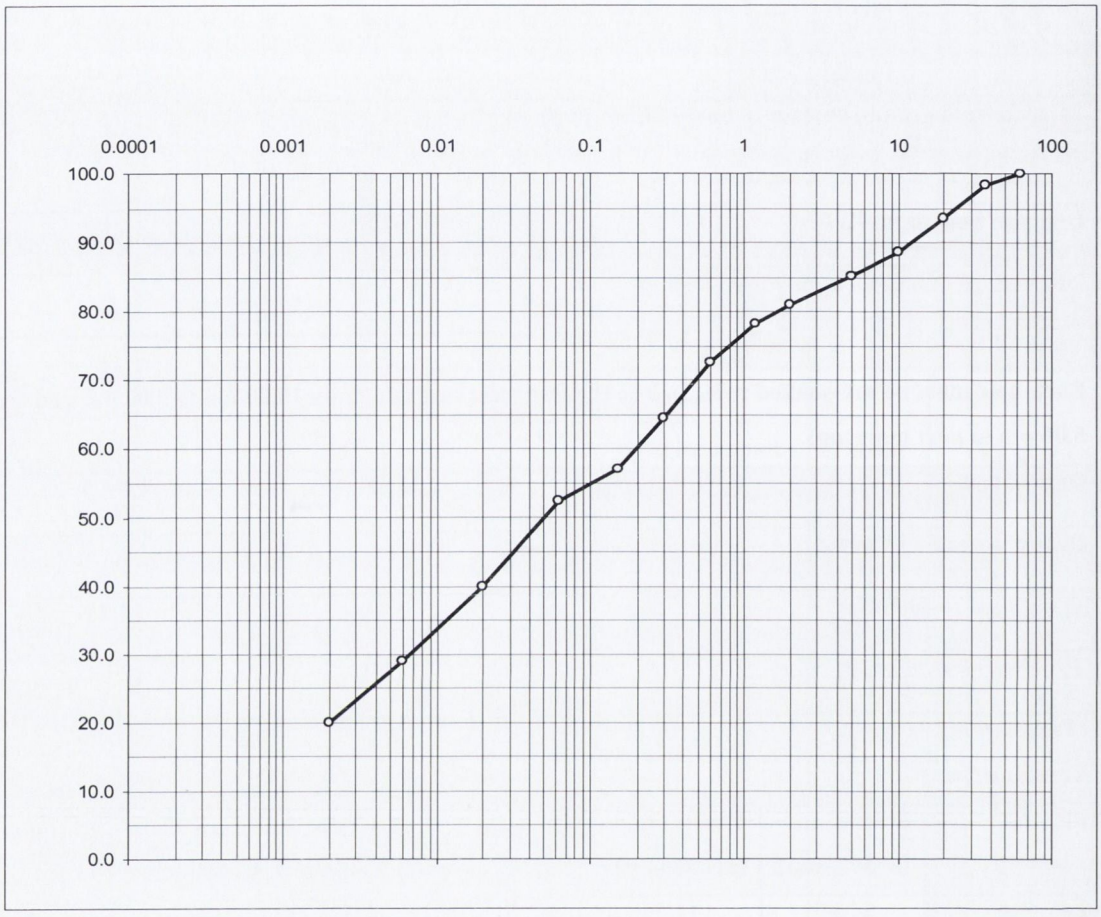
T value* = $(t_1 + t_2)/2$ = 4.45 **(min/25 mm)**

Result of Test : T = 4.45 (< 5)

COMMENTS: Site suitable based on T-value

PARTICLE SIZE DISTRIBUTION ANALYSIS – SITE A

1.0m Depth

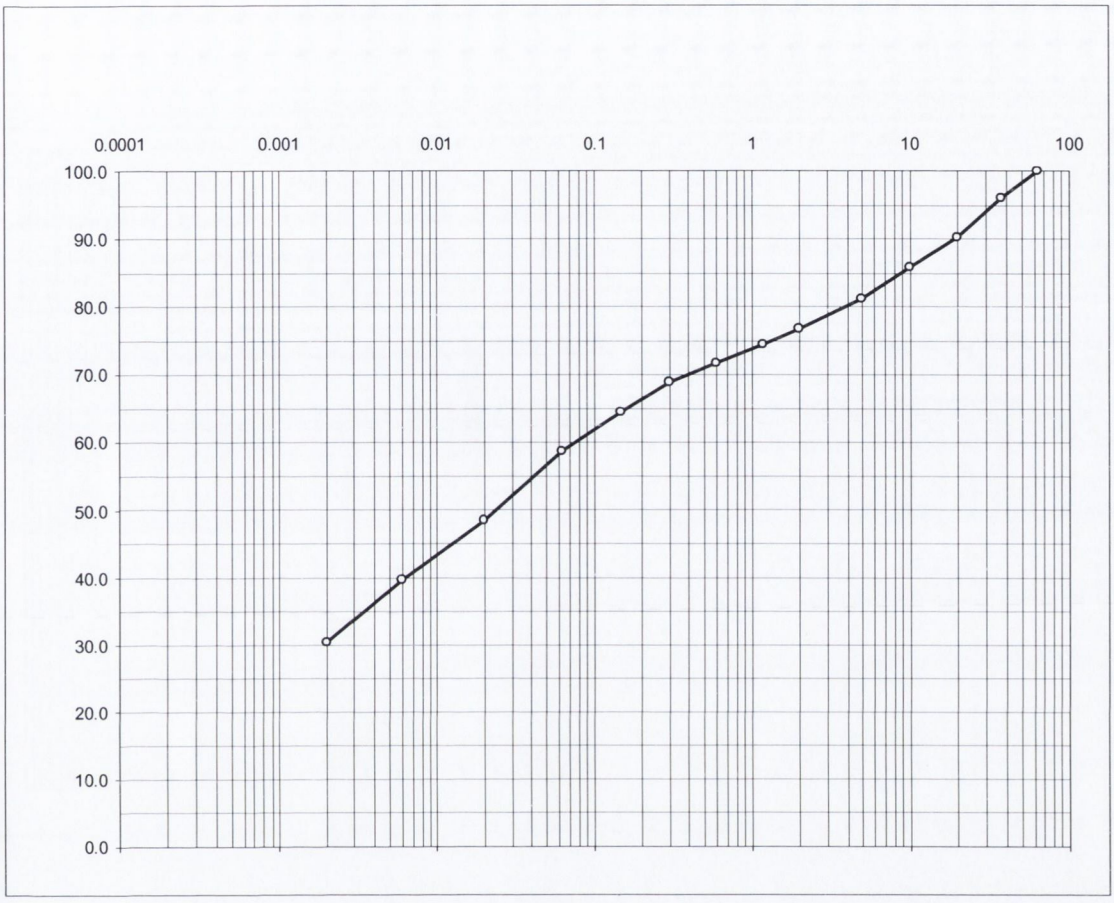


B.S. sieve size	% Passing
63	100.0
37.5	98.4
20	93.5
10	88.6
5	85.0
2	80.9
1.18	78.1
0.6	72.5
0.3	64.5
0.15	57.0
0.063	52.5
0.02	39.9
0.006	28.9
0.002	20.0

Soil Fraction	Total %
Gravel	19.1
Sand	28.4
Silt	32.5
Clay	20.0

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

1.5m Depth

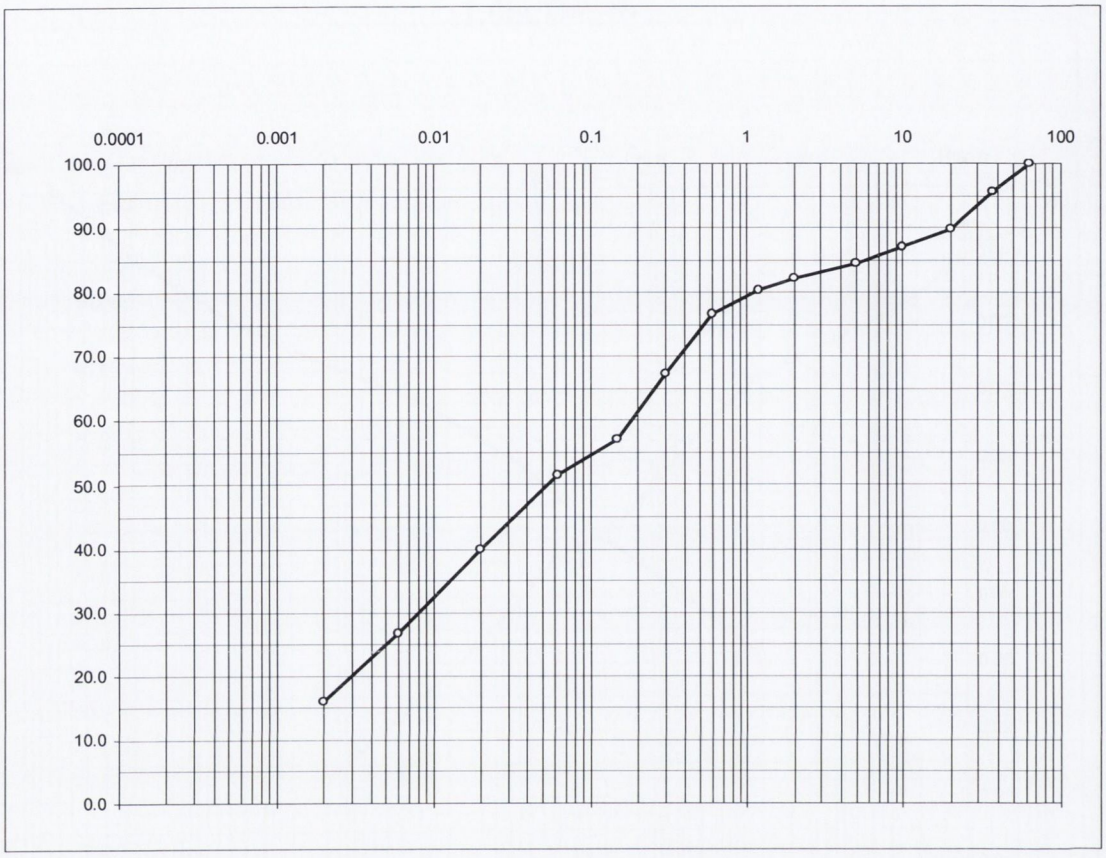


B.S. sieve size	% Passing
63	100.0
37.5	96.1
20	90.2
10	85.7
5	81.2
2	76.9
1.18	74.5
0.6	71.8
0.3	69.0
0.15	64.5
0.063	58.7
0.02	46.1
0.006	33.1
0.002	23.2

Soil Fraction	Total %
Gravel	23.1
Sand	18.2
Silt	35.5
Clay	23.2

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

2.0m Depth

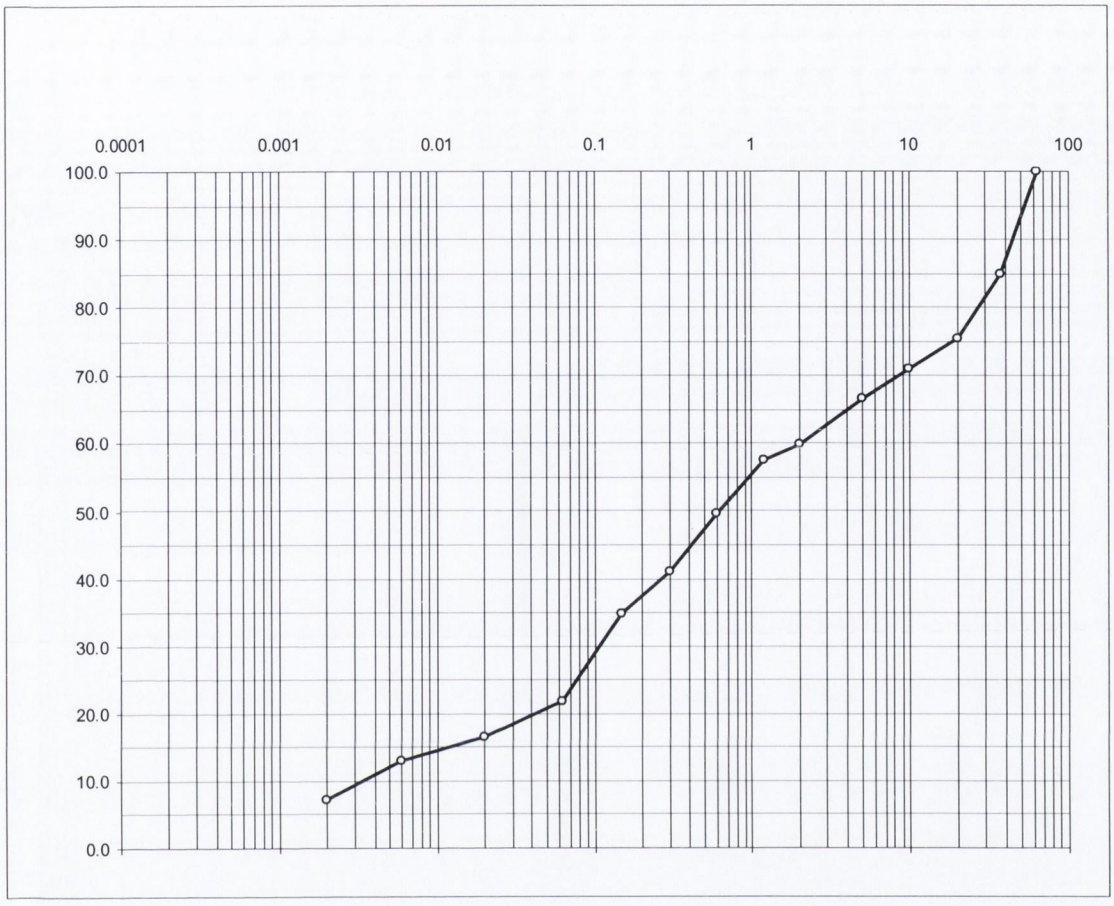


B.S. sieve size	% Passing
63	100.0
37.5	95.7
20	89.8
10	86.9
5	84.5
2	82.1
1.18	80.4
0.6	76.5
0.3	67.2
0.15	57.2
0.063	51.6
0.02	40.0
0.006	26.7
0.002	16.1

Soil Fraction	Total %
Gravel	17.9
Sand	30.5
Silt	35.5
Clay	16.1

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

2.1m Depth



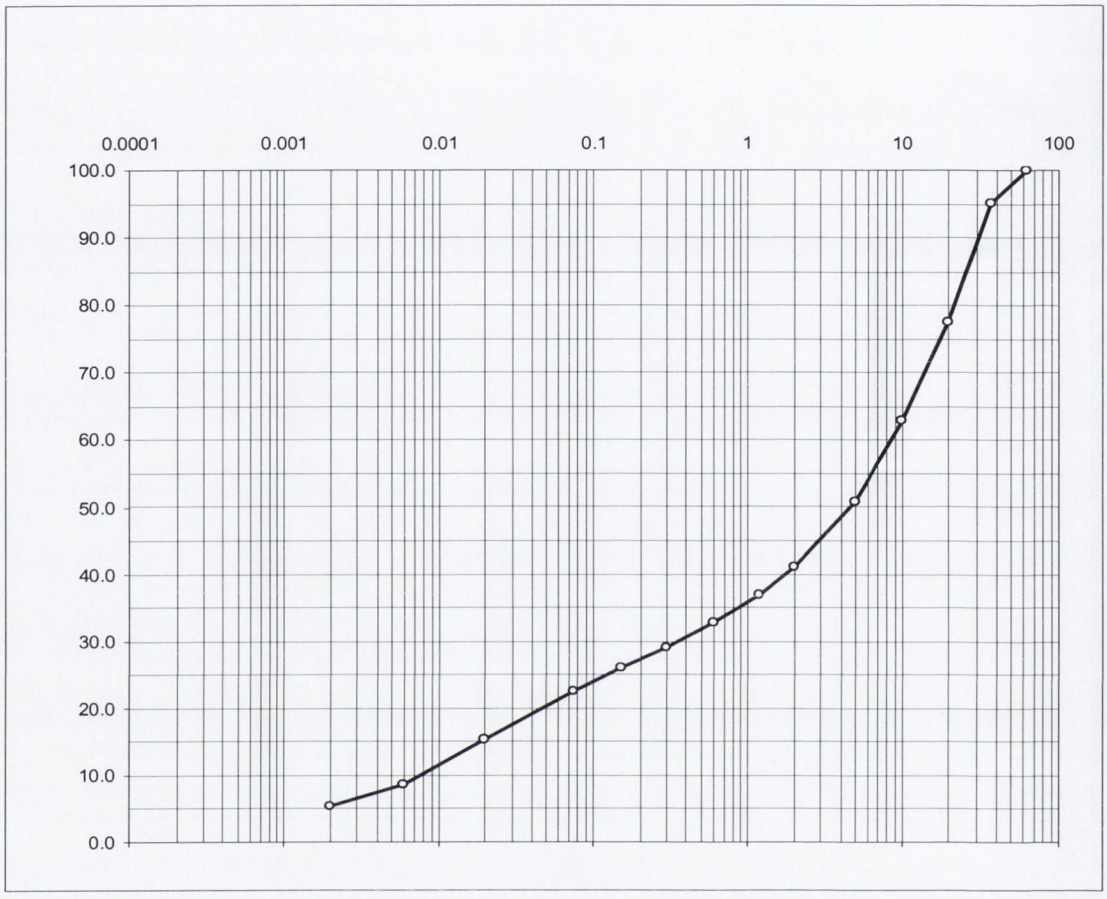
B.S. sieve size	% Passing
63	100.0
37.5	84.9
20	75.3
10	71.1
5	66.7
2	59.9
1.18	57.6
0.6	49.6
0.3	41.1
0.15	34.7
0.063	21.9
0.02	16.5
0.006	12.9
0.002	7.2

Soil Fraction	Total %
Gravel	40.1
Sand	38.0
Silt	14.7
Clay	7.2

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

PARTICLE SIZE DISTRIBUTION ANALYSIS – SITE B

0.5m Depth

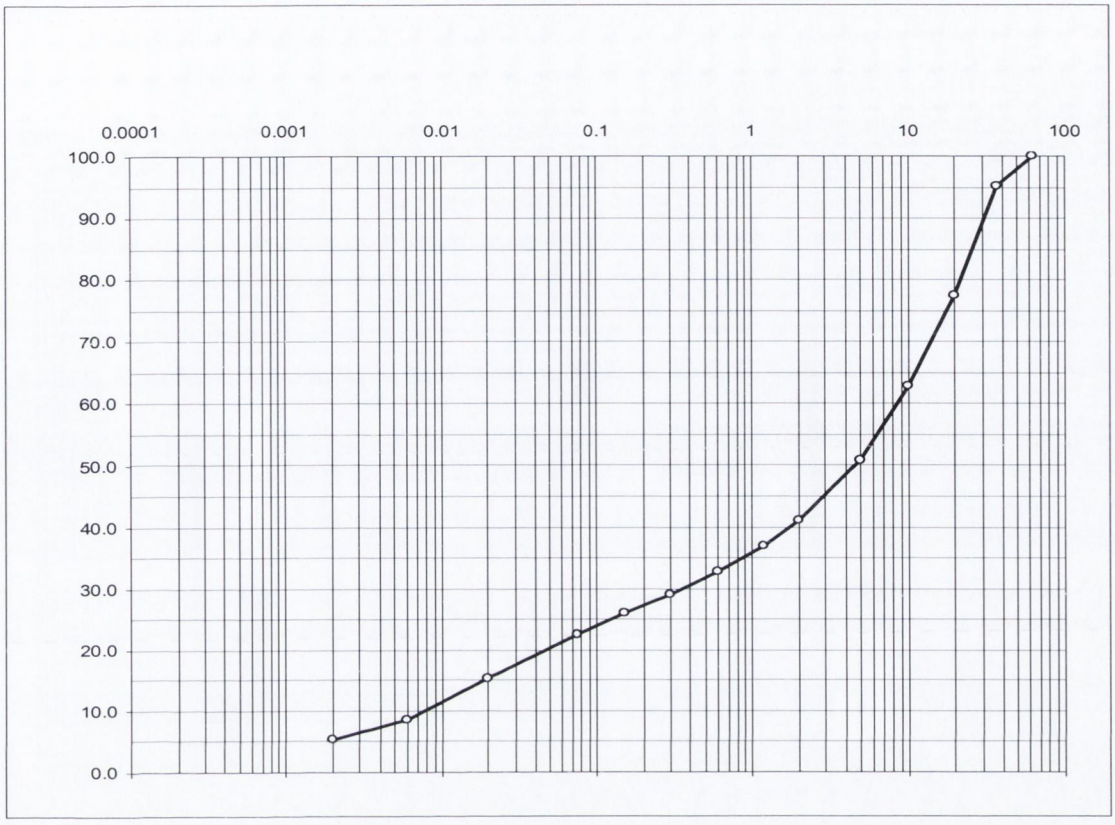


B.S. sieve size	% Passing
63	100.0
37.5	95.1
20	77.5
10	62.8
5	50.9
2	41.1
1.18	36.8
0.6	32.6
0.3	29.0
0.15	26.0
0.075	22.4
0.02	15.4
0.006	8.6
0.002	5.3

Soil Fraction	Total %
Gravel	58.9
Sand	18.7
Silt	17.1
Clay	5.3

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

1.0m Depth

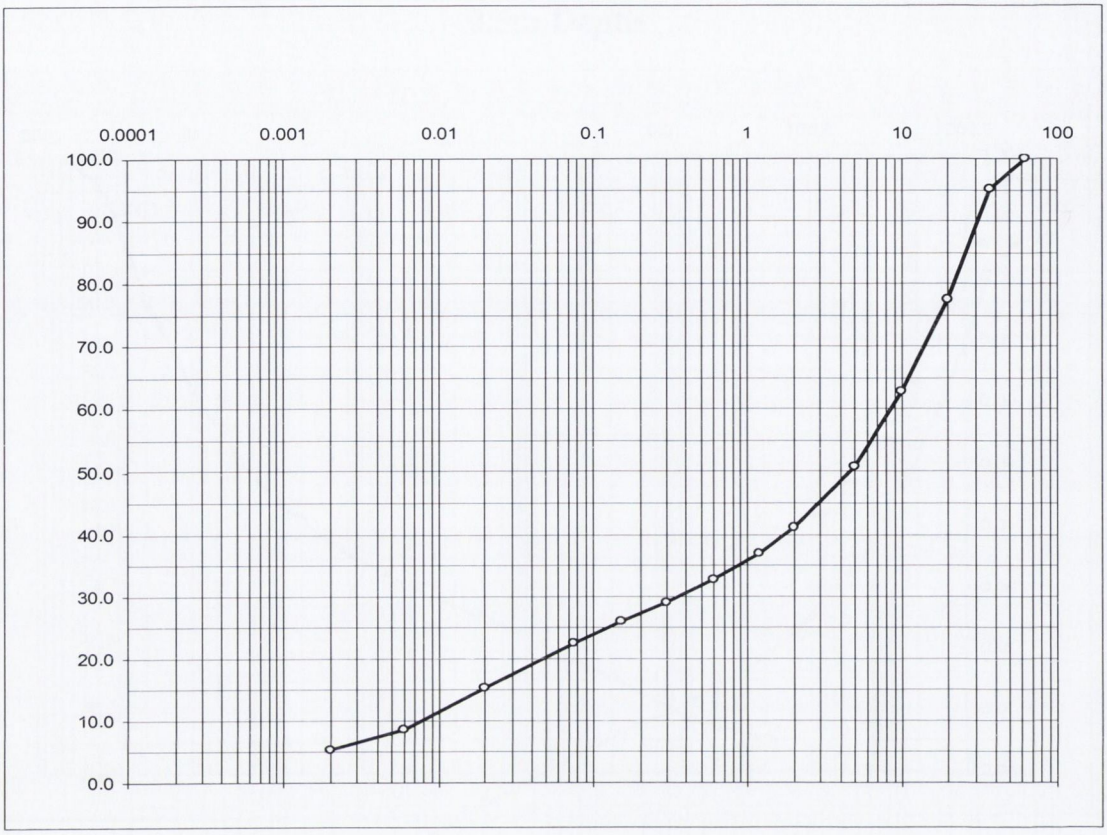


B.S. sieve size	% Passing
63	100.0
37.5	91.8
20	75.4
10	64.0
5	54.8
2	45.1
1.18	39.9
0.6	33.4
0.3	26.6
0.15	20.8
0.075	15.6
0.02	22.4
0.006	15.9
0.002	10.8

Soil Fraction		Total %
Gravel		45.2
Sand		34.0
Silt		10.0
Clay		10.8

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

1.5m Depth

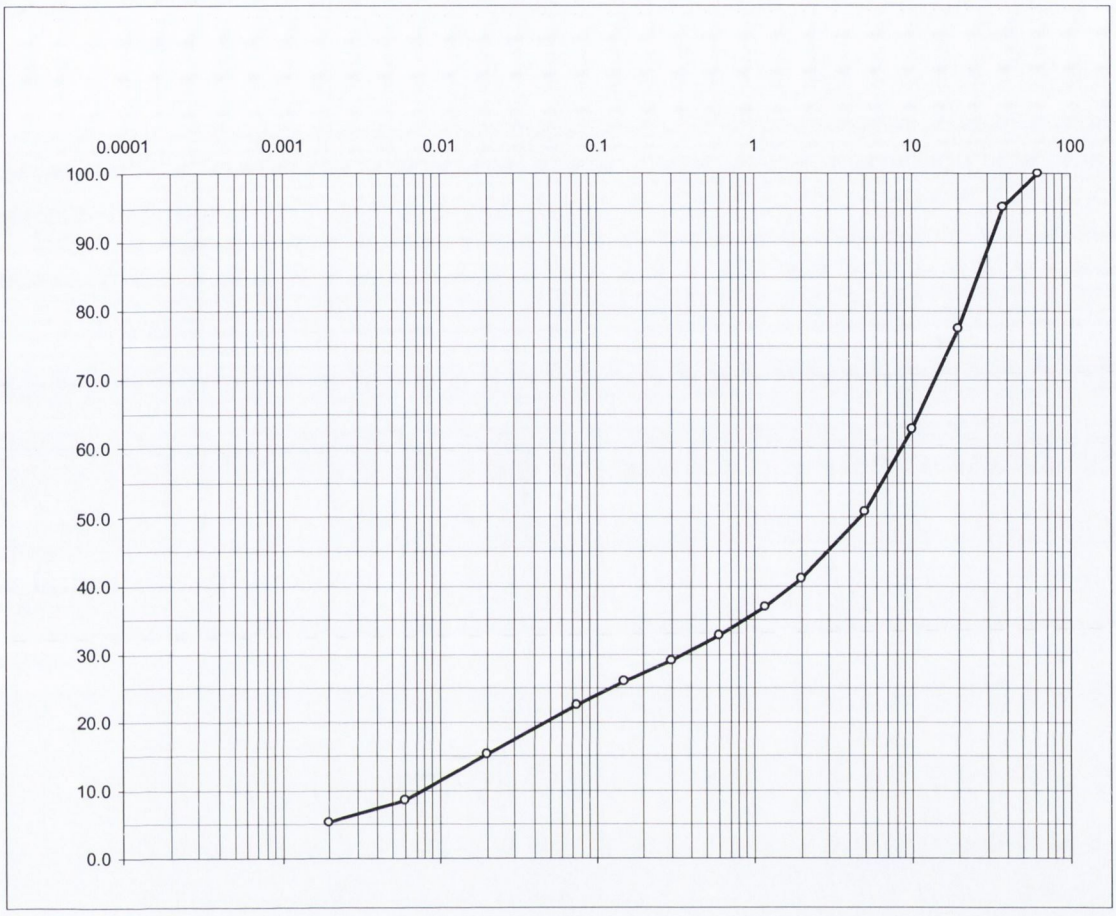


B.S. sieve size	% Passing
63	100.0
37.5	87.8
20	77.7
10	62.6
5	50.6
2	38.5
1.18	32.3
0.6	25.7
0.3	19.8
0.15	15.3
0.075	11.9
0.02	12.4
0.006	8.6
0.002	4.8

Soil Fraction	Total %
Gravel	61.5
Sand	26.6
Silt	7.1
Clay	4.8

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

2.0m Depth



B.S. sieve size	% Passing
63	100.0
37.5	94.6
20	78.8
10	68.8
5	59.5
2	45.3
1.18	37.8
0.6	28.9
0.3	20.6
0.15	13.6
0.063	8.0
0.02	24.3
0.006	18.9
0.002	14.7

Soil Fraction	Total %
Gravel	56.7
Sand	35.3
Silt	5.7
Clay	2.3

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

Department of Geology

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29th January 2008

XRD analysis of soils for Niall O'Luanaigh (Department of Civil, Structural & Environmental Engineering, TCD)

7 samples were supplied:

Lab Number	**I.D.**	
NOL01	Wicklow BLACK	1.9m below G.L.
NOL02	Wicklow BLUE	1.4m below G.L.
NOL03	Wicklow RED	1.1m below G.L.
NOL04	Wicklow	0.8m below G.L.
NOL05	Site A Kildare	TP: 1.5 – 2m
NOL06	Site A Kildare	TP: 1 – 1.5m
NOL07	Site A Kildare	TP: 0 – 1m

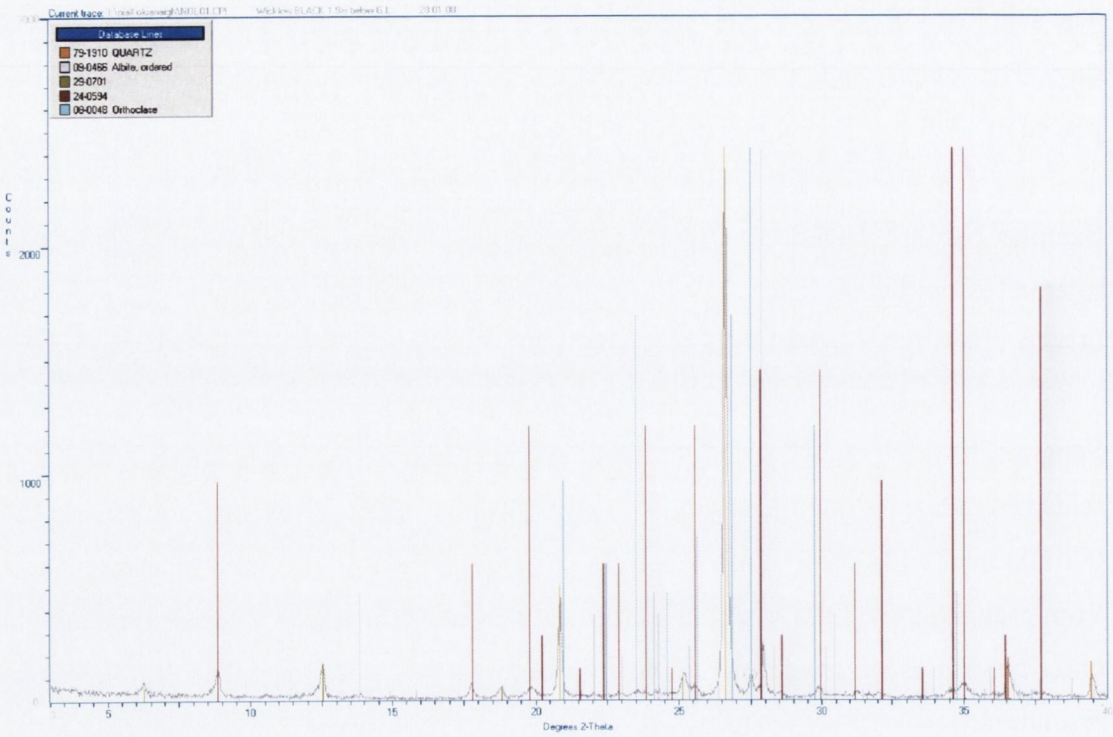
The supplied samples were sub-sampled and ~15g was dried in an oven at 40°C for two days. The samples were then powdered by hand using a pestle and mortar before ~1g was placed in a bulk cavity mount and run on the XRD[1] under standard operating conditions.

Samples NOL01, NOL02, NOL03 and NOL04 are indistinguishable by XRD and are interpreted to contain quartz [79-1910], feldspars (albite [09-0466] and orthoclase [08-0048]), chlorite (? clinochlore, ferroan [29-0701]) and mica (? lepidolite [24-0594]).

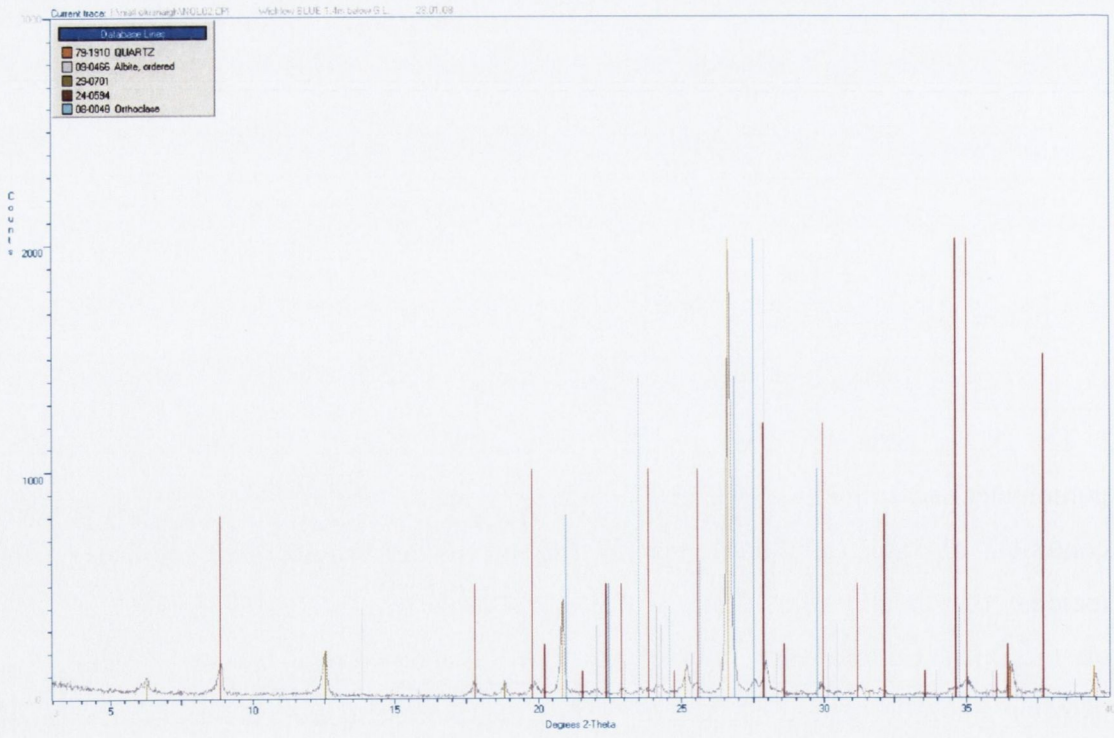
Samples NOL05, NOL06 and NOL07 are interpreted to contain quartz [79-1910], feldspars (albite [09-0466] and orthoclase [08-0048]), chlorite (? clinochlore, ferroan [29-0701]), calcite [05-0586] and manganoan calcite [02-0714]. They are indistinguishable from each other by XRD. A small peak is seen around 6°2θ which suggests there may be other clays present, but further sample preparation would be required to improve their resolution.

Dr Robbie Goodhue
Senior Experimental Officer

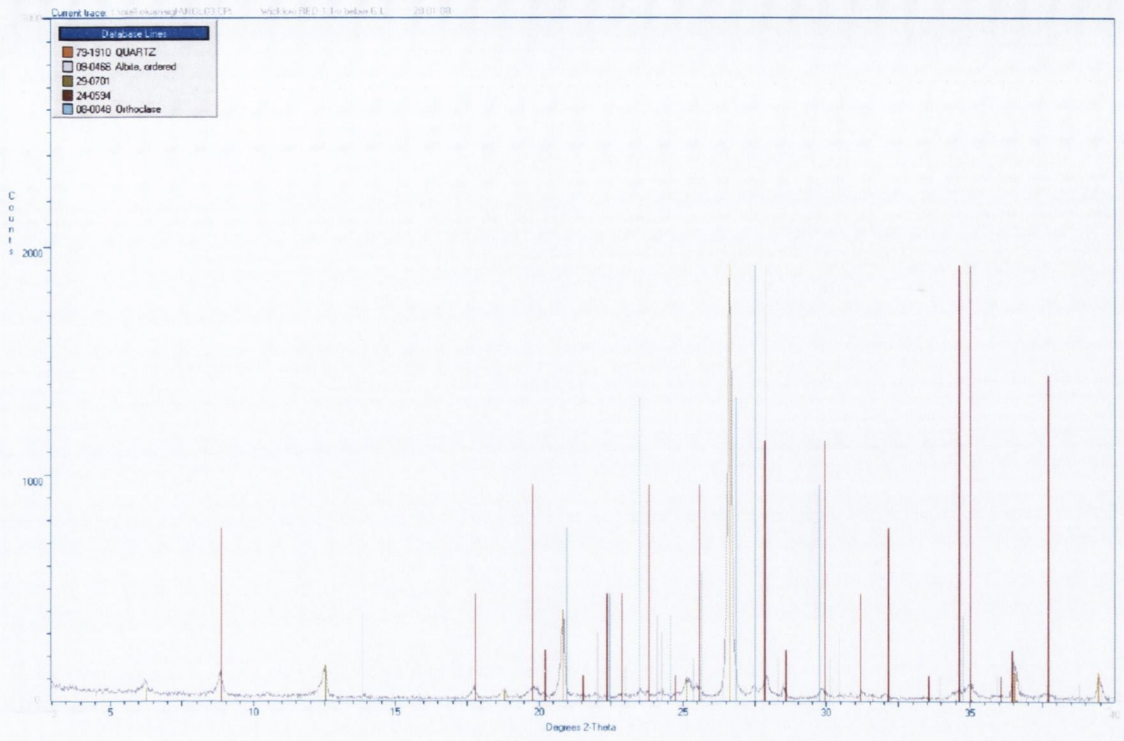
[1] The X-ray generator used was a Phillips PW1720 with a Phillips PW1050/80 goniometer and a Phillips PW3313/20 Cu k-alpha anode tube that was run with standard conditions of 35kV and 20mA. A soller slit and a 1° divergence slit were used on the incident x-ray beam and a 1° anti-scatter slit followed by a 0.2° receiving slit were used on the diffracted beam, in front of the PW1711 Proportional counter detector. The detector controller was a Philips 1710. All measurements were taken from 3 to 40 degrees (2θ) at a step size of 0.02 degrees/second.


Database Lines
79-1910 QUARTZ
09-0466 Albite, ordered
29-0701
24-0594
08-0048 Orthoclase
Counts
2000
1000
5
10
15
20
25
30
35
Degrees 2-Theta

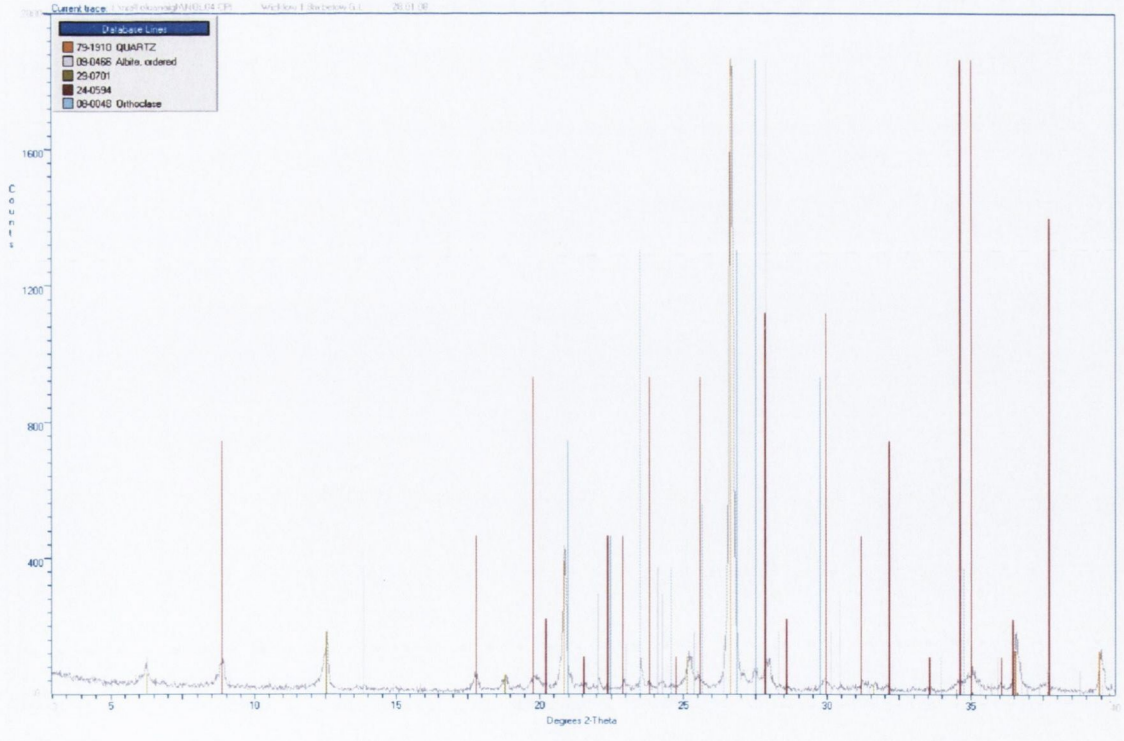
NOL01


Database Lines
79-1910 QUARTZ
09-0466 Albite, ordered
29-0701
24-0594
08-0048 Orthoclase
Counts
2000
1000
5
10
15
20
25
30
35
Degrees 2-Theta

NOL02


Database Lines
79-1910 QUARTZ
08-0466 Albite, ordered
29-0701
24-0594
08-0048 Orthoclase
Counts
2000
1000
5
10
15
20
25
30
35
Degrees 2-Theta

NOL03


Database Lines
79-1910 QUARTZ
08-0466 Albite, ordered
29-0701
24-0594
08-0048 Orthoclase
Counts
1600
1200
800
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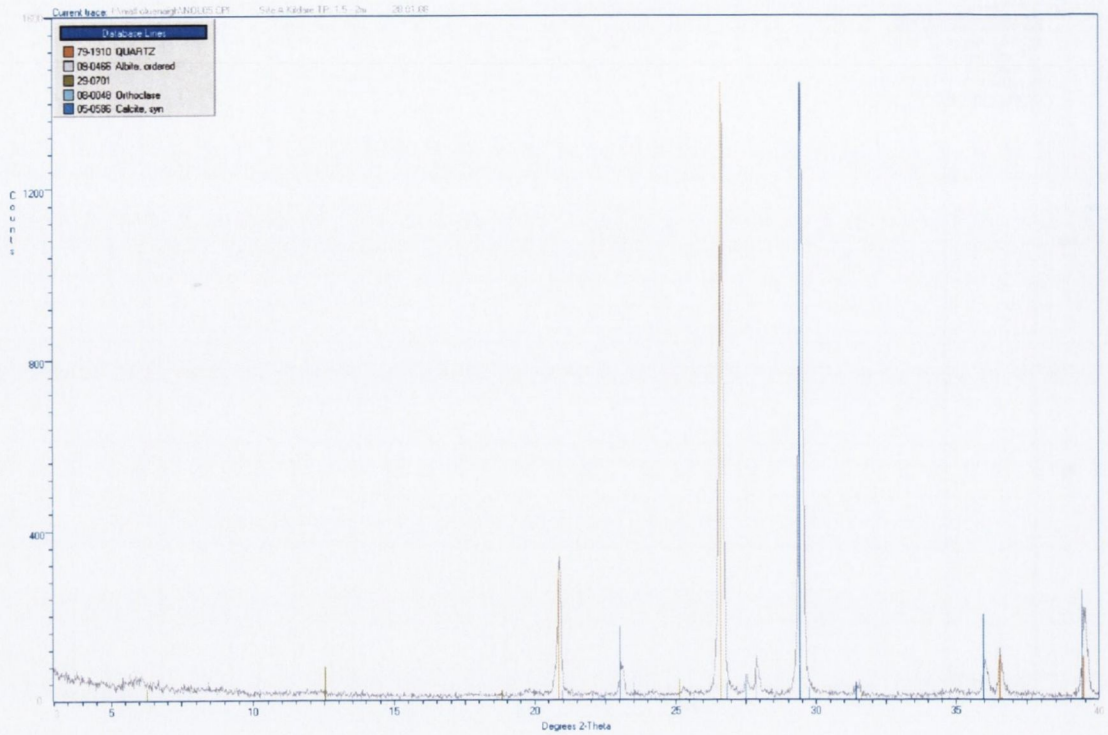
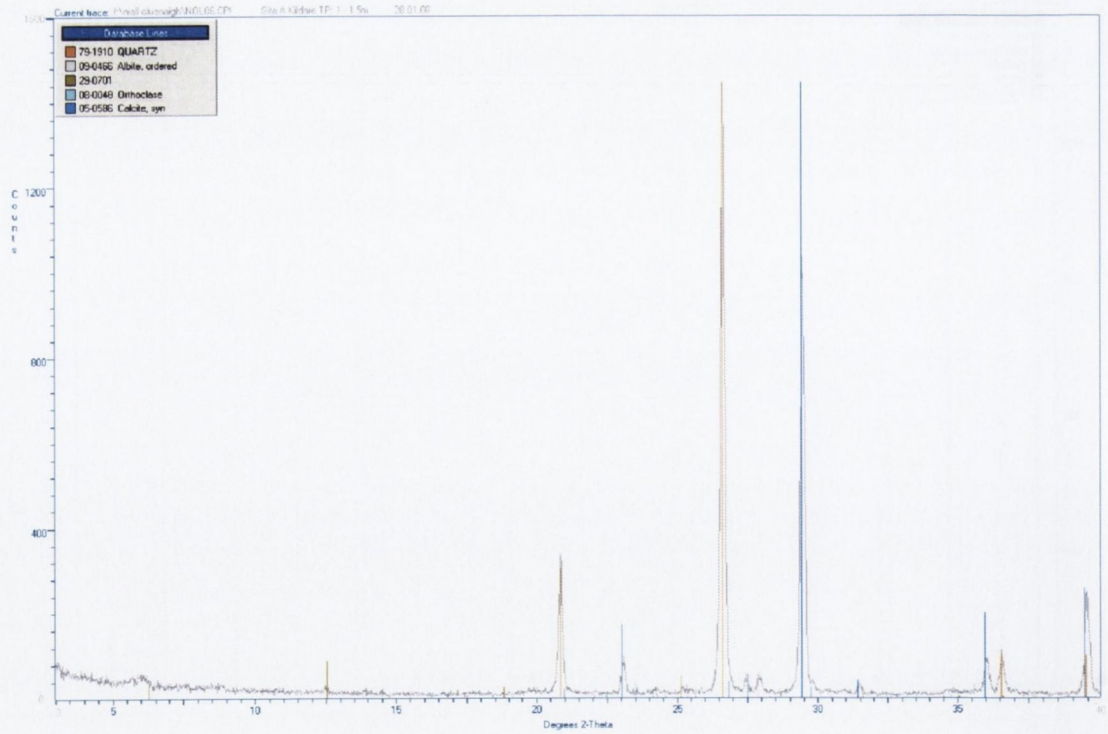
10
15
20
25
30
35
Degrees 2-Theta

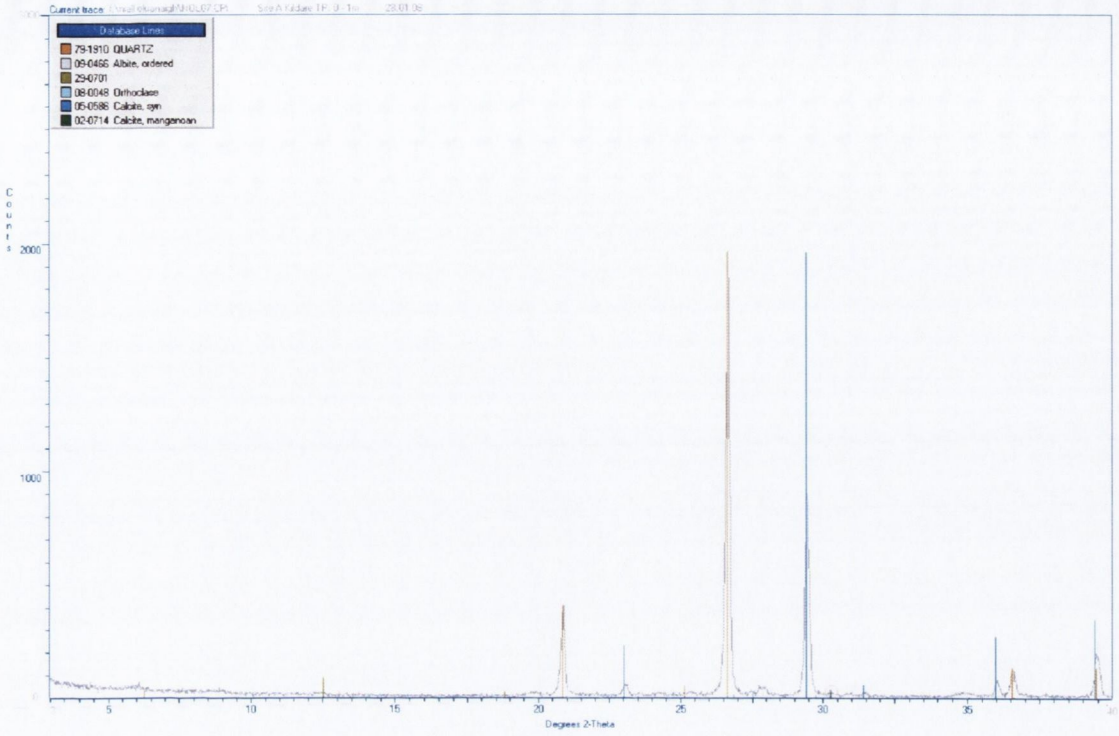
NOL04


Database Lines
79-1910 QUARTZ
09-0466 Albite, ordered
29-0701
08-0048 Orthoclase
05-0586 Calcite, syn
Counts
1200
800
400
0
5
10
15
20
25
30
35
Degrees 2-Theta

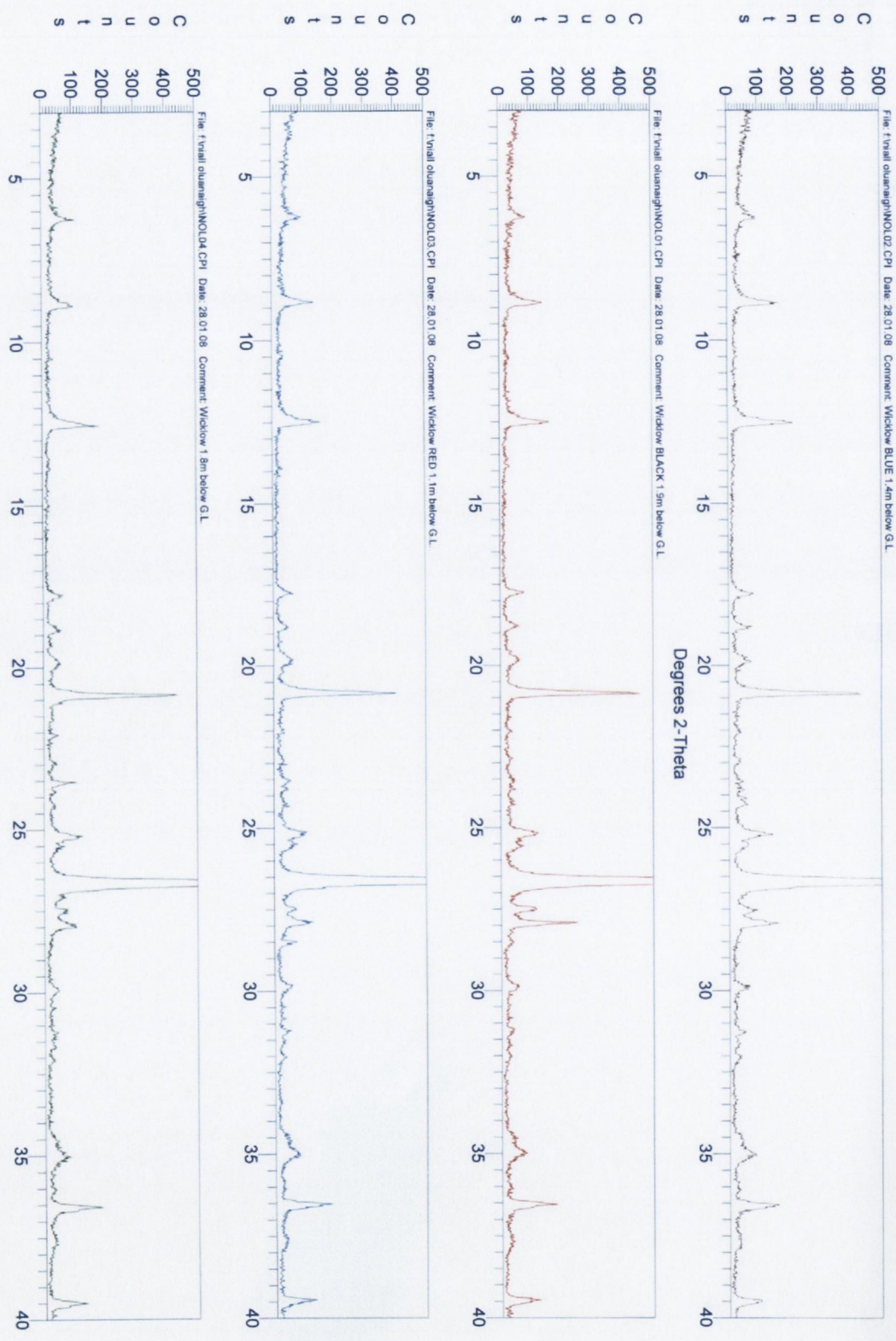
NOL05


Database Lines
79-1910 QUARTZ
09-0466 Albite, ordered
29-0701
08-0048 Orthoclase
05-0586 Calcite, syn
Counts
1200
800
400
0
5
10
15
20
25
30
35
Degrees 2-Theta

NOL06


Database Lines
79-1910 QUARTZ
09-0466 Albite, ordered
29-0701
08-0048 Orthoclase
05-0586 Calcite, syn
02-0714 Calcite, manganoan
Counts
2000
1000
5
10
15
20
25
30
35
Degrees 2-Theta

NOL07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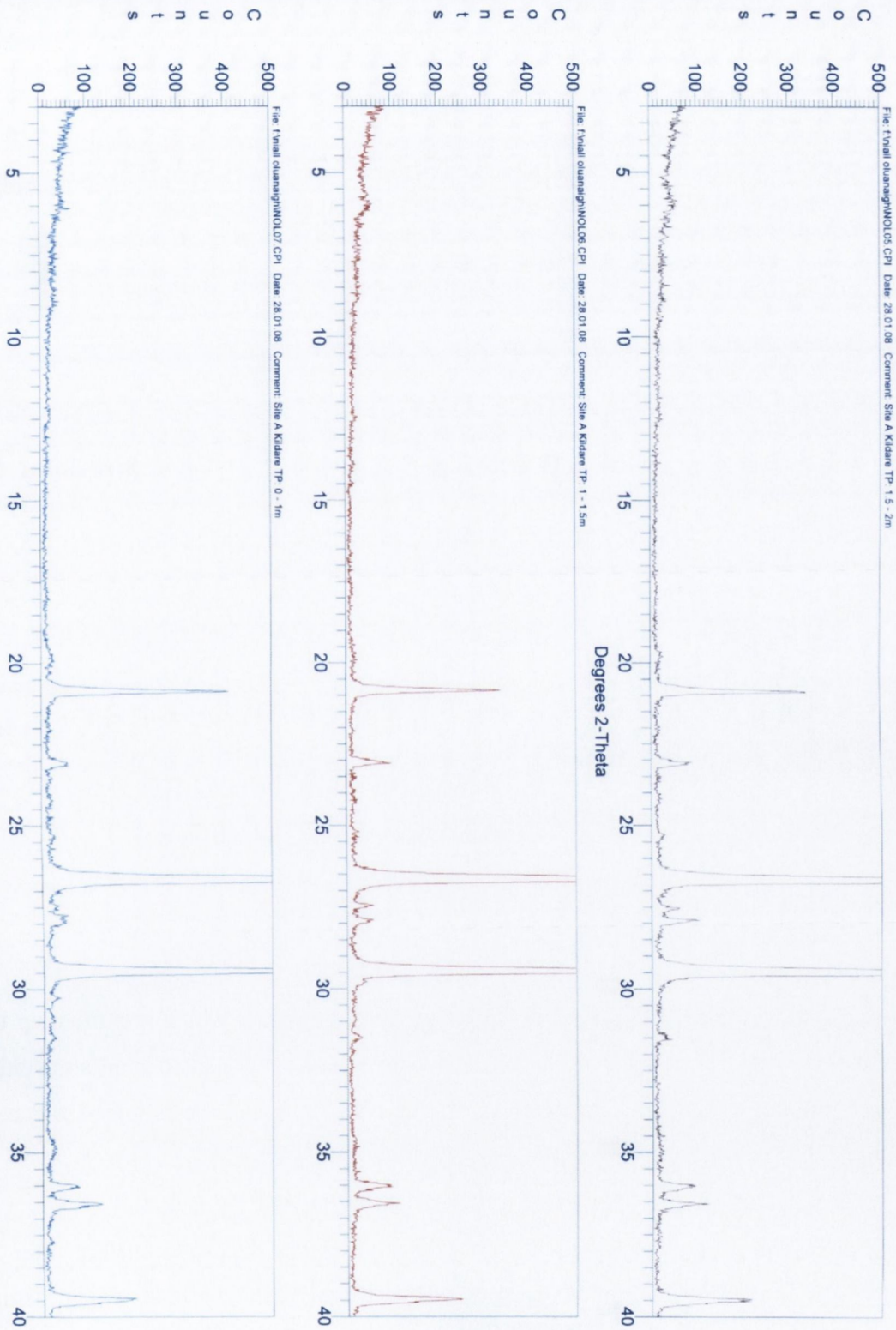
File: f:\niall oluanaigh\NOL03.CPI Date: 28.01.08 Comment: Wicklow RED 1.1m below G.L
File: f:\niall oluanaigh\NOL04.CPI Date: 28.01.08 Comment: Wicklow 1.8m below G.L
Counts
Degrees 2-Theta

NOL01 – NOL04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File: f:\niall oluanaigh\NOL06.CPI Date: 28.01.08 Comment: Site A Kildare TP: 1 - 1.5m
File: f:\niall oluanaigh\NOL07.CPI Date: 28.01.08 Comment: Site A Kildare TP: 0 - 1m
Counts
Degrees 2-Theta

NOL05 – NOL07

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4th February 2008

XRD analysis of soils for Niall O'Luanaigh (Department of Civil, Structural & Environmental Engineering, TCD)

2 samples were supplied for <2μm (clay) fraction analysis:

Lab Number	**I.D.**	
NOL02	Wicklow BLUE	1.4m below G.L.
NOL06	Site A Kildare	TP: 1 – 1.5m

Sample preparation

5.0g of sample was taken and placed in a 50ml graduated cylinder which was filled up to the 50ml mark with deionised water and shaken. The cylinder was placed in an ultrasonic bath for 5 minutes to disaggregate the clays, shaken once more and then allowed to stand for 3 hours.

2ml of liquid were removed by pipette from 39mm beneath the water surface after 3 hours, which, according to Stokes' Law is calculated to be the level at which <2μm fraction particles of 2.65 specific gravity will have settled to in this time. The water plus the <2μm (i.e. clay fraction) was pipetted onto a low-background oriented silicon mount

and allowed to air dry overnight. The sample was then run on the XRD[2], transferred to a dessicator with ethylene glycol in the base and placed in an oven at 60°C overnight, allowing the vapours to interact with the sample. The sample was then run for a second time on the XRD to assess if there had been any changes in peak positions which would indicate the presence of swelling clays.

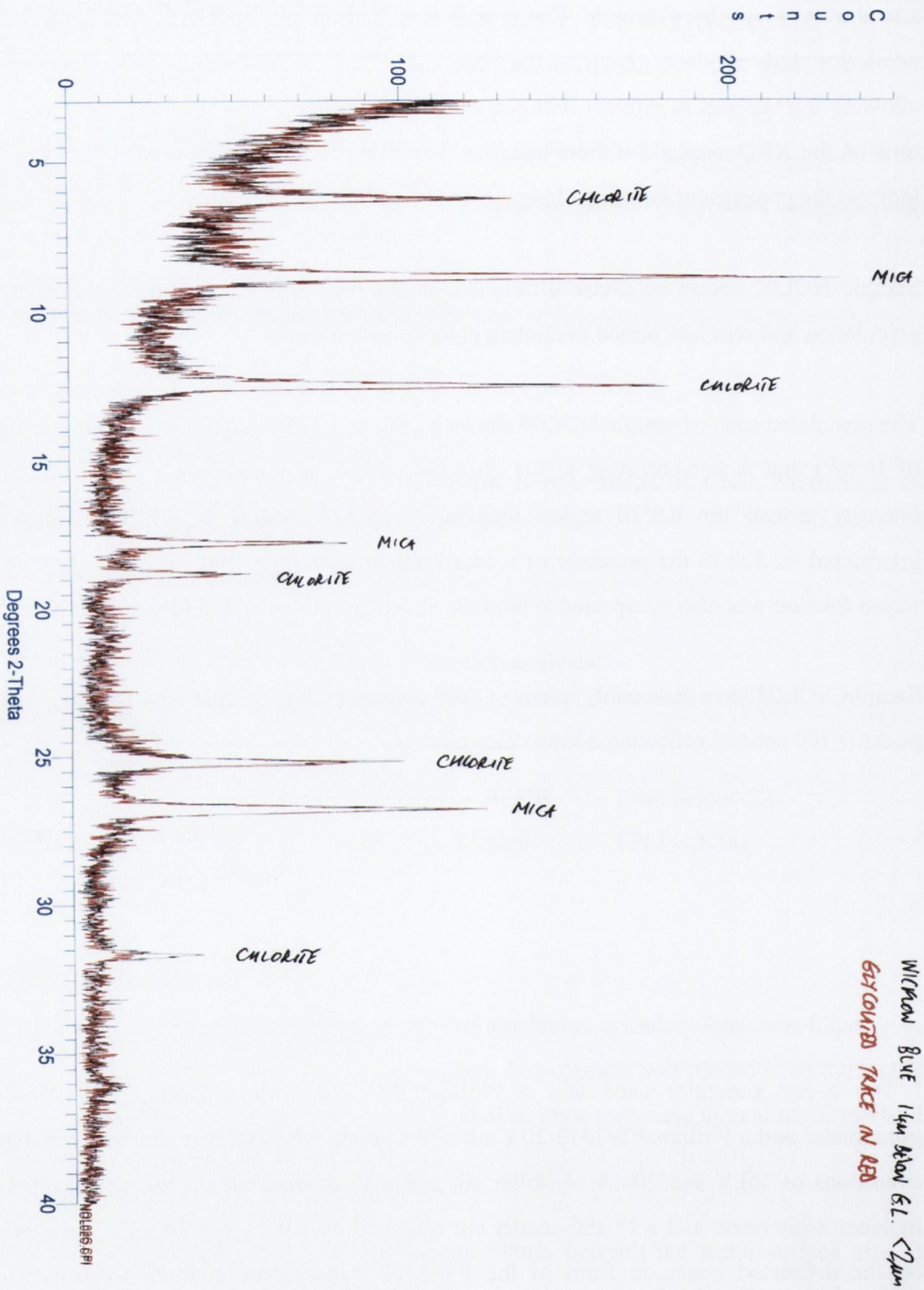
Sample NOL02 shows no phase differences in the on <2μm fraction before and after glycolation and was interpreted to contain chlorite and mica.

The glycolated scan of sample NOL06 shows a peak at 5.31°2θ (equivalent to a d-spacing of 16.6Å) that is not observed in the air-dried sample which shows a slightly higher intensity around the 6.5°2θ region (equivalent to a d-spacing of ~13.7Å). This is interpreted as due to the presence of a small amount swelling illite-smectite clay. The <2μm fraction was also interpreted to contain chlorite, mica, quartz, feldspar and calcite.

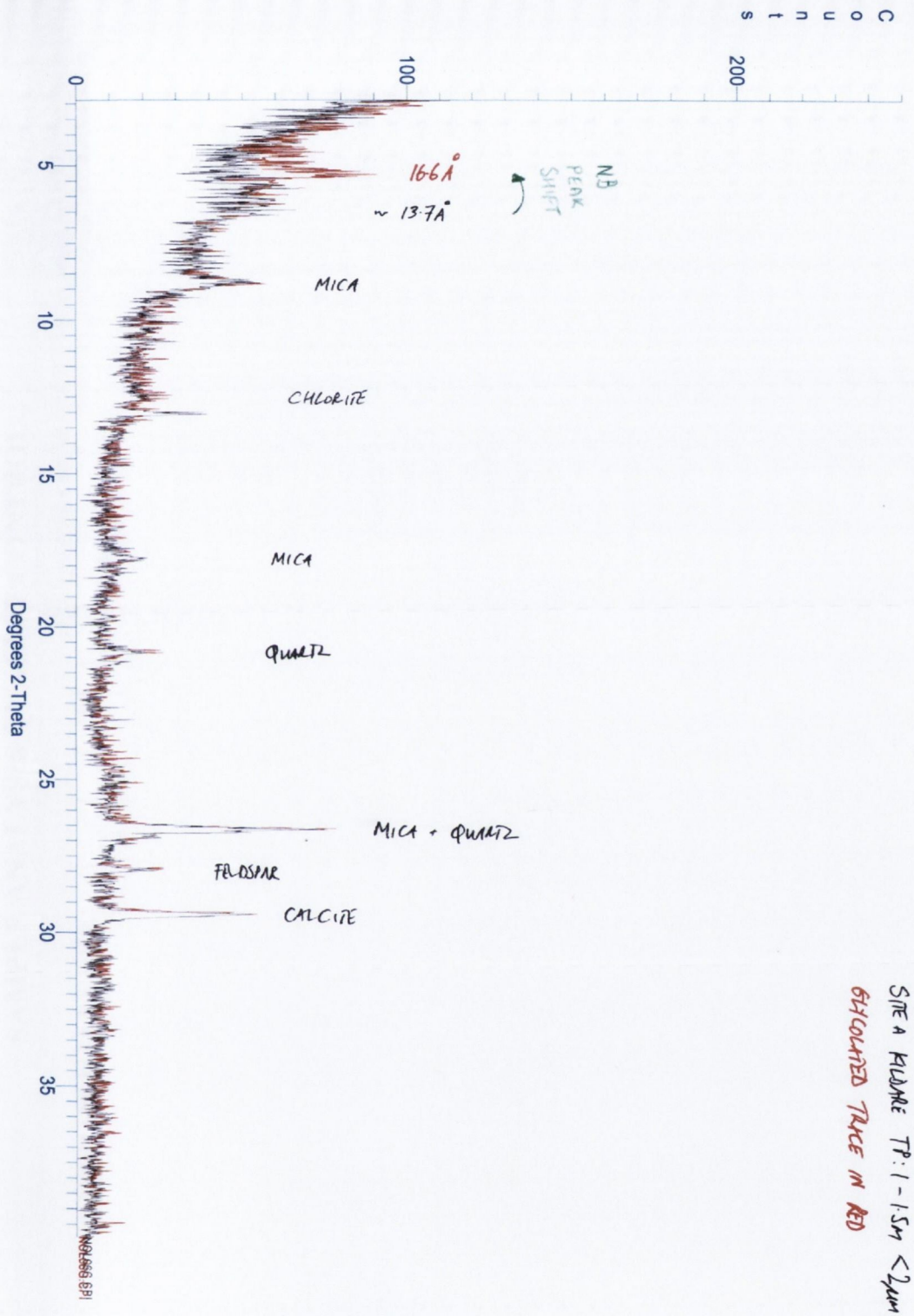
Sample NOL02 gave reasonably intense (>100 counts) peaks. Sample NOL06 gave weak peaks (<100 counts) reflecting a lower clay content.

Dr Robbie Goodhue
Senior Experimental Officer

[2] The X-ray generator used was a Phillips PW1720 with a Phillips PW1050/80 goniometer and a Phillips PW3313/20 Cu k-alpha anode tube that was run with standard conditions of 35kV and 20mA. A soller slit and a 1° divergence slit were used on the incident x-ray beam and a 1° anti-scatter slit followed by a 0.2° receiving slit were used on the diffracted beam, in front of the PW1711 Proportional counter detector. The detector controller was a Philips 1710. All measurements were taken from 3 to 40 degrees (2θ) at a step size of 0.02 degrees/second.


Counts
0
100
200
5
10
15
20
25
30
35
40
Degrees 2-Theta
CHLORITE
MICA
CHLORITE
MICA
CHLORITE
CHLORITE
MICA
CHLORITE
WICKLOW BLUE 1.4m BELOW G.L. <2μm FRACTION
GLYCOLATED TRACE IN RED

NOL02



SITE A KILDARE TP: 1 - 1.5m <2μm FRACTION
GLYCOLATED TRACE IN RED

NOL06

Appendix B

Quality Control and Sampling Methodologies

SAMPLE ANALYSIS QUALITY CONTROL

TCD Analysis

(All concentrations reported in mg L^{-1} except *E.coli* counts in MPN)

	COD	BOD_5	TN	NO_3-N	NO_2-N	NH_4-N	PO_4-P	Cl	TSS	*E.coli* 100mL^{-1}
A1	709	187	116	0.5	0.25	111	37.3	326	82.5	480000
A2	74	20.6	75.9	0.5	0.03	74	22.2	374	45	17890
A3	20	-	44.2	26.8	0.17	7	2.26	414	-	<1
A4	22.1	-	39.1	15.2	0.29	25	2.38	398	-	<1
A5	21.4	-	45.2	39.2	0.03	0.19	0.05	442	-	2
A6	50	-	32.1	8.8	0.16	24	4.04	448	-	<1
A7	15	-	45.5	11.6	0.22	27	5.68	398	-	<1
A8	29	-	17	6.8	0.03	0.14	0.05	142	-	1
A9	62.5	-	53.4	2.8	0.53	38	6.12	522	-	<1
B1	375	62.4	61.3	0.85	0.9	51	31.4	149	146	1110
B2	122	13.7	48.9	3.8	0.5	29	28.1	146	25.4	410
B3	28	-		68.55	0.03	0.42	1.71	91	-	<10
B4	30	-	-	38.52	0.03	0.08	0.06	47	-	1
B5	47	-	-	38.5	0.02	0.01	0.54	59	-	<1
B6	5	-	-	23	<0.02	0.025	0.31	23	-	<1
B7	5	-	-	31.5	<0.02	0.05	0.24	8	-	<1
B8	5	-	-	37.4	0.02	0.09	0.52	11	-	<1

SAMPLE ANALYSIS QUALITY CONTROL

City Analyst Laboratory (CAL) Analysis

(All concentrations reported in mg L^{-1} except *E.coli* counts in MPN)

	COD	BOD_5	TN	NO_3-N	NO_2-N	NH_4-N	PO_4-P	Cl	TSS	*E.coli* $100mL^{-1}$
A1	710	183	112.6	0.421	0.15	94	14.6	298	108	3500
A2	80.2	15	72.7	0.23	<0.015	54	11.1	552	34	2100
A3	23.2	-	39.4	35.6	4.72	0.025	0.916	403	-	<1
A4	23.3	-	33	21.9	15	0.027	1.892	406	-	<1
A5	13.5	-	44.6	42.6	0.305	0.021	0.05	449	-	<1
A6	19.1	-	31.2	18.1	18.8	0.034	3.28	485	-	<1
A7	25.1	-	43.8	20.9	14.4	8.62	4.96	425	-	<1
A8	7.32	-	11.1	11.4	<0.015	0.082	0.05	124	-	<1
A9	34.1	-	50	16.2	23.5	10.6	5.28	557	-	<1
B1	384	61.3	56.2	0.708	0.988	46.8	29.4	88.2	138	8
B2	195	5.5	39	6	0.562	29.2	26.2	110	13	23
B3	10.6	-	-	65	<0.015	0.075	1.538	78	-	<1
B4	6.48	-	-	42.55	0.023	0.077	0.056	42.6	-	<1
B5	2.5	-	-	45.55	<0.015	0.015	0.702	51.8	-	<1
B6	2.5	-	-	21.8	<0.015	0.022	0.204	24.8	-	<1
B7	2.5	-	-	31.75	<0.015	0.056	0.28	11.56	-	<1
B8	2.5	-	-	35.65	0.025	0.1	0.579	12.5	-	<1

S.O.P. No. CAL 005-01	Version No. 01	Page 1 of 10
Applies from: 07/10/05		
S.O.P. Title: DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND		
Written by: Sean Walsh		Date: 3/2/94

S.O.P. No. CAL 005-01		
Written by: Sean Walsh	Date:	Expiry Date:
Technical Approval:	Date:	Status: Current
Authorized by:	Date:	
Effective Date: 7/10/05		

Chemical Analysis Laboratory Ltd.,

Rear 114 Lower Georges Street,

Dun Laoghaire,

Co Dublin

Version	Reason for Revision
00	First Edition of S.O.P. 3294
01	S.O.P. Update for IMB

1.0 INTRODUCTION

Biochemical oxygen demand is a measure of how much dissolved oxygen is being consumed as microbes break down organic matter. A high demand, therefore, can indicate that levels of dissolved oxygen are falling, with potentially dangerous implications for the river's biodiversity.

High biochemical oxygen demand can be caused by:

- high levels of organic pollution, caused usually by poorly treated wastewater
- high nitrate levels, which trigger high plant growth.

Both result in higher amounts of organic matter in the river. When this matter decays, the microbiological activity uses up the oxygen. Biochemical oxygen demand is therefore one of the main parameters used in the Urban Wastewater Treatment Directive for controlling discharges. The test has its widest application in measuring waste loadings to treatment plants and in evaluating the efficiency (B.O.D. removal) of such treatment systems.

2.0 PRINCIPLE OF TEST METHOD

The amount of Dissolved Oxygen (D.O.) in a sample is measured, using an oxygen meter. In most cases, it is preferred if incubation begins within 6 hours of sampling. The following nutrients are then added to the sample to ensure the survival of the microbial population: phosphate buffer solution, magnesium sulphate solution,

calcium chloride solution and ferric chloride solution. The sample is then incubated in the dark for 5 days in an airtight incubation bottle, after which the D.O. is again measured using an oxygen meter. The extent of change in D.O. appears to be a function of the amount of organic matter (food supply) and the number and types of organisms (biological population) present in the sample.

3.0 SCOPE AND LIMITATIONS

B.O.D. values cannot be compared unless the results have been obtained under identical test conditons. The test is of limited value in measuring the actual oxygen demand of surface waters. The extrapolation of test results to actual stream oxygen demands is highly questionable because the laboratory environment does not reproduce stream conditions such as temperature, sunlight, biological population, water movement or oxygen concentration.

Samples for B.O.D. analysis may undergo significant degradation during handling and storage resulting in a low estimation of the true B.O.D. Incubation should begin not more than 6hrs after the sample is collected to prevent this. The maximum time allowed to put on a B.O.D. sample analysis is 48 hours.

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All water samples requiring B.O.D. determination must have all relevant sample reception procedures completed. See S.O.P. No: CAL 500-01, prior to analysis. The only other information required is the C.O.D. of the sample, which will govern the degree of dilution.

5.0 HAZARDS

As many of the samples undergoing this analysis are effluents, care should be taken to avoid contamination of laboratory personnel and the work area / equipment as well as the samples themselves. Normal laboratory procedures should be adhered to in all cases.

6.0 EQUIPMENT

6.1 Oxygen meter. Jenway Oxygen Meter or Jenway 970 DO_2 Meter.

6.2 Gilson micropipette.

6.3 Incubation bottles, 250 ml with ground glass stoppers.

6.4 Stirring Box.

6.5 Magnetic stirrer

7.0 REAGENTS

7.1 Distilled Water.

7.2 Phosphate Buffer Solution.

7.3 Magnesium Sulphate Solution.

7.4 Calcium Chloride Solution.

7.5 Ferric Chloride Solution.

8.0 PREPARATION OF REAGENTS

8.1 **Distilled Water.** Use only high quality distilled water. Alternatively use deionised water. The water must contain less than 0.1mg/L copper and be free from chlorine, chloramines, caustic alkalinity, organic materials, or acids.

8.2 **Phosphate Buffer Solution.** Dissolve:

8.5g	potassium dihydrogen phosphate, KH_2PO_4;
21.75g	dipotassium hydrogen phosphate $K_2H\ PO_4$;
33.4g	disodium hydrogen phosphate heptahydrate, $Na_2\ HPO_4.7H_20$;
1.7g	ammonium chloride, NH_4 Cl,

in about 500mls of distilled water and dilute to 1L. The pH of this buffer should be 7.2 without further adjustment. Discard the reagent (or any of the following reagents) if there is any sign of biological growth in the bottles.

8.3 **Magnesium Sulphate Solution.** Dissolve 22.5g $MgSO_4.7H_2O$ in distilled water and dilute to 1L.

8.4 Calcium Chloride Solution. Dissolve 27.5g $CaCl_2$ in distilled water and dilute to 1L.

8.5 Ferric Chloride Solution. Dissolve 0.25g $FeCl_3.6H_2O$ in distilled water and dilute to 1L.

9.0 EXPERIMENTAL PROCEDURES

9.1 Sample Preparation.

Samples containing Caustic Alkalinity or Acidity.
Neutralize to about pH 7.0 with 1M H_2SO_4 or 1 M NaOH using a pH meter.

Samples containing Residual Chlorine Compounds.
If the samples stand for 1 - 2 hours the residual chlorine will often be dissipated. Destroy higher chlorine residuals in neutralized samples by adding Na_2SO_3. To determine the appropriate quantity of sodium sulphite to add to a 100 - 1000mls sample, add 10ml of 1 + 1 acetic acid or 1 + 50 H_2SO_4 followed by 10ml KI solution (10g/100ml) and titrating with 0.025M Na_2SO_3 solution to the starch iodine end point. Add to a volume of sample the quantity of Na_2SO_3 solution determined by the above test, mix and after 10 - 20 min. test a sample for residual chlorine to check the treatment. Prepare B.O.D. dilutions with seeded standard dilution water.

Samples Supersaturated with D.O.(>9mg/L D.O.)
To prevent loss of oxygen during incubation of these samples, reduce the D.O. to saturation by bringing the sample to about 20_C in a partly filled bottle and agitating it by vigorous shaking or by aeration with compressed air.

9.1 Procedure for using the Jenway Oxygen Meter 7090.

Switch the meter on by pressing the ON key. Remove the probe from the protective case and place it in distilled water. Place the temperature probe into the distilled water also, and allow both probes to equilibrate for 10 minutes. The oxygen meter is calibrated using the blank solution of the BOD analysis run. Place the blank solution on the stirrer and insert the DO probe into the solution, ensuring there are no bubbles on the membrane of the probe. Stir the solution. Press the MODE key until the percentage is shown. Turn the SLOPE knob until the value settles at 100.0%. Press the MODE key until the zero value is shown. Turn the ZERO knob until 0.00 is shown. Before recording a measurement, check that both values are stable by scrolling through the percentage and zero values. When satisfied, press the MODE key until the mg/l value is shown. Read this value as the blank value. Remove the probe and rinse with distilled water. Place the probe into the next solution, stir and read the value when it has equilibrated. Repeat for all samples. When finished analyzing all the samples, rinse the probe with distilled water and replace protective cover. Add a small amount of distilled water to the inside of the protective cover before storage.

9.2 Procedure for using the Jenway 970 DO_2 Meter.

Switch the meter on by pressing the I/O button. Remove the probe from the protective case and place it in distilled water, and allow to equilibrate for 10 minutes. The DO2 meter is calibrated using the blank solution of the BOD analysis run. Place the blank solution on the stirrer and insert the probe into the solution, ensuring there are no bubbles on the membrane of the probe. Stir the solution. Press the CAL button. A value for percentage is shown. Adjust this value to 100.0% by using the UP and DOWN arrow buttons on

the DO2 meter. When the value is at 100.0% press the CAL button to return to analysis

mode. Press the MODE button to view the reading. Read this value as the blank value. Remove the probe and rinse with distilled water. Place the probe

into the next solution, stir and read the value when it has equilibrated. Repeat for all samples. When finished analyzing all the samples, rinse the probe with distilled water and replace protective cover. Add a small amount of distilled water to the inside of the protective cover before storage

9.3 **Dilution Technique.** Make several dilutions of the prepared sample to obtain the required dilution (C.O.D. results will give a guideline to dilutions). B.O.D. is usually 1/2 - 1/3 the C.O.D. See previous reports for guidelines to dilutions.

9.4 **To prepare nutrient mixture**: Make 1ml for each 250ml B.O.D. bottle (0.25ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride. Add 1ml of nutrient mixture to each B.O.D. bottle. (If say 18 bottles are required, make 20mls i.e. 5mls of each) Add an appropriate amount of sample to the bottle, depending on the dilution required and make up to the mark with distilled water.

Mix carefully using a stirring box and magnetic stirrer and measure the D.O. (D_1) of the resulting solution with the oxygen meter. Stopper - avoiding trapping any air bubbles (care should also be taken when filling the incubation bottle to avoid bubbling the solution thus causing an increase in the D.O.)

9.5 Incubation. Incubate the blank dilution water and the diluted samples for 5 days in the dark at 20°C. Then measure the D.O. (D_2) again using the oxygen meter.

10.0 RECORDING OF RAW DATA

All raw data should be recorded in the appropriate B.O.D. analysis sheet which should be dated and signed.

11.0 Calculations.

10.1.1 Definitions.

D_0 = D.O. of original dilution water (Blank).
D_1 = D.O. of diluted sample after preparation.
D_2 = D.O. of diluted sample after incubation.
D_3 = D.O. of incubated dilution water (Blank).
R = Dilution factor used.

10.1.2 Biochemical Oxygen Demand.

mg/L B.O.D. = (D1 - D2) x R

Note: If $D_0 - D_3 \leq \pm 0.2$ then use D_3 as original D.O. for all samples therefore

mg/l B.O.D. = (D3 - D2) x R.

12.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either ppm or mg/l. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

13.0 RECORDS

13.1 All records should be archived and not discarded.

14.0 REFERENCE AND APPENDICES

Organic constituents (500) 507 Oxygen Demand (Biochemical) pp 543 - 550, from "Standard Methods for the Examination of Water and Waster Water". (17th Ed.).

S.O.P. No. CAL 032-01	Version No. 01	Page 1 of 6
Applies from: 18/10/05		
S.O.P. Title: Analysis of Total Suspended Solids		
Written by: Sean Walsh		**Date: 10/02/94**

S.O.P. No. CAL 031-01		
Written by: **Sean Walsh**	**Date:** **10/02/94**	**Expiry Date:**
Technical Approval:	**Date:**	**Status:** **Current**
Authorized by:	**Date:**	
Effective Date: 18/10/05		

Chemical Analysis Laboratory Ltd.,

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Version	Reason for Revision
00	First Edition of S.O.P. 10/02/94
01	Update for IMB

1.0 INTRODUCTION

Total suspended solids (TSS) include all particles suspended in water, which will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater. There are also nonpoint sources of suspended solids, such as soil erosion from agricultural and construction sites.

As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels.

TSS can also destroy fish habitat because suspended solids settle to the bottom and can eventually blanket the river bed. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in a diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may be disrupted.

Adequate treatment is necessary to insure that suspended solids are not present at levels of concern in waters of the state. Treatment typically consists of settling prior to discharge of the wastewater. Settling allows solids to sink to the bottom, where they can be removed.

Generally a TSS concentration less than 20 mg/L is considered to be clear. Water with TSS levels between 40 and 80 mg/L tends to appear cloudy, while water with concentrations over 150 mg/L usually appears dirty. The EU criteria and recommended limit values are as follows:

Water Definition	Requirement	Notes
Surface Water	50 mg/L	Mandatory
Freshwater Fish	< 25 mg/L	Recommended
Salmonoid Waters	< 25 mg/L	Mandatory
Shellfish	-	(1)
Drinking Water	-	(2)

(1) "A discharge affecting shellfish waters must not cause the suspended solid content of the waters to exceed more by than 30% the content of waters not affected".
(2) "No persistently visible suspended solids"

2.0 PRINCIPLE OF TEST METHOD

The procedure consists of filtering the sample through a glass microfibre filter paper, thereby trapping the suspended solids. The paper is dried, and the weight of the suspended solids are calculated by subtracting the initial weight of the dried filter paper from the final weight of the final paper.

3.0 SCOPE AND LIMITATIONS

If the sample contains too high an amount of suspended solids, the filter paper will become blocked and no water will run through. If this happens, simply use a lower amount of sample.

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All samples requiring settleable solids determination must have all relevant sample reception procedures completed. See S.O.P. No: Cal 500-01 prior to analysis.

5.0 HAZARDS

Many of the samples undergoing this analysis are effluents and sludges and therefore gloves should be worn by the analyst. All precautions should be taken to prevent contamination of samples. Normal laboratory procedures should be adhered to in all cases.

6.0 APPARATUS

- Graduated cylinder
- Filtration apparatus (including pump)
- Glass fibre filter paper
- Oven
- Analytical balance

7.0 EXPERIMENTAL PROCEDURES

(1) Turn on oven to 100°C, with filter paper in metal dish inside.

(2) Remove filter paper from oven and weigh. Wait until reading stabilizes before noting it down.

(3) Filter sample. The amount used depends on the dirtyness of the sample. If solution is clear, use up to 200 ml, if solution is dirty, use 50 ml sample.

(4) Dry paper in oven for at least 1 hour, remove, place on balance, wait until value stabilizes and then record value.

8.0 CALCULATION OF THE VALUE OF THE UNKNOWNS

The initial weight of the filter paper is subtracted from the final weight. The difference in weight is then multiplied by 20 if 50 mls was used initially, or by 5 if 200 mls was used initially. This is to express the result in litres. Then the result is multiplied by 1000 to express the result in mg/L.

9.0 REPORTING TEST RESULTS

Results are recorded in the lab book and also in the TSS section of the results file. Finally results are reported on the Job Sheet and are normally expressed mg/L. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

10.0 RECORDS

All records should be archived and not discarded.

S.O.P. No. CAL 007-01	Version No. 01	Page 1 of 5
Applies from: 07/10/05		
S.O.P. Title: ANALYSIS OF CHEMICAL OXYGEN DEMAND		
Written by: Sean Walsh		Date: 05/02/94

S.O.P. No. CAL 007-01		
Written by: Sean Walsh	Date:	Expiry Date:
Technical Approval:	Date:	Status: Current
Authorized by:	Date:	
Effective Date: 7/10/05		

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Version	Reason for Revision
00	First Edition of S.O.P. 050294
01	S.O.P. Update for IMB

1.0 INTRODUCTION

Chemical Oxygen Demand (C.O.D.) is an indicator of overall water quality and is naturally occurring, though most probably due to added organic matter. It is therefore applicable to heavily polluted and waste waters. It differs from Biochemical Oxygen Demand (B.O.D.) (see S.O.P. No.: CAL 500-01) in that it takes into account oxidizible "chemicals" in the sample. The ratio of C.O.D. to B.O.D. in domestic effluent should be 100 : 65 or 1.54 : 1. The E.C. gives very little reference to C.O.D. limits, except that surface water must have no more than 40mg/l O_2.

2.0 PRINCIPLE OF TEST METHOD

Oxidizable substances react with sulphuric acid - potassium dichromate solution in the presence of silver sulphate as a catalyst. Chloride is masked by mercuric sulphate. The yellow colour of hexavalent chromium is used for the measurement.

3.0 SCOPE AND LIMITATIONS

This depends on the measuring range of the Cuvette Test used. The ranges are 5 – 60 mg/l C.O.D., 15 – 150 mg/l C.O.D., 100 - 2000 mg/l C.O.D., and 1000-10000 mg/l C.O.D. A chloride content of >1500mg/l in the sample will cause interference.

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All water samples undergoing this analysis must have all relevant sample reception procedures completed (see S.O.P. No.: Cal-500-01) prior to analysis. In many cases these samples are effluent and need diluting in order to make them less turbid. No other information is required.

5.0 HAZARDS

Many of the samples undergoing C.O.D. analysis are effluents and therefore gloves should be worn by the analyst. The Cuvette Test contains chromosulphuric acid which is very toxic on inhalation, in contact with the skin and if swallowed. Extreme caution should be taken. All precautions must be taken to prevent contamination of the samples and the equipment. Normal laboratory procedures should be adhered to.

6.0 EQUIPMENT

6.1 Digital Photometer (Dr. Lange LP1W).

6.2 Filters and Adapter (see 9.2).

6.3 Thermostat.

6.4 1ml Pipette & Tips.

6.5 Vortex Mixer.

7.0 REAGENTS

7.1 Dr. Lange Cuvette Test LCK 014 (1000-10000 mg/l C.O.D.)
or LCK 514 (100 – 2000 mg/l C.O.D.)
or LCK 314 (15 – 150 mg/l C.O.D.)
or LCK 414 (5 – 60 mg/l C.O.D.)

8.0 PREPARATION OF REAGENTS

N/A.

9.0 EXPERIMENTAL PROCEDURES

9.1 Sample Preparation.

Note: All Cuvettes should be well shaken prior to analysis and measurement to bring the sediment into suspension. Allow the sediment to settle prior to final measurement Pipette into Cuvette Test 2mls of sample for C.O.D. Tests LCK 514, LCK 314, LCK 414 (0.2ml of sample is used for C.O.D. Test LCK 014). Mix the analysis cuvette, heat for 2 hours at 148 °C in the thermostat. Measure after cooling.

9.2 Sample Analysis.

LCK 014 - Insert 620nm filter, enter factor 2130 and store. Insert blank Cuvette (distilled water), press the Zero key.

LCK 514 - Insert 620nm filter, enter factor 2130 and store. Insert blank Cuvette (distilled water), press the Zero key.

LCK 314 - Insert 435nm filter, enter factor 270 and store. Insert Cuvette with zero solution, press the Zero key.

LCK 414 - Insert nitrate 339 filter, enter factor 52.5 and store. Insert Cuvette with zero solution, press the Zero key.
Insert analysis cuvette and press the result key. (When using C.O.D. Test LCK 014 multiply result by 10).

10.0 RECORDING OF RAW DATA

All raw data should be recorded in hard-back lab note-books and should be dated and signed. All raw data and results should be recorded in the appropriate C.O.D. analysis sheet, dated and signed. Results are also recorded on the appropriate Job Sheet.

11.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either ppm or mg/l. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

12.0 RECORDS

12.1 All records are archived and not discarded.

13.0 REFERENCE AND APPENDICES

13.1 "Parameters of Water Quality" by the Environmental Research Unit.

13.2 Dr. Lange Cuvette Test Kit LCK 014, LCK 514, LCK 314 and LCK 414 information sheets.

S.O.P. No. CAL 008-00	Version No. 00	Page 1 of 5
Applies from: 07/10/05		
S.O.P. Title: ANALYSIS OF CHLORIDE		
Written by: David Matthews		Date: 05/02/94

S.O.P. No. CAL 008-00		
Written by: David Matthews	Date:	Expiry Date:
Technical Approval:	Date:	Status: Current
Authorized by:	Date:	
Effective Date: 7/10/05		

Chemical Analysis Laboratory Ltd.,

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Version	Reason for Revision
00	First Edition of S.O.P.

1.0 INTRODUCTION

Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents.

Health/Sanitary Significance: Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability.

Background Information: At levels above 250 mg/l Cl water will begin to taste salty and will become increasingly objectionable as the concentration rises further. However, external circumstances govern acceptability and in some arid areas waters containing up to 2,000 mg/l Cl are consumed, though not by people unfamiliar with such concentrations. High chloride levels may similarly render freshwater unsuitable for agricultural irrigation.

Comments: Because sewage is such a rich source of chloride, a high result may indicate pollution of a water by a sewage effluent. Natural levels in rivers and other fresh waters are usually in the range 15-35 mg/l Cl - much below drinking water standards. What is normally important to note in a series of results from a river, for example, is not the absolute level, but rather the relative levels from one sampling point to another. An increase of even 5 mg/l at one station may give rise to suspicions of a sewage discharge, especially if the free ammonia levels (q.v.) are also elevated. In coastal areas, however, elevated chloride values may be due to sea spray, or sea water

infiltration, and not necessarily to discharges. Normal raw water treatment processes do not remove chloride.

2.0 PRINCIPLE OF TEST METHOD

During the reaction of chloride ions with mercury thiocyanate, the slightly dissociated mercury (II) chloride is formed. Simultaneously, an equivalent amount of thiocyanate ions are set free, which react with iron (III) salts to form iron (III) thiocyanate.

3.0 SCOPE AND LIMITATIONS

The measuring range is 1 - 70 mg/L chloride. The pH and temperature of the sample should be between 3 and 10 and 15 and 25 °C respectively.

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All water samples requiring chloride analysis must have all relevant sample reception procedures completed (See S.O.P. No.: 27194) prior to analysis. No further information is required.

5.0 HAZARDS

Many of the samples undergoing this analysis are processed effluents and therefore care should be taken when handling these. All precautions must be taken to prevent contamination of the samples and the equipment. Normal laboratory procedures should be

adhered to in all cases.

6.0 EQUIPMENT

6.1 Digital Photometer (Dr. Lange LP1W).

6.2 Clock

6.3 470 nm filter

7.0 REAGENTS

7.1 Cuvette Test LCK 311.

8.0 PREPARATION OF REAGENTS

N/A.

9.0 EXPERIMENTAL PROCEDURES

Sample Preparation

Add 1 ml of sample into the cuvette. Shake the cuvette and leave for 3 minutes. Evaluate using the 470 nm filter.

10.0 RECORDING OF RAW DATA

All raw data should be recorded in hard-back lab note-books and should be dated and signed. This information should also be recorded in the chloride analysis sheet
file, signed and dated. Results are also recorded on the appropriate Job Sheet.

11.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either ppm or mg/l. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

12.0 RECORDS

All records are archived and not discarded.

13.0 REFERENCE AND APPENDICES

1. "Parameters of Water Analysis" by the E.R.U.
2. Dr. Lange Cuvette Test kit LCK 311 Information sheet.

S.O.P. No. CAL 025-00	Version No. 00	Page 1 of 6
Applies from: 17/10/05		
S.O.P. Title: Analysis of Phosphate in Water		
Written by: David Matthews		**Date: 27/09/05**

S.O.P. No. CAL 025-00		
Written by: **David Matthews**	**Date:** **27/09/05**	**Expiry Date:**
Technical Approval:	**Date:**	**Status:** **Current**
Authorized by:	**Date:**	
Effective Date: 17/10/05		

Chemical Analysis Laboratory Ltd.,

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Version	Reason for Revision
00	First Edition of S.O.P. 27/09/05

1.0 INTRODUCTION

Phosphorus occurs widely in nature in plants, in micro-organisms, in animal wastes and so on. It is widely used as an agricultural fertiliser and as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are thus important contributors of phosphorus to surface waters.

The significance of phosphorus is principally in regard to the phenomenon of eutrophication (over-enrichment) of lakes and, to a lesser extent, rivers. Phosphorus gaining access to such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variations of great magnitude and related problems, as discussed elsewhere in this volume.

There is considerable debate as to the availability of the various forms of phosphorus (orthophosphate, polyphosphate, organic phosphate and so on) for the growth of algae although it is considered that orthophosphate is the most readily used form. Phosphorus may be in true solution, in colloidal suspension or adsorbed onto particulate matter, and it is very difficult to differentiate between the various fractions by separation (e.g. filtration) or analysis. A useful parameter is orthosphosphate (strictly, total filtrable and non-filtrable orthophosphate) which is the phosphate responding to the analytical procedure without any pre-treatment such as hydrolysis or oxidative digestion. Caution must be exercised in considering the results of phosphorus analysis as the element exists in bound and unbound forms which are very difficult to separate totally in analysis. There is always the likelihood, for example, of some of the bound polyphosphate forms being changed by hydrolysis to

orthophosphate under the actual analytical conditions. However, the determination of orthophosphate as specified is of great use in highlighting the presence of one of the most important nutrients and the results are of special interest in waters receiving sewage discharges.

The importance of controlling phosphorus levels in the Irish aquatic environment is highlighted by the publication (in May 1997) by the Minister for the Environment and Local Government of a 10-year strategy paper entitled *Managing Ireland's Rivers and Lakes – A Catchment-Ba-sed Strategy Against Eutrophication.* This document deals with the topic of phosphorus levels (expressed as mg/l median Molybdate-Reactive Phosphate [MRP] 9) and it sets out interim statutory standards, in terms of MRP, for the year 2007 for water in several quality classes, rivers and lakes being treated separately.

2.0 PRINCIPLE OF TEST METHOD

Phosphate ions react molybdate and antimony ions in an acidic solution to form an antimonyl phosphomolybdenum complex, which is reduced by ascorbic acid to phosphomolybdenum blue.

3.0 SCOPE AND LIMITATIONS

The measuring range is 0.15 – 4.50 mg/l PO_4, 0.05 – 1.50 mg/l PO_4-P and 0.15 – 3.50 P_2O_5. The pH and temperature of the sample should be between 2 and 10, and 15 and 25 °C respectively.

10.0 RECORDING OF RAW DATA

All raw data should be recorded in hard-back lab note-books and should be dated and signed. This information should also be recorded in the Phosphate analysis sheet file, signed and dated. Results are also recorded on the appropriate Job Sheet.

11.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either ppm or mg/l. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

12.0 RECORDS

All records are archived and not discarded.

13.0 REFERENCE AND APPENDICES

1. "Parameters of Water Analysis" by the E.R.U.
2. Dr. Lange Cuvette Test kit LCK 349 Information sheet.

S.O.P. No. CAL 003-01	Version No. 01	Page 1 of 6
Applies from: 07/10/05		
S.O.P. Title: DETERMINATION OF AMMONIUM (2.0 - 47.0mg/l NH_4 - N)		
Written by: Sean Walsh		Date: 30895

S.O.P. No. CAL 002-01		
Written by: Sean Walsh	Date:	Expiry Date:
Technical Approval:	Date:	Status: Current
Authorised by:	Date:	
Effective Date: 7/10/05		

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Version	Reason for Revision
00	First Edition of S.O.P. 3494
01	S.O.P. Update for IMB

1.0 INTRODUCTION

Ammonia is generally present in natural waters, though in very small amounts, as a result of microbiological activity which causes the reduction of nitrogen-containing compounds. When present in levels much above 0.1mg/l NH_4-N, sewage or industrial contamination may be indicated.

2.0 PRINCIPLE OF TEST METHOD

Ammonium ions react at an approximate pH of 12.6 with hypochlorite and salicylate ions in the presence of sodium nitroferricyanide as catalyst to form a green dye (indophenol blue).

3.0 SCOPE AND LIMITATIONS

Samples containing 2.0 - 47.0mg/l Ammonium as Nitrogen (NH_4 - N) and 2.5 - 60mg/l Ammonium (NH_4) may be analysed. The ions listed below have been checked individually up to the levels of concentration indicated. The aggregate effect or the influence of other ions has not been determined. The following do not interfere:

1000mg/l	:	$C1^-$, SO_4^{2-}
500mg/l	:	Na^+, K^+, Ca^{2+}
50mg/l	:	CO_3^{2-}, NO_3^-, Fe^{3+}, Cr^{3+}, Cr^{6+}
		Zn^{2+}, Cu^{2+}, Ni^{2+}, Co^{2+}, Hg^{2+}
25mg/l	:	Fe^{2+}
10mg/l	:	Sn^{2+}
5mg/l	:	Pb^{2+}
2mg/l	:	Ag^+

Primary amines are also detected and produce high results. A 10,000 fold excess of urea has no effect. Any substances that consume chlorine interfere and lead to low results.

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All samples requiring Ammonium analysis must have all relevant sample reception procedures completed (See S.O.P. No : Cal 500-01) prior to analysis. No further information is required.

5.0 HAZARDS

There is little hazard involved in handling of the water samples as most samples are routinely potable water, unless the sample is an effluent. All precautions must be taken to prevent contamination of the samples and the equipment. The reagents are harmful if swallowed. Contact with acid liberates toxic gas, which is irritating to the eyes and respiratory system. Normal laboratory procedures should be adhered to in all cases.

6.0 EQUIPMENT

6.1 Dr. Lange Digital Photometer (model LP1W).

6.2 Dr. Lange Cuvettes.

6.3 Gilson Micropette & Pipette Tips

7.0 REAGENTS

7.1 Cuvette Test LCK 303 containing hypochlorite and salicylate ions at pH 12.6 in the presence of sodium nitroferricyanide.

7.2 Dosicap.

7.3 Cuvette with zero solution.

8.0 PREPARATION OF REAGENTS

8.1 N/A.

9.0 EXPERIMENTAL PROCEDURES

9.1 Procedure.

Pipette 0.2mls sample into the Cuvette Test. Immediately screw on Dosicap, swirl cuvette and turn it upside down several times. Mix Well! Clean the outside of the cuvette well and measure after 15 minutes. Close the Dosicap bottle immediately after use.

9.2 Measurement.

9.2.1 Insert filter 695nm and Adapter.

9.2.2 Enter factor (s. below) and store.

9.2.3 Insert cuvette with zero solution, press the Null Key. Display >0<<.

9.2.4 Insert analysis cuvette. Press "Ergebnis null factor" (Result) key.

10.0 RECORDING OF RAW DATA

All raw data should be recorded in hard-back lab note-books and should be dated and signed. If the results are above the measuring range, the sample should be diluted with distilled water and the analysis repeated. Results are recorded on the appropriate Ammonium (2.5-60.0mg/l NH_4) analysis sheet, dated and signed. Results are also recorded on the appropriate Job Sheet.

11.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either mg/l or ppm Ammonium (NH_4). Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request from the client.

12.0 RECORDS

12.1 All records are archived and not discarded.

13.0 REFERENCE AND APPENDICES

13.1 Dr. Lange Cuvette Test LCK 303 for Ammonium instruction leaflet.

13.2 Parameters of Water Quality, Interpretation and Standards by Environmental Research Unit, 1990.

S.O.P. No. CAL 023-01	Version No. 00	Page 1 of 6
Applies from: 17/10/05		
S.O.P. Title: Analysis of Nitrate in Water		
Written by: David Matthews		**Date: 25/09/05**

S.O.P. No. CAL 023-00		
Written by: **David Matthews**	**Date:** **25/09/05**	**Expiry Date:**
Technical Approval:	**Date:**	**Status:** **Current**
Authorized by:	**Date:**	
Effective Date: 17/10/05		

Chemical Analysis Laboratory Ltd.,

Rear 114 Lower Georges Street,

Dun Laoghaire,

Co Dublin

Version	Reason for Revision
00	First Edition of S.O.P. 250905

1.0 INTRODUCTION

Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centred on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite [see also below] which reacts with blood haemoglobin to cause methaemoglobinaemia.

Of increasing importance is the degree to which fertiliser run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitrate in ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels of fertilisers or manure slurries spread on land. (High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation). In rivers high levels of nitrate are more likely to indicate significant run-off from agricultural land than anything else and the parameter is not of primary importance per se. However, it should be noted that there is a general tendency for nitrate concentrations in rivers to increase as a result of enhanced nutrient run-off; this may ultimately lessen their utility as potential sources of public water supply. Nitrite concentrations in rivers are rarely more than 1 - 2 per cent of the nitrate level so that it may therefore be acceptable to carry out the

analytically convenient determination of nitrate + nitrite at the same time. This determination is correctly referred to as *total oxidised nitrogen.*

2.0 PRINCIPLE OF TEST METHOD

Nitrate ions in solutions containing sulphuric acid and phosphoric acids react with 2, 6-dimethylphenol to form 4-nitro-2, 6-dimethylphenol.

3.0 SCOPE AND LIMITATIONS

The measuring range is 1 – 60 mg/l NO_3. The pH and temperature of the sample should be between 3 and 10, and 20 and 24°C respectively. High levels of oxidizable organic substances (COD) cause the reagent to change colour and to give high-bias results. The test can thus only be used for waste water analysis if the COD is less than 200 mg/L

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All water samples requiring Nitrate Analysis must have all relevant sample reception procedures completed (See S.O.P. No.: 27194) prior to analysis. No further information is required.

5.0 HAZARDS

Many of the samples undergoing this analysis are processed effluents and therefore care should be taken when handling these. All precautions must be taken

to prevent contamination of the samples and the equipment. Normal laboratory procedures should be adhered to in all cases.

6.0 EQUIPMENT

6.1 Digital Photometer (Dr. Lange LP1W).

6.2 339 nm Filter and Adapter.

6.3 Clock Timer.

7.0 REAGENTS

7.1 Cuvette Test LCK 339.

7.2 2-propanol (A).

7.3 Cuvette with Zero Solution.

8.0 PREPARATION OF REAGENTS

N/A.

9.0 EXPERIMENTAL PROCEDURES

9.1 Sample Preparation. Fill Cuvette Test with 1 ml of sample. Add 0.2 ml of Solution A. Shake cuvette. Measure after 15 minutes.

9.2 Sample/Standard Analysis. Insert filter. Enter factor 43 for NO3 or factor 9.71 for NO3-N and store. Insert cuvette with zero solution, press Zero key. Insert analysis cuvette and press Result key.

10.0 RECORDING OF RAW DATA

All raw data should be recorded in hard-back lab note-books and should be dated and signed. This information should also be recorded in the Chlorine analysis sheet file, signed and dated. Results are also recorded on the appropriate Job Sheet.

11.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either ppm or mg/l. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

12.0 RECORDS

All records are archived and not discarded.

13.0 REFERENCE AND APPENDICES

1. "Parameters of Water Analysis" by the E.R.U.

2. Dr. Lange Cuvette Test kit LCK 339 Information sheet.

S.O.P. No. CAL 024-00	Version No. 00	Page 1 of 5
Applies from: 17/10/05		
S.O.P. Title: Analysis of Nitrite in Water		
Written by: David Matthews		**Date: 02/10/05**

S.O.P. No. CAL 024-00		
Written by: **David Matthews**	**Date:** **02/10/05**	**Expiry Date:**
Technical Approval:	**Date:**	**Status:** **Current**
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Effective Date: 17/10/05		

Chemical Analysis Laboratory Ltd.,

Rear 114 Lower Georges Street,

Dun Laoghaire,

Co Dublin

Version	Reason for Revision
00	First Edition of S.O.P. 021005

1.0 INTRODUCTION

Nitrite exists normally in very low concentrations and even in waste treatment plants, effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH3) or more oxidised (nitrate; NO3) forms. Because nitrite is an intermediate in the oxidisation of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.03 mg/l NC). Values greater than this may indicate sewage pollution.

Comments: The significance of nitrite (at the low levels often found in surface waters) is mainly seen as an indicator of possible sewage pollution rather than as a hazard itself although, as mentioned above under "Nitrate" (q.v.), it is nitrite rather than nitrate which is the direct toxicant. There is, accordingly, a stricter limit for nitrite in drinking waters. In addition, nitrites can give rise to the presence of nitrosamines by reaction with organic compounds and there may be carcinogenic
effects.

2.0 PRINCIPLE OF TEST METHOD

Nitrites react with primary aromatic amines in acidic solution to form diazonium salts. These combine with aromatic compounds that contain an amino group or a hydroxyl group to form intensively coloured azo dyes.

3.0 SCOPE AND LIMITATIONS

The measuring range is 0.05 – 2.0 mg/L Nitrite. The pH and temperature of the sample should be between 1 and 15 and 25 °C respectively.

4.0 INFORMATION REQUIRED ON TEST SUBSTANCES

All water samples requiring Nitrite Analysis must have all relevant sample reception procedures completed (See S.O.P. No: CAL 500-01) prior to analysis. No further information is required.

5.0 HAZARDS

Many of the samples undergoing this analysis are processed effluents and therefore care should be taken when handling these. All precautions must be taken to prevent contamination of the samples and the equipment. Normal laboratory procedures should be adhered to in all cases.

6.0 EQUIPMENT

6.1 Digital Photometer (Dr. Lange LP1W).

6.2 535 nm Filter.

6.3 Clock Timer.

7.0 REAGENTS

7.1 Cuvette Test LCK 341.

8.0 PREPARATION OF REAGENTS

N/A.

9.0 EXPERIMENTAL PROCEDURES

Sample Preparation

Insert 535 nm filter. Use distilled water as the blank. Press zero key. Add 2ml of sample to cuvette and shake. Leave for 10 minutes for colour to develop. Insert sample cuvette and press result key. Make a note of the display.

10.0 RECORDING OF RAW DATA

All raw data should be recorded in hard-back lab note-books and should be dated and signed. This information should also be recorded in the Nitrite analysis sheet file, signed and dated. Results are also recorded on the appropriate Job Sheet.

11.0 REPORTING TEST RESULTS

Results are reported from the Job Sheet and are normally expressed in either ppm

or mg/l. Reports are issued only after all results have been checked by the analyst and should be signed and dated. This method of reporting should only be altered following a direct request by the client.

12.0 RECORDS

All records are archived and not discarded.

13.0 REFERENCE AND APPENDICES

1. "Parameters of Water Analysis" by the E.R.U.
2. Dr. Lange Cuvette Test kit LCK 341 Information sheet.

ECLIPSE SCIENTIFIC GROUP

Enumeration of Presumptive Coliforms, Confirmed Coliforms, presumptive *E.coli* and *E. coli* in water by a Single Membrane Filtration Technique

In House Method No. ESGM107

Diagram of Procedure

Water sample, 100ml

↓

Filter through 0.45µm membrane filter under vacuum

↓

Transfer filter to the surface of a pre-poured MLGA plate

↓

Incubate at 30±1°C for 4± 1 hr then at 37±1°C for 14-15 hr

↓

Examine for the presence of typical colonies - report as presumptive coliforms / *E.coli* or carry out confirmation test.

Confirmation : Lactose Peptone Water and Tryptone Water

References: Microbiology of Drinking Water 2002

VFA Analysis

Outline methodology is as follows :

- Sample ground in presence of dry ice then left to warm up.
- 4 g taken and shaken with 25 ml water to extract.
- Extract centrifuged and filtered through 0.54um membrane to clean up.
- Extract spiked with internal standard of 4-Methylvaleric acid.
- 0.2 ul analysed by GC vs a series of standard solutions containing the 10 analytes measured plus the internal standard spike.
- Run time approximately 13 minutes, all peaks of interest eluted within 8 minutes using ramped GC program with oven between 40 and 200C

Appendix C

FLOW MEASUREMENT DATA

Site A

	C_0	C_1	C_2	C_3
Volume per tip (litres)	0.12	0.11	0.12	0.12
	0.2			

Date	Tips (1)	Tips (2)	Tips (3)	Tips (4)	Reed bed (L d^{-1})	Trenches (L d-1)	Split fraction
01 March 2006	20	43	120	216	21.0	118.6	0.85
02 March 2006	0	274	459	673	30.1	135.8	0.82
03 March 2006	154	660	910	1177	91.1	250.4	0.73
04 March 2006	130	539	719	973	74.9	203.0	0.73
05 March 2006	440	1254	1582	1786	190.7	404.2	0.68
06 March 2006	508	1353	1692	1805	209.8	419.6	0.67
07 March 2006	1382	3106	3833	3678	507.5	901.3	0.64
08 March 2006	1216	2738	3370	3186	447.1	786.7	0.64
09 March 2006	807	1880	2294	2253	303.6	545.6	0.64
10 March 2006	247	689	895	984	105.4	225.5	0.68
11 March 2006	1682	3572	4224	4145	594.8	1004.3	0.63
12 March 2006	704	1817	2312	2169	284.4	537.7	0.65
13 March 2006	1081	2633	3222	2941	419.4	739.6	0.64
14 March 2006	469	1604	2003	1891	232.7	467.3	0.67
15 March 2006	100	1332	1682	1608	158.5	394.8	0.71
16 March 2006	18	1497	1826	1779	166.8	432.6	0.72
17 March 2006	10	1300	1592	1555	144.2	377.6	0.72
18 March 2006	6	928	1114	1130	102.8	269.3	0.72
19 March 2006	6	1134	1473	1342	125.5	337.8	0.73
20 March 2006	4	1871	2419	2190	206.3	553.1	0.73
21 March 2006	0	1057	1314	1330	116.3	317.3	0.73
22 March 2006	0	1645	2061	1943	181.0	480.5	0.73
23 March 2006	0	1183	1450	1396	130.1	341.5	0.72
24 March 2006	25	1760	2150	1910	196.6	487.2	0.71
25 March 2006	0	1288	1602	1457	141.7	367.1	0.72
26 March 2006	0	2710	2741	2478	298.1	626.3	0.68
27 March 2006	0	2797	2430	2194	307.7	554.9	0.64
28 March 2006	0	1093	1189	1130	120.2	278.3	0.70
29 March 2006	0	2500	2869	2612	275.0	657.7	0.71
30 March 2006	0	3183	3459	3441	350.1	828.0	0.70
31 March 2006	160	2045	2045	1916	244.2	475.3	0.66
01 April 2006	1260	1576	1475	1463	324.6	352.6	0.52
02 April 2006	1695	2241	1971	1996	449.9	476.0	0.51
03 April 2006	2404	3237	2648	2681	644.6	639.5	0.50
04 April 2006	1140	1563	1221	1314	308.7	304.2	0.50
05 April 2006	1598	1892	1752	1793	399.9	425.4	0.52
06 April 2006	1182	1075	1365	1742	260.1	372.8	0.59
07 April 2006	1486	1334	1627	1869	325.1	419.5	0.56
08 April 2006	446	355	479	891	92.6	164.4	0.64
09 April 2006	538	443	613	1185	113.3	215.8	0.66
10 April 2006	595	473	635	1178	123.4	217.6	0.64
11 April 2006	1759	1568	1997	2267	383.6	511.7	0.57
12 April 2006	1723	1498	1867	2138	371.5	480.6	0.56
13 April 2006	1038	1047	1257	1505	239.7	331.4	0.58
14 April 2006	1247	1307	1625	1615	293.4	388.8	0.57
15 April 2006	1024	1071	1318	1299	240.7	314.0	0.57
16 April 2006	1000	1005	1260	1296	230.6	306.7	0.57
17 April 2006	1449	1401	1879	1737	328.0	433.9	0.57
18 April 2006	1165	1132	1517	1454	264.3	356.5	0.57
19 April 2006	1429	1396	1819	1798	325.0	434.0	0.57
20 April 2006	836	884	1068	1174	197.6	269.0	0.58
21 April 2006	1023	1108	1299	1350	244.6	317.9	0.57
22 April 2006	923	1004	1229	1270	221.2	299.9	0.58
23 April 2006	1172	1077	1257	1334	259.1	310.9	0.55
24 April 2006	1014	910	1082	1165	221.8	269.6	0.55
25 April 2006	883	784	964	1057	192.2	242.5	0.56
26 April 2006	1365	1079	1526	1534	282.5	367.2	0.57
27 April 2006	1191	1056	1364	1339	259.1	324.4	0.56
28 April 2006	1490	1282	1604	1581	319.8	382.2	0.54
29 April 2006	698	647	745	876	154.9	194.5	0.56
30 April 2006	1497	1350	1695	1692	328.1	406.4	0.55
01 May 2006	1303	1218	1592	1606	290.3	383.8	0.57

02 May 2006	1235	1096	1426	1475	**268.8**	**348.1**	**0.56**
03 May 2006	2068	1758	2329	2261	**441.5**	**550.8**	**0.56**
04 May 2006	1018	1062	1137	1162	**239.0**	**275.9**	**0.54**
05 May 2006	1578	1625	1791	1770	**368.1**	**427.3**	**0.54**
06 May 2006	636	666	716	766	**149.6**	**177.8**	**0.54**
07 May 2006	860	862	972	968	**198.0**	**232.8**	**0.54**
08 May 2006	1726	1622	2003	1864	**385.5**	**464.0**	**0.55**
09 May 2006	1252	1199	1417	1436	**282.1**	**342.4**	**0.55**
10 May 2006	1948	1851	2274	2013	**437.4**	**514.4**	**0.54**
11 May 2006	913	768	1100	855	**194.0**	**234.6**	**0.55**
12 May 2006	1412	1296	1732	1568	**312.0**	**396.0**	**0.56**
13 May 2006	746	674	988	875	**163.7**	**223.6**	**0.58**
14 May 2006	4356	3033	7058	7112	**856.4**	**1700.4**	**0.67**
15 May 2006	1371	574	1980	1905	**227.7**	**466.2**	**0.67**
16 May 2006	918	347	1609	1131	**148.3**	**328.8**	**0.69**
17 May 2006	0	1245	1894	0	**137.0**	**227.3**	**0.62**
18 May 2006	0	4656	4809	0	**512.2**	**577.1**	**0.53**
19 May 2006	0	1420	1609	0	**156.2**	**193.1**	**0.55**
20 May 2006	0	680	709	0	**74.8**	**85.1**	**0.53**
21 May 2006	0	4226	5406	0	**464.9**	**648.7**	**0.58**
22 May 2006	0	3755	4597	0	**413.1**	**551.6**	**0.57**
23 May 2006	0	1552	1805	0	**170.7**	**216.6**	**0.56**
24 May 2006	0	934	1026	0	**102.7**	**123.1**	**0.55**
25 May 2006	0	1381	1697	0	**151.9**	**203.6**	**0.57**
26 May 2006	0	1868	2350	0	**205.5**	**282.0**	**0.58**
27 May 2006	0	1072	1378	0	**117.9**	**165.4**	**0.58**
28 May 2006	0	1188	1562	0	**130.7**	**187.4**	**0.59**
29 May 2006	0	2093	2633	0	**230.2**	**316.0**	**0.58**
30 May 2006	0	1695	2060	0	**186.5**	**247.2**	**0.57**
31 May 2006	0	1708	2102	0	**187.9**	**252.2**	**0.57**
01 June 2006	0	919	1088	0	**101.1**	**130.6**	**0.56**
02 June 2006	0	1529	1973	0	**168.2**	**236.8**	**0.58**
03 June 2006	0	1639	1953	0	**180.3**	**234.4**	**0.57**
04 June 2006	0	1262	1463	0	**138.8**	**175.6**	**0.56**
05 June 2006	0	1577	1905	0	**173.5**	**228.6**	**0.57**
06 June 2006	0	2193	2791	0	**241.2**	**334.9**	**0.58**
07 June 2006	179	1322	1827	0	**166.9**	**219.2**	**0.57**
08 June 2006	0	1237	1410	0	**136.1**	**169.2**	**0.55**
09 June 2006	0	1792	2146	0	**197.1**	**257.5**	**0.57**
10 June 2006	0	1250	1425	0	**137.5**	**171.0**	**0.55**
11 June 2006	0	1194	1515	0	**131.3**	**181.8**	**0.58**
12 June 2006	0	1921	2415	0	**211.3**	**289.8**	**0.58**
13 June 2006	0	1675	2204	0	**184.3**	**264.5**	**0.59**
14 June 2006	0	1154	1481	0	**126.9**	**177.7**	**0.58**
15 June 2006	0	1380	1625	0	**151.8**	**195.0**	**0.56**
16 June 2006	506	1022	1291	742	**173.1**	**244.0**	**0.58**
17 June 2006	1285	1674	1494	1686	**338.3**	**381.6**	**0.53**
18 June 2006	1593	1854	1852	1643	**395.1**	**419.4**	**0.51**
19 June 2006	1527	1567	1767	1531	**355.6**	**395.8**	**0.53**
20 June 2006	1441	1445	1669	1450	**331.9**	**374.3**	**0.53**
21 June 2006	1898	1881	2207	1754	**434.7**	**475.3**	**0.52**
22 June 2006	1098	1163	1310	1012	**259.7**	**278.6**	**0.52**
23 June 2006	1227	1370	1927	1479	**297.9**	**408.7**	**0.58**
24 June 2006	0	0	1419	935	**0.0**	**282.5**	**1.00**
25 June 2006	2	0	2780	2664	**0.2**	**653.3**	**1.00**
26 June 2006	25	0	4108	3413	**3.0**	**902.5**	**1.00**
27 June 2006	32	0	2604	2626	**3.8**	**627.6**	**0.99**
28 June 2006	534	11	2982	2734	**65.3**	**685.9**	**0.91**
29 June 2006	1460	194	1585	1665	**196.5**	**390.0**	**0.66**
30 June 2006	880	1076	928	1102	**224.0**	**243.6**	**0.52**
01 July 2006	1726	2092	1874	414	**437.2**	**274.6**	**0.39**
02 July 2006	991	1117	1059	1247	**241.8**	**276.7**	**0.53**

03 July 2006	2131	2203	2179	2345	**498.1**	**542.9**	**0.52**
04 July 2006	1744	2059	2069	2176	**435.8**	**509.4**	**0.54**
05 July 2006	673	1691	1767	1759	**266.8**	**423.1**	**0.61**
06 July 2006	462	2016	2154	2068	**277.2**	**506.6**	**0.65**
07 July 2006	1525	2038	2263	1983	**407.2**	**509.5**	**0.56**
08 July 2006	590	896	738	677	**169.4**	**169.8**	**0.50**
09 July 2006	794	1083	1058	966	**214.4**	**242.9**	**0.53**
10 July 2006	1854	2957	3150	3032	**547.8**	**741.8**	**0.58**
11 July 2006	1514	2036	1894	1985	**405.6**	**465.5**	**0.53**
12 July 2006	1044	1735	1628	1774	**316.1**	**408.2**	**0.56**
13 July 2006	1232	1328	1380	1451	**293.9**	**339.7**	**0.54**
14 July 2006	903	896	929	1050	**206.9**	**237.5**	**0.53**
15 July 2006	1132	1271	1365	1401	**275.7**	**331.9**	**0.55**
16 July 2006	1818	1792	2206	2005	**415.3**	**505.3**	**0.55**
17 July 2006	1477	1491	1844	1784	**341.3**	**435.4**	**0.56**
18 July 2006	1663	1969	2355	2364	**416.2**	**566.3**	**0.58**
19 July 2006	962	1266	1447	1443	**254.7**	**346.8**	**0.58**
20 July 2006	1156	1695	1712	1582	**325.2**	**395.3**	**0.55**
21 July 2006	1119	1488	1777	1409	**298.0**	**382.3**	**0.56**
22 July 2006	1234	1533	2082	1665	**316.7**	**449.6**	**0.59**
23 July 2006	1718	1898	2685	2604	**414.9**	**634.7**	**0.60**
24 July 2006	1587	1606	2178	2183	**367.1**	**523.3**	**0.59**
25 July 2006	1614	1404	1934	1688	**348.1**	**434.6**	**0.56**
26 July 2006	2207	2287	2511	2575	**516.4**	**610.3**	**0.54**
27 July 2006	1418	1886	1651	1744	**377.6**	**407.4**	**0.52**
28 July 2006	1569	2052	1864	1878	**414.0**	**449.0**	**0.52**
29 July 2006	661	885	685	840	**176.7**	**183.0**	**0.51**
30 July 2006	1866	2566	2451	2668	**506.2**	**614.3**	**0.55**
31 July 2006	869	1201	1013	1279	**236.4**	**275.0**	**0.54**
01 August 2006	963	1203	1123	1165	**247.9**	**274.6**	**0.53**
02 August 2006	1222	1430	1401	1405	**303.9**	**336.7**	**0.53**
03 August 2006	914	974	1022	913	**216.8**	**232.2**	**0.52**
04 August 2006	1209	1200	1412	1157	**277.1**	**308.3**	**0.53**
05 August 2006	1706	1984	2118	2071	**423.0**	**502.7**	**0.54**
06 August 2006	1029	1156	1435	1400	**250.6**	**340.2**	**0.58**
07 August 2006	705	899	931	936	**183.5**	**224.0**	**0.55**
08 August 2006	309	510	356	334	**93.2**	**82.8**	**0.47**
09 August 2006	1246	1613	1614	1443	**327.0**	**366.8**	**0.53**
10 August 2006	1086	1231	1168	1116	**265.7**	**274.1**	**0.51**
11 August 2006	656	673	644	669	**152.8**	**157.6**	**0.51**
12 August 2006	439	394	345	493	**96.0**	**100.6**	**0.51**
13 August 2006	1258	1042	1407	1208	**265.6**	**313.8**	**0.54**
14 August 2006	1532	1350	1729	1648	**332.3**	**405.2**	**0.55**
15 August 2006	1350	949	1393	1354	**266.4**	**329.6**	**0.55**
16 August 2006	2171	1965	2435	2137	**476.7**	**548.6**	**0.54**
17 August 2006	1977	1969	2476	1967	**453.8**	**533.2**	**0.54**
18 August 2006	957	927	1382	1064	**216.8**	**293.5**	**0.58**
19 August 2006	1613	1900	2418	1890	**402.6**	**517.0**	**0.56**
20 August 2006	1648	1804	2333	1905	**396.2**	**508.6**	**0.56**
21 August 2006	992	982	1529	1224	**227.1**	**330.4**	**0.59**
22 August 2006	191	197	307	243	**44.6**	**66.0**	**0.60**
23 August 2006	718	655	855	730	**158.2**	**190.2**	**0.55**
24 August 2006	401	328	342	301	**84.2**	**77.2**	**0.48**
25 August 2006	1553	1073	1702	1815	**304.4**	**422.0**	**0.58**
26 August 2006	956	321	1122	1332	**150.0**	**294.5**	**0.66**
27 August 2006	1132	565	1462	1322	**198.0**	**334.1**	**0.63**
28 August 2006	1480	889	1963	1496	**275.4**	**415.1**	**0.60**
29 August 2006	425	228	2075	1878	**76.1**	**474.4**	**0.86**
30 August 2006	609	695	1990	1876	**149.5**	**463.9**	**0.76**
31 August 2006	1955	2266	2348	2380	**483.9**	**567.4**	**0.54**
01 September 2006	1688	1883	1928	1881	**409.7**	**457.1**	**0.53**
02 September 2006	1414	1632	1618	1522	**349.2**	**376.8**	**0.52**
03 September 2006	1178	1248	1263	1197	**278.6**	**295.2**	**0.51**

04 September 2006	647	622	625	584	**146.1**	**145.1**	**0.50**
05 September 2006	1393	1734	1640	1761	**357.9**	**408.1**	**0.53**
06 September 2006	1177	1354	1360	1572	**290.2**	**351.8**	**0.55**
07 September 2006	1144	1285	1342	1524	**278.6**	**343.9**	**0.55**
08 September 2006	1197	1356	1423	2037	**292.8**	**415.2**	**0.59**
09 September 2006	331	329	267	671	**75.9**	**112.6**	**0.60**
10 September 2006	884	1130	1134	1857	**230.4**	**358.9**	**0.61**
11 September 2006	990	1459	1259	2458	**279.3**	**446.0**	**0.61**
12 September 2006	1152	1313	1278	2244	**282.7**	**422.6**	**0.60**
13 September 2006	940	1060	1140	1828	**229.4**	**356.2**	**0.61**
14 September 2006	1242	1158	1334	2344	**276.4**	**441.4**	**0.61**
15 September 2006	1257	1309	1524	2519	**294.8**	**485.2**	**0.62**
16 September 2006	585	611	723	1426	**137.4**	**257.9**	**0.65**
17 September 2006	1214	1395	1390	1493	**299.1**	**346.0**	**0.54**
18 September 2006	1321	1678	1645	2700	**343.1**	**521.4**	**0.60**
19 September 2006	1926	2354	2361	2785	**490.1**	**617.5**	**0.56**
20 September 2006	958	1290	1239	1184	**256.9**	**290.8**	**0.53**
21 September 2006	343	531	526	785	**99.6**	**157.3**	**0.61**
22 September 2006	891	954	1072	1189	**211.9**	**271.3**	**0.56**
23 September 2006	1184	1354	1321	1675	**291.0**	**359.5**	**0.55**
24 September 2006	1399	1396	1551	1629	**321.4**	**381.6**	**0.54**
25 September 2006	1262	1247	1446	1636	**288.6**	**369.8**	**0.56**
26 September 2006	1637	1789	2070	1386	**393.2**	**414.7**	**0.51**
27 September 2006	874	908	1146	989	**204.8**	**256.2**	**0.56**
28 September 2006	805	959	1160	1143	**202.1**	**276.4**	**0.58**
29 September 2006	619	711	883	926	**152.5**	**217.1**	**0.59**
30 September 2006	1720	1950	2308	1769	**420.9**	**489.2**	**0.54**
01 October 2006	1085	1104	1464	1095	**251.6**	**307.1**	**0.55**
02 October 2006	1500	1188	1984	953	**310.7**	**352.4**	**0.53**
03 October 2006	1495	520	1696	694	**236.6**	**286.8**	**0.55**
04 October 2006	1962	1027	3072	1472	**348.4**	**545.3**	**0.61**
05 October 2006	811	329	2031	763	**133.5**	**335.3**	**0.72**
06 October 2006	1138	464	2238	1101	**187.6**	**400.7**	**0.68**
07 October 2006	597	667	1302	1137	**145.0**	**292.7**	**0.67**
08 October 2006	1531	1778	2721	2235	**379.3**	**594.7**	**0.61**
09 October 2006	1931	1906	3771	1265	**441.4**	**604.3**	**0.58**
10 October 2006	590	587	1969	424	**135.4**	**287.2**	**0.68**
11 October 2006	1349	1346	3163	1003	**309.9**	**499.9**	**0.62**
12 October 2006	903	904	1704	724	**207.8**	**291.4**	**0.58**
13 October 2006	682	743	1772	788	**163.6**	**307.2**	**0.65**
14 October 2006	1318	968	2299	862	**264.6**	**379.3**	**0.59**
15 October 2006	1877	1070	2176	1000	**342.9**	**381.1**	**0.53**
16 October 2006	1464	739	1588	1213	**257.0**	**336.1**	**0.57**
17 October 2006	1442	784	1611	1303	**259.3**	**349.7**	**0.57**
18 October 2006	1395	745	1552	1306	**249.4**	**343.0**	**0.58**
19 October 2006							
20 October 2006	1142	535	1270	929	**195.9**	**263.9**	**0.57**
21 October 2006	1194	1051	1405	1222	**258.9**	**315.2**	**0.55**
22 October 2006	1086	1526	1232	847	**298.2**	**249.5**	**0.46**
23 October 2006	1332	1791	1609	897	**356.9**	**300.7**	**0.46**
24 October 2006	790	1212	1030	574	**228.1**	**192.5**	**0.46**
25 October 2006	1284	1778	1719	900	**349.7**	**314.3**	**0.47**
26 October 2006	1076	1375	1699	735	**280.4**	**292.1**	**0.51**
27 October 2006	1127	1038	1797	842	**249.4**	**316.7**	**0.56**
28 October 2006	565	528	951	442	**125.9**	**167.2**	**0.57**
29 October 2006	1700	2382	2562	1324	**466.0**	**466.3**	**0.50**
30 October 2006	1362	1910	1963	1017	**373.5**	**357.6**	**0.49**
31 October 2006	931	1285	1391	658	**253.1**	**245.9**	**0.49**
01 November 2006	985	1404	1553	663	**272.6**	**265.9**	**0.49**
02 November 2006	858	1170	1486	639	**231.7**	**255.0**	**0.52**
03 November 2006	724	1118	1354	588	**209.9**	**233.0**	**0.53**
04 November 2006	938	1430	1638	708	**269.9**	**281.5**	**0.51**

05 November 2006	1993	2863	2993	1623	**554.1**	**553.9**	**0.50**
06 November 2006	1070	1756	1869	1023	**321.6**	**347.0**	**0.52**
07 November 2006	544	955	904	634	**170.3**	**184.6**	**0.52**
08 November 2006	1121	1834	2099	1200	**336.3**	**395.9**	**0.54**
09 November 2006	453	1263	1072	854	**193.3**	**231.1**	**0.54**
10 November 2006	645	1854	1387	1221	**281.3**	**313.0**	**0.53**
11 November 2006	377	1277	886	821	**185.7**	**204.8**	**0.52**
12 November 2006	954	2727	1964	1603	**414.5**	**428.0**	**0.51**
13 November 2006	1487	3357	2608	1953	**547.7**	**547.3**	**0.50**
14 November 2006	1023	2574	1991	957	**405.9**	**353.8**	**0.47**
15 November 2006	714	1885	1701	739	**293.0**	**292.8**	**0.50**
16 November 2006	416	1151	1002	574	**176.5**	**189.1**	**0.52**
17 November 2006	513	1513	1016	606	**228.0**	**194.6**	**0.46**
18 November 2006	950	1983	1616	1126	**332.1**	**329.0**	**0.50**
19 November 2006	801	1409	1570	900	**251.1**	**296.4**	**0.54**
20 November 2006	1114	1876	1996	1195	**340.0**	**382.9**	**0.53**
21 November 2006	657	1175	1206	810	**208.1**	**241.9**	**0.54**
22 November 2006	607	1191	1198	816	**203.9**	**241.7**	**0.54**
23 November 2006	507	940	978	654	**164.2**	**195.8**	**0.54**
24 November 2006	462	958	1029	685	**160.8**	**205.7**	**0.56**
25 November 2006	891	1527	1638	1126	**274.9**	**331.7**	**0.55**
26 November 2006	861	1417	1516	977	**259.2**	**299.2**	**0.54**
27 November 2006	727	1221	1431	975	**221.6**	**288.7**	**0.57**
28 November 2006	596	802	1185	751	**159.7**	**232.3**	**0.59**
29 November 2006	901	854	1608	928	**202.1**	**304.3**	**0.60**
30 November 2006	1029	579	2057	1044	**187.2**	**372.1**	**0.67**
01 December 2006	409	196	859	499	**70.6**	**163.0**	**0.70**
02 December 2006	1271	838	2125	1081	**244.7**	**384.7**	**0.61**
03 December 2006	2192	925	3470	1564	**364.8**	**604.1**	**0.62**
04 December 2006	3176	1766	4885	2269	**575.4**	**858.5**	**0.60**
05 December 2006	3307	1829	6228	2267	**598.0**	**1019.4**	**0.63**
06 December 2006	2773	992	4128	1640	**441.9**	**692.2**	**0.61**
07 December 2006	8117	5247	9736	3925	**1551.2**	**1639.3**	**0.51**
08 December 2006	7055	3846	8541	3541	**1269.7**	**1449.8**	**0.53**
09 December 2006	5315	2507	6761	2136	**913.6**	**1067.6**	**0.54**
10 December 2006	7248	4058	8436	3051	**1316.1**	**1378.4**	**0.51**
11 December 2006	9092	5436	10664	4187	**1689.0**	**1782.1**	**0.51**
12 December 2006	5654	4713	8071	2597	**1196.9**	**1280.2**	**0.52**
13 December 2006							
14 December 2006							
15 December 2006							
16 December 2006							
17 December 2006							
18 December 2006							
19 December 2006							
20 December 2006	1052	1320	1118	2564	**271.4**	**441.8**	**0.62**
21 December 2006	1243	1525	823	2036	**316.9**	**343.1**	**0.52**
22 December 2006	1732	2155	1213	2923	**444.9**	**496.3**	**0.53**
23 December 2006	905	1100	601	1584	**229.6**	**262.2**	**0.53**
24 December 2006	622	753	438	1113	**157.5**	**186.1**	**0.54**
25 December 2006	1625	2101	1415	3255	**426.1**	**560.4**	**0.57**
26 December 2006	1617	2107	1335	3381	**425.8**	**565.9**	**0.57**
27 December 2006	1346	1719	1394	3755	**350.6**	**617.9**	**0.64**
28 December 2006	624	798	716	2040	**162.7**	**330.7**	**0.67**
29 December 2006	803	1166	915	2689	**224.6**	**432.5**	**0.66**
30 December 2006	789	1112	899	2748	**217.0**	**437.6**	**0.67**
31 December 2006	1338	1817	1402	4128	**360.4**	**663.6**	**0.65**
01 January 2007	1130	1683	1317	3303	**320.7**	**554.4**	**0.63**
02 January 2007	48	66	68	311	**13.0**	**45.5**	**0.78**
03 January 2007	18	16	14	259	**3.9**	**32.8**	**0.89**
04 January 2007	619	779	647	2025	**160.0**	**320.6**	**0.67**
05 January 2007	878	1102	755	2852	**226.6**	**432.8**	**0.66**

06 January 2007	815	1103	627	2796	**219.1**	**410.8**	**0.65**
07 January 2007	1361	1993	1433	4108	**382.6**	**664.9**	**0.63**
08 January 2007	904	1267	1113	3356	**247.9**	**536.3**	**0.68**
09 January 2007	1353	1906	1518	4399	**372.0**	**710.0**	**0.66**
10 January 2007	1291	2372	1345	3765	**415.8**	**613.2**	**0.60**
11 January 2007	1696	3048	1612	4409	**538.8**	**722.5**	**0.57**
12 January 2007	1204	2233	1070	3187	**390.1**	**510.8**	**0.57**
13 January 2007	1447	2516	1098	3510	**450.4**	**553.0**	**0.55**
14 January 2007	2008	3397	1411	4881	**614.6**	**755.0**	**0.55**
15 January 2007	2076	3399	1436	5871	**623.0**	**876.8**	**0.58**
16 January 2007	1490	2459	874	4643	**449.3**	**662.0**	**0.60**
17 January 2007	969	1387	371	3204	**268.9**	**429.0**	**0.61**
18 January 2007	3707	5392	2446	10398	**1038.0**	**1541.3**	**0.60**
19 January 2007	2702	2619	1916	7132	**612.3**	**1085.8**	**0.64**
20 January 2007	3548	3213	2590	9348	**779.2**	**1432.6**	**0.65**
21 January 2007	4497	3852	2954	11333	**963.4**	**1714.4**	**0.64**
22 January 2007	2340	1537	1455	6391	**449.9**	**941.5**	**0.68**
23 January 2007	3313	2450	2321	8730	**667.1**	**1326.1**	**0.67**
24 January 2007	1731	1596	1623	6255	**383.3**	**945.4**	**0.71**
25 January 2007	1868	1056	1397	4697	**340.3**	**731.3**	**0.68**
26 January 2007	1550	465	888	3277	**237.2**	**499.8**	**0.68**
27 January 2007	1166	676	845	2372	**214.3**	**386.0**	**0.64**
28 January 2007	1679	934	1181	3045	**304.2**	**507.1**	**0.63**
29 January 2007	1441	482	895	2224	**225.9**	**374.3**	**0.62**
30 January 2007	2031	1124	1306	3348	**367.4**	**558.5**	**0.60**
31 January 2007	1743	1073	976	2183	**327.2**	**379.1**	**0.54**
01 February 2007	1871	1633	850	1662	**404.2**	**301.4**	**0.43**
02 February 2007	1547	1708	1119	2190	**373.5**	**397.1**	**0.52**
03 February 2007	861	907	784	1498	**203.1**	**273.8**	**0.57**
04 February 2007	1131	1307	1036	2043	**279.5**	**369.5**	**0.57**
05 February 2007	736	655	635	1221	**160.4**	**222.7**	**0.58**
06 February 2007	1451	1665	1220	2333	**357.3**	**426.4**	**0.54**
07 February 2007	1605	1780	1208	2418	**388.4**	**435.1**	**0.53**
08 February 2007	1738	2005	1371	2550	**429.1**	**470.5**	**0.52**
09 February 2007	1556	1863	1267	2281	**391.7**	**425.8**	**0.52**
10 February 2007	1189	1468	904	1536	**304.2**	**292.8**	**0.49**
11 February 2007	1634	2087	1344	2258	**425.7**	**432.2**	**0.50**
12 February 2007	2503	3421	2740	4681	**676.7**	**890.5**	**0.57**
13 February 2007	1355	1745	1832	3251	**354.6**	**610.0**	**0.63**
14 February 2007	678	793	882	1705	**168.6**	**310.4**	**0.65**
15 February 2007	1177	1854	1518	2967	**345.2**	**538.2**	**0.61**
16 February 2007	753	1052	987	2000	**206.1**	**358.4**	**0.63**
17 February 2007	876	1357	1275	2182	**254.4**	**414.8**	**0.62**
18 February 2007	728	979	1428	1931	**195.1**	**403.1**	**0.67**
19 February 2007	1277	1769	2560	3976	**347.8**	**784.3**	**0.69**
20 February 2007	860	1213	2382	3806	**236.6**	**742.6**	**0.76**
21 February 2007	655	892	1874	3015	**176.7**	**586.7**	**0.77**
22 February 2007	765	1185	2297	3855	**222.2**	**738.2**	**0.77**
23 February 2007	901	1516	2216	4182	**274.9**	**767.8**	**0.74**
24 February 2007	581	962	1780	3664	**175.5**	**653.3**	**0.79**
25 February 2007	1148	1890	2514	5168	**345.7**	**921.8**	**0.73**
26 February 2007	1107	1729	2341	5052	**323.0**	**887.2**	**0.73**
27 February 2007	1402	2804	2676	6427	**476.7**	**1092.4**	**0.70**
28 February 2007	972	1896	2138	4247	**325.2**	**766.2**	**0.70**
01 March 2007	861	1185	2336	3784	**233.7**	**734.4**	**0.76**
02 March 2007	661	1172	2180	3456	**208.2**	**676.3**	**0.76**
03 March 2007	404	1076	2243	3270	**166.8**	**661.6**	**0.80**
04 March 2007	1074	2682	3323	4760	**423.9**	**970.0**	**0.70**
05 March 2007	1328	3200	3745	4734	**511.4**	**1017.5**	**0.67**
06 March 2007	779	1977	2690	3573	**311.0**	**751.6**	**0.71**

07 March 2007	795	2848	2639	3538	**408.7**	**741.2**	**0.64**
08 March 2007	890	2917	2755	3695	**427.7**	**774.0**	**0.64**
09 March 2007	1208	3892	2936	3022	**573.1**	**715.0**	**0.56**
10 March 2007	1643	5026	3421	3573	**750.0**	**839.3**	**0.53**
11 March 2007	1188	3091	2368	2469	**482.6**	**580.4**	**0.55**
12 March 2007	1759	3915	2889	2526	**641.7**	**649.8**	**0.50**
13 March 2007	2375	7432	4143	1071	**1102.5**	**625.7**	**0.36**
14 March 2007	823	8512	3890	2454	**1035.1**	**761.3**	**0.42**
15 March 2007	626	5905	2691	4976	**724.7**	**920.0**	**0.56**
16 March 2007	600	5868	2581	3627	**717.5**	**745.0**	**0.51**
17 March 2007	958	7302	3548	3384	**918.2**	**831.8**	**0.48**
18 March 2007	911	6445	2628	1095	**818.3**	**446.8**	**0.35**
19 March 2007	442	4585	1928	438	**557.4**	**283.9**	**0.34**
20 March 2007	370	4087	2094	1659	**494.0**	**450.4**	**0.48**
21 March 2007	923	5728	3112	4131	**740.8**	**869.2**	**0.54**
22 March 2007	1440	6855	4167	10154	**926.9**	**1718.5**	**0.65**
23 March 2007	1440	6407	3168	8044	**877.6**	**1345.4**	**0.61**
24 March 2007	1440	5559	3108	6831	**784.3**	**1192.7**	**0.60**
25 March 2007	1440	7754	3011	6242	**1025.7**	**1110.4**	**0.52**
26 March 2007							
27 March 2007							
28 March 2007							
29 March 2007							
30 March 2007							
31 March 2007							
01 April 2007							
02 April 2007							
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13 April 2007							
14 April 2007							
15 April 2007							
16 April 2007							
17 April 2007							
18 April 2007							
19 April 2007	327	3470	2363	1010	**420.9**	**404.8**	**0.49**
20 April 2007	350	1516	909	461	**208.8**	**164.4**	**0.44**
21 April 2007	62	1188	577	151	**138.1**	**87.4**	**0.39**
22 April 2007	130	1965	1082	444	**231.8**	**183.1**	**0.44**
23 April 2007	24	1810	690	354	**202.0**	**125.3**	**0.38**
24 April 2007	8	2673	1447	719	**295.0**	**259.9**	**0.47**
25 April 2007	1192	2108	1192	453	**375.0**	**197.4**	**0.34**
26 April 2007	1256	2088	1359	496	**380.4**	**222.6**	**0.37**
27 April 2007	551	1063	567	111	**183.0**	**81.4**	**0.31**
28 April 2007	956	1560	1042	396	**286.3**	**172.6**	**0.38**
29 April 2007	864	1444	874	395	**262.5**	**152.3**	**0.37**
30 April 2007	2027	2986	2246	1099	**571.7**	**401.4**	**0.41**
01 May 2007	1238	1929	1363	584	**360.8**	**233.6**	**0.39**
02 May 2007	274	576	266	27	**96.2**	**35.2**	**0.27**
03 May 2007	1190	1502	1597	597	**308.1**	**263.3**	**0.46**
04 May 2007	1211	1406	1666	679	**300.0**	**281.4**	**0.48**
05 May 2007	1059	1202	1610	464	**259.3**	**248.9**	**0.49**
06 May 2007	741	1361	1899	645	**238.6**	**305.3**	**0.56**
07 May 2007	1863	2349	2068	819	**482.0**	**346.4**	**0.42**
08 May 2007	1715	2009	1711	606	**426.8**	**278.0**	**0.39**
09 May 2007	1231	1349	880	297	**296.1**	**141.2**	**0.32**
10 May 2007	1942	1808	1558	540	**431.9**	**251.8**	**0.37**

11 May 2007	1281	1134	813	294	**278.5**	**132.8**	**0.32**
12 May 2007	1091	904	577	127	**230.4**	**84.5**	**0.27**
13 May 2007	1060	897	615	168	**225.9**	**94.0**	**0.29**
14 May 2007	2092	2325	2240	765	**506.8**	**360.6**	**0.42**
15 May 2007	1278	1977	1387	571	**370.8**	**235.0**	**0.39**
16 May 2007	1324	2213	1685	1153	**402.3**	**340.6**	**0.46**
17 May 2007	842	2116	1143	983	**333.8**	**255.1**	**0.43**
18 May 2007	536	1541	1011	781	**233.8**	**215.0**	**0.48**
19 May 2007	236	793	409	278	**115.6**	**82.4**	**0.42**
20 May 2007	312	1505	914	565	**203.0**	**177.5**	**0.47**
21 May 2007	876	1357	742	561	**254.4**	**156.4**	**0.38**
22 May 2007	1292	1917	1023	797	**365.9**	**218.4**	**0.37**
23 May 2007	630	1835	1450	919	**277.5**	**284.3**	**0.51**
24 May 2007	228	1297	1070	609	**170.0**	**201.5**	**0.54**
25 May 2007	120	1395	593	248	**167.9**	**100.9**	**0.38**
26 May 2007	106	762	273	129	**96.5**	**48.2**	**0.33**
27 May 2007	208	1759	678	492	**218.5**	**140.4**	**0.39**
28 May 2007	432	1664	668	555	**234.9**	**146.8**	**0.38**
29 May 2007	588	2151	735	747	**307.2**	**177.8**	**0.37**
30 May 2007	164	1759	364	393	**213.2**	**90.8**	**0.30**
31 May 2007	88	1639	190	309	**190.9**	**59.9**	**0.24**
01 June 2007	166	1879	458	439	**226.6**	**107.6**	**0.32**
02 June 2007	44	1862	264	279	**210.1**	**65.2**	**0.24**
03 June 2007	12	2119	250	239	**234.5**	**58.7**	**0.20**
04 June 2007	152	2249	250	552	**265.6**	**96.2**	**0.27**
05 June 2007	522	2783	278	697	**368.8**	**117.0**	**0.24**
06 June 2007	164	1539	83	131	**189.0**	**25.7**	**0.12**
07 June 2007	408	2199	96	487	**290.9**	**70.0**	**0.19**
08 June 2007	156	2156	204	222	**255.9**	**51.1**	**0.17**
09 June 2007	548	3282	1381	623	**426.8**	**240.5**	**0.36**
10 June 2007	392	2563	770	286	**329.0**	**126.7**	**0.28**
11 June 2007	622	3126	561	714	**418.5**	**153.0**	**0.27**
12 June 2007	575	3121	448	1031	**412.3**	**177.5**	**0.30**
13 June 2007	1070	1675	982	1587	**312.7**	**308.3**	**0.50**
14 June 2007	628	1081	588	243	**194.3**	**99.7**	**0.34**
15 June 2007	1122	1938	987	189	**347.8**	**141.1**	**0.29**
16 June 2007	1076	1792	929	131	**326.2**	**127.2**	**0.28**
17 June 2007	786	1647	276	39	**275.5**	**37.8**	**0.12**
18 June 2007	544	1235	486	31	**201.1**	**62.0**	**0.24**
19 June 2007	668	1592	545	111	**255.3**	**78.7**	**0.24**
20 June 2007	1092	1951	639	72	**345.7**	**85.3**	**0.20**
21 June 2007	572	1196	215	108	**200.2**	**38.8**	**0.16**
22 June 2007	618	1498	483	176	**238.9**	**79.1**	**0.25**
23 June 2007	496	531	226	652	**117.9**	**105.4**	**0.47**
24 June 2007	524	882	325	521	**159.9**	**101.5**	**0.39**
25 June 2007	1334	1357	1034	1210	**309.4**	**269.3**	**0.47**
26 June 2007	1194	1990	1635	3276	**362.2**	**589.3**	**0.62**
27 June 2007	1318	2566	2198	3719	**440.4**	**710.0**	**0.62**
28 June 2007	574	1173	1312	2590	**197.9**	**468.2**	**0.70**
29 June 2007	612	1671	864	1670	**257.3**	**304.1**	**0.54**
30 June 2007	156	834	468	409	**110.5**	**105.2**	**0.49**
01 July 2007	62	895	313	60	**105.9**	**44.8**	**0.30**
02 July 2007	1108	2929	689	162	**455.2**	**102.1**	**0.18**
03 July 2007	1633	2516	590	317	**472.7**	**108.8**	**0.19**
04 July 2007	461	1437	276	72	**213.4**	**41.8**	**0.16**
05 July 2007	212	1215	183	39	**159.1**	**26.6**	**0.14**
06 July 2007	902	2284	1121	159	**359.5**	**153.6**	**0.30**
07 July 2007	608	872	726	145	**168.9**	**104.5**	**0.38**
08 July 2007	296	550	486	212	**96.0**	**83.8**	**0.47**
09 July 2007	708	1048	1050	684	**200.2**	**208.1**	**0.51**
10 July 2007	342	525	811	1453	**98.8**	**271.7**	**0.73**
11 July 2007	712	1215	0	1021	**219.0**	**122.5**	**0.36**
12 July 2007	757	894	807	645	**189.2**	**174.2**	**0.48**
13 July 2007	877	1135	1246	345	**230.1**	**190.9**	**0.45**
14 July 2007	666	950	1058	70	**184.5**	**135.4**	**0.42**
15 July 2007	641	777	1188	24	**162.4**	**145.4**	**0.47**
16 July 2007	708	983	1172	50	**193.1**	**146.6**	**0.43**

17 July 2007	614	913	984	22	**174.1**	**120.7**	**0.41**
18 July 2007	671	1290	796	33	**222.4**	**99.5**	**0.31**
19 July 2007	122	1351	593	248	**163.3**	**100.9**	**0.38**
20 July 2007	1814	1512	1266	2790	**384.0**	**486.7**	**0.56**
21 July 2007	1233	838	890	2040	**240.1**	**351.6**	**0.59**
22 July 2007	2371	1603	1466	4179	**460.9**	**677.4**	**0.60**
23 July 2007	2095	1222	1482	3682	**385.8**	**619.7**	**0.62**
24 July 2007	659	1742	1754	3695	**270.7**	**653.9**	**0.71**
25 July 2007	0	2127	935	2760	**234.0**	**443.4**	**0.65**
26 July 2007	112	1375	790	2260	**164.7**	**366.0**	**0.69**
27 July 2007	1738	1981	1005	2392	**426.4**	**407.6**	**0.49**
28 July 2007	1392	1235	984	2060	**302.9**	**365.3**	**0.55**
29 July 2007	1704	1469	1222	2542	**366.0**	**451.7**	**0.55**
30 July 2007	2082	1874	1344	3185	**456.0**	**543.5**	**0.54**
31 July 2007	1674	1436	1084	2623	**358.9**	**444.8**	**0.55**
01 August 2007	1518	1205	898	2550	**314.7**	**413.8**	**0.57**
02 August 2007	1015	732	608	1766	**202.3**	**284.9**	**0.58**
03 August 2007	1379	1043	979	2203	**280.3**	**381.8**	**0.58**
04 August 2007	1911	1576	1317	2970	**402.6**	**514.4**	**0.56**
05 August 2007	2114	1994	1437	3078	**473.1**	**541.8**	**0.53**
06 August 2007	1226	1577	756	1477	**320.6**	**268.0**	**0.46**
07 August 2007	3388	3567	3027	3868	**799.0**	**827.4**	**0.51**
08 August 2007	1148	1260	1073	1217	**276.4**	**274.8**	**0.50**
09 August 2007	848	927	824	871	**203.8**	**203.4**	**0.50**
10 August 2007	1146	1116	1024	1310	**260.3**	**280.1**	**0.52**
11 August 2007	1392	1197	1303	1776	**298.7**	**369.5**	**0.55**
12 August 2007	1030	608	1192	1341	**190.5**	**304.0**	**0.61**
13 August 2007	1461	1174	1531	1776	**304.5**	**396.8**	**0.57**
14 August 2007	1667	1257	1536	2314	**338.4**	**462.0**	**0.58**
15 August 2007	239	718	1162	1674	**107.7**	**340.3**	**0.76**
16 August 2007	785	1154	1018	1370	**221.1**	**286.6**	**0.56**
17 August 2007	712	1419	1458	1731	**241.5**	**382.7**	**0.61**
18 August 2007	340	675	803	714	**115.1**	**182.0**	**0.61**
19 August 2007	377	1338	1510	1792	**192.4**	**396.2**	**0.67**
20 August 2007	411	1821	2072	2526	**249.7**	**551.8**	**0.69**
21 August 2007	834	1779	1467	2591	**295.8**	**487.0**	**0.62**
22 August 2007	506	898	522	1086	**200.0**	**193.0**	**0.49**
23 August 2007	504	806	523	853	**189.4**	**165.1**	**0.47**
24 August 2007	384	632	508	590	**146.3**	**131.8**	**0.47**
25 August 2007	896	1390	816	1512	**332.1**	**279.4**	**0.46**
26 August 2007	1054	1734	896	2115	**401.5**	**361.3**	**0.47**
27 August 2007	638	1192	1073	1142	**258.8**	**265.8**	**0.51**
28 August 2007	1440	595	1879	2720	**353.5**	**551.9**	**0.61**
29 August 2007	1075	93	77	2328	**225.2**	**288.6**	**0.56**
30 August 2007	744	2660	1238	2562	**441.4**	**456.0**	**0.51**
31 August 2007	540	1872	1537	1557	**313.9**	**371.3**	**0.54**
01 September 2007	210	1239	890	1057	**178.3**	**233.6**	**0.57**
02 September 2007	348	1683	1261	1008	**254.7**	**272.3**	**0.52**
03 September 2007	1040	2516	2166	2511	**484.8**	**561.2**	**0.54**
04 September 2007	756	2887	1518	2693	**468.8**	**505.3**	**0.52**
05 September 2007	844	2866	1129	2763	**484.1**	**467.0**	**0.49**
06 September 2007	676	2439	787	2073	**403.5**	**343.2**	**0.46**
07 September 2007	538	378	1683	3001	**149.2**	**562.1**	**0.79**
08 September 2007	480	1008	1158	1946	**206.9**	**372.5**	**0.64**
09 September 2007	522	2216	955	2227	**348.2**	**381.8**	**0.52**
10 September 2007	1086	1121	1426	3159	**340.5**	**550.2**	**0.62**
11 September 2007	1820	811	3300	6411	**453.2**	**1165.3**	**0.72**
12 September 2007	1098	2084	1102	3014	**448.8**	**493.9**	**0.52**
13 September 2007	1150	1714	464	3398	**418.5**	**463.4**	**0.53**
14 September 2007	706	984	683	2401	**249.4**	**370.1**	**0.60**
15 September 2007	698	1057	408	2624	**255.9**	**363.8**	**0.59**
16 September 2007	394	707	269	1521	**156.6**	**214.8**	**0.58**
17 September 2007	1244	1092	1516	3698	**368.9**	**625.7**	**0.63**
18 September 2007	972	363	1912	2384	**234.3**	**515.5**	**0.69**
19 September 2007	810	439	1612	2674	**210.3**	**514.3**	**0.71**
20 September 2007	768	1363	1656	1658	**303.5**	**397.7**	**0.57**
21 September 2007	660	2238	1304	2462	**378.2**	**451.9**	**0.54**
22 September 2007	232	861	688	1053	**141.1**	**208.9**	**0.60**
23 September 2007	488	1686	947	1401	**283.1**	**281.8**	**0.50**

24 September 2007	122	873	210	492	**120.4**	**84.2**	**0.41**
25 September 2007	644	2304	671	2220	**382.2**	**346.9**	**0.48**
26 September 2007	454	2171	788	1647	**329.6**	**292.2**	**0.47**
27 September 2007	674	1272	1031	987	**274.7**	**242.2**	**0.47**
28 September 2007	796	1278	783	960	**299.8**	**209.2**	**0.41**
29 September 2007	650	1461	1114	1081	**290.7**	**263.4**	**0.48**
30 September 2007	720	2088	1396	1595	**373.7**	**358.9**	**0.49**
01 October 2007	480	1608	968	1086	**272.9**	**246.5**	**0.47**
02 October 2007	788	2148	1155	1411	**393.9**	**307.9**	**0.44**
03 October 2007	986	2790	1288	1808	**504.1**	**371.5**	**0.42**
04 October 2007	1352	2649	1422	1993	**561.8**	**409.8**	**0.42**
05 October 2007	736	1884	669	945	**354.4**	**193.7**	**0.35**
06 October 2007	1078	2428	1257	1757	**482.7**	**361.7**	**0.43**
07 October 2007	920	2972	1852	1803	**510.9**	**438.6**	**0.46**
08 October 2007	462	2169	1381	1207	**331.0**	**310.6**	**0.48**
09 October 2007	966	3680	979	2238	**598.0**	**386.0**	**0.39**
10 October 2007	788	2390	621	1806	**420.5**	**291.2**	**0.41**
11 October 2007	840	1900	1535	2096	**377.0**	**435.7**	**0.54**
12 October 2007	312	1607	1134	1396	**239.2**	**303.6**	**0.56**
13 October 2007	334	2190	1204	1614	**307.7**	**338.2**	**0.52**
14 October 2007	154	2038	1011	1406	**255.0**	**290.0**	**0.53**
15 October 2007	178	1783	782	1237	**231.7**	**242.3**	**0.51**
16 October 2007	630	3502	1704	2331	**511.2**	**484.2**	**0.49**
17 October 2007	282	1949	873	1392	**270.8**	**271.8**	**0.50**
18 October 2007	652	2817	1421	2085	**440.3**	**420.7**	**0.49**
19 October 2007	356	1625	864	1142	**250.0**	**240.7**	**0.49**
20 October 2007	26	887	394	510	**102.8**	**108.5**	**0.51**
21 October 2007	422	1919	1467	1833	**295.5**	**396.0**	**0.57**
22 October 2007	212	279	1453	2052	**73.1**	**420.6**	**0.85**
23 October 2007	500	361	2501	3135	**139.7**	**676.3**	**0.83**
24 October 2007	392	252	2391	2818	**106.1**	**625.1**	**0.85**
25 October 2007	136	102	1477	1533	**38.4**	**361.2**	**0.90**
26 October 2007	142	138	1645	2018	**43.6**	**439.6**	**0.91**
27 October 2007	332	282	1565	1707	**97.4**	**392.6**	**0.80**
28 October 2007	444	319	2318	3238	**123.9**	**666.7**	**0.84**
29 October 2007	332	255	1710	2520	**94.5**	**507.6**	**0.84**
30 October 2007	134	131	1777	2133	**41.2**	**469.2**	**0.92**
31 October 2007	278	251	2037	2490	**83.2**	**543.2**	**0.87**
01 November 2007	326	273	1902	2184	**95.2**	**490.3**	**0.84**
02 November 2007	64	114	1795	1773	**25.3**	**428.2**	**0.94**
03 November 2007	306	314	2031	2298	**95.7**	**519.5**	**0.84**
04 November 2007	140	181	2136	2382	**47.9**	**542.2**	**0.92**
05 November 2007	66	260	1040	906	**41.8**	**233.5**	**0.85**
06 November 2007	230	1676	1535	1659	**230.4**	**383.3**	**0.62**
07 November 2007	166	2002	1583	1863	**253.4**	**413.5**	**0.62**
08 November 2007	552	1590	1763	780	**285.3**	**305.2**	**0.52**
09 November 2007	962	1362	2385	1135	**342.2**	**422.4**	**0.55**
10 November 2007	1342	2805	2079	1427	**577.0**	**420.8**	**0.42**
11 November 2007	2003	4146	3092	2109	**856.7**	**624.1**	**0.42**
12 November 2007	1365	3172	2387	1660	**621.9**	**485.6**	**0.44**
13 November 2007	1066	1718	1698	1742	**402.2**	**412.8**	**0.51**
14 November 2007	502	944	1083	1546	**204.2**	**315.4**	**0.61**
15 November 2007	580	882	1177	1755	**213.0**	**351.8**	**0.62**
16 November 2007	1000	1225	1842	2735	**334.8**	**549.2**	**0.62**
17 November 2007	700	983	1568	2637	**248.1**	**504.6**	**0.67**
18 November 2007	1184	1907	2144	2710	**446.6**	**582.5**	**0.57**
19 November 2007	798	3093	1869	1442	**499.8**	**397.3**	**0.44**
20 November 2007	790	2986	1880	1587	**486.5**	**416.1**	**0.46**
21 November 2007	1006	3313	2231	1978	**565.6**	**505.1**	**0.47**
22 November 2007	540	2530	1528	1365	**386.3**	**347.2**	**0.47**
23 November 2007	330	1997	1138	1028	**285.7**	**259.9**	**0.48**
24 November 2007	422	1761	1110	1011	**278.1**	**254.5**	**0.48**
25 November 2007	1138	2444	1963	1750	**496.4**	**445.5**	**0.47**
26 November 2007	842	2046	1623	1587	**393.5**	**385.2**	**0.49**
27 November 2007	992	2153	1734	1575	**435.2**	**397.1**	**0.48**
28 November 2007	1199	2103	1782	1421	**471.1**	**384.4**	**0.45**
29 November 2007	1125	1636	1569	1332	**405.0**	**348.1**	**0.46**
30 November 2007	792	1424	1224	1047	**315.0**	**272.6**	**0.46**

01 December 2007	924	1958	1657	1635	**400.2**	**395.0**	**0.50**
02 December 2007	1042	1763	1526	1224	**402.3**	**330.0**	**0.45**
03 December 2007	516	1570	1103	1009	**275.9**	**253.4**	**0.48**
04 December 2007	878	2148	1326	1748	**411.9**	**368.9**	**0.47**
05 December 2007	876	1523	1177	1270	**342.7**	**293.6**	**0.46**
06 December 2007	612	1463	1092	1245	**283.3**	**280.4**	**0.50**
07 December 2007	1144	2240	1717	2088	**475.2**	**456.6**	**0.49**
08 December 2007	624	1706	891	840	**312.5**	**207.7**	**0.40**
09 December 2007	804	2498	1697	1917	**435.6**	**433.7**	**0.50**
10 December 2007	828	2550	1750	1827	**446.1**	**429.2**	**0.49**
11 December 2007	622	2258	1456	1565	**372.8**	**362.5**	**0.49**
12 December 2007	36	907	869	562	**107.0**	**171.7**	**0.62**
13 December 2007	166	1455	1182	969	**193.3**	**258.1**	**0.57**
14 December 2007	152	3600	2410	1842	**426.4**	**510.2**	**0.54**
15 December 2007							
16 December 2007							
17 December 2007							
18 December 2007							
19 December 2007							
20 December 2007							
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27 December 2007							
28 December 2007							
29 December 2007							
30 December 2007							
31 December 2007							
01 January 2008							
02 January 2008							
03 January 2008							
04 January 2008	440	3162	3162	3162	**435.8**	**758.9**	**0.64**
05 January 2008	0	1784	1784	1784	**196.2**	**428.2**	**0.69**
06 January 2008	0	2277	2277	2277	**250.5**	**546.5**	**0.69**
07 January 2008	0	3489	3489	3489	**383.8**	**837.4**	**0.69**
08 January 2008	0	2229	2229	2229	**245.2**	**535.0**	**0.69**
09 January 2008	0	1785	1785	1785	**196.4**	**428.4**	**0.69**
10 January 2008	0	1738	1738	1738	**191.2**	**417.1**	**0.69**
11 January 2008	0	1731	1731	1731	**190.4**	**415.4**	**0.69**
12 January 2008	0	2396	2396	2396	**263.6**	**575.0**	**0.69**
13 January 2008	0	3508	3508	3508	**385.9**	**841.9**	**0.69**
14 January 2008	0	2031	2031	2031	**223.4**	**487.4**	**0.69**
15 January 2008	0	2706	2706	2706	**297.7**	**649.4**	**0.69**
16 January 2008	0	3036	3036	3036	**334.0**	**728.6**	**0.69**
17 January 2008	0	2726	2726	2726	**299.9**	**654.2**	**0.69**
18 January 2008	0	2133	2133	2133	**234.6**	**511.9**	**0.69**
19 January 2008	0	4036	4036	4036	**444.0**	**968.6**	**0.69**
20 January 2008	0	6350	6350	6350	**698.5**	**1524.0**	**0.69**
21 January 2008	0	7527	7527	7527	**828.0**	**1806.5**	**0.69**
22 January 2008	0	4006	4006	4006	**440.7**	**961.4**	**0.69**
23 January 2008	0	4272	4272	4272	**469.9**	**1025.3**	**0.69**
24 January 2008	0	2714	2714	2714	**298.5**	**651.4**	**0.69**
25 January 2008	0	1656	1656	1656	**182.2**	**397.4**	**0.69**
26 January 2008	0	1344	1344	1344	**147.8**	**322.6**	**0.69**
27 January 2008	0	717	717	717	**78.9**	**172.1**	**0.69**
28 January 2008	0	1261	1261	1261	**138.7**	**302.6**	**0.69**
29 January 2008	0	1187	1187	1187	**130.6**	**284.9**	**0.69**
30 January 2008	0	1750	1750	1750	**192.5**	**420.0**	**0.69**
31 January 2008	0	959	959	959	**105.5**	**230.2**	**0.69**
01 February 2008	1069	1069	1069	1069	**331.4**	**256.6**	**0.44**
02 February 2008	2375	2375	2375	2375	**736.3**	**570.0**	**0.44**
03 February 2008	1507	1507	1507	1507	**467.2**	**361.7**	**0.44**
04 February 2008	1739	1739	1739	1739	**539.1**	**417.4**	**0.44**
05 February 2008	1038	1038	1038	1038	**321.8**	**249.1**	**0.44**
06 February 2008	1293	1293	1293	1293	**400.8**	**310.3**	**0.44**

07 February 2008	927	927	927	927	**287.4**	**222.5**	**0.44**
08 February 2008	1381	1381	1381	1381	**428.1**	**331.4**	**0.44**
09 February 2008	1152	1152	1152	1152	**357.1**	**276.5**	**0.44**
10 February 2008	266	266	266	266	**82.5**	**63.8**	**0.44**
11 February 2008	2067	2067	2067	2067	**640.8**	**496.1**	**0.44**
12 February 2008	774	774	774	774	**239.9**	**185.8**	**0.44**
13 February 2008	1233	1233	1233	1233	**382.2**	**295.9**	**0.44**
14 February 2008	1341	1341	1341	1341	**415.7**	**321.8**	**0.44**
15 February 2008	676	676	676	676	**209.6**	**162.2**	**0.44**
16 February 2008	896	896	896	896	**277.8**	**215.0**	**0.44**
17 February 2008	1286	1286	1286	1286	**398.7**	**308.6**	**0.44**
18 February 2008	1417	1417	1417	1417	**439.3**	**340.1**	**0.44**
19 February 2008	728	728	728	728	**225.7**	**174.7**	**0.44**
20 February 2008	1557	1557	1557	1557	**482.7**	**373.7**	**0.44**
21 February 2008	1069	1069	1069	1069	**331.4**	**256.6**	**0.44**
22 February 2008	1091	1091	1091	1091	**338.2**	**261.8**	**0.44**
23 February 2008	636	636	636	636	**197.2**	**152.6**	**0.44**
24 February 2008	106	116	603	1794	**34.0**	**287.6**	**0.89**
25 February 2008	479	736	1614	1556	**176.8**	**380.4**	**0.68**
26 February 2008	636	1892	2044	1968	**335.3**	**481.4**	**0.59**
27 February 2008	1020	2559	2753	2715	**485.5**	**656.2**	**0.57**
28 February 2008	662	2300	2331	2266	**385.4**	**551.6**	**0.59**
29 February 2008	344	1695	1468	1247	**255.3**	**325.8**	**0.56**
01 March 2008	56	1188	799	569	**141.9**	**164.2**	**0.54**
02 March 2008	110	1430	841	718	**179.3**	**187.1**	**0.51**
03 March 2008	288	2328	1140	1193	**313.7**	**280.0**	**0.47**
04 March 2008	320	2319	1421	1426	**319.1**	**341.6**	**0.52**
05 March 2008	122	1721	1124	879	**213.7**	**240.4**	**0.53**
06 March 2008	212	2276	1388	1433	**292.8**	**338.5**	**0.54**
07 March 2008	232	1830	1036	1170	**247.7**	**264.7**	**0.52**
08 March 2008	536	2096	1154	1521	**337.8**	**321.0**	**0.49**
09 March 2008	374	1362	1124	1389	**224.6**	**301.6**	**0.57**
10 March 2008	794	2642	1854	2473	**449.4**	**519.2**	**0.54**
11 March 2008	422	2539	1284	1646	**363.7**	**351.6**	**0.49**
12 March 2008	292	3004	1605	1813	**388.8**	**410.2**	**0.51**
13 March 2008	122	1917	983	1259	**235.3**	**269.0**	**0.53**
14 March 2008	254	2728	534	1176	**350.9**	**205.2**	**0.37**
15 March 2008	102	2613	122	799	**307.8**	**110.5**	**0.26**
16 March 2008	344	3237	53	1290	**424.9**	**161.2**	**0.28**
17 March 2008	108	1773	1278	1338	**216.6**	**313.9**	**0.59**
18 March 2008	436	2596	1623	1799	**372.8**	**410.6**	**0.52**
19 March 2008	922	2159	1651	2110	**421.9**	**451.3**	**0.52**
20 March 2008	572	1275	198	1174	**254.7**	**164.6**	**0.39**
21 March 2008	330	1158	19	883	**193.4**	**108.2**	**0.36**
22 March 2008	978	2398	2025	2247	**459.4**	**512.6**	**0.53**
23 March 2008	342	777	635	623	**153.9**	**151.0**	**0.50**
24 March 2008	678	1932	1547	1740	**348.1**	**394.4**	**0.53**
25 March 2008	490	1448	1110	1179	**257.3**	**274.6**	**0.52**
26 March 2008	1088	2027	1879	1966	**440.6**	**461.4**	**0.51**
27 March 2008	944	1926	1602	1466	**400.7**	**368.1**	**0.48**
28 March 2008	216	1163	730	763	**171.1**	**179.1**	**0.51**
29 March 2008	462	2059	1390	1514	**318.9**	**348.5**	**0.52**
30 March 2008	736	3139	1874	1518	**492.5**	**407.0**	**0.45**
31 March 2008	950	3622	2207	1717	**588.4**	**470.9**	**0.44**
01 April 2008	568	3242	1796	1470	**470.2**	**391.9**	**0.45**
02 April 2008	620	3518	1982	1689	**511.0**	**440.6**	**0.46**
03 April 2008	238	2569	1281	1091	**330.2**	**284.6**	**0.46**
04 April 2008	122	1643	812	727	**205.1**	**184.7**	**0.47**
05 April 2008	106	2387	1152	1092	**283.8**	**269.3**	**0.49**
06 April 2008	518	2408	1618	1784	**368.5**	**408.3**	**0.53**
07 April 2008	886	4150	2516	2268	**633.7**	**574.1**	**0.48**
08 April 2008	590	3885	2190	2023	**545.4**	**505.5**	**0.48**
09 April 2008	835	4460	2723	2688	**657.6**	**649.3**	**0.50**
10 April 2008	457	3240	1836	1776	**447.8**	**433.4**	**0.49**
11 April 2008	768	2253	1523	1223	**401.4**	**329.5**	**0.45**
12 April 2008	1653	2711	2309	1687	**628.8**	**479.5**	**0.43**
13 April 2008	1127	2081	1736	1422	**454.3**	**379.0**	**0.45**

14 April 2008	552	1515	1148	1136	**277.1**	**274.1**	**0.50**
15 April 2008	1058	2110	1756	1570	**443.7**	**399.1**	**0.47**
16 April 2008	1312	2681	2262	2142	**557.3**	**528.5**	**0.49**
17 April 2008	608	2309	1551	1523	**375.6**	**368.9**	**0.50**
18 April 2008	434	1584	1145	1260	**261.0**	**288.6**	**0.53**
19 April 2008	190	624	590	882	**106.6**	**176.7**	**0.62**
20 April 2008	424	1002	1019	1432	**195.0**	**294.1**	**0.60**
21 April 2008	1610	3340	122	2424	**689.4**	**305.5**	**0.31**
22 April 2008	942	2874	18	1749	**504.5**	**212.0**	**0.30**
23 April 2008	398	3011	0	1946	**410.8**	**233.5**	**0.36**
24 April 2008	558	3466	370	1438	**492.9**	**217.0**	**0.31**
25 April 2008	321	2318	1334	389	**319.2**	**206.8**	**0.39**
26 April 2008	345	2906	1552	24	**388.7**	**189.1**	**0.33**
27 April 2008	358	3234	1841	12	**427.3**	**222.4**	**0.34**
28 April 2008	1073	3826	2441	1420	**635.5**	**463.3**	**0.42**
29 April 2008	1622	1632	1540	1323	**503.9**	**343.6**	**0.41**
30 April 2008	1595	1989	1761	446	**537.8**	**264.8**	**0.33**
01 May 2008	850	1270	1406	1329	**309.7**	**328.2**	**0.51**
02 May 2008	536	1443	1298	1174	**265.9**	**296.6**	**0.53**
03 May 2008	406	1523	1354	1143	**248.7**	**299.7**	**0.55**
04 May 2008	44	1121	830	645	**132.1**	**177.0**	**0.57**
05 May 2008	1940	2720	2633	2788	**687.2**	**650.5**	**0.49**
06 May 2008	1432	1615	1806	1891	**464.1**	**443.7**	**0.49**
07 May 2008	648	757	912	896	**212.9**	**217.0**	**0.50**
08 May 2008	1248	1294	1549	1605	**391.9**	**378.5**	**0.49**
09 May 2008	841	815	925	1025	**257.9**	**234.0**	**0.48**
10 May 2008	1228	1126	1283	1454	**369.5**	**328.4**	**0.47**
11 May 2008	1351	1245	1404	1599	**407.2**	**360.4**	**0.47**
12 May 2008	1317	1364	1491	1645	**413.4**	**376.4**	**0.48**
13 May 2008	621	713	717	803	**202.6**	**182.3**	**0.47**
14 May 2008	1418	2047	1612	1951	**508.8**	**427.5**	**0.46**
15 May 2008	1165	1744	1239	1593	**424.8**	**339.9**	**0.44**
16 May 2008	638	1278	743	994	**268.2**	**208.4**	**0.44**
17 May 2008	347	1477	820	918	**231.9**	**208.6**	**0.47**
18 May 2008	394	1480	951	988	**241.6**	**232.7**	**0.49**
19 May 2008	1264	2069	1591	1865	**480.4**	**414.7**	**0.46**
20 May 2008	1074	1840	1322	1600	**417.2**	**350.6**	**0.46**
21 May 2008	1488	2357	1673	2106	**556.9**	**453.4**	**0.45**
22 May 2008	1186	1824	1258	1637	**437.8**	**347.4**	**0.44**
23 May 2008	807	1319	862	1139	**306.5**	**240.1**	**0.44**
24 May 2008	751	1724	1036	1289	**339.8**	**279.0**	**0.45**
25 May 2008	1326	2166	1842	2014	**503.5**	**462.7**	**0.48**
26 May 2008	1294	1976	1742	1908	**476.2**	**438.0**	**0.48**
27 May 2008	531	1124	941	32	**229.8**	**116.8**	**0.34**
28 May 2008	1280	1546	1527	657	**426.1**	**262.1**	**0.38**
29 May 2008	1464	288	699	1328	**324.5**	**243.2**	**0.43**
30 May 2008	1844	363	880	1673	**408.7**	**306.3**	**0.43**
31 May 2008	1388	681	458	1188	**352.5**	**197.5**	**0.36**
01 June 2008	994	1239	1162	693	**335.1**	**222.6**	**0.40**
02 June 2008	1074	1697	1485	1109	**401.5**	**311.3**	**0.44**
03 June 2008	1702	2404	2416	2208	**604.8**	**554.9**	**0.48**
04 June 2008	1094	2073	1684	1327	**446.8**	**361.3**	**0.45**
05 June 2008	780	1629	1264	1000	**335.2**	**271.7**	**0.45**
06 June 2008	1117	1669	1571	1322	**407.0**	**347.2**	**0.46**
07 June 2008	1330	1957	1698	1083	**481.3**	**333.7**	**0.41**
08 June 2008	882	1330	1159	787	**322.7**	**233.5**	**0.42**
09 June 2008	1772	2492	2477	2193	**628.5**	**560.4**	**0.47**
10 June 2008	919	1162	1185	957	**311.6**	**257.0**	**0.45**
11 June 2008	1100	1447	1398	1034	**379.2**	**291.8**	**0.43**
12 June 2008	1149	1576	1473	1060	**403.2**	**304.0**	**0.43**

Site B

	C0	C1	C2	C3
Volume per tip (litres)	0.1425	0.15	0.1425	0.1425

Date	Tips (1)	Tips (2)	Tips (3)	Tips (4)	Trenches (litres)	Reed Bed (litres)	Split fraction
20 February 2006	22	151	277	183	**51.6**	**131.1**	**0.72**
21 February 2006	12	891	165	655	**135.4**	**116.9**	**0.46**
22 February 2006	161	623	283	523	**116.4**	**114.9**	**0.50**
23 February 2006	460	839	331	828	**191.4**	**165.2**	**0.46**
24 February 2006	705	1225	464	997	**284.2**	**208.2**	**0.42**
25 February 2006	154	217	180	65	**54.5**	**34.9**	**0.39**
26 February 2006	183	941	150	805	**167.2**	**136.1**	**0.45**
27 February 2006	142	872	39	787	**151.0**	**117.7**	**0.44**
28 February 2006	135	814	20	833	**141.3**	**121.6**	**0.46**
01 March 2006	89	647	90	522	**109.7**	**87.2**	**0.44**
02 March 2006	68	615	118	533	**101.9**	**92.8**	**0.48**
03 March 2006	21	412	31	418	**64.8**	**64.0**	**0.50**
04 March 2006	21	243	82	118	**39.4**	**28.5**	**0.42**
05 March 2006	55	311	48	251	**54.5**	**42.6**	**0.44**
06 March 2006	72	1294	19	372	**204.4**	**55.7**	**0.21**
07 March 2006	744	2741	471	862	**517.2**	**190.0**	**0.27**
08 March 2006	326	1227	19	353	**230.5**	**53.0**	**0.19**
09 March 2006	306	1410	67	540	**255.1**	**86.5**	**0.25**
10 March 2006	253	1465	42	437	**255.8**	**68.3**	**0.21**
11 March 2006	236	1700	138	629	**288.6**	**109.3**	**0.27**
12 March 2006	479	2622	1024	1370	**461.6**	**341.1**	**0.42**
13 March 2006	1531	5285	1951	3143	**1010.9**	**725.9**	**0.42**
14 March 2006	318	2379	636	878	**402.2**	**215.7**	**0.35**
15 March 2006	107	956	148	272	**158.6**	**59.9**	**0.27**
16 March 2006	177	1157	174	325	**198.8**	**71.1**	**0.26**
17 March 2006	147	802	78	180	**141.2**	**36.8**	**0.21**
18 March 2006	6	167	0	6	**25.9**	**0.9**	**0.03**
19 March 2006	142	1082	192	287	**182.5**	**68.3**	**0.27**
20 March 2006	124	1133	160	310	**187.6**	**67.0**	**0.26**
21 March 2006	134	1175	168	317	**195.3**	**69.1**	**0.26**
22 March 2006	54	678	63	138	**109.4**	**28.6**	**0.21**
23 March 2006	64	933	90	218	**149.1**	**43.9**	**0.23**
24 March 2006	723	3156	860	1275	**576.4**	**304.2**	**0.35**
25 March 2006	559	2557	655	858	**463.2**	**215.6**	**0.32**
26 March 2006	422	2452	676	934	**427.9**	**229.4**	**0.35**
27 March 2006	590	3283	620	726	**576.5**	**191.8**	**0.25**
28 March 2006	891	2560	22	5	**511.0**	**3.8**	**0.01**
29 March 2006	731	1899	616	915	**389.0**	**218.2**	**0.36**
30 March 2006	717	1428	446	764	**316.4**	**172.4**	**0.35**
31 March 2006	309	206	130	210	**74.9**	**48.5**	**0.39**
01 April 2006	254	170	114	169	**61.7**	**40.3**	**0.40**
02 April 2006	302	257	262	246	**81.5**	**72.4**	**0.47**
03 April 2006	157	157	229	110	**45.9**	**48.3**	**0.51**
04 April 2006	227	123	31	123	**50.7**	**21.9**	**0.30**
05 April 2006	241	128	28	128	**53.5**	**22.2**	**0.29**
06 April 2006	277	143	24	143	**60.9**	**23.8**	**0.28**
07 April 2006	297	151	20	151	**64.9**	**24.3**	**0.27**
08 April 2006	469	224	1	224	**100.4**	**32.0**	**0.24**
09 April 2006	277	132	0	132	**59.2**	**18.7**	**0.24**
10 April 2006	252	120	0	120	**53.9**	**17.1**	**0.24**

11 April 2006	349	43	1	188	**56.2**	**26.9**	**0.32**
12 April 2006	132	494	68	46	**92.9**	**16.2**	**0.15**
13 April 2006	46	1910	174	126	**293.1**	**42.8**	**0.13**
14 April 2006	25	1019	107	8	**156.4**	**16.4**	**0.09**
15 April 2006	22	1383	93	92	**210.6**	**26.4**	**0.11**
16 April 2006	23	1492	95	83	**227.1**	**25.4**	**0.10**
17 April 2006	9	1913	96	169	**288.2**	**37.8**	**0.12**
18 April 2006	37	1814	79	104	**277.4**	**26.1**	**0.09**
19 April 2006	166	2599	35	173	**413.5**	**29.6**	**0.07**
20 April 2006	105	1921	24	83	**303.1**	**15.2**	**0.05**
21 April 2006	107	2523	8	252	**393.7**	**37.1**	**0.09**
22 April 2006	0	1864	0	174	**279.6**	**24.8**	**0.08**
23 April 2006	127	2454	970	353	**386.2**	**188.6**	**0.33**
24 April 2006	9	1641	596	144	**247.4**	**105.4**	**0.30**
25 April 2006	8	1615	566	78	**243.4**	**91.7**	**0.27**
26 April 2006	13	1231	423	28	**186.5**	**64.3**	**0.26**
27 April 2006	3	971	325	1	**146.1**	**46.4**	**0.24**
28 April 2006	56	2034	696	0	**313.1**	**99.1**	**0.24**
29 April 2006	0	1611	537	0	**241.7**	**76.5**	**0.24**
30 April 2006	18	2939	39	75	**443.4**	**16.2**	**0.04**
01 May 2006	0	1822	5	188	**273.3**	**27.5**	**0.09**
02 May 2006	279	2094	37	411	**353.9**	**63.8**	**0.15**
03 May 2006	824	1595	589	1060	**356.7**	**235.0**	**0.40**
04 May 2006	969	394	1144	1545	**197.2**	**383.2**	**0.66**
05 May 2006	840	276	713	1183	**161.1**	**270.2**	**0.63**
06 May 2006	532	205	433	789	**106.6**	**174.1**	**0.62**
07 May 2006	571	296	676	897	**125.8**	**224.2**	**0.64**
08 May 2006	957	430	901	1220	**200.9**	**302.2**	**0.60**
09 May 2006	756	339	603	854	**158.6**	**207.6**	**0.57**
10 May 2006	369	149	149	256	**74.9**	**57.7**	**0.44**
11 May 2006	67	332	239	343	**59.3**	**82.9**	**0.58**
12 May 2006	99	241	189	384	**50.3**	**81.7**	**0.62**
13 May 2006	168	70	349	511	**34.4**	**122.6**	**0.78**
14 May 2006	207	70	387	499	**40.0**	**126.3**	**0.76**
15 May 2006	262	99	436	574	**52.2**	**143.9**	**0.73**
16 May 2006	7	25	92	268	**4.7**	**51.3**	**0.92**
17 May 2006	195	298	332	449	**72.5**	**111.3**	**0.61**
18 May 2006	229	270	287	415	**73.1**	**100.0**	**0.58**
19 May 2006	90	214	202	312	**44.9**	**73.2**	**0.62**
20 May 2006	19	181	136	238	**29.9**	**53.3**	**0.64**
21 May 2006	814	598	739	786	**205.7**	**217.3**	**0.51**
22 May 2006	157	251	304	403	**60.0**	**100.7**	**0.63**
23 May 2006	77	321	342	451	**59.1**	**113.0**	**0.66**
24 May 2006	6	220	187	314	**33.9**	**71.4**	**0.68**
25 May 2006	1	148	54	213	**22.3**	**38.0**	**0.63**
26 May 2006	0	231	236	337	**34.7**	**81.7**	**0.70**
27 May 2006	0	131	24	182	**19.7**	**29.4**	**0.60**
28 May 2006	0	253	159	355	**38.0**	**73.2**	**0.66**
29 May 2006	0	190	88	271	**28.5**	**51.2**	**0.64**
30 May 2006	0	235	168	347	**35.3**	**73.4**	**0.68**
31 May 2006	190	289	468	489	**70.4**	**136.4**	**0.66**
01 June 2006	733	57	819	242	**113.0**	**151.2**	**0.57**
02 June 2006	218	66	911	460	**41.0**	**195.4**	**0.83**
03 June 2006	109	18	718	465	**18.2**	**168.6**	**0.90**
04 June 2006	113	0	926	632	**16.1**	**222.0**	**0.93**
05 June 2006	43	11	944	615	**7.8**	**222.2**	**0.97**
06 June 2006	1	41	752	505	**6.3**	**179.1**	**0.97**
07 June 2006	0	12	635	314	**1.8**	**135.2**	**0.99**
08 June 2006	343	120	595	211	**66.9**	**114.9**	**0.63**
09 June 2006	967	656	69	576	**236.2**	**91.8**	**0.28**
10 June 2006	880	742	129	597	**236.7**	**103.4**	**0.30**

11 June 2006	1417	494	77	671	**276.0**	**106.6**	**0.28**
12 June 2006	2310	690	201	1079	**432.7**	**182.5**	**0.30**
13 June 2006	1427	690	554	902	**306.8**	**207.5**	**0.40**
14 June 2006	667	232	150	354	**129.8**	**71.8**	**0.36**
15 June 2006	704	229	209	385	**134.7**	**84.6**	**0.39**
16 June 2006	781	195	264	417	**140.5**	**97.0**	**0.41**
17 June 2006	1251	363	525	719	**232.7**	**177.3**	**0.43**
18 June 2006	729	947	707	811	**245.9**	**216.3**	**0.47**
19 June 2006	988	723	204	651	**249.2**	**121.8**	**0.33**
20 June 2006	1148	818	258	756	**286.3**	**144.5**	**0.34**
21 June 2006	842	563	123	519	**204.4**	**91.5**	**0.31**
22 June 2006	1558	839	221	887	**347.9**	**157.9**	**0.31**
23 June 2006	943	502	208	560	**209.7**	**109.4**	**0.34**
24 June 2006	1402	679	360	826	**301.6**	**169.0**	**0.36**
25 June 2006	2071	1084	441	1218	**457.7**	**236.4**	**0.34**
26 June 2006	727	554	61	457	**186.7**	**73.8**	**0.28**
27 June 2006	991	665	121	604	**241.0**	**103.3**	**0.30**
28 June 2006	674	480	59	413	**168.0**	**67.2**	**0.29**
29 June 2006	936	581	258	602	**220.5**	**122.6**	**0.36**
30 June 2006	1397	785	253	825	**316.8**	**153.7**	**0.33**
01 July 2006	992	949	176	722	**283.7**	**128.0**	**0.31**
02 July 2006	1154	1174	156	849	**340.5**	**143.2**	**0.30**
03 July 2006	499	694	252	202	**175.2**	**64.7**	**0.27**
04 July 2006	191	403	344	363	**87.7**	**100.7**	**0.53**
05 July 2006	146	327	238	407	**69.9**	**91.9**	**0.57**
06 July 2006	131	307	230	338	**64.7**	**80.9**	**0.56**
07 July 2006	265	335	240	320	**88.0**	**79.8**	**0.48**
08 July 2006	669	670	501	403	**195.8**	**128.8**	**0.40**
09 July 2006	1181	1294	622	979	**362.4**	**228.1**	**0.39**
10 July 2006	489	745	268	538	**181.4**	**114.9**	**0.39**
11 July 2006	379	688	226	466	**157.2**	**98.6**	**0.39**
12 July 2006	328	657	223	531	**145.3**	**107.4**	**0.43**
13 July 2006	357	476	248	466	**122.3**	**101.7**	**0.45**
14 July 2006	394	990	291	644	**204.6**	**133.2**	**0.39**
15 July 2006	551	364	297	249	**133.1**	**77.8**	**0.37**
16 July 2006	1455	421	645	315	**270.5**	**136.8**	**0.34**
17 July 2006	964	220	313	152	**170.4**	**66.3**	**0.28**
18 July 2006	844	417	481	513	**182.8**	**141.6**	**0.44**
19 July 2006	747	413	161	483	**168.4**	**91.8**	**0.35**
20 July 2006	742	425	29	515	**169.5**	**77.5**	**0.31**
21 July 2006	574	372	25	452	**137.6**	**68.0**	**0.33**
22 July 2006	247	18	168	36	**37.9**	**29.1**	**0.43**
23 July 2006	260	135	289	146	**57.3**	**62.0**	**0.52**
24 July 2006	788	751	713	250	**224.9**	**137.2**	**0.38**
25 July 2006	234	567	639	425	**118.4**	**151.6**	**0.56**
26 July 2006	398	768	675	134	**171.9**	**115.3**	**0.40**
27 July 2006	873	59	483	419	**133.3**	**128.5**	**0.49**
28 July 2006	384	632	8	863	**149.5**	**124.1**	**0.45**
29 July 2006	822	657	1028	693	**215.7**	**245.2**	**0.53**
30 July 2006	1206	622	814	553	**265.2**	**194.8**	**0.42**
31 July 2006	1457	900	1726	795	**342.6**	**359.2**	**0.51**
01 August 2006	990	641	974	533	**237.2**	**214.7**	**0.48**
02 August 2006	566	880	298	517	**212.7**	**116.1**	**0.35**
03 August 2006	61	312	284	136	**55.5**	**59.9**	**0.52**
04 August 2006	539	1004	189	493	**227.4**	**97.2**	**0.30**
05 August 2006	378	324	152	280	**102.5**	**61.6**	**0.38**
06 August 2006	43	387	97	526	**64.2**	**88.8**	**0.58**
07 August 2006	151	222	335	497	**54.8**	**118.6**	**0.68**
08 August 2006	533	611	317	554	**167.6**	**124.1**	**0.43**
09 August 2006	217	261	180	126	**70.1**	**43.6**	**0.38**
10 August 2006	298	625	250	313	**136.2**	**80.2**	**0.37**
11 August 2006	238	770	141	436	**149.4**	**82.2**	**0.35**

12 August 2006	389	286	277	459	**98.3**	**104.9**	**0.52**
13 August 2006	261	320	429	1026	**85.2**	**207.3**	**0.71**
14 August 2006	110	254	275	1109	**53.8**	**197.2**	**0.79**
15 August 2006	460	828	1257	1535	**189.8**	**397.9**	**0.68**
16 August 2006	780	596	1177	748	**200.6**	**274.3**	**0.58**
17 August 2006	815	343	1000	486	**167.6**	**211.8**	**0.56**
18 August 2006	587	292	734	458	**127.4**	**169.9**	**0.57**
19 August 2006	963	470	1166	563	**207.7**	**246.4**	**0.54**
20 August 2006	1008	410	1198	339	**205.1**	**219.0**	**0.52**
21 August 2006	819	340	672	235	**167.7**	**129.2**	**0.44**
22 August 2006	837	385	782	351	**177.0**	**161.5**	**0.48**
23 August 2006	1173	856	469	194	**295.6**	**94.5**	**0.24**
24 August 2006	696	832	786	786	**224.0**	**224.0**	**0.50**
25 August 2006	927	868	920	920	**262.3**	**262.3**	**0.50**
26 August 2006	198	242	226	226	**64.5**	**64.5**	**0.50**
27 August 2006	346	678	530	530	**151.0**	**151.0**	**0.50**
28 August 2006	453	1162	838	838	**238.9**	**238.9**	**0.50**
29 August 2006	451	1198	856	856	**244.0**	**244.0**	**0.50**
30 August 2006	453	1320	921	921	**262.6**	**262.6**	**0.50**
31 August 2006	342	1305	858	858	**244.5**	**244.5**	**0.50**
01 September 2006	453	1095	803	803	**228.8**	**228.8**	**0.50**
02 September 2006	2748	2197	11	3	**721.1**	**2.0**	**0.00**
03 September 2006	1086	1131	0	0	**324.4**	**0.0**	**0.00**
04 September 2006	1060	1335	148	94	**351.3**	**34.5**	**0.09**
05 September 2006	501	244	738	461	**108.0**	**170.9**	**0.61**
06 September 2006	194	315	466	366	**74.9**	**118.6**	**0.61**
07 September 2006	363	441	710	334	**117.9**	**148.8**	**0.56**
08 September 2006	378	197	349	513	**83.4**	**122.8**	**0.60**
09 September 2006	419	128	188	295	**78.9**	**68.8**	**0.47**
10 September 2006	561	225	365	905	**113.7**	**181.0**	**0.61**
11 September 2006	982	661	1440	1262	**239.1**	**385.0**	**0.62**
12 September 2006	644	401	1062	833	**151.9**	**270.0**	**0.64**
13 September 2006	1289	652	413	445	**281.5**	**122.3**	**0.30**
14 September 2006	576	408	550	467	**143.3**	**144.9**	**0.50**
15 September 2006	1084	639	80	77	**250.3**	**22.4**	**0.08**
16 September 2006	297	935	36	556	**182.6**	**84.4**	**0.32**
17 September 2006	10	944	4	979	**143.0**	**140.1**	**0.49**
18 September 2006	538	530	162	921	**156.2**	**154.3**	**0.50**
19 September 2006	1067	293	215	789	**196.0**	**143.1**	**0.42**
20 September 2006	990	353	386	800	**194.0**	**169.0**	**0.47**
21 September 2006	793	325	705	552	**161.8**	**179.1**	**0.53**
22 September 2006	194	39	239	23	**33.5**	**37.3**	**0.53**
23 September 2006	28	64	211	11	**13.6**	**31.6**	**0.70**
24 September 2006	259	78	379	183	**48.6**	**80.1**	**0.62**
25 September 2006	120	72	228	174	**27.9**	**57.3**	**0.67**
26 September 2006	28	151	27	11	**26.6**	**5.4**	**0.17**
27 September 2006	330	5	349	57	**47.8**	**57.9**	**0.55**
28 September 2006	154	6	15	11	**22.8**	**3.7**	**0.14**
29 September 2006	222	73	173	66	**42.6**	**34.1**	**0.44**
30 September 2006	92	15	236	20	**15.4**	**36.5**	**0.70**
01 October 2006	425	74	714	317	**71.7**	**146.9**	**0.67**
02 October 2006	607	176	716	448	**112.9**	**165.9**	**0.60**
03 October 2006	346	310	860	230	**95.8**	**155.3**	**0.62**
04 October 2006	643	258	703	225	**130.3**	**132.2**	**0.50**
05 October 2006	445	56	453	187	**71.8**	**91.2**	**0.56**
06 October 2006	1054	342	618	276	**201.5**	**127.4**	**0.39**
07 October 2006	236	153	709	172	**56.6**	**125.5**	**0.69**
08 October 2006	595	251	601	278	**122.4**	**125.3**	**0.51**
09 October 2006	214	413	1039	193	**92.4**	**175.6**	**0.66**
10 October 2006	432	20	678	157	**64.6**	**119.0**	**0.65**
11 October 2006	195	245	703	592	**64.5**	**184.5**	**0.74**
12 October 2006	65	131	622	351	**28.9**	**138.7**	**0.83**

13 October 2006	209	32	592	134	**34.6**	**103.5**	**0.75**
14 October 2006	7	85	406	1096	**13.7**	**214.0**	**0.94**
15 October 2006	590	444	688	452	**150.7**	**162.5**	**0.52**
16 October 2006	592	203	393	454	**114.8**	**120.7**	**0.51**
17 October 2006	349	366	736	494	**104.6**	**175.3**	**0.63**
18 October 2006	49	282	304	781	**49.3**	**154.6**	**0.76**
19 October 2006	826	509	561	906	**194.1**	**209.0**	**0.52**
20 October 2006	717	297	238	439	**146.7**	**96.5**	**0.40**
21 October 2006	875	394	701	630	**183.8**	**189.7**	**0.51**
22 October 2006	596	174	855	348	**111.0**	**171.4**	**0.61**
23 October 2006	514	266	784	346	**113.1**	**161.0**	**0.59**
24 October 2006	614	281	898	451	**129.6**	**192.2**	**0.60**
25 October 2006	2240	1566	2771	1941	**554.1**	**671.5**	**0.55**
26 October 2006	476	159	741	250	**91.7**	**141.2**	**0.61**
27 October 2006	614	205	914	378	**118.2**	**184.1**	**0.61**
28 October 2006	364	74	648	186	**63.0**	**118.8**	**0.65**
29 October 2006	208	13	458	54	**31.6**	**73.0**	**0.70**
30 October 2006	668	213	892	445	**127.1**	**190.5**	**0.60**
31 October 2006	216	15	338	129	**33.0**	**66.5**	**0.67**
01 November 2006	6	7	184	58	**1.9**	**34.5**	**0.95**
02 November 2006	50	0	54	8	**7.1**	**8.8**	**0.55**
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27 November 2006							
28 November 2006	228	83	310	138	**110.6**	**157.1**	**0.59**
29 November 2006	362	117	493	114	**69.1**	**86.5**	**0.56**
30 November 2006	2442	1616	2851	1912	**590.4**	**678.7**	**0.53**
01 December 2006	1315	590	1481	858	**275.9**	**333.3**	**0.55**
02 December 2006	631	212	756	389	**121.7**	**163.2**	**0.57**
03 December 2006	1776	1012	1923	1464	**404.9**	**482.6**	**0.54**
04 December 2006	1042	413	1014	767	**210.4**	**253.8**	**0.55**
05 December 2006	858	341	1002	599	**173.4**	**228.1**	**0.57**
06 December 2006	772	300	926	527	**155.0**	**207.1**	**0.57**
07 December 2006	913	369	1050	631	**185.5**	**239.5**	**0.56**
08 December 2006	906	376	1062	642	**185.5**	**242.8**	**0.57**
09 December 2006	528	207	679	373	**106.3**	**149.9**	**0.59**
10 December 2006	748	298	898	539	**151.3**	**204.8**	**0.58**
11 December 2006	976	414	1124	728	**201.2**	**263.9**	**0.57**
12 December 2006	783	365	924	547	**166.3**	**209.6**	**0.56**
13 December 2006	613	266	754	399	**127.3**	**164.3**	**0.56**
14 December 2006	415	180	542	275	**86.1**	**116.4**	**0.57**

15 December 2006	1022	537	1142	746	**226.2**	**269.0**	**0.54**
16 December 2006	308	114	477	187	**61.0**	**94.6**	**0.61**
17 December 2006	601	298	727	420	**130.3**	**163.4**	**0.56**
18 December 2006	429	195	577	295	**90.4**	**124.3**	**0.58**
19 December 2006	514	242	671	357	**109.5**	**146.5**	**0.57**
20 December 2006	587	297	713	429	**128.2**	**162.7**	**0.56**
21 December 2006	428	197	541	299	**90.5**	**119.7**	**0.57**
22 December 2006	639	315	757	467	**138.3**	**174.4**	**0.56**
23 December 2006	560	264	683	395	**119.4**	**153.6**	**0.56**
24 December 2006	548	255	669	386	**116.3**	**150.3**	**0.56**
25 December 2006	693	347	822	501	**150.8**	**188.5**	**0.56**
26 December 2006	615	300	720	440	**132.6**	**165.3**	**0.55**
27 December 2006	1057	580	1076	813	**237.6**	**269.2**	**0.53**
28 December 2006	1040	530	1114	761	**227.7**	**267.2**	**0.54**
29 December 2006	1524	870	1552	1207	**347.7**	**393.2**	**0.53**
30 December 2006	935	484	965	668	**205.8**	**232.7**	**0.53**
31 December 2006	751	395	799	547	**166.3**	**191.8**	**0.54**
01 January 2007	633	315	676	431	**137.5**	**157.7**	**0.53**
02 January 2007	595	286	630	405	**127.7**	**147.5**	**0.54**
03 January 2007	516	239	545	337	**109.4**	**125.7**	**0.53**
04 January 2007	540	253	558	345	**114.9**	**128.7**	**0.53**
05 January 2007	605	298	627	379	**130.9**	**143.4**	**0.52**
06 January 2007	711	366	750	488	**156.2**	**176.4**	**0.53**
07 January 2007	693	370	756	482	**154.3**	**176.4**	**0.53**
08 January 2007	976	523	1060	684	**217.5**	**248.5**	**0.53**
09 January 2007	731	368	782	480	**159.4**	**179.8**	**0.53**
10 January 2007	482	225	556	110	**102.4**	**94.9**	**0.48**
11 January 2007	815	433	889	539	**181.1**	**203.5**	**0.53**
12 January 2007	440	202	474	260	**93.0**	**104.6**	**0.53**
13 January 2007	566	137	334	551	**101.2**	**126.1**	**0.55**
14 January 2007	601	77	253	762	**97.2**	**144.6**	**0.60**
15 January 2007	605	64	126	460	**95.8**	**83.5**	**0.47**
16 January 2007	674	69	518	1377	**106.4**	**270.0**	**0.72**
17 January 2007	569	52	102	483	**88.9**	**83.4**	**0.48**
18 January 2007	1254	68	340	2003	**188.9**	**333.9**	**0.64**
19 January 2007	512	39	245	1051	**78.8**	**184.7**	**0.70**
20 January 2007	442	28	260	950	**67.2**	**172.4**	**0.72**
21 January 2007	553	29	347	1229	**83.2**	**224.6**	**0.73**
22 January 2007	479	26	369	1444	**72.2**	**258.4**	**0.78**
23 January 2007	149	20	441	1317	**24.2**	**250.5**	**0.91**
24 January 2007	141	19	63	401	**22.9**	**66.1**	**0.74**
25 January 2007	96	18	419	1095	**16.4**	**215.7**	**0.93**
26 January 2007	63	16	286	944	**11.4**	**175.3**	**0.94**
27 January 2007	38	14	379	1043	**7.5**	**202.6**	**0.96**
28 January 2007	25	13	396	1139	**5.5**	**218.7**	**0.98**
29 January 2007	24	12	522	1356	**5.2**	**267.6**	**0.98**
30 January 2007	25	9	474	1341	**4.9**	**258.6**	**0.98**
31 January 2007	20	9	211	762	**4.2**	**138.7**	**0.97**
01 February 2007	21	7	260	935	**4.0**	**170.3**	**0.98**
02 February 2007	20	7	583	1515	**3.9**	**299.0**	**0.99**
03 February 2007	18	6	188	657	**3.5**	**120.4**	**0.97**
04 February 2007	14	5	231	841	**2.7**	**152.8**	**0.98**
05 February 2007	14	4	393	1419	**2.6**	**258.2**	**0.99**
06 February 2007	14	5	405	1343	**2.7**	**249.1**	**0.99**
07 February 2007	13	3	295	982	**2.3**	**182.0**	**0.99**
08 February 2007	309	95	1157	2918	**58.3**	**580.7**	**0.91**
09 February 2007	12	6	814	2669	**2.6**	**496.3**	**0.99**
10 February 2007	18	4	728	2788	**3.2**	**501.0**	**0.99**
11 February 2007	582	148	162	1934	**105.1**	**298.7**	**0.74**
12 February 2007	448	83	93	1932	**76.3**	**288.6**	**0.79**
13 February 2007	104	7	172	2424	**15.9**	**369.9**	**0.96**
14 February 2007	153	11	3	1684	**23.5**	**240.4**	**0.91**
15 February 2007	621	36	13	2099	**93.9**	**301.0**	**0.76**

16 February 2007	255	5	1	1339	**37.1**	**191.0**	**0.84**
17 February 2007	54	10	185	1212	**9.2**	**199.1**	**0.96**
18 February 2007	6	3	185	1470	**1.3**	**235.8**	**0.99**
19 February 2007	534	2	6	2613	**76.4**	**373.2**	**0.83**
20 February 2007	840	135	0	2346	**140.0**	**334.3**	**0.70**
21 February 2007	346	31	0	1761	**54.0**	**250.9**	**0.82**
22 February 2007	1663	954	715	753	**380.1**	**209.2**	**0.36**
23 February 2007	607	106	839	249	**102.4**	**155.0**	**0.60**
24 February 2007	22	37	1204	1383	**8.7**	**368.6**	**0.98**
25 February 2007	29	311	1	1384	**50.8**	**197.4**	**0.80**
26 February 2007	51	304	344	843	**52.9**	**169.1**	**0.76**
27 February 2007	54	539	1434	542	**88.5**	**281.6**	**0.76**
28 February 2007	48	153	2024	449	**29.8**	**352.4**	**0.92**
01 March 2007	48	35	1050	401	**12.1**	**206.8**	**0.94**
02 March 2007	1332	1201	1424	841	**370.0**	**322.8**	**0.47**
03 March 2007	1610	64	1128	0	**239.0**	**160.7**	**0.40**
04 March 2007	1975	558	1441	329	**365.1**	**252.2**	**0.41**
05 March 2007	2179	592	1318	222	**399.3**	**219.5**	**0.35**
06 March 2007	1954	160	1331	22	**302.4**	**192.8**	**0.39**
07 March 2007	1204	82	873	0	**183.9**	**124.4**	**0.40**
08 March 2007	1019	304	558	0	**190.8**	**79.5**	**0.29**
09 March 2007	1238	367	341	0	**231.5**	**48.6**	**0.17**
10 March 2007	1583	711	2	2	**332.2**	**0.6**	**0.00**
11 March 2007	136	1055	130	429	**177.6**	**79.7**	**0.31**
12 March 2007	80	1104	1	281	**177.0**	**40.2**	**0.19**
13 March 2007	384	819	8	282	**177.6**	**41.3**	**0.19**
14 March 2007	173	442	5	48	**90.9**	**7.6**	**0.08**
15 March 2007	327	789	4	147	**165.0**	**21.5**	**0.12**
16 March 2007	383	845	5	256	**181.4**	**37.2**	**0.17**
17 March 2007	287	223	413	214	**74.4**	**89.3**	**0.55**
18 March 2007	154	31	418	12	**26.6**	**61.3**	**0.70**
19 March 2007	550	733	550	327	**188.3**	**125.0**	**0.40**
20 March 2007	599	1147	6	584	**257.4**	**84.1**	**0.25**
21 March 2007	517	976	4	521	**220.1**	**74.8**	**0.25**
22 March 2007	393	908	2	221	**192.2**	**31.8**	**0.14**
23 March 2007	374	809	1	268	**174.6**	**38.3**	**0.18**
24 March 2007	452	942	0	363	**205.6**	**51.7**	**0.20**
25 March 2007	422	850	1	371	**187.7**	**53.0**	**0.22**
26 March 2007	313	712	1	190	**151.5**	**27.2**	**0.15**
27 March 2007	911	1569	78	1003	**365.1**	**154.0**	**0.30**
28 March 2007	563	992	16	628	**229.0**	**91.8**	**0.29**
29 March 2007	521	860	245	414	**203.3**	**93.9**	**0.32**
30 March 2007	490	318	1133	3	**117.6**	**161.9**	**0.58**
31 March 2007	488	400	1043	0	**129.5**	**148.6**	**0.53**
01 April 2007	727	623	1526	0	**197.1**	**217.5**	**0.52**
02 April 2007	406	253	952	1	**95.9**	**135.8**	**0.59**
03 April 2007	527	354	1208	0	**128.2**	**172.1**	**0.57**
04 April 2007	517	300	1230	4	**118.6**	**175.8**	**0.60**
05 April 2007	404	0	1208	5	**57.6**	**172.9**	**0.75**
06 April 2007	168	1	502	1	**24.1**	**71.7**	**0.75**
07 April 2007	64	0	193	0	**9.2**	**27.5**	**0.75**
08 April 2007	259	2	776	0	**37.3**	**110.6**	**0.75**
09 April 2007	491	421	1029	0	**133.1**	**146.6**	**0.52**
10 April 2007	407	459	737	1	**126.9**	**105.2**	**0.45**
11 April 2007	511	375	1137	1	**129.1**	**162.2**	**0.56**
12 April 2007	451	330	1007	0	**113.8**	**143.5**	**0.56**
13 April 2007	532	377	1200	0	**132.4**	**171.0**	**0.56**
14 April 2007	449	314	1016	0	**111.1**	**144.8**	**0.57**
15 April 2007	546	451	1162	1	**145.4**	**165.7**	**0.53**
16 April 2007	569	416	1268	1	**143.5**	**180.8**	**0.56**

17 April 2007	538	394	1196	3	**135.8**	**170.9**	**0.56**
18 April 2007	327	211	757	1	**78.2**	**108.0**	**0.58**
19 April 2007	619	577	1239	10	**174.7**	**178.0**	**0.50**
20 April 2007	335	263	723	4	**87.1**	**103.6**	**0.54**
21 April 2007	9	2	24	0	**1.5**	**3.4**	**0.69**
22 April 2007	76	204	13	0	**41.4**	**1.9**	**0.04**
23 April 2007	90	217	30	13	**45.4**	**6.1**	**0.12**
24 April 2007	254	328	261	155	**85.4**	**59.3**	**0.41**
25 April 2007	185	255	560	691	**64.6**	**178.3**	**0.73**
26 April 2007	50	238	104	689	**42.8**	**113.0**	**0.73**
27 April 2007	286	9	18	830	**42.1**	**120.8**	**0.74**
28 April 2007	753	87	728	1440	**120.4**	**308.9**	**0.72**
29 April 2007	701	8	24	2071	**101.1**	**298.5**	**0.75**
30 April 2007	555	0	492	1173	**79.1**	**237.3**	**0.75**
01 May 2007	628	0	1183	701	**89.5**	**268.5**	**0.75**
02 May 2007	285	1	841	13	**40.8**	**121.7**	**0.75**
03 May 2007	390	530	607	4	**135.0**	**87.1**	**0.39**
04 May 2007	344	398	607	6	**108.7**	**87.4**	**0.45**
05 May 2007	169	17	483	7	**26.7**	**69.8**	**0.72**
06 May 2007	229	26	630	30	**36.6**	**94.1**	**0.72**
07 May 2007	532	593	704	267	**164.7**	**138.4**	**0.46**
08 May 2007	588	176	202	1378	**110.3**	**225.2**	**0.67**
09 May 2007	573	132	42	1538	**101.5**	**225.2**	**0.69**
10 May 2007	503	59	130	1318	**80.6**	**206.3**	**0.72**
11 May 2007	857	311	297	1947	**168.8**	**319.8**	**0.65**
12 May 2007	693	457	187	1412	**167.4**	**227.9**	**0.58**
13 May 2007	602	76	7	1720	**97.2**	**246.1**	**0.72**
14 May 2007	372	61	15	1038	**62.2**	**150.1**	**0.71**
15 May 2007	830	13	10	2465	**120.2**	**352.7**	**0.75**
16 May 2007	450	40	6	1301	**70.1**	**186.2**	**0.73**
17 May 2007	420	26	3	1231	**63.8**	**175.8**	**0.73**
18 May 2007	20	15	1	44	**5.1**	**6.4**	**0.56**
19 May 2007	16	11	4	31	**3.9**	**5.0**	**0.56**
20 May 2007	100	21	16	261	**17.4**	**39.5**	**0.69**
21 May 2007	384	11	316	825	**56.4**	**162.6**	**0.74**
22 May 2007	831	26	2432	35	**122.4**	**351.5**	**0.74**
23 May 2007	198	343	1233	82	**79.7**	**187.4**	**0.70**
24 May 2007	328	381	84	572	**103.9**	**93.5**	**0.47**
25 May 2007	21	19	24	14	**5.8**	**5.4**	**0.48**
26 May 2007	17	329	52	969	**51.8**	**145.5**	**0.74**
27 May 2007	41	1396	36	4330	**215.2**	**622.2**	**0.74**
28 May 2007	264	456	379	797	**106.0**	**167.6**	**0.61**
29 May 2007	121	92	118	49	**31.0**	**23.8**	**0.43**
30 May 2007	56	58	121	6	**16.7**	**18.1**	**0.52**
31 May 2007	79	392	39	1121	**70.1**	**165.3**	**0.70**
01 June 2007	102	655	36	1930	**112.8**	**280.2**	**0.71**
02 June 2007	71	316	782	145	**57.5**	**132.1**	**0.70**
03 June 2007	63	580	1707	60	**95.9**	**251.8**	**0.72**
04 June 2007	29	331	911	104	**53.8**	**144.6**	**0.73**
05 June 2007	97	428	1110	141	**78.0**	**178.3**	**0.70**
06 June 2007	112	188	448	32	**44.1**	**68.4**	**0.61**
07 June 2007	199	114	68	93	**45.5**	**22.9**	**0.34**
08 June 2007	234	256	60	512	**71.7**	**81.5**	**0.53**
09 June 2007	573	409	322	397	**143.1**	**102.5**	**0.42**
10 June 2007	1310	530	352	11	**266.2**	**51.7**	**0.16**
11 June 2007	266	451	1142	11	**105.5**	**164.3**	**0.61**
12 June 2007	112	543	1504	97	**97.4**	**228.1**	**0.70**
13 June 2007	225	382	973	8	**89.4**	**139.8**	**0.61**
14 June 2007	508	585	1185	154	**160.1**	**190.8**	**0.54**
15 June 2007	289	440	1009	90	**107.1**	**156.6**	**0.59**
16 June 2007	166	563	92	1520	**108.1**	**229.7**	**0.68**
17 June 2007	222	331	322	501	**81.3**	**117.3**	**0.59**

18 June 2007	325	285	162	414	**89.1**	**82.1**	**0.48**
19 June 2007	825	97	762	1887	**132.1**	**377.5**	**0.74**
20 June 2007	223	310	783	1068	**78.3**	**263.8**	**0.77**
21 June 2007	7	0	1202	355	**1.0**	**221.9**	**1.00**
22 June 2007	6	138	837	200	**21.6**	**147.8**	**0.87**
23 June 2007	17	0	1125	160	**2.4**	**183.1**	**0.99**
24 June 2007	35	11	1385	513	**6.6**	**270.5**	**0.98**
25 June 2007	67	366	983	106	**64.5**	**155.2**	**0.71**
26 June 2007	66	615	1418	457	**101.6**	**267.2**	**0.72**
27 June 2007	77	315	826	91	**58.2**	**130.7**	**0.69**
28 June 2007	113	370	1056	0	**71.6**	**150.5**	**0.68**
29 June 2007	167	404	1110	0	**84.5**	**158.2**	**0.65**
30 June 2007	186	516	1318	124	**103.8**	**205.5**	**0.66**
01 July 2007	114	490	1165	268	**89.7**	**204.2**	**0.69**
02 July 2007	214	627	1360	405	**124.5**	**251.5**	**0.67**
03 July 2007	294	590	1418	151	**130.4**	**223.6**	**0.63**
04 July 2007	202	398	1053	2	**88.5**	**150.3**	**0.63**
05 July 2007	216	402	1040	15	**91.2**	**150.3**	**0.62**
06 July 2007	64	376	1007	117	**65.6**	**160.2**	**0.71**
07 July 2007	45	182	520	10	**33.7**	**75.5**	**0.69**
08 July 2007	30	355	1090	0	**57.5**	**155.3**	**0.73**
09 July 2007	32	268	815	0	**44.8**	**116.1**	**0.72**
10 July 2007	25	605	1885	0	**94.3**	**268.6**	**0.74**
11 July 2007	14	374	1168	0	**58.1**	**166.4**	**0.74**
12 July 2007	44	278	800	34	**48.0**	**118.8**	**0.71**
13 July 2007	30	373	568	579	**60.2**	**163.4**	**0.73**
14 July 2007	278	302	375	301	**84.9**	**96.3**	**0.53**
15 July 2007	451	368	277	434	**119.5**	**101.3**	**0.46**
16 July 2007	222	483	1042	260	**104.0**	**185.5**	**0.64**
17 July 2007	28	503	1266	295	**79.5**	**222.4**	**0.74**
18 July 2007	26	297	853	58	**48.2**	**129.8**	**0.73**
19 July 2007	98	471	1164	226	**84.6**	**198.1**	**0.70**
20 July 2007	7	396	1010	233	**60.4**	**177.1**	**0.75**
21 July 2007	5	81	252	0	**12.9**	**35.9**	**0.74**
22 July 2007	4	274	860	0	**41.6**	**122.6**	**0.75**
23 July 2007	3	675	2128	0	**101.7**	**303.2**	**0.75**
24 July 2007	55	475	1445	0	**79.1**	**205.9**	**0.72**
25 July 2007	77	282	582	230	**53.2**	**115.7**	**0.69**
26 July 2007	158	143	2	291	**43.9**	**41.8**	**0.49**
27 July 2007	392	308	102	478	**102.0**	**82.7**	**0.45**
28 July 2007	182	561	1303	285	**110.0**	**226.3**	**0.67**
29 July 2007	334	698	1469	401	**152.3**	**266.5**	**0.64**
30 July 2007	188	568	1363	241	**112.1**	**228.6**	**0.67**
31 July 2007	143	586	1017	643	**108.3**	**236.6**	**0.69**
01 August 2007	125	425	444	51	**159.8**	**138.2**	**0.46**
02 August 2007							
03 August 2007							
04 August 2007							
05 August 2007							
06 August 2007							
07 August 2007							
08 August 2007							
09 August 2007							
10 August 2007							
11 August 2007							
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13 August 2007							
14 August 2007							
15 August 2007							
16 August 2007							
17 August 2007							
18 August 2007							
19 August 2007							
20 August 2007							
21 August 2007	295	276	362	138	**157.1**	**134.1**	**0.46**

22 August 2007	397	535	547	257	**136.8**	**114.6**	**0.46**
23 August 2007	419	362	685	331	**114.0**	**144.8**	**0.56**
24 August 2007	174	205	319	153	**55.5**	**67.3**	**0.55**
25 August 2007	108	81	97	42	**27.5**	**19.8**	**0.42**
26 August 2007	220	230	318	189	**65.9**	**72.2**	**0.52**
27 August 2007	412	389	580	235	**117.0**	**116.1**	**0.50**
28 August 2007	481	433	678	209	**133.5**	**126.4**	**0.49**
29 August 2007	400	348	472	226	**109.2**	**99.5**	**0.48**
30 August 2007	432	389	418	378	**119.9**	**113.4**	**0.49**
31 August 2007	486	412	389	425	**131.0**	**116.0**	**0.47**
01 September 2007	482	368	347	334	**123.9**	**97.0**	**0.44**
02 September 2007	244	154	55	187	**57.9**	**34.5**	**0.37**
03 September 2007	434	113	616	415	**78.8**	**146.9**	**0.65**
04 September 2007	365	476	737	398	**123.5**	**161.7**	**0.57**
05 September 2007	151	271	529	175	**62.2**	**100.3**	**0.62**
06 September 2007	232	347	680	185	**85.2**	**123.3**	**0.59**
07 September 2007	270	335	637	151	**88.7**	**112.3**	**0.56**
08 September 2007	280	265	488	69	**79.7**	**79.4**	**0.50**
09 September 2007	562	496	841	164	**154.5**	**143.2**	**0.48**
10 September 2007	531	515	1029	66	**153.0**	**156.0**	**0.50**
11 September 2007	456	403	643	172	**125.5**	**116.1**	**0.48**
12 September 2007	644	506	730	225	**167.7**	**136.1**	**0.45**
13 September 2007	483	445	710	210	**135.5**	**131.1**	**0.49**
14 September 2007	351	481	857	310	**122.1**	**166.3**	**0.58**
15 September 2007	284	331	575	187	**90.2**	**108.6**	**0.55**
16 September 2007	315	396	725	208	**104.2**	**133.0**	**0.56**
17 September 2007	210	249	379	196	**67.2**	**81.9**	**0.55**
18 September 2007	364	458	658	424	**120.6**	**154.2**	**0.56**
19 September 2007	302	307	429	238	**89.1**	**95.0**	**0.52**
20 September 2007	340	110	463	330	**65.0**	**113.0**	**0.64**
21 September 2007	581	242	749	504	**119.1**	**178.6**	**0.60**
22 September 2007	524	294	523	533	**118.8**	**150.5**	**0.56**
23 September 2007	664	528	690	715	**173.8**	**200.2**	**0.54**
24 September 2007	353	440	281	362	**116.3**	**91.6**	**0.44**
25 September 2007	379	302	263	301	**99.3**	**80.4**	**0.45**
26 September 2007	346	233	259	273	**84.3**	**75.8**	**0.47**
27 September 2007	417	386	320	382	**117.3**	**100.0**	**0.46**
28 September 2007	433	411	364	394	**123.4**	**108.0**	**0.47**
29 September 2007	476	508	399	473	**144.0**	**124.3**	**0.46**
30 September 2007	664	731	595	658	**204.3**	**178.6**	**0.47**
01 October 2007	345	480	451	474	**121.2**	**131.8**	**0.52**
02 October 2007	457	260	392	431	**104.1**	**117.3**	**0.53**
03 October 2007	397	61	421	518	**65.7**	**133.8**	**0.67**
04 October 2007	456	325	460	574	**113.7**	**147.3**	**0.56**
05 October 2007	420	236	388	509	**95.3**	**127.8**	**0.57**
06 October 2007	499	369	431	577	**126.5**	**143.6**	**0.53**
07 October 2007	441	279	298	454	**104.7**	**107.2**	**0.51**
08 October 2007	418	276	312	444	**101.0**	**107.7**	**0.52**
09 October 2007	593	532	431	610	**164.4**	**148.3**	**0.47**
10 October 2007	358	417	438	522	**113.6**	**136.8**	**0.55**
11 October 2007	192	231	228	308	**61.9**	**76.4**	**0.55**
12 October 2007	227	346	382	484	**84.3**	**123.4**	**0.59**
13 October 2007	204	293	317	404	**73.0**	**102.7**	**0.58**
14 October 2007	341	540	643	720	**129.5**	**194.2**	**0.60**
15 October 2007	130	237	278	341	**54.1**	**88.2**	**0.62**
16 October 2007	137	265	312	389	**59.3**	**99.9**	**0.63**
17 October 2007	198	341	403	477	**79.4**	**125.4**	**0.61**
18 October 2007	151	280	324	410	**63.6**	**104.6**	**0.62**
19 October 2007	118	206	232	300	**47.7**	**75.8**	**0.61**
20 October 2007	18	40	47	62	**8.6**	**15.5**	**0.64**
21 October 2007	97	187	207	285	**41.8**	**70.1**	**0.63**
22 October 2007	15	53	61	92	**10.1**	**21.8**	**0.68**
23 October 2007	1	15	17	30	**2.4**	**6.7**	**0.73**
24 October 2007	12	48	55	83	**8.8**	**19.7**	**0.69**
25 October 2007	4	26	30	47	**4.4**	**11.0**	**0.71**
26 October 2007	6	38	46	68	**6.6**	**16.2**	**0.71**
27 October 2007	1	22	24	44	**3.4**	**9.7**	**0.74**
28 October 2007	33	120	154	191	**22.7**	**49.2**	**0.68**

29 October 2007	58	239	306	390	**44.1**	**99.2**	**0.69**
30 October 2007	38	370	585	544	**60.8**	**160.9**	**0.73**
31 October 2007	12	202	343	283	**32.0**	**89.2**	**0.74**
01 November 2007	230	230	272	205	**67.4**	**68.0**	**0.50**
02 November 2007	286	286	378	216	**83.8**	**84.6**	**0.50**
03 November 2007	245	245	369	145	**71.6**	**73.2**	**0.51**
04 November 2007	522	522	772	323	**152.6**	**156.0**	**0.51**
05 November 2007	424	424	636	256	**124.1**	**127.1**	**0.51**
06 November 2007	290	290	457	154	**84.9**	**87.1**	**0.51**
07 November 2007	466	466	721	259	**136.2**	**139.7**	**0.51**
08 November 2007	367	367	581	191	**107.3**	**110.0**	**0.51**
09 November 2007	459	459	703	263	**134.2**	**137.7**	**0.51**
10 November 2007	244	244	384	130	**71.4**	**73.2**	**0.51**
11 November 2007	391	391	615	209	**114.5**	**117.4**	**0.51**
12 November 2007	335	335	526	178	**98.0**	**100.3**	**0.51**
13 November 2007	654	654	998	379	**191.3**	**196.2**	**0.51**
14 November 2007	420	420	657	228	**123.0**	**126.1**	**0.51**
15 November 2007	479	479	747	261	**140.0**	**143.6**	**0.51**
16 November 2007	542	542	832	309	**158.7**	**162.6**	**0.51**
17 November 2007	519	519	782	310	**151.7**	**155.6**	**0.51**
18 November 2007	730	730	1092	445	**213.5**	**219.0**	**0.51**
19 November 2007	409	409	612	248	**119.5**	**122.6**	**0.51**
20 November 2007	185	225	650	300	**60.1**	**135.4**	**0.69**
21 November 2007	287	355	505	266	**94.1**	**109.9**	**0.54**
22 November 2007	234	318	417	179	**81.0**	**84.9**	**0.51**
23 November 2007	326	481	648	396	**118.6**	**148.8**	**0.56**
24 November 2007	345	473	641	383	**120.1**	**145.9**	**0.55**
25 November 2007	251	374	549	275	**91.9**	**117.4**	**0.56**
26 November 2007	317	439	776	472	**111.0**	**177.8**	**0.62**
27 November 2007	343	450	723	435	**116.4**	**165.0**	**0.59**
28 November 2007	231	291	457	239	**76.6**	**99.2**	**0.56**
29 November 2007	254	277	405	182	**77.7**	**83.6**	**0.52**
30 November 2007	272	308	534	298	**85.0**	**118.6**	**0.58**
01 December 2007	294	309	445	212	**88.2**	**93.6**	**0.51**
02 December 2007	398	474	776	481	**127.8**	**179.1**	**0.58**
03 December 2007	328	354	737	437	**99.8**	**167.3**	**0.63**
04 December 2007	222	234	734	489	**66.7**	**174.3**	**0.72**
05 December 2007	181	182	670	312	**53.1**	**139.9**	**0.72**
06 December 2007	272	269	1012	471	**79.1**	**211.3**	**0.73**
07 December 2007	232	220	768	387	**66.1**	**164.6**	**0.71**
08 December 2007	458	449	1139	634	**132.6**	**252.7**	**0.66**
09 December 2007	471	457	950	516	**135.7**	**208.9**	**0.61**
10 December 2007	354	364	1093	576	**105.0**	**237.8**	**0.69**
11 December 2007	341	359	689	286	**102.4**	**138.9**	**0.58**
12 December 2007	277	261	551	145	**78.6**	**99.2**	**0.56**
13 December 2007	323	341	744	215	**97.2**	**136.7**	**0.58**
14 December 2007	692	668	1622	484	**198.8**	**300.1**	**0.60**
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11 March 2008							
12 March 2008	11	12	15	8	**31.4**	**30.1**	**0.49**
13 March 2008	59	43	48	26	**136.1**	**99.4**	**0.42**
14 March 2008	78	46	48	26	**166.5**	**98.5**	**0.37**
15 March 2008	75	44	45	24	**159.1**	**93.2**	**0.37**
16 March 2008	61	35	37	20	**128.5**	**75.4**	**0.37**
17 March 2008	30	16	16	9	**60.5**	**33.3**	**0.36**
18 March 2008	30	16	17	9	**61.9**	**35.7**	**0.37**
19 March 2008	17	8	8	4	**33.4**	**15.5**	**0.32**
20 March 2008	12	5	5	3	**22.7**	**10.8**	**0.32**
21 March 2008	19	8	9	5	**37.0**	**18.4**	**0.33**
22 March 2008	11	3	4	2	**19.4**	**8.6**	**0.31**
23 March 2008	37	21	21	11	**77.0**	**43.6**	**0.36**
24 March 2008	61	44	45	24	**139.5**	**92.7**	**0.40**
25 March 2008	75	41	39	21	**155.3**	**79.5**	**0.34**
26 March 2008	51	40	31	17	**121.8**	**63.1**	**0.34**
27 March 2008	63	48	45	24	**147.6**	**92.4**	**0.38**
28 March 2008	44	65	32	17	**146.5**	**65.2**	**0.31**
29 March 2008	70	68	48	26	**183.9**	**99.1**	**0.35**
30 March 2008	100	67	67	36	**223.4**	**136.8**	**0.38**
31 March 2008	87	33	55	29	**160.1**	**112.2**	**0.41**
01 April 2008	629	380	373	201	**146.6**	**81.8**	**0.36**
02 April 2008	572	345	346	186	**133.3**	**75.9**	**0.36**
03 April 2008	566	342	341	184	**131.9**	**74.8**	**0.36**
04 April 2008	405	244	234	126	**94.4**	**51.3**	**0.35**
05 April 2008	619	371	371	200	**143.9**	**81.3**	**0.36**
06 April 2008	936	578	574	309	**220.1**	**125.8**	**0.36**
07 April 2008	458	267	268	144	**105.3**	**58.8**	**0.36**
08 April 2008	628	378	381	205	**146.2**	**83.5**	**0.36**
09 April 2008	456	262	261	141	**104.3**	**57.2**	**0.35**
10 April 2008	545	324	319	172	**126.3**	**69.9**	**0.36**
11 April 2008	379	225	224	125	**87.8**	**49.7**	**0.36**
12 April 2008	97	55	54	29	**22.1**	**11.8**	**0.35**
13 April 2008	247	131	130	70	**54.8**	**28.5**	**0.34**
14 April 2008	803	507	493	265	**190.5**	**108.1**	**0.36**
15 April 2008	566	509	497	268	**157.0**	**109.0**	**0.41**
16 April 2008	328	288	282	152	**89.9**	**61.8**	**0.41**
17 April 2008	360	212	201	119	**83.1**	**45.6**	**0.35**
18 April 2008	433	261	238	125	**100.9**	**51.7**	**0.34**
19 April 2008	553	337	316	170	**129.4**	**69.3**	**0.35**
20 April 2008	630	382	343	185	**147.1**	**75.2**	**0.34**
21 April 2008	567	315	246	132	**128.0**	**53.9**	**0.30**
22 April 2008	691	358	235	127	**152.2**	**51.5**	**0.25**
23 April 2008	706	323	215	116	**149.1**	**47.1**	**0.24**
24 April 2008	656	307	184	99	**139.5**	**40.3**	**0.22**
25 April 2008	421	212	145	78	**91.8**	**31.8**	**0.26**
26 April 2008	502	258	166	89	**110.2**	**36.4**	**0.25**
27 April 2008	1275	810	513	276	**303.2**	**112.5**	**0.27**
28 April 2008	842	516	397	214	**197.4**	**87.0**	**0.31**
29 April 2008	702	426	333	179	**163.9**	**73.0**	**0.31**
30 April 2008	499	325	247	133	**119.9**	**54.2**	**0.31**
01 May 2008	674	449	341	184	**163.4**	**74.8**	**0.31**
02 May 2008	522	346	262	141	**126.3**	**57.4**	**0.31**
03 May 2008	214	126	104	56	**49.4**	**22.8**	**0.32**
04 May 2008	186	120	90	48	**44.5**	**19.7**	**0.31**
05 May 2008	246	163	123	66	**59.5**	**27.0**	**0.31**
06 May 2008	236	151	118	64	**56.3**	**25.9**	**0.31**
07 May 2008	550	349	282	152	**130.7**	**61.8**	**0.32**
08 May 2008	536	347	292	157	**128.4**	**64.0**	**0.33**
09 May 2008	725	468	372	225	**173.5**	**85.1**	**0.33**
10 May 2008	431	269	218	233	**101.8**	**64.3**	**0.39**
11 May 2008	993	644	528	171	**238.1**	**99.6**	**0.29**
12 May 2008	604	423	342	101	**149.5**	**63.1**	**0.30**
13 May 2008	670	159	427	162	**119.3**	**83.9**	**0.41**
14 May 2008	514	102	306	251	**88.5**	**79.4**	**0.47**

15 May 2008	733	369	311	331	**159.8**	**91.5**	**0.36**
16 May 2008	557	342	280	277	**130.7**	**79.4**	**0.38**
17 May 2008	293	206	175	185	**72.7**	**51.3**	**0.41**
18 May 2008	604	428	376	396	**150.3**	**110.0**	**0.42**
19 May 2008	579	419	368	389	**145.4**	**107.9**	**0.43**
20 May 2008	561	351	338	354	**132.6**	**98.6**	**0.43**
21 May 2008	525	338	290	308	**125.5**	**85.2**	**0.40**
22 May 2008	651	445	381	421	**159.5**	**114.3**	**0.42**
23 May 2008	453	293	209	229	**108.5**	**62.4**	**0.37**
24 May 2008	679	447	315	366	**163.8**	**97.0**	**0.37**
25 May 2008	701	476	375	348	**171.3**	**103.0**	**0.38**
26 May 2008	537	371	287	338	**132.2**	**89.1**	**0.40**
27 May 2008	582	408	316	370	**144.1**	**97.8**	**0.40**
28 May 2008	628	433	339	354	**154.4**	**98.8**	**0.39**
29 May 2008	306	208	184	159	**74.8**	**48.9**	**0.40**
30 May 2008	461	233	264	121	**100.6**	**54.9**	**0.35**
31 May 2008	320	0	171	98	**45.6**	**38.3**	**0.46**
01 June 2008	485	0	261	71	**69.1**	**47.3**	**0.41**
02 June 2008	404	1	230	123	**57.7**	**50.3**	**0.47**
03 June 2008	508	0	286	172	**72.4**	**65.3**	**0.47**
04 June 2008	727	0	52	54	**103.6**	**15.1**	**0.13**
05 June 2008	281	0	27	29	**40.0**	**8.0**	**0.17**
06 June 2008	0	0	0	0	**0.0**	**0.0**	
07 June 2008	0	0	0	0	**0.0**	**0.0**	
08 June 2008	0	0	0	0	**0.0**	**0.0**	
09 June 2008	0	0	0	0	**0.0**	**0.0**	
10 June 2008	0	0	0	0	**0.0**	**0.0**	
11 June 2008	0	0	0	0	**0.0**	**0.0**	
12 June 2008	0	0	0	0	**0.0**	**0.0**	
13 June 2008	0	0	0	0	**0.0**	**0.0**	
14 June 2008	294	145	135	137	**63.6**	**38.8**	**0.38**
15 June 2008	1057	574	530	537	**236.7**	**152.0**	**0.39**
16 June 2008	474	391	351	345	**126.2**	**99.2**	**0.44**
17 June 2008	527	450	420	420	**142.6**	**119.7**	**0.46**
18 June 2008	723	619	527	539	**195.9**	**151.9**	**0.44**
19 June 2008	778	612	674	913	**202.7**	**226.1**	**0.53**
20 June 2008	334	261	231	341	**86.7**	**81.5**	**0.48**
21 June 2008	1948	1552	1432	1839	**510.4**	**466.1**	**0.48**
22 June 2008	834	621	798	1114	**212.0**	**272.5**	**0.56**
23 June 2008	412	310	388	516	**105.2**	**128.8**	**0.55**

Appendix D

CHEMICAL & BACTERIOLOGICAL ANALYSIS RESULTS

RESULTS FROM DIURNAL SAMPLING TRIALS

Site A : Septic Tank Effluent

Date	Time	COD	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
24/07/2007	11:00:00	599	73	0.3	0.2	19.2	4.84E+07	1.22E+06
	14:00:00	629	75.5	1.8	0.22	18.5	5.36E+07	1.29E+06
	17:00:00	508	73	0.1	0.21	15.6	1.55E+07	1.20E+06
	20:00:00	642	78	<0.1	0.21	17.2	2.42E+07	1.08E+06
	23:00:00	721	74	0.3	0.23	15.05	2.42E+07	1.12E+06
25/07/2007	02:00:00	995	75.5	0.4	0.2	14.6	2.42E+07	9.89E+05
	05:00:00	748	74	0.5	0.19	15.4	9.65E+07	1.42E+06
	08:00:00	514	79.5	0.7	0.3	16.1	7.88E+07	1.15E+06
	11:00:00	526	67.5	2	0.21	16.95	3.69E+07	1.35E+06
	14:00:00	435	88.5	<0.1	0.25	11.5	2.61E+07	1.60E+06
	17:00:00	444	85	<0.1	0.21	12.4	3.45E+07	1.46E+06
	20:00:00	351	98.5	<0.1	0.2	15	2.76E+07	1.21E+06
	23:00:00	386	99	<0.1	0.26	15.5	1.72E+07	1.10E+06
26/07/2007	02:00:00	416	95	<0.1	0.38	15.15	2.05E+07	1.60E+06
	05:00:00	516	106	<0.1	0.29	17.65	2.49E+07	1.87E+06
	08:00:00	483	111	<0.1	0.28	16	4.11E+07	1.34E+06
	11:00:00	583	93.5	<0.1	0.27	17.45	2.76E+07	1.34E+06
Mean		**559**	**85.1**	**0.8**	**0.24**	**15.8**	**3.66E+07**	**1.31E+06**
Std Deviation		**±158**	**±13.2**	**±0.6**	**±0.1**	**±2.0**	**±2.20E+07**	**±2.25E+05**

Site A : Centre of Reed Bed

Date	Time	COD	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
24/07/2007	11am	257	55	<1.0	0.15	16.8	2.61E+05	1.10E+04
	2pm	228	56.5	0.7	0.11	21.45	5.48E+05	4.00E+04
	5pm	118	57	0.7	0.15	11.6	3.87E+05	4.73E+04
	8pm	99	50	1.5	0.16	11.65	8.66E+05	3.54E+04
	11pm	81	51	1	0.09	11.9	6.49E+05	3.84E+04
25/07/2007	2am	95	49	0.9	0.19	10.9	6.49E+05	6.20E+04
	5am	203	42	1.1	0.15	11.5	1.05E+06	5.39E+04
	8am	266	20.5	1.4	0.14	10.95	2.42E+06	1.21E+05
	11am	82	11.5	2.3	0.37	9.75	1.05E+06	8.58E+04
	2pm	179	89	<0.1	0.07	13.35	1.99E+06	2.10E+05
	5pm	69	71.5	<0.1	0.12	14.45	1.55E+06	1.13E+05
	8pm	59	78	<0.1	0.14	14.75	1.99E+06	1.37E+05
	11pm	52	78.5	<0.1	0.38	14.25	1.73E+06	1.79E+05
26/07/2007	2am	92	79.5	<0.1	0.18	13	2.42E+07	1.46E+05
	5am	79	86.5	<0.1	0.08	12.45	1.99E+06	8.84E+04
	8am	94	91	<0.1	0.07	12	1.99E+06	1.35E+05
	11am	68	84.5	<0.1	0.08	13.8	6.87E+05	8.80E+04
Mean		**125**	**61.8**	**1.2**	**0.15**	**13.2**	**2.59E+06**	**9.36E+04**
Std Deviation		**±72**	**±23.5**	**±0.7**	**±0.1**	**±2.7**	**±5.61E+06**	**±5.55E+04**

Site A : Reed Bed Effluent (RBE)

Date	Time	COD	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
24/07/2007	11am	98	44	1.3	0.09	14.65	2.28E+05	3.19E+04
	2pm	140	38	1.9	0.07	12.4	7.27E+05	5.66E+04
	5pm	98	44.5	<1.0	0.08	15.3	6.87E+05	5.04E+04
	8pm	192	47	0.2	0.07	17.15	9.21E+05	5.91E+04
	11pm	86	39	1.6	0.08	13.4	8.16E+05	7.33E+04
25/07/2007	2am	221	35.5	0.1	0.09	12.8	1.20E+06	5.73E+04
	5am	158	2.5	0.7	0.11	13.9	6.13E+05	4.09E+04
	8am	165	10.1	1.2	0.22	12.8	5.79E+05	2.76E+04
	11am	113	47.5	0.5	0.21	18.55	4.61E+05	2.66E+04
	2pm	95	93.5	<0.1	0.08	13.75	6.49E+05	7.17E+04
	5pm	139	91	<0.1	0.07	14.35	8.16E+05	7.54E+04
	8pm	33	100.5	<0.1	0.06	15.3	5.48E+05	8.57E+04
	11pm	100	87.5	<0.1	0.05	14.7	6.13E+05	5.76E+04
26/07/2007	2am	40	28.5	<0.1	0.06	13.95	9.21E+05	6.20E+04
	5am	59	9.5	<0.1	0.09	14.4	9.21E+05	6.89E+04
	8am	104	12	<0.1	0.08	14.5	7.22E+05	5.22E+04
	11am	66	2.5	<0.1	0.05	12.9	6.13E+05	6.54E+04
Mean		**112**	**43.1**	**0.9**	**0.09**	**14.4**	**7.08E+05**	**5.66E+04**
Std Deviation		**±52**	**±32.5**	**±0.7**	**±0.05**	**±1.6**	**±2.19E+05**	**±1.70E+04**

Site B : Biodisc® SE

Date	Time	COD	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
21/08/2007	10am	243	2.42	16	0.45	34.3	5.48E+05	1.04E+04
	1pm	117	2.56	23.4	0.89	46	1.30E+06	5.75E+04
	4pm	99	2.4	19.2	0.99	25.9	6.49E+05	2.62E+04
	7pm	135	2.36	24.4	0.95	24.2	7.70E+05	4.81E+04
	10pm	*24*	2.7	23	0.65	30.2	9.80E+05	5.38E+04
22/08/2007	1am	*168*	3.18	21.8	0.6	28.2	1.30E+06	6.12E+04
	4am	*30*	3.38	21	0.42	28.7	1.20E+06	5.48E+04
	7am	*36*	3.48	23	0.38	33.3	2.42E+06	6.34E+04
	10am	*60*	3.28	26	0.35	21.8	1.73E+06	6.47E+04
	1pm	-	2.22	-	0.34	25.7	-	-
	4pm	-	3.62	-	0.35	31.8	-	-
	7pm	-	3.56	-	0.39	29.2	-	-
	10pm	-	3.62	-	0.55	29.7	-	-
23/08/2007	1am	-	3.74	-	0.66	25.3	-	-
	4am	-	3.48	-	0.77	23.8	-	-
	7am	-	3.34	-	0.88	27.9	-	-
	10am	-	3.5	-	1.07	26	-	-
Mean		**101**	**3.1**	**22.0**	**0.63**	**28.9**	**1.21E+06**	**4.89E+04**
Std Deviation		**±73**	**±0.5**	**±3.0**	**±0.25**	**±5.5**	**±5.86E+05**	**±1.85E+04**

Site B : Reed Bed Effluent (RB1)

Date	Time	COD	NH_4	NO_3	NO_2	PO_4	Total Coliforms	*E.coli*
21/08/2007	10am	75	1.77	10.6	0.47	28.6	5.48E+03	1.35E+02
	1pm	117	1.81	13.6	0.43	29	1.30E+04	1.71E+02
	4pm	30	2.08	11.4	0.4	26.6	5.80E+03	1.20E+02
	7pm	78	1.56	13.2	0.43	33.4	8.64E+03	1.46E+02
	10pm	24	1.99	13.2	0.44	28.7	5.79E+03	2.66E+02
22/08/2007	1am	96	1.94	12.5	0.48	34.2	1.05E+04	1.20E+02
	4am	54	1.97	14.3	0.46	28.3	1.12E+04	2.53E+02
	7am	57	2	12.9	0.48	26.5	1.12E+04	7.50E+01
	10am	75	1.96	14.1	0.49	25	2.61E+03	1.35E+02
	1pm	-	1.57	-	0.42	32.1	-	-
	4pm	-	1.43	-	0.48	26.4	-	-
	7pm	-	1.86	-	0.44	26.6	-	-
	10pm	-	1.68	-	0.41	24.1	-	-
23/08/2007	1am	-	1.58	-	0.46	27.8	-	-
	4am	-	1.2	-	0.47	23.4	-	-
	7am	-	1.74	-	0.48	25.3	-	-
	10am	-	1.5	-	0.44	26.5	-	-
Mean		**67**	**1.7**	**12.9**	**0.45**	**27.8**	**8.25E+03**	**1.58E+02**
Std Deviation		**±30**	**±0.2**	**±1.2**	**±0.03**	**±3.1**	**±3.48E+03**	**±6.31E+01**

SITE A

Results from Chemical & Bacteriological Analysis

Septic Tank Effluent (STE)

Sample Position	Ref	Date	pH	Temp	BOD	COD	TN	NO_3-N	NO_2-N	NH_4-N	Total Inorg.N	Ortho-P	Cl	SS
	CLX	10/04/2006	-	-	-	843	-	1.2	0.43	0.11	-	10.15	269	-
	CLX	27/04/2006	-	-	-	436	-	1.1	0.28	0.1	-	18.3	410	376.9
	CLX	12/07/2006	-	-	-	676	-	0.5	0.24	76	76.74	7.4	96	122
	CLX	02/08/2006	-	-	-	442	85.8	0.2	0.26	86	86.46	14.25	95	152
	CLX	06/09/2006	-	-	-	580	148	0.7	0.2	112	112.9	22.8	520	-
	CLX	18/10/2006	7.05	-	-	572	133	0.2	0.3	88	88.5	10.7	728	83.8
	CLX	16/11/2006	-	-	-	502	80.5	1.1	0.29	80	81.39	13.3	830	125
	CLX	23/01/2007	7.31	-	-	412	51.7	1	0.23	30.5	31.73	5.54	50	-
	CLX	02/02/2007	7.86	-	-	278	77	0.4	0.14	63	63.54	13.75	92	-
Septic Tank	CLX	08/02/2007	8.35	-	-	342	88.5	0.9	0.17	57.8	58.87	8.85	64	-
	CLX	19/04/2007	7.41	-	-	941	135	0.05	0.28	70.2	70.53	6.04	336	140
	CLX	16/05/2007	7.69	-	-	409	130	0.2	0.14	76	76.34	36.5	520	-
	CLX	26/06/2007	7.26	-	-	393	105	0.05	0.08	-	-	7.68	66	-
	CLX	11/07/2007	7.41	-	-	686	-	-	-	-	-	13.9	60	-
	CLX	29/08/2007	-	15.7	260.0	410	119	0.8	0.27	82	83.07	15.15	166	-
	CLX	27/09/2007	-	-		469	114	2	0.19	101	103.19	37.4	960	-
	CLX	05/12/2007	7.38	-	108.8	561	75	0.5	0.08	67	67.58	11.6	588	-
	CLX	12/02/2008	-	-	-	289	-	1.6	-	10.5	12.1	8.58	310	-
	CLX	25/02/2008	7.90	7.5	-	786	96	0.7	-	72	72.7	-	-	-
	CLX	22/04/2008	-	-	-	-	-	1.4	-	82	83.4	-	-	-
	CLX	23/04/2008	-	-	-	-	123	0.6	-	95	95.6	-	-	-
	CLX	24/04/2008	-	-	-	-	127	1.5	-	91	92.5	-	-	-
	CLX	03/06/2008	-	-	187.0	709	116	2.4	0.25	111	113.65	37.3	326	-
	CLX	13/06/2008	6.80	-	183.0	743	125	0.05	0.14	49.5	49.69	32.3	840	82.5

Secondary Reed Bed Effluent (RBE)

Sample Position	Ref	Date	pH	Temp	BOD	COD	TN	NO_3-N	NO_2-N	NH_4-N	Total Inorg.N	Ortho-P	Cl	SS
	CLZ	10/04/2006	-	-	-	369	-	0.3	0.05	2.5	-	3.42	257	-
	CLZ	27/04/2006	-	-	-	293	-	0.3	0.07	0.05	-	4.71	512	87.2
	CLZ	12/07/2006	-	-	-	414	-	0.2	0.09	72.1	72.39	3.4	86	36
	CLZ	02/08/2006	-	-	-	368	74.5	0.2	0.07	64.2	64.47	6.98	95	42.1
	CLZ	06/09/2006	-	-	-	264	61.6	2.2	0.08	49.1	51.38	13.3	414	-
	CLZ	18/10/2006	7.47	-	-	-	77.0	0.2	0.05	86	86.25	9.2	688	39.2
	CLZ	16/11/2006	-	-	-	154	72.9	0.2	0.15	91	91.35	9.6	800	23
	CLZ	23/01/2007	7.40	-	-	133	25.8	0.3	0.03	18.05	18.38	2.85	28	-
	CLZ	02/02/2007	8.32	-	-	67	36.5	0.1	0.02	34	34.12	3.7	68	-
Reed Bed	CLZ	08/02/2007	8.35	-	-	182	59	0.1	0.03	35.6	35.73	7.06	52	-
	CLZ	19/04/2007	7.87	-	-	436	104.0	0	0.08	116.4	116.48	3.14	616	14.7
	CLZ	16/05/2007	7.53	-	-	72	92.6	0.2	0.06	68	68.26	22	540	-
	CLZ	26/06/2007	7.46	-	-	305	89.3	0	0.02	-	-	2.96	93	-
	CLZ	11/07/2007	7.47	-	-	97	-	0.4	-	-	-	4.8	31	-
	CLZ	19/07/2007	6.27	16.5	-	-	-	-	-	-	-	-	-	-
	CLZ	15/08/2007	6.39	14.6	-	-	-	-	-	-	-	-	-	-
	CLZ	29/08/2007	6.93	15.4	-	106	89.2	0.7	0.08	77.5	78.28	14.65	316	-
	CLZ	27/09/2007	-	-	-	123	105.0	0.8	0.08	115	115.88	16.75	796	-
	CLZ	06/11/2007	5.70	10.9	-	-	-	-	-	-	-	-	-	-
	CLZ	05/12/2007	7.08	9.2	33.2	100	72.1	1.2	0.01	61	62.21	18.6	576	-
	CLZ	12/02/2008	-	-	-	241	-	0	-	12.5	12.5	8.22	209	-
	CLZ	25/02/2008	7.41	7.1	-	282	69.9	0	-	11	11	-	-	-
	CLZ	23/04/2008	-	-	-	-	110.8	0.3	-	91	91.3	12.2	-	-
	CLZ	24/04/2008	-	-	-	-	93.2	0.3	-	80	80.3	13.54	-	-
	CLZ	03/06/2008	-	-	20.6	65	75.9	0.5	0.030	74	74.53	22.2	374	-
	CLZ	13/06/2008	7.27	-	91.0	262	102.0	0	0.070	58.1	58.17	7.8	476	45

Bacteria (MPN/100ml)	Date	CLX	CLZ
Total Coliforms	27/04/2006	5.17E+08	-
	12/07/2006	8.78E+07	2.61E+06
	02/08/2006	3.09E+07	3.65E+05
	06/09/2006	3.27E+08	2.16E+05
	18/10/2006	8.60E+06	1.88E+05
	16/11/2006	3.39E+06	1.41E+05
	23/01/2007	1.54E+07	4.64E+04
	02/02/2007	9.21E+06	4.68E+05
	08/02/2007	3.45E+07	6.44E+05
	18/04/2007	2.54E+07	
	16/05/2007	8.84E+05	1.80E+05
	21/06/2007		
	26/06/2007	1.01E+07	3.10E+05
	11/07/2007	1.11E+07	3.97E+04
	29/08/2007	1.99E+07	2.48E+04
	27/09/2007	2.31E+06	7.27E+04
	05/12/2007	6.84E+05	1.55E+06
	12/02/2008	2.23E+06	7.55E+04
	25/02/2008	3.58E+07	1.95E+05
	20/03/2008	1.74E+06	5.17E+05
	13/06/2008	1.99E+07	1.30E+05
E.Coli	27/04/2006	9.20E+06	-
	12/07/2006	2.31E+07	3.10E+05
	02/08/2006	4.88E+06	2.30E+05
	06/09/2006	3.55E+07	6.48E+04
	18/10/2006	1.00E+06	1.11E+04
	16/11/2006	1.80E+05	1.56E+04
	23/01/2007	3.74E+05	1.23E+04
	02/02/2007	8.49E+04	8.20E+03
	08/02/2007	1.29E+05	1.30E+04
	18/04/2007	1.71E+06	
	16/05/2007	2.05E+05	3.32E+04
	21/06/2007		
	26/06/2007	9.81E+05	1.17E+05
	11/07/2007	4.80E+05	1.20E+04
	29/08/2007	8.54E+05	3.10E+03
	27/09/2007	5.20E+04	2.20E+04
	05/12/2007	4.32E+05	1.32E+05
	12/02/2008	-	
	25/02/2008	3.45E+05	2.32E+04
	20/03/2008	4.45E+04	1.10E+04
	13/06/2008	2.72E+06	3.51E+04

Percolation Trenches Receiving Septic Tank Effluent (STE)

Trench 3

Sample Position	Ref	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	VOL
3,Red,0m	P1	10/04/2006	-	66.0	-	14.80	1.21	-	0.17	123	800
3,Red,0m	P1	27/04/2006	-	290.0	-	0.80	0.15	0.65	<0.05	250	75
3,Red,0m	P1	12/07/2006	-	190	-	1.1	0.08	35.6	<0.05	168	255
3,Red,0m	P1	02/08/2006	-	200	31.4	<0.5	0.01	2.97	0.13	50	170
3,Red,0m	P1	06/09/2006	-	118	68.6	0.4	0.1	52.7	0.25	175	120
3,Red,0m	P1	18/10/2006	-	176	-	35.3	0.11	27.6	1.79	564	50
3,Red,0m	P1	16/11/2006	-	-	13.5	-	-	<2	0.19	70	30
3,Red,0m	P1	08/02/2007	7.36	104	-	14	0.78	14.6	<0.05	488	-
3,Red,0m	P1	18/04/2007	7.76	54.0	-	8.10	1.40	28.6	2.26	207	90
3,Red,0m	P1	16/05/2007	7.93	40.0	41	1.20	0.17	35.9	0.81	326	270
3,Red,0m	P1	26/06/2007	8.21	39.0	56.2	3.10	0.88	-	0.14	197	120
3,Red,0m	P1	11/07/2007	7.69	109.0	-	10.50	-	-	0.67	175	60
3,Red,0m	P1	29/08/2007	-	46.0	-	4.00	0.95	24.5	0.88	374	140
3,Red,0m	P1	27/09/2007	-	190.0	71.2	14.00	1.35	27.1	2.98	546	275
3,Red,0m	P1	05/12/2007	7.38	<25	81.6	11.00	4.00	4.35	2.17	488	280
3,Red,0m	P1	12/02/2008		44.0		15.90		4.2	8.02	278	
3,Red,0m	P1	25/02/2008				11.20				197	
3,Red,0m	P1	24/04/2008				12.80				185	
3,Red,0m	P1	27/04/2008				9.60		59		344	
3,Red,0m	P1	13/06/2008	-	-	-	-	-	-	-	-	
3,Red,0m	P1										
3,Red,0m	P1										
3,Red,0m	P1										
3,Blue,0m	P2	10/04/2006	-	-	-	-	-	-	-	-	0
3,Blue,0m	P2	27/04/2006	-	240.0	-	9.40	0.65	0.45	<0.05	58	60
3,Blue,0m	P2	12/07/2006	-	-	-	-	-	-	-	-	0
3,Blue,0m	P2	02/08/2006	-	27	124	72	18.2	2.75	0.95	89	60
3,Blue,0m	P2	06/09/2006	-	24	80	58.4	2.6	18.5	1.37	86	115
3,Blue,0m	P2	18/10/2006	-	62	-	66	0.26	0.2	0.88	264	80
3,Blue,0m	P2	16/11/2006	8.01	162	-	47	0.14	0.8	-	254	125
3,Blue,0m	P2	08/02/2007	7.69	<25	-	9.4	0.01	0.03	0.25	70	-
3,Blue,0m	P2	18/04/2007	7.80	10	-	25.2	0.01	<0.05	<0.05	91	250
3,Blue,0m	P2	16/05/2007	-	-	-	-	-	-	-	-	0
3,Blue,0m	P2	26/06/2007	-	-	-	-	-	-	-	-	0
3,Blue,0m	P2	11/07/2007	-	74	-	1.4	-	-	-	138	115
3,Blue,0m	P2	29/08/2007	-	179	-	3.6	0.05	-	-	282	115
3,Blue,0m	P2	27/09/2007	-	-	-	-	-	-	-	-	-
3,Blue,0m	P2	05/12/2007	7.78	<25	-	36	0.04	2.61	0.45	376	50
3,Blue,0m	P2	12/02/2008		69		23		4	4.38	260	
3,Blue,0m	P2	25/02/2008	7.38	<10	-	28					
3,Blue,0m	P2	24/04/2008				36					
3,Blue,0m	P2	27/04/2008				71					
3,Blue,0m	P2	13/06/2008	8.23	32	20.1	15.2	-	0.42	24.2	267	
3,Blue,0m	P2										
3,Blue,0m	P2										
3,Blue,0m	P2										
3,Black,0m	P3	10/04/2006	-	54.0		43.90	0.26	-	0.36	62	220
3,Black,0m	P3	27/04/2006	-	152.0		11.40	0.07	<0.05	<0.05	60	185
3,Black,0m	P3	12/07/2006	-	182		45	-	-	-	207	125
3,Black,0m	P3	02/08/2006	-	115	71.6	70.6	0.02	0.07	0.22	171	170
3,Black,0m	P3	06/09/2006	-	-	74.5	53.6	0.4	17.1	0.27	91	35
3,Black,0m	P3	18/10/2006	-	58	-	43.4	0.03	<0.2	1.34	328	45
3,Black,0m	P3	16/11/2006	8.11	25	-	32	0.01	2.14	0.14	466	520
3,Black,0m	P3	08/02/2007	7.76	126	-	6.4	<0.02	<0.05	0.12	6	-
3,Black,0m	P3	18/04/2007	7.48	61	-	1.2	-	-	-	-	5
3,Black,0m	P3	16/05/2007	7.02	45.0		9.4	0.05	0.75	74.25	14	20
3,Black,0m	P3	26/06/2007	-	-	-	-	-	-	-	-	0
3,Black,0m	P3	11/07/2007	7.97	26	-	23.3	-	-	0.25	159	70
3,Black,0m	P3	29/08/2007	-	94	-	25.2	0.02	0.45	1.02	452	1430
3,Black,0m	P3	27/09/2007	-	30	-	21.2	0.01	0.26	0.6	384	65
3,Black,0m	P3	05/12/2007	7.86	<25	-	37.8	<0.02	1.6	0.7	376	100
3,Black,0m	P3	12/02/2008		<10		7.9		1.1	6.1	164	
3,Black,0m	P3	25/02/2008	7.71	21	-	9.2					
3,Black,0m	P3	13/06/2008	-	-	-	-	-	-	-	-	
3,Black,0m	P3										
3,Black,0m	P3										
3,Black,0m	P3										
3,Red,5m	P4	10/04/2006	-	90.0	-	19.60	-	-	0.23	144	25
3,Red,5m	P4	27/04/2006	-	-	-	-	-	-	-	-	0
3,Red,5m	P4	12/07/2006	-	18	-	75	14.5	11.5	<0.05	144	110
3,Red,5m	P4	02/08/2006	-	28	-	82	47.5	14	0.29	101	210
3,Red,5m	P4	06/09/2006	-	52	-	102.4	0.8	4	0.45	352	265
3,Red,5m	P4	18/10/2006	-	90	-	-	-	-	-	-	200
3,Red,5m	P4	16/11/2006	8.19	52	-	56	0.05	0.06	0.06	464	220
3,Red,5m	P4	08/02/2007	8.05	128	-	10.7	0.03	0.01	0.05	22	-
3,Red,5m	P4	18/04/2007	7.81	73.0	-	31.2	0.02	<0.05	<0.05	49	130
3,Red,5m	P4	16/05/2007	8.15	60	-	45.00	0.01	0.05	<0.05	146	75
3,Red,5m	P4	26/06/2007	7.73	122	-	23.7	<0.02	-	0.14	168	40
3,Red,5m	P4	11/07/2007	7.66	164	-	22.3	-	-	0.11	189	150
3,Red,5m	P4	29/08/2007	-	<25	-	32.6	0.07	0.09	0.14	205	30
3,Red,5m	P4	27/09/2007	-	185	-	-	-	-	-	-	20
3,Red,5m	P4	05/12/2007	7.55	<25	-	56.2	<0.02	2.13	0.37	352	110
3,Red,5m	P4	12/02/2008		19		5.6		2.1	3.24	67	
3,Red,5m	P4	13/06/2008	7.72	16	63.2	37.2	-	1.65	7.2	576	
3,Red,5m	P4										
3,Red,5m	P4										
3,Red,5m	P4										
3,Blue,5m	P5	10/04/2006	-	32.0	-	16.10	0.23	-	0.16	109	110
3,Blue,5m	P5	27/04/2006	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	12/07/2006	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	02/08/2006	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	06/09/2006	-	-	-	13.4	0.2	15.7	-	51	5
3,Blue,5m	P5	18/10/2006	-	-	-	-	-	-	-	-	-
3,Blue,5m	P5	16/11/2006	-	23	-	24.2	0.04	0.02	0.04	472	150
3,Blue,5m	P5	08/02/2007	8.01	122	-	18.1	0.02	1.18	0.05	191	-
3,Blue,5m	P5	18/04/2007	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	16/05/2007	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	26/06/2007	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	11/07/2007	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	29/08/2007	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	27/09/2007	-	-	-	-	-	-	-	-	0
3,Blue,5m	P5	05/12/2007	-	-	-	-	-	-	-	-	-
3,Blue,5m	P5	12/02/2008		-		-					
3,Blue,5m	P5	25/02/2008	8.29	57	-	16.4					
3,Blue,5m	P5	13/06/2008	-	-	-	-	-	-	-	-	
3,Blue,5m	P5										
3,Blue,5m	P5										
3,Blue,5m	P5										
3,Black,5m	Pe	10/04/2006	-	70.0	-	20.30	0.25	-	<0.05	29	510
3,Black,5m	Pe	27/04/2006	-	240.0	-	8.40	0.08	0.35	<0.05	46	350
3,Black,5m	Pe	12/07/2006	-	348	-	29.5	0.02	1.54	0.86	182	85
3,Black,5m	Pe	02/08/2006	-	124	-	80.8	<0.02	0.25	0.13	112	90
3,Black,5m	Pe	06/09/2006	-	176	-	55.6	<0.02	1.74	0.06	152	50
3,Black,5m	Pe	18/10/2006	-	64	-	69	0.03	0.4	0.48	340	80
3,Black,5m	Pe	16/11/2006	-	76	-	45	0.27	2.36	0.21	354	80
3,Black,5m	Pe	08/02/2007	8.15	112	-	3.9	0.02	0.09	0.06	19	-
3,Black,5m	Pe	18/04/2007	-	-	-	-	-	-	-	-	100
3,Black,5m	Pe	16/05/2007	8.07	42.0	-	18.4	<0.02	0.03	<0.05	97	60
3,Black,5m	Pe	26/06/2007	-	-	-	-	-	-	-	-	0
3,Black,5m	Pe	11/07/2007	7.70	60	-	14.8	-	-	0.24	124	35
3,Black,5m	Pe	29/08/2007	-	<25	-	31.6	<0.02	1.4	<0.05	196	500
3,Black,5m	Pe	27/09/2007	-	50	-	-	<0.02	1.68	1.56	340	85
3,Black,5m	Pe	05/12/2007	-	-	-	-	-	-	-	-	-
3,Black,5m	Pe	12/02/2008		-		-					
3,Black,5m	Pe	25/02/2008	7.71	11	-	12.8					
3,Black,5m	Pe	13/06/2008	7.77	11	49	29.6	-	1.91	1.86	432	
3,Black,5m	Pe										
3,Black,5m	Pe										
3,Black,5m	Pe										

Trench 2

Sample Position	Ref	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	VOL
4,Red,0m	P16	10/04/2006	-	148	-	21.10	0.37	-	0.30	58	150
4,Red,0m	P16	27/04/2006	-	168	-	5.90	0.12	0.72	<0.05	74	60
4,Red,0m	P16	12/07/2006	-	120	-	8.1	0.09	32.7	<0.05	247	170
4,Red,0m	P16	02/08/2006	-	38	-	-	-	-	-	104	110
4,Red,0m	P16	06/09/2006	-	62	82.1	43.5	1.6	31.5	0.06	137	30
4,Red,0m	P16	18/10/2006	-	100	97.5	76.5	1.2	17.9	3.73	305	20
4,Red,0m	P16	16/11/2006	7.70	92	-	64.5	3.16	17.6	0.2	300	40
4,Red,0m	P16	08/02/2007	7.85	188	-	76	0.06	0.38	<0.05	217	-
4,Red,0m	P16	18/04/2007	7.92	43	-	44.40	0.34	1.24	<0.05	155	90
4,Red,0m	P16	16/05/2007	8.24	43	-	15.60	0.30	3.7	<0.05	61	60
4,Red,0m	P16	26/06/2007	8.04	184	87	29.50	0.22	-	0.13	112	55
4,Red,0m	P16	11/07/2007	7.66	20	-	20.60	-	-	0.1	134	60
4,Red,0m	P16	29/08/2007	-	91	-	8.40	0.18	15.65	0.12	346	70
4,Red,0m	P16	27/09/2007	-	261	53.2	26.80	1.40	15.75	2.34	354	60
4,Red,0m	P16	05/12/2007	8.14	20	-	23.60	5.20	6	<0.05	364	50
4,Red,0m	P16	12/02/2008		16		10.00		2.3	12.6	199	
4,Red,0m	P16	25/02/2008	-	28	30.6	20.40				154	
4,Red,0m	P16	23/04/2008				97.60				212	
4,Red,0m	P16	27/04/2008				84.50		<5		296	
4,Red,0m	P16	13/06/2008	-	-	-	-	-	-	-	-	
4,Red,0m	P16										
4,Red,0m	P16										
4,Red,0m	P16										
4,Blue,0m	P17	10/04/2006	-	137	-	18.30	0.41	-	0.16	74	100
4,Blue,0m	P17	27/04/2006	-	282	-	5.30	0.08	0.59	<0.05	60	100
4,Blue,0m	P17	12/07/2006	-	34	-	20.1	0.2	34.5	<0.05	245	215
4,Blue,0m	P17	02/08/2006	-	150	74.9	41.2	1.75	32	<0.05	42	140
4,Blue,0m	P17	06/09/2006	-	86	132	88.4	2.6	21.5	<0.05	142	155
4,Blue,0m	P17	18/10/2006	-	86	-	73	0.72	19.8	0.56	210	120
4,Blue,0m	P17	16/11/2006	7.76	88	-	71	0.79	4.7	<0.05	270	160
4,Blue,0m	P17	08/02/2007	7.65	160	-	50.8	0.29	4.48	0.01	151	150
4,Blue,0m	P17	18/04/2007	8.11	199	-	25.3	0.14	2.12	<0.05	79	125
4,Blue,0m	P17	16/05/2007	8.25	73	-	44.60	0.65	4.1	<0.05	131	
4,Blue,0m	P17	26/06/2007	7.70	94	-	39.3	0.15	-	2.79	139	180
4,Blue,0m	P17	11/07/2007	6.93	30	-	20.7	-	-	0.16	152	300
4,Blue,0m	P17	29/08/2007	-	90	-	28.4	0.17	0.6	<0.05	344	130
4,Blue,0m	P17	27/09/2007	-	65	-	27.2	0.13	3.44	4.16	394	125
4,Blue,0m	P17	05/12/2007	7.66	95	-	82.2	0.28	3.31	<0.05	384	230
4,Blue,0m	P17	12/02/2008		32		8.3		2.1	80.42	209	
4,Blue,0m	P17	25/02/2008	6.95	<10	-	20.8					
4,Blue,0m	P17	24/04/2008				68.4					
4,Blue,0m	P17	27/04/2008				38.5					
4,Blue,0m	P17	13/06/2008	-	-	-	-	-	-	-	-	
4,Blue,0m	P17										
4,Blue,0m	P17										
4,Blue,0m	P17										
4,Black,0m	P18	10/04/2006	-	-		-	-	-	-	-	0
4,Black,0m	P18	27/04/2006	-	156		6.70	0.07	0.79	<0.05	36	100
4,Black,0m	P18	12/07/2006	-	-		-	-	-	-	-	0
4,Black,0m	P18	02/08/2006	-	29	92.1	73	0.26	0.13	0.02	96	35
4,Black,0m	P18	06/09/2006	-	-	-	-	-	-	-	-	0
4,Black,0m	P18	18/10/2006	-	34	-	76.5	0.02	6.4	0.21	172	95
4,Black,0m	P18	16/11/2006	8.24	162	-	113	0.2	1.5	0.06	372	460
4,Black,0m	P18	08/02/2007	7.57	130	-	13.7	0.08	0.78	<0.05	48	10
4,Black,0m	P18	18/04/2007	-	50	-	1.7	-	-	-	-	80
4,Black,0m	P18	16/05/2007	8.19	13	-	34.8	<0.02	0.01	14.3	49	
4,Black,0m	P18	26/06/2007	8.18	48	-	22.90	0.05	-	0.11	58	110
4,Black,0m	P18	11/07/2007	7.34	5	-	25	-	-	0.19	79	120
4,Black,0m	P18	29/08/2007	-	<25	-	36	0.04	0.07	0.14	284	210
4,Black,0m	P18	27/09/2007	-	25	-	30	0.24	1.45	3.06	271	65
4,Black,0m	P18	05/12/2007	7.91	39	-	63.4	0.2	2.82	<0.05	304	80
4,Black,0m	P18	12/02/2008		<10		7.7		0.91	6.18	258	
4,Black,0m	P18	25/02/2008	6.86	<10	-	31.6					
4,Black,0m	P18	13/06/2008	-	-	-	-	-	-	-	-	
4,Black,0m	P18										
4,Black,0m	P18										
4,Black,0m	P18										
4,Red,5m	P19	10/04/2006	-	85	-	23.60	0.23	-	0.16	163	35
4,Red,5m	P19	27/04/2006	-	-	-	-	-	-	-	-	0
4,Red,5m	P19	12/07/2006	-	54	-	18.7	0.08	2.7	<0.05	226	100
4,Red,5m	P19	02/08/2006	-	64	-	41.4	0.03	0.15	0.17	117	160
4,Red,5m	P19	06/09/2006	-	28	-	54.8	0.06	12.8	0.01	94	140
4,Red,5m	P19	18/10/2006	-	56	-	81.5	-	7.2	1.77	151	110
4,Red,5m	P19	16/11/2006	-	-	-	-	-	-	-	-	100
4,Red,5m	P19	08/02/2007	7.87	206	-	32.6	0.01	0.53	<0.05	106	0
4,Red,5m	P19	18/04/2007	-	-	-	-	-	-	-	-	10
4,Red,5m	P19	16/05/2007	-	73	-	13.80	0.15	-	-	10	
4,Red,5m	P19	26/06/2007	-	-	-	-	-	-	-	-	0
4,Red,5m	P19	11/07/2007	7.72	72	-	8	-	-	0.15	26	185
4,Red,5m	P19	29/08/2007	-	<25	-	11.6	0.04	0.06	0.11	29	30
4,Red,5m	P19	27/09/2007	-	115	-	15.6	<0.02	<0.05	0.54	32	105
4,Red,5m	P19	05/12/2007	8.63	7	-	11.2	0.07	0.69	3.47	32	40
4,Red,5m	P19	12/02/2008		<10		4.3		1.6	2.36	122	
4,Red,5m	P19	13/06/2008	-	-	-	-	-	-	-	-	
4,Red,5m	P19										
4,Red,5m	P19										
4,Blue,5m	P20	10/04/2006	-	70	-	18.90	0.21	-	0.14	82	400
4,Blue,5m	P20	27/04/2006	-	168	-	8.10	<0.02	0.03	<0.05	45	510
4,Blue,5m	P20	12/07/2006	-	33	-	-	0.02	-	<0.05	130	180
4,Blue,5m	P20	02/08/2006	-	76	-	51.4	0.07	0.68	0.42	94	125
4,Blue,5m	P20	06/09/2006	-	19	-	50.8	0.4	13.6	0.21	122	135
4,Blue,5m	P20	18/10/2006	-	70	-	67	0.02	4.4	4.93	283	125
4,Blue,5m	P20	16/11/2006	8.30	24	-	44.5	0.01	1.42	0.07	194	375
4,Blue,5m	P20	08/02/2007	7.98	182	-	6.7	0.02	0.13	0.02	16	-
4,Blue,5m	P20	18/04/2007	-	-	-	15.3	-	-	-	-	100
4,Blue,5m	P20	16/05/2007	8.08	26	-	13.40	<0.02	0.03	<0.05	11	100
4,Blue,5m	P20	26/06/2007	8.33	49	-	5.2	0.03	-	0.07	15	30
4,Blue,5m	P20	11/07/2007	-	-	-	-	-	-	-	-	0
4,Blue,5m	P20	29/08/2007	-	<25	-	35.6	0.02	1.48	0.18	181	150
4,Blue,5m	P20	27/09/2007	-	-	-	42.4	<0.02	0.3	0.1	191	125
4,Blue,5m	P20	05/12/2007	-	-	-	-	-	-	-	-	-
4,Blue,5m	P20	12/02/2008		<10		1.1		0.82	4.04	139	
4,Blue,5m	P20	13/06/2008	-	-	-	-	-	-	-	-	
4,Blue,5m	P20		8.17								
4,Blue,5m	P20										
4,Blue,5m	P20										
4,Blue,5m	P20										
4,Black,5m	P21	10/04/2006	-	66	-	22.50	0.19	-	0.12	49	500
4,Black,5m	P21	27/04/2006	-	214	-	4.20	<0.02	0.01	<0.05	49	510
4,Black,5m	P21	12/07/2006	-	26	-	26.3	0.03	0.84	<0.05	108	100
4,Black,5m	P21	02/08/2006	-	-	-	-	-	-	-	-	100
4,Black,5m	P21	06/09/2006	-	24	-	42.2	<0.02	0.05	0.02	76	80
4,Black,5m	P21	18/10/2006	-	22	-	38.4	0.01	7.8	0.88	67	36
4,Black,5m	P21	16/11/2006	-	122	-	36	-	<2	0.05	50	110
4,Black,5m	P21	08/02/2007	7.72	136	-	10.4	<0.02	0.08	<0.05	38	-
4,Black,5m	P21	18/04/2007	7.94	9	-	12.4	<0.02	<0.05	<0.05	40	100
4,Black,5m	P21	16/05/2007	8.43	15	-	9.8	0.15	0.16	<0.05	42	60
4,Black,5m	P21	26/06/2007	-	-	-	-	-	-	-	-	0
4,Black,5m	P21	11/07/2007	-	40	-	3.8	-	-	0.38	14	10
4,Black,5m	P21	29/08/2007	-	<25	-	17.2	0.03	1.49	0.12	72	100
4,Black,5m	P21	27/09/2007	-	42	-	6.8	<0.02	0.07	3	58	75
4,Black,5m	P21	05/12/2007	-	-	-	-	-	-	-	-	-
4,Black,5m	P21	12/02/2008		19		3.4		1.1	<0.05	122	
4,Black,5m	P21	25/02/2008	7.81	<10	-	13.2					
4,Black,5m	P21	13/06/2008	8.32	102	33.2	<1	-	-	-	234	
4,Black,5m	P21										
4,Black,5m	P21										
4,Black,5m	P21										

1 in 5 dilution

1 in 5 dilution

TCDUser: 1 in 50 dilution

TCDUser: 1 in 5 dilution

TCDUser: 1 in 5 dilution

TCDUser: No suction

TCDUser: 1 in 2 dilution

TCDUser: 1 in 2 dilution

TCDUser: 1 in 2 dilution

≈ 10.4 mg/l

3,Red,10m	P7	10/04/2006	-	162.0	-	9.20	0.21	-	0.95	84	140	4,Red,10m	P22	10/04/2006	-	48	-	19.40	0.20	-	0.30	119	180
3,Red,10m	P7	27/04/2006	-	138.0	-	1.00	0.10	0.87	<0.05	197	90	4,Red,10m	P22	27/04/2006	-	-	-	-	-	-	-	-	0
3,Red,10m	P7	12/07/2006	-	168	-	0.8	0.16	>15	1.7	75	385	4,Red,10m	P22	12/07/2006	-	368	-	14.5	-	-	0.71	139	
3,Red,10m	P7	02/08/2006	-	26	-	12.4	0.5	25.8	1.82	74	160	4,Red,10m	P22	02/08/2006	-	-	-	-	-	-	-	-	0
3,Red,10m	P7	06/09/2006	-	30	-	8.5	0.94	41.8	3.82	424	225	4,Red,10m	P22	06/09/2006	-	-	-	-	-	-	-	84	100
3,Red,10m	P7	18/10/2006	-	170	-	5.4	-	-	-	704	420	4,Red,10m	P22	18/10/2006	-	78	-	18.1	0.01	7.2	0.35	44	70
3,Red,10m	P7	16/11/2006	8.44	56	-	5.8	0.36	9.9	4.8	532	450	4,Red,10m	P22	16/11/2006	-	30	-	11.5	0.07	0.18	0.6	20	350
3,Red,10m	P7	08/02/2007	8.18	84	-	4.2	0.19	1.29	1.46	85	-	4,Red,10m	P22	08/02/2007	7.94	110	-	8.5	0.01	0.07	0.11	44	-
3,Red,10m	P7	18/04/2007	8.15	36.0	-	7.6	1.2	29.1	3.57	270	180	4,Red,10m	P22	18/04/2007	-	-	-	-	-	-	-	-	0
3,Red,10m	P7	16/05/2007	8.25	64	-	16.00	0.63	11	0.82	392	70	4,Red,10m	P22	16/05/2007	-	-	-	-	-	-	-	-	0
3,Red,10m	P7	26/06/2007	8.16	176	-	12.6	0.12	-	1.18	175	50	4,Red,10m	P22	26/06/2007	8.48	159	-	8.4	0.02	-	0.29	8	35
3,Red,10m	P7	11/07/2007	7.93	39	-	4.8	-	-	1.56	52	360	4,Red,10m	P22	11/07/2007	7.51	25	-	4.3	-	-	0.29	9	135
3,Red,10m	P7	29/08/2007	-	<25	-	7.6	0.23	0.3	1.1	-	175	4,Red,10m	P22	29/08/2007	-	-	-	-	-	-	-	-	0
3,Red,10m	P7	27/09/2007	-	128	-	25.2	0.21	27	1.66	668	280	4,Red,10m	P22	27/09/2007	-	-	-	17.2	<0.02	0.21	1.86	21	30
3,Red,10m	P7	05/12/2007	7.29	17	-	11	0.04	17	3.79	512	300	4,Red,10m	P22	05/12/2007	-	-	-	-	-	-	-	-	-
3,Red,10m	P7	12/02/2008		<10		1.2		2.8	2.84	258		4,Red,10m	P22	12/02/2008		28		2.7		0.57	2.28	96	
3,Red,10m	P7	13/06/2008	7.79	128	40.7	29.8	-	1.85	8.42	496		4,Red,10m	P22	13/06/2008	-	-	-	-	-	-	-	-	
3,Red,10m	P7					TCDUser: 1 in 2 dilution						4,Red,10m	P22						TCDUser: 1 in 2 dilution				
3,Red,10m	P7											4,Red,10m	P22										
3,Red,10m	P7											4,Red,10m	P22										
3,Blue,10m	P8	10/04/2006	-	140.0	-	18.70	0.20		0.29	113	90	4,Blue,10m	P23	10/04/2006	x	x	x	x	x	x	x	x	x
3,Blue,10m	P8	27/04/2006	-	-	-	-	-		-	-	0	4,Blue,10m	P23	27/04/2006	-	274	-	4.10	0.20	1.00	<0.05	25	20
3,Blue,10m	P8	12/07/2006	-	14	-	10.3	0.18	2.4	<0.05	273	85	4,Blue,10m	P23	12/07/2006	-	116	-	-	0.1	1.04	<0.05	-	30
3,Blue,10m	P8	02/08/2006	-	25	-	33.6	0.69	0.2	0.2	143	60	4,Blue,10m	P23	02/08/2006	-	20	-	<0.5	0.04	0.12	0.07	51	75
3,Blue,10m	P8	06/09/2006	-	42	-	33.6	-	16.9	0.12	224	10	4,Blue,10m	P23	06/09/2006	-	25	-	2.1	<0.02	12.8	<0.05	36	70
3,Blue,10m	P8	18/10/2006	-	70	-	17.8	0.13	8.1	0.99	660	80	4,Blue,10m	P23	18/10/2006	-	70	-	2.3	0.01	7.7	0.25	32	40
3,Blue,10m	P8	16/11/2006	8.41	24	-	40.5	-	2.8	0.11	-	99	4,Blue,10m	P23	16/11/2006	8.39	34	-	2.9	0.01	<0.05	0.02	36	180
3,Blue,10m	P8	08/02/2007	8.36	86	-	9.4	0.1	2.78	0.17	168	-	4,Blue,10m	P23	08/02/2007	8.06	140	-	2	0.01	0.61	<0.05	31	-
3,Blue,10m	P8	18/04/2007		-	-	-	-	-	-	-	0	4,Blue,10m	P23	18/04/2007	-	-	-	-	-	-	-	-	0
3,Blue,10m	P8	16/05/2007	-	-	-	-	-	-	-	-	0	4,Blue,10m	P23	16/05/2007	-	-	-	-	-	-	-	-	0
3,Blue,10m	P8	26/06/2007	7.90	74	-	22.3	0.21	-	0.06	187	45	4,Blue,10m	P23	26/06/2007	-	188	-	-	-	-	0.25	-	10
3,Blue,10m	P8	11/07/2007		-	-	-	-	-	-	-	85	4,Blue,10m	P23	11/07/2007	7.73	46	-	0.4	-	-	0.26	5	295
3,Blue,10m	P8	29/08/2007		-	-	-	-	-	-	-	0	4,Blue,10m	P23	29/08/2007	-	95	-	-	-	-	-	-	60
3,Blue,10m	P8	27/09/2007		33	-	33.2	0.27	2.6	3.32	408	100	4,Blue,10m	P23	27/09/2007	-	-	-	2.8	0.08	0.01	6.76	7	10
3,Blue,10m	P8	05/12/2007	8.08	<25	-	31	-	1.56	-	288	10	4,Blue,10m	P23	05/12/2007	7.22	-	-	1.5	-	1.31	0.05	40	330
3,Blue,10m	P8	12/02/2008		16		10.7		1.42	<0.05	216		4,Blue,10m	P23	12/02/2008		<10		<1		-	0.68	54	
3,Blue,10m	P8	25/02/2008	8.20	23	-	16.4						4,Blue,10m	P23	25/02/2008	7.38	<10	-	3.6					
3,Blue,10m	P8	13/06/2008	7.65	<10	65.5	53.2		1.73	1.46	580		4,Blue,10m	P23	13/06/2008	8.45	95	15.9	6	-	-	0.42	26	
3,Blue,10m	P8					TCDUser: 1 in 2 dilution						4,Blue,10m	P23										
3,Blue,10m	P8											4,Blue,10m	P23						TCDUser: 1 in 2 dilution				
3,Blue,10m	P8											4,Blue,10m	P23										
3,Black,10m	P9	10/04/2006	-	72	-	16.30	0.52	-	0.20	28	420	4,Black,10m	P24	10/04/2006	-	-	-	-	-	-	-	-	0
3,Black,10m	P9	27/04/2006	-	234	-	6.20	0.12	0.61	<0.05	74	110	4,Black,10m	P24	27/04/2006	-	216	-	15.30	0.01	<0.05	<0.05	23	75
3,Black,10m	P9	12/07/2006	-	76	-	61	0.04	2.7	<0.05	239	115	4,Black,10m	P24	12/07/2006	-	14	-	9.3	0.05	0.72	0.08	106	135
3,Black,10m	P9	02/08/2006	-	214	-	58	0.01	0.28	0.05	124	145	4,Black,10m	P24	02/08/2006	-	18	-	11.2	<0.02	0.13	0.02	65	65
3,Black,10m	P9	06/09/2006	-	-	-	54.4	<0.02	1.83	<0.05	253	120	4,Black,10m	P24	06/09/2006	-	18	-	12.4	0.02	<0.05	0.05	51	125
3,Black,10m	P9	18/10/2006	-	94	-	34.1	-	3.5	1.39	468	120	4,Black,10m	P24	18/10/2006	-	40	-	14	0.01	4.2	0.42	68	50
3,Black,10m	P9	16/11/2006	8.67	132	-	32	0.01	0.46	0.11	370	210	4,Black,10m	P24	16/11/2006	-	60	-	20.4	-	-	<0.05	-	110
3,Black,10m	P9	08/02/2007	7.65	58	-	8.7	0.1	2.54	0.08	22	-	4,Black,10m	P24	08/02/2007	8.37	<25	-	14.6	0.03	1.03	1.27	72	-
3,Black,10m	P9	18/04/2007	7.16	<25	-	38	0.05	<0.05	0.13	90	400	4,Black,10m	P24	18/04/2007	6.12	<25	-	0.5	0.1	0.16	23.5	30	40
3,Black,10m	P9	16/05/2007	8.59	89	-	67.00	0.27	0.85	0.56	211	10	4,Black,10m	P24	16/05/2007	8.17	308	-	24.40	4.1	4.48	2.57	18	60
3,Black,10m	P9	26/06/2007	8.18	44	-	23.1	<0.02	-	0.4	177	110	4,Black,10m	P24	26/06/2007	8.43	315	-	12.1	0.31	-	0.76	15	75
3,Black,10m	P9	11/07/2007	8.06	58	-	22.3	-	-	0.19	151	130	4,Black,10m	P24	11/07/2007	7.56	71	-	14.8	-	-	0.63	17	85
3,Black,10m	P9	29/08/2007	-	<25	-	51.2	<0.02	1.2	<0.05	247	60	4,Black,10m	P24	29/08/2007	-	134	-	16	<0.02	1.17	0.36	11	90
3,Black,10m	P9	27/09/2007	-	12	-	40	<0.02	1.34	<0.05	428	100	4,Black,10m	P24	27/09/2007	-	-	-	14.8		2.57	1.54	115	10
3,Black,10m	P9	05/12/2007	8.31	19	-	16.4	-	1.25	0.43	96	20	4,Black,10m	P24	05/12/2007	8.62	-	-	2.6	0.23	-	0.14	64	45
3,Black,10m	P9	12/02/2008		<10		4		1.7	1.18	100		4,Black,10m	P24	12/02/2008		17		1.1		-	0.21	34	
3,Black,10m	P9	25/02/2008	7.84	2	-	10						4,Black,10m	P24	25/02/2008	7.96	<10	-	5.6					
3,Black,10m	P9	13/06/2008	7.96	46	54.9	40.4	-	0.12	0.48	476		4,Black,10m	P24	13/06/2008	-	-	-	-	-	-	-	-	
3,Black,10m	P9					TCDUser: 1 in 5 dilution						4,Black,10m	P24										
3,Black,10m	P9											4,Black,10m	P24										
3,Black,10m	P9											4,Black,10m	P24										
3,Red,15m	P10	10/04/2006	-	58	-	23.40	0.25		0.39	82	420	4,Red,15m	P25	10/04/2006	-	-	-	-	-	-	-	-	0
3,Red,15m	P10	27/04/2006	-	528	-	10.10	0.14	0.48	<0.05	52	30	4,Red,15m	P25	27/04/2006	-	-	-	-	-	-	-	-	0
3,Red,15m	P10	12/07/2006	-	4	-	31.7	0.96	9.9	0.86	84	180	4,Red,15m	P25	12/07/2006	-	66	-	20.7	0.03	0.8	<0.05	84	60
3,Red,15m	P10	02/08/2006	-	16	-	65	0.03	0.21	0.48	78	135	4,Red,15m	P25	02/08/2006	-	30	-	19.8	0.01	0.1	0.11	68	60
3,Red,15m	P10	06/09/2006	-	140	-	112.4	0.02	13.7	0.71	67	215	4,Red,15m	P25	06/09/2006	-	14	-	18.9	0.02	14.3	0.26	52	50
3,Red,15m	P10	18/10/2006	-	38	-	124	0.01	5.9	3.33	59	220	4,Red,15m	P25	18/10/2006	-	32	-	20.2	0.02	6.4	11.8	59	25
3,Red,15m	P10	16/11/2006	8.81	14	-	99.5	0.01	1.54	0.2	88	250	4,Red,15m	P25	16/11/2006	8.15	10	-	15.6	0.01	0.01	0.05	44	40
3,Red,15m	P10	08/02/2007	8.09	216	-	7.20	0.01	0.08	0.28	8	-	4,Red,15m	P25	08/02/2007	8.13	<25	-	5.10	0.01	0.26	0.02	4	-
3,Red,15m	P10	18/04/2007	7.89	99	-	22.8	0.17	-	<0.05	36	40	4,Red,15m	P25	18/04/2007	-	-	-	-	-	-	-	-	0
3,Red,15m	P10	16/05/2007	8.38	32	-	30.80	0.03	0.50	<0.05	16	50	4,Red,15m	P25	16/05/2007	-	-	-	-	-	-	-	-	0
3,Red,15m	P10	26/06/2007	8.64	153	-	7.9	0.02	-	0.15	5	35	4,Red,15m	P25	26/06/2007	-	-	-	-	-	-	-	-	0
3,Red,15m	P10	11/07/2007	-	-	-	-	-	-	-	-	0	4,Red,15m	P25	11/07/2007	-	-	-	-	-	-	-	-	0
3,Red,15m	P10	29/08/2007	-	<25	-	-	-	-	-	<10	120	4,Red,15m	P25	29/08/2007	-	-	-	2.8	-	0.8	-	<10	35
3,Red,15m	P10	27/09/2007	-	-	-	-	-	-	-	-	-	4,Red,15m	P25	27/09/2007	-	-	-	-	-	-	-	7	45
3,Red,15m	P10	05/12/2007	-	-	-	-	-	-	-	-	-	4,Red,15m	P25	05/12/2007	8.43	-	-	-	-	-	-	<10	40
3,Red,15m	P10	13/06/2008	-	-	-	-	-	-	-	-		4,Red,15m	P25	13/06/2008	-	-	-	-	-	-	-	129	
3,Red,15m	P10											4,Red,15m	P25										
3,Red,15m	P10											4,Red,15m	P25										
3,Red,15m	P10					TCDUser: 1 in 2 dilution						4,Red,15m	P25										
3,Blue,15m	P11	10/04/2006	-	-	-	-	-	-	-	-	0	4,Blue,15m	P26	10/04/2006	-	84	-	34.20	0.22	-	0.16	102	200
3,Blue,15m	P11	27/04/2006	-	-	-	-	-	-	-	-	0	4,Blue,15m	P26	27/04/2006	-	-	-	-	-	-	-	-	0
3,Blue,15m	P11	12/07/2006	-	14	-	48.6	0.07	2.82	0.45	166		4,Blue,15m	P26	12/07/2006	-	-	-	-	-	-	-	-	0
3,Blue,15m	P11	02/08/2006	-	32	-	53.4	0.01	0.09	0.17	37	235	4,Blue,15m	P26	02/08/2006	-	30	-	-	-	-	-	87	105
3,Blue,15m	P11	06/09/2006	-	20	-	47.2	0.01	12.6	0.21	65	225	4,Blue,15m	P26	06/09/2006	-	18	-	16.5	<0.02	12.8	0.16	67	140
3,Blue,15m	P11	18/10/2006	-	24	-	73	0.02	4.4	0.34	75	200	4,Blue,15m	P26	18/10/2006	-	36	-	16.1	0.02	7	0.33	61	120
3,Blue,15m	P11	16/11/2006	7.84	154	-	65.5	<0.01	0.77	0.01	62	200	4,Blue,15m	P26	16/11/2006	-	4	-	7.5	<0.02	<0.05	<0.05	10	320
3,Blue,15m	P11	08/02/2007	8.02	144	-	6.20	0.04	<0.05	0.1	4	-	4,Blue,15m	P26	08/02/2007	-	<25	-	-	-	-	-	-	-
3,Blue,15m	P11	18/04/2007	7.78	58	-	40.1	0.7	<0.05	<0.05	24	120	4,Blue,15m	P26	18/04/2007	-	-	-	-	-	-	-	-	0
3,Blue,15m	P11	16/05/2007	-	-	-	-	-	-	-	-	0	4,Blue,15m	P26	16/05/2007	-	-	-	-	-	-	-	-	0
3,Blue,15m	P11	26/06/2007	8.29	101	-	37.6	0.08	-	0.37	20	75	4,Blue,15m	P26	26/06/2007	8.36	33	-	3	-	-	0.03	6	100
3,Blue,15m	P11	11/07/2007	-	-	-	-	-	-	-	-	0	4,Blue,15m	P26	11/07/2007	7.76	45	-	1.7	-	-	0.54	7	195
3,Blue,15m	P11	29/08/2007	-	<25	-	-	-	-	-	<10	185	4,Blue,15m	P26	29/08/2007	-	-	-	-	-	-	-	<10	40
3,Blue,15m	P11	27/09/2007	-	42	-	-	-	-	-	<10	190	4,Blue,15m	P26	27/09/2007	-	-	-	-	-	-	-	-	-
3,Blue,15m	P11	05/12/2007	7.52	-	-	-	-	-	-	15	130	4,Blue,15m	P26	05/12/2007	8.17	-	-	-	-	-	-	<10	90
3,Blue,15m	P11	13/06/2008	-	-	-	-	-	-	-	-		4,Blue,15m	P26	13/06/2008	7.91	4	-	<1	-	0.15	<0.05	24	
3,Blue,15m	P11											4,Blue,15m	P26										
3,Blue,15m	P11			TCDUser: 1 in 10		TCDUser: 1 in 5 dilution						4,Blue,15m	P26										
3,Blue,15m	P11											4,Blue,15m	P26										
3,Black,15m	P12	10/04/2006	-	44	-	16.50	0.17	-	0.23	17	320	4,Black,15m	P27	10/04/2006	-	70	-	16.80	0.15	-	0.13	84	350
3,Black,15m	P12	27/04/2006	-	-	-	-	-	-	-	-	0	4,Black,15m	P27	27/04/2006	-	62	-	3.30	<0.02	0.06	<0.05	9	550
3,Black,15m	P12	12/07/2006	-	12	-	37.70	0.24	>15	0.99	91	375	4,Black,15m	P27	12/07/2006	-	117	-	47.00	0.07	1.34	<0.05	110	1000
3,Black,15m	P12	02/08/2006	-	28	-	83.8	1.25	10.3	0.29	75	630	4,Black,15m	P27	02/08/2006	-	42	-	60.4	<0.02	0.08	0.13	93	545
3,Black,15m	P12	06/09/2006	-	18	-	124.4	0.15	0.3	0.41	71	500	4,Black,15m	P27	06/09/2006	-	50	-	44	<0.02	0.54	<0.05	96	440
3,Black,15m	P12	18/10/2006	-	38	-	97.5	0.03	10.1	0.77	62	600	4,Black,15m	P27	18/10/2006	-	86	-	44.5	<0.02	3.4	0.21	104	700
3,Black,15m	P12	16/11/2006	-	22	-	27	0.01	0.05	0.1	30	510	4,Black,15m	P27	16/11/2006	8.10	44	-	25.6	<0.01	0.08	0.01	28	800
3,Black,15m	P12	08/02/2007	7.69	104	-	3.3	0.02	0.13	0.83	8	-	4,Black,15m	P27	08/02/2007	7.51	10	-	3.1	<0.02	0.41	<0.05	3	-
3,Black,15m	P12	18/04/2007	6.96	7	-	4.5	0.01	<0.05	1.47	12	420	4,Black,15m	P27	18/04/2007	7.10	37	-	3.9	0.01	<0.05	<0.05	32	430
3,Black,15m	P12	16/05/2007	7.34	54	-	3.40	0.01	0.81	<0.05	<10	370	4,Black,15m	P27	16/05/2007	7.22	25	-	36.40	<0.02	1.84	<0.05	21	375
3,Black,15m	P12	26/06/2007	7.83	<25	-	2.3	<0.02	-	0.57	1	375	4,Black,15m	P27	26/06/2007	7.11	75	-	6.5	0.03	-	1.17	39	350
3,Black,15m	P12	11/07/2007	8.30	<25	-	2.4	-	-	0.1	5	700	4,Black,15m	P27	11/07/2007	7.44	105	-	7.7	-	-	0.17	15	1060
3,Black,15m	P12	29/08/2007	-	<25	-	-	-	-	-	<10	260	4,Black,15m	P27	29/08/2007	-	41	-	-	-	-	-	<10	320
3,Black,15m	P12	27/09/2007	-	35	-	-	-	-	-	10	530	4,Black,15m	P27	27/09/2007	-	-	-	-	-	-	-	-	-
3,Black,15m	P12	05/12/2007	7.21	-	-	-	-	-	-	5	410	4,Black,15m	P27	05/12/2007	7.26	-	-	-	-	-	-	30	550
3,Black,15m	P12	13/06/2008	7.30	<10	15	7	-	0.09	0.22	19		4,Black,15m	P27	13/06/2008	7.26	30	-	10.4	-	-	0.15	166	
3,Black,15m	P12					TCDUser: 1 in 2 dilution						4,Black,15m	P27										
3,Black,15m	P12											4,Black,15m	P27										
3,Black,15m	P12											4,Black,15m	P27										

3, Red, 20m	P13	10/04/2006	-	145	-	11.30	0.21	-	0.48	112	340
3, Red, 20m	P13	27/04/2006	-	-	-	-	-	-	-	-	0
3, Red, 20m	P13	12/07/2006	-	18	-	20.3	0.03	1.56	0.46	129	190
3, Red, 20m	P13	02/08/2006	-	32	-	26	<0.02	0.11	0.4	50	190
3, Red, 20m	P13	06/09/2006	-	16	-	23.9	0.01	12	-	41	115
3, Red, 20m	P13	18/10/2006	-	36	-	36	0.02	6.1	3.71	42	165
3, Red, 20m	P13	16/11/2006	7.91	32	-	39.8	<0.01	<0.05	0.04	88	200
3, Red, 20m	P13	08/02/2007	-	-	-	-	-	-	-	-	-
3, Red, 20m	P13	18/04/2007	7.95	<25	-	5	0.01	<0.05	<0.05	10	70
3, Red, 20m	P13	16/05/2007	-	28	-	7.60	0.02	0.01	-	<10	110
3, Red, 20m	P13	26/06/2007	8.10	94	-	1.2	<0.02	-	0.14	2	175
3, Red, 20m	P13	11/07/2007	-	-	-	-	-	-	-	-	80
3, Red, 20m	P13	29/08/2007	-	<25	-	-	-	-	-	<10	185
3, Red, 20m	P13	27/09/2007	-	-	-	-	-	-	-	6	20
3, Red, 20m	P13	05/12/2007	7.84	-	-	-	-	-	-	1	140
3, Red, 20m	P13	13/06/2008	-	-	-	-	-	-	-	-	
3, Red, 20m	P13										
3, Red, 20m	P13										
3, Red, 20m	P13										
3, Blue, 20m	P14	10/04/2006	-	-	-	-	-	-	-	-	0
3, Blue, 20m	P14	27/04/2006	-	-	-	-	-	-	-		0
3, Blue, 20m	P14	12/07/2006	-	-	-	-	-	-	-	TCDUser: No suction	0
3, Blue, 20m	P14	02/08/2006	-	-	-	-	-	-	-		0
3, Blue, 20m	P14	06/09/2006	-	28	-	9.9	<0.02	13.4	0.29	36	35
3, Blue, 20m	P14	18/10/2006	-	36	-	11.4	0.02	7.4	2.72	18	50
3, Blue, 20m	P14	16/11/2006	7.89	20	-	13	0.02	1.2	0.06	38	40
3, Blue, 20m	P14	08/02/2007	-	-	-	-	-	-	-	-	-
3, Blue, 20m	P14	18/04/2007	-	-	-	-	-	-	-	-	0
3, Blue, 20m	P14	16/05/2007	8.30	18	-	2.6	0.01	0.04	<0.05	<10	15
3, Blue, 20m	P14	26/06/2007	8.59	149	-	1.9	0.12	-	0.76	3	40
3, Blue, 20m	P14	11/07/2007	7.91	161	-	4.1	-	-	0.2	6	40
3, Blue, 20m	P14	29/08/2007	-	<25	-	-	-	-	-	<10	30
3, Blue, 20m	P14	27/09/2007	-	-	-	-	-	-	-	-	-
3, Blue, 20m	P14	05/12/2007	-	-	-	-	-	-	-	-	-
3, Blue, 20m	P14	13/06/2008	8.58	133	12.2	6.5	-	-	4.34	26	
3, Blue, 20m	P14										
3, Blue, 20m	P14										
3, Blue, 20m	P14										
3, Black, 20m	P15	10/04/2006	-	-	-	-	-	-	-	-	0
3, Black, 20m	P15	27/04/2006	-	-	-	-	-	-	-	-	0
3, Black, 20m	P15	12/07/2006	-	72	-	20.90	-	-	-	137	10
3, Black, 20m	P15	02/08/2006	-	136	-	-	-	-	0.44	58	25
3, Black, 20m	P15	06/09/2006	-	132	-	8.5	0.01	0.01	0.94	31	31
3, Black, 20m	P15	18/10/2006	-	40	-	6.2	0.01	6.3	19.05	6	150
3, Black, 20m	P15	16/11/2006	8.51	-	-	-	-	-	-	-	100
3, Black, 20m	P15	08/02/2007	7.90	126	-	3.4	0.01	0.43	0.08	5	-
3, Black, 20m	P15	18/04/2007	-	-	-	-	-	-	-	-	0
3, Black, 20m	P15	16/05/2007	8.29	62	-	2	0.03	0.42	<0.05	13	20
3, Black, 20m	P15	26/06/2007	-	164	-	0.8	-	-	-	1	10
3, Black, 20m	P15	11/07/2007	-	-	-	-	-	-	-	-	10
3, Black, 20m	P15	29/08/2007	-	-	-	-	-	-	-	<10	0
3, Black, 20m	P15	27/09/2007	-	-	-	-	-	-	-	34	45
3, Black, 20m	P15	05/12/2007	8.29	-	-	-	-	-	-	2	70
3, Black, 20m	P15	13/06/2008	-	-	-	-	-	-	-	-	

4, Red, 20m	P28	10/04/2006	-	-	-	-	-	-	-	-	0
4, Red, 20m	P28	27/04/2006	-	-	-	-	-	-	-	-	0
4, Red, 20m	P28	12/07/2006	-	28	-	13.9	0.02	1.36	<0.05	94	28
4, Red, 20m	P28	02/08/2006	-	29	-	20.6	<0.02	<0.05	0.09	77	75
4, Red, 20m	P28	06/09/2006	-	24	-	24.8	0.01	11.8	0.4	45	60
4, Red, 20m	P28	18/10/2006	-	-	-	-	-	-	-	-	70
4, Red, 20m	P28	16/11/2006	8.13	20	-	7	<0.01	0.06	0.05	8	375
4, Red, 20m	P28	08/02/2007	-	-	-	-	-	-	-	-	-
4, Red, 20m	P28	18/04/2007	-	-	-	-	-	-	-	-	0
4, Red, 20m	P28	16/05/2007	-	-	-	-	-	-	-	-	0
4, Red, 20m	P28	26/06/2007	8.34	272	-	3.1	-	-	0.21	3	80
4, Red, 20m	P28	11/07/2007	7.63	-	-	1.8	-	-	1.13	5	90
4, Red, 20m	P28	29/08/2007	-	111	-	-	-	-	-	<10	10
4, Red, 20m	P28	27/09/2007	-	-	-	-	-	-	-	17	135
4, Red, 20m	P28	05/12/2007	-	-	-	-	-	-	-	-	-
4, Red, 20m	P28	13/06/2008	8.53	211	-	17.8	-	-	1.95	127	
4, Red, 20m	P28										
4, Red, 20m	P28										
4, Red, 20m	P28										
4, Blue, 20m	P29	10/04/2006	-	-	-	-	-	-	-	-	0
4, Blue, 20m	P29	27/04/2006	-	-	-	-	-	-	-	-	0
4, Blue, 20m	P29	12/07/2006	-	110	-	25.6	0.03	1	0.13	107	135
4, Blue, 20m	P29	02/08/2006	-	20	-	22.4	0.01	0.06	0.29	47	150
4, Blue, 20m	P29	06/09/2006	-	48	-	30.6	0.05	12.5	-	29	110
4, Blue, 20m	P29	18/10/2006	-	72	-	22.2	-	-	-	85	130
4, Blue, 20m	P29	16/11/2006	-	30	-	17.6	0.08	0.51	0.34	18	150
4, Blue, 20m	P29	08/02/2007	8.07	104	-	5.80	0.02	0.16	0.04	7	-
4, Blue, 20m	P29	18/04/2007	6.85	63	-	16.8	1.35	0.88	18.25	31	130
4, Blue, 20m	P29	16/05/2007	-	-	-	-	-	-	-	-	0
4, Blue, 20m	P29	26/06/2007	-	-	-	-	-	-	-	-	0
4, Blue, 20m	P29	11/07/2007	-	-	-	-	-	-	-	-	0
4, Blue, 20m	P29	29/08/2007	-	-	-	-	-	-	-	<10	0
4, Blue, 20m	P29	27/09/2007	-	-	-	-	-	-	-	3	30
4, Blue, 20m	P29	05/12/2007	-	-	-	-	-	-	-	-	-
4, Blue, 20m	P29	13/06/2008	-	-	-	-	-	-	-	-	
4, Blue, 20m	P29										
4, Blue, 20m	P29										
4, Blue, 20m	P29										
4, Black, 20m	P30	10/04/2006	-	-	-	-	-	-	-	-	0
4, Black, 20m	P30	27/04/2006	-	234	-	4.80	0.08	0.18	<0.05	7	35
4, Black, 20m	P30	12/07/2006	-	-	-	-	-	-	-	-	0
4, Black, 20m	P30	02/08/2006	-	-	-	-	-	-	-	-	0
4, Black, 20m	P30	06/09/2006	-	166	-	1.6	<0.02	<0.05	0.67	8	50
4, Black, 20m	P30	18/10/2006	-	-	-	-	-	-	-	-	100
4, Black, 20m	P30	16/11/2006	-	54	-	16.4	-	0.1	0.25	44	120
4, Black, 20m	P30	08/02/2007	8.17	42	-	3.1	0.01	0.12	0.23	9	-
4, Black, 20m	P30	18/04/2007	-	-	-	-	-	-	-	-	0
4, Black, 20m	P30	16/05/2007	8.34	77	-	1.60	0.04	0.01	<0.05	65	75
4, Black, 20m	P30	26/06/2007	8.72	107	-	1.6	0.02	-	0.4	2	80
4, Black, 20m	P30	11/07/2007	-	-	-	-	-	-	-	-	0
4, Black, 20m	P30	29/08/2007	-	71	-	-	-	-	-	<10	65
4, Black, 20m	P30	27/09/2007	-	-	-	-	-	-	-	-	0
4, Black, 20m	P30	05/12/2007	-	-	-	-	-	-	-	-	-
4, Black, 20m	P30	13/06/2008	-	-	-	-	-	-	-	-	

		PRIMARY TRENCH 1														
Bacteria (MPN/100ml)	**Date**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**	**P15**
Total Coliforms	12/07/2006			980.4								204.6	37.3	410.6		
	02/08/2006	33.6		19.1				2419.6		22.6	>2419.6	7.4	48.7	23.1		
	06/09/2006	3844	2419.6		1732.9			648.8		214.3	770.1	547.5	224.7	>2419.6		
	18/10/2006	24196	24196	-	6378.2	-	-	336.3	-	1553.1	920.8	106.7	20.9	134	-	60.9
	16/11/2006	-	16824	1553.1	3562.2	3462.2	-	2419.6	1732.9	2419.6	770.1	579.4	613.1	2419.6	-	2419.6
	08/02/2007	579.4	2419.6	686.7	118.7	43.5	34.5	105	365.4	201.4	275.5	196.6	86.3	193.5	-	55.4
	18/04/2007	4106	28868.6	-	422.5	-	2578.2	4352	-	301.5	-	>24196	529.8	17329	-	-
	16/05/2007	1413.6	-	85	171	-	1274	9804	-	-	2419.6	-	12.8	64.8	-	>24196
	26/06/2007	258.5	-	-	870	-	-	100	100	100	2380	>20050	7.5	2380	>20050	<100
	11/07/2007	2495	2419.6	24196	15340	-	34124	9684.4	5172	2419.6	-	-	>2419.6	19863	>24,196	>24,196
	29/08/2007	2419.6	2484.8	579.4	750	-	199	1299.7	-	100	-	1299.7	1732.9	>2419.6	-	-
	27/09/2007	686		2755	19863	-	1050	686.7	557	135	-	-	-	-	-	-
	05/12/2007	5172	3873	481	4106	-	-	24196	-	-	-	-	-	-	-	-
	25/02/2008	-	579.4	1046.2	-	-	67	-	-	2419.6	-	-	-	-	-	-
	20/03/2008	135	292	-	1281	-	-	279	393	6488	-	-	-	-	-	-
	13/06/2008		527.5		2595		3728	5510	26030	5200			>2419.6			
E.Coli	12/07/2006			2								1	<1	56.5		
	02/08/2006	2		<1				<1		<1	<1	<1	<1	<1		
	06/09/2006	83.5	127.9		<1			4.1		<1	7.4	1	<1	18.5		
	18/10/2006	20	10	-	<1	-	-	<1	-	<1	1	<1	<1	<1	-	1
	16/11/2006	-	127.9	<1	<1	<1	-	2	<1	1	<1	<1	<1	3	-	<1
	08/02/2007	1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	-	<1
	18/04/2007	<10	1	-	<1	-	<1	<1	-	<1	-	<10	<1	<10	-	-
	16/05/2007	23.1	-	10	<10	-	<10	<10	-	-	<1	-	<1	3.1	-	10
	26/06/2007	<1	-	-	<1	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
	11/07/2007	<10	1	<10	<1	-	<1	<1	<10	<1	-	-	<1	<10	<10	<10
	29/08/2007	<1	<1	<1	<1	-	<1	<1	-	<10	-	<1	<1	<1	-	-
	27/09/2007	<1	-	10	10	-	<10	<1	<1	10	-	-	-	-	-	-
	05/12/2007	3.1	146	20	295	-	-	1	-	-	-	-	-	-	-	-
	25/02/2008	-	<1	9.6	-	-	<1	-	-	<1	-	-	-	-	-	-
	20/03/2008	<10	<10	-	<10	-	-	<10	<10	<10	-	-	-	-	-	-
	13/06/2008		<10		<10		<10	<10	<10	<10			<1			

		PRIMARY TRENCH 2														
Bacteria (MPN/100ml)	**Date**	**P16**	**P17**	**P18**	**P19**	**P20**	**P21**	**P22**	**P23**	**P24**	**P25**	**P26**	**P27**	**P28**	**P29**	**P30**
Total Coliforms	12/07/2006		8482.2							>2419.6			>2419.6		686.7	
	02/08/2006	9804	137.9	517.2	135.5	70.8	57.6					>2419.6	12.2		18.7	
	06/09/2006		2419.6		18340	648.8		1553.1		>2419.6		>2419.6	261.3		>2419.6	
	18/10/2006	1789	7701	-	5968.8	1986.3	-	-	345	373	10,462	>2419.6	1413.6	317.6	727	>2419.6
	16/11/2006	-	2419.6	2419.6	1299.7	613.1	5684.4	307.6	816.4	816.4	-	307.6	727	>2419.6	1732.9	>2419.6
	08/02/2007	40.4	47.1	114.5	111.2	13.5	70.6	-	-	20.3	-	214.3	53.7	-	-	-
	18/04/2007	20	1299.7	-	-	8268	3255	-	-	-	-	-	>2419.6	-	>24196	-
	16/05/2007	556	53.7	492	-	495	2143	-	-	>24196	-	-	2419.6	-	-	>24196
	26/06/2007	42	3.1	10	-	100	-	2710	20050	>20050	-	200	<100	<100	-	<100
	11/07/2007	1067	410.6	-	4442.2	-	8164	>2419.6	>2419.6	19,863	-	>2419.6	>2419.6	>24,196	-	-
	29/08/2007	347824	248.9	435.2	100	238.2	-	-	-	-	-	-	>2419.6	-	-	-
	27/09/2007	1013	7030	1650	2060	16530	-	-	-	-	-	-	-	-	-	-
	05/12/2007	341	223	4352	34148	-	-	-	-	-	-	-	-	-	-	-
	25/02/2008	-	-	-	-	-	3568.2	-	-	102	-	-	-	-	-	-
	20/03/2008	-	146	4106	5475	-	867	345	176	769	-	-	-	-	-	-
	13/06/2008						891						<2419.6			
E.Coli	12/07/2006		387.3							>2419.6			4.1		579.4	
	02/08/2006	3.1	<1	1	<1	<1	<1					<1	<1		<1	
	06/09/2006		1		<1	1		<1		3		<1	1		1	
	18/10/2006	<10	2	-	5	1	-	-	<10	<10	<10	<1	<1	<1	<1	<1
	16/11/2006	-	1	<1	<1	<1	<1	<1	<1	<1	-	<1	1	1	<1	2
	08/02/2007	<1	<1	<1	<1	<1	<1	-	-	<1	-	1	<1	-	-	-
	18/04/2007	<10	<1	-	-	<1	<10	-	-	-	-	-	<1	-	<10	-
	16/05/2007	189	23.8	<10	-	<10	<10	-	-	<10	-	-	<1	-	-	<10
	26/06/2007	<1	<1	<1	-	<1	-	<1	100	<1	-	<1	<1	<1	-	<1
	11/07/2007	<10	<1	-	<1	-	10	<1	<1	<10	-	6.3	1	<10	-	-
	29/08/2007	<100	1	<1	<1	<1	-	-	-	-	-	-	<1	-	-	-
	27/09/2007	<10	<1	<10	<10	61.8	-	-	-	-	-	-	-	-	-	-
	05/12/2007	<1	<1	<1	<10	-	-	-	-	-	-	-	-	-	-	-
	25/02/2008	-	-	-	-	-	<1	-	-	1	-	-	-	-	-	-
	20/03/2008	-	<10	<10	<10	-	<10	<10	<10	<10	-	-	-	-	-	-
	13/06/2008						10						<1			

Percolation Trenches Receiving Reed Bed Effuent (RBE)

SECONDARY TRENCH 1

Sample Position	Ref	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	VOL
1,Red,0m	S1	10/04/2006	-	-	-	8.7	0.14		0.14	59	30
1,Red,0m	S1	27/04/2006	-	9	-	0.1	0.05	0.11	<0.05	46.6	130
1,Red,0m	S1	12/07/2006	-	-	-	-	-	-	-	-	0
1,Red,0m	S1	02/08/2006	-	< 10	-	>25	0.04	0.37	0.05	187	50
1,Red,0m	S1	18/10/2006	-	-	-	-	-	-	-	-	0
1,Red,0m	S1	16/11/2006	-	53	-	85.6	0.2	2.12	1.12	>250	20
1,Red,0m	S1	08/02/2007	8.33	78	-	20	0.06	0.6	0.3	186	-
1,Red,0m	S1	18/04/2007	8.41	99	-	47	0.18	1.51	0.82	178	90
1,Red,0m	S1	16/05/2007	-	-	-	-	-	-	-	-	0
1,Red,0m	S1	26/06/2007	8.37	115	-	20.9	0.24	-	0.4	174	180
ef: ed BOD = 5.7 mg/l	S1	11/07/2007	8.15	142	-	24.5	-	-	0.28	55	85
1,Red,0m	S1	29/08/2007	-	<25	-	33.2	0.16	10	3.28	406	85
[illegible]	S1	27/09/2007	-	103	-	94	0.48	10	1.13	550	55
1,Red,0m	S1	05/12/2007	-	<25	-	29	0.19	11	3.1	456	30
1,Red,0m	S1	12/02/2008	-	42		11.2		4.2	18.2	242	
1,Red,0m	S1	13/06/2008	-	-	-	-	-	-	-	-	
1,Red,0m	S1										
1,Red,0m	S1										
1,Red,0m	S1										
1,Blue,0m	S2	10/04/2006	-	-		-	-	-	-	-	-
1,Blue,0m	S2	27/04/2006	-	114	-	0.01	0.01	0.04	0.8	55	550
1,Blue,0m	S2	12/07/2006	-	176	-	24.4	0.25	2.41	<0.05	176	65
1,Blue,0m	S2	02/08/2006	-	< 10	-	>25	0.33	2.27	0.13	106	35
1,Blue,0m	S2	18/10/2006	-	46	-	160.5	0.03	1.97	18.6	143	140
1,Blue,0m	S2	16/11/2006	-	38	-	64.8	0.15	2.65	0.93	278	320
1,Blue,0m	S2	08/02/2007	8.39	32	-	96	0.22	1.61	0.1	151	-
1,Blue,0m	S2	18/04/2007	8.30	-	-	51.4	0.2	1.36	<0.05	162	120
1,Blue,0m	S2	16/05/2007	7.85	158	-	2.6	0.44	14.85	2.89	410	260
1,Blue,0m	S2	26/06/2007	8.63	156	-	16.2	0.3	-	1.1	123	5
1,Blue,0m	S2	11/07/2007	8.03	15	-	13.2	-	-	0.84	61	230
1,Blue,0m	S2	29/08/2007	-	<25	-	40.4	0.41	11.05	1.04	388	290
1,Blue,0m	S2	27/09/2007	-	81	-	94.5	0.5	11	1.38	414	150
1,Blue,0m	S2	05/12/2007	7.03	53	-	18	0.24	28	4.78	456	460
1,Blue,0m	S2	12/02/2008		70		3.8		4	1.3	240	
1,Blue,0m	S2	25/02/2008	7.38	24	-	9.2					
1,Blue,0m	S2	13/06/2008	7.30	65	28.7	3.2	-	2.65	2.62	462	219
1,Blue,0m	S2										
1,Blue,0m	S2										
1,Blue,0m	S2										
1,Black,0m	S3	10/04/2006	-	-	-	-	-	-	-	-	0
1,Black,0m	S3	27/04/2006	-	36	-	0.04	0.04	0.08	1.4	11	580
1,Black,0m	S3	12/07/2006	-	-	-	-	-	-	-	-	0
1,Black,0m	S3	02/08/2006	-	-	-	-	-	-	-	-	0
1,Black,0m	S3	18/10/2006	-	-	-	-	-	-	-	-	0
1,Black,0m	S3	16/11/2006	8.34	48	-	30.8	-	-	1.05	188	40
1,Black,0m	S3	08/02/2007	7.67	<25	-	37.8	0.01	0.58	0.11	65	-
1,Black,0m	S3	18/04/2007	-	-	-	-	-	-	-	-	0
1,Black,0m	S3	16/05/2007	-	-	-	-	-	-	-	-	Broken
1,Black,0m	S3	26/06/2007	-	-	-	-	-	-	-	-	Broken
1,Black,0m	S3	11/07/2007	-	-	-	-	-	-	-	-	Broken
1,Black,0m	S3	29/08/2007	-	-	-	-	-	-	-	-	Broken
1,Black,0m	S3	27/09/2007	-	-	-	-	-	-	-	-	Broken
1,Black,0m	S3	05/12/2007	-	-	-	-	-	-	-	-	Broken
1,Black,0m	S3	12/02/2008		< 10		2.4		1.1	-	112	
1,Black,0m	S3	13/06/2008	-	-	-	-	-	-	-	-	
1,Black,0m	S3										
1,Black,0m	S3										
1,Black,0m	S3										
1,Red,2.5m	S4	10/04/2006	-	-	-	8.6	0.23	-	0.17	71	875
1,Red,2.5m	S4	27/04/2006	-	-	-	-	-	-	-	-	0
1,Red,2.5m	S4	12/07/2006	-	18	-	>25	-	-	-	-	110
1,Red,2.5m	S4	02/08/2006	-	< 10	-	>25	<0.02	0.66	0.11	112	180
1,Red,2.5m	S4	18/10/2006	-	100	-	76	<0.02	0.91	3.56	45	170
1,Red,2.5m	S4	16/11/2006	7.68	27	-	78.4	0.07	3.12	0.29	74	250
1,Red,2.5m	S4	08/02/2007	8.09	<25	-	17.3	<0.02	0.11	0.03	<10	-
1,Red,2.5m	S4	18/04/2007	8.01	60	-	127.5	<0.02	2.01	<0.05	104	90
1,Red,2.5m	S4	16/05/2007	-	-	-	-	-	-	-	-	Broken
1,Red,2.5m	S4	26/06/2007	7.58	52	-	49.7	0.03	-	0.28	141	190
1,Red,2.5m	S4	11/07/2007	8.44	75	-	43.1	-	-	0.61	68	150
1,Red,2.5m	S4	29/08/2007	-	<25	-	88	0.04	2.03	10	338	120
1,Red,2.5m	S4	27/09/2007	-	81	-	124.5	0.01	1.99	2.11	326	105
1,Red,2.5m	S4	05/12/2007	7.21	135	-	69	0.19	6	3.1	436	750
1,Red,2.5m	S4	12/02/2008		19		3.9		1.53	1.18	114	
1,Red,2.5m	S4	13/06/2008	7.68	37	54.8	47.2	2.15	10.52	2.56	351	
1,Red,2.5m	S4										
1,Red,2.5m	S4										
1,Blue,2.5m	S5	10/04/2006	-	-	-	-	-	-	-	-	-
1,Blue,2.5m	S5	27/04/2006	-	-	-	-	-	-	-	-	0
1,Blue,2.5m	S5	12/07/2006	-	192	-	20.5	0.47	1.82	<0.05	80	140
1,Blue,2.5m	S5	02/08/2006	-	40	-	24.9	0.28	2.44	0.21	64	135
1,Blue,2.5m	S5	18/10/2006	-	58	-	75	-	1.31	5.35	68	120
1,Blue,2.5m	S5	16/11/2006	-	60	-	72.2	0.2	<0.05	<0.05	72	130
1,Blue,2.5m	S5	08/02/2007	8.22	<25	-	5.6	<0.02	<0.05	0.01	<10	-
1,Blue,2.5m	S5	18/04/2007	8.72	70	-	20.1	<0.02	0.6	0.3	42	230
1,Blue,2.5m	S5	16/05/2007	8.24	46	-	19	0.01	<0.05	<0.05	51	160
1,Blue,2.5m	S5	26/06/2007	8.02	72	-	20.3	<0.02	-	0.13	113	140
1,Blue,2.5m	S5	11/07/2007	7.46	56	-	21.7	-	-	<0.05	137	180
1,Blue,2.5m	S5	29/08/2007	-	<25	-	72	0.05	2.51	1.63	440	150
1,Blue,2.5m	S5	27/09/2007	-	72	-	48.1	0.04	2.57	<0.05	362	160
1,Blue,2.5m	S5	05/12/2007	7.51	16	-	35.5	<0.02	2.4	<0.05	265	200
1,Blue,2.5m	S5	12/02/2008		10		6.4		0.82	7.3	78	
1,Blue,2.5m	S5	25/02/2008	7.72	< 10	-	44.8					
1,Blue,2.5m	S5	13/06/2008	7.15	< 10	45.2	43.2	-	0.76	2.3	489	
1,Blue,2.5m	S5										
1,Blue,2.5m	S5										
1,Black,2.5m	S6	10/04/2006	-	-	-	-	-	-	-	-	-
1,Black,2.5m	S6	27/04/2006	-	-	-	-	-	-	-	-	-
1,Black,2.5m	S6	12/07/2006	-	136	-	4.2	0.34	2.18	<0.05	230	105
1,Black,2.5m	S6	02/08/2006	-	45	-	>25	0.13	0.57	0.09	69	150
1,Black,2.5m	S6	18/10/2006	-	60	-	74	0.02	0.77	3.91	11	210
1,Black,2.5m	S6	16/11/2006	7.84	-	-	-	-	-	-	-	100
1,Black,2.5m	S6	08/02/2007	8.19	<25	-	8	<0.02	0.1	0.02	<10	-
1,Black,2.5m	S6	18/04/2007	8.80	74	-	8.2	<0.02	0.09	0.14	21	120
1,Black,2.5m	S6	16/05/2007	7.94	131	-	9.5	0.03	0.14	<0.05	9	250
1,Black,2.5m	S6	26/06/2007	7.86	97	-	18.2	<0.02	-	0.1	54	160
1,Black,2.5m	S6	11/07/2007	7.48	-	-	20.2	-	-	<0.05	101	265
1,Black,2.5m	S6	29/08/2007	-	<25	-	18.8	0.02	1.62	<0.05	103	500
1,Black,2.5m	S6	27/09/2007	-	38	-	40.3	0.02	2.29	3.1	209	250
1,Black,2.5m	S6	05/12/2007	7.06	86	-	38.2	0.02	2.16	0.48	161	1000
1,Black,2.5m	S6	12/02/2008		19		4		0.41	<0.05	82	
1,Black,2.5m	S6	25/02/2008	7.55	16	-	17.2					
1,Black,2.5m	S6	13/06/2008	6.99	29	27.9	25.6	-	0.53	<0.05	324	282.7273
1,Black,2.5m	S6										
1,Black,2.5m	S6										

SECONDARY TRENCH 2

Sample Position	Ref	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	VOL
2,Red,0m	S16	10/04/2006	-		-	-					0
2,Red,0m	S16	27/04/2006	-	9.0	-	0.6	1.02	0.25	0.4	45.9	80
2,Red,0m	S16	12/07/2006	-	140	-	21.6	0.26	1.81	<0.05	>250	50
2,Red,0m	S16	02/08/2006	-	<10	-	>25	0.19	1.38	0.21	164	45
2,Red,0m	S16	18/10/2006	-	72	-	148.5	0.02	1.91	0.43	224	40
2,Red,0m	S16	16/11/2006	-	30	-	59.6	0.48	2.25	1.6	>250	60
2,Red,0m	S16	08/02/2007	8.46	<25	-	43.5	0.08	2.03	0.47	70	-
2,Red,0m	S16	18/04/2007	8.41	215	-	49	0.23	4.3	0.46	127	120
2,Red,0m	S16	16/05/2007	-	-	-	-	-	-	-	-	0
2,Red,0m	S16	26/06/2007	8.58	212	-	30.1	0.17	-	1.17	141	20
2,Red,0m	S16	11/07/2007	-	<25	-	<1	-	-	1.79	54	45
2,Red,0m	S16	29/08/2007	-	-	-	-	-	1.55	3.84	-	90
2,Red,0m	S16	27/09/2007	-	124	-	141	0.14	9	2.39	482	45
2,Red,0m	S16	05/12/2007	7.76	123		22.5	1.4	36	10.28	376	30
2,Red,0m	S16	12/02/2008		63		19.5		1.78	3.48	226	
2,Red,0m	S16	13/06/2008	7.88	-	-	-	-	-	-	-	
2,Red,0m	S16										
2,Red,0m	S16										
2,Red,0m	S16										
2,Blue,0m	S17	10/04/2006	-	-	-	2.5	>1	-	0.6	86	325
2,Blue,0m	S17	27/04/2006	-	-	-	-	-	-	-	-	0
2,Blue,0m	S17	12/07/2006	-	76	-	53.9	2.7	14.75	<0.05	151	205
2,Blue,0m	S17	02/08/2006	-	-	-	-	-	-	-	123	105
2,Blue,0m	S17	18/10/2006	-	134	-	153.3	-	-	-	224	110
2,Blue,0m	S17	16/11/2006	7.93	50	-	23.6	0.31	2.93	4.83	325	440
2,Blue,0m	S17	08/02/2007	8.51	<25	-	10.9	0.02	7.5	1.16	20	-
2,Blue,0m	S17	18/04/2007	8.62	76	-	53.2	0.77	0.48	0.43	129	125
2,Blue,0m	S17	16/05/2007	8.57	183	-	14.1	0.49	10.3	1.03	470	140
2,Blue,0m	S17	26/06/2007	-	117	-	18	-	-	0.78	-	40
2,Blue,0m	S17	11/07/2007	-	73	-	<1	-	-	1.81	57	90
2,Blue,0m	S17	29/08/2007	-	<25	-	57.4	0.82	6.6	6.42	496	190
2,Blue,0m	S17	27/09/2007	-	91	-	103.5	0.19	2.53	1.85	510	60
2,Blue,0m	S17	05/12/2007	6.84	45	-	47	0.42	14	10.2	492	725
2,Blue,0m	S17	12/02/2008		<10		11		2.04	5.26	218	
2,Blue,0m	S17	25/02/2008	7.64	21	-	20.8					
2,Blue,0m	S17	13/06/2008	-	13	74.1	3.6	-	2.29	6.76	356	213
2,Blue,0m	S17										
2,Blue,0m	S17										
2,Blue,0m	S17										
2,Black,0m	S18	10/04/2006	-	-	-	-	-	-	-	-	0
2,Black,0m	S18	27/04/2006	-	22	-	0.3	0.06	0.35	<0.05	30.5	400
2,Black,0m	S18	12/07/2006	-	98	-	17.3	0.31	2.59	<0.05	143	195
2,Black,0m	S18	02/08/2006	-	<10	-	34.3	<0.02	0.14	0.13	97	175
2,Black,0m	S18	18/10/2006	-	44	-	38.1	<0.02	0.85	0.53	91	170
2,Black,0m	S18	16/11/2006	7.43	31	-	34.8	0.08	<0.05	<0.05	120	250
2,Black,0m	S18	08/02/2007	8.33	<25	-	46	0.01	1.16	0.09	112	-
2,Black,0m	S18	18/04/2007	9.01	126	-	-	-	0.29	<0.04	60	110
2,Black,0m	S18	16/05/2007	8.03	102	-	48.9	0.4	2.76	<0.05	154	190
2,Black,0m	S18	26/06/2007	7.72	126	-	28.5	0.41	-	0.42	127	35
2,Black,0m	S18	11/07/2007	8.34	23	-	<1	-	-	0.23	152	200
2,Black,0m	S18	29/08/2007	-	<25	-	42.8	0.09	2.47	1.42	414	275
2,Black,0m	S18	27/09/2007	-	24	-	43.5	-	2.73	2.45	422	120
2,Black,0m	S18	05/12/2007	7.23	<25	-	57.8	<0.02	2.43	1.04	460	375
2,Black,0m	S18	12/02/2008		<10		8.3		0.88	4.87	173	
2,Black,0m	S18	25/02/2008	7.64	<10	-	25.2					
2,Black,0m	S18										
2,Black,0m	S18										
2,Black,0m	S18										
2,Red,2.5m	S18	10/04/2006	-	-	-	15.7	0.06	-	1.1	117	275
2,Red,2.5m	S18	27/04/2006	-	-	-	-	-	-	-	-	0
2,Red,2.5m	S18	12/07/2006	-	366	-	14	0.11	2.48	<0.05	>250	30
2,Red,2.5m	S18	02/08/2006	-	-	-	-	-	-	-	-	
2,Red,2.5m	S18	18/10/2006	-	66	-	56	-	0.8	0.59	68	
2,Red,2.5m	S18	16/11/2006	-	-	-	39.6	-	-	-	-	100
2,Red,2.5m	S18	08/02/2007	8.41	30	-	16.2	0.01	0.18	0.2	46	-
2,Red,2.5m	S18	18/04/2007	8.77	151	-	6.4	<0.02	0.1	0.08	31	60
2,Red,2.5m	S18	16/05/2007	8.52	33	-	10.8	0.05	-	-	57	10
2,Red,2.5m	S18	26/06/2007	8.48	91	-	9	<0.02	-	0.06	39	50
2,Red,2.5m	S18	11/07/2007	7.66	-	-	<1	-	-	0.14	49	140
2,Red,2.5m	S18	29/08/2007	-	<25	-	15.6	<0.02	1.14	<0.05	136	110
2,Red,2.5m	S18	27/09/2007	-	-	-	-	-	-	-	-	-
2,Red,2.5m	S18	05/12/2007	7.06	8	-	64	<0.02	2.13	<0.05	488	340
2,Red,2.5m	S18	12/02/2008		29		4		0.64	2.16	79	
2,Red,2.5m	S18	13/06/2008	8.32	405	-	23.6	-	3.36	2.22	476	
2,Red,2.5m	S19										
2,Red,2.5m	S19										
2,Blue,2.5m	S20	10/04/2006	-	-	-	11.3	0.15	-	0.3	47	520
2,Blue,2.5m	S20	27/04/2006	-	-	-	-	-	-	-	-	0
2,Blue,2.5m	S20	12/07/2006	-	64	-	26.3	0.04	1.59	0.06	175	400
2,Blue,2.5m	S20	02/08/2006	-	<10	-	30.8	<0.02	<0.05	0.13	87	480
2,Blue,2.5m	S20	18/10/2006	-	48	-	58	<0.02	0.79	2.89	76	400
2,Blue,2.5m	S20	16/11/2006	7.86	23	-	48.8	0.08	0.12	<0.05	37	340
2,Blue,2.5m	S20	08/02/2007	7.93	<25	-	6.9	<0.02	0.06	<0.05	114	-
2,Blue,2.5m	S20	18/04/2007	8.19	158	-	6.3	<0.02	0.05	0.03	26	250
2,Blue,2.5m	S20	16/05/2007	8.33	56	-	14.5	0.01	0.19	<0.05	40	175
2,Blue,2.5m	S20	26/06/2007	7.96	46	-	10.1	<0.02	-	0.04	37	220
2,Blue,2.5m	S20	11/07/2007	-	-	-	<1	-	-	0.13	44	10
2,Blue,2.5m	S20	29/08/2007	-	<25	-	20.2	<0.02	1.3	<0.05	130	335
2,Blue,2.5m	S20	27/09/2007	-	-	-	-	-	-	-	-	-
2,Blue,2.5m	S20	05/12/2007	6.88	<25	-	44.5	<0.02	2	<0.05	352	500
2,Blue,2.5m	S20	12/02/2008		18		4.6		0.19	1.84	84	
2,Blue,2.5m	S20	25/02/2008	7.36	<10	-	14.4					
2,Blue,2.5m	S20	13/06/2008	-	-	-	-	-	-	-	-	
2,Blue,2.5m	S20										
2,Blue,2.5m	S20										
2,Black,2.5m	S21	10/04/2006	-	-	-	-	-	-	-	-	-
2,Black,2.5m	S21	27/04/2006	-	-	-	-	-	-	-	-	-
2,Black,2.5m	S21	12/07/2006	-	12	-	9.4	-	-	<0.05	233	45
2,Black,2.5m	S21	02/08/2006	-	39	-	39.8	0.04	0.23	0.15	106	90
2,Black,2.5m	S21	18/10/2006	-	50	-	29.3	0.03	0.07	0.09	83	20
2,Black,2.5m	S21	16/11/2006	-	10	-	34.4	0.1	<0.05	0.17	94	140
2,Black,2.5m	S21	08/02/2007	8.24	<25	-	24.4	<0.02	0.52	0.14	38	-
2,Black,2.5m	S21	18/04/2007	8.67	63	-	6	<0.02	0.07	<0.05	28	80
2,Black,2.5m	S21	16/05/2007	8.34	219	-	7.8	0.15	0.13	<0.05	15	15
2,Black,2.5m	S21	26/06/2007	8.15	73	-	13.4	<0.02	-	0.09	75	150
2,Black,2.5m	S21	11/07/2007	7.84	-	-	17.9	-	-	<0.05	109	180
2,Black,2.5m	S21	29/08/2007	-	<25	-	19.4	<0.02	1.17	0.88	93	700
2,Black,2.5m	S21	27/09/2007	-	-	-	-	-	-	-	-	-
2,Black,2.5m	S21	05/12/2007	7.38	<25	-	33.6	<0.02	2.1	0.6	210	250
2,Black,2.5m	S21	12/02/2008		27		4.8		0.42	<0.05	60	
2,Black,2.5m	S21	25/02/2008	7.21	13	-	8					
2,Black,2.5m	S21	13/06/2008	7.01	34	-	74.4	-	1.43	2.73	533	167
2,Black,2.5m	S21										
2,Black,2.5m	S21										
2,Black,2.5m	S21										

TCDUser: 1 in 5 dilution

TCDUser: 1 in 5 dilution

TCDU ser:

TCDUser: No suction - ring dropped

TCDUser: Poor suction

1,Red,5m	S7	10/04/2006	-	-	-	-	-	-	-	-	0		2,Red,5m	S22	10/04/2006	-	-	-	11.7	0.03	-	0.2	82	40
1,Red,5m	S7	27/04/2006	-	-	-	-	-	-	-	-	0		2,Red,5m	S22	27/04/2006	-	26.0	-	-	-	-	-	-	320
1,Red,5m	S7	12/07/2006	-	16	-	17.6	0.02	0.49	<0.05	149	325		2,Red,5m	S22	12/07/2006	-	140	-	3.4	-	1.05	-	85	20
1,Red,5m	S7	02/08/2006	-	-	-	-	-	-	-	-	0		2,Red,5m	S22	02/08/2006	-	<10	-	6.7	0.17	1.25	0.01	52	95
1,Red,5m	S7	18/10/2006	-	42	-	26.1	<0.02	0.21	0.22	22	290		2,Red,5m	S22	18/10/2006	-	62	-	14.3	-	0.46	-	53	110
1,Red,5m	S7	16/11/2006	8.32	39	-	8.3	0.08	<0.05	0.18	18	270		2,Red,5m	S22	16/11/2006	8.63	<10	-	13.8	-	<0.05	0.69	29	120
1,Red,5m	S7	08/02/2007	8.06	<25	-	8	<0.02	<0.05	<0.05	15	-		2,Red,5m	S22	08/02/2007	8.25	<25	-	4.5	<0.02	0.25	<0.05	180	-
1,Red,5m	S7	18/04/2007	8.08	125	-	65.4	1.55	31.1	0.49	148	240		2,Red,5m	S22	18/04/2007	8.94	103	-	-	0.04	<0.05	0.09	22	15
1,Red,5m	S7	16/05/2007	8.42	105	-	109.5	0.7	3.8	0.8	460	170		2,Red,5m	S22	16/05/2007	7.63	30	-	3.6	0.01	<0.05	<0.05	18	475
1,Red,5m	S7	26/06/2007	8.09	57	-	33.9	<0.02	-	0.04	107	275		2,Red,5m	S22	26/06/2007	8.47	124	-	2.7	<0.02	-	<0.05	<25	40
1,Red,5m	S7	11/07/2007	7.33	-	-	20.3	-	-	0.42	107	430		2,Red,5m	S22	11/07/2007	7.95	-	-	2.7	-	-	0.2	<10	150
1,Red,5m	S7	29/08/2007	-	<25	-	44.2	<0.02	0.88	3.68	73	215		2,Red,5m	S22	29/08/2007	-	<25	-	2	<0.02	0.98	<0.05	15	95
1,Red,5m	S7	27/09/2007	-	49	-	41.5	<0.02	0.04	1.74	69	365		2,Red,5m	S22	27/09/2007	-	-	-	0.9	-	0.05	1.06	11	120
1,Red,5m	S7	05/12/2007	7.52	103	-	21.8	<0.02	0.36	0.1	45	320		2,Red,5m	S22	05/12/2007	-	<10	-	2.4	-	0.62	4.14	32	100
1,Red,5m	S7	12/02/2008		19		1.5		0.88	<0.05	78			2,Red,5m	S22	12/02/2008	-	-	-	-	-	-	-	-	
1,Red,5m	S7	13/06/2008	8.00	11	98.7	88.4	-	0.1	3.86	550			2,Red,5m	S22	13/06/2008	7.75	1	-	17.6	-	0.09	16.48	102	
1,Red,5m	S7												2,Red,5m	S22										
1,Red,5m	S7												2,Red,5m	S22										
1,Blue,5m	S8	10/04/2006	-	-	-	-	-	-	-	-	-		2,Blue,5m	S23	10/04/2006	-	-	-	-	-	-	-	-	-
1,Blue,5m	S8	27/04/2006	-	-	-	-	-	-	-	-	-		2,Blue,5m	S23	27/04/2006	-	-	-	-	-	-	-	-	-
1,Blue,5m	S8	12/07/2006	-	116	-	7.2	0.05	0.29	<0.05	53	90		2,Blue,5m	S23	12/07/2006	-	90	-	8.7	0.09	1.38	3.98	138	290
1,Blue,5m	S8	02/08/2006	-	-	-	-	-	-	-	-	0	TCDU ser.	2,Blue,5m	S23	02/08/2006	-	28	-	14.1	<0.02	0.15	<0.05	59	475
1,Blue,5m	S8	18/10/2006	-	50	-	28.8	0.03	0.68	0.58	15	80		2,Blue,5m	S23	18/10/2006	-	44	-	18.4	<0.02	0.7	<0.05	48	340
1,Blue,5m	S8	16/11/2006	-	<10	-	9.1	0.01	<0.05	0.92	12	220		2,Blue,5m	S23	16/11/2006	8.37	<10	-	10.9	0.14	0.05	0.58	23	700
1,Blue,5m	S8	08/02/2007	8.05	<25	-	9.5	<0.02	0.03	0.06	<10	-		2,Blue,5m	S23	08/02/2007	8.03	<25	-	9.2	<0.02	0.44	0.17	210	-
1,Blue,5m	S8	18/04/2007	8.06	235	-	10.4	<0.02	0.91	<0.05	50	240		2,Blue,5m	S23	18/04/2007	7.21	57	-	3.5	<0.02	0.06	0.73	52	520
1,Blue,5m	S8	16/05/2007	8.07	41	-	28.9	0.02	1.52	<0.05	225	40		2,Blue,5m	S23	16/05/2007	-	-	-	-	-	-	-	-	0
1,Blue,5m	S8	26/06/2007	7.58	135	-	39.7	<0.02	-	0.35	188	35		2,Blue,5m	S23	26/06/2007	7.55	-	-	5.4	<0.02	-	0.03	37	720
1,Blue,5m	S8	11/07/2007	-	-	-	-	-	-	-	-	100		2,Blue,5m	S23	11/07/2007	-	-	-	-	-	-	-	-	0
1,Blue,5m	S8	29/08/2007	-	<25	-	48.8	<0.02	0.8	7.42	179	105		2,Blue,5m	S23	29/08/2007	-	<25	-	10	<0.02	1.27	<0.05	19	680
1,Blue,5m	S8	27/09/2007	-	47	-	40.7	<0.02	1.28	0.71	152	75		2,Blue,5m	S23	27/09/2007	-	-	-	6.9	0.05	<0.05	<0.05	28	250
1,Blue,5m	S8	05/12/2007	7.85	<25		28.8	<0.02	1.15	0.05	48	90		2,Blue,5m	S23	05/12/2007	7.12	-	-	4.2	<0.02	1.5	<0.05	24	705
1,Blue,5m	S8	12/02/2008		<10		7.4		0.92	6.32	40			2,Blue,5m	S23	12/02/2008		17		3.3		0.28	2.82	60	
1,Blue,5m	S8	25/02/2008	7.82	<10	-	20							2,Blue,5m	S23	25/02/2008	7.57	<10	-	6.4					
1,Blue,5m	S8	13/06/2008	7.96	61	55.6	36	-	0.23	2.35	347			2,Blue,5m	S23	13/06/2008	-	-	-	-	-	-	-	-	
1,Blue,5m	S8											TCDU ser.	2,Blue,5m	S23										
1,Blue,5m	S8												2,Blue,5m	S23										
1,Black,5m	S9	10/04/2006	-	-	-	-	-	-	-	-	-		2,Black,5m	S24	10/04/2006	-	-	-	-	-	-	-	-	-
1,Black,5m	S9	27/04/2006	-	-	-	-	-	-	-	-	-		2,Black,5m	S24	27/04/2006	-	-	-	-	-	-	-	-	-
1,Black,5m	S9	12/07/2006	-	108	-	3.9	0.06	1.87	<0.05	240	85		2,Black,5m	S24	12/07/2006	-	152	-	2.2	0.05	1.7	<0.05	102	45
1,Black,5m	S9	02/08/2006	-	-	-	-	-	-	-	-	0	TCDU ser.	2,Black,5m	S24	02/08/2006	-	21	-	5.5	0.96	2.91	0.99	46	125
1,Black,5m	S9	18/10/2006	-	-	-	-	-	-	-	-	105		2,Black,5m	S24	18/10/2006	-	48	-	29.6	0.03	0.34	0.22	63	150
1,Black,5m	S9	16/11/2006	7.94	91	-	11.9	0.09	<0.05	0.08	21	220		2,Black,5m	S24	16/11/2006	-	14	-	24.3	0.1	0.05	0.11	82	130
1,Black,5m	S9	08/02/2007	8.41	<25	-	<	0.05	5.54	0.9	12	-		2,Black,5m	S24	08/02/2007	8.13	<25	-	12.5	<0.02	0.43	0.11	176	-
1,Black,5m	S9	18/04/2007	8.59	247	-	1.7	0.31	0.63	0.46	29	120		2,Black,5m	S24	18/04/2007	8.87	56	-	-	-	0.54	4.67	38	110
1,Black,5m	S9	16/05/2007	-	19	-	14.6	0.06	-	-	76	110		2,Black,5m	S24	16/05/2007	-	36	-	10.9	0.05	-	-	36	115
1,Black,5m	S9	26/06/2007	8.70	68	-	19.5	0.02	-	0.42	53	40		2,Black,5m	S24	26/06/2007	8.34	-	-	6.9	<0.02	-	0.09	<25	140
1,Black,5m	S9	11/07/2007	8.26	-	-	19.6	-	-	0.22	75	145		2,Black,5m	S24	11/07/2007	8.07	-	-	6.6	-	-	<0.05	16	170
1,Black,5m	S9	29/08/2007	-	<25	-	14.8	0.04	1.11	1.44	59	840		2,Black,5m	S24	29/08/2007	-	<25	-	41	0.06	1.55	0.82	-	425
1,Black,5m	S9	27/09/2007	-	58	-	38.1	-	0.35	-	139	115		2,Black,5m	S24	27/09/2007	-	-	-	-	-	-	-	-	-
1,Black,5m	S9	05/12/2007	7.76	<25	-	29.6	<0.02	1.76	<0.05	129	100		2,Black,5m	S24	05/12/2007	-	-	-	-	-	-	-	-	-
1,Black,5m	S9	12/02/2008		18		7.8		0.29	4.69	56			2,Black,5m	S24	12/02/2008		12		4.6		0.38	4.33	29	
1,Black,5m	S9	25/02/2008	7.04	<10	-	16.4							2,Black,5m	S24	25/02/2008	8.01	8	-	8.8					
1,Black,5m	S9	13/06/2008	7.30	6	58.1	54	-	1.74	1.02	476	188		2,Black,5m	S24	13/06/2008	8.26	4	-	37.2	-	0.25	16.12	241	156.66667
1,Black,5m	S9												2,Black,5m	S24										
1,Black,5m	S9												2,Black,10m	S24										
1,Red,10m	S10	10/04/2006	-	-	-	10.3	0.15	-	0.29	82	170		2,Red,10m	S25	10/04/2006	-	-	-	8.9	0.05	-	0.18	74	440
1,Red,10m	S10	27/04/2006	-	39	-	4.2	0.03	0.10	<0.05	7.7	150		2,Red,10m	S25	27/04/2006	-	-	-	-	-	-	-	-	0
1,Red,10m	S10	12/07/2006	-	66	-	12.4	-	1.36	-	189	20		2,Red,10m	S25	12/07/2006	-	-	-	-	-	-	-	-	0
1,Red,10m	S10	02/08/2006	-	-	-	-	-	-	-	-	0		2,Red,10m	S25	02/08/2006	-	-	-	-	-	-	-	-	TCDUser: No suction
1,Red,10m	S10	18/10/2006	-	-	-	-	-	-	-	-	0	TCDUser:	2,Red,10m	S25	18/10/2006	-	186	-	14.9	<0.02	0.16	0.42	40	320
1,Red,10m	S10	16/11/2006	8.06	97	-	10.2	0.12	0.06	0.38	15	130		2,Red,10m	S25	16/11/2006	-	<10	-	15.9	0.09	0.06	0.06	26	350
1,Red,10m	S10	08/02/2007	8.35	<25	-	14.3	<0.02	0.05	0.05	<10	-		2,Red,10m	S25	08/02/2007	7.98	<25	-	23.2	<0.02	0.33	0.09	<10	-
1,Red,10m	S10	18/04/2007	8.84	174	-	-	-	0.06	0.33	6	10		2,Red,10m	S25	18/04/2007	-	<25	-	-	-	-	-	-	0
1,Red,10m	S10	16/05/2007	-	-	-	-	-	-	-	-	0		2,Red,10m	S25	16/05/2007	8.08	23	-	<1	0.02	<0.05	<0.05	2	185
1,Red,10m	S10	26/06/2007	8.42	49	-	12.7	0.02	-	0.16	49	80		2,Red,10m	S25	26/06/2007	7.52	-	-	0.3	<0.02	-	0.38	<25	300
1,Red,10m	S10	11/07/2007	-	-	-	12.6	-	-	0.16	45	135		2,Red,10m	S25	11/07/2007	8.17	-	-	<1	-	-	<0.05	<10	450
1,Red,10m	S10	29/08/2007	-	-	-	-	-	-	-	18	50		2,Red,10m	S25	29/08/2007	-	51	-	-	-	-	-	99	120
1,Red,10m	S10	27/09/2007	-	-	-	-	-	-	-	19	60		2,Red,10m	S25	27/09/2007	-	-	-	-	0.01	-	0.04	10	335
1,Red,10m	S10	05/12/2007	7.49	-	-	-	-	-	-	8	250		2,Red,10m	S25	05/12/2007	7.25	-	-	-	-	-	-	15	370
1,Red,10m	S10	13/06/2008	7.48	31	-	186	-	1.75	4.92	57			2,Red,10m	S25	13/06/2008	-	-	-	-	-	-	-	-	
1,Red,10m	S10												2,Red,10m	S25										
1,Red,10m	S10												2,Red,10m	S25										
1,Red,10m	S10												2,Red,10m	S25										
1,Blue,10m	S11	10/04/2006	-	-	-	9.2	0.09	-	0.08	64	520		2,Blue,10m	S26	10/04/2006	-	-	-	8.7	0.07	-	<0.05	37	105
1,Blue,10m	S11	27/04/2006	-	-	-	-	-	-	-	-	0		2,Blue,10m	S26	27/04/2006	-	32	-	0.6	0.01	0.29	<0.05	3	440
1,Blue,10m	S11	12/07/2006	-	-	-	8.3	-	-	-	-	0		2,Blue,10m	S26	12/07/2006	-	-	-	-	-	-	-	-	0
1,Blue,10m	S11	02/08/2006	-	<10	-	8.3	<0.02	0.08	0.09	22	280		2,Blue,10m	S26	02/08/2006	-	<10	-	-	-	-	15		TCDUser: Poor suction
1,Blue,10m	S11	18/10/2006	-	40	-	10.4	<0.02	0.14	0.3	<10	320		2,Blue,10m	S26	18/10/2006	-	70	-	20	<0.02	0.07	0.13	47	
1,Blue,10m	S11	16/11/2006	8.14	<10	-	8	0.09	0.08	0.73	13	390		2,Blue,10m	S26	16/11/2006	8.51	23	-	-	-	<0.05	-	-	5
1,Blue,10m	S11	08/02/2007	8.12	<25	-	6.4	<0.02	<0.05	0.06	<10	-		2,Blue,10m	S26	08/02/2007	7.88	<25	-	7.6	<0.02	0.17	<0.05	<10	-
1,Blue,10m	S11	18/04/2007	8.11	53	-	1.2	<0.01	0.05	0.04	11	320		2,Blue,10m	S26	18/04/2007	6.89	-	-	1.50	<0.02	0.36	-	13	250
1,Blue,10m	S11	16/05/2007	8.17	16	-	3.4	0.01	<0.05	<0.05	15	190		2,Blue,10m	S26	16/05/2007	7.73	66	-	5.2	0.04	0.1	2.44	7	270
1,Blue,10m	S11	26/06/2007	7.52	69	-	1.9	-	-	0.13	<25	380		2,Blue,10m	S26	26/06/2007	7.78	-	-	2.8	<0.02	-	0.17	<25	400
1,Blue,10m	S11	11/07/2007	-	-	-	-	-	-	-	-	-		2,Blue,10m	S26	11/07/2007	7.85	-	-	<1	-	-	<0.05	<10	620
1,Blue,10m	S11	29/08/2007	-	-	-	-	-	-	-	-	0		2,Blue,10m	S26	29/08/2007	-	<25	-	-	-	-	-	<10	325
1,Blue,10m	S11	27/09/2007	-	-	-	-	-	-	-	-	-		2,Blue,10m	S26	27/09/2007	-	-	-	-	-	-	-	12	205
1,Blue,10m	S11	05/12/2007	-	-	-	-	-	-	-	-	-		2,Blue,10m	S26	05/12/2007	7.10	-	-	-	-	-	-	-	350
1,Blue,10m	S11	13/06/2008	-	-	-	-	-	-	-	-			2,Blue,10m	S26	13/06/2008	7.52	<10	-	18.5	-	0.09	9.32	35	
1,Blue,10m	S11												2,Blue,10m	S26										
1,Blue,10m	S11												2,Blue,10m	S26										
1,Black,10m	S12	10/04/2006	-	-		-	-	-	-	-	0		2,Black,10m	S27	10/04/2006	-	-	-	12	0.08	-	0.05	9	50
1,Black,10m	S12	27/04/2006	-	20	-	<1.0	<0.02	0.46	0.29	5.8	300		2,Black,10m	S27	27/04/2006	-	27	-	1.4	0.04	0.32	<0.05	3.2	300
1,Black,10m	S12	12/07/2006	-	118		5	0.04	1.72	<0.05	250	95		2,Black,10m	S27	12/07/2006	-	82	-	7.00	0.04	0.48	<0.05	65	35
1,Black,10m	S12	02/08/2006	-	-		-	-	-	-	-	0		2,Black,10m	S27	02/08/2006	-	<10	-	11.2	<0.02	0.05	0.11	29	95
1,Black,10m	S12	18/10/2006	-	96	-	3.5	-	<0.05	0.86	67	120		2,Black,10m	S27	18/10/2006	-	-	-	20.5	0.03	0.18	7.45	47	180
1,Black,10m	S12	16/11/2006	8.19	-	-	-	-	-	-	-	0		2,Black,10m	S27	16/11/2006	7.89	<10	-	20.1	0.09	<0.05	<0.05	31	180
1,Black,10m	S12	08/02/2007	8.38	<25	-	7.5	0.02	<0.05	0.23	<10	-		2,Black,10m	S27	08/02/2007	-	-	-	-	-	-	-	-	-
1,Black,10m	S12	18/04/2007	-	-	-	-	-	-	-	-	100		2,Black,10m	S27	18/04/2007	-	-	-	-	-	-	27	105	
1,Black,10m	S12	16/05/2007	-	-	-	-	-	-	-	-	0		2,Black,10m	S27	16/05/2007	-	-	-	-	-	-	-	-	0
1,Black,10m	S12	26/06/2007	-	-	-	3.5	-	-	0.08	-	10		2,Black,10m	S27	26/06/2007	8.39	-	-	6.3	<0.02	-	0.2	<25	130
1,Black,10m	S12	11/07/2007	7.76	-	-	2.2	-	-	0.59	<10	220		2,Black,10m	S27	11/07/2007	8.35	-	-	<1	-	-	<0.05	<10	135
1,Black,10m	S12	29/08/2007	-	-	-	-	-	-	-	<10	240		2,Black,10m	S27	29/08/2007	-	-	-	-	-	-	-	-	220
1,Black,10m	S12	27/09/2007	-	-	-	-	-	-	-	14	105		2,Black,10m	S27	27/09/2007	-	-	-	-	-	-	13		155
1,Black,10m	S12	05/12/2007	-	-	-	-	-	-	-	-	-		2,Black,10m	S27	05/12/2007	7.79	-	-	-	-	-	-	-	100
1,Black,10m	S12	13/06/2008	-	-	-	-	-	-	-	-			2,Black,10m	S27	13/06/2008	7.97	<10	-	32.3	-	0.07	8.28	23	
1,Black,10m	S12												2,Black,10m	S27										
1,Black,10m	S12												2,Black,10m	S27										

1,Red,15m	S13	10/04/2006	-	-	-	10.5	0.02	-	<0.05	77	30		2,Red,15m	S28	10/04/2006	-	-	-	12.1	0.02	-	0.34	63	430
1,Red,15m	S13	27/04/2006	-	-	-	-	-	-	-	-	0		2,Red,15m	S28	27/04/2006	-	<10	-	12.7	0.07	0.22	0.43	29.8	60
1,Red,15m	S13	12/07/2006	-	38	-	10.2	0.02	1.51	<0.05	234	60		2,Red,15m	S28	12/07/2006	-	24	-	10.5	0.02	0.54	<0.05	44	165
1,Red,15m	S13	02/08/2006	-	<10	-	17.6	<0.02	0.16	0.37	139	45		2,Red,15m	S28	02/08/2006	-	<10	-	16.7	-	0.07	<0.05	33	215
1,Red,15m	S13	18/10/2006	-	-	-	-	-	-	-	-	0		2,Red,15m	S28	18/10/2006	-	124	-	19.7	<0.02	0.09	4.42	30	230
1,Red,15m	S13	16/11/2006	7.90	41	-	19.9	0.09	0.08	0.32	17	160		2,Red,15m	28	16/11/2006	8.02	32	-	18.3	0.09	<0.05	0.68	17	280
1,Red,15m	S13	08/02/2007	8.24	<25	-	7.2	<0.02	0.02	0.13	22	-		2,Red,15m	28	08/02/2007	7.84	<25	-	6.5	<0.02	0.21	0.08	<10	-
1,Red,15m	S13	18/04/2007	-	-	-	-	-	-	-	-	0		2,Red,15m	28	18/04/2007	-	-	-	-	-	-	-	-	0
1,Red,15m	S13	16/05/2007	-	94	-	7.6	0.02	-	-	22	15		2,Red,15m	28	16/05/2007	-	-	-	-	-	-	-	-	0
1,Red,15m	S13	26/06/2007	8.31	-	-	2	0.04	-	0.12	<25	130		2,Red,15m	28	26/06/2007	7.53	-	-	2	<0.02	-	0.04	<25	30
1,Red,15m	S13	11/07/2007	7.35	-	-	1.1	-	-	0.25	<10	175		2,Red,15m	28	11/07/2007	7.96	-	-	3.3	-	-	<0.05	<10	220
1,Red,15m	S13	29/08/2007	-	33	-	-	-	-	-	<10	90		2,Red,15m	28	29/08/2007	-	<25	-	-	-	-	-	<10	145
1,Red,15m	S13	27/09/2007	-	-	-	-	-	-	-	11	115		2,Red,15m	28	27/09/2007	-	-	-	-	-	-	-	15	110
1,Red,15m	S13	05/12/2007	8.09	-	-	-	-	-	-	2	30		2,Red,15m	28	05/12/2007	8.10	-	-	-	-	-	-	6	75
1,Red,15m	S13	13/06/2008	-	-	-	2.4	-	0.17	3.23	2			2,Red,15m	28	13/06/2008	-	-	-	-	-	-	-	-	
1,Red,15m	S13												2,Red,15m	28										
1,Blue,15m	S14	10/04/2006	-	-	-	-	-	-	-	-	-		2,Blue,15m	S29	10/04/2006	-	-	-	-	-	-	-	-	0
1,Blue,15m	S14	27/04/2006	-	-	-	-	-	-	-	-	0		2,Blue,15m	S29	27/04/2006	-	-	-	-	-	-	-	-	0
1,Blue,15m	S14	12/07/2006	-	14	-	6.3	0.04	2.32	<0.05	>240	80		2,Blue,15m	S29	12/07/2006	-	-	-	-	-	-	-	-	TCDUser:
1,Blue,15m	S14	02/08/2006	-	5	-	11.9	<0.02	<0.05	0.02	62	165		2,Blue,15m	S29	02/08/2006	-	-	-	-	-	-	-	-	No station
1,Blue,15m	S14	18/10/2006	-	58	-	20.5	-	0.17	3.06	21	125		2,Blue,15m	S29	18/10/2006	-	-	-	-	-	-	-	-	0
1,Blue,15m	S14	16/11/2006	8.23	5	-	16.1	0.09	<0.05	0.18	15	500		2,Blue,15m	S29	16/11/2006	-	-	-	-	-	-	-	-	0
1,Blue,15m	S14	08/02/2007	8.14	32	-	6.1	<0.02	0.01	0.05	<10	-		2,Blue,15m	S29	08/02/2007	-	-	-	-	-	-	-	-	-
1,Blue,15m	S14	18/04/2007	8.53	135	-	-	-	0.08	-	7	10		2,Blue,15m	S29	18/04/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	16/05/2007	8.37	60	-	5.8	0.02	<0.05	0.05	4	40		2,Blue,15m	S29	16/05/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	26/06/2007	-	-	-	-	-	-	-	-	0		2,Blue,15m	S29	26/06/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	11/07/2007	7.54	-	-	<1	-	-	<0.05	<10	580		2,Blue,15m	S29	11/07/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	29/08/2007	-	10	-	-	-	-	-	<10	390		2,Blue,15m	S29	29/08/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	27/09/2007	-	-	-	-	-	-	-	16	195		2,Blue,15m	S29	27/09/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	05/12/2007	7.28	-	-	-	-	-	-	<10	350		2,Blue,15m	S29	05/12/2007	-	-	-	-	-	-	-	-	Broken
1,Blue,15m	S14	13/06/2008	-	-	-	-	-	-	-	-			2,Blue,15m	S29	13/06/2008	-	-	-	-	-	-	-	-	
1,Blue,15m	S14												2,Blue,15m	S29										
1,Black,15m	S15	10/04/2006	-	-	-	-	-	-	-	-	-		2,Black,15m	S30	10/04/2006	-	-	-	-	-	-	-	-	-
1,Black,15m	S15	27/04/2006	-	-	-	-	-	-	-	-	-		2,Black,15m	S30	27/04/2006	-	-	-	-	-	-	-	-	-
1,Black,15m	S15	12/07/2006	-	-	-	-	-	-	-	-	0		2,Black,15m	S30	12/07/2006	-	-	-	-	-	-	-	-	0
1,Black,15m	S15	02/08/2006	-	-	-	-	-	-	-	-	0		2,Black,15m	S30	02/08/2006	-	-	-	-	-	-	-	-	TCDUser:
1,Black,15m	S15	18/10/2006	-	60	-	14.2	0.03	0.25	1.31	34	35		2,Black,15m	S30	18/10/2006	-	104	-	7.6	-	0.5	-	60	No station
1,Black,15m	S15	16/11/2006	-	<10	-	8	0.09	<0.05	0.1	<10	115		2,Black,15m	S30	16/11/2006	-	<10	-	8.6	0.1	0.19	0.11	11	15
1,Black,15m	S15	08/02/2007	8.14	<25	-	4.3	<0.02	<0.05	<0.05	-	-		2,Black,15m	S30	08/02/2007	8.17	<25	-	5.1	<0.02	0.42	0.1	<10	10
1,Black,15m	S15	18/04/2007	-	-	-	-	-	-	-	-	0		2,Black,15m	S30	18/04/2007	-	-	-	-	-	-	-	-	-
1,Black,15m	S15	16/05/2007	8.51	52	-	5.4	0.03	<0.05	<0.05	6	30		2,Black,15m	S30	16/05/2007	-	-	-	-	-	-	-	-	0
1,Black,15m	S15	26/06/2007	-	-	-	-	-	-	-	-	0		2,Black,15m	S30	26/06/2007	-	-	-	-	-	-	-	-	0
1,Black,15m	S15	11/07/2007	8.34	-	-	<1	-	-	<0.05	<10	55		2,Black,15m	S30	11/07/2007	7.60	-	-	1.4	-	-	<0.05	<10	45
1,Black,15m	S15	29/08/2007	-	<25	-	-	-	-	-	<10	50		2,Black,15m	S30	29/08/2007	-	<25	-	-	-	-	-	<10	160
1,Black,15m	S15	27/09/2007	-	-	-	-	-	-	-	-	-		2,Black,15m	S30	27/09/2007	-	-	-	-	-	-	-	-	-
1,Black,15m	S15	05/12/2007	-	-	-	-	-	-	-	-	-		2,Black,15m	S30	05/12/2007	-	-	-	-	-	-	-	-	-
1,Black,15m	S15	13/06/2008	-	-	-	-	-	-	-	-			2,Black,15m	S30	13/06/2008	-	-	-	-	-	-	-	-	

		SECONDARY TRENCH 1														
Bacteria (MPN/100ml)	**Date**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
Total Coliforms	12/07/2006				>2419.6	1413.6		214.3								
	02/08/2006				78.9	285.1	>2419.6					248.1			>2419.6	
	06/09/2006		2419.6		70.6	866.4	135.5	>2419.6				344.8		117.8	>2419.6	
	18/10/2006	-	>2419.6	-	1986.3	>2419.6	1166	1782	1301	>2419.6	-	4352	>2419.6	1732.9	373	-
	16/11/2006	>24,196	7270	>24,196	2419.6	2419.6	>2419.6	>2419.6	>2419.6	>2419.6	-	>24,196	-	>2419.6	1986.3	-
	08/02/2007	-	686.7	>2419.6	410.6	-	1553.1	>2419.6	>2419.6	>2419.6	-	>2419.6	>2419.6	-	816.4	>2419.6
	18/04/2007	>2419.6	1553.1	-	189	344.8	177.7	>24196	9804	>2419.6	-	261	>2419.6	-	-	-
	16/05/2007	-	>2419.6	-		296.7	1986.3	86.9	>2419.6	1986.3	-	9.4	-	-	<2419.6	<2419.6
	26/06/2007	>2005	>2005	-	8850	20050	20050	<100	2220	1780	12980	1240	6970	8850	-	-
	11/07/2007	>24,196	>2419.6	-	1986.3	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	147.3	-	>2419.6	>2419.6	>2419.6	708
	29/08/2007	77010	>241960	-	11530	61310	64880	12590	27550	1046.2	-	-	>2419.6	-	>2419.6	-
	27/09/2007	2174	39680	-	22470	1732.9	>2419.6	>2419.6	-	>2419.6	-	-	-	435.2	>2419.6	-
	05/12/2007	-	>2419.6	-	613.1	1299.7	>2419.6	>2419.6	-	-	-	-	-	-	-	-
	25/02/2008	-	980.4	-	-	84.7	148.3	-	-	-	-	-	-	-	-	-
	13/06/2008		>241960		17329	>241960	>241960	>241960	98040	>241960	241960			>241960		
E.Coli	12/07/2006				3.1	2		1								
	02/08/2006				1	4.1	59.1					<1			<1	
	06/09/2006		1		<1	<1	<1	2				<1		<1	<1	
	18/10/2006	-	3	3	1	2	2	<1	<10	2	-	<1	<1	<1	<10	-
	16/11/2006	<10	<1	10	<1	<1	<1	1	<1	1	-	<1	-	<1	<1	-
	08/02/2007	-	6.3	107.1	<1	-	<1	<1	<1	>2419.6	-	1	<1	-	<1	<1
	18/04/2007	<1	<1	-	<10	<1	<1	<10	<1	<1	-	<1	<1	-	-	-
	16/05/2007	-	35.9	-	-	4	6.2	<1	<1	<1	-	<1	-	-	<1	<1
	26/06/2007	<1	<1	-	<1	<10	<10	<1	<1	<1	<1	<1	<1	<1	-	-
	11/07/2007	<10	<1	-	3.1	<1	<1	<1	2	<1	<1	-	<1	<1	<1	<10
	29/08/2007	<1	<1	-	1	<1	<1	<1	<100	<1	-	-	1	-	<1	-
	27/09/2007	<10	<1	-	<10	<1	<1	<1	-	<1	-	-	-	<1	<1	-
	05/12/2007	-	<1	-	<1	<1	<1	2	-	-	-	-	-	-	-	-
	25/02/2008	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	-
	13/06/2008		63		<10	1	<10	<10	<10	<10	<1			<1		
				5												
		SECONDARY TRENCH 2														
Bacteria (MPN/100ml)	**Date**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
Total Coliforms	12/07/2006		>2419.6	>2419.6					116.2					261.3		
	02/08/2006		>2419.6	517.2		45.7			48	>2419.6				5.2		
	06/09/2006		127.4	307.6		36.4		137.9	1011.2	547.5	461.1	307.6	>2419.6			
	18/10/2006	5475	>2419.6	>2419.6	>2419.6	>2419.6	-	>2419.6	>2419.6	>2419.6	1553.1	1299.7	>2419.6	984	-	-
	16/11/2006	1497	1203.3	980.4	>2419.6	2419.6	1119.9	2419.6	>2419.6	1553.1	1986.3	-	913.9	1986.3	-	-
	08/02/2007	-	>2419.6	>2419.6	547.5	248.1	727	-	108.6	547.5	125	45.5	90.5	261.3	-	387.3
	18/04/2007	>2419.6	1046.2	1119.9	-	325.5	-	-	727	>2419.6	-	196.1	499.6	-	-	-
	16/05/2007	-	>2419.6	>2419.6	-	7.4	-	16	-	1553.1	1	-	-	-	-	-
	26/06/2007	>20,050	>20050	>20050	>20050	>20050	>20050	310	100	200	-	1110	8310	20050	-	-
	11/07/2007	>24,196	>24,196	>2419.6	>2419.6	>24,196	>2419.6	261.3	-	>2419.6	1986.3	-	>2419.6	387.3	816.4	223
	29/08/2007	-	29090	3190	-	24810	920.8	18720	816	54.6	70.8	186	1732.9	228.2	-	-
	27/09/2007	-	-	>2419.6	-	-	3664	3256	196.6	-	>2419.6	>2419.6	179.3	187.2	-	-
	05/12/2007	-	275.5	275.5	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	-	-	-	-	-	-	-
	25/02/2008	-	579.4	36.9	-	-	-	-	204.6	<1	-	-	-	-	-	-
	13/06/2008		4374	9033	1080		820	3690		2330						
E.Coli	12/07/2006		<1	<1					<1					<1		
	02/08/2006		6.2	<1		<1			<1	5.2				<1		
	06/09/2006		1	3		<1		<1	<1	<1	<1	<1	<1			
	18/10/2006	<10	<1	<1	3	3	-	6	<1	1	<1	1	<1	<1	-	-
	16/11/2006	<10	<1	<1	<1	<1	<1	<1	<1	<1	1	-	<1	<1	-	-
	08/02/2007	-	<1	<1	<1	<1	<1	-	1	1	<1	<1	<1	<1	-	<1
	18/04/2007	15.8	<1	<1	-	<1	-	-	<1	<1	-	<1	1	-	-	-
	16/05/2007	-	1	4.1	-	2	-	1	-	9.7	<1	-	-	-	-	-
	26/06/2007	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	<1	<1	<1	-	-
	11/07/2007	10	<10	>2419.6	<1	<10	<1	<1	-	<1	<1	-	<1	<1	<1	<10
	29/08/2007	-	1	<1	-	<1	2	<100	<1	<1	<1	<1	4	<1	-	-
	27/09/2007	-	-	<1	-	-	<10	59.9	<1	-	<1	<1	<1	2	-	-
	05/12/2007	-	<1	<1	3	<1	<1	<1	<1	-	-	-	-	-	-	-
	25/02/2008	-	<1	12.2	-	-	-	-	-	<1	-	-	-	-	-	-
	13/06/2008		125.5	152	100		20	10		<10						

Zero-Tension Samplers

ZT1	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	SS	Volume
	26/06/2007	-	298	-	8.7	-	-	-	-		
	11/07/2007	8.07	105	-	17.9	-	-	<0.05	146		65
	29/08/2007	-	110	-	68	1.96	12.1	14.05	338		60
	27/09/2007	-	120	-	87	2.5	4	0.05	388		30
	05/12/2007	7.94	88	-	54.2	1.42	4.35	0.37	320		40
	25/02/2008	-	22	42	45.2						
	23/04/2008				7.6						
	24/04/2008				0.8						
	27/04/2008				146		8				
	13/06/2008	7.05	113	100							

ZT2	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	SS	Volume
	26/06/2007	8.33	276	-	20.6	-	-	-	125		
	11/07/2007	-	-	-	28.8	-	-	-	172		10
	29/08/2007	-	95	-	15.8	1.68	3.7	13.15	282		30
	27/09/2007	-	145	-	46.5	-	11	1.04	268		10
	05/12/2007	-	56	-	-	-	-	-	268		10
	25/02/2008	-	<25	-							
	24/04/2008				36.4						
	27/04/2008				72						
	13/06/2008	6.26	96	53.4							

ZT3	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	SS	Volume
	26/06/2007	7.67	226	-	27.8	2.44	-	0.35	132		
	11/07/2007	7.3	63	-	23.8	-	-	<0.05	126		185
	29/08/2007	-	47	-	25.8	0.45	8.6	15	128		280
	27/09/2007	-	149	-	-	-	-	-	252		10
	05/12/2007	8.33	-	-	39.8	0.38	0.4	0.75	196		30

Total Coliforms	ZT1	ZT2	ZT3
	360.5	3817.0	382.5
	203.5	<100	185.5
	8664.0	72.0	325.5
	>2.419E+05	19180	307.6
	9400	970	7430.0
	>24196	20	7880.0
	1483	63	-
	>2419.6	292	-
	18500	784	692.0

E.Coli	ZT1	ZT2	ZT3
	<10	<10	<10
	<10	<10	<10
	10.0	<1	4.1
	1.20E+05	1200	12
	310	<100	<100
	12997	<10	<100
	233	<10	-
	1986	16	-
	756	1	<1

Groundwater Monitoring Points

U/S Groundwater Point	Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	SS	Depth
	02/08/2006	No groundwater present									
	06/09/2006	Issue with bailer									
	18/10/2006	7.82	-	-	5.1	0.15	4	0.29	228		
	16/11/2006		<26	-	4.3	0.12	0.05	0.01	45	17.8	
	08/02/2007	8.12	-	-	5.6	0.02	0.67	1.3	<10		
	18/04/2007	7.68	100	-	0.6	0.02	0.29	1.07	18		3.1m
	16/05/2007	No groundwater present									
	11/07/2007	7.11	46	-	2.4	-	-	<0.05	41		
	29/08/2007		<25	7.36	6.3	0.04	1.06	<0.05	<20		
	27/09/2007	-	57	-	-	-	-	-	-	-	
	05/12/2007	7.32	5	-	5.4	-	1.02	<0.05	107		
	12/02/2008	-	<10	-	1.5	-	0.19	<0.05	32		
					3.9						
D/S Grundwater Point	**Date**	**pH**	**COD**	**TN**	**NO_3-N**	**NO_2-N**	**NH_4-N**	**Ortho-P**	**Cl**	**SS**	**Depth**
	02/08/2006	No groundwater present									
	06/09/2006	-	66	-	5.9	0.1	0.02	0.13	188		
	18/10/2006	7.27	-	-	114	0.26	2.22	0.08	171		
	16/11/2006		70	-	65	0.15	2.13	0.05	375	48.9	
	08/02/2007	7.15	-	-	26	0.04	1.12	0.32	80		
	18/04/2007	7.68	74	-	10.9	0.02	<0.05	1.62	52		3.1m
	16/05/2007	No groundwater present									
	11/07/2007	7.16	19	-	20.2	-	-	0.05	105		
	29/08/2007		<25	34.6	31.4	0.06	1.76	<0.05	256		
	27/09/2007	-	14	-	15.5	3.8	7	0.01	192		
	05/12/2007	6.71	12	27.8	35.6	-	2.33	<0.05	288		
	12/02/2008	-	18	-	14.5	-	0.94	<0.05	148		
	25/02/2008		6	-	1						

	U/S GW	D/S GW	Tap			U/S GW	D/S GW	Tap
Total Coliforms	No GW present				***E.Coli***	No GW present		
	Pump fail	1.14 x 105				Pump fail	<1	
	40800	20300				<10	30	
	2481	918				2	31	
	-	2053				-	360	
	-	-				-	-	
	149	16810				1	100.5	
	6.3	166.4	1			<1	36.8	<1
	No GW present					No GW present		
	No GW present					No GW present		
	10859.08	8049.48				-	-	
	>24196	>24196				228.2	3	
	1299.7	>24196				2	90	
	3480	1523	9.6			<10	131	<1
	>24196	>24196	-			<10	<1	-
	-	12.1	-			-	<1	-
	-	-	-			-	-	-

SITE B

Results from Chemical & Bacteriological Analysis

Biodisc® RBC Effluent (SE)

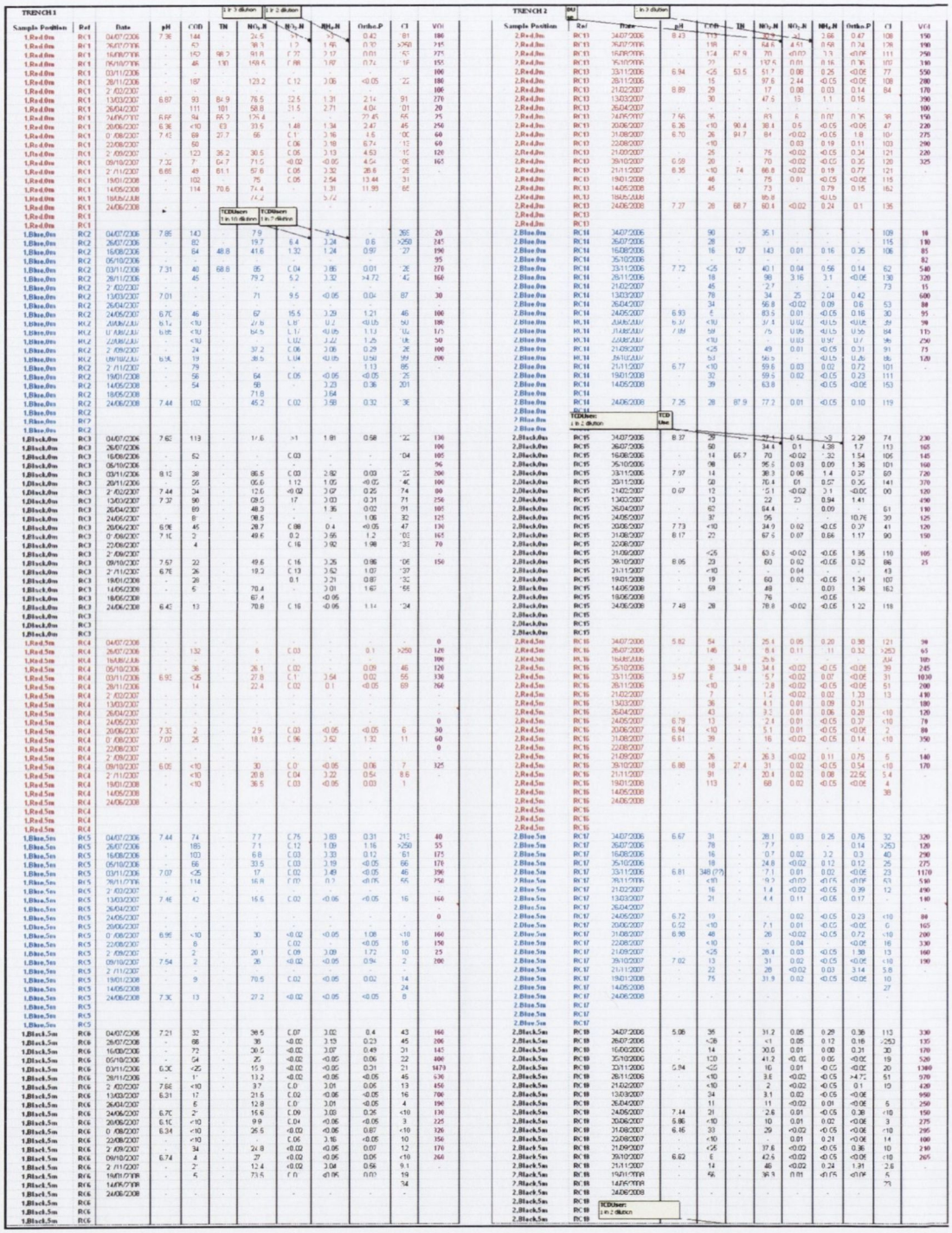
Sample Position	Ref	Date	Temp (deg)	pH	BOD	COD	TN	NO_3-N	NO_2-N	NH_4-N	Total Inorg-N	Ortho-P	Cl	SS
	RCX	09/05/2006	-	-	-	308	-	8.7	0.99	2.22	11.9	12.4	99	88.75
	RCX	01/06/2006	-	-	-	266	-	21.5	1.21	4.66	27.4	9.9	136	43
	RCX	04/07/2006	-	7.63	-	150	-	21.2	1.1	8.9	31.2	27.2	157	19.5
	RCX	26/07/2006	-	8.07	-	208	-	34.3	2.28	4.25	40.8	26.3	150	45
	RCX	16/08/2006	-	-	-	362	261.0	64.8	2.34	88	155.1	37.6	136	55
	RCX	05/10/2006	-	-	-	182	138.0	91.5	1.2	21.8	114.5	35.9	130	28
	RCX	03/11/2006	-	6.65	-	116	98.3	93.5	0.16	26.2	119.9	97.5	133	33
	RCX	28/11/2006	-	-	-	239	-	26	62	10.3	98.3	12.0	116	-
RBC	RCX	26/01/2007	-	7.64	-	224	109.0	19.6	55.4	30	105.0	24.6	116	-
	RCX	21/02/2007	-	-	-	207	-	7.3	58.6	31	96.9	18.0	48	-
	RCX	13/03/2007	-	-	-	293	87.5	34	55.4	17.4	106.8	22.3	103	47
	RCX	26/04/2007	-	-	-	207	93.0	14.7		46	60.7	28.3	97	-
	RCX	24/05/2007	-	7.48	-	175	79.8	17.7	52.4	11	81.1	37.5	89	-
	RCX	20/06/2007	-	7.41	-	86	63.6	8.5	0.58	5.1	14.2	14.3	45	-
	RCX	01/08/2007	-	7.38	-	148	45.7	34	1.12	2.4	37.5	25.3	112	-
	RCX	11/08/2007	16.5	7.42	-	-	-	-	-	-	-	-	-	-
	RCX	22/08/2007	-	-	-	123	-	21.98	0.7	2.82	25.5	29.8	118	-
	RCX	21/09/2007	15.0	-	-	182	79.9	41	0.93	7.21	49.1	26.3	120	-
	RCX	09/10/2007	-	6.92	-	105	66.4	53	0.79	5.84	59.6	32.1		-
	RCX	21/11/2007	-	6.82	-	115	69.1	44.4	0.62	2.5	47.5	25.0	145	-
	RCX	19/01/2008	-	-	74.01	193	49.3	61.5	0.58	17.9	80.0	28.4	133	-
	RCX	28/02/2008	11.4	6.96	66.15	258	-	90.8	0.26	34.4	125.5	45.4	180	-
	RCX	14/05/2008	17.3	7.20	162.40	375	125.0	1.2	0.9	51	53.1	38.8	149	-
	RCX	30/05/2008	-	-	-	52	68.3	9	6.2	15.5	30.7	24.0	-	-
	RCX	24/06/2008	-	6.38	-	60	50.2	27.4	0.25	14.8	42.5	25.4	144	24

Tertiary Reed Bed Effluent (RBE)

Sample Position	Ref	Date	Temp (deg)	pH	BOD	COD	TN	NO_3-N	NO_2-N	NH_4-N	Total Inorg-N	Ortho-P	Cl	SS
	RCZ	09/05/2006	-	-	-	250	-	5.2	>1.0	1.93	7.1	10.56	105	58.4
	RCZ	01/06/2006	-	-	-	126	-	11.7	0.82	11.52	24.0	10.22	91	18.2
	RCZ	04/07/2006	-	8.53	-	82	-	5.7	0.48	7.10	13.3	4.57	119	2
	RCZ	26/07/2006	-	8.31	-	190	-	22.1	0.42	13.9	36.4	18.4	108	11.8
	RCZ	16/08/2006	-	-	-	226	135.0	80	0.58	34.9	115.5	27.4	136	38.25
	RCZ	05/10/2006	-	-	-	106	107.0	55.6	1.1	9.2	65.9	27.9	111	17
	RCZ	03/11/2006	-	7.83	-	40	53.0	7.6	0.75	41.6	50.0	104.75	105	5.3
	RCZ	28/11/2006	-	-	-	161	-	12.6	43	8.9	64.5	12.2	97	-
Reed Bed	RCZ	26/01/2007	-	8.34	-	182	85.3	15.5	43.9	22	81.4	24.6	105	-
	RCZ	21/02/2007	-	-	-	159	-	7.8	48.1	39	94.9	19.8	97	-
	RCZ	13/03/2007	-	-	-	97	51.6	8	19.5	22.5	50.0	14.4	80	7.2
	RCZ	26/04/2007	-	-	-	131	72.3	6.5	29	69	104.5	56	118	-
	RCZ	24/05/2007	-	7.82	-	83	47.8	11.3	8.6	1	20.9	13.95	87	-
	RCZ	20/06/2007	-	7.34	-	7	44.3	8.5	0.99	4.2	13.7	7.8	50	-
	RCZ	01/08/2007	-	7.34	-	98	17.9	12	0.31	1.2	13.5	21.3	109	-
	RCZ	11/08/2007	16.4	6.77	-	-	-	-	-	-	-	-	-	-
	RCZ	22/08/2007	-	-	-	72	-	12.87	0.44	1.9	15.2	26.5	102	-
	RCZ	21/09/2007	14.7	-	-	43	51.9	27.3	0.26	0.22	27.8	24.2	159	-
	RCZ	09/10/2007	-	6.91	-	47	55.1	51.4	0.42	2.65	54.5	20.25	-	-
	RCZ	21/11/2007	-	7.11	-	49	49.6	41	0.54	3.1	44.6	24.3	144	-
	RCZ	19/01/2008	-	-	4.55	182	40.5	34.4	0.32	2.95	37.7	22.75	113	-
	RCZ	28/02/2008	7.04	7.04	2.61	132	-	51.2	0.84	34.5	86.5	41	145	-
	RCZ	12/04/2008	-	7.17	-	73	66.4	39.6	1.32	40	80.9	31.15	-	-
	RCZ	14/04/2008	-	7.37	-	71	77.2	41.4	1.1	37	79.5	32.3	-	-
	RCZ	15/04/2008	-	7.47	-	76	74.8	40	1.26	40	81.3	33.4	-	-
	RCZ	14/05/2008	16.2	7.09	13.70	122	48.9	3.8	0.5	29	33.3	28.1	146	-
	RCZ	30/05/2008	-	-	-	49	79.1	18.5	5.8	15.1	39.4	27.3		-
	RCZ	24/06/2008	-	7.00	-	46	55.6	32.6	0.34	17.3	50.2	20.2	125	-

Bacteria (MPN/100ml)		RCX	RCZ
Total Coliforms	***04/07/2006***		
	26/07/2006	198,600	4,710
	16/08/2006	3690000	579,400
	05/10/2006	547,500	209,800
	03/11/2006	27,800	26,500
	28/11/2006	310,000	315,150
	21/02/2007	-	-
	13/03/2007	148,000	-
	24/05/2007	104,400	6,480
	01/08/2007	101,700	9,700
	22/08/2007	712,000	5,110
	21/09/2007	166,000	3,200
	09/10/2007	1,119,900	36,540
	21/11/2007	504,000	7,127
	28/02/2008	421,000	2,750
	12/04/2008		5,720
	14/04/2008		1,919
	15/04/2008		2,873
	14/05/2008	736,000	35,900
	30/05/2008	69,000	1,800
	24/06/2008	22,240	19,863
E.Coli	***04/07/2006***		
	26/07/2006	57,900	310
	16/08/2006	520,000	65,000
	05/10/2006	28,800	3,100
	03/11/2006	2,010	1,467
	28/11/2006	31,000	9,925
	21/02/2007	-	-
	13/03/2007	26,000	-
	24/05/2007	11,100	200
	01/08/2007	3,100	380
	22/08/2007	58,500	143
	21/09/2007	10,800	42
	09/10/2007	12,200	<100
	21/11/2007	10,000	10
	28/02/2008	1,890	<100
	12/04/2008		<100
	14/04/2008		<100
	15/04/2008		<100
	14/05/2008	11,100	410
	30/05/2008	910	9.5
	24/06/2008	690	1554

Percolation Trenches Receiving SE



1,Red,10m	RC7	04/07/2006	7.31	21	-	23.5	0.13	0.51	0.56	97	40
1,Red,10m	RC7	26/07/2006	-	76	-	30.7	-	-	0.14	90	110
1,Red,10m	RC7	16/08/2006	-	40	-	29.5	<0.02	0.07	0.09	30	60
1,Red,10m	RC7	05/10/2006	-	112	-	48.8	0.01	<0.05	0.18	20	130
1,Red,10m	RC7	03/11/2006	-	-	-	-	-	-	-		100
1,Red,10m	RC7	28/11/2006	-	81	-	38.4	<0.02	<0.05	<0.05	52	110
1,Red,10m	RC7	21/02/2007	-	-	-	-	-	-	-		-
1,Red,10m	RC7	13/03/2007	7.09	<10	-	23.5	0.01	<0.05	<0.05	17	230
1,Red,10m	RC7	26/04/2007	-	5	-	18.8	0.06	0.08	<0.05	5	115
1,Red,10m	RC7	24/05/2007	-	-	-	-	-	-	-		0
1,Red,10m	RC7	20/06/2007	6.20	<10	-	12.9	0.03	<0.05	2.69	8	160
1,Red,10m	RC7	01/08/2007	6.25	123	-	26	<0.02	<0.05	1.15	<10	100
1,Red,10m	RC7	22/08/2007	-	<10	-	-	0.04	0.12	<0.05	5	130
1,Red,10m	RC7	21/09/2007	-	<25	-	-	-	-	-	9	160
1,Red,10m	RC7	21/11/2007	-	<10	-	24.3	<0.02	0.15	1.44	8.5	-
1,Red,10m	RC7	14/05/2008									
1,Red,10m	RC7	24/06/2008	7.10	<10	-	1.8	<0.02	<0.05	<0.05	8	
1,Red,10m	RC7										
1,Red,10m	RC7										
1,Red,10m	RC7										
1,Blue,10m	RC8	04/07/2006	6.55	97	-	15.7	0.05	0.01	4.68	99	190
1,Blue,10m	RC8	26/07/2006	-	70	-	15.8	0.01	0.71	0.27	>250	155
1,Blue,10m	RC8	16/08/2006	-	28	-	26.1	0.02	0.1	0.19	78	125
1,Blue,10m	RC8	05/10/2006	-	10	-	30.8	<0.02	<0.05	0.1	18	800
1,Blue,10m	RC8	03/11/2006	2.91	<25	-	7.1	<0.02	<0.05	38.25	12	1030
1,Blue,10m	RC8	28/11/2006	-	7	-	34.8	<0.02	<0.05	<0.05	64	720
1,Blue,10m	RC8	21/02/2007	7.53	<10	-	3.5	<0.02	0.02	0.09	13	520
1,Blue,10m	RC8	13/03/2007		8	-	5.5	0.01	<0.05	0.04	15	760
1,Blue,10m	RC8	26/04/2007	-	10	-	19.4	<0.02	0.01	4.15	3	380
1,Blue,10m	RC8	24/05/2007	-	-	-	-	-	-	-	-	0
1,Blue,10m	RC8	20/06/2007	-	-	-	-	-	-	-	-	-
1,Blue,10m	RC8	01/08/2007	6.94	33	-	20.5	0.07	<0.05	0.02	<10	625
1,Blue,10m	RC8	22/08/2007	-	<10	-	-	0.01	0.23	0.22	13	400
1,Blue,10m	RC8	21/09/2007	-	<25	-	-	-	-	-	16	330
1,Blue,10m	RC8	21/11/2007	-	<10	-	17.6	<0.02	0.19	0.35	7.1	-
1,Blue,10m	RC8	14/05/2008								41	
1,Blue,10m	RC8	24/06/2008	6.70	1	-	66.8	<0.02	0.15	0.28	49	
1,Blue,10m	RC8										
1,Blue,10m	RC8										
1,Blue,10m	RC8										
1,Black,10m	RC9	04/07/2006	-	-	-	-	-	-	-	-	-
1,Black,10m	RC9	26/07/2006	-	-	-	-	-	-	-	-	-
1,Black,10m	RC9	16/08/2006	-	-	-	-	-	-	-	-	-
1,Black,10m	RC9	05/10/2006	-	88	-	26.6	0.14	0.26	1.46	35	80
1,Black,10m	RC9	03/11/2006	6.28	<25	-	8.7	0.03	0.17	<0.05	12	1250
1,Black,10m	RC9	28/11/2006	-	35	-	22	0.01	0.05	<0.05	53	40
1,Black,10m	RC9	21/02/2007	-	-	-	-	-	-	-		-
1,Black,10m	RC9	13/03/2007		<10	-	8.5	0.03	0.02	0.07	13	550
1,Black,10m	RC9	26/04/2007	-	-	-	-	-	-	-		-
1,Black,10m	RC9	24/05/2007	-	-	-	-	-	-	-		0
1,Black,10m	RC9	20/06/2007	-	-	-	-	-	-	-		-
1,Black,10m	RC9	01/08/2007	-	73	-	5.5	-	0.4	-	22	45
1,Black,10m	RC9	22/08/2007	-	-	-	-	-	-	-		0
1,Black,10m	RC9	21/09/2007	-	-	-	-	-	-	-		-
1,Black,10m	RC9	21/11/2007	-	-	-	-	-	-	-		NS
1,Black,10m	RC9	14/05/2008								27	
1,Black,10m	RC9	24/06/2008	-	-	-	-	-	-	-		
1,Black,10m	RC9										
1,Black,10m	RC9										
1,Black,10m	RC9										
1,Red,15m	RC10	04/07/2006	8.25	<10	-	30.0	0.21	0.68	1.58	162	120
1,Red,15m	RC10	26/07/2006	-	114	-	28.8	0.02	2.63	5.22	>250	60
1,Red,15m	RC10	16/08/2006	-	134	-	73	<0.02	0.92	2.69	129	155
1,Red,15m	RC10	05/10/2006	-	54	-	55	0.01	<0.05	1.76	84	180
1,Red,15m	RC10	03/11/2006	6.51	<25	-	38	0.02	0.12	0.83	29	360
1,Red,15m	RC10	28/11/2006	-	109	-	31.2	<0.02	<0.05	0.33	57	510
1,Red,15m	RC10	21/02/2007	8.50	23	-	2.6	<0.02	0.07	0.96	9	500
1,Red,15m	RC10	13/03/2007		<10	-	11	0.03	<0.05	0.78	13	330
1,Red,15m	RC10	26/04/2007	-	12	-	12.1	<0.02	0.09	0.01	<10	320
1,Red,15m	RC10	24/05/2007	-	-	-	-	-	-	-	-	0
1,Red,15m	RC10	20/06/2007	6.73	<10	-	11.8	0.01	0.08	0.33	5	410
1,Red,15m	RC10	01/08/2007	7.06	33	-	20.5	0.02	<0.05	1.33	<10	475
1,Red,15m	RC10	22/08/2007	-	-	-	-	-	-	-	-	0
1,Red,15m	RC10	21/09/2007	-	21	-	-	-	-	-	12	350
1,Red,15m	RC10	21/11/2007	-	-	-	-	-	-	-	-	NS
1,Red,15m	RC10	14/05/2008								-	
1,Red,15m	RC10	24/06/2008	6.86	62	-	58.4	0.01	0.07	0.2	39	
1,Red,15m	RC10										
1,Red,15m	RC10										
1,Red,15m	RC10										
1,Blue,15m	RC11	04/07/2006	-	-	-	-	-	-	-	-	-
1,Blue,15m	RC11	26/07/2006	-	66	-	69.2	0.02	1.83	0.26	>250	140
1,Blue,15m	RC11	16/08/2006	-	134	86.9	94	0.01	0.6	0.01	126	165
1,Blue,15m	RC11	05/10/2006	-	144	-	83	<0.02	0.17	0.08	28	220
1,Blue,15m	RC11	03/11/2006	6.27	<25	-	47.4	0.02	0.23	<0.05	17	300
1,Blue,15m	RC11	28/11/2006	-	49	-	64.4	0.06	0.17	<0.05	42	350
1,Blue,15m	RC11	21/02/2007	8.34	<10	-	4.1	<0.02	0.02	0.03	11	250
1,Blue,15m	RC11	13/03/2007		7	-	16	0.11	<0.05	<0.05	12	50
1,Blue,15m	RC11	26/04/2007	-	14	-	17.1	<0.02	<0.05	1.11	4	115
1,Blue,15m	RC11	24/05/2007	7.12	5	-	20.2	0.02	<0.05	0.37	<10	105
1,Blue,15m	RC11	20/06/2007	5.97	<10	-	9.5	0.02	<0.05	<0.05	3	190
1,Blue,15m	RC11	01/08/2007	-	28	-	20	0.22	0.28	1.66	<10	30
1,Blue,15m	RC11	22/08/2007	-	<10	-	-	0.01	0.06	<0.05	11	170
1,Blue,15m	RC11	21/09/2007	-	<25	-	-	-	-	-	11	200
1,Blue,15m	RC11	21/11/2007	-	-	-	-	-	-	-	-	NS
1,Blue,15m	RC11	14/05/2008									
1,Blue,15m	RC11	24/06/2008	-	-	-	-	-	-	-	-	
1,Blue,15m	RC11										
1,Blue,15m	RC11										
1,Blue,15m	RC11										
1,Black,15m	RC12	04/07/2006	6.28	15	-	39.2	0.04	0.01	0.40	19	400
1,Black,15m	RC12	26/07/2006	-	58	-	42.5	0.01	0.89	0.14	268	375
1,Black,15m	RC12	16/08/2006	-	124	-	49.3	<0.02	0.09	<0.01	42	300
1,Black,15m	RC12	05/10/2006	-	86	-	42.8	<0.02	<0.05	0.07	34	900
1,Black,15m	RC12	03/11/2006	6.19	<25	-	5.4	<0.02	0.05	<0.05	8	1100
1,Black,15m	RC12	28/11/2006	-	<10	-	12.8	<0.02	<0.05	<0.05	10	550
1,Black,15m	RC12	21/02/2007	7.82	<10	-	1	<0.02	0.03	0.04	9	450
1,Black,15m	RC12	13/03/2007		2	-	3	0.02	<0.05	<0.05	9	570
1,Black,15m	RC12	26/04/2007	-	<10	-	7.8	0.01	0.04	0.23	2	400
1,Black,15m	RC12	24/05/2007	5.89	9	-	11.5	0.04	0.48	0.19	<10	450
1,Black,15m	RC12	20/06/2007	-	-	-	-	-	-	-	-	-
1,Black,15m	RC12	01/08/2007	6.48	15	-	11	<0.02	<0.05	0.73	<10	620
1,Black,15m	RC12	22/08/2007	-	<10	-	-	0.02	0.23	<0.05	6	35
1,Black,15m	RC12	21/09/2007	-	<25	-	-	-	-	-	9	500
1,Black,15m	RC12	09/10/2007	6.06	<10	-	16.5	<0.02	<0.05	1.3	<10	680
1,Black,15m	RC12	21/11/2007	-	-	-	-	-	-	-	-	NS
1,Black,15m	RC12	14/05/2008								13	
1,Black,15m	RC12	24/06/2008	-	<10	-	12.4	<0.02	<0.05	0.18	12	

TCDUser: No suction - cap needs to be replaced

TCDUser: 1 in 3 dilution

TCDUser: No suction - top of lysimeter is damaged

2,Red,10m	RC19	04/07/2006	7.64	18	-	14.3	0.07	0.04	0.19	189	60
2,Red,10m	RC19	26/07/2006	-	89	-	16.3	0.14	-	0.46	145	125
2,Red,10m	RC19	16/08/2006	-	-	-	-	-	-	-		100
2,Red,10m	RC19	05/10/2006	-	56	-	9.2	<0.02	0.05	0.17	12	320
2,Red,10m	RC19	03/11/2006	6.69	<25	-	16.1	0.01	0.04	<0.05	14	550
2,Red,10m	RC19	28/11/2006	-	11	-	13.2	<0.02	<0.05	<0.05	48	270
2,Red,10m	RC19	21/02/2007	-	-	-	-	-	-	-		-
2,Red,10m	RC19	13/03/2007		36	-	3.8	0.02	0.53	0.08		260
2,Red,10m	RC19	26/04/2007	-	-	-	-	-	-	-		-
2,Red,10m	RC19	24/05/2007	7.34	29	-	11	0.01	0.02	0.2	<10	55
2,Red,10m	RC19	20/06/2007	6.66	<10	-	8.6	0.02	<0.05	<0.05	3	125
2,Red,10m	RC19	01/08/2007	7.20	42	-	30.5	0.02	0.05	0.15	<10	205
2,Red,10m	RC19	22/08/2007	-	-	-	-	-	-	-		0
2,Red,10m	RC19	21/09/2007	-	<25	-	-	-	-	-	7	80
2,Red,10m	RC19	21/11/2007	-	<10	-	31.6	<0.02	0.07	2.13	15	-
2,Red,10m	RC19	14/05/2008								48	
2,Red,10m	RC19	24/06/2008	7.19	1	-	40.2	<0.02	0.02	<0.05	46	
2,Red,10m	RC19										
2,Red,10m	RC19										
2,Red,10m	RC19										
2,Blue,10m	RC20	04/07/2006	6.68	100	-	18.6	0.07	0.31	0.46	121	90
2,Blue,10m	RC20	26/07/2006	-	54	-	16.8	0.08	0.89	0.32	>250	95
2,Blue,10m	RC20	16/08/2006	-	-	-	22.3	-	-	-	231	105
2,Blue,10m	RC20	05/10/2006	-	50	-	11.6	<0.02	0.11	0.24	31	300
2,Blue,10m	RC20	03/11/2006	6.00	<25	-	23.8	<0.02	0.09	0.15	11	470
2,Blue,10m	RC20	28/11/2006	-	<10	-	12.4	<0.02	<0.05	>4.72	52	320
2,Blue,10m	RC20	21/02/2007	-	<10	-	1.8	<0.02	0.04	0.12	12	170
2,Blue,10m	RC20	13/03/2007		21	-	1.5	0.01	0.06	0.01		260
2,Blue,10m	RC20	26/04/2007	-	18	-	7	0.01	0.02	0.11	3	40
2,Blue,10m	RC20	24/05/2007	7.41	23	-	11.9	0.01	<0.05	0.07	<10	55
2,Blue,10m	RC20	20/06/2007	6.79	<10	-	9	0.01	<0.05	<0.05	3	120
2,Blue,10m	RC20	01/08/2007	6.29	42	-	20.5	<0.02	<0.05	1.12	<10	240
2,Blue,10m	RC20	22/08/2007	-	<10	-	-	0.03	0.16	<0.05	13	305
2,Blue,10m	RC20	21/09/2007	-	<25	-	-	-	-	-	14	50
2,Blue,10m	RC20	21/11/2007	-	<10	-	23	<0.02	0.14	0.15	5.9	-
2,Blue,10m	RC20	14/05/2008								43	
2,Blue,10m	RC20	24/06/2008	7.05	<10	-	40.0	<0.02	<0.05	0.2	41	
2,Blue,10m	RC20										
2,Blue,10m	RC20										
2,Blue,10m	RL17										
2,Black,10m	RC21	04/07/2006	7.49	87	-	6.0	0.14	0.23	<0.05	[illegible]	[illegible]
2,Black,10m	RC21	26/07/2006	-	96	-	2.1	0.12	0.46	0.2	[illegible]	[illegible]
2,Black,10m	RC21	16/08/2006	-	-	-	-	-	-	-		100
2,Black,10m	RC21	05/10/2006	-	-	-	-	-	-	-		0
2,Black,10m	RC21	03/11/2006	6.32	<25	-	25	<0.02	0.03	1.26	22	930
2,Black,10m	RC21	28/11/2006	-	<10	-	10.8	<0.02	<0.05	<0.05	12	430
2,Black,10m	RC21	21/02/2007	-	<10	-	2.6	<0.02	<0.05	0.18	11	360
2,Black,10m	RC21	13/03/2007		34	-	1.9	0.04	0.09	0.21		800
2,Black,10m	RC21	26/04/2007	-	27	-	12.1	0.02	0.08	1.62	6	20
2,Black,10m	RC21	24/05/2007	7.58	26	-	12.6	0.03	<0.05	0.16	<10	40
2,Black,10m	RC21	20/06/2007	-	<10	-	6.1	0.03	<0.05	<0.05	2	25
2,Black,10m	RC21	01/08/2007	-	45	-	14.5	<0.02	<0.05	12.55	<10	90
2,Black,10m	RC21	22/08/2007	-	<10	-	-	0.01	0.08	<0.05	2	260
2,Black,10m	RC21	21/09/2007	-	<25	-	-	-	-	-	4	35
2,Black,10m	RC21	21/11/2007	-	<10	-	22	0.01	0.14	0.58	6.7	NS
2,Black,10m	RC21	14/05/2008								7	
2,Black,10m	RC21	24/06/2008	6.97	<10	-	31.2	0.01	<0.05	0.15	10	
2,Black,10m	RC21										
2,Black,10m	RC21										
2,Black,10m	RC21										
2,Red,15m	RC22	04/07/2006	6.31	20	-	8.5	0.02	0.02	<0.05	90	250
2,Red,15m	RC22	26/07/2006	-	-	-	-	-	-	-	-	-
2,Red,15m	RC22	16/08/2006	-	110	-	12	0.02	0.4	<0.05	181	155
2,Red,15m	RC22	05/10/2006	-	32	-	11.5	<0.02	0.07	0.09	16	560
2,Red,15m	RC22	03/11/2006	4.40	<25	-	7.5	0.01	0.06	<0.05	21	450
2,Red,15m	RC22	28/11/2006	-	<10	-	33.6	<0.02	0.05	<0.05	36	480
2,Red,15m	RC22	21/02/2007	-	-	-	-	-	-	-	-	-
2,Red,15m	RC22	13/03/2007	-	-	-	-	-	-	-	-	-
2,Red,15m	RC22	26/04/2007	-	-	-	-	-	-	-	-	-
2,Red,15m	RC22	24/05/2007	-	-	-	-	-	-	-	-	0
2,Red,15m	RC22	20/06/2007	-	<10	-	3	-	-	-	-	5
2,Red,15m	RC22	01/08/2007	6.59	73	-	32.5	<0.02	<0.05	0.16	<10	485
2,Red,15m	RC22	22/08/2007	-	<10	-	-	0.03	0.63	<0.05	12	450
2,Red,15m	RC22	21/09/2007	-	<25	-	-	-	-	-	14	270
2,Red,15m	RC22	21/11/2007	-	-	-	-	-	-	-	-	NS
2,Red,15m	RC22	14/05/2008								3	
2,Red,15m	RC22	24/06/2008	-	-	-	-	-	-	-	-	
2,Red,15m	RC22										
2,Red,15m	RC22										
2,Red,15m	RC22										
2,Blue,15m	RC23	04/07/2006	-	-	-	-	-	-	-	-	-
2,Blue,15m	RC23	26/07/2006	-	98	-	4.3	0.1	1.41	0.23	>250	225
2,Blue,15m	RC23	16/08/2006	-	<25	-	8.3	<0.02	0.09	0.11	61	160
2,Blue,15m	RC23	05/10/2006	-	44	-	8.4	<0.02	0.06	<0.05	37	255
2,Blue,15m	RC23	03/11/2006	5.95	<25	-	6.4	<0.02	<0.05	<0.05	16	950
2,Blue,15m	RC23	28/11/2006	-	<10	-	26	<0.02	<0.05	<0.05	10	250
2,Blue,15m	RC23	21/02/2007	-	<10	-	0.80	<0.02	0.27	0.12	11	220
2,Blue,15m	RC23	13/03/2007		4	-	4.5	0.06	0.46	<0.05	-	330
2,Blue,15m	RC23	26/04/2007	-	32	-	6.3	-	0.06	2.87	1	125
2,Blue,15m	RC23	24/05/2007	7.12	18	-	9.4	-	-	0.5	<10	125
2,Blue,15m	RC23	20/06/2007	6.52	<10	-	4.4	0.01	<0.05	<0.05	1	120
2,Blue,15m	RC23	01/08/2007	-	-	-	-	-	-	-	-	-
2,Blue,15m	RC23	22/08/2007	-	-	-	-	-	-	-	-	0
2,Blue,15m	RC23	21/09/2007	-	<25	-	-	-	-	-	7	65
2,Blue,15m	RC23	21/11/2007	-	-	-	-	-	-	-	-	NS
2,Blue,15m	RC23	14/05/2008								21	
2,Blue,15m	RC23	24/06/2008	7.08	27	-	21.6	<0.02	<0.05	<0.05	8	
2,Blue,15m	RC23										
2,Blue,15m	RC23										
2,Blue,15m	RC23										
2,Black,15m	RC24	04/07/2006	6.46	<10	-	9.9	0.04	0.04	0.05	31	140
2,Black,15m	RC24	26/07/2006	-	10	-	11.80	0.1	<0.05	0.38	>250	30
2,Black,15m	RC24	16/08/2006	-	34	-	11.9	<0.02	0.01	<0.05	218	165
2,Black,15m	RC24	05/10/2006	-	12	-	13.5	<0.02	0.09	0.09	17	460
2,Black,15m	RC24	03/11/2006	5.90	26	-	7.4	<0.02	0.08	<0.05	18	850
2,Black,15m	RC24	28/01/2006	-	<10	-	8.4	<0.02	0.05	<0.05	46	870
2,Black,15m	RC24	21/02/2007	-	<10	-	2.6	<0.02	0.04	0.08	13	70
2,Black,15m	RC24	13/03/2007		4	-	3.8	<0.02	0.11	0.08	-	400
2,Black,15m	RC24	26/04/2007	-	16	-	7.3	-	0.25	0.1	7	130
2,Black,15m	RC24	24/05/2007	7.16	<10	-	9.6	0.01	0.1	0.17	<10	140
2,Black,15m	RC24	20/06/2007	-	-	-	-	0.01	-	-	-	-
2,Black,15m	RC24	01/08/2007	6.57	36	-	12	<0.02	<0.05	<0.05	<10	360
2,Black,15m	RC24	22/08/2007	-	<10	-	-	0.04	0.05	<0.05	<10	410
2,Black,15m	RC24	21/09/2007	-	<25						6	165
2,Black,15m	RC24	21/11/2007	-	-	-	-	-	-	-	-	NS
2,Black,15m	RC24	14/05/2008								6	
2,Black,15m	RC24	24/06/2008	-	-	-	-	-	-	-	-	
2,Black,15m	RC24										

TCDUser: No suction

TCDUser: No suction - replaced cap

TCDUser: No suction - cap may need replacing

Bacteria (MPN/100ml)		RC1	RC2	RC3	RC4	RC5	RC6	RC7	RC8	RC9	RC10	RC11	RC12
Total Coliforms	04/07/2006	307.6					10.8		913.9				179.3
	26/07/2006	3	2	307.6	146.4		686.7	140.8	2419.6			179.3	2419.6
	16/08/2006	7428	2636.4	2419.6	>2419.6	>2419.6	>2419.6		>2419.6		>2419.6	2419.6	>2419.6
	05/10/2006	2419.6	1935	8164	911	399	495	325.5	259	2359	>2419.6	410.6	1
	03/11/2006	10341	1870	2230	1350	4040	16640	>2419.6	1870	1211	9208	6020	17250
	28/11/2006	1421	98	<1	135	259	706	145	20	<1	2178	>24,196	932
	21/02/2007	1986.3	-	243	-	-	50.1	-	560	-	689.3	4611	1523
	13/03/2007	129.6	111.6	79.4	-	71.7	-	16	66.3	-	86	541.6	-
	26/04/2007	435	-	83.3	-	-	7.1	56.3	54	-	276.8	>2419.6	>24,196
	24/05/2007	420	2064	36.4	-	-	19.5	-	-	-	-	4106	>2419.6
	01/08/2007	48342	25368	2359	>24196	2909	4884	12033	>24196	>24196	>24196	>24196	52
	22/08/2007	198630	68670	241960	-	750	3840	326.5	100	-	-	200	-
	21/09/2007	26724.8	2524	2419.6	-	-	>2419.6	>2419.6	>2419.6	-	>2419.6	>2419.6	>2419.6
	09/10/2007	4500	4350	6830	38730	41060	38730	-	-	-	-	-	>2419.6
	21/11/2007	1872	4840	310	920.8	-	648.8	>2419.6	238.2	-	-	-	-
	14/05/2008	30760	6830	1415	-	-	-	-	-	-	-	-	-
	24/06/2008	-	81640	51720	-	61310	-	38730	15530	-	>241960	-	98040
E.Coll	04/07/2006	1					<1		<1				<1
	26/07/2006	<1	<1	1	<1		<1	<1	<1			<1	<1
	16/08/2006	5.2	7.4	1	1	3.1	<1		<1		58.3	1	18.5
	05/10/2006	10	7.1	3	6	<1	<1	10	1	<1	6.3	2	<1
	03/11/2006	2	4	1	5	2	7.5	11	<1	<1	4.1	1	2
	28/11/2006	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
	21/02/2007	<1	-	<1	-	-	<1	-	<1	-	<1	<1	<1
	13/03/2007	<1	<1	<1	-	<1	-	<1	<1	-	<1	<1	-
	26/04/2007	<1	-	<1	-	-	<1	<1	<1	-	2	9.7	1
	24/05/2007	<10	<10	<1			<1		-	-	-	<10	<1
	01/08/2007	1624	31	<10	183	20	<10	41	197	231	41	20	<10
	22/08/2007	<100	100	259.9	-	<1	100	<1	<1	-	-	<1	-
	21/09/2007	6.3	20.3	19.9	-	-	214.2	770.1	1413.6	-	1046.2	1986.3	1986.3
	09/10/2007	5.2	4.1	19.5	4.1	3.1	2	-	-	-	-	-	125.9
	21/11/2007	<10	<10	<10	1	-	1	<1	<1	-	-	-	-
	14/05/2008	<10	<10	<10	-	-	-	-	-	-	-	-	-
	24/06/2008	-	<100	8.2	-	4	-	<100	2	-	10	-	100

Bacteria (MPN/100ml)		RC13	RC14	RC15	RC16	RC17	RC18	RC19	RC20	RC21	RC22	RC23	RC24
Total Coliforms	04/07/2006	24.9		2419.6		14.8	<1				<1		
	26/07/2006	478.6	140.8	261.3		135.5	1986.3	186		261.3		1299.7	
	16/08/2006	4824		2419.6	>2419.6	>2419.6	>2419.6	261.3	>2419.6	579.4	1011.2	>2419.6	>2419.6
	05/10/2006	3228.2	905	959	1553.1	410.6	>2419.6	727	461.1		648.8	461.1	1100
	03/11/2006	2851	34480	738	4100	7330	2310	657	>2419.6	3450	15760	3654	3282
	28/11/2006	1223	605	1379	1224	617	2481	462	1022	650	1112	1236	1515
	21/02/2007	293	345	934	127.4	30	172.2	-	41	307.6	798	201	-
	13/03/2007	72.7	143.9	-	344.8	>2419.6	-	>2419.6	1732.9	-	-	980.4	-
	26/04/2007	67.7	52	10.7	193.5	-	59.6	-	132	135	-	151.5	259
	24/05/2007	441	75	19.7	97	301	152.3	426	>2419.6	97	-	74.4	3.1
	01/08/2007	148	108	24196	933	203	1086	>24196	1793	2143	1266	-	6867
	22/08/2007	1460	9208	-	-	61310	648.8	-	22240	1046.2	6020	-	435.2
	21/09/2007	3950	235.9	111.2	691	>2419.6	>2419.6	-	-	-	>2419.6	-	>2419.6
	09/10/2007	2419.6	1732.9	461.1	48840	64880	61310	-	-	-	-	-	-
	21/11/2007	563.2	2541.5	310	934	>2419.6	1413.6	>2419.6	248.1	2247	-	-	-
	14/05/2008	3960	2130	2419.6	-	-	-	-	-	-	-	-	-
	24/06/2008	86640	48110	241960	-	-	-	5630	17230	>9678.4	-	>241960	-
E.Coll	04/07/2006	<1		<1		<1	<1				<1		
	26/07/2006	<1	<1	<1		<1	<1	<1		<1		<1	
	16/08/2006	<1		<1	1	1	2	2	<1	8.5	13.4	<1	14.6
	05/10/2006	<1	<1	<1	<1	<1	2	<1	<1		<1	<1	<1
	03/11/2006	2	2	6	5	5	2	5.1	1	2	29	17	6.1
	28/11/2006	10	<10	31	<10	<10	<10	10	<10	<10	<10	10	<10
	21/02/2007	<1	<1	<1	<1	1	<1	-	<1	<1	<1	<1	-
	13/03/2007	<1	<1	-	<1	<1	<1	<1	<1	-	-	<1	-
	26/04/2007	<1	<10	<1	1	-	2	-	<1	<1	-	<1	<1
	24/05/2007	<1	<10	<1	<1	<10	<1	<10	<10	<10	-	<1	<1
	01/08/2007	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	<10
	22/08/2007	<1	4.1	-	-	2	<1	-	<1	1	11.6	-	<1
	21/09/2007	4.1	<1	<1	49.6	90.8	48	-	-	-	816.4	-	13.4
	09/10/2007	2	1	<1	<1	3	<1	-	-	-	-	-	-
	21/11/2007	1	<10	<1	<10	<1	<1	2	<1	<10	-	-	-
	14/05/2008	<10	<10	<10	-	-	-	-	-	-	-	-	-
	24/06/2008	<100	8	4	-	-	-	<100	<4	<4	-	10	-

Groundwater Monitoring Points

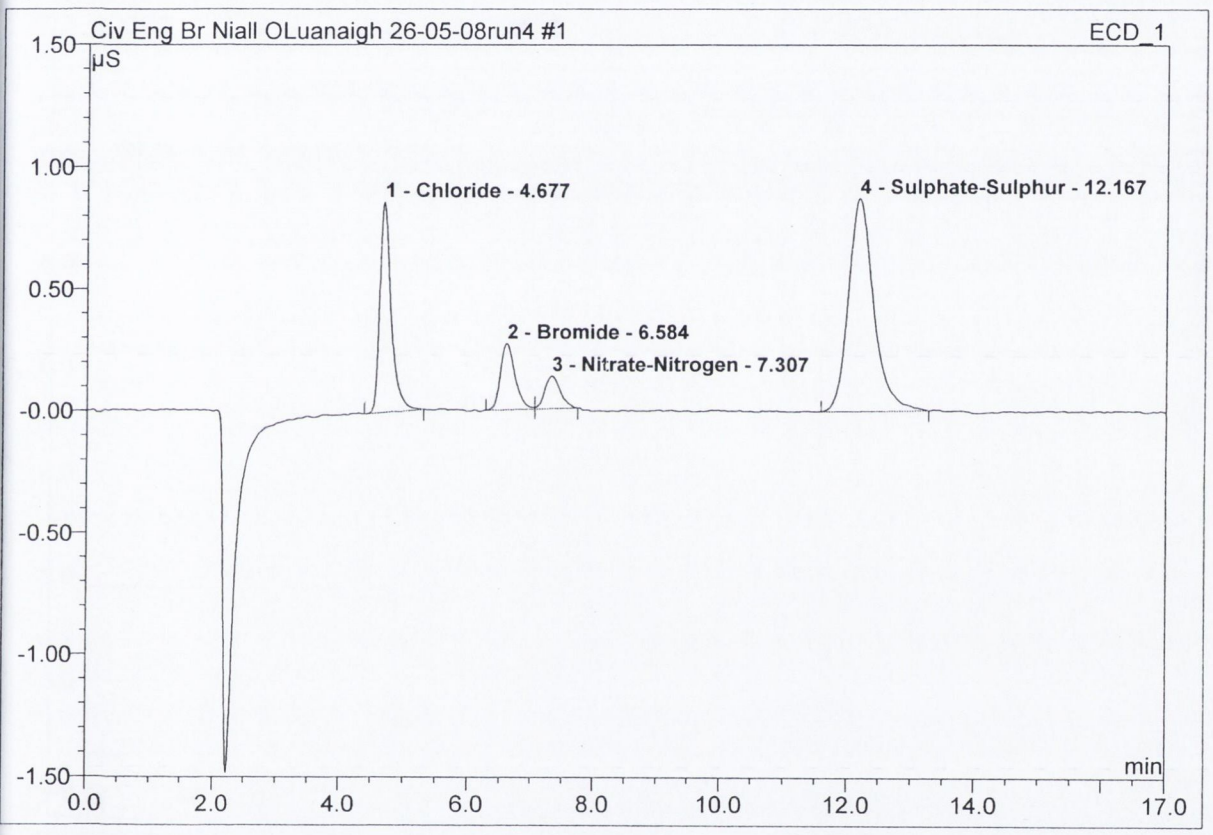
Date	pH	COD	TN	NO_3-N	NO_2-N	NH_4-N	Ortho-P	Cl	SS
03/11/2006	6.58	<25	-	8.2	0.01	0.06	<0.05	40	444
28/11/2006		<10		15.4	0.27	0.05	<0.05	47	
13/03/2007		<10	-	11.8	0.1	0.26	0.25	19	
19/01/2008	-	52	-	13.3	0.15	<0.05	0.03	15	

Appendix E

BROMIDE TRACER STUDY RESULTS

1 Standard1

Sample Name:	**Standard1**	*Injection Volume:*	**20.0**
Vial Number:	**1**	*Channel:*	**ECD_1**
Sample Type:	**standard**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 12:38**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

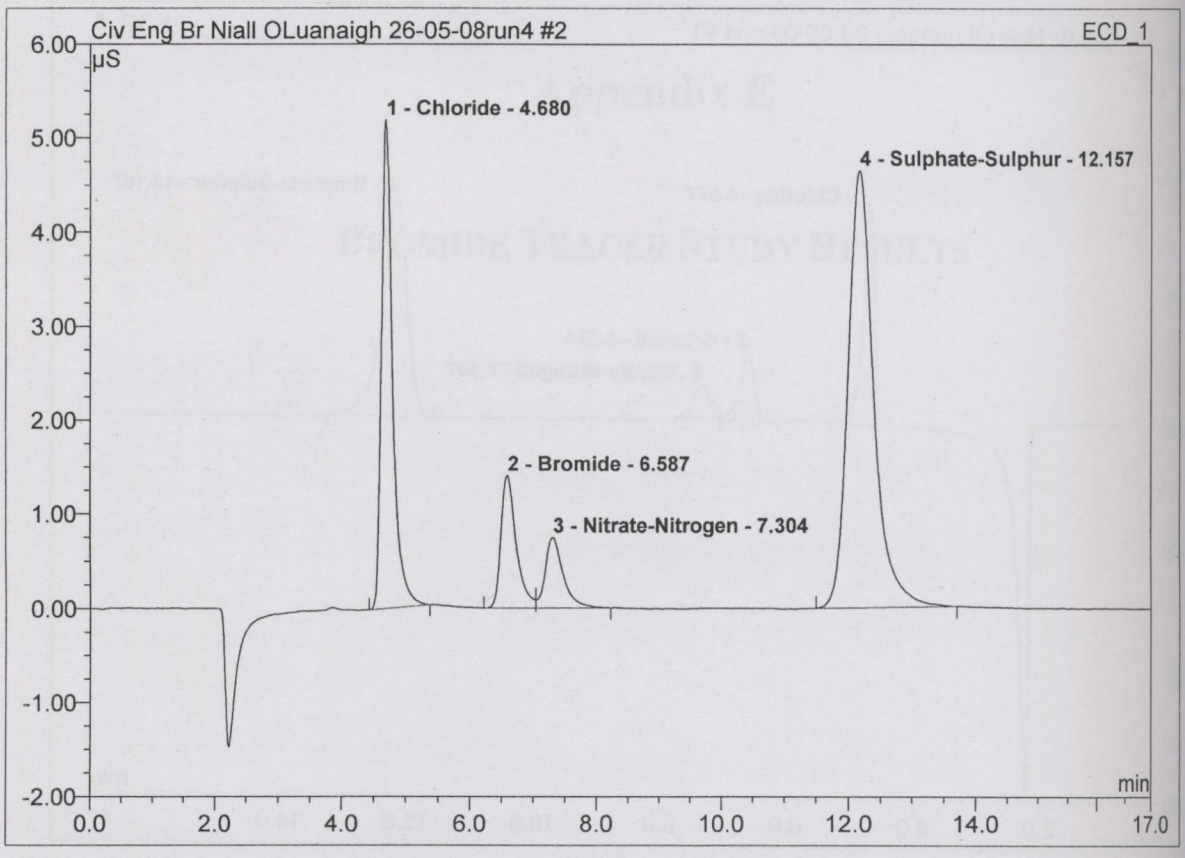


No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	0.864	0.177	25.56	n.a.	BMB
2	6.58	Bromide	0.273	0.074	10.64	n.a.	BM
3	7.31	Nitrate-Nitrogen	0.134	0.039	5.60	n.a.	MB
4	12.17	Sulphate-Sulphur	0.873	0.404	58.20	n.a.	BMB
Total:			2.144	0.694	100.00	0.000	

Chromeleon (c) Dionex 1996-2001
Version 6.60 Build 1428

2 Standard2

Sample Name:	**Standard2**	*Injection Volume:*	**20.0**
Vial Number:	**2**	*Channel:*	**ECD_1**
Sample Type:	**standard**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 12:58**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

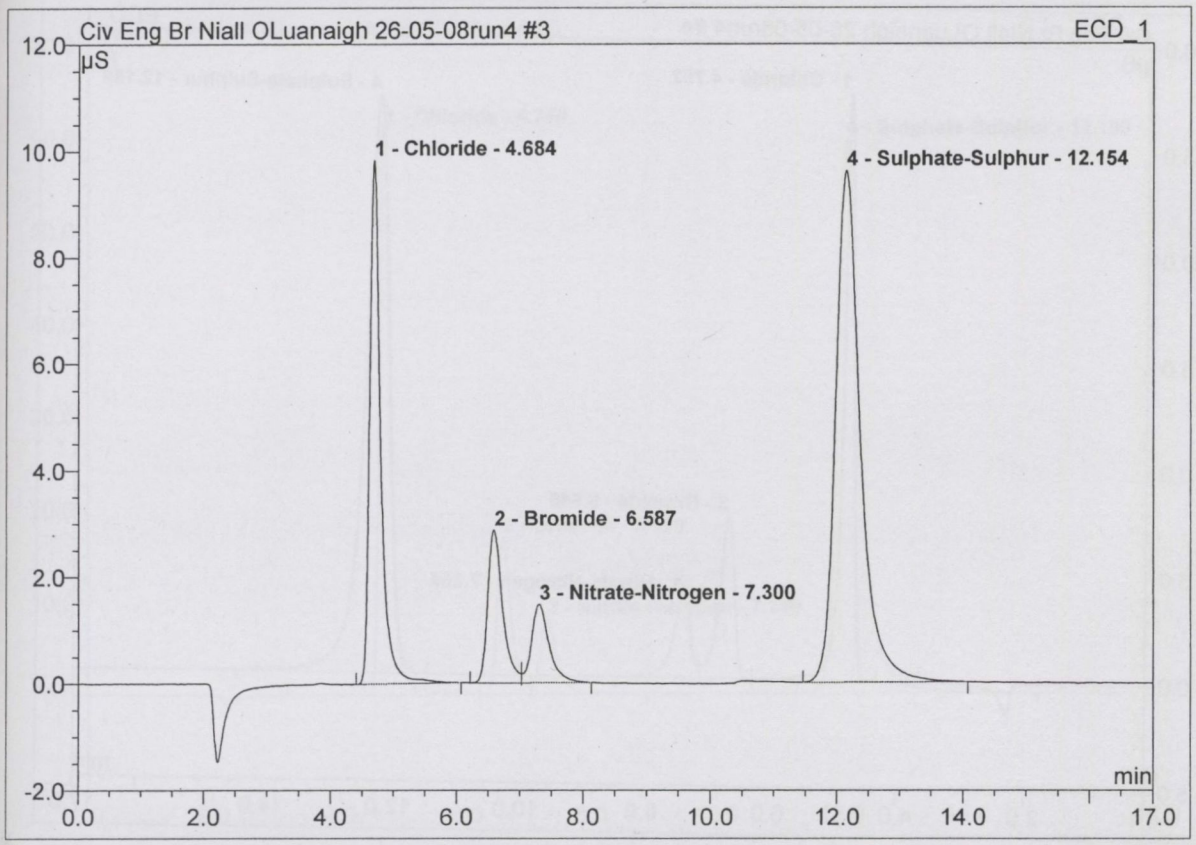


No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	5.189	1.048	27.37	5.000	BMB
2	6.59	Bromide	1.404	0.392	10.24	5.000	BM
3	7.30	Nitrate-Nitrogen	0.746	0.244	6.37	0.500	MB
4	12.16	Sulphate-Sulphur	4.643	2.145	56.02	5.000	BMB
Total:			11.981	3.829	100.00	15.500	

Chromeleon (c) Dionex 1996-2001
Version 6.60 Build 1428

3 Standard3

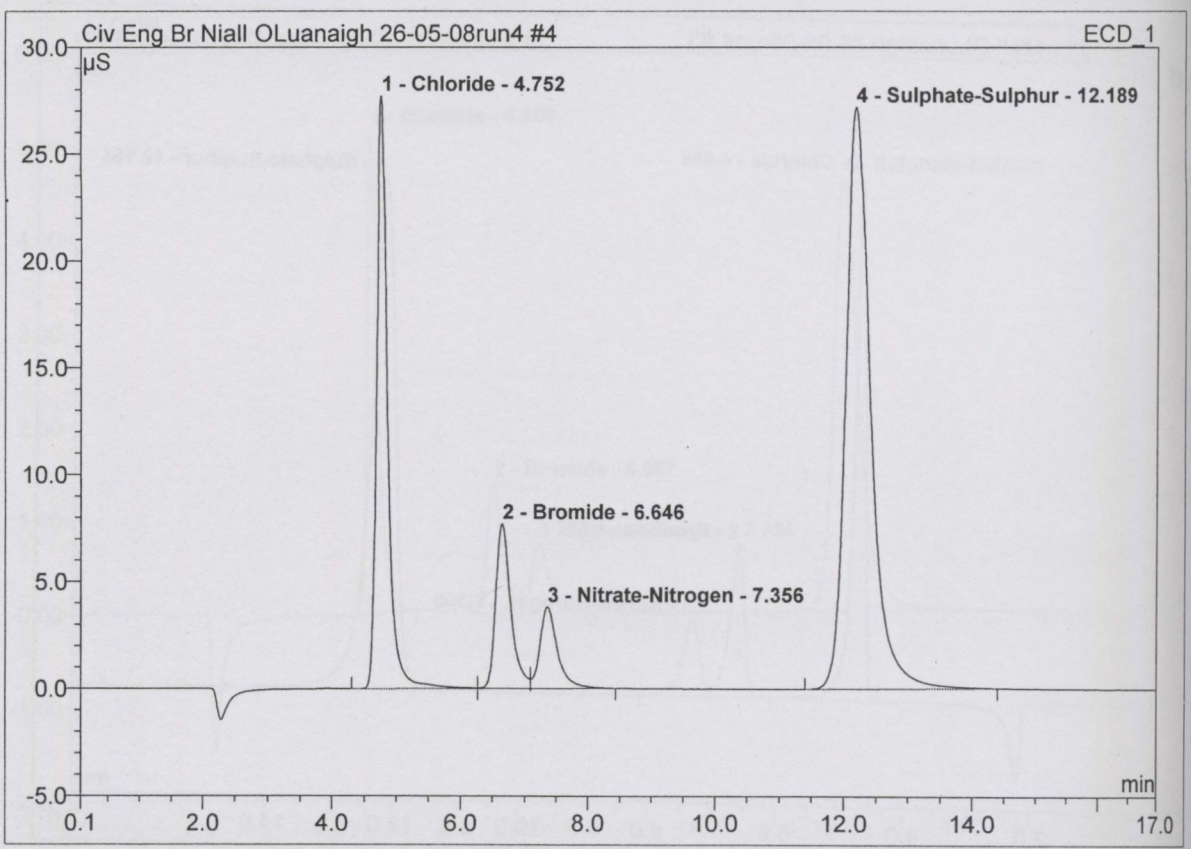
Sample Name:	**Standard3**	*Injection Volume:*	**20.0**
Vial Number:	**3**	*Channel:*	**ECD_1**
Sample Type:	**standard**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 13:17**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	9.839	2.005	26.16	9.983	BMB
2	6.59	Bromide	2.861	0.789	10.30	9.999	BM
3	7.30	Nitrate-Nitrogen	1.470	0.475	6.20	0.999	MB
4	12.15	Sulphate-Sulphur	9.609	4.393	57.34	9.998	BMB
Total:			23.779	7.662	100.00	30.980	

4 Standard4

Sample Name:	**Standard4**	*Injection Volume:*	**20.0**
Vial Number:	**4**	*Channel:*	**ECD_1**
Sample Type:	**standard**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 13:37**	*Sample Weight:*	**1.0000**
Run Time (min):	**16.94**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.75	Chloride	27.715	5.486	26.18	25.016	BM
2	6.65	Bromide	7.699	2.097	10.01	25.001	M
3	7.36	Nitrate-Nitrogen	3.827	1.246	5.94	2.500	MB
4	12.19	Sulphate-Sulphur	27.170	12.129	57.87	25.001	BMB
Total:			66.410	20.958	100.00	77.519	

Chromeleon (c) Dionex 1996-200
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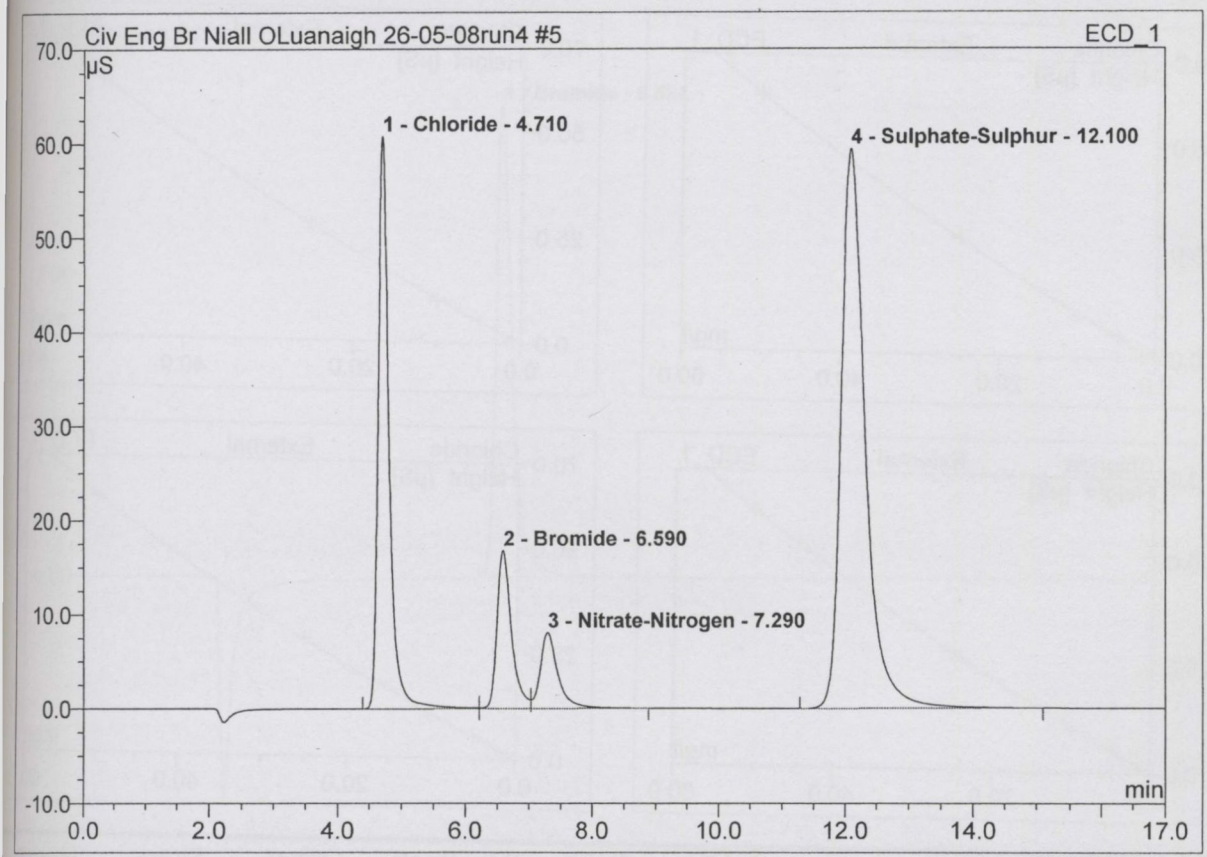
5 Standard5

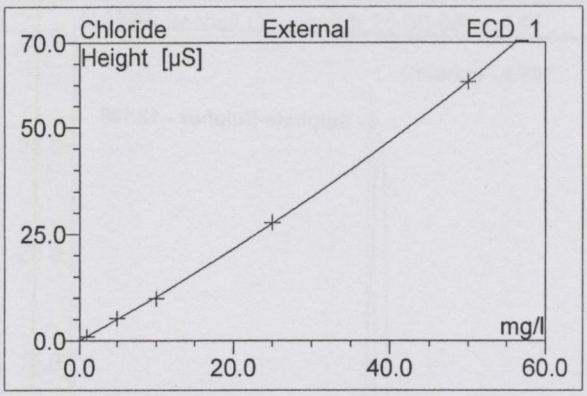
Sample Name:	**Standard5**	*Injection Volume:*	**20.0**
Vial Number:	**5**	*Channel:*	**ECD_1**
Sample Type:	**standard**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 13:56**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

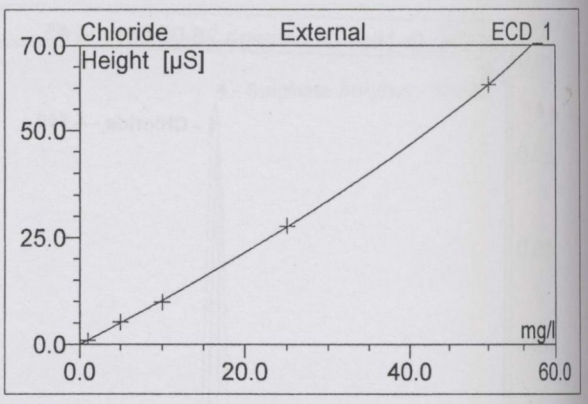


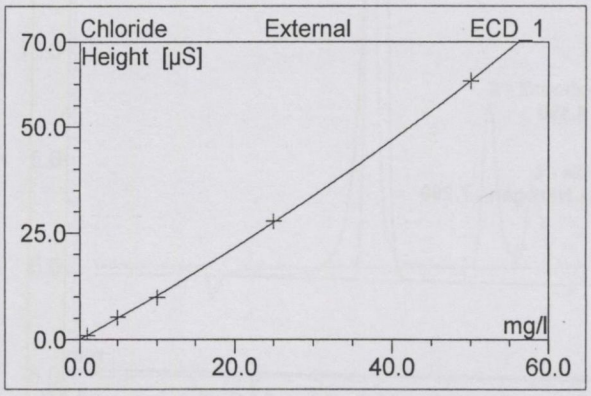
No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.71	Chloride	60.784	12.009	26.36	49.970	BM
2	6.59	Bromide	16.802	4.445	9.76	49.987	M
3	7.29	Nitrate-Nitrogen	8.071	2.619	5.75	5.000	MB
4	12.10	Sulphate-Sulphur	59.361	26.480	58.13	49.950	BMB
Total:			145.019	45.552	100.00	154.907	

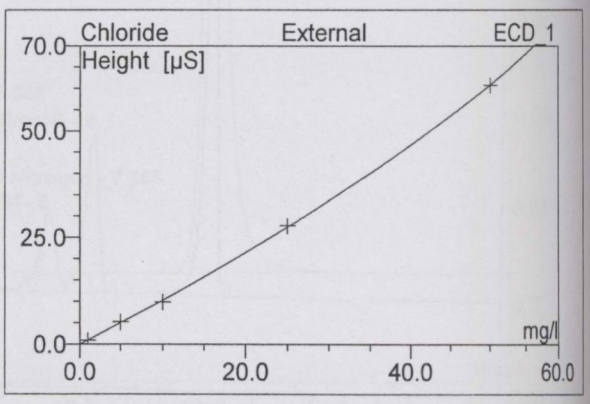
5 Standard5

Sample Name:	**Standard5**	*Injection Volume:*	**20.0**
Vial Number:	**5**	*Channel:*	**ECD_1**
Sample Type:	**standard**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 13:56**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**





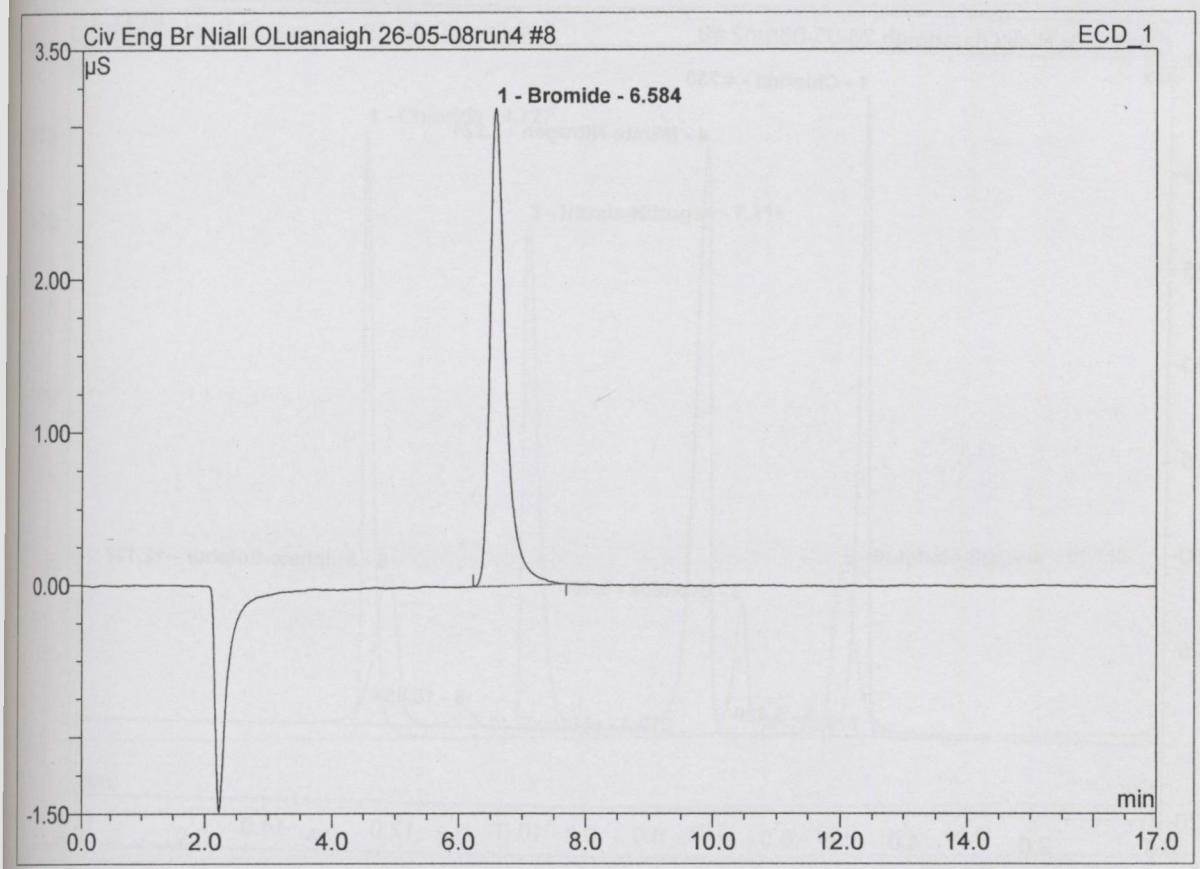




No.	Ret.Time min	Peak Name	Cal.Type	Points	Corr.Coeff. %	Offset	Slope	Curve
1	4.71	Chloride	Quad	5	99.8865	0.0000	0.9816	0.0047
2	6.59	Bromide	Quad	5	99.9076	0.0000	0.2777	0.0012
3	7.29	Nitrate-Nitrogen	Quad	5	99.9652	0.0000	1.4458	0.0337
4	12.10	Sulphate-Sulphur	Quad	5	99.8984	0.0000	0.9558	0.0047
Average:					99.9144	0.0000	0.9152	0.0111

8 QC Br

Sample Name:	**QC Br**	*Injection Volume:*	**20.0**
Vial Number:	**22**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 14:54**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	6.58	Bromide	3.127	0.891	100.00	10.772	BMB
Total:			3.127	0.891	100.00	10.772	

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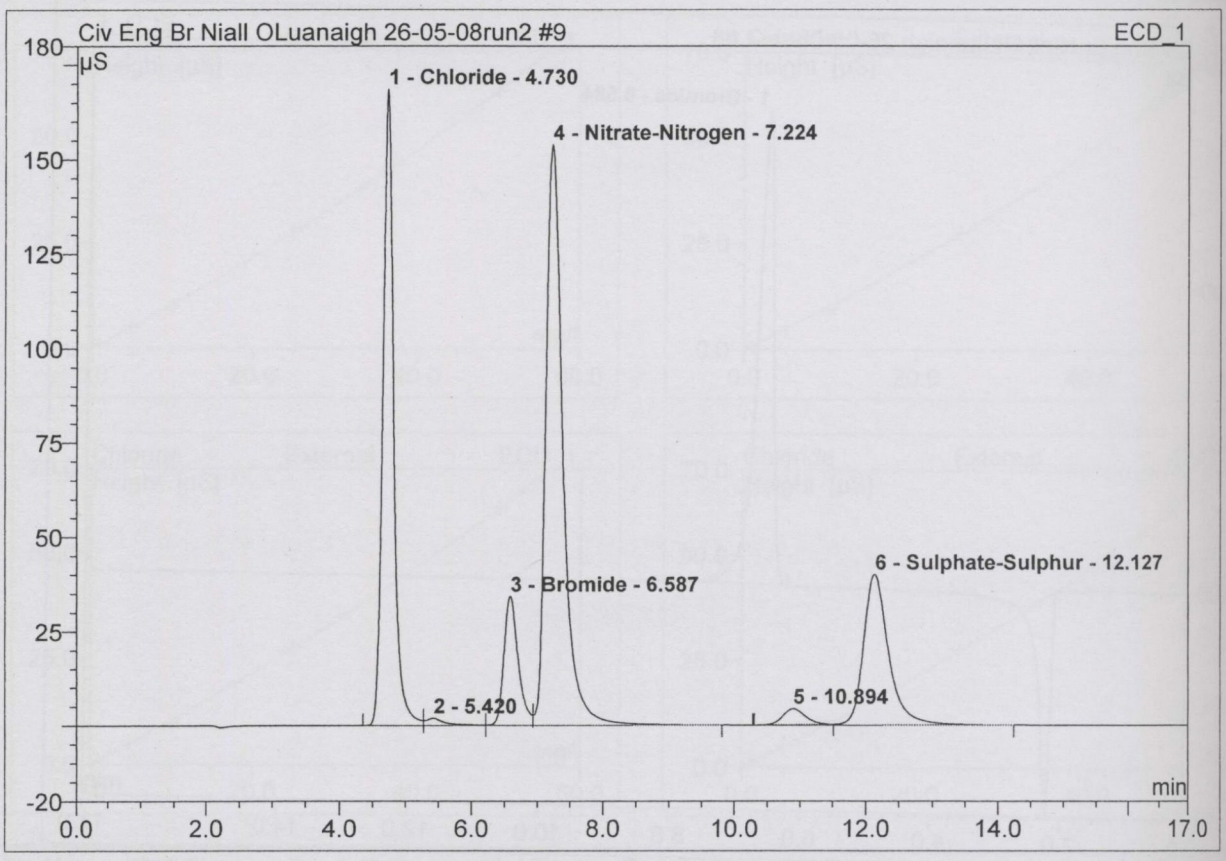
9 L1 (D1)

Sample Name:	**L1 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**8**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**28/5/2008 19:51**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	168.537	32.047	29.85	111.820	BM
2	5.42	n.a.	1.916	0.633	0.59	n.a.	M
3	6.59	Bromide	34.255	8.633	8.04	90.111	M
4	7.22	Nitrate-Nitrogen	153.846	46.531	43.34	50.561	MB
5	10.89	n.a.	4.239	1.696	1.58	n.a.	Ru
6	12.13	Sulphate-Sulphur	39.956	17.828	16.60	35.756	BMB
Total:			402.749	107.367	100.00	288.247	

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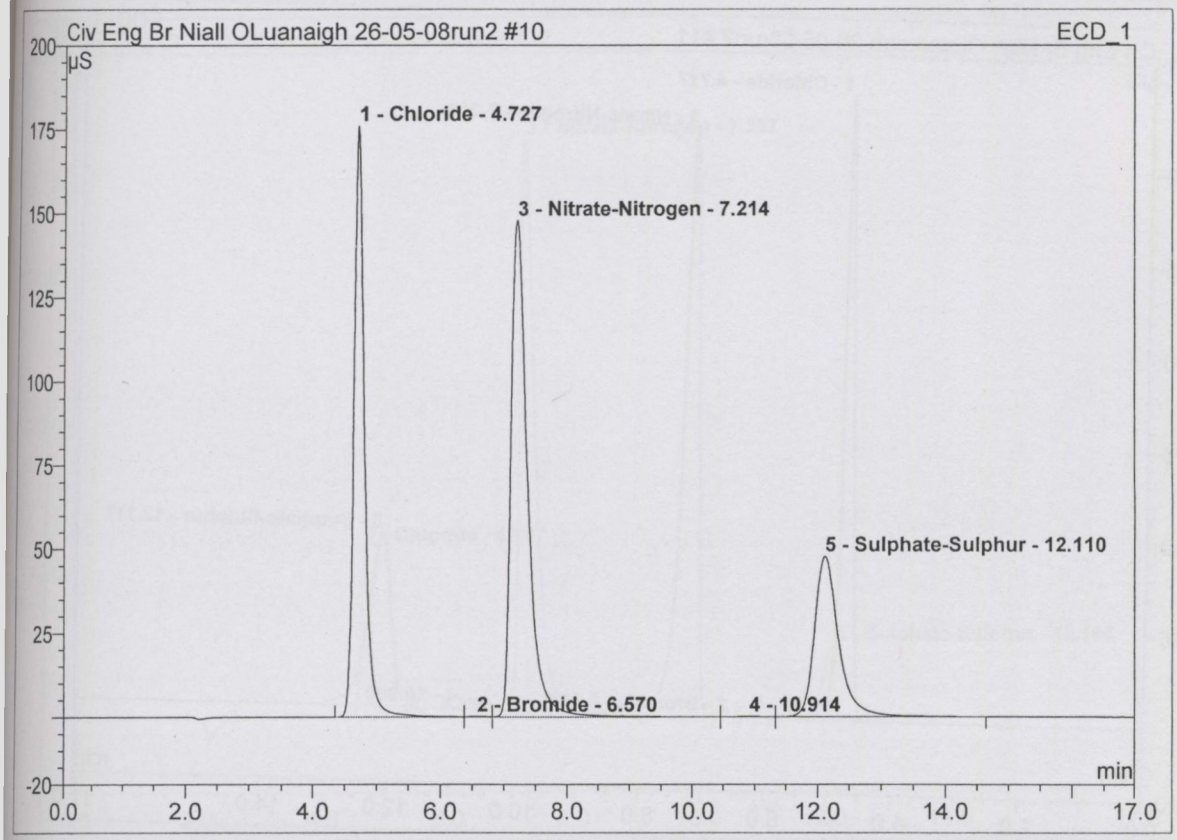
10 L2 (D1)

Sample Name:	**L2 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**9**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000 /100**
Recording Time:	**28/5/2008 20:10**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	176.027	33.529	33.72	115.469	BM
2	6.57	Bromide	0.185	0.060	0.06	0.660	M
3	7.21	Nitrate-Nitrogen	147.869	44.597	44.85	49.261	M
4	10.91	n.a.	0.125	0.053	0.05	n.a.	M
5	12.11	Sulphate-Sulphur	47.801	21.201	21.32	41.733	MB
Total:			372.006	99.439	100.00	207.122	

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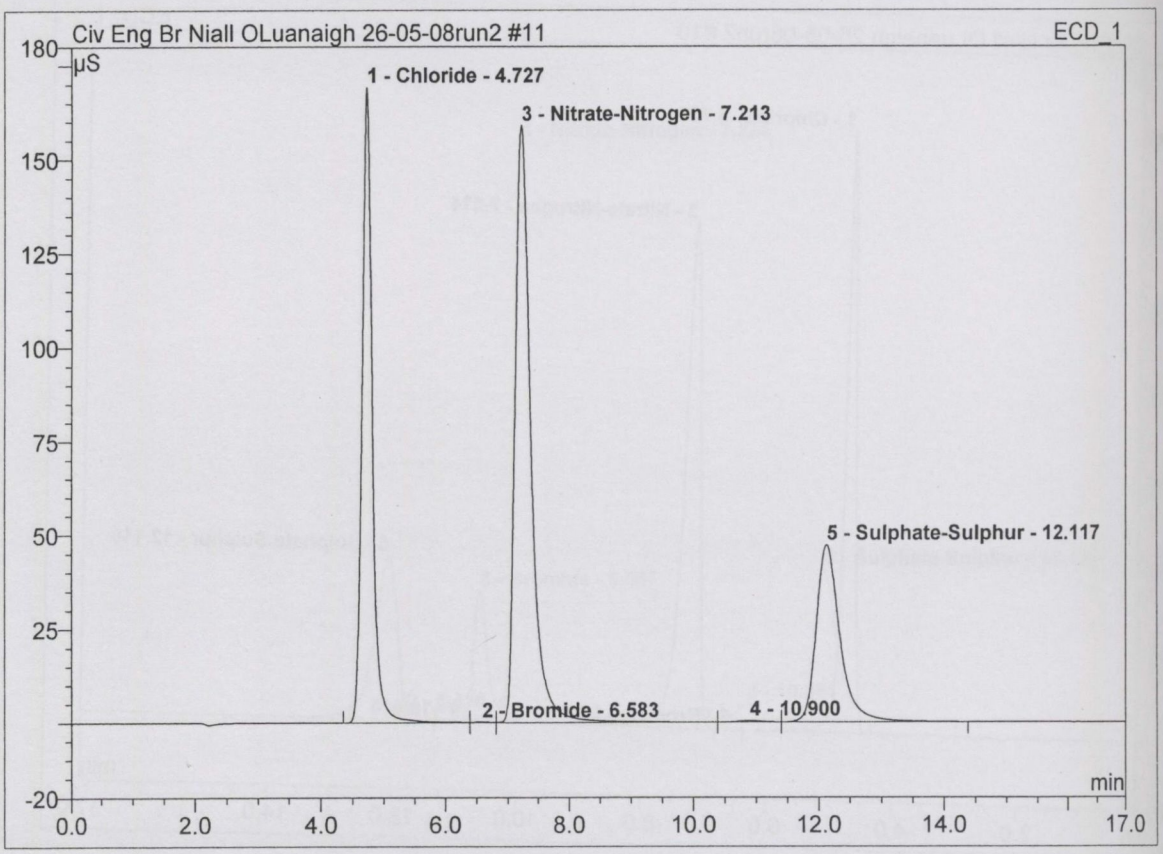
11 L3 (D1)

Sample Name:	**L3 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**9**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**28/5/2008 20:29**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	169.133	32.247	31.86	112.113	BM
2	6.58	Bromide	0.125	0.040	0.04	0.445	M
3	7.21	Nitrate-Nitrogen	158.911	47.948	47.37	51.646	M
4	10.90	n.a.	0.386	0.162	0.16	n.a.	M
5	12.12	Sulphate-Sulphur	47.034	20.827	20.57	41.160	MB
Total:			375.588	101.224	100.00	205.363	

(1/100)

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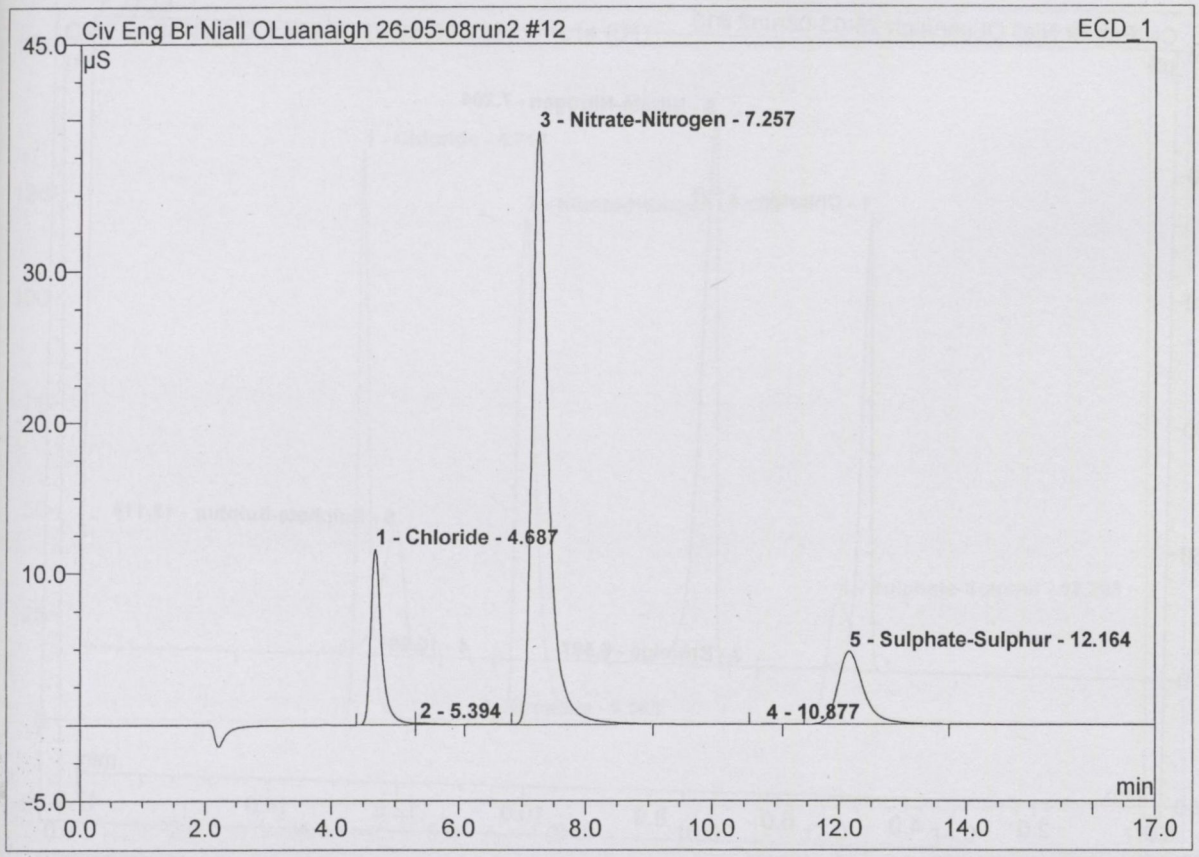
12 L6 (D1)

Sample Name:	**L6 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**11**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**28/5/2008 20:49**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	11.590	2.314	14.31	11.226	BM
2	5.39	n.a.	0.103	0.035	0.21	n.a.	MB
3	7.26	Nitrate-Nitrogen	39.142	11.601	71.74	19.087	BMB
4	10.88	n.a.	0.020	0.005	0.03	n.a.	BMB
5	12.16	Sulphate-Sulphur	4.817	2.217	13.71	4.948	BMB
Total:			55.672	16.172	100.00	35.261	

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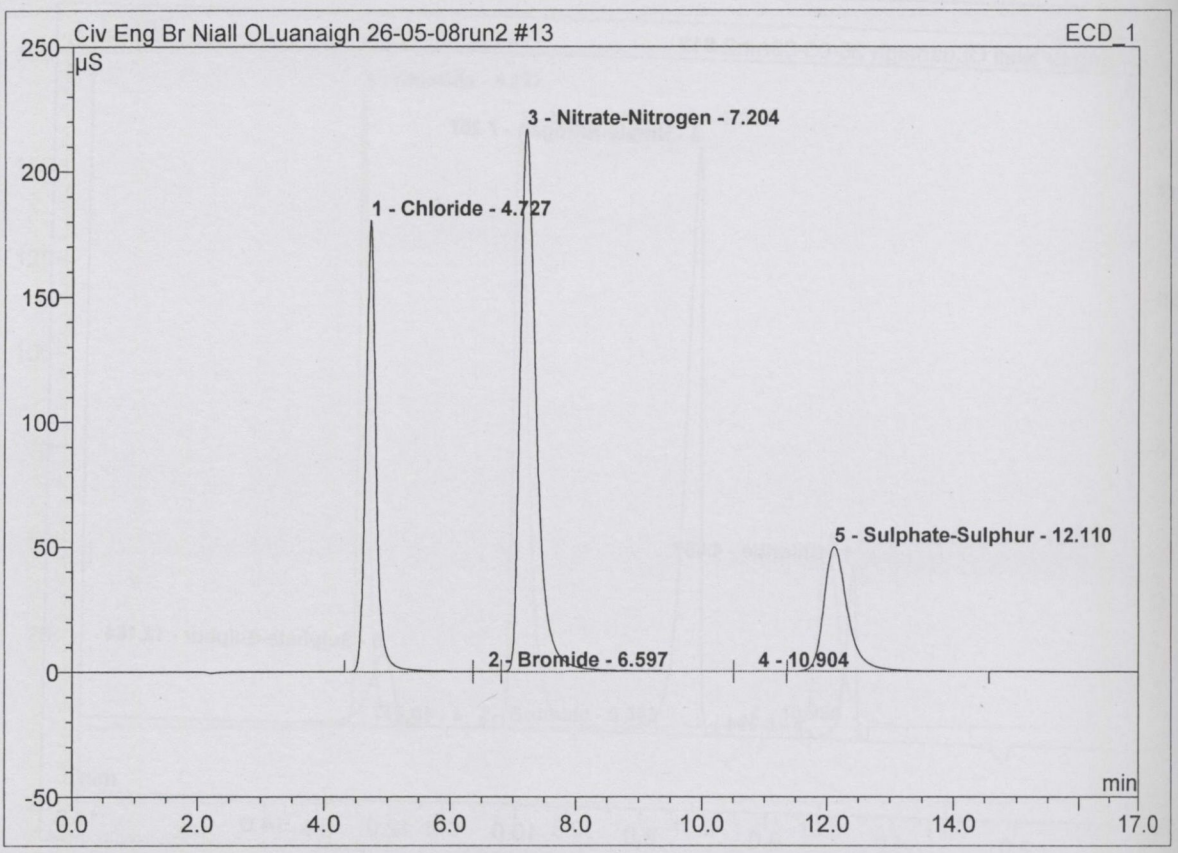
13 L13 (D1)

Sample Name:	**L13 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**11**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**28/5/2008 21:08**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

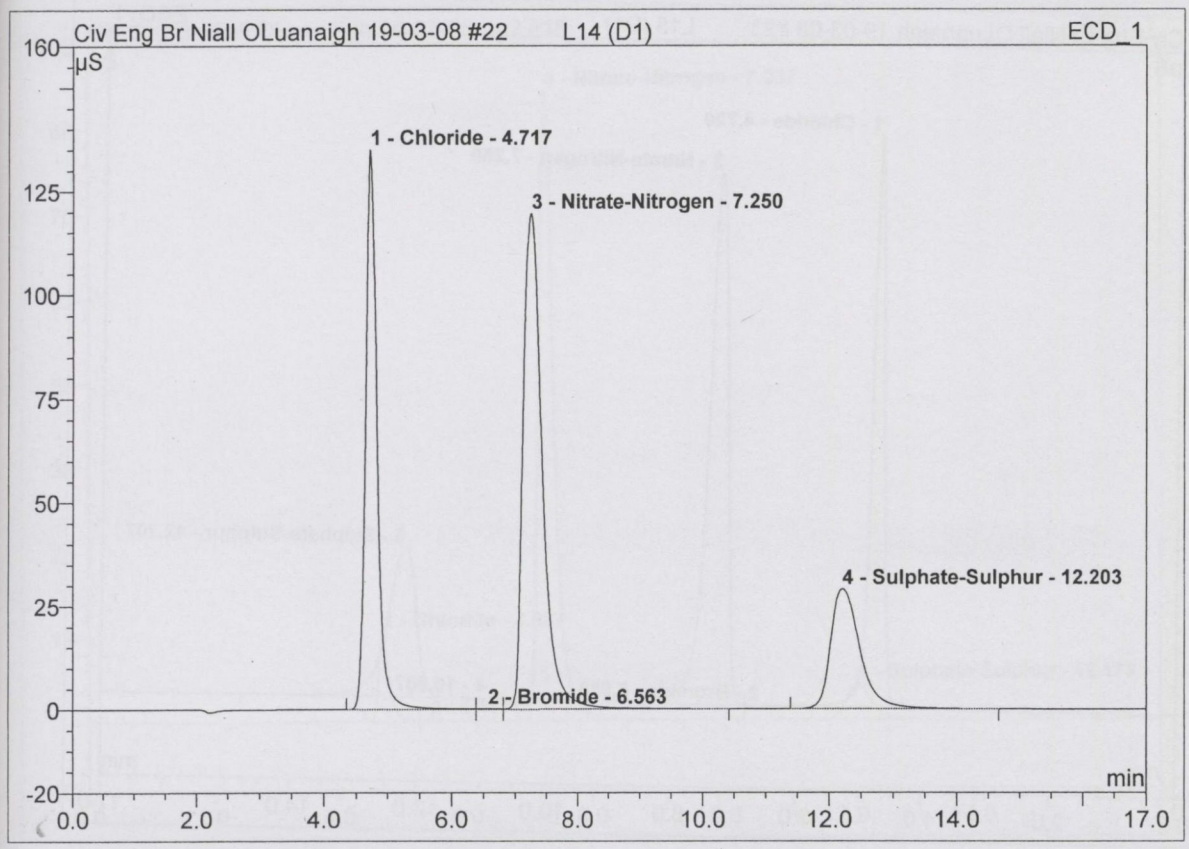


No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	180.354	34.679	28.30	117.551	BM
2	6.60	Bromide	0.137	0.048	0.04	0.488	M
3	7.20	Nitrate-Nitrogen	216.720	65.651	53.58	63.060	M
4	10.90	n.a.	0.064	0.032	0.03	n.a.	MB
5	12.11	Sulphate-Sulphur	49.805	22.114	18.05	43.220	BMB
Total:			447.080	122.524	100.00	224.319	

(1/100)

22 L14 (D1)

Sample Name:	**L14 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**19**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**19/3/2008 18:38**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

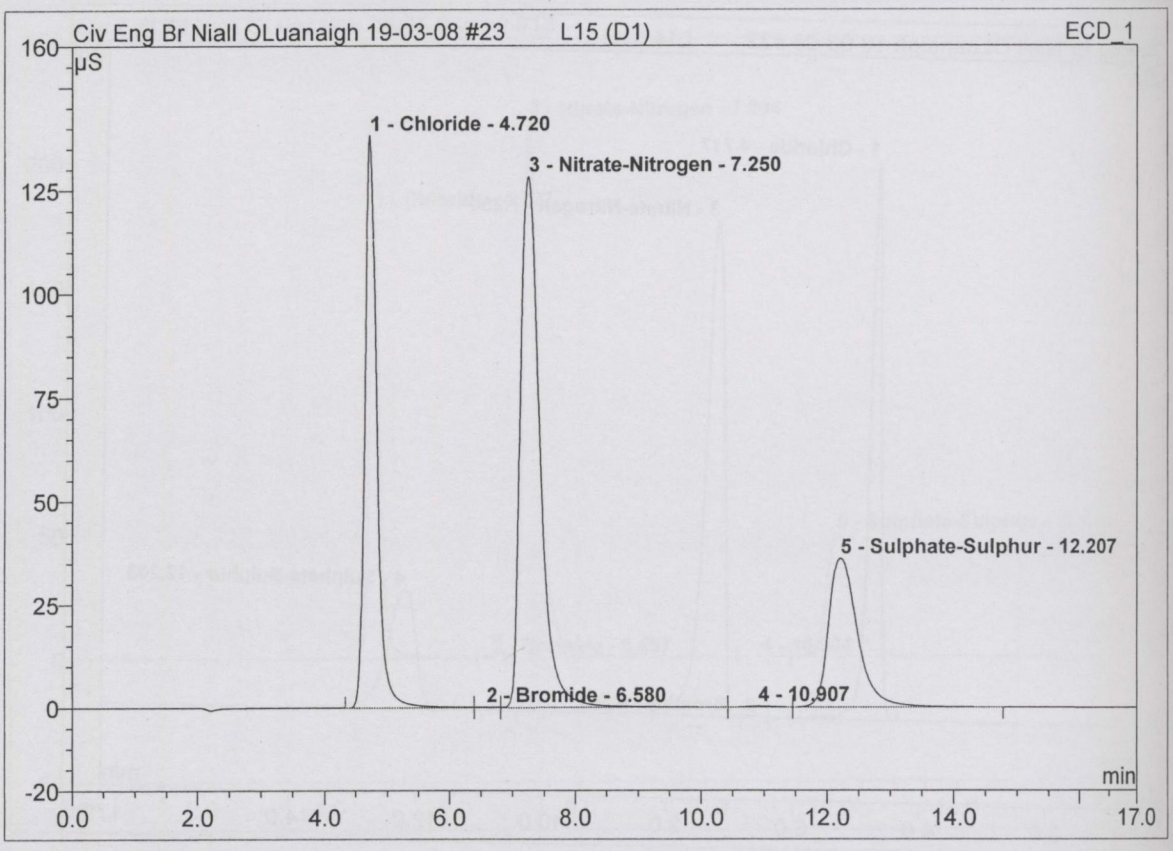


No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.72	Chloride	134.932	28.827	33.28	103.149	BM
2	6.56	Bromide	0.159	0.055	0.06	0.678	M
3	7.25	Nitrate-Nitrogen	119.541	42.293	48.83	48.558	MB
4	12.20	Sulphate-Sulphur	28.975	15.440	17.83	32.629	BMB
Total:			283.606	86.616	100.00	185.013	

(1/100)

23 L15 (D1)

Sample Name:	**L15 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**20**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**19/3/2008 18:57**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.72	Chloride	138.245	30.235	31.82	104.961	BM
2	6.58	Bromide	0.149	0.052	0.06	0.635	M
3	7.25	Nitrate-Nitrogen	128.169	45.413	47.79	50.837	MB
4	10.91	n.a.	0.266	0.120	0.13	n.a.	bM
5	12.21	Sulphate-Sulphur	35.974	19.212	20.22	39.408	MB
Total:			302.803	95.031	100.00	195.841	

(1/100)

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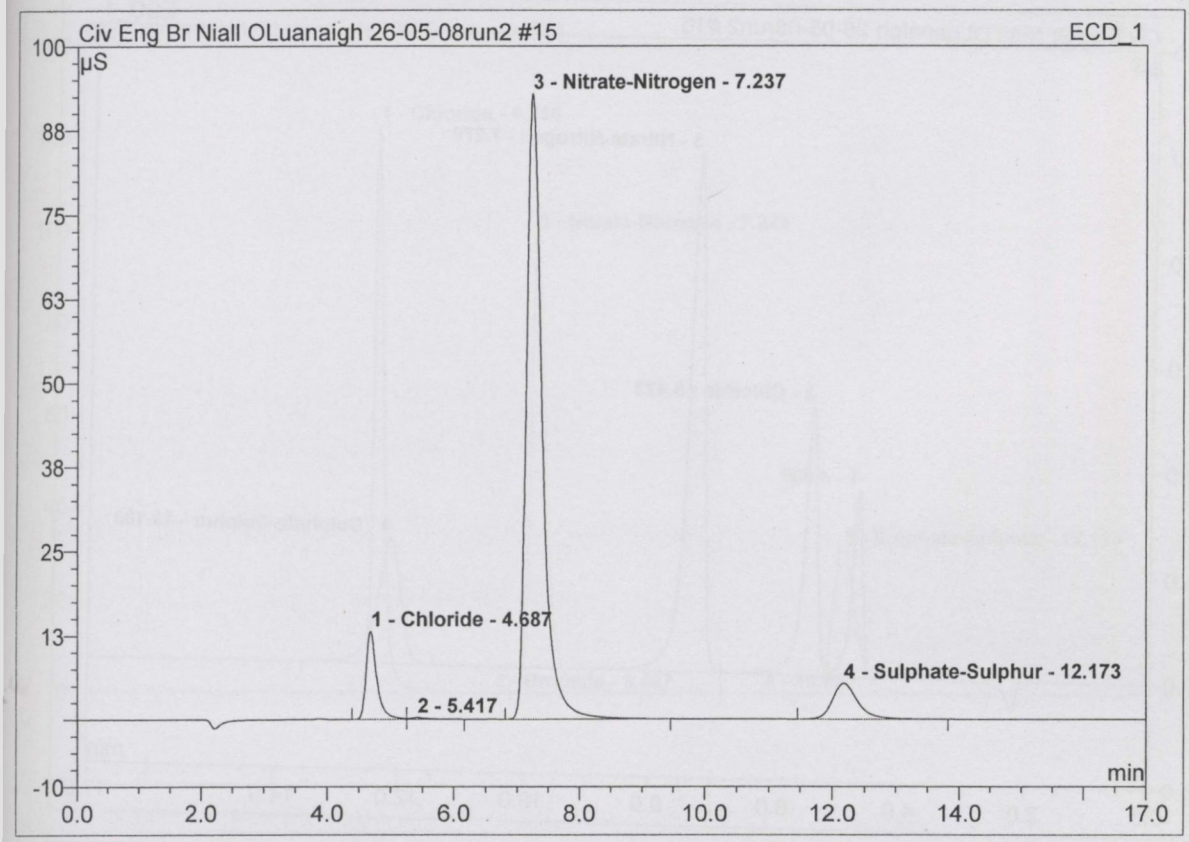
15 L16 (D1)

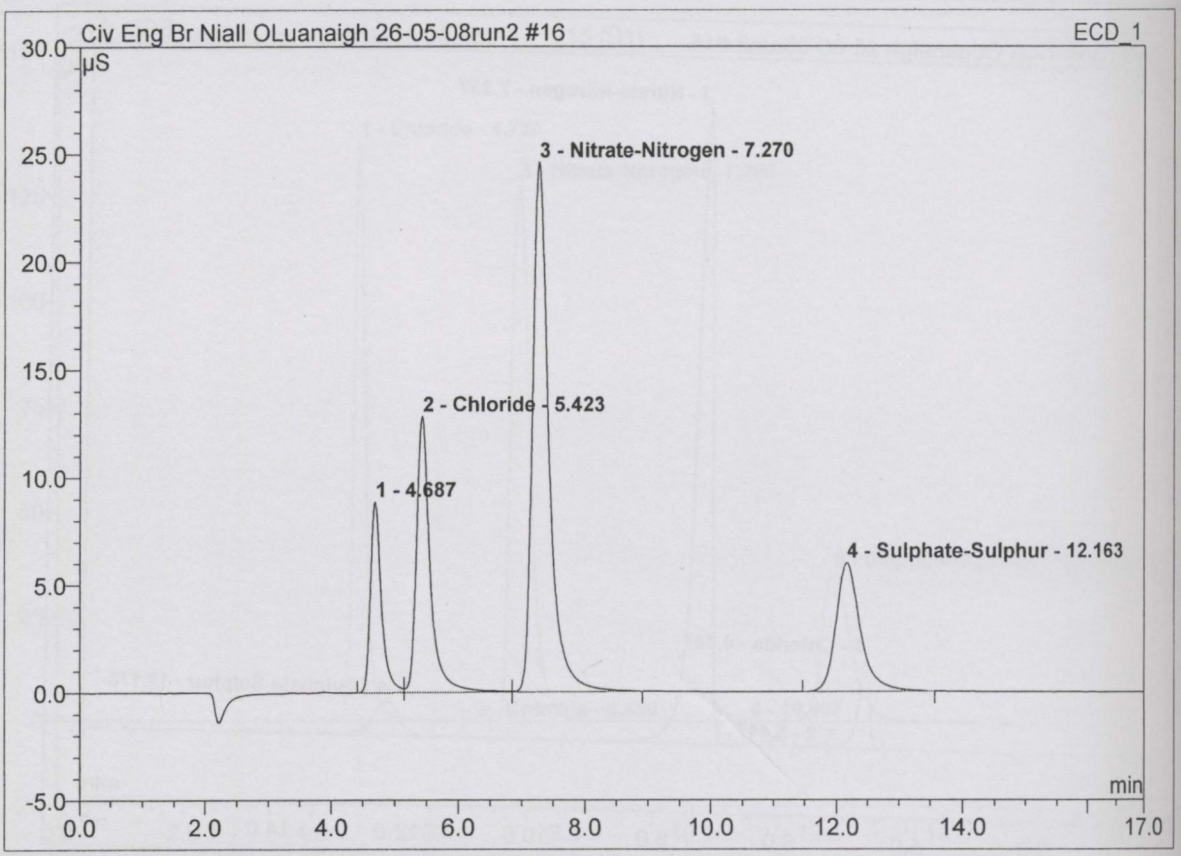
Sample Name:	**L16 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**13**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**28/5/2008 21:47**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	13.123	2.620	8.00	12.631	BM
2	5.42	n.a.	0.279	0.092	0.28	n.a.	MB
3	7.24	Nitrate-Nitrogen	92.921	27.559	84.18	35.974	BMB
4	12.17	Sulphate-Sulphur	5.361	2.468	7.54	5.493	BMB
Total:			111.684	32.739	100.00	54.097	

16 L18 (D1)

Sample Name:	**L18 (D1)**	*Injection Volume:*	**20.0**
Vial Number:	**14**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**28/5/2008 22:06**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	n.a.	8.873	1.777	11.73	n.a.	BM
2	5.42	Chloride	12.828	3.230	21.32	12.361	M
3	7.27	Nitrate-Nitrogen	24.574	7.408	48.89	13.180	MB
4	12.16	Sulphate-Sulphur	5.985	2.737	18.06	6.114	BMB
Total:			52.260	15.153	100.00	31.655	

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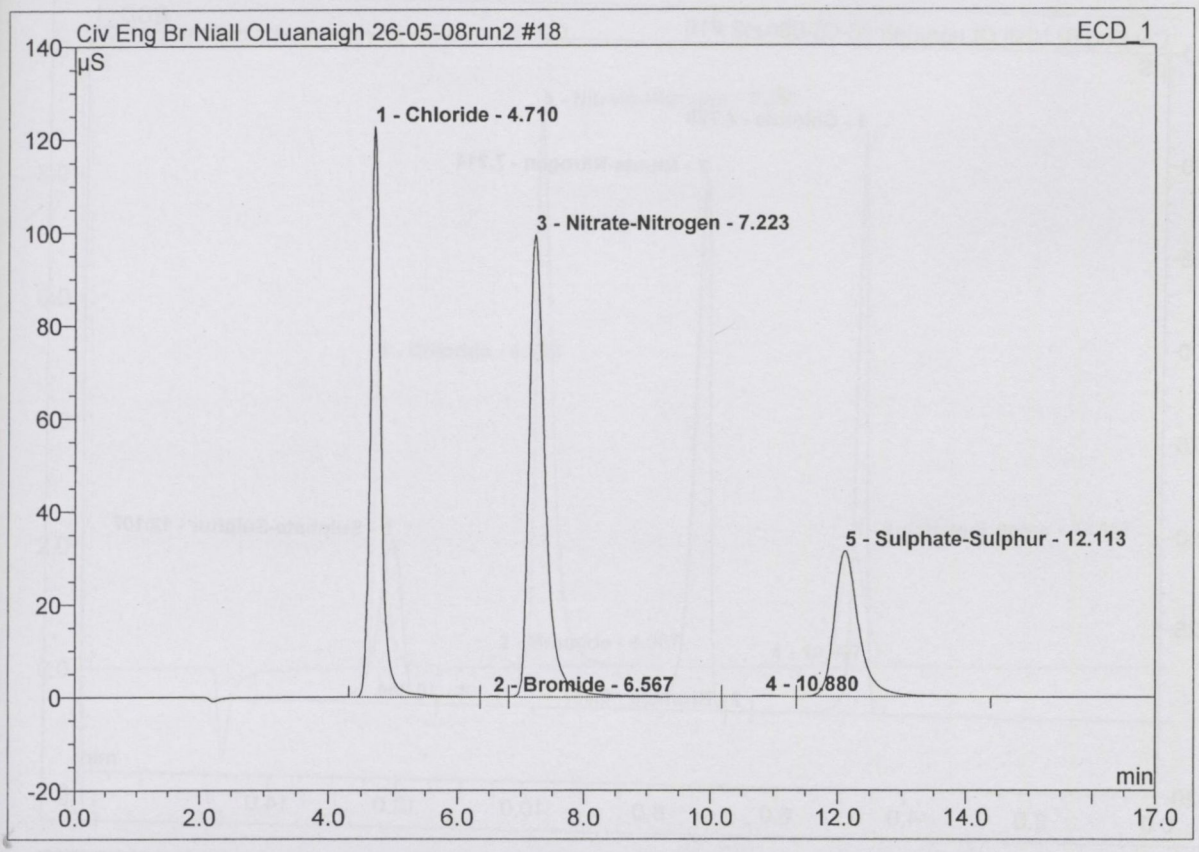
18 L2 (D2)

Sample Name:	**L2 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**16**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000 /100**
Recording Time:	**28/5/2008 22:45**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

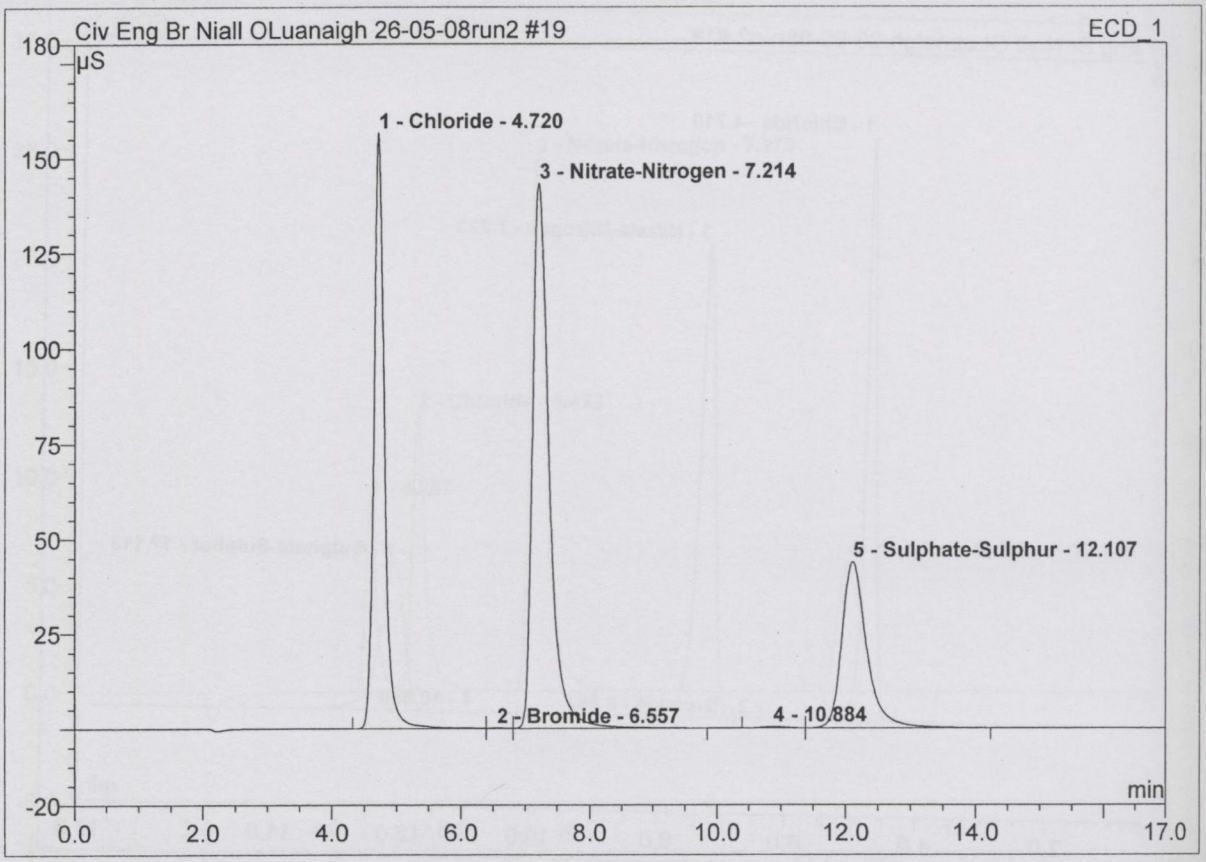


No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.71	Chloride	122.683	23.137	34.55	87.968	BM
2	6.57	Bromide	0.123	0.041	0.06	0.441	M
3	7.22	Nitrate-Nitrogen	99.445	29.712	44.37	37.704	M
4	10.88	n.a.	0.187	0.090	0.13	n.a.	M
5	12.11	Sulphate-Sulphur	31.417	13.990	20.89	28.940	MB
Total:			253.855	66.970	100.00	155.052	

(1/100)

19 L3 (D2)

Sample Name:	**L3 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**17**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**28/5/2008 23:05**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.72	Chloride	156.547	29.920	32.22	105.845	BM
2	6.56	Bromide	0.103	0.032	0.03	0.368	M
3	7.21	Nitrate-Nitrogen	143.209	43.324	46.66	48.230	MB
4	10.88	n.a.	0.364	0.144	0.16	n.a.	BM
5	12.11	Sulphate-Sulphur	43.843	19.430	20.93	38.749	MB
Total:			344.065	92.850	100.00	193.192	

(1/100)

Chromeleon (c) Dionex 1996-20
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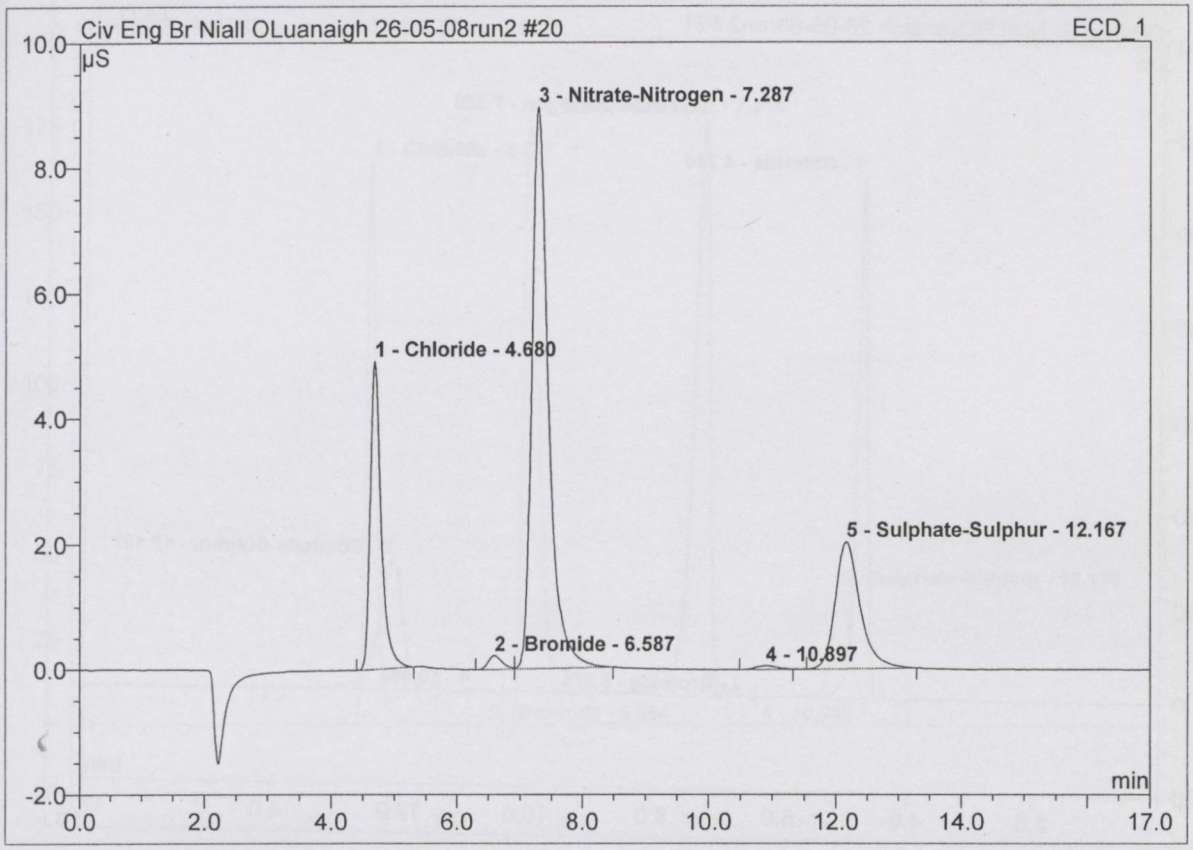
20 L6 (D2)

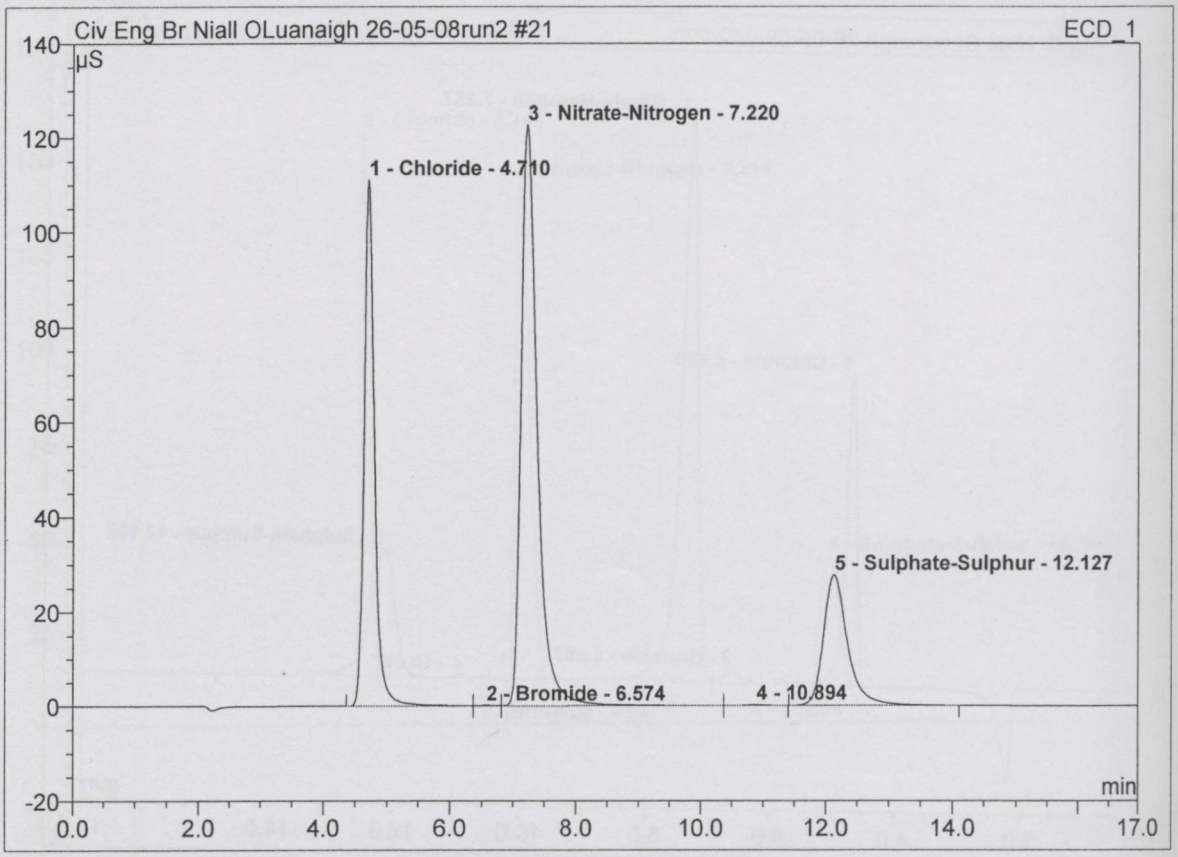
Sample Name:	**L6 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**18**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**28/5/2008 23:24**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	4.913	0.990	20.75	4.901	BMB
2	6.59	Bromide	0.221	0.057	1.20	0.789	BM
3	7.29	Nitrate-Nitrogen	8.957	2.769	58.04	5.519	MB
4	10.90	n.a.	0.059	0.023	0.47	n.a.	BMB
5	12.17	Sulphate-Sulphur	2.026	0.932	19.53	2.110	BMB
Total:			16.177	4.770	100.00	13.319	

21 L13 (D2)

Sample Name:	**L13 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**19**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**28/5/2008 23:43**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.71	Chloride	111.044	20.922	29.86	81.426	BM
2	6.57	Bromide	0.120	0.037	0.05	0.430	M
3	7.22	Nitrate-Nitrogen	122.679	36.728	52.42	43.500	M
4	10.89	n.a.	0.168	0.070	0.10	n.a.	MB
5	12.13	Sulphate-Sulphur	27.677	12.313	17.57	25.839	BMB
Total:			261.688	70.070	100.00	151.195	

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Chromeleon (c) Dionex 1996-2001
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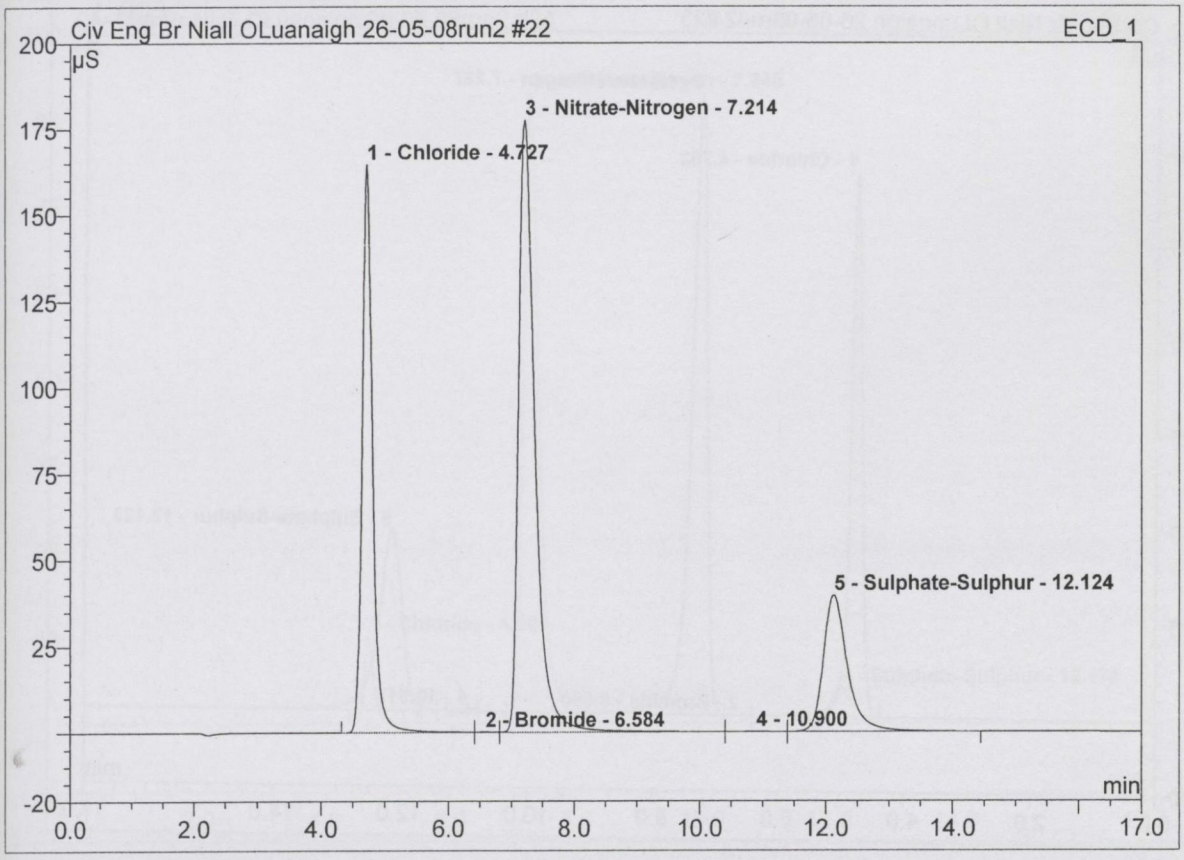
22 L14 (D2)

Sample Name:	**L14 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**20**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /100
Recording Time:	**29/5/2008 0:03**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	164.627	31.527	30.55	109.890	BM
2	6.58	Bromide	0.124	0.038	0.04	0.444	M
3	7.21	Nitrate-Nitrogen	177.560	53.993	52.31	55.509	M
4	10.90	n.a.	0.135	0.060	0.06	n.a.	M
5	12.12	Sulphate-Sulphur	39.600	17.590	17.04	35.478	MB
Total:			382.046	103.209	100.00	201.321	

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Chromeleon (c) Dionex 1996-2001
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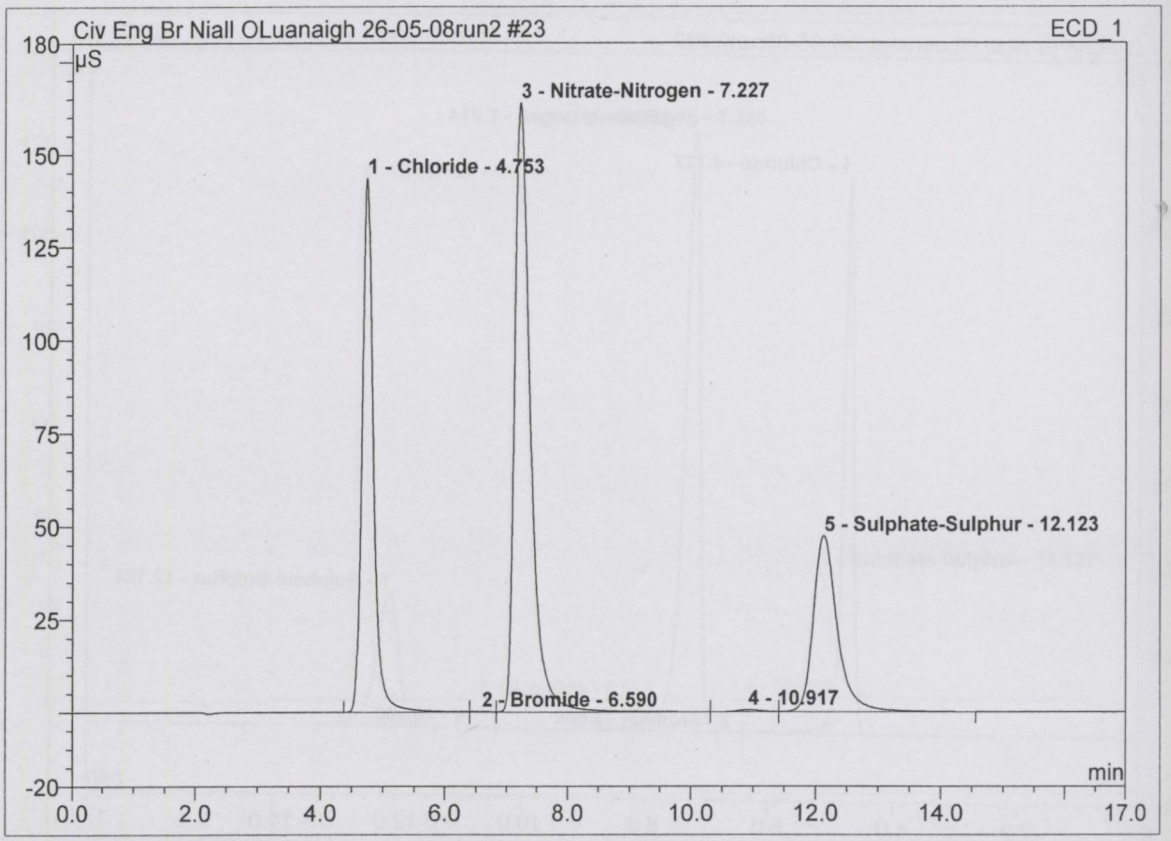
23 L15 (D2)

Sample Name:	**L15 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**21**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000** /10
Recording Time:	**29/5/2008 0:22**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.75	Chloride	143.506	30.374	29.95	99.147	BM
2	6.59	Bromide	0.143	0.048	0.05	0.510	M
3	7.23	Nitrate-Nitrogen	163.871	49.683	48.98	52.693	M
4	10.92	n.a.	0.578	0.258	0.25	n.a.	M
5	12.12	Sulphate-Sulphur	47.332	21.066	20.77	41.383	MB
Total:			355.430	101.428	100.00	193.733	

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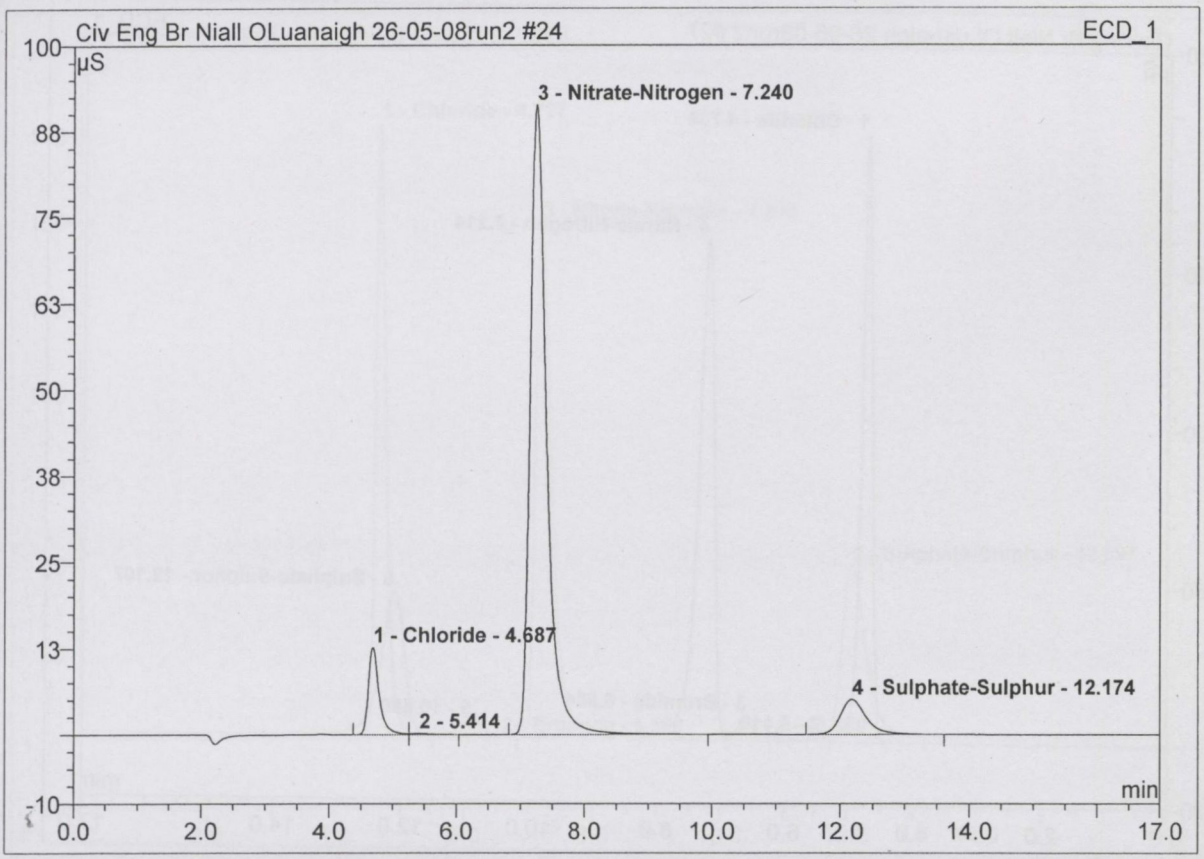
24 L16 (D2)

Sample Name:	**L16 (D2)**	*Injection Volume:*	**20.0**
Vial Number:	**22**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 0:42**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	12.695	2.540	7.89	12.241	BM
2	5.41	n.a.	0.193	0.063	0.20	n.a.	MB
3	7.24	Nitrate-Nitrogen	91.380	27.218	84.60	35.558	BMB
4	12.17	Sulphate-Sulphur	5.104	2.350	7.30	5.235	BMB
Total:			109.373	32.170	100.00	53.034	

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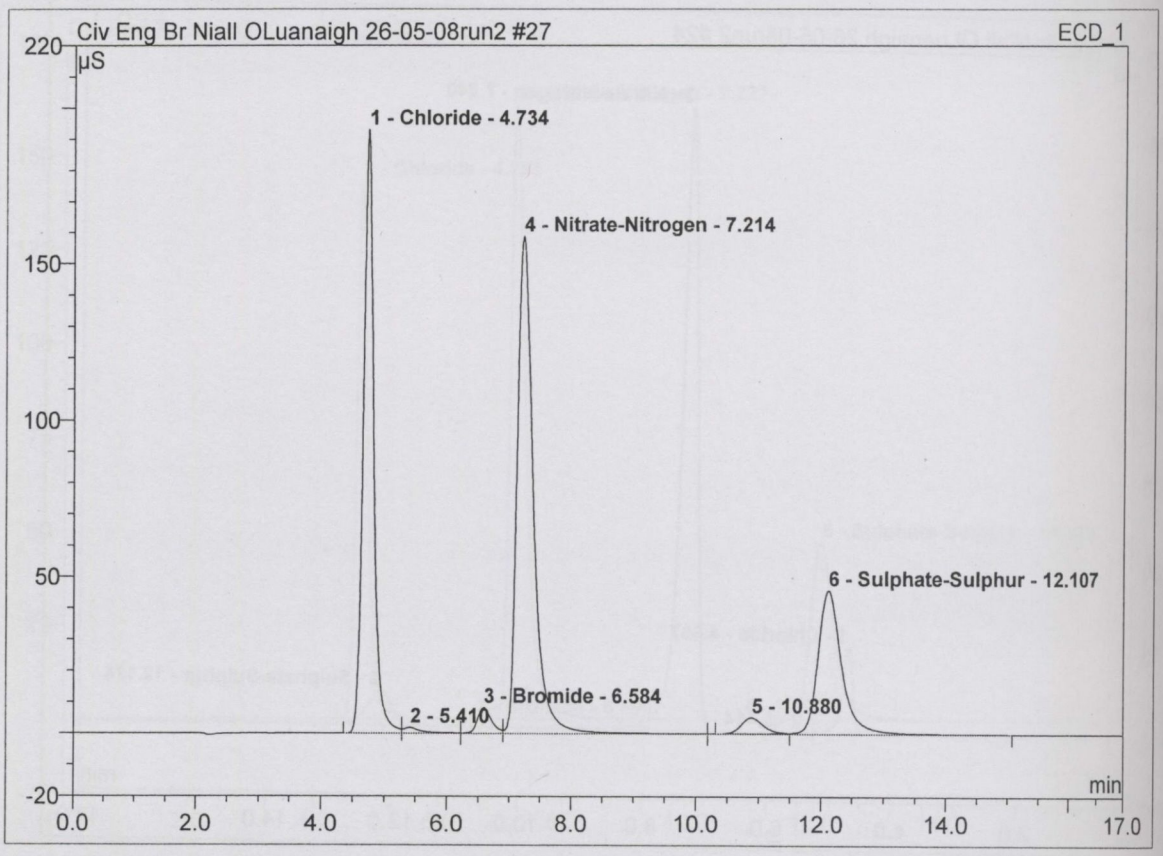
27 L1 (D3)

Sample Name:	**L1 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**23**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 1:40**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	193.015	36.763	33.16	123.530	BM
2	5.41	n.a.	1.884	0.652	0.59	n.a.	M
3	6.58	Bromide	8.305	2.212	1.99	26.827	M
4	7.21	Nitrate-Nitrogen	158.880	48.463	43.71	51.639	M
5	10.88	n.a.	5.084	2.043	1.84	n.a.	Ru
6	12.11	Sulphate-Sulphur	45.772	20.746	18.71	40.212	MB
Total:			412.940	110.878	100.00	242.207	

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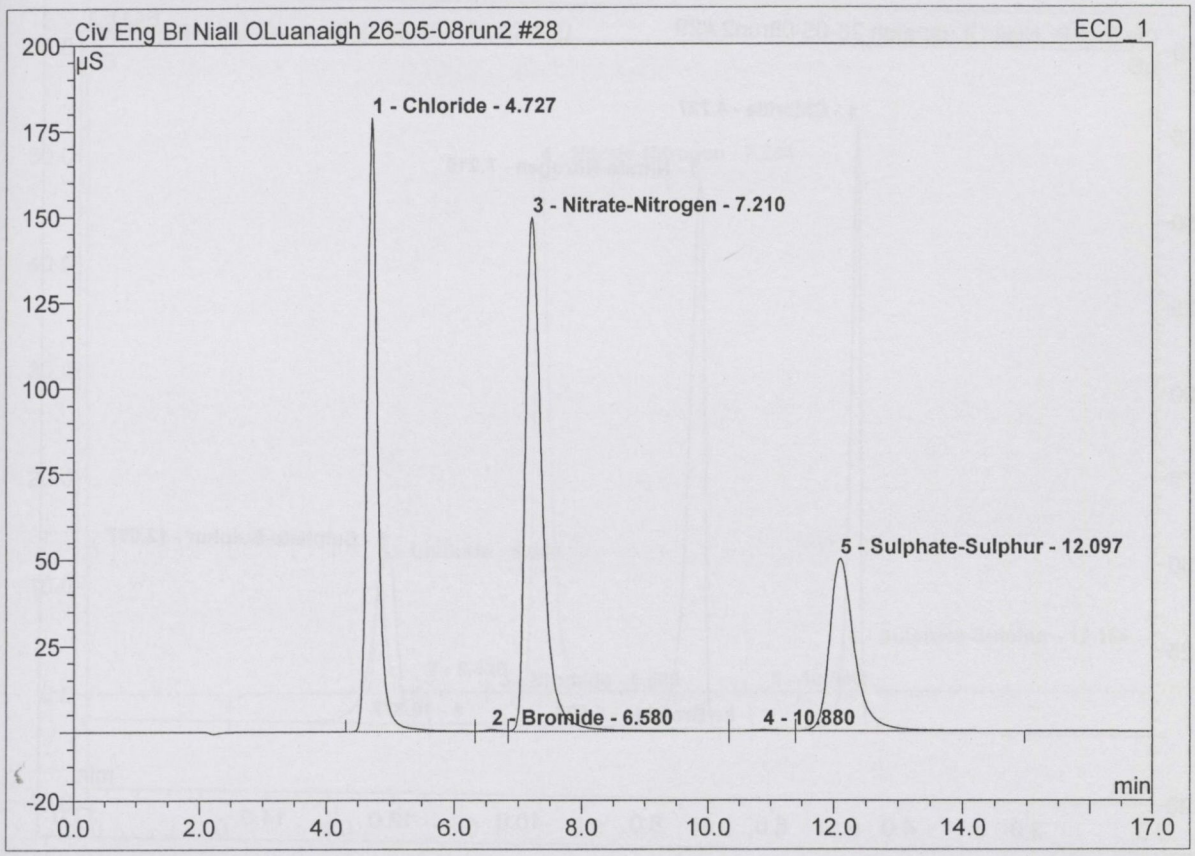
28 L2 (D3)

Sample Name:	**L2 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**24**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000 /10**
Recording Time:	**29/5/2008 1:59**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	178.600	34.253	33.42	116.709	BM
2	6.58	Bromide	0.493	0.146	0.14	1.750	M
3	7.21	Nitrate-Nitrogen	149.596	45.550	44.44	49.639	M
4	10.88	n.a.	0.394	0.179	0.17	n.a.	M
5	12.10	Sulphate-Sulphur	50.051	22.358	21.82	43.402	MB
Total:			379.134	102.487	100.00	211.500	

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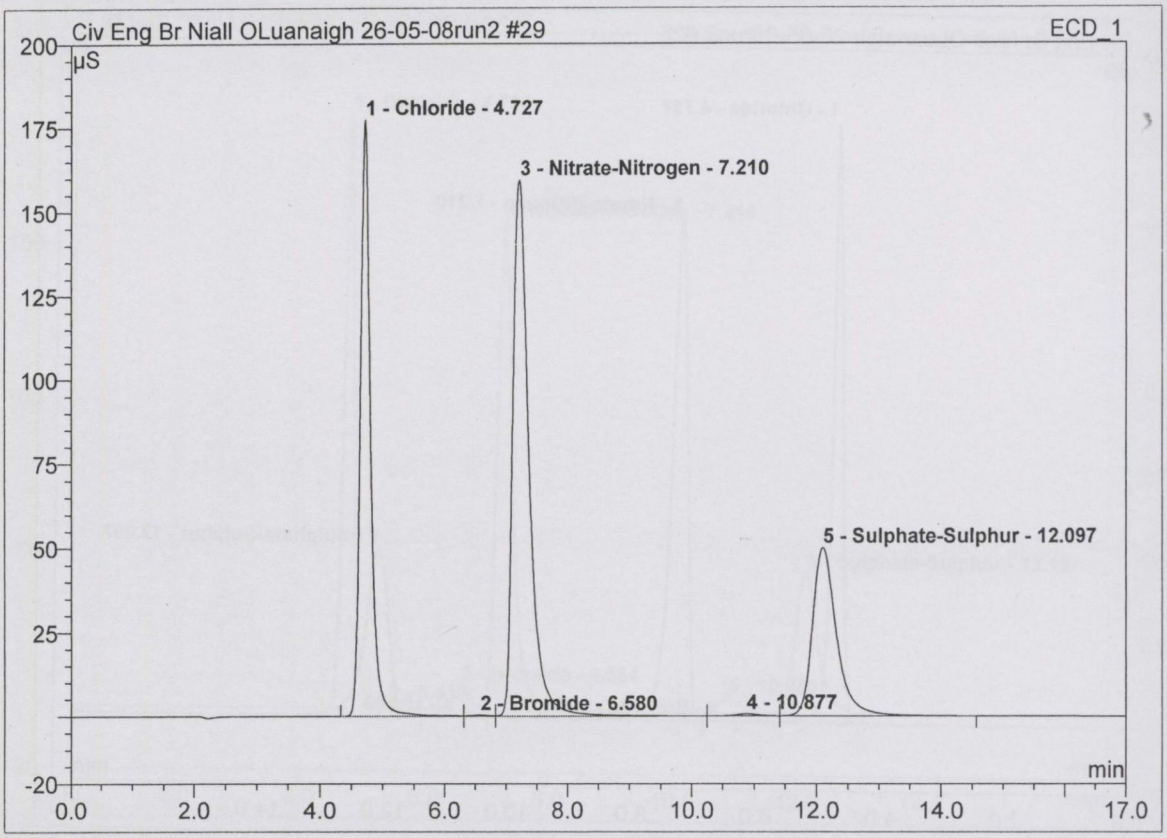
29 L3 (D3)

Sample Name:	**L3 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**25**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000/10**
Recording Time:	**29/5/2008 2:19**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	177.279	34.023	32.34	116.074	BM
2	6.58	Bromide	0.379	0.117	0.11	1.349	M
3	7.21	Nitrate-Nitrogen	159.317	48.462	46.06	51.732	M
4	10.88	n.a.	0.653	0.288	0.27	n.a.	M
5	12.10	Sulphate-Sulphur	50.067	22.319	21.21	43.414	MB
Total:			387.694	105.210	100.00	212.568	

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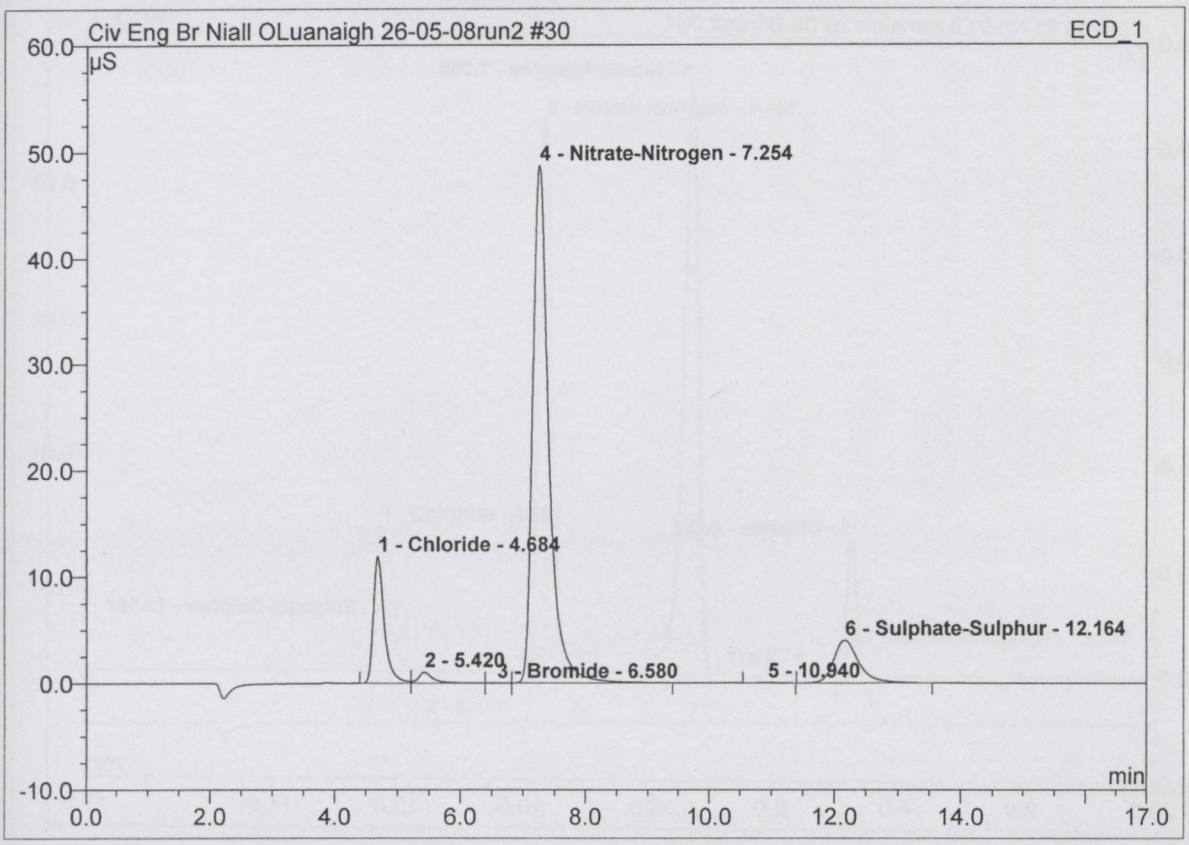
30 L4 (D3)

Sample Name:	**L4 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**11**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 2:38**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	11.935	2.389	12.50	11.544	BM
2	5.42	n.a.	1.041	0.289	1.51	n.a.	M
3	6.58	Bromide	0.028	0.007	0.04	0.099	M
4	7.25	Nitrate-Nitrogen	48.763	14.546	76.11	22.570	MB
5	10.94	n.a.	0.046	0.018	0.09	n.a.	BMB
6	12.16	Sulphate-Sulphur	4.025	1.863	9.75	4.151	BMB
Total:			65.838	19.112	100.00	38.364	

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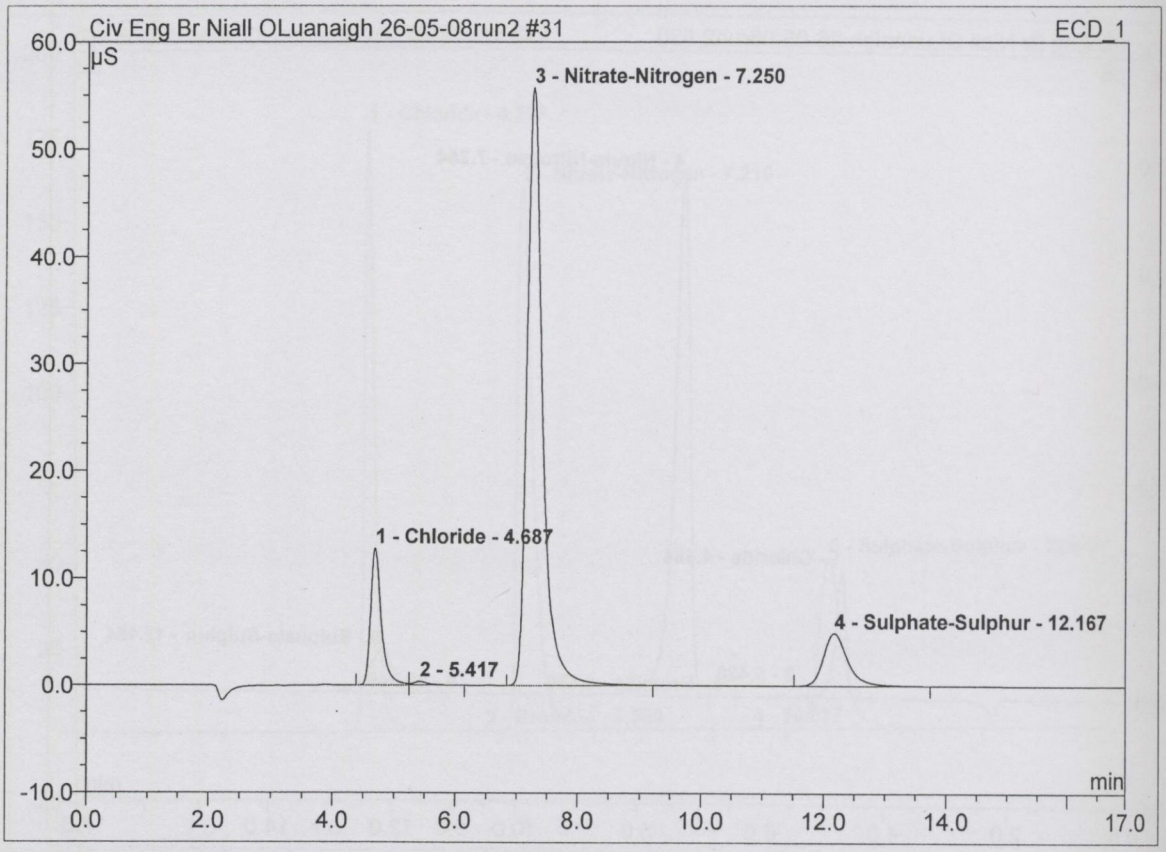
31 L5 (D3)

Sample Name:	**L5 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**12**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 2:57**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	12.810	2.556	11.86	12.345	BM
2	5.42	n.a.	0.361	0.109	0.50	n.a.	MB
3	7.25	Nitrate-Nitrogen	55.716	16.572	76.94	24.930	BMB
4	12.17	Sulphate-Sulphur	4.981	2.303	10.69	5.112	BMB
Total:			73.867	21.539	100.00	42.388	

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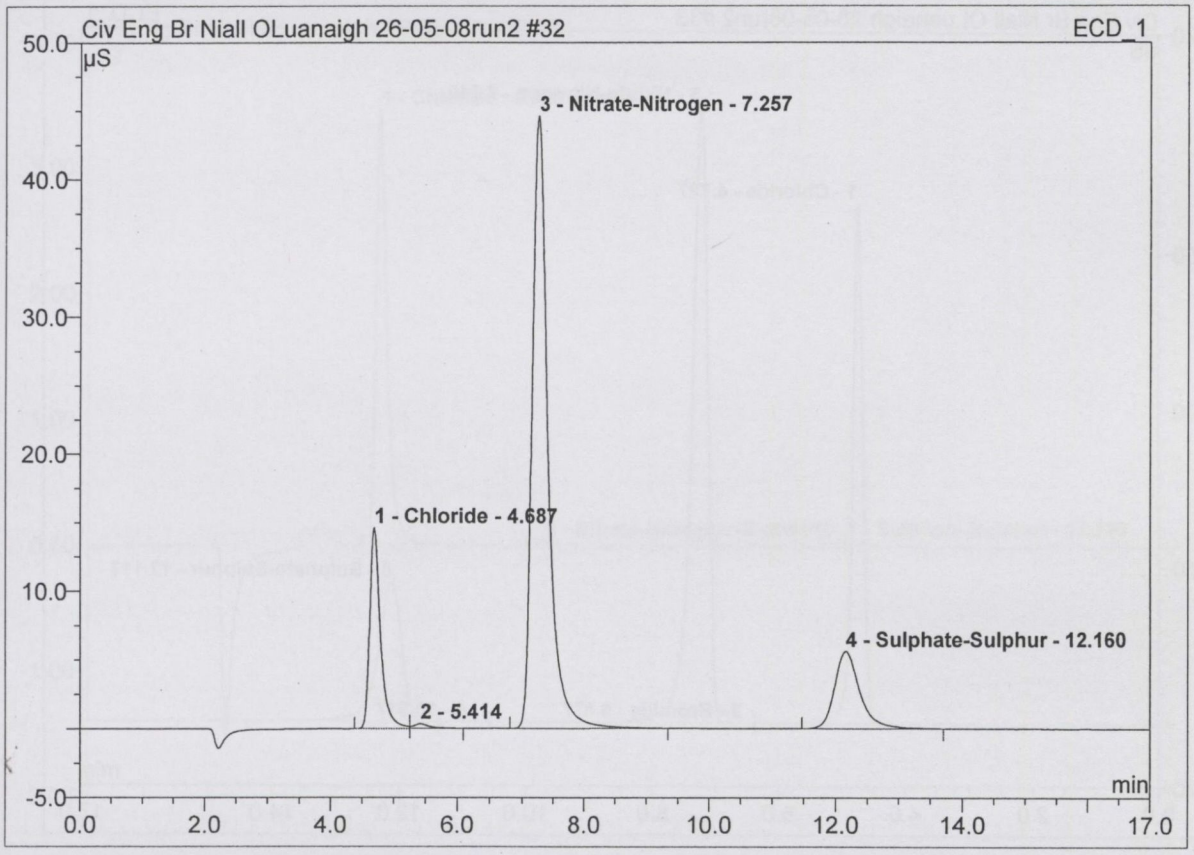
32 L6 (D3)

Sample Name:	**L6 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**13**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 3:17**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	14.608	2.901	15.33	13.974	BM
2	5.41	n.a.	0.352	0.105	0.55	n.a.	MB
3	7.26	Nitrate-Nitrogen	44.611	13.322	70.42	21.101	BMB
4	12.16	Sulphate-Sulphur	5.621	2.591	13.70	5.751	BMB
Total:			65.192	18.919	100.00	40.827	

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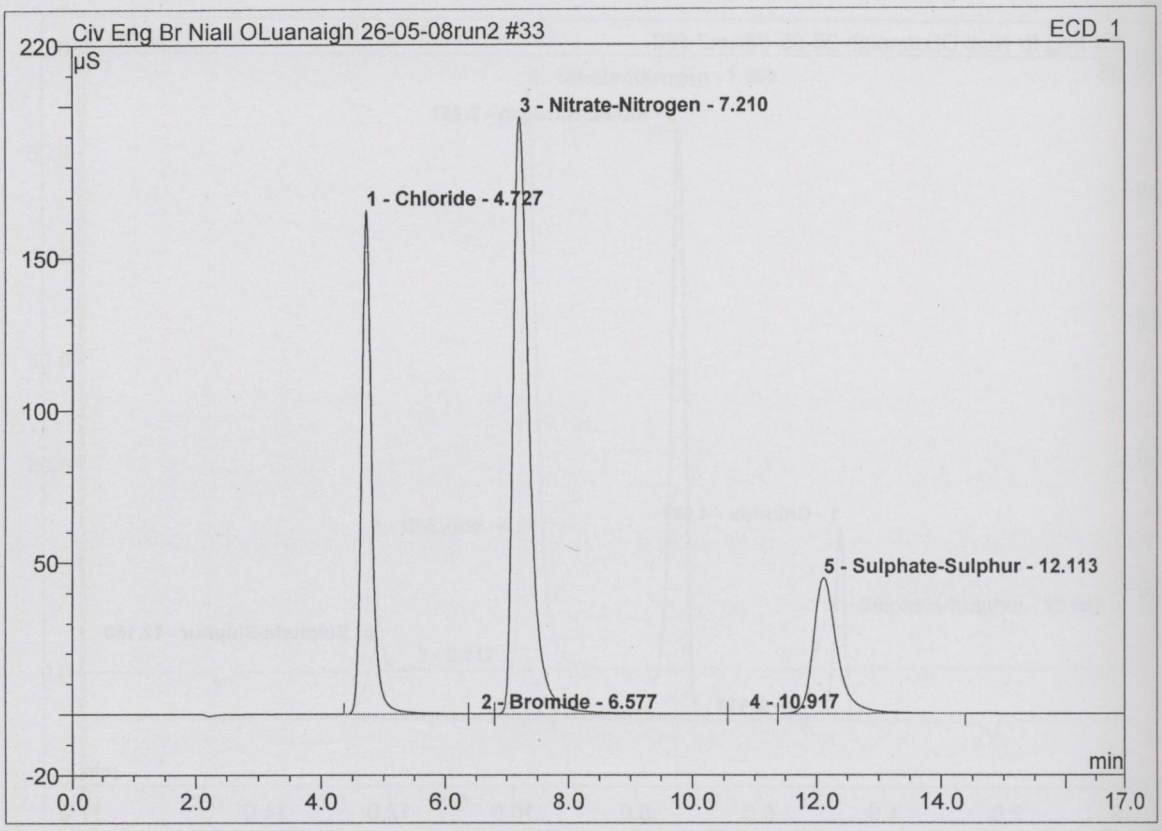
33 L13 (D3)

Sample Name:	**L13 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**14**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000 /100**
Recording Time:	**29/5/2008 3:36**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.73	Chloride	165.591	31.776	28.50	110.367	BM
2	6.58	Bromide	0.123	0.042	0.04	0.441	M
3	7.21	Nitrate-Nitrogen	196.139	59.849	53.67	59.178	M
4	10.92	n.a.	0.071	0.031	0.03	n.a.	MB
5	12.11	Sulphate-Sulphur	44.546	19.810	17.77	39.284	BMB
Total:			406.471	111.509	100.00	209.271	

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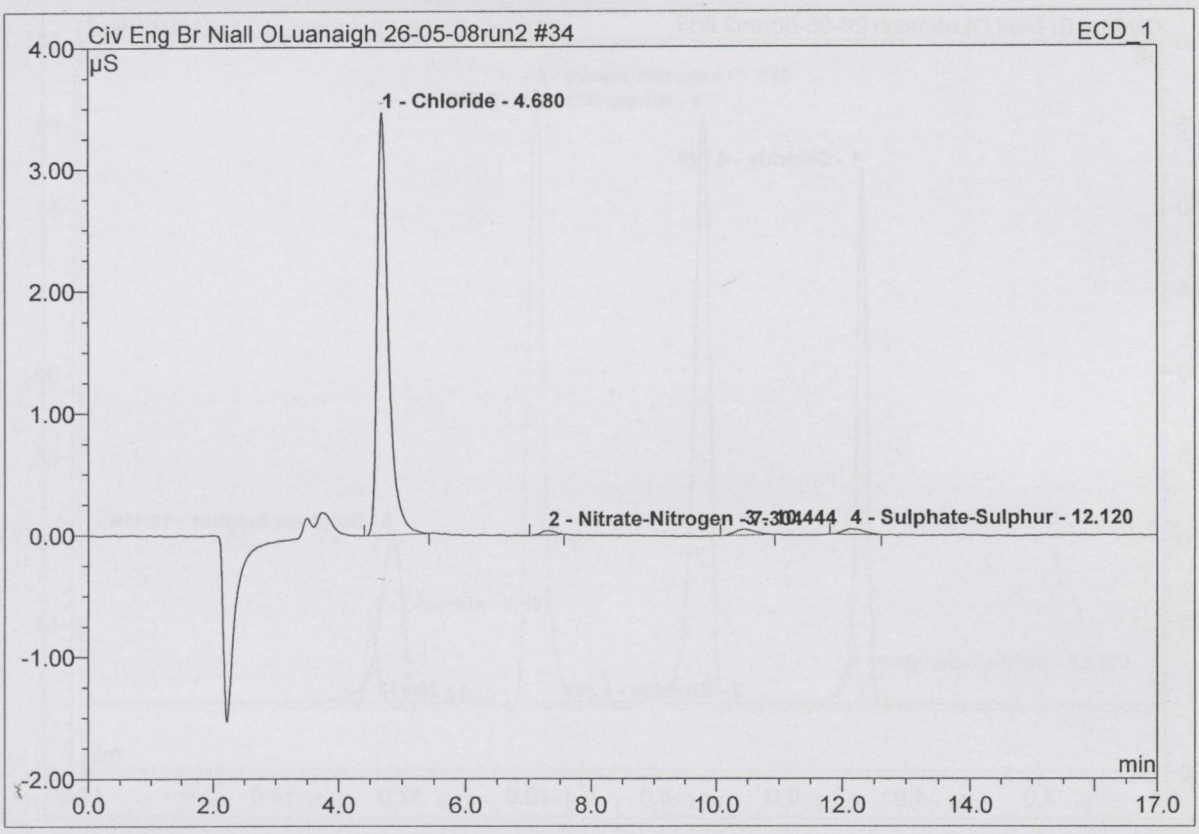
34 L14 (D3)

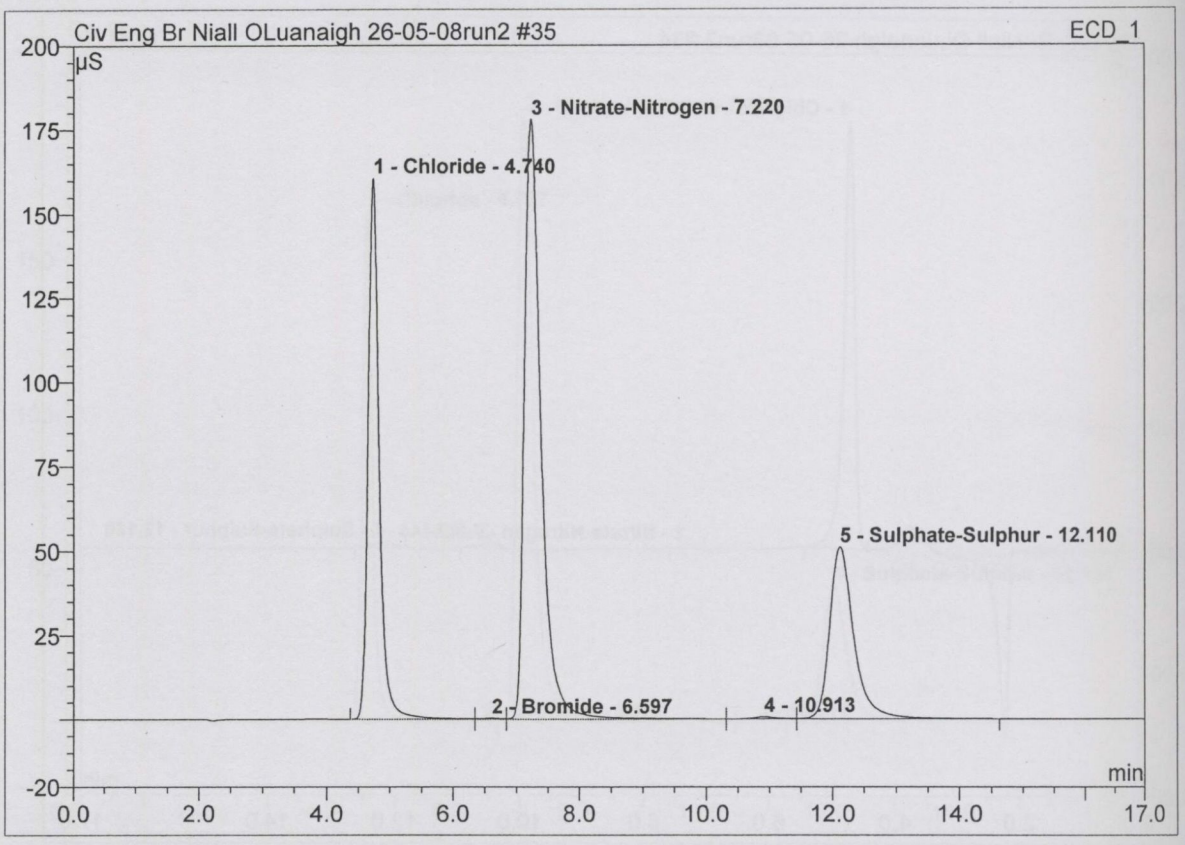
Sample Name:	**L14 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**15**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 3:56**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	3.466	0.712	93.82	3.481	BMB
2	7.30	Nitrate-Nitrogen	0.035	0.010	1.29	0.024	BMB
3	10.44	n.a.	0.049	0.019	2.50	n.a.	BMB
4	12.12	Sulphate-Sulphur	0.047	0.018	2.39	0.049	BMB
Total:			3.597	0.759	100.00	3.554	

35 L15 (D3)

Sample Name:	**L15 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**16**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 4:15**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.74	Chloride	160.580	33.035	29.95	107.874	BM
2	6.60	Bromide	0.303	0.098	0.09	1.079	M
3	7.22	Nitrate-Nitrogen	177.971	54.135	49.08	55.592	M
4	10.91	n.a.	0.599	0.270	0.25	n.a.	M
5	12.11	Sulphate-Sulphur	50.992	22.755	20.63	44.094	MB
Total:			390.444	110.294	100.00	208.639	

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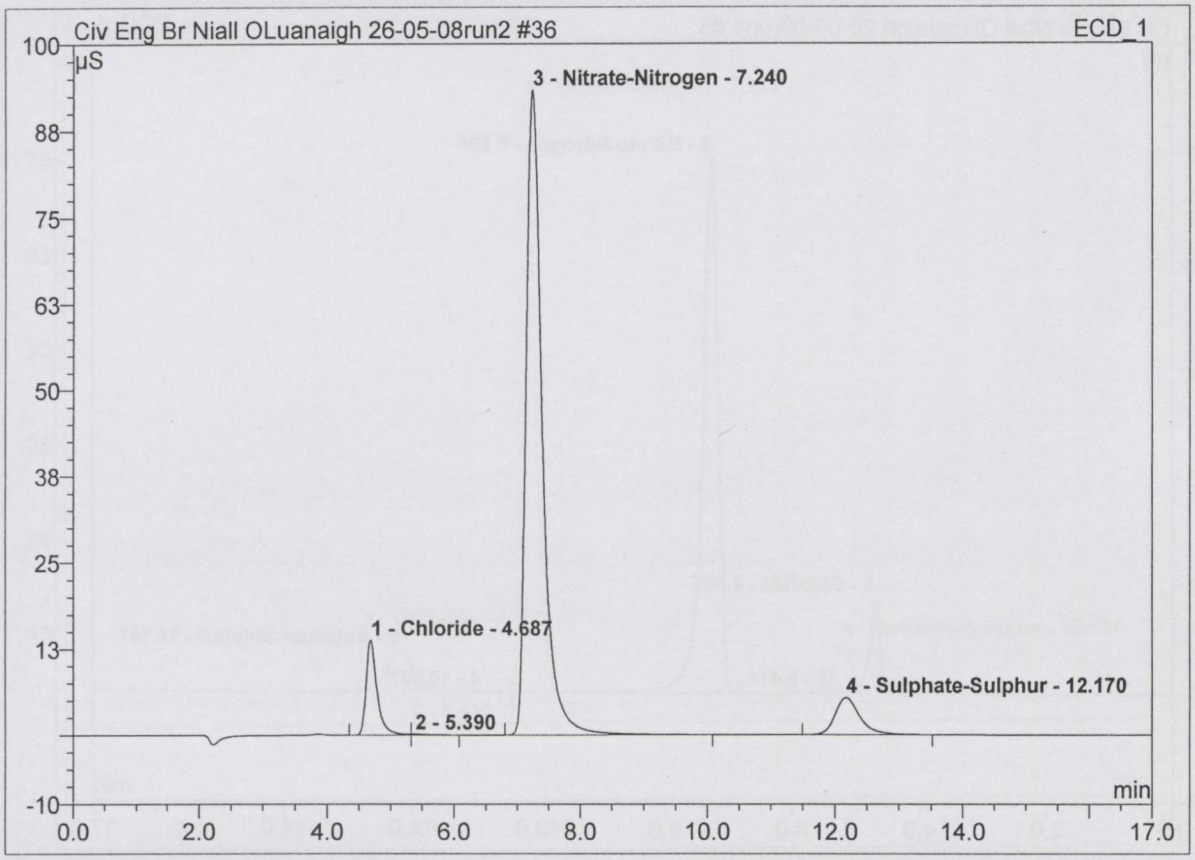
36 L16 (D3)

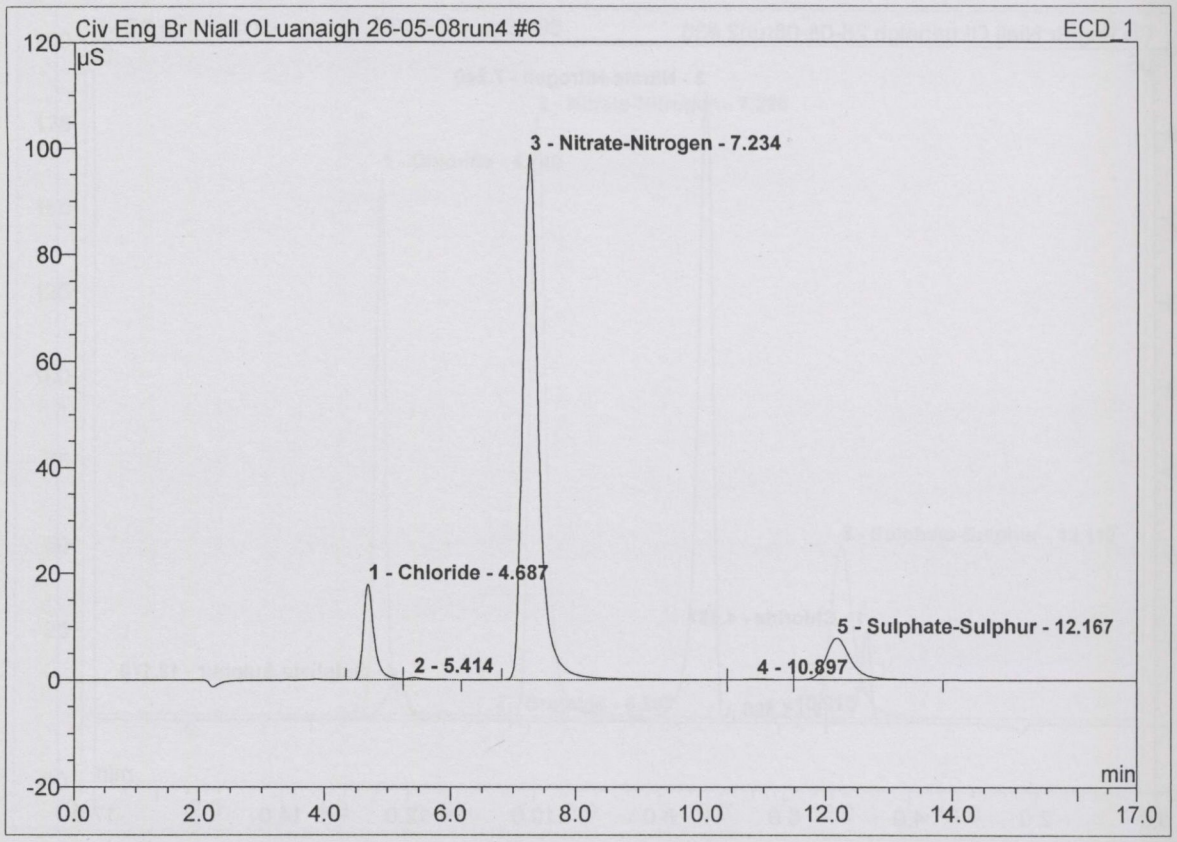
Sample Name:	**L16 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**14**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 4:34**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	13.775	2.759	8.31	13.223	BM
2	5.39	n.a.	0.128	0.040	0.12	n.a.	MB
3	7.24	Nitrate-Nitrogen	93.339	27.928	84.11	36.087	BMB
4	12.17	Sulphate-Sulphur	5.393	2.478	7.46	5.525	BMB
Total:			112.635	33.205	100.00	54.834	

6 L17 (D3)

Sample Name:	**L17 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**15**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 14:15**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**

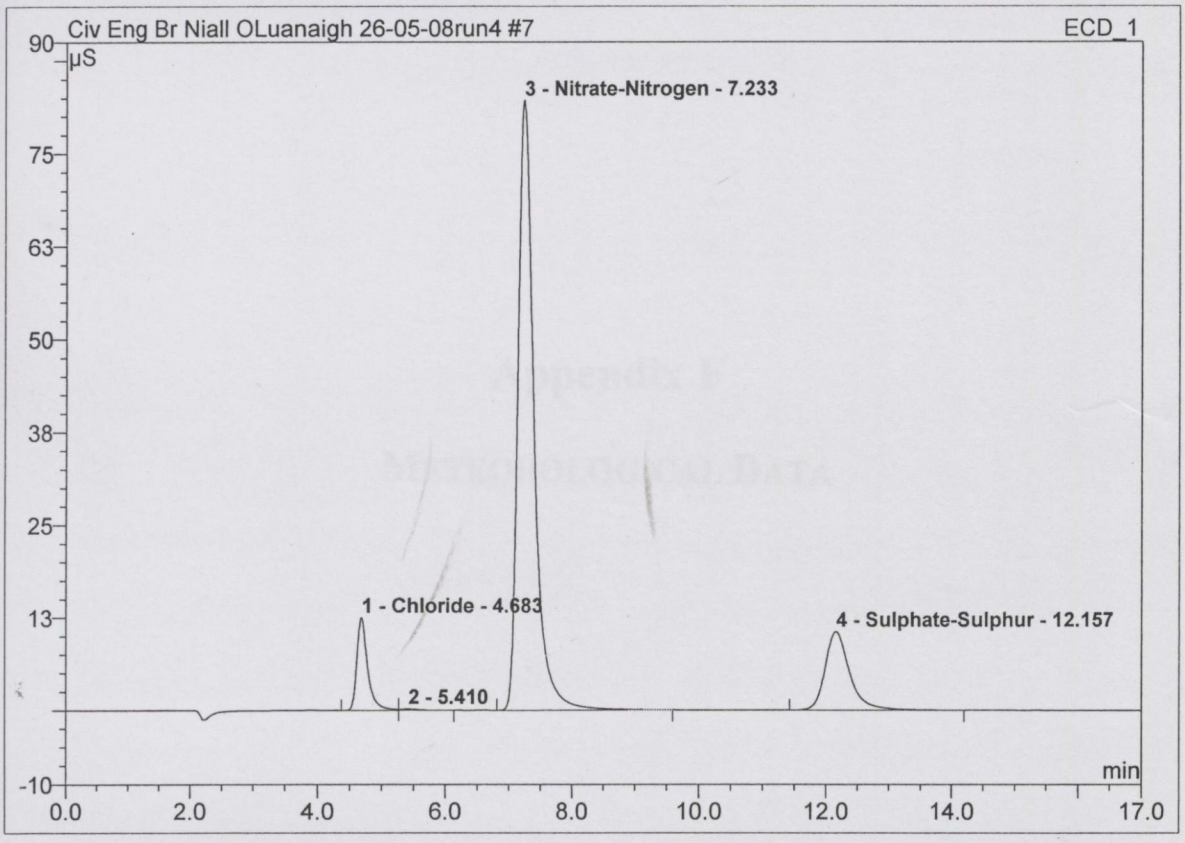


No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.69	Chloride	17.922	3.524	9.61	16.891	BM
2	5.41	n.a.	0.429	0.128	0.35	n.a.	MB
3	7.23	Nitrate-Nitrogen	98.748	29.357	80.04	36.778	BM
4	10.90	n.a.	0.172	0.074	0.20	n.a.	M
5	12.17	Sulphate-Sulphur	7.862	3.593	9.80	7.919	MB
Total:			125.133	36.676	100.00	61.589	

Chromeleon (c) Dionex 1996-2001
Version 6.60 Build 1428

7 L18 (D3)

Sample Name:	**L18 (D3)**	*Injection Volume:*	**20.0**
Vial Number:	**14**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions using ASRS_4mm Bromide**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions+Bromide MK15-01-08**	*Dilution Factor:*	**1.0000**
Recording Time:	**29/5/2008 14:35**	*Sample Weight:*	**1.0000**
Run Time (min):	**17.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount mg/l	Type
1	4.68	Chloride	12.539	2.500	7.89	12.075	BM
2	5.41	n.a.	0.207	0.066	0.21	n.a.	MB
3	7.23	Nitrate-Nitrogen	82.141	24.308	76.69	32.380	BMB
4	12.16	Sulphate-Sulphur	10.584	4.822	15.21	10.533	BMB
Total:			105.471	31.696	100.00	54.989	

Appendix F

METEOROLOGICAL DATA

Date	Meaured Rainfall mm/day	Calculated ET_o mm/day	Calculated SMD (mm)	ET actual mm/day	Effective Rainfall mm/d
19 May 06	6.2	0.702016415	0.0	0.702016415	5.50
20 May 06	2.8	2.454595103	0.0	2.454595103	0.35
21 May 06	16.0	0.48182787	0.0	0.48182787	15.52
22 May 06	1.0	2.227351846	1.2	2.227351846	0.00
23 May 06	5.2	1.717733965	0.0	1.717733965	2.25
24 May 06	1.0	3.1546496	2.2	3.1546496	0.00
25 May 06	2.0	3.205383676	3.4	3.205383676	0.00
26 May 06	7.4	1.625897848	0.0	1.625897848	2.41
27 May 06	1.8	2.274669607	0.5	2.274669607	0.00
28 May 06	0.0	2.219444374	2.7	2.219444374	0.00
29 May 06	0.2	2.758922766	5.3	2.758922766	0.00
30 May 06	0.0	3.055351904	8.3	3.055351904	0.00
31 May 06	0.0	3.204152649	11.5	3.204152649	0.00
01 Jun 06	0.0	4.111822896	15.6	4.111822896	0.00
02 Jun 06	0.0	4.286386301	19.9	4.286386301	0.00
03 Jun 06	0.0	4.551849433	24.5	4.551849433	0.00
04 Jun 06	0.0	4.202546108	28.7	4.202546108	0.00
05 Jun 06	0.0	4.284081199	32.9	4.284081199	0.00
06 Jun 06	0.0	4.669276222	37.6	4.669276222	0.00
07 Jun 06	0.0	4.192305217	41.8	4.192305217	0.00
08 Jun 06	0.0	4.077545551	45.4	3.542444324	0.00
09 Jun 06	0.0	4.690245548	49.2	3.890128587	0.00
10 Jun 06	0.0	4.120387668	52.5	3.239385532	0.00
11 Jun 06	0.0	4.261482434	55.7	3.196927799	0.00
12 Jun 06	0.0	3.209929972	58.0	2.294040835	0.00
13 Jun 06	0.0	2.797033417	59.9	1.927661487	0.00
14 Jun 06	0.0	3.299048463	62.1	2.202980034	0.00
15 Jun 06	0.0	3.616538674	64.4	2.326463985	0.00
16 Jun 06	0.2	2.77369562	65.9	1.712577025	0.00
17 Jun 06	0.0	3.958016785	68.3	2.37729842	0.00
18 Jun 06	8.0	0.735814995	60.7	0.422515462	0.00
19 Jun 06	0.8	1.896286254	61.2	1.248531048	0.00
20 Jun 06	2.4	1.382546069	59.7	0.903389962	0.00
21 Jun 06	1.0	3.259151468	60.9	2.183807001	0.00
22 Jun 06	0.0	2.556814358	62.6	1.679572483	0.00
23 Jun 06	0.0	3.600888781	64.9	2.298225948	0.00
24 Jun 06	2.2	0.89391784	63.2	0.547705858	0.00
25 Jun 06	0.0	3.590658025	65.5	2.265926061	0.00
26 Jun 06	0.0	0.501391536	65.8	0.303785385	0.00
27 Jun 06	0.0	1.301127314	66.6	0.783941121	0.00
28 Jun 06	0.0	3.780891508	68.8	2.245088461	0.00
29 Jun 06	1.6	1.803195485	68.2	1.025753652	0.00
30 Jun 06	2.6	3.644834326	67.7	2.096631853	0.00
01 Jul 06	0.0	4.06246443	70.1	2.35958808	0.00
02 Jul 06	1.4	2.250381046	69.9	1.248081855	0.00
03 Jul 06	5.6	2.821336773	65.9	1.569501467	0.00
04 Jul 06	0.4	3.941550106	67.9	2.369188585	0.00
05 Jul 06	0.0	3.645771268	70.0	2.111632704	0.00
06 Jul 06	0.4	3.021039718	71.3	1.678906447	0.00
07 Jul 06	0.2	2.372228337	72.3	1.2846278	0.00
08 Jul 06	9.6	1.123315561	63.3	0.594769155	0.00
09 Jul 06	0.8	3.029296717	64.4	1.907047061	0.00
10 Jul 06	0.0	2.829674827	66.2	1.746571696	0.00
11 Jul 06	0.0	3.07912493	68.0	1.840786215	0.00
12 Jul 06	0.2	1.407221086	68.6	0.812493617	0.00
13 Jul 06	0.8	3.858664879	70.1	2.201634747	0.00
14 Jul 06	0.0	4.344660013	72.5	2.411266011	0.00

15 Jul 06	0.0	4.066277286	74.6	2.147821829	0.00
16 Jul 06	0.0	4.330734305	76.8	2.18415733	0.00
17 Jul 06	0.0	5.259824141	79.3	2.525085786	0.00
18 Jul 06	0.0	4.154460289	81.2	1.877873688	0.00
19 Jul 06	0.0	3.940235374	82.9	1.698827006	0.00
20 Jul 06	0.0	3.154275683	84.2	1.300421925	0.00
21 Jul 06	0.0	3.53001855	85.6	1.404324766	0.00
22 Jul 06	0.0	3.076405338	86.8	1.17586369	0.00
23 Jul 06	0.0	3.278430962	88.0	1.210248728	0.00
24 Jul 06	0.0	4.506192312	89.6	1.602887093	0.00
25 Jul 06	0.0	4.306367691	91.0	1.455112156	0.00
26 Jul 06	0.0	3.421823018	92.1	1.100902723	0.00
27 Jul 06	0.0	4.046814536	93.4	1.252479514	0.00
28 Jul 06	8.2	1.718854592	85.7	0.50806109	0.00
29 Jul 06	1.4	2.017682055	85.1	0.768832058	0.00
30 Jul 06	4.8	2.702713472	81.3	1.048815416	0.00
31 Jul 06	9.0	1.240286183	72.9	0.533000567	0.00
01 Aug 06	0.2	3.260748962	74.4	1.70803821	0.00
02 Aug 06	0	3.512707217	76.1	1.781159566	0.00
03 Aug 06	0	3.774001577	78.0	1.83896196	0.00
04 Aug 06	0.4	1.029401219	78.1	0.480563818	0.00
05 Aug 06	0	2.822724841	79.4	1.315229026	0.00
06 Aug 06	4.8	1.039211636	75.0	0.46902676	0.00
07 Aug 06	0	3.180554868	76.6	1.588532329	0.00
08 Aug 06	2.6	1.617765328	74.8	0.779440891	0.00
09 Aug 06	0	2.902259851	76.3	1.45701976	0.00
10 Aug 06	1.2	0.905935763	75.5	0.440140091	0.00
11 Aug 06	0	2.014801207	76.5	0.995882338	0.00
12 Aug 06	0.2	2.2761144	77.4	1.09985903	0.00
13 Aug 06	0	2.108665754	78.4	0.997861506	0.00
14 Aug 06	0	1.833460313	79.3	0.847300741	0.00
15 Aug 06	5.4	0.204791793	73.9	0.092712845	0.00
16 Aug 06	0	1.572174539	74.8	0.804461961	0.00
17 Aug 06	0	2.768717733	76.1	1.391969991	0.00
18 Aug 06	18	2.247819779	59.2	1.09532355	0.00
19 Aug 06	20.6	1.139237926	39.4	0.769113623	0.00
20 Aug 06	0.4	2.481381625	41.5	2.481381625	0.00
21 Aug 06	0	2.698919011	43.8	2.354345579	0.00
22 Aug 06	0.6	1.864375081	44.8	1.577577703	0.00
23 Aug 06	0	2.326941663	46.8	1.943712348	0.00
24 Aug 06	0.2	2.684961913	48.8	2.184782833	0.00
25 Aug 06	8.2	0.693110224	41.1	0.5487061	0.00
26 Aug 06	0.2	2.076774698	42.7	1.820650551	0.00
27 Aug 06	2.2	2.017768632	42.3	1.732587156	0.00
28 Aug 06	6.6	1.873242562	37.3	1.618216329	0.00
29 Aug 06	0.2	2.185011831	39.3	2.185011831	0.00
30 Aug 06	3	2.049609413	38.3	2.049609413	0.00
31 Aug 06	0.4	1.084566107	39.0	1.084566107	0.00
01 Sep 06	0.2	2.123752567	40.9	2.123752567	0.00
02 Sep 06	20.2	2.663571183	23.1	2.340571746	0.00
03 Sep 06	3.8	1.437560801	20.7	1.437560801	0.00
04 Sep 06	5	2.465169019	18.2	2.465169019	0.00
05 Sep 06	0.2	1.224595835	19.2	1.224595835	0.00
06 Sep 06	3.4	2.820380352	18.6	2.820380352	0.00
07 Sep 06	0.2	2.035642167	20.4	2.035642167	0.00
08 Sep 06	0.2	1.831199149	22.1	1.831199149	0.00
09 Sep 06	0	1.956315514	24.0	1.956315514	0.00
10 Sep 06	0	1.642992695	25.7	1.642992695	0.00
11 Sep 06	6.4	1.15003233	20.4	1.15003233	0.00
12 Sep 06	0.6	0.30234334	20.1	0.30234334	0.00
13 Sep 06	1.6	1.252747938	19.8	1.252747938	0.00

14 Sep 06	0.2	0.498497215	20.1	0.498497215	0.00
15 Sep 06	0	1.68032242	21.8	1.68032242	0.00
16 Sep 06	1	1.960418884	22.7	1.960418884	0.00
17 Sep 06	0.8	1.798932832	23.7	1.798932832	0.00
18 Sep 06	12	1.794701398	13.5	1.794701398	0.00
19 Sep 06	0.2	0.421593357	13.7	0.421593357	0.00
20 Sep 06	11	1.717410046	4.4	1.717410046	0.00
21 Sep 06	7.6	0.181511777	0.0	0.181511777	2.97
22 Sep 06	3.2	1.914544849	0.0	1.914544849	1.29
23 Sep 06	3.8	1.268932007	0.0	1.268932007	2.53
24 Sep 06	2.8	0.599286098	0.0	0.599286098	2.20
25 Sep 06	6.8	0.733678331	0.0	0.733678331	6.07
26 Sep 06	0.2	0.909949123	0.7	0.909949123	0.00
27 Sep 06	6.8	0.721655855	0.0	0.721655855	5.37
28 Sep 06	0.2	0.094177236	0.0	0.094177236	0.11
29 Sep 06	0	0.728484936	0.7	0.728484936	0.00
30 Sep 06	25	1.375384427	0.0	1.375384427	22.90
01 Oct 06	0.4	0.033434652	0.0	0.033434652	0.37
02 Oct 06	0.2	0.802459131	0.6	0.802459131	0.00
03 Oct 06	0.2	0.997981835	1.4	0.997981835	0.00
04 Oct 06	1.2	1.166543577	1.4	1.166543577	0.00
05 Oct 06	15.8	0.890474624	0.0	0.890474624	13.54
06 Oct 06	5.8	0.141519521	0.0	0.141519521	5.66
07 Oct 06	0	0.367819046	0.4	0.367819046	0.00
08 Oct 06	4.2	0.481564342	0.0	0.481564342	3.35
09 Oct 06	1.8	0.259177053	0.0	0.259177053	1.54
10 Oct 06	1.8	0.715493817	0.0	0.715493817	1.08
11 Oct 06	16.2	1.352857344	0.0	1.352857344	14.85
12 Oct 06	0	0.853302198	0.9	0.853302198	0.00
13 Oct 06	0.2	0.761582059	1.4	0.761582059	0.00
14 Oct 06	0.2	0.703218631	1.9	0.703218631	0.00
15 Oct 06	0	0.825825429	2.7	0.825825429	0.00
16 Oct 06	0.2	0.477166502	3.0	0.477166502	0.00
17 Oct 06	8	0.232399724	0.0	0.232399724	4.75
18 Oct 06	0.2	0	0.0	0	0.20
19 Oct 06	8.8	0.396259822	0.0	0.396259822	8.40
20 Oct 06	0.2	0	0.0	0	0.20
21 Oct 06	8.2	0.141052392	0.0	0.141052392	8.06
22 Oct 06	0.8	0.509673754	0.0	0.509673754	0.29
23 Oct 06	0	0.166725373	0.2	0.166725373	0.00
24 Oct 06	0.6	0.043192096	0.0	0.043192096	0.39
25 Oct 06	26	0.624870608	0.0	0.624870608	25.38
26 Oct 06	1.6	0	0.0	0	1.60
27 Oct 06	1.6	1.132998261	0.0	1.132998261	0.47
28 Oct 06	0	0.240813873	0.2	0.240813873	0.00
29 Oct 06	1.2	0	0.0	0	0.96
30 Oct 06	1.2	0.092465113	0.0	0.092465113	1.11
31 Oct 06	0.2	0.107253594	0.0	0.107253594	0.09
01 Nov 06	0.2	0.825939146	0.6	0.825939146	0.00
02 Nov 06	0.2	0.105890742	0.5	0.105890742	0.00
03 Nov 06	0	0	0.5	0	0.00
04 Nov 06	0.2	0	0.3	0	0.00
05 Nov 06	0.2	0	0.1	0	0.00
06 Nov 06	0	0	0.1	0	0.00
07 Nov 06	3	0.063486331	0.0	0.063486331	2.80
08 Nov 06	0.2	0.174643845	0.0	0.174643845	0.03
09 Nov 06	0.4	0	0.0	0	0.40
10 Nov 06	4.2	0	0.0	0	4.20
11 Nov 06	0.2	0	0.0	0	0.20
12 Nov 06	0.4	0.27550343	0.0	0.27550343	0.12
13 Nov 06	1.4	0.28168923	0.0	0.28168923	1.12

14 Nov 06	0.6	0.429247203	0.0	0.429247203	0.17
15 Nov 06	35.4	0	0.0	0	35.40
16 Nov 06	0.2	0.008420292	0.0	0.008420292	0.19
17 Nov 06	11.2	0	0.0	0	11.20
18 Nov 06	5.4	0	0.0	0	5.40
19 Nov 06	6.2	0.018030362	0.0	0.018030362	6.18
20 Nov 06	0.2	0	0.0	0	0.20
21 Nov 06	0	0	0.0	0	0.00
22 Nov 06	8	0.243079625	0.0	0.243079625	7.76
23 Nov 06	2.2	0	0.0	0	2.20
24 Nov 06	3.2	0	0.0	0	3.20
25 Nov 06	1	0	0.0	0	1.00
26 Nov 06	1.8	0	0.0	0	1.80
27 Nov 06	14.6	0	0.0	0	14.60
28 Nov 06	2.2	0.224666357	0.0	0.224666357	1.98
29 Nov 06	0	0	0.0	0	0.00
30 Nov 06	15.8	0	0.0	0	15.80
01 Dec 06	1.4	0.390562288	0.0	0.390562288	1.01
02 Dec 06	5	0	0.0	0	5.00
03 Dec 06	21.4	0.045408328	0.0	0.045408328	21.35
04 Dec 06	8	0.225228031	0.0	0.225228031	7.77
05 Dec 06	2.6	0	0.0	0	2.60
06 Dec 06	3.2	0	0.0	0	3.20
07 Dec 06	22.8	0	0.0	0	22.80
08 Dec 06	0.2	0.030136376	0.0	0.030136376	0.17
09 Dec 06	0.4	0	0.0	0	0.40
10 Dec 06	11.2	0	0.0	0	11.20
11 Dec 06	8.6	0.036599353	0.0	0.036599353	8.56
12 Dec 06	0.8	0.019750755	0.0	0.019750755	0.78
13 Dec 06	0.4	0.005051855	0.0	0.005051855	0.39
14 Dec 06	14.4	0.231863894	0.0	0.231863894	14.17
15 Dec 06	7.6	0	0.0	0	7.60
16 Dec 06	0.2	0	0.0	0	0.20
17 Dec 06	2.4	0	0.0	0	2.40
18 Dec 06	0.2	0	0.0	0	0.20
19 Dec 06	0.4	0.044598434	0.0	0.044598434	0.36
20 Dec 06	0.2	0.047306566	0.0	0.047306566	0.15
21 Dec 06	0.2	0	0.0	0	0.20
22 Dec 06	0	0	0.0	0	0.00
23 Dec 06	0.2	0	0.0	0	0.20
24 Dec 06	0	0	0.0	0	0.00
25 Dec 06	0.2	0.118149894	0.0	0.118149894	0.08
26 Dec 06	0.6	0	0.0	0	0.60
27 Dec 06	8.2	0	0.0	0	8.20
28 Dec 06	2	0	0.0	0	2.00
29 Dec 06	4.8	0	0.0	0	4.80
30 Dec 06	2.4	0.307904943	0.0	0.307904943	2.09
31 Dec 06	4.8	0	0.0	0	4.80
01 Jan 07	1.8	0.69273521	0.0	0.69273521	1.11
02 Jan 07	1.2	0	0.0	0	1.20
03 Jan 07	2	0.016662328	0.0	0.016662328	1.98
04 Jan 07	0	0.18352548	0.2	0.18352548	0.00
05 Jan 07	1	0.254271059	0.0	0.254271059	0.56
06 Jan 07	1.2	0	0.0	0	1.20
07 Jan 07	8	0	0.0	0	8.00
08 Jan 07	7.4	0	0.0	0	7.40
09 Jan 07	9	0.044824151	0.0	0.044824151	8.96
10 Jan 07	7.8	0.1797525	0.0	0.1797525	7.62
11 Jan 07	6.4	0.098473726	0.0	0.098473726	6.30
12 Jan 07	0.6	0.471513488	0.0	0.471513488	0.13
13 Jan 07	4.8	0.352566047	0.0	0.352566047	4.45

16 May 07	6.8	0.382522991	25.5	0.382522991	0.00
17 May 07	1	2.556851479	27.0	2.556851479	0.00
18 May 07	4	2.390083133	25.4	2.390083133	0.00
19 May 07	0.8	2.606217494	27.2	2.606217494	0.00
20 May 07	0	2.808204881	30.0	2.808204881	0.00
21 May 07	0	3.429845488	33.5	3.429845488	0.00
22 May 07	0	2.765470652	36.2	2.765470652	0.00
23 May 07	0	2.024963951	38.3	2.024963951	0.00
24 May 07	0.6	1.397268776	39.1	1.397268776	0.00
25 May 07	1.8	2.259388977	39.5	2.259388977	0.00
26 May 07	2.6	1.927998409	38.9	1.927998409	0.00
27 May 07	0.8	2.024154087	40.1	2.024154087	0.00
28 May 07	0	2.484682036	42.3	2.206513722	0.00
29 May 07	0	3.109946868	45.0	2.685532098	0.00
30 May 07	1.2	0.852409211	44.5	0.71064559	0.00
31 May 07	5.4	2.017618106	40.8	1.69303969	0.00
01 Jun 07	0	3.410201276	43.8	3.00205601	0.00
02 Jun 07	5.6	0.52124416	38.6	0.441473054	0.00
03 Jun 07	22.6	0.154326917	16.2	0.154326917	0.00
04 Jun 07	0	1.382460538	17.6	1.382460538	0.00
05 Jun 07	0	3.199789793	20.8	3.199789793	0.00
06 Jun 07	0	2.184727086	22.9	2.184727086	0.00
07 Jun 07	0	3.455086754	26.4	3.455086754	0.00
08 Jun 07	0	3.722213552	30.1	3.722213552	0.00
09 Jun 07	0	3.787633689	33.9	3.787633689	0.00
10 Jun 07	0	3.708719288	37.6	3.708719288	0.00
11 Jun 07	1.4	2.009853989	38.2	2.009853989	0.00
12 Jun 07	0.8	2.905147329	40.3	2.905147329	0.00
13 Jun 07	32	1.117472749	9.3	0.98927361	0.00
14 Jun 07	1.8	0.302835229	7.8	0.302835229	0.00
15 Jun 07	1	0.232549462	7.0	0.232549462	0.00
16 Jun 07	0	0.341037229	7.4	0.341037229	0.00
17 Jun 07	0	1.939371151	9.3	1.939371151	0.00
18 Jun 07	0.2	0.878576441	10.0	0.878576441	0.00
19 Jun 07	21.4	0.824023176	0.0	0.824023176	10.57
20 Jun 07	5	1.124164113	0.0	1.124164113	3.88
21 Jun 07	1	0.777580596	0.0	0.777580596	0.22
22 Jun 07	7.2	1.731981834	0.0	1.731981834	5.47
23 Jun 07	0.4	1.704960023	1.3	1.704960023	0.00
24 Jun 07	3.4	1.730724113	0.0	1.730724113	0.36
25 Jun 07	0.8	2.345345554	1.5	2.345345554	0.00
26 Jun 07	0.4	2.553657772	3.7	2.553657772	0.00
27 Jun 07	0	3.171050375	6.9	3.171050375	0.00
28 Jun 07	6.6	0.668365163	0.9	0.668365163	0.00
29 Jun 07	1.8	2.49347844	1.6	2.49347844	0.00
30 Jun 07	3.8	2.013184404	0.0	2.013184404	0.15
01 Jul 07	19.4	1.745509464	0.0	1.745509464	17.65
02 Jul 07	6.6	1.967750245	0.0	1.967750245	4.63
03 Jul 07	4.2	1.543436926	0.0	1.543436926	2.66
04 Jul 07	9.8	1.221657405	0.0	1.221657405	8.58
05 Jul 07	6.2	0.756825113	0.0	0.756825113	5.44
06 Jul 07	16.2	2.109718289	0.0	2.109718289	14.09
07 Jul 07	0.4	2.699151625	2.3	2.699151625	0.00
08 Jul 07	3	1.613439971	0.9	1.613439971	0.00
09 Jul 07	16	0.5237976	0.0	0.5237976	14.56
10 Jul 07	0.8	1.462807428	0.7	1.462807428	0.00
11 Jul 07	1.2	1.774030245	1.2	1.774030245	0.00
12 Jul 07	2.6	1.983269926	0.6	1.983269926	0.00
13 Jul 07	12.8	0.251839623	0.0	0.251839623	11.93
14 Jul 07	8	2.479872489	0.0	2.479872489	5.52
15 Jul 07	3.2	2.565701317	0.0	2.565701317	0.63

16 Jul 07	5.8	2.988353269	0.0	2.988353269	2.81
17 Jul 07	3.6	1.796115482	0.0	1.796115482	1.80
18 Jul 07	2.8	2.157437601	0.0	2.157437601	0.64
19 Jul 07	0.6	2.21078685	1.6	2.21078685	0.00
20 Jul 07	8.4	0.371812134	0.0	0.371812134	6.42
21 Jul 07	2.2	0.807890677	0.0	0.807890677	1.39
22 Jul 07	2.8	1.816472964	0.0	1.816472964	0.98
23 Jul 07	1	1.143150185	0.1	1.143150185	0.00
24 Jul 07	2	2.173317448	0.3	2.173317448	0.00
25 Jul 07	2.8	2.064715063	0.0	2.064715063	0.42
26 Jul 07	2.2	2.00603488	0.0	2.00603488	0.19
27 Jul 07	1.6	2.389537396	0.8	2.389537396	0.00
28 Jul 07	2	1.793118265	0.6	1.793118265	0.00
29 Jul 07	0.6	2.268239457	2.3	2.268239457	0.00
30 Jul 07	0	3.084465274	5.3	3.084465274	0.00
31 Jul 07	0	3.342440039	8.7	3.342440039	0.00
01 Aug 07	0.4	0.964126413	9.2	0.964126413	0.00
02 Aug 07	0.2	2.878342697	11.9	2.878342697	0.00
03 Aug 07	0	2.149664009	14.1	2.149664009	0.00
04 Aug 07	8	1.990689524	8.1	1.990689524	0.00
05 Aug 07	29.2	0.966398142	0.0	0.966398142	20.17
06 Aug 07	4.8	1.525137717	0.0	1.525137717	3.27
07 Aug 07	0	2.808177546	2.8	2.808177546	0.00
08 Aug 07	0	2.058151089	4.9	2.058151089	0.00
09 Aug 07	0.6	1.024880965	5.3	1.024880965	0.00
10 Aug 07	2.8	1.446799418	3.9	1.446799418	0.00
11 Aug 07	20	0.282345063	0.0	0.282345063	15.78
12 Aug 07	6	1.333104189	0.0	1.333104189	4.67
13 Aug 07	0.2	2.184258435	2.0	2.184258435	0.00
14 Aug 07	3.8	0.803679564	0.0	0.803679564	1.01
15 Aug 07	6.4	1.594126056	0.0	1.594126056	4.81
16 Aug 07	1.4	1.798542991	0.4	1.798542991	0.00
17 Aug 07	1.8	0.723273283	0.0	0.723273283	0.68
18 Aug 07	8.8	0.672005308	0.0	0.672005308	8.13
19 Aug 07	0	1.964477769	2.0	1.964477769	0.00
20 Aug 07	8.4	1.834630905	0.0	1.834630905	4.60
21 Aug 07	0	1.62875099	1.6	1.62875099	0.00
22 Aug 07	0	2.4328106	4.1	2.4328106	0.00
23 Aug 07	0	2.118255254	6.2	2.118255254	0.00
24 Aug 07	0	2.301080041	8.5	2.301080041	0.00
25 Aug 07	0.4	1.505306802	9.6	1.505306802	0.00
26 Aug 07	0	2.24392581	11.8	2.24392581	0.00
27 Aug 07	0	1.49134741	13.3	1.49134741	0.00
28 Aug 07	0.2	1.764366099	14.9	1.764366099	0.00
29 Aug 07	0	2.26077108	17.1	2.26077108	0.00
30 Aug 07	0	1.804061055	19.0	1.804061055	0.00
31 Aug 07	0	1.602591208	20.6	1.602591208	0.00
01 Sep 07	0.4	1.589138922	21.7	1.589138922	0.00
02 Sep 07	4	0.413035568	18.2	0.413035568	0.00
03 Sep 07	0	1.615161265	19.8	1.615161265	0.00
04 Sep 07	0	1.24267546	21.0	1.24267546	0.00
05 Sep 07	0.4	1.528069223	22.1	1.528069223	0.00
06 Sep 07	0	2.142639939	24.3	2.142639939	0.00
07 Sep 07	0	2.233200722	26.5	2.233200722	0.00
08 Sep 07	0.2	1.180829757	27.5	1.180829757	0.00
09 Sep 07	0	1.370820614	28.9	1.370820614	0.00
10 Sep 07	0	1.957804717	30.8	1.957804717	0.00
11 Sep 07	0.2	0.887712963	31.5	0.887712963	0.00
12 Sep 07	0	1.394593149	32.9	1.394593149	0.00
13 Sep 07	0	1.302041809	34.2	1.302041809	0.00
14 Sep 07	0.6	1.276383897	34.9	1.276383897	0.00

15 Sep 07	0.2	1.839488531	36.5	1.839488531	0.00
16 Sep 07	1.6	1.037952451	36.0	1.037952451	0.00
17 Sep 07	1.2	1.063317194	35.8	1.063317194	0.00
18 Sep 07	0.2	0.772324205	36.4	0.772324205	0.00
19 Sep 07	2.4	0.755218523	34.8	0.755218523	0.00
20 Sep 07	6.8	0.191350577	28.1	0.191350577	0.00
21 Sep 07	10.6	0.364196817	17.9	0.364196817	0.00
22 Sep 07	0.2	1.488721453	19.2	1.488721453	0.00
23 Sep 07	0.8	0.719434651	19.1	0.719434651	0.00
24 Sep 07	3.2	0.716029829	16.6	0.716029829	0.00
25 Sep 07	0.4	0.859500869	17.1	0.859500869	0.00
26 Sep 07	0	0.825917877	17.9	0.825917877	0.00
27 Sep 07	0	0.741739273	18.7	0.741739273	0.00
28 Sep 07	0.4	0.59235117	18.9	0.59235117	0.00
29 Sep 07	1.6	0.322252565	17.6	0.322252565	0.00
30 Sep 07	1.6	0.885154103	16.9	0.885154103	0.00
01 Oct 07	0.2	0.783081586	17.4	0.783081586	0.00
02 Oct 07	0	0.845033893	18.3	0.845033893	0.00
03 Oct 07	3.6	0.249848341	14.9	0.249848341	0.00
04 Oct 07	0	0.525195156	15.5	0.525195156	0.00
05 Oct 07	0	0.559104322	16.0	0.559104322	0.00

06 Oct 07	0	0.770225979	16.8	0.770225979	0.00
07 Oct 07	0	0.426277921	17.2	0.426277921	0.00
08 Oct 07	0	0.558062749	17.8	0.558062749	0.00
09 Oct 07	0	0.260431393	18.0	0.260431393	0.00
10 Oct 07	0	1.088135426	19.1	1.088135426	0.00
11 Oct 07	0	0.612768479	19.7	0.612768479	0.00
12 Oct 07	0	0.623673838	20.4	0.623673838	0.00
13 Oct 07	0	0.816332236	21.2	0.816332236	0.00
14 Oct 07	0	0.352626229	21.5	0.352626229	0.00
15 Oct 07	1	0	20.5	0	0.00
16 Oct 07	0.8	0.304541153	20.0	0.304541153	0.00
17 Oct 07	0.2	0.078022328	19.9	0.078022328	0.00
18 Oct 07	0.2	0.208413494	19.9	0.208413494	0.00
19 Oct 07	0	0	19.9	0	0.00
20 Oct 07	0	0.269146677	20.2	0.269146677	0.00
21 Oct 07	0	0.167662533	20.4	0.167662533	0.00
22 Oct 07	1.6	0	18.8	0	0.00
23 Oct 07	0	0	18.8	0	0.00
24 Oct 07	0.2	0.08347121	18.6	0.08347121	0.00
25 Oct 07	0.2	0	18.4	0	0.00
26 Oct 07	3	0	15.4	0	0.00
27 Oct 07	0.4	0.021508775	15.1	0.021508775	0.00
28 Oct 07	8.8	0	6.3	0	0.00
29 Oct 07	0.2	0.039274145	6.1	0.039274145	0.00
30 Oct 07	0	0.208097087	6.3	0.208097087	0.00
31 Oct 07	0	0.558729033	6.9	0.558729033	0.00
01 Nov 07	0	0.493400697	7.4	0.493400697	0.00
02 Nov 07	0	0.260624964	7.6	0.260624964	0.00
03 Nov 07	0.2	0.203626216	7.6	0.203626216	0.00
04 Nov 07	0	0.221327155	7.9	0.221327155	0.00
05 Nov 07	0.4	0	7.5	0	0.00
06 Nov 07	0	0.138402323	7.6	0.138402323	0.00
07 Nov 07	0	0.372876603	8.0	0.372876603	0.00
08 Nov 07	1.8	0.346139079	6.5	0.346139079	0.00
09 Nov 07	0	0.300379395	6.8	0.300379395	0.00
10 Nov 07	0	0.394613964	7.2	0.394613964	0.00
11 Nov 07	1.2	0.298660667	6.3	0.298660667	0.00
12 Nov 07	1.2	0.025128628	5.1	0.025128628	0.00
13 Nov 07	0.2	0.232171568	5.2	0.232171568	0.00
14 Nov 07	1.8	0.060146179	3.4	0.060146179	0.00
15 Nov 07	1	0.031975953	2.5	0.031975953	0.00
16 Nov 07	0	0.03667489	2.5	0.03667489	0.00
17 Nov 07	12.4	0	0.0	0	9.91
18 Nov 07	11.4	0	0.0	0	11.40
19 Nov 07	8.2	0	0.0	0	8.20
20 Nov 07	0.8	0	0.0	0	0.80
21 Nov 07	1	0	0.0	0	1.00
22 Nov 07	0	0	0.0	0	0.00
23 Nov 07	0	0	0.0	0	0.00
24 Nov 07	3	0.238203922	0.0	0.238203922	2.76
25 Nov 07	0.4	0.145152838	0.0	0.145152838	0.25
26 Nov 07	1	0	0.0	0	1.00
27 Nov 07	0	0.004470656	0.0	0.004470656	0.00
28 Nov 07	7	0	0.0	0	7.00
29 Nov 07	3.4	0	0.0	0	3.40
30 Nov 07	11.4	0	0.0	0	11.40
01 Dec 07	8.4	0	0.0	0	8.40
02 Dec 07	9.6	0	0.0	0	9.60
03 Dec 07	0.4	0	0.0	0	0.40
04 Dec 07	6.8	0.181725378	0.0	0.181725378	6.62
05 Dec 07	0.8	0	0.0	0	0.80

06 Dec 07	13.8	0.0932534	0.0	0.0932534	13.71
07 Dec 07	1	0	0.0	0	1.00
08 Dec 07	24.6	0	0.0	0	24.60
09 Dec 07	3	0	0.0	0	3.00
10 Dec 07	0	0	0.0	0	0.00
11 Dec 07	0.4	0	0.0	0	0.40
12 Dec 07	0	0.138832102	0.1	0.138832102	0.00
13 Dec 07	0	0.139726156	0.3	0.139726156	0.00
14 Dec 07	0	0	0.3	0	0.00
15 Dec 07	0	0.151907085	0.4	0.151907085	0.00
16 Dec 07	0	0.334837352	0.8	0.334837352	0.00
17 Dec 07	0.2	0	0.6	0	0.00
18 Dec 07	0	0	0.6	0	0.00
19 Dec 07	0	0	0.6	0	0.00
20 Dec 07	0	0	0.6	0	0.00
21 Dec 07	0.4	0	0.2	0	0.00
22 Dec 07	2	0	0.0	0	1.83
23 Dec 07	0.4	0	0.0	0	0.40
24 Dec 07	5.4	0	0.0	0	5.40
25 Dec 07	1	0	0.0	0	1.00
26 Dec 07	0.6	0	0.0	0	0.60
27 Dec 07	14.8	0	0.0	0	14.80
28 Dec 07	1.6	0	0.0	0	1.60
29 Dec 07	4.4	0	0.0	0	4.40
30 Dec 07	0.2	0	0.0	0	0.20
31 Dec 07	0.6	0.055666268	0.0	0.055666268	0.54
01 Jan 08	0.2	0	0.0	0	0.20
02 Jan 08	0	0.572294379	0.6	0.572294379	0.00
03 Jan 08	0	0.287622692	0.9	0.287622692	0.00
04 Jan 08	9	0	0.0	0	8.14
05 Jan 08	0.6	0	0.0	0	0.60
06 Jan 08	6.4	0	0.0	0	6.40
07 Jan 08	1.8	0	0.0	0	1.80
08 Jan 08	13.2	0	0.0	0	13.20
09 Jan 08	5.6	0	0.0	0	5.60
10 Jan 08	8.4	0	0.0	0	8.40
11 Jan 08	0.2	0	0.0	0	0.20
12 Jan 08	5.2	0	0.0	0	5.20
13 Jan 08	11.2	0	0.0	0	11.20
14 Jan 08	2.2	0	0.0	0	2.20
15 Jan 08	2	0	0.0	0	2.00
16 Jan 08	0	0	0.0	0	0.00
17 Jan 08	10	0	0.0	0	10.00
18 Jan 08	10.2	0	0.0	0	10.20
19 Jan 08	13.2	0	0.0	0	13.20
20 Jan 08	6	0	0.0	0	6.00
21 Jan 08	5.2	0.156307585	0.0	0.156307585	5.04
22 Jan 08	4.6	0	0.0	0	4.60
23 Jan 08	3	0.111473156	0.0	0.111473156	2.89
24 Jan 08	1	0	0.0	0	1.00
25 Jan 08	0	0.879372714	0.9	0.879372714	0.00
26 Jan 08	0	0.613837807	1.5	0.613837807	0.00
27 Jan 08	0	0.063228056	1.6	0.063228056	0.00
28 Jan 08	0.4	0	1.2	0	0.00
29 Jan 08	4	0	0.0	0	2.84
30 Jan 08	0.4	0	0.0	0	0.40
31 Jan 08	10.4	0.425377163	0.0	0.425377163	9.97
01 Feb 08	1.8	0	0.0	0	1.80
02 Feb 08	0.4	0	0.0	0	0.40
03 Feb 08	9.2	0	0.0	0	9.20
04 Feb 08	7.6	0	0.0	0	7.60

05 Feb 08	4.6	0	0.0	0	4.60
06 Feb 08	1.6	0.123071395	0.0	0.123071395	1.48
07 Feb 08	0.4	0.322352444	0.0	0.322352444	0.08
08 Feb 08	0.4	0	0.0	0	0.40
09 Feb 08	0	0.100427611	0.1	0.100427611	0.00
10 Feb 08	0.2	0	0.0	0	0.10
11 Feb 08	0.2	0	0.0	0	0.20
12 Feb 08	0	0	0.0	0	0.00
13 Feb 08	0.2	0	0.0	0	0.20
14 Feb 08	0.2	0.174862989	0.0	0.174862989	0.03
15 Feb 08	0.2	0.266160367	0.1	0.266160367	0.00
16 Feb 08	0	0.126326918	0.2	0.126326918	0.00
17 Feb 08	0	0	0.2	0	0.00
18 Feb 08	0.4	0	0.0	0	0.21
19 Feb 08	0.4	0.228168837	0.0	0.228168837	0.17
20 Feb 08	0	0.05947244	0.1	0.05947244	0.00
21 Feb 08	0.6	0.505798164	0.0	0.505798164	0.03
22 Feb 08	1	0.793523904	0.0	0.793523904	0.21
23 Feb 08	0	0.43909627	0.4	0.43909627	0.00
24 Feb 08	1.2	0.242928614	0.0	0.242928614	0.52
25 Feb 08	2.2	0	0.0	0	2.20
26 Feb 08	0.2	0.735460855	0.5	0.735460855	0.00
27 Feb 08	0	0.352274127	0.9	0.352274127	0.00
28 Feb 08	0	0.325746971	1.2	0.325746971	0.00
29 Feb 08	7.4	0.161839929	0.0	0.161839929	6.02
01 Mar 08	0.8	0.664090672	0.0	0.664090672	0.14
02 Mar 08	1.2	0.760901515	0.0	0.760901515	0.44
03 Mar 08	1	0.067294122	0.0	0.067294122	0.93
04 Mar 08	1.2	0.530702241	0.0	0.530702241	0.67
05 Mar 08	0	0.673783122	0.7	0.673783122	0.00
06 Mar 08	3	0.782206337	0.0	0.782206337	1.54
07 Mar 08	1.2	0.480516638	0.0	0.480516638	0.72
08 Mar 08	3.6	0.774091831	0.0	0.774091831	2.83
09 Mar 08	3.6	0.571188597	0.0	0.571188597	3.03
10 Mar 08	6.2	0.406241456	0.0	0.406241456	5.79
11 Mar 08	3	0.931108766	0.0	0.931108766	2.07
12 Mar 08	7.6	0.981215499	0.0	0.981215499	6.62
13 Mar 08	2	0.302740269	0.0	0.302740269	1.70
14 Mar 08	0.2	0.421853082	0.2	0.421853082	0.00
15 Mar 08	11.4	0.050314979	0.0	0.050314979	11.13
16 Mar 08	2.8	0.565501122	0.0	0.565501122	2.23
17 Mar 08	0	0.718629062	0.7	0.718629062	0.00
18 Mar 08	0.2	0.788845294	1.3	0.788845294	0.00
19 Mar 08	0	0.854505453	2.2	0.854505453	0.00
20 Mar 08	1.6	0.379310559	0.9	0.379310559	0.00
21 Mar 08	2	1.275198539	0.2	1.275198539	0.00
22 Mar 08	0	1.190460716	1.4	1.190460716	0.00
23 Mar 08	1	1.084014212	1.5	1.084014212	0.00
24 Mar 08	1.8	0.842488506	0.5	0.842488506	0.00
25 Mar 08	1.8	0.6549242	0.0	0.6549242	0.61
26 Mar 08	0.6	0.757235913	0.2	0.757235913	0.00
27 Mar 08	2	1.418138016	0.0	1.418138016	0.42
28 Mar 08	6.4	0.779786284	0.0	0.779786284	5.62
29 Mar 08	8.8	0.025251996	0.0	0.025251996	8.77
30 Mar 08	9.2	1.051968098	0.0	1.051968098	8.15
31 Mar 08	0.6	1.169240567	0.6	1.169240567	0.00
01 Apr 08	1	1.819427116	1.4	1.819427116	0.00
02 Apr 08	1.2	1.270776205	1.5	1.270776205	0.00
03 Apr 08	0	1.913212681	3.4	1.913212681	0.00
04 Apr 08	0.6	1.101224106	3.9	1.101224106	0.00
05 Apr 08	0.2	1.26271131	4.9	1.26271131	0.00

06 Apr 08	0.4	1.03827959	5.6	1.03827959	0.00
07 Apr 08	0.8	0.90163201	5.7	0.90163201	0.00
08 Apr 08	0	0.955649737	6.6	0.955649737	0.00
09 Apr 08	0	1.439145029	8.1	1.439145029	0.00
10 Apr 08	3.2	1.134082295	6.0	1.134082295	0.00
11 Apr 08	4.4	1.142243654	2.7	1.142243654	0.00
12 Apr 08	7.4	0.150995594	0.0	0.150995594	4.50
13 Apr 08	1.8	1.060417469	0.0	1.060417469	0.74
14 Apr 08	0	1.791089079	1.8	1.791089079	0.00
15 Apr 08	0	1.418063753	3.2	1.418063753	0.00
16 Apr 08	0	1.38154642	4.6	1.38154642	0.00
17 Apr 08	0.6	0.996914318	5.0	0.996914318	0.00
18 Apr 08	0	1.04426347	6.0	1.04426347	0.00
19 Apr 08	0	1.497303283	7.5	1.497303283	0.00
20 Apr 08	1	0.615146459	7.1	0.615146459	0.00
21 Apr 08	0.2	1.296087062	8.2	1.296087062	0.00
22 Apr 08	6.8	2.159211677	3.6	2.159211677	0.00
23 Apr 08	0.8	1.714833327	4.5	1.714833327	0.00
24 Apr 08	2	1.576359705	4.1	1.576359705	0.00
25 Apr 08	0.8	0.785848447	4.1	0.785848447	0.00
26 Apr 08	0.6	2.244201279	5.7	2.244201279	0.00
27 Apr 08	5	2.232494928	3.0	2.232494928	0.00
28 Apr 08	4.6	1.311437491	0.0	1.311437491	0.34
29 Apr 08	0	1.151514404	1.2	1.151514404	0.00
30 Apr 08	0.2	1.216805756	2.2	1.216805756	0.00
01 May 08	0.2	1.70950158	3.7	1.70950158	0.00
02 May 08	3.8	1.198	1.1	1.198147646	0.00
03 May 08	2.2	2.479	1.4	2.479389265	0.00
04 May 08	3	2.337	0.7	2.336844892	0.00
05 May 08	0	2.781	3.5	2.780709545	0.00
06 May 08	0	2.788	6.3	2.787716505	0.00
07 May 08	2.2	2.876	6.9	2.875611427	0.00
08 May 08	0.8	3.228	9.4	3.227792877	0.00
09 May 08	1.6	0.546	8.3	0.546188484	0.00
10 May 08	0.2	1.077	9.2	1.077194187	0.00
11 May 08	0	2.897	12.1	2.897237498	0.00
12 May 08	0.4	2.801	14.5	2.800751465	0.00
13 May 08	0	2.553	17.0	2.553256828	0.00
14 May 08	0	2.635917925	19.7	2.635917925	0.00
15 May 08	0	2.163586105	21.8	2.163586105	0.00
16 May 08	0	2.038395445	23.9	2.038395445	0.00
17 May 08	0	1.720354671	25.6	1.720354671	0.00
18 May 08	1	2.274893356	26.9	2.274893356	0.00
19 May 08	0	2.404189561	29.3	2.404189561	0.00
20 May 08	0	1.540682842	30.8	1.540682842	0.00
21 May 08	2	2.926148552	31.7	2.926148552	0.00
22 May 08	5	0.151276658	26.9	0.151276658	0.00
23 May 08	0	2.25350885	29.1	2.25350885	0.00
24 May 08	0	2.773761871	31.9	2.773761871	0.00
25 May 08	0	3.279687022	35.2	3.279687022	0.00
26 May 08	0	2.486529888	37.7	2.486529888	0.00
27 May 08	1.2	0.636552513	37.1	0.636552513	0.00
28 May 08	0	0.83455497	38.0	0.83455497	0.00
29 May 08	0	2.971391908	40.9	2.971391908	0.00
30 May 08	0	2.168413644	42.8	1.905069577	0.00
31 May 08	0.2	3.469399657	45.6	2.974618392	0.00
01 Jun 08	0	2.690798584	47.8	2.224101022	0.00
02 Jun 08	1.8	2.462041477	48.0	1.974177468	0.00
03 Jun 08	0	3.371821546	50.7	2.697155236	0.00
04 Jun 08	6.4	0.319945259	44.6	0.246339306	0.00
05 Jun 08	1	1.931068474	45.2	1.618845695	0.00

06 Jun 08	0.8	2.155393483	46.2	1.792080329	0.00
07 Jun 08	0.2	3.13922155	48.5	2.575470325	0.00
08 Jun 08	0	2.190056878	50.3	1.738955001	0.00
09 Jun 08	0	3.342007707	52.9	2.58905683	0.00
10 Jun 08	0	3.821397095	55.7	2.850509016	0.00
11 Jun 08	4.2	1.3918638	52.5	0.994154606	0.00
12 Jun 08	0	2.402147338	54.3	1.801326856	0.00

SITE B

Redcross, Co. Wicklow

Date	Measured Rainfall mm/day	Calculated ET_o mm/day	Calculated SMD (mm)	ET actual mm/day	Effective Rainfall mm/d
03 Jul 06	0	2.55698598	78.0	1.22888309	0.00
04 Jul 06	0	3.88718853	79.8	1.81509949	0.00
05 Jul 06	0	3.50234424	81.4	1.56476426	0.00
06 Jul 06	0	2.89605543	82.6	1.24353721	0.00
07 Jul 06	0.0	1.77777306	83.3	0.73879432	0.00
08 Jul 06	12.4	0.93612937	71.3	0.38134548	0.00
09 Jul 06	0.0	2.89016667	72.9	1.56330471	0.00
10 Jul 06	0.0	2.73749368	74.3	1.43317276	0.00
11 Jul 06	0.0	2.96350536	75.8	1.50430642	0.00
12 Jul 06	0.0	1.29364981	76.5	0.63504749	0.00
13 Jul 06	0.0	3.62066984	78.2	1.75182452	0.00
14 Jul 06	0.0	4.33419099	80.2	2.01269072	0.00
15 Jul 06	0.0	3.84121925	81.9	1.69786481	0.00
16 Jul 06	0.0	4.35628291	83.8	1.84334711	0.00
17 Jul 06	0.0	4.97313897	85.8	2.00250975	0.00
18 Jul 06	0.0	3.7489927	87.2	1.42617322	0.00
19 Jul 06	0.0	3.96180517	88.6	1.44435005	0.00
20 Jul 06	0.0	2.93663874	89.7	1.02347833	0.00
21 Jul 06	0.0	3.41936809	90.8	1.15283434	0.00
22 Jul 06	0.0	2.75474545	91.7	0.89347163	0.00
23 Jul 06	0.0	3.20988487	92.7	1.00922512	0.00
24 Jul 06	0.0	4.35654831	94.0	1.32089679	0.00
25 Jul 06	0.8	4.38512167	94.5	1.26520136	0.00
26 Jul 06	0.0	3.3982622	95.5	0.96290601	0.00
27 Jul 06	0.0	4.18424081	96.6	1.14084799	0.00
28 Jul 06	7.2	1.70292824	89.8	0.44272291	0.00
29 Jul 06	7.6	1.6769379	82.8	0.56187194	0.00
30 Jul 06	10.0	2.63444139	73.9	1.08870849	0.00
31 Jul 06	3.0	1.13157591	71.5	0.57967699	0.00
01 Aug 06	0.0	3.07522436	73.1	1.65805808	0.00
02 Aug 06	0.0	3.29119134	74.8	1.71386706	0.00
03 Aug 06	0.0	3.44613641	76.6	1.72892907	0.00
04 Aug 06	0.0	0.99743487	77.1	0.48125273	0.00
05 Aug 06	0.0	2.64603644	78.3	1.26253811	0.00
06 Aug 06	3.2	0.92943897	75.6	0.43043706	0.00
07 Aug 06	0.0	2.87879588	77.0	1.42180231	0.00
08 Aug 06	0.0	1.608621	77.7	0.76906569	0.00
09 Aug 06	0.2	2.33398336	78.6	1.09590992	0.00
10 Aug 06	0	0.81502223	79.0	0.37457632	0.00
11 Aug 06	0.2	1.98498589	79.7	0.90401886	0.00

12 Aug 06	0	2.20526225	80.7	0.98708845	0.00
13 Aug 06	0	1.80149522	81.5	0.78660177	0.00
14 Aug 06	0	1.68208967	82.2	0.71976324	0.00
15 Aug 06	13	0.21557894	69.3	0.09052179	0.00
16 Aug 06	1.2	1.39147346	68.9	0.78387201	0.00
17 Aug 06	3	2.43389725	67.3	1.38236402	0.00
18 Aug 06	1.6	1.97422525	66.8	1.15677145	0.00
19 Aug 06	11.8	0.821095	55.5	0.48515357	0.00
20 Aug 06	1.8	2.43884286	55.5	1.74763136	0.00
21 Aug 06	0.6	2.74638481	56.8	1.96960849	0.00
22 Aug 06	0	2.03702412	58.3	1.42988133	0.00
23 Aug 06	1	2.00383064	58.6	1.37474529	0.00
24 Aug 06	0	2.59120364	60.4	1.76692825	0.00
25 Aug 06	4.8	0.4770031	55.9	0.31590114	0.00
26 Aug 06	0	2.04888185	57.4	1.4589792	0.00
27 Aug 06	4.4	1.99396898	54.4	1.38755254	0.00
28 Aug 06	0.6	1.78470008	55.1	1.30166445	0.00
29 Aug 06	0.2	2.05572103	56.3	1.48330562	0.00
30 Aug 06	1.4	1.91930377	56.3	1.35750649	0.00
31 Aug 06	5	1.09891064	52.1	0.77776857	0.00
01 Sep 06	0.8	2.14523282	52.9	1.61895773	0.00
02 Sep 06	26.4	2.53355741	28.4	1.88896316	0.00
03 Sep 06	1	1.36031366	28.7	1.36031366	0.00
04 Sep 06	9.8	2.08972483	21.0	2.08972483	0.00
05 Sep 06	0.2	1.23365692	22.1	1.23365692	0.00
06 Sep 06	1.2	2.71314148	23.6	2.71314148	0.00
07 Sep 06	0	1.72668613	25.3	1.72668613	0.00
08 Sep 06	0	1.52616683	26.8	1.52616683	0.00
09 Sep 06	0.2	1.94552347	28.6	1.94552347	0.00
10 Sep 06	0	1.35638185	29.9	1.35638185	0.00
11 Sep 06	21	0.91165234	9.9	0.91165234	0.00
12 Sep 06	3	0.17195894	7.0	0.17195894	0.00
13 Sep 06	8.2	1.15756503	0.0	1.15756503	0.02
14 Sep 06	0.2	0.25043174	0.1	0.25043174	0.00
15 Sep 06	0	1.70862662	1.8	1.70862662	0.00
16 Sep 06	0	1.72150384	3.5	1.72150384	0.00
17 Sep 06	1.2	1.63869142	3.9	1.63869142	0.00
18 Sep 06	5.2	1.70895002	0.4	1.70895002	0.00
19 Sep 06	0	0.33653247	0.8	0.33653247	0.00
20 Sep 06	26.6	1.53557371	0.0	1.53557371	24.30
21 Sep 06	6.6	0.0036426	0.0	0.0036426	6.60
22 Sep 06	1.4	1.34494475	0.0	1.34494475	0.06

23 Sep 06	2.4	1.091327604	0.0	1.0913276	1.31
24 Sep 06	5.4	0.332926521	0.0	0.33292652	5.07
25 Sep 06	7	0.410719822	0.0	0.41071982	6.59
26 Sep 06	0.2	0.763272445	0.6	0.76327244	0.00
27 Sep 06	13.6	0.728221441	0.0	0.72822144	12.31
28 Sep 06	0	0.000000000	0.0	0	0.00
29 Sep 06	2.6	0.660254201	0.0	0.6602542	1.94
30 Sep 06	5.6	1.421673765	0.0	1.42167376	4.18
01 Oct 06	25.8	0.000000000	0.0	0	25.80
02 Oct 06	0.2	0.935220297	0.7	0.9352203	0.00
03 Oct 06	0	0.919380382	1.7	0.91938038	0.00
04 Oct 06	2.4	0.88958601	0.1	0.88958601	0.00
05 Oct 06	8.8	0.90558365	0.0	0.90558365	7.75
06 Oct 06	1	0.07684285	0.0	0.07684285	0.92
07 Oct 06	0	0.22534566	0.2	0.22534566	0.00
08 Oct 06	28	0.50921748	0.0	0.50921748	27.27
09 Oct 06	3.8	0.15281232	0.0	0.15281232	3.65
10 Oct 06	8.6	0.67596829	0.0	0.67596829	7.92
11 Oct 06	20.4	0.99622091	0.0	0.99622091	19.40
12 Oct 06	0.2	0.76738157	0.6	0.76738157	0.00
13 Oct 06	0.2	0.53186096	0.9	0.53186096	0.00
14 Oct 06	0	0.40709947	1.3	0.40709947	0.00
15 Oct 06	0	0.86584565	2.2	0.86584565	0.00
16 Oct 06	0.6	0.35638436	1.9	0.35638436	0.00
17 Oct 06	12	0.13545174	0.0	0.13545174	9.94
18 Oct 06	0	0	0.0	0	0.00
19 Oct 06	14.4	0.24894308	0.0	0.24894308	14.15
20 Oct 06	0.2	0	0.0	0	0.20
21 Oct 06	13.8	0.17548433	0.0	0.17548433	13.62
22 Oct 06	0.2	0.3541016	0.2	0.3541016	0.00
23 Oct 06	0	0.12215908	0.3	0.12215908	0.00
24 Oct 06	0	0.18689217	0.5	0.18689217	0.00
25 Oct 06	57.6	0.69383396	0.0	0.69383396	56.44
26 Oct 06	1.6	0	0.0	0	1.60
27 Oct 06	1.6	0.86245557	0.0	0.86245557	0.74
28 Oct 06	1	0.16951273	0.0	0.16951273	0.83
29 Oct 06	0	0	0.0	0	0.00
30 Oct 06	0.2	0.00750229	0.0	0.00750229	0.19
31 Oct 06	0	0.03121488	0.0	0.03121488	0.00
01 Nov 06	0	0.53624313	0.6	0.53624313	0.00
02 Nov 06	0	0.14930134	0.7	0.14930134	0.00
03 Nov 06	0	0.13648108	0.9	0.13648108	0.00

04 Nov 06	0	0	0.9	0	0.00
05 Nov 06	0.2	0.06697026	0.7	0.06697026	0.00
06 Nov 06	0.2	0.06846211	0.6	0.06846211	0.00
07 Nov 06	0.2	0.05224004	0.4	0.05224004	0.00
08 Nov 06	1.8	0.15368514	0.0	0.15368514	1.21
09 Nov 06	0	0	0.0	0	0.00
10 Nov 06	5	0	0.0	0	5.00
11 Nov 06	0.2	0	0.0	0	0.20
12 Nov 06	0.2	0.05570493	0.0	0.05570493	0.14
13 Nov 06	0.8	0.20551624	0.0	0.20551624	0.59
14 Nov 06	0.2	0.15546279	0.0	0.15546279	0.04
15 Nov 06	39.8	0	0.0	0	39.80
16 Nov 06	3.8	0	0.0	0	3.80
17 Nov 06	1.4	0	0.0	0	1.40
18 Nov 06	0.8	0	0.0	0	0.80
19 Nov 06	1	0	0.0	0	1.00
20 Nov 06	1	0	0.0	0	1.00
21 Nov 06	0.6	0	0.0	0	0.60
22 Nov 06	0.4	0.08062479	0.0	0.08062479	0.32
23 Nov 06	1.8	0	0.0	0	1.80
24 Nov 06	14	0	0.0	0	14.00
25 Nov 06	0	0	0.0	0	0.00
26 Nov 06	8	0	0.0	0	8.00
27 Nov 06	16.4	0	0.0	0	16.40
28 Nov 06	1.4	0	0.0	0	1.40
29 Nov 06	0.4	0	0.0	0	0.40
30 Nov 06	38.6	0	0.0	0	38.60
01 Dec 06	3.6	0	0.0	0	3.60
02 Dec 06	12.6	0	0.0	0	12.60
03 Dec 06	17.0	0	0.0	0	17.00
04 Dec 06	6.4	0	0.0	0	6.40
05 Dec 06	7.0	0	0.0	0	7.00
06 Dec 06	5.0	0	0.0	0	5.00
07 Dec 06	4.0	0	0.0	0	4.00
08 Dec 06	0.0	0	0.0	0	0.00
09 Dec 06	0.0	0	0.0	0	0.00
10 Dec 06	11.6	0	0.0	0	11.60
11 Dec 06	5.0	0	0.0	0	5.00
12 Dec 06	5.8	0	0.0	0	5.80
13 Dec 06	0.2	0	0.0	0	0.20
14 Dec 06	0.2	0.16960025	0.0	0.16960025	0.03
15 Dec 06	13.4	0.06617251	0.0	0.06617251	13.33

16 Dec 06	0.4	0	0.0	0	0.40
17 Dec 06	0.4	0	0.0	0	0.40
18 Dec 06	0.0	0	0.0	0	0.00
19 Dec 06	0.2	0.04269162	0.0	0.04269162	0.16
20 Dec 06	0.2	0.04864702	0.0	0.04864702	0.15
21 Dec 06	0.0	0	0.0	0	0.00
22 Dec 06	0.2	0	0.0	0	0.20
23 Dec 06	0.2	0	0.0	0	0.20
24 Dec 06	0.0	0	0.0	0	0.00
25 Dec 06	0.4	0.07338233	0.0	0.07338233	0.33
26 Dec 06	0.4	0	0.0	0	0.40
27 Dec 06	13.0	0	0.0	0	13.00
28 Dec 06	2.4	0	0.0	0	2.40
29 Dec 06	26.0	0	0.0	0	26.00
30 Dec 06	1.2	0	0.0	0	1.20
31 Dec 06	6.2	0	0.0	0	6.20
01 Jan 07	2.0	0.21501385	0.0	0.21501385	1.78
02 Jan 07	0.2	0	0.0	0	0.20
03 Jan 07	4.0	0	0.0	0	4.00
04 Jan 07	0.0	0.08611809	0.1	0.08611809	0.00
05 Jan 07	0.2	0.11039055	0.0	0.11039055	0.00
06 Jan 07	5.2	0	0.0	0	5.20
07 Jan 07	4.8	0	0.0	0	4.80
08 Jan 07	6.0	0	0.0	0	6.00
09 Jan 07	3.2	0	0.0	0	3.20
10 Jan 07	4.6	0.13828275	0.0	0.13828275	4.46
11 Jan 07	7.4	0	0.0	0	7.40
12 Jan 07	0.2	0.22085174	0.0	0.22085174	0.00
13 Jan 07	1.2	0.30875891	0.0	0.30875891	0.87
14 Jan 07	0.0	0.25178029	0.3	0.25178029	0.00
15 Jan 07	2.2	0.23311722	0.0	0.23311722	1.72
16 Jan 07	3.2	0.07480682	0.0	0.07480682	3.13
17 Jan 07	2.0	0.94352743	0.0	0.94352743	1.06
18 Jan 07	15.6	0	0.0	0	15.60
19 Jan 07	1.0	0.5931051	0.0	0.5931051	0.41
20 Jan 07	2.6	0.27791953	0.0	0.27791953	2.32
21 Jan 07	1.4	0.67003737	0.0	0.67003737	0.73
22 Jan 07	5.6	0	0.0	0	5.60
23 Jan 07	0.2	4.44172549	4.2	4.44172549	0.00
24 Jan 07	0.0	1.93787785	6.2	1.93787785	0.00
25 Jan 07	0.0	0	6.2	0	0.00
26 Jan 07	0.0	0.32015958	6.5	0.32015958	0.00

27 Jan 07	0.0	0.10746116	6.6	0.10746116	0.00
28 Jan 07	0.0	0.12178265	6.7	0.12178265	0.00
29 Jan 07	0.0	0.10279894	6.8	0.10279894	0.00
30 Jan 07	0.0	0.16924766	7.0	0.16924766	0.00
31 Jan 07	0.0	0.09946088	7.1	0.09946088	0.00
01 Feb 07	0.0	0.02102969	7.1	0.02102969	0.00
02 Feb 07	0.2	1.28722488	8.2	1.28722488	0.00
03 Feb 07	0.2	0.054	8.1	0.05351143	0.00
04 Feb 07	0.2	0.000	7.9	0	0.00
05 Feb 07	0.0	0.113	8.0	0.1132418	0.00
06 Feb 07	0.0	0.000	8.0	0	0.00
07 Feb 07	1.0	0.000	7.0	0	0.00
08 Feb 07	14.2	0.000	0.0	0	7.22
09 Feb 07	4.6	0.000	0.0	0	4.60
10 Feb 07	8.8	0.000	0.0	0	8.80
11 Feb 07	4.4	0.000	0.0	0	4.40
12 Feb 07	4.0	0.075	0.0	0.07472687	3.93
13 Feb 07	6.0	0.000	0.0	0	6.00
14 Feb 07	0.0	0.055	0.1	0.05452487	0.00
15 Feb 07	6.4	0.000	0.0	0	6.35
16 Feb 07	0.4	0.021	0.0	0.02103647	0.38
17 Feb 07	0.0	0.060	0.1	0.06007109	0.00
18 Feb 07	0.2	0.073	0.0	0.07341466	0.07
19 Feb 07	12.0	0.000	0.0	0	12.00
20 Feb 07	1.6	0.045	0.0	0.04494124	1.56
21 Feb 07	11.0	0.056	0.0	0.05602246	10.94
22 Feb 07	6.2	0.042	0.0	0.04154166	6.16
23 Feb 07	5.2	0.000	0.0	0	5.20
24 Feb 07	1.4	0.031	0.0	0.03134952	1.37
25 Feb 07	0.0	0.132	0.1	0.13185412	0.00
26 Feb 07	3.8	0.115	0.0	0.11539733	3.55
27 Feb 07	6.6	0.106	0.0	0.10583413	6.49
28 Feb 07	2.6	0.196	0.0	0.1961806	2.40
01 Mar 07	0.0	0.262	0.3	0.26193819	0.00
02 Mar 07	29.2	0.000	0.0	0	28.94
03 Mar 07	2.0	0.142	0.0	0.14183795	1.86
04 Mar 07	18.8	0.000	0.0	0	18.80
05 Mar 07	20.6	0.000	0.0	0	20.60
06 Mar 07	3.6	0.142	0.0	0.14162107	3.46
07 Mar 07	0.2	0.127	0.0	0.12711443	0.07
08 Mar 07	3.8	0.021	0.0	0.02126919	3.78
09 Mar 07	0.0	0.204	0.2	0.20360486	0.00

10 Mar 07	0.0	0.133	0.3	0.13335372	0.00
11 Mar 07	1.0	0.077	0.0	0.07710239	0.59
12 Mar 07	2.2	0.180	0.0	0.17978084	2.02
13 Mar 07	0.0	0.109	0.1	0.10850425	0.00
14 Mar 07	0.0	0.080	0.2	0.07962945	0.00
15 Mar 07	0	0.152	0.3	0.15156015	0.00
16 Mar 07	0.8	0.109	0.0	0.1094486	0.35
17 Mar 07	0.6	0.174	0.0	0.17353654	0.43
18 Mar 07	2.6	0.874	0.0	0.87350515	1.73
19 Mar 07	1.4	0.751	0.0	0.75125743	0.65
20 Mar 07	0	0.583	0.6	0.58333988	0.00
21 Mar 07	5	0.461	0.0	0.46144993	3.96
22 Mar 07	0.8	0.099	0.0	0.0985885	0.70
23 Mar 07	0	0.109	0.1	0.10931267	0.00
24 Mar 07	0	0.086	0.2	0.08561924	0.00
25 Mar 07	0	0.102	0.3	0.10245	0.00
26 Mar 07	0	0.045	0.3	0.0453463	0.00
27 Mar 07	0	0.040	0.4	0.03995995	0.00
28 Mar 07	0.6	0.129	0.0	0.12914702	0.09
29 Mar 07	3.2	0.273	0.0	0.27342164	2.93
30 Mar 07	0	0.082	0.1	0.0824962	0.00
31 Mar 07	0	0.130	0.2	0.12985885	0.00
01 Apr 07	0	0.146	0.4	0.14598535	0.00
02 Apr 07	0	0.204	0.6	0.20382265	0.00
03 Apr 07	0	0.167	0.7	0.16691395	0.00
04 Apr 07	0	0.130	0.9	0.12971722	0.00
05 Apr 07	0	0.098	1.0	0.09830276	0.00
06 Apr 07	0	0.093	1.0	0.09253813	0.00
07 Apr 07	0	0.103	1.2	0.10315832	0.00
08 Apr 07	0	0.146	1.3	0.14595487	0.00
09 Apr 07	0	0.116	1.4	0.11557462	0.00
10 Apr 07	0	0.084	1.5	0.08356335	0.00
11 Apr 07	0	0.134	1.6	0.13432697	0.00
12 Apr 07	0	0.139	1.8	0.13912416	0.00
13 Apr 07	0	0.094	1.9	0.0938689	0.00
14 Apr 07	0	0.066	1.9	0.06606439	0.00
15 Apr 07	0	0.053	2.0	0.05339535	0.00
16 Apr 07	0	0.092	2.1	0.09159085	0.00
17 Apr 07	0	0.092	2.2	0.09232568	0.00
18 Apr 07	0	0.144	2.3	0.1436231	0.00
19 Apr 07	0	0.107	2.4	0.10687712	0.00
20 Apr 07	0	0.065	2.5	0.06539705	0.00

21 Apr 07	0	0.120	2.6	0.11978784	0.00
22 Apr 07	2.2	0.086	0.5	0.08613288	0.00
23 Apr 07	8.2	0.057	0.0	0.05707563	7.65
24 Apr 07	13.8	0.066	0.0	0.06603494	13.73
25 Apr 07	1.6	0.123	0.0	0.1228863	1.48
26 Apr 07	0	0.093	0.1	0.09301868	0.00
27 Apr 07	0.8	0.097	0.0	0.09699539	0.61
28 Apr 07	0	0.065	0.1	0.06506404	0.00
29 Apr 07	0	0.081	0.1	0.0810388	0.00
30 Apr 07	0.8	0.098	0.0	0.09774799	0.56
01 May 07	0	0.085	0.1	0.08452659	0.00
02 May 07	0	0.097	0.2	0.09665847	0.00
03 May 07	0	0.154	0.3	0.15440364	0.00
04 May 07	0	0.086	0.4	0.0863597	0.00
05 May 07	0	0.108	0.5	0.10792432	0.00
06 May 07	0	0.117	0.6	0.11659117	0.00
07 May 07	2.4	0.218	0.0	0.21830248	1.54
08 May 07	0.2	0.217	0.0	0.21680862	0.00
09 May 07	2.4	0.092	0.0	0.09159028	2.29
10 May 07	0	0.238	0.2	0.23782745	0.00
11 May 07	8.8	0.168	0.0	0.16772408	8.39
12 May 07	0.6	0.070	0.0	0.07040384	0.53
13 May 07	0.8	0.072	0.0	0.07164605	0.73
14 May 07	0.4	0.171	0.0	0.17070612	0.23
15 May 07	2.6	0.051	0.0	0.05054517	2.55
16 May 07	2	0.062	0.0	0.06197974	1.94
17 May 07	0	0.122	0.1	0.12237961	0.00
18 May 07	0.8	0.231	0.0	0.23129551	0.45
19 May 07	0.6	0.297	0.0	0.29656526	0.30
20 May 07	0	0.140	0.1	0.14042767	0.00
21 May 07	0	0.146	0.3	0.14568699	0.00
22 May 07	0	0.106	0.4	0.10552341	0.00
23 May 07	0.6	0.087	0.0	0.08726965	0.12
24 May 07	0	0.068	0.1	0.06823006	0.00
25 May 07	0	0.137	0.2	0.13664216	0.00
26 May 07	11.2	0.641	0.0	0.64081329	10.35
27 May 07	9.4	0.437	0.0	0.43654874	8.96
28 May 07	1.4	0.222	0.0	0.22160754	1.18
29 May 07	0.0	0.200	0.2	0.19955257	0.00
30 May 07	0.6	0.091	0.0	0.09105791	0.31
31 May 07	0.2	0.107	0.0	0.10696294	0.09
01 Jun 07	0.4	0.094	0.0	0.0935827	0.31

02 Jun 07	1.0	0.024	0.0	0.02405557	0.98
03 Jun 07	1.4	0.016	0.0	0.01587078	1.38
04 Jun 07	1.2	0.057	0.0	0.05657895	1.14
05 Jun 07	0.4	0.059	0.0	0.05886578	0.34
06 Jun 07	0.0	0.057	0.1	0.05714033	0.00
07 Jun 07	0.0	0.065	0.1	0.06523335	0.00
08 Jun 07	0.0	0.087	0.2	0.08709885	0.00
09 Jun 07	0.0	0.072	0.3	0.0716757	0.00
10 Jun 07	0.0	0.074	0.4	0.07433991	0.00
11 Jun 07	0.0	0.051	0.4	0.05077424	0.00
12 Jun 07	0.0	0.083	0.5	0.08345418	0.00
13 Jun 07	0.0	0.031	0.5	0.03067102	0.00
14 Jun 07	0.0	0.015	0.5	0.01514887	0.00
15 Jun 07	24.4	0.034	0.0	0.03352459	23.83
16 Jun 07	3.6	0.024	0.0	0.0238113	3.58
17 Jun 07	0.2	0.053	0.0	0.05330247	0.15
18 Jun 07	0.0	0.038	0.0	0.03797311	0.00
19 Jun 07	22.6	0.140	0.0	0.13995499	22.42
20 Jun 07	5.6	0.108	0.0	0.10820582	5.49
21 Jun 07	11.6	0.121	0.0	0.12077075	11.48
22 Jun 07	3.2	0.068	0.0	0.06814225	3.13
23 Jun 07	1.4	0.113	0.0	0.11311467	1.29
24 Jun 07	10.6	0.241	0.0	0.24111373	10.36
25 Jun 07	1.2	0.100	0.0	0.09982998	1.10
26 Jun 07	0.8	0.183	0.0	0.18259138	0.62
27 Jun 07	0.6	0.180	0.0	0.18042575	0.42
28 Jun 07	0.4	0.059	0.0	0.05906412	0.34
29 Jun 07	0.2	0.101	0.0	0.10086626	0.10
30 Jun 07	0.4	0.047	0.0	0.04720204	0.35
01 Jul 07	0.8	0.072	0.0	0.07210097	0.73
02 Jul 07	0.8	0.10434131	0.0	0.10434131	0.70
03 Jul 07	0.4	0.10298233	0.0	0.10298233	0.30
04 Jul 07	0.4	0.12735079	0.0	0.12735079	0.27
05 Jul 07	0.4	0.07885144	0.0	0.07885144	0.32
06 Jul 07	0.2	0.15148365	0.0	0.15148365	0.05
07 Jul 07	0.4	0.15042031	0.0	0.15042031	0.25
08 Jul 07	0.0	0.06902354	0.1	0.06902354	0.00
09 Jul 07	0.2	0.07204613	0.0	0.07204613	0.06
10 Jul 07	0.0	0.07556493	0.1	0.07556493	0.00
11 Jul 07	0.0	0.04999133	0.1	0.04999133	0.00
12 Jul 07	0.0	0.07721505	0.2	0.07721505	0.00
13 Jul 07	0.0	0.01536491	0.2	0.01536491	0.00

14 Jul 07	0.0	0.09847581	0.3	0.09847581	0.00
15 Jul 07	3.2	0.11140244	0.0	0.11140244	2.77
16 Jul 07	5.8	0.17209483	0.0	0.17209483	5.63
17 Jul 07	3.6	0.09578724	0.0	0.09578724	3.50
18 Jul 07	2.8	0.13916115	0.0	0.13916115	2.66
19 Jul 07	0.6	0.09515068	0.0	0.09515068	0.50
20 Jul 07	8.4	0.03715435	0.0	0.03715435	8.36
21 Jul 07	2.2	0.04217437	0.0	0.04217437	2.16
22 Jul 07	2.8	0.076811	0.0	0.076811	2.72
23 Jul 07	1	0.03407937	0.0	0.03407937	0.97
24 Jul 07	0	0.13056792	0.1	0.13056792	0.00
25 Jul 07	0	0.12190419	0.3	0.12190419	0.00
26 Jul 07	0	0.13934457	0.4	0.13934457	0.00
27 Jul 07	0	0.18118783	0.6	0.18118783	0.00
28 Jul 07	0	0.08548215	0.7	0.08548215	0.00
29 Jul 07	0	0.08568799	0.7	0.08568799	0.00
30 Jul 07	0.2	0.13949921	0.7	0.13949921	0.00
31 Jul 07	0.2	0.15152809	0.6	0.15152809	0.00
01 Aug 07	0	0.09567181	0.7	0.09567181	0.00
02 Aug 07	1.2	0.11202183	0.0	0.11202183	0.36
03 Aug 07	2.8	0.11620564	0.0	0.11620564	2.68
04 Aug 07	0	0.09280208	0.1	0.09280208	0.00
05 Aug 07	0	0.03602114	0.1	0.03602114	0.00
06 Aug 07	3.4	0.09272227	0.0	0.09272227	3.18
07 Aug 07	4.8	0.11441555	0.0	0.11441555	4.69
08 Aug 07	1.8	0.1072275	0.0	0.1072275	1.69
09 Aug 07	2.8	0.06994266	0.0	0.06994266	2.73
10 Aug 07	0.2	0.05201455	0.0	0.05201455	0.15
11 Aug 07	2.2	0.0127635	0.0	0.0127635	2.19
12 Aug 07	8.8	0.10515888	0.0	0.10515888	8.69
13 Aug 07	0.6	0.1441034	0.0	0.1441034	0.46
14 Aug 07	27.4	0.04051821	0.0	0.04051821	27.36
15 Aug 07	14	0.1075731	0.0	0.1075731	13.89
16 Aug 07	0	0.17146332	0.2	0.17146332	0.00
17 Aug 07	4	0.06409683	0.0	0.06409683	3.76
18 Aug 07	11.2	0.0452078	0.0	0.0452078	11.15
19 Aug 07	0	0.23274553	0.2	0.23274553	0.00
20 Aug 07	12.4	0.05825469	0.0	0.05825469	12.11
21 Aug 07	0.4	0.06553103	0.0	0.06553103	0.33
22 Aug 07	0	0.04548532	0.0	0.04548532	0.00
23 Aug 07	0	0.05200241	0.1	0.05200241	0.00
24 Aug 07	0	0.05752957	0.2	0.05752957	0.00

25 Aug 07	0	0.08582091	0.2	0.08582091	0.00
26 Aug 07	0	0.07567097	0.3	0.07567097	0.00
27 Aug 07	0	0.06613273	0.4	0.06613273	0.00
28 Aug 07	0	0.06169478	0.4	0.06169478	0.00
29 Aug 07	0	0.09920923	0.5	0.09920923	0.00
30 Aug 07	0	0.13127423	0.7	0.13127423	0.00
31 Aug 07	0	0.09651475	0.8	0.09651475	0.00
01 Sep 07	0	0.09896382	0.9	0.09896382	0.00
02 Sep 07	1.6	0.07695367	0.0	0.07695367	0.65
03 Sep 07	0	0.09164438	0.1	0.09164438	0.00
04 Sep 07	0	0.0493274	0.1	0.0493274	0.00
05 Sep 07	0	0.05960215	0.2	0.05960215	0.00
06 Sep 07	0	0.03373391	0.2	0.03373391	0.00
07 Sep 07	0	0.05552839	0.3	0.05552839	0.00
08 Sep 07	0	0.04300016	0.3	0.04300016	0.00
09 Sep 07	0	0.05376525	0.4	0.05376525	0.00
10 Sep 07	0	0.11192041	0.5	0.11192041	0.00
11 Sep 07	0	0.03882384	0.5	0.03882384	0.00
12 Sep 07	0	0.04688761	0.6	0.04688761	0.00
13 Sep 07	0	0.0539639	0.6	0.0539639	0.00
14 Sep 07	0.2	0.11875076	0.6	0.11875076	0.00
15 Sep 07	0	0.11118111	0.7	0.11118111	0.00
16 Sep 07	1	0.11986819	0.0	0.11986819	0.21
17 Sep 07	0.2	0.12815438	0.0	0.12815438	0.07
18 Sep 07	0	0.16225678	0.2	0.16225678	0.00
19 Sep 07	4.2	0.08591038	0.0	0.08591038	3.95
20 Sep 07	1.2	0.06663434	0.0	0.06663434	1.13
21 Sep 07	25.2	0.03647533	0.0	0.03647533	25.16
22 Sep 07	0	0.07526718	0.1	0.07526718	0.00
23 Sep 07	7.8	0.0814355	0.0	0.0814355	7.64
24 Sep 07	3.8	0.16514971	0.0	0.16514971	3.63
25 Sep 07	0	0.16521798	0.2	0.16521798	0.00
26 Sep 07	0	0.16095722	0.3	0.16095722	0.00
27 Sep 07	0	0.10258212	0.4	0.10258212	0.00
28 Sep 07	1.4	0.04849828	0.0	0.04849828	0.92
29 Sep 07	0.6	0.02502109	0.0	0.02502109	0.57
30 Sep 07	0.4	0.04693608	0.0	0.04693608	0.35
01 Oct 07	0.4	0.05820872	0.0	0.05820872	0.34
02 Oct 07	1	0.02779638	0.0	0.02779638	0.97
03 Oct 07	6.4	0.05094841	0.0	0.05094841	6.35
04 Oct 07	0	0.05010374	0.1	0.05010374	0.00
05 Oct 07	0	0.03345458	0.1	0.03345458	0.00

06 Oct 07	0.2	0.03466482	0.0	0.03466482	0.08
07 Oct 07	0	0.02842781	0.0	0.02842781	0.00
08 Oct 07	1.4	0.01942838	0.0	0.01942838	1.35
09 Oct 07	5.8	0.07026542	0.0	0.07026542	5.73
10 Oct 07	0	0.05060393	0.1	0.05060393	0.00
11 Oct 07	0	0.03938168	0.1	0.03938168	0.00

12 Oct 07	0.4	0.03459266	0.0	0.03459266	0.28
13 Oct 07	0	0.04863803	0.0	0.04863803	0.00
14 Oct 07	0	0.04660224	0.1	0.04660224	0.00
15 Oct 07	0.2	0.0459049	0.0	0.0459049	0.06
16 Oct 07	2	0.06731349	0.0	0.06731349	1.93
17 Oct 07	0	0.05710271	0.1	0.05710271	0.00
18 Oct 07	0	0.03439967	0.1	0.03439967	0.00
19 Oct 07	0	0.03018638	0.1	0.03018638	0.00
20 Oct 07	0	0.02994287	0.2	0.02994287	0.00
21 Oct 07	0.2	0.03321327	0.0	0.03321327	0.02
22 Oct 07	0.6	0.01667851	0.0	0.01667851	0.58
23 Oct 07	0	0.02768167	0.0	0.02768167	0.00
24 Oct 07	0.2	0.05131326	0.0	0.05131326	0.12
25 Oct 07	0	0.03568425	0.0	0.03568425	0.00
26 Oct 07	1.8	0.02115087	0.0	0.02115087	1.74
27 Oct 07	0	0.02692153	0.0	0.02692153	0.00
28 Oct 07	5.4	0.06832927	0.0	0.06832927	5.30
29 Oct 07	0.2	0.11456177	0.0	0.11456177	0.09
30 Oct 07	0	0.04932884	0.0	0.04932884	0.00
31 Oct 07	0	0.07820595	0.1	0.07820595	0.00
01 Nov 07	0	0.06165121	0.2	0.06165121	0.00
02 Nov 07	0	0.06701089	0.3	0.06701089	0.00
03 Nov 07	0.2	0.02428431	0.1	0.02428431	0.00
04 Nov 07	0	0.00987086	0.1	0.00987086	0.00
05 Nov 07	0	0.08744537	0.2	0.08744537	0.00
06 Nov 07	0	0.093688589	0.3	0.09368859	0.00
07 Nov 07	0	0.094052511	0.4	0.09405251	0.00
08 Nov 07	0.8	0.202866778	0.0	0.20286678	0.23
09 Nov 07	0	0.200228640	0.2	0.20022864	0.00
10 Nov 07	0	0.142633885	0.3	0.14263388	0.00
11 Nov 07	0.8	0.142688749	0.0	0.14268875	0.31
12 Nov 07	0	0.155851221	0.2	0.15585122	0.00
13 Nov 07	0	0.111405528	0.3	0.11140553	0.00
14 Nov 07	5.4	0.025366869	0.0	0.02536687	5.11
15 Nov 07	1.6	0.01716188	0.0	0.01716188	1.58
16 Nov 07	0	0.04117155	0.0	0.04117155	0.00
17 Nov 07	24	0.0435417	0.0	0.0435417	23.92
18 Nov 07	7.4	0.01456166	0.0	0.01456166	7.39
19 Nov 07	9.8	0.07939201	0.0	0.07939201	9.72
20 Nov 07	3.6	0.0353766	0.0	0.0353766	3.56
21 Nov 07	1.4	0.06597186	0.0	0.06597186	1.33
22 Nov 07	0	0.09818433	0.1	0.09818433	0.00
23 Nov 07	0.2	0	0.0	0	0.10
24 Nov 07	0.8	0.14115795	0.0	0.14115795	0.66
25 Nov 07	0	0.04723062	0.0	0.04723062	0.00
26 Nov 07	0	0.00881489	0.1	0.00881489	0.00
27 Nov 07	0	0.0270491	0.1	0.0270491	0.00
28 Nov 07	4.4	0.04338208	0.0	0.04338208	4.27
29 Nov 07	1.2	0.0500524	0.0	0.0500524	1.15
30 Nov 07	1.6	0.05065095	0.0	0.05065095	1.55
01 Dec 07	1.4	0.11295324	0.0	0.11295324	1.29
02 Dec 07	4.2	0.14489057	0.0	0.14489057	4.06
03 Dec 07	0	0.09376954	0.1	0.09376954	0.00

04 Dec 07	3.2	0.07818083	0.0	0.07818083	3.03
05 Dec 07	2.2	0.21539912	0.0	0.21539912	1.98
06 Dec 07	15.2	0.0906937	0.0	0.0906937	15.11
07 Dec 07	1.6	0.16622999	0.0	0.16622999	1.43
08 Dec 07	23.4	0.11302464	0.0	0.11302464	23.29
09 Dec 07	0.6	0.09438013	0.0	0.09438013	0.51
10 Dec 07	0	0	0.0	0	0.00
11 Dec 07	0.2	0	0.0	0	0.20
12 Dec 07	0	0.03125198	0.0	0.03125198	0.00
13 Dec 07	0	0.06312831	0.1	0.06312831	0.00
14 Dec 07	0	0	0.1	0	0.00
15 Dec 07	0	0.15190708	0.2	0.15190708	0.00
16 Dec 07	0	0.33483735	0.6	0.33483735	0.00
17 Dec 07	0	0	0.6	0	0.00
18 Dec 07	0	0	0.6	0	0.00
19 Dec 07	0	0	0.6	0	0.00
20 Dec 07	0	0	0.6	0	0.00
21 Dec 07	0.2	0	0.4	0	0.00
22 Dec 07	3.2	0	0.0	0	2.82
23 Dec 07	0.2	0	0.0	0	0.20
24 Dec 07	3.4	0	0.0	0	3.40
25 Dec 07	0.4	0	0.0	0	0.40
26 Dec 07	0	0	0.0	0	0.00
27 Dec 07	6	0	0.0	0	6.00
28 Dec 07	7.4	0	0.0	0	7.40
29 Dec 07	0.8	0	0.0	0	0.80
30 Dec 07	0.6	0	0.0	0	0.60
31 Dec 07	1.4	0.05566627	0.0	0.05566627	1.34
01 Jan 08	2.2	0	0.0	0	2.20
02 Jan 08	0	0.57229438	0.6	0.57229438	0.00
03 Jan 08	0	0.28762269	0.9	0.28762269	0.00
04 Jan 08	9.6	0	0.0	0	8.74
05 Jan 08	2.4	0	0.0	0	2.40
06 Jan 08	10.2	0	0.0	0	10.20
07 Jan 08	2	0	0.0	0	2.00
08 Jan 08	12.2	0	0.0	0	12.20
09 Jan 08	16.2	0	0.0	0	16.20
10 Jan 08	16.4	0	0.0	0	16.40
11 Jan 08	0	0	0.0	0	0.00
12 Jan 08	12.8	0	0.0	0	12.80
13 Jan 08	14.6	0	0.0	0	14.60
14 Jan 08	3.6	0	0.0	0	3.60
15 Jan 08	2.8	0	0.0	0	2.80
16 Jan 08	0.6	0	0.0	0	0.60
17 Jan 08	8.8	0	0.0	0	8.80
18 Jan 08	11.4	0.07099717	0.0	0.07099717	11.33
19 Jan 08	6	0	0.0	0	6.00
20 Jan 08	3.4	0	0.0	0	3.40
21 Jan 08	1.2	0.1102884	0.0	0.1102884	1.09
22 Jan 08	0.4	0	0.0	0	0.40
23 Jan 08	0.4	0.05101375	0.0	0.05101375	0.35
24 Jan 08	0	0	0.0	0	0.00
25 Jan 08	0.2	0.63503462	0.4	0.63503462	0.00

26 Jan 08	0.2	0.5743083	0.8	0.5743083	0.00
27 Jan 08	0	0.16251019	1.0	0.16251019	0.00
28 Jan 08	0	0	1.0	0	0.00
29 Jan 08	0.2	0	0.8	0	0.00
30 Jan 08	0	0	0.8	0	0.00
31 Jan 08	0	0.35121254	1.1	0.35121254	0.00
01 Feb 08	0	0	1.1	0	0.00
02 Feb 08	8	0	0.0	0	6.88
03 Feb 08	5.4	0	0.0	0	5.40
04 Feb 08	3.6	0	0.0	0	3.60
05 Feb 08	6.6	0	0.0	0	6.60
06 Feb 08	0.8	0.02282948	0.0	0.02282948	0.78
07 Feb 08	3.2	0.2114243	0.0	0.2114243	2.99
08 Feb 08	1.2	0	0.0	0	1.20
09 Feb 08	0.2	0	0.0	0	0.20
10 Feb 08	0	0	0.0	0	0.00
11 Feb 08	0.2	0	0.0	0	0.20
12 Feb 08	0.2	0	0.0	0	0.20
13 Feb 08	0	0	0.0	0	0.00
14 Feb 08	0	0.08091894	0.1	0.08091894	0.00
15 Feb 08	0	0.22807855	0.3	0.22807855	0.00
16 Feb 08	0.4	0.20316891	0.1	0.20316891	0.00
17 Feb 08	0.6	0	0.0	0	0.49
18 Feb 08	0.2	0	0.0	0	0.20
19 Feb 08	0.4	0.23815065	0.0	0.23815065	0.16
20 Feb 08	0	0.11757262	0.1	0.11757262	0.00
21 Feb 08	0	0.47128048	0.6	0.47128048	0.00
22 Feb 08	0	0.74738362	1.3	0.74738362	0.00
23 Feb 08	0	0.49363899	1.8	0.49363899	0.00
24 Feb 08	0.6	0.22993664	1.5	0.22993664	0.00
25 Feb 08	0.4	0	1.1	0	0.00
26 Feb 08	0.4	0.60155451	1.3	0.60155451	0.00
27 Feb 08	0	0.43215213	1.7	0.43215213	0.00
28 Feb 08	0	0.35508286	2.0	0.35508286	0.00
29 Feb 08	0	0.10437257	2.2	0.10437257	0.00
01 Mar 08	0.4	0.56116868	2.3	0.56116868	0.00
02 Mar 08	0.6	0.69481137	2.4	0.69481137	0.00
03 Mar 08	1	0.0965126	1.5	0.0965126	0.00
04 Mar 08	0	0.45534657	2.0	0.45534657	0.00
05 Mar 08	0	0.6580434	2.6	0.6580434	0.00
06 Mar 08	1.6	0.69484408	1.7	0.69484408	0.00
07 Mar 08	1	0.49619415	1.2	0.49619415	0.00
08 Mar 08	0.8	0.75792281	1.2	0.75792281	0.00
09 Mar 08	3.2	0.59491058	0.0	0.59491058	1.44
10 Mar 08	17.6	0.31594335	0.0	0.31594335	17.28
11 Mar 08	1.2	0.88896564	0.0	0.88896564	0.31
12 Mar 08	1.2	0.95417697	0.0	0.95417697	0.25
13 Mar 08	0	0.27791664	0.3	0.27791664	0.00
14 Mar 08	0.4	0.36506968	0.2	0.36506968	0.00
15 Mar 08	7.6	0	0.0	0	7.36
16 Mar 08	6.8	0.36821141	0.0	0.36821141	6.43
17 Mar 08	0	0.69731676	0.7	0.69731676	0.00
18 Mar 08	0	0.73839414	1.4	0.73839414	0.00

19 Mar 08	0	0.81472449	2.3	0.81472449	0.00
20 Mar 08	0.2	0.31891408	2.4	0.31891408	0.00
21 Mar 08	0.8	1.09614669	2.7	1.09614669	0.00
22 Mar 08	0	0.96986878	3.6	0.96986878	0.00
23 Mar 08	1	0.95550871	3.6	0.95550871	0.00
24 Mar 08	0	0.78803211	4.4	0.78803211	0.00
25 Mar 08	0.6	0.65788976	4.4	0.65788976	0.00
26 Mar 08	0.6	0.76798118	4.6	0.76798118	0.00
27 Mar 08	1.8	1.39185255	4.2	1.39185255	0.00
28 Mar 08	13	0.75609126	0.0	0.75609126	8.05
29 Mar 08	6.2	0.03844796	0.0	0.03844796	6.16
30 Mar 08	1	1.03634605	0.0	1.03634605	0.00
31 Mar 08	9.6	1.15437479	0.0	1.15437479	8.41
01 Apr 08	1.2	1.7591996	0.6	1.7591996	0.00
02 Apr 08	0.2	1.27055428	1.6	1.27055428	0.00
03 Apr 08	0	1.90520047	3.5	1.90520047	0.00
04 Apr 08	0	1.07883714	4.6	1.07883714	0.00
05 Apr 08	0.4	1.08151042	5.3	1.08151042	0.00
06 Apr 08	0.6	0.90502622	5.6	0.90502622	0.00
07 Apr 08	2.6	0.84252443	3.8	0.84252443	0.00
08 Apr 08	0	0.9647138	4.8	0.9647138	0.00
09 Apr 08	0	1.42213803	6.2	1.42213803	0.00
10 Apr 08	5	1.13499329	2.4	1.13499329	0.00
11 Apr 08	4	1.14320202	0.0	1.14320202	0.49
12 Apr 08	1.4	0.18803534	0.0	0.18803534	1.21
13 Apr 08	2	0.95296284	0.0	0.95296284	1.05
14 Apr 08	0.2	1.71020023	1.5	1.71020023	0.00
15 Apr 08	0	1.41974355	2.9	1.41974355	0.00
16 Apr 08	0	1.31486815	4.2	1.31486815	0.00
17 Apr 08	0	0.94540756	5.2	0.94540756	0.00
18 Apr 08	0	0.86926451	6.1	0.86926451	0.00
19 Apr 08	2.6	1.27394408	4.7	1.27394408	0.00
20 Apr 08	0	0.42883954	5.2	0.42883954	0.00
21 Apr 08	0	1.15797144	6.3	1.15797144	0.00
22 Apr 08	4.2	2.16083133	4.3	2.16083133	0.00
23 Apr 08	0.4	1.69679071	5.6	1.69679071	0.00
24 Apr 08	7.6	1.53919092	0.0	1.53919092	0.48
25 Apr 08	2.8	0.75237442	0.0	0.75237442	2.05
26 Apr 08	6	2.16183104	0.0	2.16183104	3.84
27 Apr 08	2.2	2.23807292	0.0	2.23807292	0.00
28 Apr 08	1.2	1.31225796	0.2	1.31225796	0.00
29 Apr 08	0	1.017042	1.2	1.017042	0.00
30 Apr 08	0	1.06473724	2.2	1.06473724	0.00
01 May 08	0.6	1.71995347	3.4	1.71995347	0.00
02 May 08	0.4	1.11672168	4.1	1.11672168	0.00
03 May 08	0.4	2.396824783	6.1	2.39682478	0.00
04 May 08	2.4	2.261839086	5.9	2.26183909	0.00
05 May 08	0	2.744890229	8.7	2.74489023	0.00
06 May 08	0	2.677215005	11.3	2.677215	0.00
07 May 08	0	2.702831154	14.1	2.70283115	0.00
08 May 08	0	3.001497618	17.1	3.00149762	0.00
09 May 08	0.8	0.515728184	16.8	0.51572818	0.00
10 May 08	6	1.069788521	11.8	1.06978852	0.00

11 May 08	0	2.899825141	14.7	2.89982514	0.00
12 May 08	0	2.682582295	17.4	2.68258229	0.00
13 May 08	0	2.493404076	19.9	2.49340408	0.00
14 May 08	0	2.534921948	22.5	2.53492195	0.00
15 May 08	0	2.089413714	24.5	2.08941371	0.00
16 May 08	0	2.020246773	26.6	2.02024677	0.00
17 May 08	0	1.671805786	28.2	1.67180579	0.00
18 May 08	1.2	2.211843271	29.2	2.21184327	0.00
19 May 08	0	2.399147791	31.6	2.39914779	0.00
20 May 08	0	1.470937520	33.1	1.47093752	0.00
21 May 08	0.2	2.817608678	35.7	2.81760868	0.00
22 May 08	9.4	0.044033277	26.4	0.04403328	0.00
23 May 08	0.6	2.195599246	28.0	2.19559925	0.00
24 May 08	0.2	2.624994339	30.4	2.62499434	0.00
25 May 08	6	3.051880683	27.4	3.05188068	0.00
26 May 08	5	1.795697655	24.2	1.79569765	0.00
27 May 08	5.8	0.360367112	18.8	0.36036711	0.00
28 May 08	0	0.799701499	19.6	0.7997015	0.00
29 May 08	0	2.974442793	22.6	2.97444279	0.00
30 May 08	0.4	2.198881968	24.4	2.19888197	0.00
31 May 08	0	3.470269681	27.8	3.47026968	0.00
01 Jun 08	0	2.646505239	30.5	2.64650524	0.00
02 Jun 08	0	2.448510644	32.9	2.44851064	0.00
03 Jun 08	0	3.370541656	36.3	3.37054166	0.00
04 Jun 08	10.4	0.209208192	26.1	0.20920819	0.00
05 Jun 08	2	1.904501068	26.0	1.90450107	0.00
06 Jun 08	0.4	2.155180646	27.8	2.15518065	0.00
07 Jun 08	0	3.166638795	30.9	3.16663879	0.00
08 Jun 08	0	2.202494474	33.2	2.20249447	0.00
09 Jun 08	0	3.345313511	36.5	3.34531351	0.00
10 Jun 08	0	3.773557814	40.3	3.77355781	0.00
11 Jun 08	4.8	1.351641794	36.7	1.1974126	0.00
12 Jun 08	0.2	2.274527735	38.7	2.27452773	0.00

Site B - Meteorological Data

Date	Time	Windvelne	Solar Radiation	Temp	Hum Idity	Pressure	Net Rad.	Windspeed	Rainfall	J	Temp			Hum Idity			u_2	Δ	P	γ	A	B	C	D	$e^0(T_{max})$	$e^0(T_{min})$	e_s	e_a	$e_s - e_a$	$e^0{}_s$	d	d_r	w_s	Re	Re	Re	ET_o	E_o
		degrees	W/m²	C	%	mb	W/m²	m/s	mm		max	min	mean	max	min	mean	m/s	kPa/C	kPa	kPa/C	(1+0.34u_2)	Δ/Δ+γ(1+)	γ/Δ+γ(1+)	900/(Tm+273 *U	kPa	kPa	kPa	kPa	kPa	kPa	rad	rad	rad	mm/day	mm/day	mm/day	mm/day	mm/day
daily		average	average	average	average	average	average	average	sum		max	min	mean	max	min																						
01 Jul 06	00:00:00	176.90	223.74	17.15	81.755	1006.67	108.78	0.54	0.0	184	21.51	12.65	17.08	95.6	67.87		0.497	0.123	100.867	0.067	1.169	0.612	0.332	1.543	2.566	1.464	2.019	1.570	0.448	0.40	0.97	2.164	16.817	7.831	3.807	2.567	4.49
04 Jul 06	00:00:00	185.16	201.71	16.40	80.3	1006.65	173.21	0.53	0.0	185	20.63	11.94	16.285	96.4	64.2		0.480	0.118	100.865	0.067	1.163	0.602	0.342	1.483	2.431	1.397	1.914	1.464	0.450	0.40	0.97	2.161	16.787	7.060	6.042	3.887	3.69
05 Jul 06	00:00:00	159.56	182.52	16.97	76.155	1006.67	149.32	0.92	0.0	186	20.76	12.04	16.4	93.6	58.71		0.850	0.119	100.867	0.067	1.269	0.576	0.328	2.643	2.451	1.404	1.828	1.576	0.551	0.40	0.97	2.158	16.754	6.388	5.236	3.542	3.89
06 Jul 06	00:00:00	96.80	142.95	15.28	72.375	1006.63	112.19	1.38	0.0	187	20.61	9.31	14.96	91.8	52.95		1.272	0.110	100.863	0.067	1.453	0.533	0.326	3.976	2.426	1.172	1.800	1.191	0.619	0.40	0.97	2.155	16.719	5.003	3.927	2.896	4.23
07 Jul 06	00:00:00	84.90	138.14	14.71	66.62	1006.62	47.45	1.46	0.0	188	19.24	11.33	15.29	81.6	51.64		1.347	0.112	100.862	0.067	1.458	0.533	0.326	4.205	2.231	1.342	1.796	1.125	0.663	0.39	0.97	2.151	16.682	4.835	1.666	1.776	3.57
08 Jul 06	00:00:00	135.48	108.33	13.04	79.8	1006.58	31.42	1.02	12.7	189	14.92	11.45	13.19	95.7	63.9		0.943	0.099	100.858	0.067	1.321	0.526	0.357	2.965	1.897	1.253	1.522	1.169	0.355	0.39	0.97	2.148	16.642	3.792	1.100	0.936	2.21
09 Jul 06	00:00:00	97.54	216.58	13.45	75.715	1006.63	109.48	2.24	0.0	190	19.38	11.14	15.26	94.4	57.05		2.056	0.111	100.863	0.067	1.700	0.465	0.267	6.429	2.290	1.325	1.788	1.267	0.521	0.39	0.97	2.144	16.601	7.580	3.812	2.890	3.62
10 Jul 06	00:00:00	85.68	206.85	14.77	80.375	1006.62	114.55	1.14	0.0	191	21.14	9.16	15.15	100	60.75		1.047	0.111	100.862	0.067	1.356	0.550	0.333	3.269	2.508	1.161	1.829	1.542	0.462	0.39	0.97	2.145	16.557	7.229	4.004	2.737	4.34
11 Jul 06	00:00:00	88.86	236.79	14.76	75.725	1006.62	118.27	1.37	0.0	192	20.61	9.06	14.84	100	51.45		1.260	0.109	100.862	0.067	1.426	0.532	0.328	3.941	2.426	1.153	1.790	1.201	0.589	0.39	0.97	2.139	16.511	8.288	4.139	2.964	4.21
12 Jul 06	00:00:00	93.21	117.79	14.97	77.765	1006.62	58.94	1.19	0.0	193	19.96	10.73	15.35	95.7	61.83		1.094	0.112	100.862	0.067	1.372	0.549	0.328	5.415	2.332	1.289	1.811	1.325	0.486	0.39	0.97	2.131	16.463	4.125	1.368	1.294	3.81
13 Jul 06	00:00:00	189.32	340.04	13.68	70.855	1006.58	155.19	0.95	0.0	194	20.50	8.27	14.39	94.7	46.97		0.872	0.106	100.858	0.067	1.297	0.550	0.347	2.752	2.412	1.093	1.752	1.084	0.668	0.38	0.97	2.127	16.412	11.901	5.433	3.821	4.26
14 Jul 06	00:00:00	188.01	366.79	15.22	66.94	1006.63	167.61	1.14	0.0	195	24.94	6.27	15.61	96.5	37.58		1.046	0.114	100.863	0.067	1.357	0.556	0.333	3.271	3.156	0.913	2.054	1.053	1.001	0.38	0.97	2.122	16.360	12.818	5.886	4.334	5.43
15 Jul 06	00:00:00	175.84	358.88	16.06	66.52	1006.61	152.91	0.97	0.0	196	23.39	7.32	15.36	96.5	36.54		0.895	0.112	100.865	0.067	1.304	0.562	0.336	2.794	2.876	1.024	1.950	1.020	0.951	0.37	0.97	2.117	16.305	12.561	5.245	3.941	4.88
16 Jul 06	00:00:00	185.05	317.08	18.57	65.06	1006.70	157.75	0.95	0.0	197	27.67	9.07	18.37	95.7	34.46		0.874	0.132	100.870	0.067	1.297	0.604	0.305	2.698	3.706	1.154	2.481	1.191	1.290	0.37	0.97	2.112	16.249	11.098	5.521	4.356	5.80
17 Jul 06	00:00:00	181.16	350.96	20.93	61.25	1006.75	174.85	0.93	0.0	198	29.04	12.80	20.92	92.4	30.1		0.853	0.152	100.875	0.067	1.290	0.638	0.281	2.612	4.015	1.478	2.745	1.287	1.459	0.37	0.97	2.107	16.190	12.284	6.119	4.873	5.81
18 Jul 06	00:00:00	312.92	312.92	21.07	65.995	1006.75	123.05	0.99	0.0	199	29.53	10.52	20.05	94.5	33.29		0.833	0.145	100.875	0.067	1.282	0.626	0.290	2.548	4.130	1.271	2.703	1.288	1.413	0.37	0.97	2.101	16.130	10.952	4.506	3.749	6.12
19 Jul 06	00:00:00	167.71	256.46	21.84	63.29	1006.77	119.57	1.13	0.0	200	30.85	13.39	22.12	92.3	34.28		1.038	0.162	100.877	0.067	1.353	0.642	0.269	3.164	4.464	1.536	2.999	1.471	1.528	0.36	0.97	2.096	16.067	8.676	4.185	3.462	6.16
20 Jul 06	00:00:00	144.70	204.71	21.25	69.37	1006.76	104.77	0.66	0.0	201	26.56	17.06	21.81	88.5	50.24		0.804	0.160	100.876	0.067	1.205	0.664	0.274	1.843	3.474	1.842	2.710	1.733	0.976	0.36	0.97	2.090	16.002	7.165	3.667	2.837	4.49
21 Jul 06	00:00:00	161.21	245.63	19.27	72.28	1006.72	128.74	0.73	0.0	202	25.88	14.38	20.13	96.2	48.36		0.867	0.146	100.872	0.067	1.227	0.640	0.294	2.048	3.339	1.638	2.488	1.595	0.893	0.36	0.97	2.084	15.935	8.597	4.506	3.418	4.73
22 Jul 06	00:00:00	224.14	214.04	18.43	71.84	1006.70	98.84	0.85	0.0	203	24.74	14.01	19.38	96	47.68		0.796	0.140	100.870	0.067	1.260	0.624	0.296	2.356	3.119	1.600	2.356	1.511	0.846	0.35	0.97	2.078	15.867	7.491	3.459	2.755	4.44
23 Jul 06	00:00:00	84.42	219.46	17.40	70.14	1006.68	115.66	1.15	0.0	204	22.96	11.73	17.85	93.7	46.58		1.064	0.129	100.868	0.067	1.362	0.595	0.305	3.291	2.977	1.378	2.177	1.339	0.838	0.35	0.97	2.072	15.796	7.881	4.048	3.210	4.53
24 Jul 06	00:00:00	179.08	307.71	19.51	67.77	1006.72	166.68	0.87	0.0	205	25.55	14.21	19.67	89	46.54		0.802	0.144	100.872	0.067	1.265	0.624	0.296	2.464	3.286	1.612	2.349	1.462	0.888	0.35	0.97	2.069	15.724	10.776	5.814	4.357	4.98
25 Jul 06	00:00:00	165.44	309.33	20.15	67.955	1006.74	158.49	0.94	0.0	206	27.90	13.18	20.54	96.1	39.77		0.869	0.148	100.874	0.067	1.295	0.632	0.284	2.664	3.756	1.515	2.637	1.475	1.161	0.34	0.97	2.059	15.648	10.827	5.547	4.385	5.29
26 Jul 06	00:00:00	129.54	237.54	19.64	72.555	1006.72	125.59	0.98	0.0	207	25.02	14.39	19.71	95.6	49.51		0.900	0.142	100.872	0.067	1.306	0.620	0.291	2.788	3.172	1.640	2.400	1.569	0.857	0.34	0.97	2.052	15.573	8.514	4.396	3.398	4.39
27 Jul 06	00:00:00	156.38	262.71	19.15	68.075	1006.71	146.62	1.40	0.0	208	25.67	13.85	19.76	94.9	41.25		1.288	0.143	100.871	0.067	1.439	0.597	0.290	3.961	3.296	1.593	2.440	1.481	1.009	0.33	0.97	2.046	15.495	9.195	5.132	4.184	4.60
28 Jul 06	00:00:00	197.85	152.88	18.91	74.07	1006.71	58.52	0.89	0.0	209	23.54	14.07	18.57	89.8	53.44		0.821	0.141	100.871	0.067	1.345	0.626	0.296	2.402	2.903	1.629	2.364	1.760	0.602	0.33	0.97	2.039	15.415	5.351	2.052	1.702	3.64
29 Jul 06	00:00:00	189.18	144.54	18.13	74.16	1006.69	39.08	1.48	14.4	210	23.64	12.95	18.30	96	52.32		1.366	0.132	100.869	0.067	1.465	0.574	0.296	4.222	2.800	1.493	2.206	1.460	0.746	0.33	0.97	2.032	15.333	6.256	1.398	1.017	4.10
30 Jul 06	00:00:00	96.42	228.38	15.3	71.58	1006.63	91.29	1.27	4.6	211	22.56	10.41	16.49	94.6	48.52		1.188	0.119	100.863	0.067	1.397	0.561	0.314	3.632	2.736	1.262	1.999	1.261	0.738	0.32	0.97	2.025	15.250	7.993	3.195	2.634	4.18
31 Jul 06	00:00:00	86.14	143.79	14.94	81.655	1006.62	55.79	1.33	8.2	212	18.35	11.39	14.87	94.6	68.71		1.228	0.109	100.862	0.067	1.418	0.535	0.328	3.639	2.110	1.347	1.728	1.362	0.366	0.32	0.97	2.017	15.165	5.033	1.253	1.132	3.01
01 Aug 06	00:00:00	118.51	223.29	15.17	74.785	1006.63	109.75	2.89	0.0	213	19.68	11.81	15.75	94.1	55.47		2.624	0.114	100.863	0.067	1.892	0.470	0.278	8.179	2.292	1.339	1.839	1.267	0.551	0.31	0.97	2.013	15.076	7.815	3.841	3.079	3.28
02 Aug 06	00:00:00	154.84	222.88	15.46	77.42	1006.64	115.66	1.11	0.0	214	19.87	12.27	16.07	95.2	58.48		1.006	0.117	100.864	0.067	1.514	0.548	0.299	5.915	2.320	1.426	1.874	1.298	0.576	0.31	0.97	2.003	14.989	7.801	4.403	3.291	3.23
03 Aug 06	00:00:00	164.58	241.42	15.7	68.45	1006.64	133.87	1.29	0.0	215	21.04	12.61	16.83	85.3	53.6		1.191	0.122	100.864	0.067	1.405	0.564	0.310	3.696	2.483	1.493	1.977	1.276	0.700	0.32	0.97	1.997	14.899	8.450	4.698	3.448	3.43
04 Aug 06	00:00:00	134.35	84.67	17.08	87.6	1006.67	36.08	1.01	0.0	216	21.06	13.18	17.12	94.9	80.3		0.934	0.124	100.867	0.067	1.317	0.584	0.316	2.896	2.496	1.518	2.006	1.721	0.285	0.30	0.97	1.988	14.807	2.963	1.265	0.997	3.34
05 Aug 06	00:00:00	144.57	166	20.05	79.955	1006.73	99.99	0.92	0.0	217	23.98	16.64	20.31	95.9	64.01		0.889	0.147	100.873	0.067	1.302	0.626	0.286	2.729	2.980	1.894	2.457	1.882	0.575	0.29	0.97	1.980	14.714	5.810	3.500	2.646	3.48
06 Aug 06	00:00:00	121.24	92.33	17.8	85.755	1006.69	28.45	1.04	3.2	218	20.27	13.75	17.01	96.7	76.77		0.965	0.123	100.869	0.067	1.326	0.580	0.316	2.679	2.378	1.575	1.975	1.602	0.373	0.29	0.97	1.972	14.619	3.282	0.995	0.826	2.69
07 Aug 06	00:00:00	166.56	259.63	15.05	72.58	1006.62	121.25	0.70	0.0	219	20.06	11.05	15.545	91	54.12		0.646	0.113	100.862	0.067	1.220	0.581	0.314	2.014	2.547	1.519	1.821	1.254	0.568	0.28	0.97	1.965	14.522	6.067	4.245	2.879	3.39
08 Aug 06	00:00:00	97.25	146.21	13.98	82.21	1006.60	60.67	1.43	0.0	220	18.97	7.92	13.445	97.4	67.02		1.320	0.101	100.860	0.067	1.449	0.509	0.339	4.148	2.193	1.067	1.630	1.255	0.376	0.28	0.97	1.957	14.424	5.117	2.123	1.600	3.45
09 Aug 06	00:00:00	186.58	217.13	14.31	74.72	1006.61	91.29	1.21	0.0	221	19	10.07	14.535	94.4	55.04		1.113	0.107	100.861	0.067	1.379	0.537	0.336	3.485	2.197	1.254	1.716	1.187	0.529	0.27	0.97	1.948	14.324	7.600	3.195	2.334	3.18
10 Aug 06	00:00:00	155.25	78.92	14.05	88.6	1006.60	21.31	3.02	0.0	222	16.07	12.06	14.075	94.6	82.6		2.794	0.104	100.860	0.067	1.950	0.444	0.289	8.759	1.835	1.413	1.618	1.424	0.194	0.27	0.97	1.941	14.223	2.762	0.748	0.815	2.08
11 Aug 06	00:00:00	117.48	141.33	14.01	84.01	1006.61	63.95	3.39	0.0	223	17.37	11.61	14.44	94.2	65.82		3.098	0.107	100.861	0.067	2.055	0.457	0.274	8.694	1.964	1.361	1.675	1.297	0.378	0.26	0.97	1.932	14.121	4.647	2.236	1.985	2.52
12 Aug 06	00:00:00	197.28	140.08	13.76	76.96	1006.60	72.85	2.77	0.0	224	17.93	11.13	14.53	92.6	61.16		2.554	0.107	100.860	0.067	1.888	0.461	0.289	7.964	2.055	1.324	1.690	1.245	0.447	0.26	0.96	1.924	14.017	4.903	2.548	2.295	2.72
13 Aug 06	00:00:00	148.51	169.63	13.35	79.38	1006.59	72.63	1.10	0.0	225	17.52	9.27	13.395	100	58.76		1.011	0.100	100.859	0.067	1.544	0.527	0.332	3.178	2.003	1.169	1.586	1.175	0.413	0.25	0.96	1.916	13.912	5.937	2.542	1.861	2.87
14 Aug 06	00:00:00	140.00	113.04	13.55	81.12	1006.58	71.57	1.03	0.0	226	16.2	10.99	13.595	92.6	69.44		0.948	0.101	100.858	0.067	1.322	0.534	0.332	2.976	1.842	1.312	1.577	1.248	0.329	0.25	0.96	1.908	13.805	3.956	2.505	1.662	2.28
15 Aug 06	00:00:00	120.27	60.88	12.41	92.7	1006.57	4.11	1.21	13.2	227	14.16	10.95	12.555	97.1	88.5		1.118	0.099	100.857	0.067	1.380	0.508	0.356	3.524	1.615	1.308	1.462	1.348	0.113	0.24	0.96	1.899	13.697	2.151	0.144	0.215	1.71
16 Aug 06	00:00:00	19.04	141.04	14.44	85.5	1006.61	57.38	0.79	3.2	228	18.02	11.4	14.71	97.7	69.36		0.700	0.106	100.861	0.067	1.236	0.566	0.351	2.191	2.067	1.348	1.707	1.375	0.332	0.23	0.96	1.891	13.589	4.936	2.008	1.391	2.61
17 Aug 06	00:00:00	39.87	228.54	15.28	73.97	1006.63	98.28	0.69	3.2	229	20.99	11.48	16.235	96.1	51.84		0.596	0.118	100.863	0.067	1.205	0.564	0.338	1.854	2.485	1.556	1.920	1.295	0.625	0.23	0.96	1.882	13.478	7.996	3.440	2.434	3.29
18 Aug 06	00:00:00	37.69	177.08	15.75	76.505	1006.64	77.35	0.57	1.8	230	21.49	13.04	17.265	97.7	55.31		0.527	0.125	100.864	0.067	1.179	0.612	0.329	1.633	2.563	1.502	2.052	1.442	0.590	0.22	0.96	1.874	13.366	6.196	2.707	1.974	3.15
19 Aug 06	00:00:00	115.71	82.25	15.34	87.87	1006.65	32.19	0.66	11.4	231	18.23	13.42	15.825	97.3	78.44		0.806	0.115	100.865	0.067	1.206	0.588	0.342	1.887	2.094	1.539	1.817	1.570	0.247	0.22	0.96	1.865	13.254	2.879	1.127	0.821	2.28
20 Aug 06	00:00:00	125.36	161.54	16.08	78.48	1006.61	78.08	2.52	1.4	232	21.43	13.54	17.485	96.2	60.76		2.319	0.126	100.865	0.067	1.788	0.515	0.272	7.164	2.565	1.535	2.052	1.533	0.520	0.22	0.96	1.856	13.143	5.654	2.731	2.439	3.04
21 Aug 06	00:00:00	121.95	180.00	14.65	77.335	1006.62	104.35	2.56	0.0	233	18.93	11.35	15.14	93.6	61.07		2.353	0.111	100.862	0.067	1.800	0.479	0.290	7.351	2.186	1.434	1.766	1.367	0.400	0.20	0.96	1.848	13.025	6.300	3.652	2.746	2.72
22 Aug 06	00:00:00	75.58	138.46	15.21	82.58	1006.63	73.60	1.73	0.0	234	21.59	9.42	15.505	100	65.18		1.595	0.115	100.863	0.067	1.542	0.523	0.315	3.091	4.999	2.579	1.181	1.880	1.481	0.449	0.20	0.96	1.839	12.909	4.846	2.576	2.037	3.45
23 Aug 06	00:00:00	18.47	160.58	15.18	74.285	1006.63	74.37	0.80	1.1	235	20.93	12.94	16.935	96	52.57		0.796	0.122	100.863	0.067	1.250	0.594	0.325	2.296	2.476	1.492	1.964	1.367	0.617	0.19	0.96	1.830	12.792	5.620	2.603	2.004	2.89
24 Aug 06	00:00:00	152.04	232.71	15.43	72.26	1006.59	102.03	1.19	0.0	236	19.62	7.32	13.47	96.4	47.72		1.070	0.101	100.859	0.067	1.364	0.524	0.348	3.362	2.264	1.023	1.654	1.041	0.613	0.19	0.96	1.821	12.674	8.148	3.573	2.591	3.20
25 Aug 06	00:00:00	176.00	86.38	14.41	86.775	1006.61	11.61	0.88	2.7	237	16.92	12.22	16.07	96.1	77.45		0.910	0.117	100.861	0.067	1.279	0.577	0.319	2.521	2.327	1.432	1.872	1.586	0.285	0.18	0.96	1.812	12.555	2.923	0.404	0.417	2.71
26 Aug 06	00:00:00	126.50	147.96	15.43	83.395	1006.65	72.51	2.84	0.0	238	19.78	13.61	16.695	95.9	70.89		2.819	0.121	100.865	0.067	1.890	0.488	0.277	8.135	2.307	1.556	1.953	1.565	0.388	0.17	0.96	1.804	12.485	5.179	2.538	2.049	2.48
27 Aug 06	00:00:00	164.06	169.17	14.22	80.08	1006.61	69.62	2.05	4.3	239	19.66	9.72	14.695	95.8	64.38		1.892	0.108	100.861	0.067	1.643	0.495	0.307	5.918	2.290	1.205	1.745	1.316	0.453	0.17	0.96	1.795	12.316	5.921	2.437	1.994	2.66
28 Aug 06	00:00:00	106.77	192.58	12.61	80.52	1006.57	62.37	2.24	0.0	240	17.54	8.8	13.17	96.8	64.14		2.066	0.099	100.857	0.067	1.702	0.465	0.314	6.496	2.005	1.113	1.569	1.192	0.377	0.16	0.96	1.786	12.192	6.733	2.193	1.785	2.57
29 Aug 06	00:00:00	126.78	200.46	12.89	77.92	1006.58	71.00	2.29	0.4	241	17.91	9.54	13.645	95.7	61.44		2.102	0.102	100.858	0.067	1.715	0.470	0.309	6.600	2.058	1.175	1.616	1.181	0.435	0.15	0.96	1.777	12.070	7.016	2.485	2.068	2.58
30 Aug 06	00:00:00	133.82	211.50	14.48	80.305	1006.61	84.21	1.00	0.0	242	17.12	7.63	12.375	96.2	64.41		0.925	0.095	100.861	0.065	1.316	0.518	0.352	2.817	1.953	1.049	1.484	1.132	0.367	0.15	0.96	1.768	11.947	5.405	2.147	1.918	2.89
31 Aug 06	00:00:00	99.96	47	15.18	94.85	1006.63	52.4	1.06	5.8	243	16.98	12.49	14.735	96.2	93.5		0.977	0.108	100.863	0.067	1.332	0.548	0.339	3.057	1.935	1.448	1.692	1.601	0.090	0.14	0.96	1.759	11.823	1.645	1.834	1.069	1.87
01 Sep 06	00:00:00	84.63	168	18.13	76.23	1006.69	72.17	1.42	0.0	244	23.41	14.29	18.85	96.7	61.76		1.305	0.136	100.869	0.067	1.444	0.585	0.307	4.024	2.880	1.628	2.254	1.677	0.577	0.14	0.95	1.750	11.699	5.880	2.550	2.145	2.98
02 Sep 06	00:00:00	188.39	208	15.87	74.48	1006.64	93	1.47	26.4	245	20.35	11.51	15.93	94.2	54.77		1.356	0.116	100.864	0.067	1.461	0.542	0.314	4.224	2.389	1.358	1.874	1.264	0.580	0.13	0.96	1.740	11.573	7.280	3.256	2.534	2.67
03 Sep 06	00:00:00	120.06	114	15.24	81.85	1006.63	38.58	0.84	0.0	246	20.01	11.72	15.865	96.1	66.99		0.844	0.115	100.863	0.067	1.243	0.522	0.330	5.269	2.342	1.317	1.854	1.446	0.409	0.12	0.95	1.731	11.448	5.960	1.752	1.393	2.58
04 Sep 06	00:00:00	146.93	179	16.3	79.5	1006.65	85.9	0.82	9.0	247	18.98	13.61	16.295	97	81.99		0.754	0.118	100.865	0.067	1.256	0.584	0.331	2.346	2.195	1.556	1.877	1.456	0.440	0.11	0.95	1.722	11.321	6.265	2.993	2.060	2.66
05 Sep 06	00:00:00	84.93	105	15.14	82.72	1006.63	42.38	1.17	0.0	248	19.07	13.37	16.22	97.1	68.33		1.079	0.118	100.863	0.067	1.367	0.562	0.325	3.356	2.207	1.534	1.871	1.499	0.372	0.11	0.95	1.713	11.194	3.675	1.483	1.234	2.66
06 Sep 06	00:00:00	105.62	179	19.46	79.81	1006.72	101.1	1.36	1.4	249	22.95	16.14	19.545	97.5	62.32		1.251	0.141	100.872	0.067	1.425	0.597	0.293	3.848	2.801	1.815	2.318	1.765	0.552	0.10	0.95	1.704	11.067	6.265	3.539	2.713	2.48
07 Sep 06	00:00:00	173.51	166	15.6	80.14	1006.64	87.88	1.05	2.2	250	18.48	11.08	14.755	97.1	63.18		0.970	0.108	100.864	0.067	1.280	0.540	0.338	3.035	2.127	1.310	1.721	1.310	0.411	0.09	0.95	1.695	10.859	5.810	2.376	1.727	2.24
08 Sep 06	00:00:00	181.36	195	13.16	75.31	1006.58	52.68	1.03	0.0	251	18.74	8.37	13.555	96.7	53.92	

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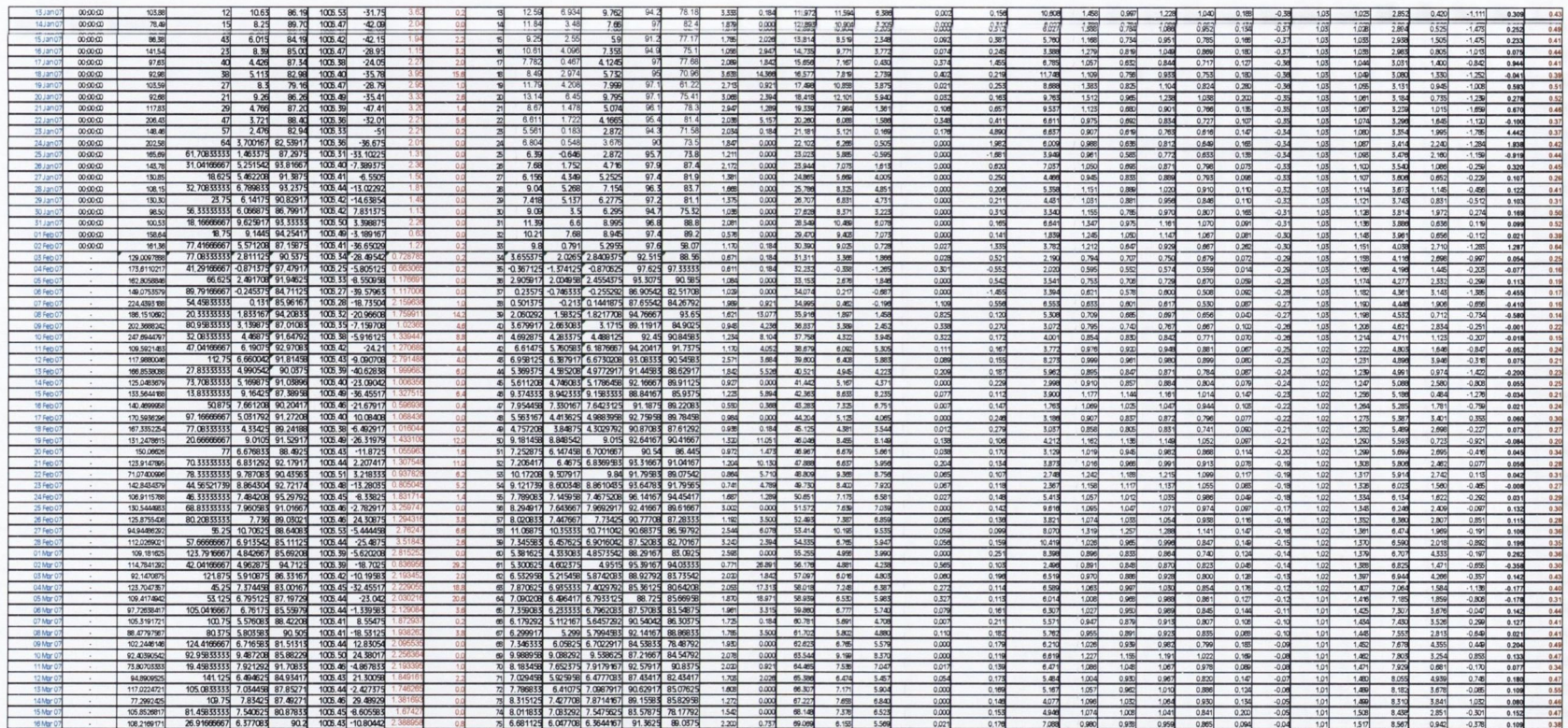

Site A

Reed Bed Water Balance

Date	Qi (l/d)	Qi (m3/d)	Area (m2)	Precip. (mm)	Precip. (m)	Penman Et (mm/d)	Penman Et (m/d)	K_c	Et_{seed} (m)	Et_{seed} (mm)	Qo (m3/d)	Qo (l/d)
19 May 2006	156.2	0.156	15	6.2	0.0062	0.702016415	0.000702016	0.7	0.000491411	0.491411491	0.241828828	**241.8**
20 May 2006	**74.8**	0.075	15	2.8	0.0028	2.454595103	0.002454595	0.7	0.001718217	1.718216572	0.091026751	**91.0**
21 May 2006	**464.9**	0.465	15	16	0.016	0.48182787	0.000481828	0.7	0.00033728	0.337279509	0.699800807	**699.8**
22 May 2006	**413.1**	0.413	15	1	0.001	2.227351846	0.002227352	0.7	0.001559146	1.559146292	0.404662806	**404.7**
23 May 2006	**170.7**	0.171	15	5.2	0.0052	1.717733965	0.001717734	0.7	0.001202414	1.202413775	0.230683793	**230.7**
24 May 2006	**102.7**	0.103	15	1	0.001	3.1546496	0.00315465	0.7	0.002208255	2.20825472	0.084616179	**84.6**
25 May 2006	**151.9**	0.152	15	2	0.002	3.205383676	0.003205384	0.7	0.002243769	2.243768573	0.148253471	**148.3**
26 May 2006	**205.5**	0.205	15	7.4	0.0074	1.625897848	0.001625898	1	0.001625898	1.625897848	0.292091532	**292.1**
27 May 2006	**117.9**	0.118	15	1.8	0.0018	2.274669607	0.00227467	1	0.00227467	2.274669607	0.110799956	**110.8**
28 May 2006	**130.7**	0.131	15	0	0	2.219444374	0.002219444	1	0.002219444	2.219444374	0.097388334	**97.4**
29 May 2006	**230.2**	0.230	15	0.2	0.0002	2.758922766	0.002758923	1	0.002758923	2.758922766	0.191846159	**191.8**
30 May 2006	**186.5**	0.186	15	0	0	3.055351904	0.003055352	1	0.003055352	3.055351904	0.140619721	**140.6**
31 May 2006	**187.9**	0.188	15	0	0	3.204152649	0.003204153	1	0.003204153	3.204152649	0.13981771	**139.8**
01 June 2006	**101.1**	0.101	15	0	0	4.111822896	0.004111823	1.2	0.004934187	4.934187476	0.027077188	**27.1**
02 June 2006	**168.2**	0.168	15	0	0	4.286386301	0.004286386	1.2	0.005143664	5.143663561	0.091035047	**91.0**
03 June 2006	**180.3**	0.180	15	0	0	4.551849433	0.004551849	1.2	0.005462219	5.462219319	0.09835671	**98.4**
04 June 2006	**138.8**	0.139	15	0	0	4.202546108	0.004202546	1.2	0.005043055	5.04305533	0.06317417	**63.2**
05 June 2006	**173.5**	0.173	15	0	0	4.284081199	0.004284081	1.2	0.005140897	5.140897438	0.096356538	**96.4**
06 June 2006	**241.2**	0.241	15	0	0	4.669276222	0.004669276	1.2	0.005603131	5.603131467	0.157183028	**157.2**
07 June 2006	**166.9**	0.167	15	0	0	4.192305217	0.004192305	1.2	0.005030766	5.030766261	0.091438506	**91.4**
08 June 2006	**136.1**	0.136	15	0	0	4.077545551	0.004077546	1.2	0.004893055	4.893054661	0.06267418	**62.7**
09 June 2006	**197.1**	0.197	15	0	0	4.690245548	0.004690246	1.2	0.005628295	5.628294658	0.11269558	**112.7**
10 June 2006	**137.5**	0.138	15	0	0	4.120387668	0.004120388	1.2	0.004944465	4.944465201	0.063333022	**63.3**
11 June 2006	**131.3**	0.131	15	0	0	4.261482434	0.004261482	1.2	0.005113779	5.11377892	0.054633316	**54.6**
12 June 2006	**211.3**	0.211	15	0	0	3.209929972	0.00320993	1.2	0.003851916	3.851915967	0.15353126	**153.5**
13 June 2006	**184.3**	0.184	15	0	0	2.797033417	0.002797033	1.2	0.00335644	3.356440101	0.133903398	**133.9**
14 June 2006	**126.9**	0.127	15	0	0	3.299048463	0.003299048	1.2	0.003958858	3.958858155	0.067557128	**67.6**
15 June 2006	**151.8**	0.152	15	0	0	3.616538674	0.003616539	1.2	0.004339846	4.339846408	0.086702304	**86.7**
16 June 2006	**173.1**	0.173	15	0.2	0.0002	2.77369562	0.002773696	1.2	0.003328435	3.328434744	0.126213479	**126.2**
17 June 2006	**338.3**	0.338	15	0	0	3.958016785	0.003958017	1.2	0.00474962	4.749620142	0.267095698	**267.1**
18 June 2006	**395.1**	0.395	15	8	0.008	0.735814995	0.000735815	1.2	0.000882978	0.882977994	0.50185533	**501.9**
19 June 2006	**355.6**	0.356	15	0.8	0.0008	1.896286254	0.001896286	1.2	0.002275544	2.275543505	0.333476847	**333.5**
20 June 2006	**331.9**	0.332	15	2.4	0.0024	1.382546069	0.001382546	1.2	0.001659055	1.659055282	0.342984171	**343.0**
21 June 2006	**434.7**	0.435	15	1	0.001	3.259151468	0.003259151	1.2	0.003910982	3.910981762	0.391005274	**391.0**
22 June 2006	**259.7**	0.260	15	0	0	2.556814358	0.002556814	1.2	0.003068177	3.068177229	0.213667342	**213.7**
23 June 2006	**297.9**	0.298	15	0	0	3.600888781	0.003600889	1.2	0.004321067	4.321066537	0.233124002	**233.1**
24 June 2006	**0.0**	0.000	15	2.2	0.0022	0.89391784	0.000893918	1.2	0.001072701	1.072701408	0.016909479	**16.9**
25 June 2006	**0.2**	0.000	15	0	0	3.590658025	0.003590658	1.2	0.00430879	4.30878963	-0.064391844	**0.0**
26 June 2006	**3.0**	0.003	15	0	0	0.501391536	0.000501392	1.2	0.00060167	0.601669844	-0.006025048	**0.0**
27 June 2006	**3.8**	0.004	15	0	0	1.301127314	0.001301127	1.2	0.001561353	1.561352777	-0.019580292	**0.0**
28 June 2006	**65.3**	0.065	15	0	0	3.780891508	0.003780892	1.2	0.00453707	4.537069809	-0.002766047	**0.0**
29 June 2006	**196.5**	0.197	15	1.6	0.0016	1.803195485	0.001803195	1.2	0.002163835	2.163834582	0.188082481	**188.1**
30 June 2006	**224.0**	0.224	15	2.6	0.0026	3.644834326	0.003644834	1.2	0.004373801	4.373801191	0.197352982	**197.4**
01 July 2006	**437.2**	0.437	15	0	0	4.06246443	0.004062464	1.2	0.004874957	4.874957316	0.36411564	**364.1**
02 July 2006	**241.8**	0.242	15	1.4	0.0014	2.250381046	0.002250381	1.2	0.002700457	2.700457255	0.222283141	**222.3**
03 July 2006	**498.1**	0.498	15	5.6	0.0056	2.821336773	0.002821337	1.2	0.003385604	3.385604127	0.531265938	**531.3**
04 July 2006	**435.8**	0.436	15	0.4	0.0004	3.941550106	0.00394155	1.2	0.00472986	4.729860128	0.370822098	**370.8**
05 July 2006	**266.8**	0.267	15	0	0	3.645771268	0.003645771	1.2	0.004374926	4.374925522	0.201146117	**201.1**
06 July 2006	**277.2**	0.277	15	0.4	0.0004	3.021039718	0.00302104	1.2	0.003625248	3.625247661	0.228821285	**228.8**
07 July 2006	**407.2**	0.407	15	0.2	0.0002	2.372228337	0.002372228	1.2	0.002846674	2.846674004	0.36747989	**367.5**
08 July 2006	**169.4**	0.169	15	9.6	0.0096	1.123315561	0.001123316	1.2	0.001347979	1.347978673	0.29314032	**293.1**
09 July 2006	**214.4**	0.214	15	0.8	0.0008	3.029296717	0.003029297	1.2	0.003635156	3.635156061	0.171882659	**171.9**
10 July 2006	**547.8**	0.548	15	0	0	2.829674827	0.002829675	1.2	0.00339561	3.395609792	0.496815853	**496.8**
11 July 2006	**405.6**	0.406	15	0	0	3.07912493	0.003079125	1.2	0.00369495	3.694949917	0.350215751	**350.2**
12 July 2006	**316.1**	0.316	15	0.2	0.0002	1.407221086	0.001407221	1.2	0.001688665	1.688665303	0.29380002	**293.8**
13 July 2006	**293.9**	0.294	15	0.8	0.0008	3.858664879	0.003858665	1.2	0.004630398	4.630397855	0.236464032	**236.5**
14 July 2006	**206.9**	0.207	15	0	0	4.344660013	0.00434466	1.2	0.005213592	5.213592015	0.12871612	**128.7**

15 July 2006	**275.7**	0.276	15	0	0	4.066277286	0.004066277	1.2	0.004879533	4.879532743	0.202457009	**202.5**
16 July 2006	**415.3**	0.415	15	0	0	4.330734305	0.004330734	1.2	0.005196881	5.196881166	0.337326783	**337.3**
17 July 2006	**341.3**	0.341	15	0	0	5.259824141	0.005259824	1.2	0.006311789	6.311788969	0.246573165	**246.6**
18 July 2006	**416.2**	0.416	15	0	0	4.154460289	0.00415446	1.2	0.004985352	4.985352347	0.341369715	**341.4**
19 July 2006	**254.7**	0.255	15	0	0	3.940235374	0.003940235	1.2	0.004728282	4.728282449	0.183775763	**183.8**
20 July 2006	**325.2**	0.325	15	0	0	3.154275683	0.003154276	1.2	0.003785131	3.785130819	0.268393038	**268.4**
21 July 2006	**298.0**	0.298	15	0	0	3.53001855	0.003530019	1.2	0.004236022	4.23602226	0.234419666	**234.4**
22 July 2006	**316.7**	0.317	15	0	0	3.076405338	0.003076405	1.2	0.003691686	3.691686405	0.261334704	**261.3**
23 July 2006	**414.9**	0.415	15	0	0	3.278430962	0.003278431	1.2	0.003934117	3.934117154	0.355928243	**355.9**
24 July 2006	**367.1**	0.367	15	0	0	4.506192312	0.004506192	1.2	0.005407431	5.407430774	0.285988538	**286.0**
25 July 2006	**348.1**	0.348	15	0	0	4.306367691	0.004306368	1.2	0.005167641	5.16764123	0.270605382	**270.6**
26 July 2006	**516.4**	0.516	15	0	0	3.421823018	0.003421823	1.2	0.004106188	4.106187621	0.454817186	**454.8**
27 July 2006	**377.6**	0.378	15	0	0	4.046814536	0.004046815	1.2	0.004856177	4.856177443	0.304777338	**304.8**
28 July 2006	**414.0**	0.414	15	8.2	0.0082	1.718854592	0.001718855	1.2	0.002062626	2.06262551	0.506060617	**506.1**
29 July 2006	**176.7**	0.177	15	1.4	0.0014	2.017682055	0.002017682	1.2	0.002421218	2.421218466	0.161351723	**161.4**
30 July 2006	**506.2**	0.506	15	4.8	0.0048	2.702713472	0.002702713	1.2	0.003243256	3.243256167	0.529531157	**529.5**
31 July 2006	**236.4**	0.236	15	9	0.009	1.240286183	0.001240286	1.2	0.001488343	1.488343419	0.349064849	**349.1**
01 August 2006	**247.9**	0.248	15	0.2	0.0002	3.260748962	0.003260749	1.2	0.003912899	3.912898754	0.192196519	**192.2**
02 August 2006	**303.9**	0.304	15	0	0	3.512707217	0.003512707	1.2	0.004215249	4.21524866	0.24071127	**240.7**
03 August 2006	**216.8**	0.217	15	0	0	3.774001577	0.003774002	1.2	0.004528802	4.528801893	0.148887972	**148.9**
04 August 2006	**277.1**	0.277	15	0.4	0.0004	1.029401219	0.001029401	1.2	0.001235281	1.235281463	0.264550778	**264.6**
05 August 2006	**423.0**	0.423	15	0	0	2.822724841	0.002822725	1.2	0.00338727	3.38726981	0.372150953	**372.2**
06 August 2006	**250.6**	0.251	15	4.8	0.0048	1.039211636	0.001039212	1.2	0.001247054	1.247053963	0.303934191	**303.9**
07 August 2006	**183.5**	0.183	15	0	0	3.180554868	0.003180555	1.2	0.003816666	3.816665842	0.126240012	**126.2**
08 August 2006	**93.2**	0.093	15	2.6	0.0026	1.617765328	0.001617765	1.2	0.001941318	1.941318394	0.103060224	**103.1**
09 August 2006	**327.0**	0.327	15	0	0	2.902259851	0.00290226	1.2	0.003482712	3.482711821	0.274709323	**274.7**
10 August 2006	**265.7**	0.266	15	1.2	0.0012	0.905935763	0.000905936	1.2	0.001087123	1.087122915	0.267423156	**267.4**
11 August 2006	**152.8**	0.153	15	0	0	2.014801207	0.002014801	1.2	0.002417761	2.417761448	0.116483578	**116.5**
12 August 2006	**96.0**	0.096	15	0.2	0.0002	2.2761144	0.002276114	1.2	0.002731337	2.731337281	0.058049941	**58.0**
13 August 2006	**265.6**	0.266	15	0	0	2.108665754	0.002108666	1.2	0.002530399	2.530398905	0.227624016	**227.6**
14 August 2006	**332.3**	0.332	15	0	0	1.833460313	0.00183346	1.2	0.002200152	2.200152375	0.299337714	**299.3**
15 August 2006	**266.4**	0.266	15	5.4	0.0054	0.204791793	0.000204792	1.2	0.00024575	0.245750152	0.343703748	**343.7**
16 August 2006	**476.7**	0.477	15	0	0	1.572174539	0.001572175	1.2	0.001886609	1.886609447	0.448370858	**448.4**
17 August 2006	**453.8**	0.454	15	0	0	2.768717733	0.002768718	1.2	0.003322461	3.32246128	0.403993081	**404.0**
18 August 2006	**216.8**	0.217	15	18	0.018	2.247819779	0.00224782	1.2	0.002697384	2.697383734	0.446349244	**446.3**
19 August 2006	**402.6**	0.403	15	20.6	0.0206	1.139237926	0.001139238	1.2	0.001367086	1.367085512	0.691053717	**691.1**
20 August 2006	**396.2**	0.396	15	0.4	0.0004	2.481381625	0.002481382	1.2	0.002977658	2.97765795	0.357535131	**357.5**
21 August 2006	**227.1**	0.227	15	0	0	2.698919011	0.002698919	1.2	0.003238703	3.238702813	0.178479458	**178.5**
22 August 2006	**44.6**	0.045	15	0.6	0.0006	1.864375081	0.001864375	1.2	0.00223725	2.237250097	0.020031249	**20.0**
23 August 2006	**158.2**	0.158	15	0	0	2.326941663	0.002326942	1.2	0.00279233	2.792329996	0.11632505	**116.3**
24 August 2006	**84.2**	0.084	15	0.2	0.0002	2.684961913	0.002684962	1.2	0.003221954	3.221954296	0.038870686	**38.9**
25 August 2006	**304.4**	0.304	15	8.2	0.0082	0.693110224	0.00069311	1.2	0.000831732	0.831732268	0.414914016	**414.9**
26 August 2006	**150.0**	0.150	15	0.2	0.0002	2.076774698	0.002076775	1.2	0.00249213	2.492129637	0.115648055	**115.6**
27 August 2006	**198.0**	0.198	15	2.2	0.0022	2.017768632	0.002017769	1.2	0.002421322	2.421322358	0.194670165	**194.7**
28 August 2006	**275.4**	0.275	15	6.6	0.0066	1.873242562	0.001873243	1.2	0.002247891	2.247891074	0.340671634	**340.7**
29 August 2006	**76.1**	0.076	15	0.2	0.0002	2.185011831	0.002185012	1.2	0.002622014	2.622014197	0.039749787	**39.7**
30 August 2006	**149.5**	0.150	15	3	0.003	2.049609413	0.002049609	1.2	0.002459531	2.459531296	0.157637031	**157.6**
31 August 2006	**483.9**	0.484	15	0.4	0.0004	1.084566107	0.001084566	1.2	0.001301479	1.301479329	0.47033781	**470.3**
01 September 2006	**409.7**	0.410	15	0.2	0.0002	2.123752567	0.002123753	0.9	0.001911377	1.91137731	0.38401934	**384.0**
02 September 2006	**349.2**	0.349	15	20.2	0.0202	2.663571183	0.002663571	0.9	0.002397214	2.397214065	0.616241789	**616.2**
03 September 2006	**278.6**	0.279	15	3.8	0.0038	1.437560801	0.001437561	0.9	0.001293805	1.293804721	0.316232929	**316.2**
04 September 2006	**146.1**	0.146	15	5	0.005	2.465169019	0.002465169	0.9	0.002218652	2.218652117	0.187780218	**187.8**
05 September 2006	**357.9**	0.358	15	0.2	0.0002	1.224595835	0.001224596	0.9	0.001102136	1.102136251	0.344367956	**344.4**
06 September 2006	**290.2**	0.290	15	3.4	0.0034	2.820380352	0.00282038	0.9	0.002538342	2.538342317	0.303104865	**303.1**
07 September 2006	**278.6**	0.279	15	0.2	0.0002	2.035642167	0.002035642	0.9	0.001832078	1.832077951	0.254148831	**254.1**
08 September 2006	**292.8**	0.293	15	0.2	0.0002	1.831199149	0.001831199	0.9	0.001648079	1.648079234	0.271078811	**271.1**
09 September 2006	**75.9**	0.076	15	0	0	1.956315514	0.001956316	0.9	0.001760684	1.760683963	0.049499741	**49.5**
10 September 2006	**230.4**	0.230	15	0	0	1.642992695	0.001642993	0.9	0.001478693	1.478693425	0.208199599	**208.2**
11 September 2006	**279.3**	0.279	15	6.4	0.0064	1.15003233	0.001150032	0.9	0.001035029	1.035029097	0.359764564	**359.8**
12 September 2006	**282.7**	0.283	15	0.6	0.0006	0.30234334	0.000302343	0.9	0.000272109	0.272109006	0.287588365	**287.6**

13 September 2006	**229.4**	0.229	15	1.6	0.0016	1.252747938	0.001252748	0.9	0.001127473	1.127473145	0.236487903	**236.5**
14 September 2006	**276.4**	0.276	15	0.2	0.0002	0.498497215	0.000498497	0.9	0.000448647	0.448647494	0.272690288	**272.7**
15 September 2006	**294.8**	0.295	15	0	0	1.68032242	0.001680322	0.9	0.00151229	1.512290178	0.272145647	**272.1**
16 September 2006	**137.4**	0.137	15	1	0.001	1.960418884	0.001960419	0.6	0.001176251	1.17625133	0.13476623	**134.8**
17 September 2006	**299.1**	0.299	15	0.8	0.0008	1.798932832	0.001798933	0.6	0.00107936	1.079359699	0.294939605	**294.9**
18 September 2006	**343.1**	0.343	15	12	0.012	1.794701398	0.001794701	0.6	0.001076821	1.076820839	0.506947687	**506.9**
19 September 2006	**490.1**	0.490	15	0.2	0.0002	0.421593357	0.000421593	0.6	0.000252956	0.252956014	0.48926566	**489.3**
20 September 2006	**256.9**	0.257	15	11	0.011	1.717410046	0.00171741	0.6	0.001030446	1.030446028	0.40640331	**406.4**
21 September 2006	**99.6**	0.100	15	7.6	0.0076	0.181511777	0.000181512	0.6	0.000108907	0.108907066	0.211936394	**211.9**
22 September 2006	**211.9**	0.212	15	3.2	0.0032	1.914544849	0.001914545	0.6	0.001148727	1.148726909	0.242629096	**242.6**
23 September 2006	**291.0**	0.291	15	3.8	0.0038	1.268932007	0.001268932	0.6	0.000761359	0.761359204	0.336599612	**336.6**
24 September 2006	**321.4**	0.321	15	2.8	0.0028	0.599286098	0.000599286	0.6	0.000359572	0.359571659	0.358046425	**358.0**
25 September 2006	**288.6**	0.289	15	6.8	0.0068	0.733678331	0.000733678	0.6	0.000440207	0.440206999	0.384006895	**384.0**
26 September 2006	**393.2**	0.393	15	0.2	0.0002	0.909949123	0.000909949	0.6	0.000545969	0.545969474	0.388040458	**388.0**
27 September 2006	**204.8**	0.205	15	6.8	0.0068	0.721655855	0.000721656	0.6	0.000432994	0.432993513	0.300265097	**300.3**
28 September 2006	**202.1**	0.202	15	0.2	0.0002	0.094177236	9.41772E-05	0.6	5.65063E-05	0.056506341	0.204242405	**204.2**
29 September 2006	**152.5**	0.152	15	0	0	0.728484936	0.000728485	0.6	0.000437091	0.437090961	0.145933636	**145.9**
30 September 2006	**420.9**	0.421	15	25	0.025	1.375384427	0.001375384	0.6	0.000825231	0.825230656	0.78352154	**783.5**
01 October 2006	**251.6**	0.252	15	0.4	0.0004	0.033434652	3.34347E-05	0.3	1.00304E-05	0.010030395	0.257489544	**257.5**
02 October 2006	**310.7**	0.311	15	0.2	0.0002	0.802459131	0.000802459	0.3	0.000240738	0.240737739	0.310068934	**310.1**
03 October 2006	**236.6**	0.237	15	0.2	0.0002	0.997981835	0.000997982	0.3	0.000299395	0.299394551	0.235109082	**235.1**
04 October 2006	**348.4**	0.348	15	1.2	0.0012	1.166543577	0.001166544	0.3	0.000349963	0.349963073	0.361160554	**361.2**
05 October 2006	**133.5**	0.134	15	15.8	0.0158	0.890474624	0.000890475	0.3	0.000267142	0.267142387	0.366502864	**366.5**
06 October 2006	**187.6**	0.188	15	5.8	0.0058	0.141519521	0.00014152	0.3	4.24559E-05	0.042455856	0.273963162	**274.0**
07 October 2006	**145.0**	0.145	15	0	0	0.367819046	0.000367819	0.3	0.000110346	0.110345714	0.143354814	**143.4**
08 October 2006	**379.3**	0.379	15	4.2	0.0042	0.481564342	0.000481564	0.3	0.000144469	0.144469303	0.44013296	**440.1**
09 October 2006	**441.4**	0.441	15	1.8	0.0018	0.259177053	0.000259177	0.3	7.77531E-05	0.077753116	0.467213703	**467.2**
10 October 2006	**135.4**	0.135	15	1.8	0.0018	0.715493817	0.000715494	0.3	0.000214648	0.214648145	0.159150278	**159.2**
11 October 2006	**309.9**	0.310	15	16.2	0.0162	1.352857344	0.001352857	0.3	0.000405857	0.405857203	0.546852142	**546.9**
12 October 2006	**207.8**	0.208	15	0	0	0.853302198	0.000853302	0.3	0.000255991	0.255990659	0.20396014	**204.0**
13 October 2006	**163.6**	0.164	15	0.2	0.0002	0.761582059	0.000761582	0.3	0.000228475	0.228474618	0.163142881	**163.1**
14 October 2006	**264.6**	0.265	15	0.2	0.0002	0.703218631	0.000703219	0.3	0.000210966	0.210965589	0.264475516	**264.5**
15 October 2006	**342.9**	0.343	15	0	0	0.825825429	0.000825825	0.3	0.000247748	0.247747629	0.339223786	**339.2**
16 October 2006	**257.0**	0.257	15	0.2	0.0002	0.477166502	0.000477167	0.2	9.54333E-05	0.0954333	0.2585385	**258.5**
17 October 2006	**259.3**	0.259	15	8	0.008	0.232399724	0.0002324	0.2	4.64799E-05	0.046479945	0.378582801	**378.6**
18 October 2006	**249.4**	0.249	15	0.2	0.0002	0	0	0.2	0	0	0.25235	**252.4**
19 October 2006				8.8	0.0088	0.396	0.00039626	0.2	7.9252E-05	0.079251964		
20 October 2006	**195.9**	0.196	15	0.2	0.0002	0	0	0.2	0	0	0.19889	**198.9**
21 October 2006	**258.9**	0.259	15	8.2	0.0082	0.141052392	0.000141052	0.2	2.82105E-05	0.028210478	0.381466843	**381.5**
22 October 2006	**298.2**	0.298	15	0.8	0.0008	0.509673754	0.000509674	0.2	0.000101935	0.101934751	0.308650979	**308.7**
23 October 2006	**356.9**	0.357	15	0	0	0.166725373	0.000166725	0.2	3.33451E-05	0.033345075	0.356349824	**356.3**
24 October 2006	**228.1**	0.228	15	0.6	0.0006	0.043192096	4.31921E-05	0.2	8.63842E-06	0.008638419	0.236990424	**237.0**
25 October 2006	**349.7**	0.350	15	26	0.026	0.624870608	0.000624871	0.2	0.000124974	0.124974122	0.737785388	**737.8**
26 October 2006	**280.4**	0.280	15	1.6	0.0016	0	0	0.2	0	0	0.30437	**304.4**
27 October 2006	**249.4**	0.249	15	1.6	0.0016	1.132998261	0.001132998	0.2	0.0002266	0.226599652	0.270021005	**270.0**
28 October 2006	**125.9**	0.126	15	0	0	0.240813873	0.000240814	0.2	4.81628E-05	0.048162775	0.125157558	**125.2**
29 October 2006	**466.0**	0.466	15	1.2	0.0012	0	0	0.2	0	0	0.48402	**484.0**
30 October 2006	**373.5**	0.374	15	1.2	0.0012	0.092465113	9.24651E-05	0.2	1.8493E-05	0.018493023	0.391262605	**391.3**
31 October 2006	**253.1**	0.253	15	0.2	0.0002	0.107253594	0.000107254	0.2	2.14507E-05	0.021450719	0.255748239	**255.7**
01 November 2006	**272.6**	0.273	15	0.2	0.0002	0.825939146	0.000825939	0.1	8.25939E-05	0.082593915	0.274401091	**274.4**
02 November 2006	**231.7**	0.232	15	0.2	0.0002	0.105890742	0.000105891	0.1	1.05891E-05	0.010589074	0.234501164	**234.5**
03 November 2006	**209.9**	0.210	15	0	0	0	0	0.1	0	0	0.20986	**209.9**
04 November 2006	**269.9**	0.270	15	0.2	0.0002	0	0	0.1	0	0	0.27286	**272.9**
05 November 2006	**554.1**	0.554	15	0.2	0.0002	0	0	0.1	0	0	0.55709	**557.1**
06 November 2006	**321.6**	0.322	15	0	0	0	0	0.1	0	0	0.32156	**321.6**
07 November 2006	**170.3**	0.170	15	3	0.003	0.063486331	6.34863E-05	0.1	6.34863E-06	0.006348633	0.215234771	**215.2**
08 November 2006	**336.3**	0.336	15	0.2	0.0002	0.174643845	0.000174644	0.1	1.74644E-05	0.017464384	0.338998034	**339.0**

09 November 2006	**193.3**	0.193	15	0.4	0.0004	0	0	0.1	0	0	0.19929	**199.3**
10 November 2006	**281.3**	0.281	15	4.2	0.0042	0	0	0.1	0	0	0.34434	**344.3**
11 November 2006	**185.7**	0.186	15	0.2	0.0002	0	0	0.1	0	0	0.18871	**188.7**
12 November 2006	**414.5**	0.414	15	0.4	0.0004	0.27550343	0.000275503	0.1	2.75503E-05	0.027550343	0.420036745	**420.0**
13 November 2006	**547.7**	0.548	15	1.4	0.0014	0.28168923	0.000281689	0.1	2.81689E-05	0.028168923	0.568287466	**568.3**
14 November 2006	**405.9**	0.406	15	0.6	0.0006	0.429247203	0.000429247	0.1	4.29247E-05	0.04292472	0.414256129	**414.3**
15 November 2006	**293.0**	0.293	15	35.4	0.0354	0	0	0.1	0	0	0.82403	**824.0**
16 November 2006	**176.5**	0.177	15	0.2	0.0002	0.008420292	8.42029E-06	0.1	8.42029E-07	0.000842029	0.17951737	**179.5**
17 November 2006	**228.0**	0.228	15	11.2	0.0112	0	0	0.1	0	0	0.39599	**396.0**
18 November 2006	**332.1**	0.332	15	5.4	0.0054	0	0	0.1	0	0	0.41313	**413.1**
19 November 2006	**251.1**	0.251	15	6.2	0.0062	0.018030362	1.80304E-05	0.1	1.80304E-06	0.001803036	0.344082954	**344.1**
20 November 2006	**340.0**	0.340	15	0.2	0.0002	0	0	0.1	0	0	0.34304	**343.0**
21 November 2006	**208.1**	0.208	15	0	0	0	0	0.1	0	0	0.20809	**208.1**
22 November 2006	**203.9**	0.204	15	8	0.008	0.243079625	0.00024308	0.1	2.4308E-05	0.024307963	0.323485381	**323.5**
23 November 2006	**164.2**	0.164	15	2.2	0.0022	0	0	0.1	0	0	0.19724	**197.2**
24 November 2006	**160.8**	0.161	15	3.2	0.0032	0	0	0.1	0	0	0.20882	**208.8**
25 November 2006	**274.9**	0.275	15	1	0.001	0	0	0.1	0	0	0.28989	**289.9**
26 November 2006	**259.2**	0.259	15	1.8	0.0018	0	0	0.1	0	0	0.28619	**286.2**
27 November 2006	**221.6**	0.222	15	14.6	0.0146	0	0	0.1	0	0	0.44055	**440.6**
28 November 2006	**159.7**	0.160	15	2.2	0.0022	0.224666357	0.000224666	0.1	2.24666E-05	0.022466636	0.192403	**192.4**
29 November 2006	**202.1**	0.202	15	0	0	0	0	0.1	0	0	0.20206	**202.1**
30 November 2006	**187.2**	0.187	15	15.8	0.0158	0	0	0.1	0	0	0.42417	**424.2**
01 December 2006	**70.6**	0.071	15	1.4	0.0014	0.390562288	0.000390562	0.1	3.90562E-05	0.039056229	0.091054157	**91.1**
02 December 2006	**244.7**	0.245	15	5	0.005	0	0	0.1	0	0	0.3197	**319.7**
03 December 2006	**364.8**	0.365	15	21.4	0.0214	0.045408328	4.54083E-05	0.1	4.54083E-06	0.004540833	0.685721888	**685.7**
04 December 2006	**575.4**	0.575	15	8	0.008	0.225228031	0.000225228	0.1	2.25228E-05	0.022522803	0.695042158	**695.0**
05 December 2006	**598.0**	0.598	15	2.6	0.0026	0	0	0.1	0	0	0.63703	**637.0**
06 December 2006	**441.9**	0.442	15	3.2	0.0032	0	0	0.1	0	0	0.48988	**489.9**
07 December 2006	**1551.2**	1.551	15	22.8	0.0228	0	0	0.1	0	0	1.89321	**1893.2**
08 December 2006	**1269.7**	1.270	15	0.2	0.0002	0.030136376	3.01364E-05	0.1	3.01364E-06	0.003013638	1.272614795	**1272.6**
09 December 2006	**913.6**	0.914	15	0.4	0.0004	0	0	0.1	0	0	0.91957	**919.6**
10 December 2006	**1316.1**	1.316	15	11.2	0.0112	0	0	0.1	0	0	1.48414	**1484.1**
11 December 2006	**1689.0**	1.689	15	8.6	0.0086	0.036599353	3.65994E-05	0.1	3.65994E-06	0.003659935	1.817945101	**1817.9**
12 December 2006	**1196.9**	1.197	15	0.8	0.0008	0.019750755	1.97508E-05	0.1	1.97508E-06	0.001975076	1.208880374	**1208.9**
13 December 2006				0.4	0.0004	0.005	5.05186E-06	0.1	5.05186E-07	0.000505186		
14 December 2006				14.4	0.0144	0.232	0.000231864	0.1	2.31864E-05	0.023186389		
15 December 2006				7.6	0.0076	0.000	0	0.1	0	0		
16 December 2006				0.2	0.0002	0.000	0	0.1	0	0		
17 December 2006				2.4	0.0024	0.000	0	0.1	0	0		
18 December 2006				0.2	0.0002	0.000	0	0.1	0	0		
19 December 2006				0.4	0.0004	0.045	4.45984E-05	0.1	4.45984E-06	0.004459843		
20 December 2006	**271.4**	0.271	15	0.2	0.0002	0.047	4.73066E-05	0.1	4.73066E-06	0.004730657	0.27436904	**274.4**
21 December 2006	**316.9**	0.317	15	0.2	0.0002	0.000	0	0.1	0	0	0.31991	**319.9**
22 December 2006	**444.9**	0.445	15	0	0	0.000	0	0.1	0	0	0.44489	**444.9**
23 December 2006	**229.6**	0.230	15	0.2	0.0002	0.000	0	0.1	0	0	0.2326	**232.6**
24 December 2006	**157.5**	0.157	15	0	0	0.000	0	0.1	0	0	0.15747	**157.5**
25 December 2006	**426.1**	0.426	15	0.2	0.0002	0.118	0.00011815	0.1	1.1815E-05	0.011814989	0.428932775	**428.9**
26 December 2006	**425.8**	0.426	15	0.6	0.0006	0.000	0	0.1	0	0	0.43481	**434.8**
27 December 2006	**350.6**	0.351	15	8.2	0.0082	0.000	0	0.1	0	0	0.47361	**473.6**
28 December 2006	**162.7**	0.163	15	2	0.002	0	0	0.1	0	0	0.19266	**192.7**
29 December 2006	**224.6**	0.225	15	4.8	0.0048	0	0	0.1	0	0	0.29662	**296.6**
30 December 2006	**217.0**	0.217	15	2.4	0.0024	0.307904943	0.000307905	0.1	3.07905E-05	0.030790494	0.252538143	**252.5**
31 December 2006	**360.4**	0.360	15	4.8	0.0048	0	0	0.1	0	0	0.43243	**432.4**
01 January 2007	**320.7**	0.321	15	1.8	0.0018	0.69273521	0.000692735	0.1	6.92735E-05	0.069273521	0.346690897	**346.7**
02 January 2007	**13.0**	0.013	15	1.2	0.0012	0	0	0.1	0	0	0.03102	**31.0**
03 January 2007	**3.9**	0.004	15	2	0.002	0.016662328	1.66623E-05	0.1	1.66623E-06	0.001666233	0.033895007	**33.9**
04 January 2007	**160.0**	0.160	15	0	0	0.18352548	0.000183525	0.1	1.83525E-05	0.018352548	0.159694712	**159.7**
05 January 2007	**226.6**	0.227	15	1	0.001	0.254271059	0.000254271	0.1	2.54271E-05	0.025427106	0.241198593	**241.2**
06 January 2007	**219.1**	0.219	15	1.2	0.0012	0	0	0.1	0	0	0.23713	**237.1**

07 January 2007	**382.6**	0.383	15	8	0.008	0	0	0.1	0	0	0.50255	**502.6**
08 January 2007	**247.9**	0.248	15	7.4	0.0074	0	0	0.1	0	0	0.35885	**358.9**
09 January 2007	**372.0**	0.372	15	9	0.009	0.044824151	4.48242E-05	0.1	4.48242E-06	0.004482415	0.506952764	**507.0**
10 January 2007	**415.8**	0.416	15	7.8	0.0078	0.1797525	0.000179753	0.1	1.79753E-05	0.01797525	0.532570371	**532.6**
11 January 2007	**538.8**	0.539	15	6.4	0.0064	0.098473726	9.84737E-05	0.1	9.84737E-06	0.009847373	0.634652289	**634.7**
12 January 2007	**390.1**	0.390	15	0.6	0.0006	0.471513488	0.000471513	0.1	4.71513E-05	0.047151349	0.39840273	**398.4**
13 January 2007	**450.4**	0.450	15	4.8	0.0048	0.352566047	0.000352566	0.1	3.52566E-05	0.035256605	0.521871151	**521.9**
14 January 2007	**614.6**	0.615	15	0	0	0	0	0.1	0	0	0.61463	**614.6**
15 January 2007	**623.0**	0.623	15	1.6	0.0016	0	0	0.1	0	0	0.64701	**647.0**
16 January 2007	**449.3**	0.449	15	0.6	0.0006	0.153789202	0.000153789	0.1	1.53789E-05	0.01537892	0.458059316	**458.1**
17 January 2007	**268.9**	0.269	15	2	0.002	0	0	0.1	0	0	0.29885	**298.9**
18 January 2007	**1038.0**	1.038	15	21.4	0.0214	0.230091185	0.000230091	0.1	2.30091E-05	0.023009119	1.358614863	**1358.6**
19 January 2007	**612.3**	0.612	15	1.2	0.0012	1.015048595	0.001015049	0.1	0.000101505	0.10150486	0.628807427	**628.8**
20 January 2007	**779.2**	0.779	15	19.6	0.0196	0.254295438	0.000254295	0.1	2.54295E-05	0.025429544	1.072808557	**1072.8**
21 January 2007	**963.4**	0.963	15	0.8	0.0008	0.048997397	4.89974E-05	0.1	4.89974E-06	0.00489974	0.975286504	**975.3**
22 January 2007	**449.9**	0.450	15	1	0.001	0.087575244	8.75752E-05	0.1	8.75752E-06	0.008757524	0.464738637	**464.7**
23 January 2007	**667.1**	0.667	15	0.2	0.0002	0.100156555	0.000100157	0.1	1.00157E-05	0.010015655	0.669909765	**669.9**
24 January 2007	**383.3**	0.383	15	0.2	0.0002	0.180963336	0.000180963	0.1	1.80963E-05	0.018096334	0.386008555	**386.0**
25 January 2007	**340.3**	0.340	15	0	0	0	0	0.1	0	0	0.34032	**340.3**
26 January 2007	**237.2**	0.237	15	0.2	0.0002	0.127741253	0.000127741	0.1	1.27741E-05	0.012774125	0.239958388	**240.0**
27 January 2007	**214.3**	0.214	15	0.2	0.0002	0.201720478	0.00020172	0.1	2.0172E-05	0.020172048	0.216977419	**217.0**
28 January 2007	**304.2**	0.304	15	0.6	0.0006	0.191433168	0.000191433	0.1	1.91433E-05	0.019143317	0.31293285	**312.9**
29 January 2007	**225.9**	0.226	15	0.2	0.0002	0	0	0.1	0	0	0.22894	**228.9**
30 January 2007	**367.4**	0.367	15	0	0	0.394684467	0.000394684	0.1	3.94684E-05	0.039468447	0.366767973	**366.8**
31 January 2007	**327.2**	0.327	15	0	0	0.30198745	0.000301987	0.1	3.01987E-05	0.030198745	0.326737019	**326.7**
01 February 2007	**404.2**	0.404	15	0.4	0.0004	0.084859219	8.48592E-05	0.1	8.48592E-06	0.008485922	0.410022711	**410.0**
02 February 2007	**373.5**	0.374	15	5.2	0.0052	0.045512322	4.55123E-05	0.1	4.55123E-06	0.004551232	0.451451732	**451.5**
03 February 2007	**203.1**	0.203	15	0.2	0.0002	0	0	0.1	0	0	0.20609	**206.1**
04 February 2007	**279.5**	0.279	15	0.2	0.0002	0	0	0.1	0	0	0.28249	**282.5**
05 February 2007	**160.4**	0.160	15	0.2	0.0002	0	0	0.1	0	0	0.16337	**163.4**
06 February 2007	**357.3**	0.357	15	0	0	0	0	0.1	0	0	0.35727	**357.3**
07 February 2007	**388.4**	0.388	15	0.6	0.0006	0.079843642	7.98436E-05	0.1	7.98436E-06	0.007984364	0.397280235	**397.3**
08 February 2007	**429.1**	0.429	15	3.8	0.0038	0	0	0.1	0	0	0.48611	**486.1**
09 February 2007	**391.7**	0.392	15	0.2	0.0002	0.120957981	0.000120958	0.1	1.20958E-05	0.012095798	0.394468563	**394.5**
10 February 2007	**304.2**	0.304	15	1.6	0.0016	0.146263814	0.000146264	0.1	1.46264E-05	0.014626381	0.327940604	**327.9**
11 February 2007	**425.7**	0.426	15	2.8	0.0028	0	0	0.1	0	0	0.46765	**467.7**
12 February 2007	**676.7**	0.677	15	6	0.006	0.193558741	0.000193559	0.1	1.93559E-05	0.019355874	0.766379662	**766.4**
13 February 2007	**354.6**	0.355	15	3.2	0.0032	0	0	0.1	0	0	0.40255	**402.6**
14 February 2007	**168.6**	0.169	15	0.2	0.0002	0	0	0.1	0	0	0.17159	**171.6**
15 February 2007	**345.2**	0.345	15	8.6	0.0086	0.071251559	7.12516E-05	0.1	7.12516E-06	0.007125156	0.474073123	**474.1**
16 February 2007	**206.1**	0.206	15	0	0	0	0	0.1	0	0	0.20608	**206.1**
17 February 2007	**254.4**	0.254	15	0.2	0.0002	0.26549399	0.000265494	0.1	2.65494E-05	0.026549399	0.256991759	**257.0**
18 February 2007	**195.1**	0.195	15	0.6	0.0006	0.069074593	6.90746E-05	0.1	6.90746E-06	0.006907459	0.203946388	**203.9**
19 February 2007	**347.8**	0.348	15	3.2	0.0032	0	0	0.1	0	0	0.39583	**395.8**
20 February 2007	**236.6**	0.237	15	4.6	0.0046	0.033030839	3.30308E-05	0.1	3.30308E-06	0.003303084	0.305580454	**305.6**
21 February 2007	**176.7**	0.177	15	2.2	0.0022	0.216588473	0.000216588	0.1	2.16588E-05	0.021658847	0.209395117	**209.4**
22 February 2007	**222.2**	0.222	15	1.8	0.0018	0.307867022	0.000307867	0.1	3.07867E-05	0.030786702	0.248688199	**248.7**
23 February 2007	**274.9**	0.275	15	3	0.003	0.011560253	1.15603E-05	0.1	1.15603E-06	0.001156025	0.31986266	**319.9**
24 February 2007	**175.5**	0.176	15	7.6	0.0076	0	0	0.1	0	0	0.28954	**289.5**
25 February 2007	**345.7**	0.346	15	4.6	0.0046	0.322432547	0.000322433	0.1	3.22433E-05	0.032243255	0.414176351	**414.2**
26 February 2007	**323.0**	0.323	15	2.4	0.0024	0.587205089	0.000587205	0.1	5.87205E-05	0.058720509	0.358149192	**358.1**
27 February 2007	**476.7**	0.477	15	10.2	0.0102	0.429212831	0.000429213	0.1	4.29213E-05	0.042921283	0.629036181	**629.0**
28 February 2007	**325.2**	0.325	15	7	0.007	0.40548251	0.000405483	0.1	4.05483E-05	0.040548251	0.429591776	**429.6**
01 March 2007	**233.7**	0.234	15	0.6	0.0006	0.339066703	0.000339067	0.2	6.78133E-05	0.067813341	0.2416528	**241.7**
02 March 2007	**208.2**	0.208	15	4.6	0.0046	0	0	0.2	0	0	0.27724	**277.2**
03 March 2007	**166.8**	0.167	15	0.4	0.0004	0.13886425	0.000138864	0.2	2.77728E-05	0.02777285	0.172423407	**172.4**
04 March 2007	**423.9**	0.424	15	3.4	0.0034	0.23639807	0.000236398	0.2	4.72796E-05	0.047279614	0.474190806	**474.2**

05 March 2007	**511.4**	0.511	15	6	0.006	0.19954381	0.000199544	0.2	3.99088E-05	0.039908762	0.600761369	**600.8**
06 March 2007	**311.0**	0.311	15	2.6	0.0026	0.405217066	0.000405217	0.2	8.10434E-05	0.081043413	0.348734349	**348.7**
07 March 2007	**408.7**	0.409	15	1.4	0.0014	0.325281176	0.000325281	0.2	6.50562E-05	0.065056235	0.428704156	**428.7**
08 March 2007	**427.7**	0.428	15	3.8	0.0038	0.021951328	2.19513E-05	0.2	4.39027E-06	0.004390266	0.484604146	**484.6**
09 March 2007	**573.1**	0.573	15	0.8	0.0008	0.706861104	0.000706861	0.2	0.000141372	0.141372221	0.582959417	**583.0**
10 March 2007	**750.0**	0.750	15	0	0	0.779577074	0.000779577	0.2	0.000155915	0.155915415	0.747681269	**747.7**
11 March 2007	**482.6**	0.483	15	12.4	0.0124	0.159619684	0.00015962	0.2	3.19239E-05	0.031923937	0.668091141	**668.1**
12 March 2007	**641.7**	0.642	15	2.4	0.0024	0.62802138	0.000628021	0.2	0.000125604	0.125604276	0.675845936	**675.8**
13 March 2007	**1102.5**	1.103	15	1.8	0.0018	0.221249766	0.00022125	0.2	4.425E-05	0.044249953	1.128856251	**1128.9**
14 March 2007	**1035.1**	1.035	15	0.2	0.0002	0.669647523	0.000669648	0.2	0.00013393	0.133929505	1.036071057	**1036.1**
15 March 2007	**724.7**	0.725	15	0.4	0.0004	0.411350157	0.00041135	0.2	8.227E-05	0.082270031	0.72943595	**729.4**
16 March 2007	**717.5**	0.717	15	0	0	0.163488991	0.000163489	0.3	4.90467E-05	0.049046697	0.7167443	**716.7**
17 March 2007	**918.2**	0.918	15	1.8	0.0018	0.638756199	0.000638756	0.3	0.000191627	0.19162686	0.942305597	**942.3**
18 March 2007	**818.3**	0.818	15	4.4	0.0044	0.75849911	0.000758499	0.3	0.00022755	0.227549733	0.880856754	**880.9**
19 March 2007	**557.4**	0.557	15	3.8	0.0038	0.81147832	0.000811478	0.3	0.000243443	0.243443496	0.610738348	**610.7**
20 March 2007	**494.0**	0.494	15	0	0	1.017780843	0.001017781	0.3	0.000305334	0.305334253	0.489389986	**489.4**
21 March 2007	**740.8**	0.741	15	4	0.004	0.472928423	0.000472928	0.3	0.000141879	0.141878527	0.798711822	**798.7**
22 March 2007	**926.9**	0.927	15	0.6	0.0006	1.174037712	0.001174038	0.3	0.000352211	0.352211313	0.93056683	**930.6**
23 March 2007	**877.6**	0.878	15	0	0	0.761365264	0.000761365	0.3	0.00022841	0.228409579	0.874143856	**874.1**
24 March 2007	**784.3**	0.784	15	0	0	0.644518458	0.000644518	0.3	0.000193356	0.193355537	0.781389667	**781.4**
25 March 2007	**1025.7**	1.026	15	0.2	0.0002	0.375427427	0.000375427	0.3	0.000112628	0.112628228	1.027050577	**1027.1**
26 March 2007				0.2	0.0002	0.845	0.000845046	0.3	0.000253514	0.253513819		
27 March 2007				0.2	0.0002	0.565	0.000565326	0.3	0.000169598	0.169597845		
28 March 2007				0.6	0.0006	0.618	0.000617895	0.3	0.000185369	0.185368616		
29 March 2007				3.4	0.0034	0.674	0.000674138	0.3	0.000202241	0.202241454		
30 March 2007				0	0	0.465	0.000464916	0.3	0.000139475	0.139474748		
31 March 2007				0	0	1.309	0.001309184	0.3	0.000392755	0.392755186		
01 April 2007				0	0	1.186	0.001186222	0.3	0.000355867	0.355866551		
02 April 2007				0	0	1.403	0.001403423	0.3	0.000421027	0.421026817		
03 April 2007				0	0	0.892	0.000891631	0.3	0.000267489	0.267489387		
04 April 2007				0	0	1.763	0.001763264	0.3	0.000528979	0.528979075		
05 April 2007				0	0	2.071	0.002070709	0.3	0.000621213	0.62121261		
06 April 2007				0.2	0.0002	1.539	0.001539416	0.3	0.000461825	0.461824766		
07 April 2007				0	0	1.903	0.001903179	0.3	0.000570954	0.570953682		
08 April 2007				0	0	1.550	0.00154965	0.3	0.000464895	0.464894861		
09 April 2007				0	0	1.557	0.001557286	0.3	0.000467186	0.467185862		
10 April 2007				0	0	1.775	0.001775257	0.3	0.000532577	0.532576965		
11 April 2007				0	0	2.025	0.002024856	0.3	0.000607457	0.607456909		
12 April 2007				0	0	2.187	0.002187161	0.3	0.000656148	0.656148204		
13 April 2007				0	0	1.523	0.001522813	0.3	0.000456844	0.456843915		
14 April 2007				0	0	2.024	0.002024464	0.3	0.000607339	0.607339064		
15 April 2007				0	0	1.654	0.001653541	0.3	0.000496062	0.496062195		
16 April 2007				0	0	2.287	0.002287396	0.6	0.001372437	1.372437494		
17 April 2007				0.2	0.0002	1.624	0.001624361	0.6	0.000974617	0.974616671		
18 April 2007				0	0	1.989	0.001988881	0.6	0.001193329	1.193328732		
19 April 2007	**420.9**	0.421	15	0	0	1.826476819	0.001826477	0.6	0.001095886	1.095886091	0.404461709	**404.5**
20 April 2007	**208.8**	0.209	15	0	0	1.668804663	0.001668805	0.6	0.001001283	1.001282798	0.193740758	**193.7**
21 April 2007	**138.1**	0.138	15	0	0	1.801242216	0.001801242	0.6	0.001080745	1.08074533	0.12190882	**121.9**
22 April 2007	**231.8**	0.232	15	4.2	0.0042	1.149213842	0.001149214	0.6	0.000689528	0.689528305	0.284407075	**284.4**
23 April 2007	**202.0**	0.202	15	3.8	0.0038	0.445872297	0.000445872	0.6	0.000267523	0.267523378	0.254967149	**255.0**
24 April 2007	**295.0**	0.295	15	4.4	0.0044	0.488671429	0.000488671	0.6	0.000293203	0.293202857	0.356591957	**356.6**
25 April 2007	**375.0**	0.375	15	10.2	0.0102	1.42009964	0.0014201	0.6	0.00085206	0.852059784	0.515192437	**515.2**
26 April 2007	**380.4**	0.380	15	0	0	2.240892549	0.002240893	0.6	0.001344536	1.34453553	0.360271967	**360.3**
27 April 2007	**183.0**	0.183	15	0	0	2.102373976	0.002102374	0.6	0.001261424	1.261424386	0.164105301	**164.1**
28 April 2007	**286.3**	0.286	15	0	0	1.898081754	0.001898082	0.6	0.001138849	1.138849053	0.269237264	**269.2**
29 April 2007	**262.5**	0.263	15	0.2	0.0002	1.711088202	0.001711088	0.6	0.001026653	1.026652921	0.250146873	**250.1**
30 April 2007	**571.7**	0.572	15	0.4	0.0004	2.105980718	0.002105981	0.6	0.001263588	1.263588431	0.55879284	**558.8**
01 May 2007	**360.8**	0.361	15	0	0	2.188879364	0.002188879	0.6	0.001313328	1.313327618	0.341100086	**341.1**

02 May 2007	**96.2**	0.096	15	0	0	2.338834521	0.002338835	0.6	0.001403301	1.403300712	0.075150489	**75.2**
03 May 2007	**308.1**	0.308	15	0	0	2.591295152	0.002591295	0.6	0.001554777	1.554777091	0.284731677	**284.7**
04 May 2007	**300.0**	0.300	15	0	0	2.107558406	0.002107558	0.6	0.001264535	1.264535044	0.281045308	**281.0**
05 May 2007	**259.3**	0.259	15	0	0	2.318906714	0.002318907	0.6	0.001391344	1.391344028	0.238383173	**238.4**
06 May 2007	**238.6**	0.239	15	1.8	0.0018	0.706980768	0.000706981	0.6	0.000424188	0.424188461	0.259267173	**259.3**
07 May 2007	**482.0**	0.482	15	1.4	0.0014	1.91022485	0.001910225	0.6	0.001146135	1.14613491	0.485757976	**485.8**
08 May 2007	**426.8**	0.427	15	1.4	0.0014	1.66762769	0.001667628	0.6	0.001000577	1.000576614	0.432781351	**432.8**
09 May 2007	**296.1**	0.296	15	2.8	0.0028	0.964810573	0.000964811	0.6	0.000578886	0.578886344	0.329426705	**329.4**
10 May 2007	**431.9**	0.432	15	0.4	0.0004	2.306448079	0.002306448	0.6	0.001383869	1.383868847	0.417161967	**417.2**
11 May 2007	**278.5**	0.278	15	6.8	0.0068	0.728963932	0.000728964	0.6	0.000437378	0.437378359	0.373899325	**373.9**
12 May 2007	**230.4**	0.230	15	3.6	0.0036	1.560130095	0.00156013	0.6	0.000936078	0.936078057	0.270318829	**270.3**
13 May 2007	**225.9**	0.226	15	0	0	1.350237491	0.001350237	0.6	0.000810142	0.810142494	0.213717863	**213.7**
14 May 2007	**506.8**	0.507	15	1.8	0.0018	2.050942818	0.002050943	0.6	0.001230566	1.230565691	0.515331515	**515.3**
15 May 2007	**370.8**	0.371	15	2.2	0.0022	0.866824572	0.000866825	0.6	0.000520095	0.520094743	0.396028579	**396.0**
16 May 2007	**402.3**	0.402	15	6.8	0.0068	0.382522991	0.000382523	0.9	0.000344271	0.344270692	0.49914594	**499.1**
17 May 2007	**333.8**	0.334	15	1	0.001	2.556851479	0.002556851	0.9	0.002301166	2.301166331	0.314282505	**314.3**
18 May 2007	**233.8**	0.234	15	4	0.004	2.390083133	0.002390083	0.9	0.002151075	2.15107482	0.261563878	**261.6**
19 May 2007	**115.6**	0.116	15	0.8	0.0008	2.606217494	0.002606217	0.9	0.002345596	2.345595744	0.092366064	**92.4**
20 May 2007	**203.0**	0.203	15	0	0	2.808204881	0.002808205	0.9	0.002527384	2.527384393	0.165079234	**165.1**
21 May 2007	**254.4**	0.254	15	0	0	3.429845488	0.003429845	0.9	0.003086861	3.086860939	0.208087086	**208.1**
22 May 2007	**365.9**	0.366	15	0	0	2.765470652	0.002765471	0.9	0.002488924	2.488923587	0.328576146	**328.6**
23 May 2007	**277.5**	0.277	15	0	0	2.024963951	0.002024964	0.9	0.001822468	1.822467556	0.250112987	**250.1**
24 May 2007	**170.0**	0.170	15	0.6	0.0006	1.397268776	0.001397269	0.9	0.001257542	1.257541898	0.160166872	**160.2**
25 May 2007	**167.9**	0.168	15	1.8	0.0018	2.259388977	0.002259389	0.9	0.00203345	2.033450079	0.164348249	**164.3**
26 May 2007	**96.5**	0.097	15	2.6	0.0026	1.927998409	0.001927998	0.9	0.001735199	1.735198568	0.109512021	**109.5**
27 May 2007	**218.5**	0.218	15	0.8	0.0008	2.024154087	0.002024154	0.9	0.001821739	1.821738678	0.20312392	**203.1**
28 May 2007	**234.9**	0.235	15	0	0	2.484682036	0.002484682	0.9	0.002236214	2.236213832	0.201336793	**201.3**
29 May 2007	**307.2**	0.307	15	0	0	3.109946868	0.003109947	0.9	0.002798952	2.798952181	0.265185717	**265.2**
30 May 2007	**213.2**	0.213	15	1.2	0.0012	0.852409211	0.000852409	0.9	0.000767168	0.76716829	0.219662476	**219.7**
31 May 2007	**190.9**	0.191	15	5.4	0.0054	2.017618106	0.002017618	0.9	0.001815856	1.815856295	0.244612156	**244.6**
01 June 2007	**226.6**	0.227	15	0	0	3.410201276	0.003410201	1.2	0.004092242	4.092241531	0.165226377	**165.2**
02 June 2007	**210.1**	0.210	15	5.6	0.0056	0.52124416	0.000521244	1.2	0.000625493	0.625492992	0.284717605	**284.7**
03 June 2007	**234.5**	0.235	15	22.6	0.0226	0.154326917	0.000154327	1.2	0.000185192	0.1851923	0.570752115	**570.8**
04 June 2007	**265.6**	0.266	15	0	0	1.382460538	0.001382461	1.2	0.001658953	1.658952646	0.24074571	**240.7**
05 June 2007	**368.8**	0.369	15	0	0	3.199789793	0.00319979	1.2	0.003839748	3.839747751	0.311173784	**311.2**
06 June 2007	**189.0**	0.189	15	0	0	2.184727086	0.002184727	1.2	0.002621673	2.621672503	0.149644912	**149.6**
07 June 2007	**290.9**	0.291	15	0	0	3.455086754	0.003455087	1.2	0.004146104	4.146104105	0.228658438	**228.7**
08 June 2007	**255.9**	0.256	15	0	0	3.722213552	0.003722214	1.2	0.004466656	4.466656262	0.188880156	**188.9**
09 June 2007	**426.8**	0.427	15	0	0	3.787633689	0.003787634	1.2	0.00454516	4.545160426	0.358602594	**358.6**
10 June 2007	**329.0**	0.329	15	0	0	3.708719288	0.003708719	1.2	0.004450463	4.450463145	0.262213053	**262.2**
11 June 2007	**418.5**	0.419	15	1.4	0.0014	2.009853989	0.002009854	1.2	0.002411825	2.411824787	0.403322628	**403.3**
12 June 2007	**412.3**	0.412	15	0.8	0.0008	2.905147329	0.002905147	1.2	0.003486177	3.486176795	0.372017348	**372.0**
13 June 2007	**312.7**	0.313	15	32	0.032	1.117472749	0.001117473	1.2	0.001340967	1.340967298	0.772535491	**772.5**
14 June 2007	**194.3**	0.194	15	1.8	0.0018	0.302835229	0.000302835	1.2	0.000363402	0.363402275	0.215818966	**215.8**
15 June 2007	**347.8**	0.348	15	1	0.001	0.232549462	0.000232549	1.2	0.000279059	0.279059354	0.35863411	**358.6**
16 June 2007	**326.2**	0.326	15	0	0	0.341037229	0.000341037	1.2	0.000409245	0.409244674	0.32010133	**320.1**
17 June 2007	**275.5**	0.275	15	0	0	1.939371151	0.001939371	1.2	0.002327245	2.327245381	0.240581319	**240.6**
18 June 2007	**201.1**	0.201	15	0.2	0.0002	0.878576441	0.000878576	1.2	0.001054292	1.054291729	0.188315624	**188.3**
19 June 2007	**255.3**	0.255	15	21.4	0.0214	0.824023176	0.000824023	1.2	0.000988828	0.988827811	0.561447583	**561.4**
20 June 2007	**345.7**	0.346	15	5	0.005	1.124164113	0.001124164	1.2	0.001348997	1.348996935	0.400415046	**400.4**
21 June 2007	**200.2**	0.200	15	1	0.001	0.777580596	0.000777581	1.2	0.000933097	0.933096715	0.201203549	**201.2**
22 June 2007	**238.9**	0.239	15	7.2	0.0072	1.731981834	0.001731982	1.2	0.002078378	2.078378201	0.315764327	**315.8**
23 June 2007	**117.9**	0.118	15	0.4	0.0004	1.704960023	0.00170496	1.2	0.002045952	2.045952027	0.09324072	**93.2**

24 June 2007	**159.9**	0.160	15	3.4	0.0034	1.730724113	0.001730724	1.2	0.002076869	2.076868936	0.179746966	**179.7**
25 June 2007	**309.4**	0.309	15	0.8	0.0008	2.345345554	0.002345346	1.2	0.002814415	2.814414665	0.27913378	**279.1**
26 June 2007	**362.2**	0.362	15	0.4	0.0004	2.553657772	0.002553658	1.2	0.003064389	3.064389326	0.32221416	**322.2**
27 June 2007	**440.4**	0.440	15	0	0	3.171050375	0.00317105	1.2	0.00380526	3.80526045	0.383341093	**383.3**
28 June 2007	**197.9**	0.198	15	6.6	0.0066	0.668365163	0.000668365	1.2	0.000802038	0.802038195	0.284879427	**284.9**
29 June 2007	**257.3**	0.257	15	1.8	0.0018	2.49347844	0.002493478	1.2	0.002992174	2.992174128	0.239367388	**239.4**
30 June 2007	**110.5**	0.110	15	3.8	0.0038	2.013184404	0.002013184	1.2	0.002415821	2.415821285	0.131222681	**131.2**
01 July 2007	**105.9**	0.106	15	19.4	0.0194	1.745509464	0.001745509	1.2	0.002094611	2.094611357	0.36547083	**365.5**
02 July 2007	**455.2**	0.455	15	6.6	0.0066	1.967750245	0.00196775	1.2	0.0023613	2.361300294	0.518730496	**518.7**
03 July 2007	**472.7**	0.473	15	4.2	0.0042	1.543436926	0.001543437	1.2	0.001852124	1.852124311	0.507938135	**507.9**
04 July 2007	**213.4**	0.213	15	9.8	0.0098	1.221657405	0.001221657	1.2	0.001465989	1.465988886	0.338400167	**338.4**
05 July 2007	**159.1**	0.159	15	6.2	0.0062	0.756825113	0.000756825	1.2	0.00090819	0.908190136	0.238467148	**238.5**
06 July 2007	**359.5**	0.359	15	16.2	0.0162	2.109718289	0.002109718	1.2	0.002531662	2.531661947	0.564505071	**564.5**
07 July 2007	**168.9**	0.169	15	0.4	0.0004	2.699151625	0.002699152	1.2	0.003238982	3.23898195	0.126295271	**126.3**
08 July 2007	**96.0**	0.096	15	3	0.003	1.613439971	0.00161344	1.2	0.001936128	1.936127966	0.111978081	**112.0**
09 July 2007	**200.2**	0.200	15	16	0.016	0.5237976	0.000523798	1.2	0.000628557	0.62855712	0.430811643	**430.8**
10 July 2007	**98.8**	0.099	15	0.8	0.0008	1.462807428	0.001462807	1.2	0.001755369	1.755368914	0.084459466	**84.5**
11 July 2007	**219.0**	0.219	15	1.2	0.0012	1.774030245	0.00177403	1.2	0.002128836	2.128836294	0.205107456	**205.1**
12 July 2007	**189.2**	0.189	15	2.6	0.0026	1.983269926	0.00198327	1.2	0.002379924	2.379923911	0.192501141	**192.5**
13 July 2007	**230.1**	0.230	15	12.8	0.0128	0.251839623	0.00025184	1.2	0.000302208	0.302207548	0.417573553	**417.6**
14 July 2007	**184.5**	0.184	15	8	0.008	2.479872489	0.002479872	1.2	0.002975847	2.975846986	0.259815629	**259.8**
15 July 2007	**162.4**	0.162	15	3.2	0.0032	2.565701317	0.002565701	1.2	0.003078842	3.078841581	0.164257376	**164.3**
16 July 2007	**193.1**	0.193	15	5.8	0.0058	2.988353269	0.002988353	1.2	0.003586024	3.586023923	0.226262974	**226.3**
17 July 2007	**174.1**	0.174	15	3.6	0.0036	1.796115482	0.001796115	1.2	0.002155339	2.155338578	0.195816588	**195.8**
18 July 2007	**222.4**	0.222	15	2.8	0.0028	2.157437601	0.002157438	1.2	0.002588925	2.588925121	0.225526123	**225.5**
19 July 2007	**163.3**	0.163	15	0.6	0.0006	2.21078685	0.002210787	1.2	0.002652944	2.65294422	0.132455837	**132.5**
20 July 2007	**384.0**	0.384	15	8.4	0.0084	0.371812134	0.000371812	1.2	0.000446175	0.446174561	0.503307382	**503.3**
21 July 2007	**240.1**	0.240	15	2.2	0.0022	0.807890677	0.000807891	1.2	0.000969469	0.969468813	0.258564634	**258.6**
22 July 2007	**460.9**	0.461	15	2.8	0.0028	1.816472964	0.001816473	1.2	0.002179768	2.179767557	0.470210153	**470.2**
23 July 2007	**385.8**	0.386	15	1	0.001	1.143150185	0.00114315	1.2	0.00137178	1.371780222	0.380209963	**380.2**
24 July 2007	**270.7**	0.271	15	2	0.002	2.173317448	0.002173317	1.2	0.002607981	2.607980938	0.261580286	**261.6**
25 July 2007	**234.0**	0.234	15	2.8	0.0028	2.064715063	0.002064715	1.2	0.002477658	2.477658076	0.238805129	**238.8**
26 July 2007	**164.7**	0.165	15	2.2	0.0022	2.00603488	0.002006035	1.2	0.002407242	2.407241856	0.161581372	**161.6**
27 July 2007	**426.4**	0.426	15	1.6	0.0016	2.389537396	0.002389537	1.2	0.002867445	2.867444875	0.407414994	**407.4**
28 July 2007	**302.9**	0.303	15	2	0.002	1.793118265	0.001793118	1.2	0.002151742	2.151741918	0.300617205	**300.6**
29 July 2007	**366.0**	0.366	15	0.6	0.0006	2.268239457	0.002268239	1.2	0.002721887	2.721887348	0.334185023	**334.2**
30 July 2007	**456.0**	0.456	15	0	0	3.084465274	0.003084465	1.2	0.003701358	3.701358328	0.400492958	**400.5**
31 July 2007	**358.9**	0.359	15	0	0	3.342440039	0.00334244	1.2	0.004010928	4.010928047	0.298729413	**298.7**
01 August 2007	**314.7**	0.315	15	0.4	0.0004	0.964126413	0.000964126	1.2	0.001156952	1.156951695	0.303299058	**303.3**
02 August 2007	**202.3**	0.202	15	0.2	0.0002	2.878342697	0.002878343	1.2	0.003454011	3.454011236	0.153509831	**153.5**
03 August 2007	**280.3**	0.280	15	0	0	2.149664009	0.002149664	1.2	0.002579597	2.57959681	0.241559381	**241.6**
04 August 2007	**402.6**	0.403	15	8	0.008	1.990689524	0.00199069	1.2	0.002388827	2.388827429	0.486794255	**486.8**
05 August 2007	**473.1**	0.473	15	29.2	0.0292	0.966398142	0.000966398	1.2	0.001159678	1.159677771	0.893658167	**893.7**
06 August 2007	**320.6**	0.321	15	4.8	0.0048	1.525137717	0.001525138	1.2	0.001830165	1.83016526	0.365160854	**365.2**
07 August 2007	**799.0**	0.799	15	0	0	2.808177546	0.002808178	1.2	0.003369813	3.369813055	0.748412804	**748.4**
08 August 2007	**276.4**	0.276	15	0	0	2.058151089	0.002058151	1.2	0.002469781	2.469781307	0.23935328	**239.4**
09 August 2007	**203.8**	0.204	15	0.6	0.0006	1.024880965	0.001024881	1.2	0.001229857	1.229857158	0.194312143	**194.3**
10 August 2007	**260.3**	0.260	15	2.8	0.0028	1.446799418	0.001446799	1.2	0.001736159	1.736159302	0.27623761	**276.2**
11 August 2007	**298.7**	0.299	15	20	0.02	0.282345063	0.000282345	1.2	0.000338814	0.338814075	0.593637789	**593.6**
12 August 2007	**190.5**	0.190	15	6	0.006	1.333104189	0.001333104	1.2	0.001599725	1.599725027	0.256497458	**256.5**
13 August 2007	**304.5**	0.304	15	0.2	0.0002	2.184258435	0.002184258	1.2	0.00262111	2.621110122	0.268150015	**268.2**
14 August 2007	**338.4**	0.338	15	3.8	0.0038	0.803679564	0.00080368	1.2	0.000964415	0.964415476	0.380893768	**380.9**
15 August 2007	**107.7**	0.108	15	6.4	0.0064	1.594126056	0.001594126	1.2	0.001912951	1.912951268	0.174965731	**175.0**
16 August 2007	**221.1**	0.221	15	1.4	0.0014	1.798542991	0.001798543	1.2	0.002158252	2.15825159	0.209746226	**209.7**
17 August 2007	**241.5**	0.241	15	1.8	0.0018	0.723273283	0.000723273	1.2	0.000867928	0.86792794	0.255461081	**255.5**
18 August 2007	**115.1**	0.115	15	8.8	0.0088	0.672005308	0.000672005	1.2	0.000806406	0.80640637	0.234983904	**235.0**
19 August 2007	**192.4**	0.192	15	0	0	1.964477769	0.001964478	1.2	0.002357373	2.357373323	0.1570394	**157.0**
20 August 2007	**249.7**	0.250	15	8.4	0.0084	1.834630905	0.001834631	1.2	0.002201557	2.201557086	0.342656644	**342.7**

21 August 2007	**295.8**	0.296	15	0	0	1.628750199	0.001628751	1.2	0.001954501	1.954501188	0.266442482	**266.4**
22 August 2007	**200.0**	0.200	15	0	0	2.4328106	0.002432811	1.2	0.002919373	2.91937272	0.156196076	**156.2**
23 August 2007	**189.4**	0.189	15	0	0	2.118255254	0.002118255	1.2	0.002541906	2.541906305	0.151311405	**151.3**
24 August 2007	**146.3**	0.146	15	0	0	2.301080041	0.00230108	1.2	0.002761296	2.761296049	0.104900559	**104.9**
25 August 2007	**332.1**	0.332	15	0.4	0.0004	1.505306802	0.001505307	1.2	0.001806368	1.806368162	0.310957811	**311.0**
26 August 2007	**401.5**	0.402	15	0	0	2.24392581	0.002243926	1.2	0.002692711	2.692710972	0.361116002	**361.1**
27 August 2007	**258.8**	0.259	15	0	0	1.49134741	0.001491347	1.2	0.001789617	1.789616892	0.231925747	**231.9**
28 August 2007	**353.5**	0.353	15	0.2	0.0002	1.764366099	0.001764366	1.2	0.002117239	2.117239319	0.32469141	**324.7**
29 August 2007	**225.2**	0.225	15	0	0	2.26077108	0.002260771	1.2	0.002712925	2.712925296	0.184536121	**184.5**
30 August 2007	**441.4**	0.441	15	0	0	1.804061055	0.001804061	1.2	0.002164873	2.164873266	0.408926901	**408.9**
31 August 2007	**313.9**	0.314	15	0	0	1.602591208	0.001602591	1.2	0.001923109	1.923109449	0.285073358	**285.1**
01 September 2007	**178.3**	0.178	15	0.4	0.0004	1.589138922	0.001589139	0.9	0.001430225	1.43022503	0.162836625	**162.8**
02 September 2007	**254.7**	0.255	15	4	0.004	0.413035568	0.000413036	0.9	0.000371732	0.371732011	0.30915402	**309.2**
03 September 2007	**484.8**	0.485	15	0	0	1.615161265	0.001615161	0.9	0.001453645	1.453645139	0.462955323	**463.0**
04 September 2007	**468.8**	0.469	15	0	0	1.24267546	0.001242675	0.9	0.001118408	1.118407914	0.451993881	**452.0**
05 September 2007	**484.1**	0.484	15	0.4	0.0004	1.528069223	0.001528069	0.9	0.001375262	1.375262301	0.469431065	**469.4**
06 September 2007	**403.5**	0.403	15	0	0	2.142639939	0.00214264	0.9	0.001928376	1.928375945	0.374564361	**374.6**
07 September 2007	**149.2**	0.149	15	0	0	2.233200722	0.002233201	0.9	0.002009881	2.009880649	0.11903179	**119.0**
08 September 2007	**206.9**	0.207	15	0.2	0.0002	1.180829757	0.00118083	0.9	0.001062747	1.062746781	0.193938798	**193.9**
09 September 2007	**348.2**	0.348	15	0	0	1.370820614	0.001370821	0.9	0.001233739	1.233738552	0.329653922	**329.7**
10 September 2007	**340.5**	0.341	15	0	0	1.957804717	0.001957805	0.9	0.001762024	1.762024245	0.314079636	**314.1**
11 September 2007	**453.2**	0.453	15	0.2	0.0002	0.887712963	0.000887713	0.9	0.000798942	0.798941667	0.444225875	**444.2**
12 September 2007	**448.8**	0.449	15	0	0	1.394593149	0.001394593	0.9	0.001255134	1.255133834	0.430012992	**430.0**
13 September 2007	**418.5**	0.419	15	0	0	1.302041809	0.001302042	0.9	0.001171838	1.171837628	0.400962436	**401.0**
14 September 2007	**249.4**	0.249	15	0.6	0.0006	1.276383897	0.001276384	0.9	0.001148746	1.148745507	0.241208817	**241.2**
15 September 2007	**255.9**	0.256	15	0.2	0.0002	1.839488531	0.001839489	0.9	0.00165554	1.655539678	0.234036905	**234.0**
16 September 2007	**156.6**	0.157	15	1.6	0.0016	1.037952451	0.001037952	0.6	0.000622771	0.62277147	0.171228428	**171.2**
17 September 2007	**368.9**	0.369	15	1.2	0.0012	1.063317194	0.001063317	1	0.001063317	1.063317194	0.370970242	**371.0**
18 September 2007	**234.3**	0.234	15	0.2	0.0002	0.772324205	0.000772324	1	0.000772324	0.772324205	0.225745137	**225.7**
19 September 2007	**210.3**	0.210	15	2.4	0.0024	0.755218523	0.000755219	1	0.000755219	0.755218523	0.234961722	**235.0**
20 September 2007	**303.5**	0.304	15	6.8	0.0068	0.191350577	0.000191351	1	0.000191351	0.191350577	0.402659741	**402.7**
21 September 2007	**378.2**	0.378	15	10.6	0.0106	0.364196817	0.000364197	1	0.000364197	0.364196817	0.531717048	**531.7**
22 September 2007	**141.1**	0.141	15	0.2	0.0002	1.488721453	0.001488721	1	0.001488721	1.488721453	0.121779178	**121.8**
23 September 2007	**283.1**	0.283	15	0.8	0.0008	0.719434651	0.000719435	1	0.000719435	0.719434651	0.28426848	**284.3**
24 September 2007	**120.4**	0.120	15	3.2	0.0032	0.716029829	0.00071603	1	0.00071603	0.716029829	0.157689553	**157.7**
25 September 2007	**382.2**	0.382	15	0.4	0.0004	0.859500869	0.000859501	1	0.000859501	0.859500869	0.375347487	**375.3**
26 September 2007	**329.6**	0.330	15	0	0	0.825917877	0.000825918	1	0.000825918	0.825917877	0.317221232	**317.2**
27 September 2007	**274.7**	0.275	15	0	0	0.741739273	0.000741739	1	0.000741739	0.741739273	0.263593911	**263.6**
28 September 2007	**299.8**	0.300	15	0.4	0.0004	0.59235117	0.000592351	1	0.000592351	0.59235117	0.296894732	**296.9**
29 September 2007	**290.7**	0.291	15	1.6	0.0016	0.322252565	0.000322253	1	0.000322253	0.322252565	0.309876212	**309.9**
30 September 2007	**373.7**	0.374	15	1.6	0.0016	0.885154103	0.000885154	1	0.000885154	0.885154103	0.384402688	**384.4**
01 October 2007	**272.9**	0.273	15	0.2	0.0002	0.783081586	0.000783082	1	0.000783082	0.783081586	0.264133776	**264.1**
02 October 2007	**393.9**	0.394	15	0	0	0.845033893	0.000845034	1	0.000845034	0.845033893	0.381204492	**381.2**
03 October 2007	**504.1**	0.504	15	3.6	0.0036	0.249848341	0.000249848	1	0.000249848	0.249848341	0.554352275	**554.4**
04 October 2007	**561.8**	0.562	15	0	0	0.525195156	0.000525195	1	0.000525195	0.525195156	0.553912073	**553.9**
05 October 2007	**354.4**	0.354	15	0	0	0.559104322	0.000559104	1	0.000559104	0.559104322	0.346053435	**346.1**
06 October 2007	**482.7**	0.483	15	0	0	0.770225979	0.000770226	1	0.000770226	0.770225979	0.47112661	**471.1**
07 October 2007	**510.9**	0.511	15	0	0	0.426277921	0.000426278	1	0.000426278	0.426277921	0.504525831	**504.5**
08 October 2007	**331.0**	0.331	15	0	0	0.558062749	0.000558063	1	0.000558063	0.558062749	0.322619059	**322.6**
09 October 2007	**598.0**	0.598	15	0	0	0.260431393	0.000260431	1	0.000260431	0.260431393	0.594093529	**594.1**
10 October 2007	**420.5**	0.421	15	0	0	1.088135426	0.001088135	1	0.001088135	1.088135426	0.404177969	**404.2**
11 October 2007	**377.0**	0.377	15	0	0	0.612768479	0.000612768	1	0.000612768	0.612768479	0.367808473	**367.8**
12 October 2007	**239.2**	0.239	15	0	0	0.623673838	0.000623674	1	0.000623674	0.623673838	0.229814892	**229.8**
13 October 2007	**307.7**	0.308	15	0	0	0.816332236	0.000816332	1	0.000816332	0.816332236	0.295455016	**295.5**
14 October 2007	**255.0**	0.255	15	0	0	0.352626229	0.000352626	1	0.000352626	0.352626229	0.249690607	**249.7**
15 October 2007	**231.7**	0.232	15	1	0.001	0	0	1	0	0	0.24673	**246.7**
16 October 2007	**511.2**	0.511	15	0.8	0.0008	0.304541153	0.000304541	1	0.000304541	0.304541153	0.518651883	**518.7**
17 October 2007	**270.8**	0.271	15	0.2	0.0002	0.078022328	7.80223E-05	1	7.80223E-05	0.078022328	0.272619665	**272.6**

18 October 2007	**440.3**	0.440	15	0.2	0.0002	0.208413494	0.000208413	1	0.000208413	0.208413494	0.440143798	**440.1**
19 October 2007	**250.0**	0.250	15	0	0	0	0	1	0	0	0.24995	**250.0**
20 October 2007	**102.8**	0.103	15	0	0	0.269146677	0.000269147	1	0.000269147	0.269146677	0.0987328	**98.7**
21 October 2007	**295.5**	0.295	15	0	0	0.167662533	0.000167663	1	0.000167663	0.167662533	0.292975062	**293.0**
22 October 2007	**73.1**	0.073	15	1.6	0.0016	0	0	1	0	0	0.09709	**97.1**
23 October 2007	**139.7**	0.140	15	0	0	0	0	1	0	0	0.13971	**139.7**
24 October 2007	**106.1**	0.106	15	0.2	0.0002	0.08347121	8.34712E-05	1	8.34712E-05	0.08347121	0.107867932	**107.9**
25 October 2007	**38.4**	0.038	15	0.2	0.0002	0	0	1	0	0	0.04142	**41.4**
26 October 2007	**43.6**	0.044	15	3	0.003	0	0	1	0	0	0.08858	**88.6**
27 October 2007	**97.4**	0.097	15	0.4	0.0004	0.021508775	2.15088E-05	1	2.15088E-05	0.021508775	0.103097368	**103.1**
28 October 2007	**123.9**	0.124	15	8.8	0.0088	0	0	1	0	0	0.25589	**255.9**
29 October 2007	**94.5**	0.094	15	0.2	0.0002	0.039274145	3.92741E-05	1	3.92741E-05	0.039274145	0.096860888	**96.9**
30 October 2007	**41.2**	0.041	15	0	0	0.208097087	0.000208097	1	0.000208097	0.208097087	0.038088544	**38.1**
31 October 2007	**83.2**	0.083	15	0	0	0.558729033	0.000558729	1	0.000558729	0.558729033	0.074829064	**74.8**
01 November 2007	**95.2**	0.095	15	0	0	0.493400697	0.000493401	0.1	4.93401E-05	0.04934007	0.094489899	**94.5**
02 November 2007	**25.3**	0.025	15	0	0	0.260624964	0.000260625	0.1	2.60625E-05	0.026062496	0.024949063	**24.9**
03 November 2007	**95.7**	0.096	15	0.2	0.0002	0.203626216	0.000203626	0.1	2.03626E-05	0.020362622	0.098434561	**98.4**
04 November 2007	**47.9**	0.048	15	0	0	0.221327155	0.000221327	0.1	2.21327E-05	0.022132716	0.047578009	**47.6**
05 November 2007	**41.8**	0.042	15	0.4	0.0004	0	0	0.1	0	0	0.0478	**47.8**
06 November 2007	**230.4**	0.230	15	0	0	0.138402323	0.000138402	0.1	1.38402E-05	0.013840232	0.230152397	**230.2**
07 November 2007	**253.4**	0.253	15	0	0	0.372876603	0.000372877	0.1	3.72877E-05	0.03728766	0.252860685	**252.9**
08 November 2007	**285.3**	0.285	15	1.8	0.0018	0.346139079	0.000346139	0.1	3.46139E-05	0.034613908	0.311780791	**311.8**
09 November 2007	**342.2**	0.342	15	0	0	0.300379395	0.000300379	0.1	3.00379E-05	0.030037939	0.341769431	**341.8**
10 November 2007	**577.0**	0.577	15	0	0	0.394613964	0.000394614	0.1	3.94614E-05	0.039461396	0.576358079	**576.4**
11 November 2007	**856.7**	0.857	15	1.2	0.0012	0.298660667	0.000298661	0.1	2.98661E-05	0.029866067	0.874212009	**874.2**
12 November 2007	**621.9**	0.622	15	1.2	0.0012	0.025128628	2.51286E-05	0.1	2.51286E-06	0.002512863	0.639882307	**639.9**
13 November 2007	**402.2**	0.402	15	0.2	0.0002	0.232171568	0.000232172	0.1	2.32172E-05	0.023217157	0.404831743	**404.8**
14 November 2007	**204.2**	0.204	15	1.8	0.0018	0.060146179	6.01462E-05	0.1	6.01462E-06	0.006014618	0.231149781	**231.1**
15 November 2007	**213.0**	0.213	15	1	0.001	0.031975953	3.1976E-05	0.1	3.1976E-06	0.003197595	0.227972036	**228.0**
16 November 2007	**334.8**	0.335	15	0	0	0.03667489	3.66749E-05	0.1	3.66749E-06	0.003667489	0.334694988	**334.7**
17 November 2007	**248.1**	0.248	15	12.4	0.0124	0	0	0.1	0	0	0.43413	**434.1**
18 November 2007	**446.6**	0.447	15	11.4	0.0114	0	0	0.1	0	0	0.61757	**617.6**
19 November 2007	**499.8**	0.500	15	8.2	0.0082	0	0	0.1	0	0	0.62283	**622.8**
20 November 2007	**486.5**	0.486	15	0.8	0.0008	0	0	0.1	0	0	0.49846	**498.5**
21 November 2007	**565.6**	0.566	15	1	0.001	0	0	0.1	0	0	0.58063	**580.6**
22 November 2007	**386.3**	0.386	15	0	0	0	0	0.1	0	0	0.3863	**386.3**
23 November 2007	**285.7**	0.286	15	0	0	0	0	0.1	0	0	0.28567	**285.7**
24 November 2007	**278.1**	0.278	15	3	0.003	0.238203922	0.000238204	0.1	2.38204E-05	0.023820392	0.322752694	**322.8**
25 November 2007	**496.4**	0.496	15	0.4	0.0004	0.145152838	0.000145153	0.1	1.45153E-05	0.014515284	0.502222271	**502.2**
26 November 2007	**393.5**	0.393	15	1	0.001	0	0	0.1	0	0	0.40846	**408.5**
27 November 2007	**435.2**	0.435	15	0	0	0.004470656	4.47066E-06	0.1	4.47066E-07	0.000447066	0.435223294	**435.2**
28 November 2007	**471.1**	0.471	15	7	0.007	0	0	0.1	0	0	0.57613	**576.1**
29 November 2007	**405.0**	0.405	15	3.4	0.0034	0	0	0.1	0	0	0.45596	**456.0**
30 November 2007	**315.0**	0.315	15	11.4	0.0114	0	0	0.1	0	0	0.48604	**486.0**
01 December 2007	**400.2**	0.400	15	8.4	0.0084	0	0	0.1	0	0	0.52618	**526.2**
02 December 2007	**402.3**	0.402	15	9.6	0.0096	0	0	0.1	0	0	0.54633	**546.3**
03 December 2007	**275.9**	0.276	15	0.4	0.0004	0	0	0.1	0	0	0.2819	**281.9**
04 December 2007	**411.9**	0.412	15	6.4	0.0064	0.181725378	0.000181725	0.1	1.81725E-05	0.018172538	0.507607412	**507.6**
05 December 2007	**342.7**	0.343	15	0.8	0.0008	0	0	0.1	0	0	0.35473	**354.7**
06 December 2007	**283.3**	0.283	15	13.8	0.0138	0.0932534	9.32534E-05	0.1	9.32534E-06	0.00932534	0.49019012	**490.2**
07 December 2007	**475.2**	0.475	15	1	0.001	0	0	0.1	0	0	0.4902	**490.2**
08 December 2007	**312.5**	0.312	15	24.6	0.0246	0	0	0.1	0	0	0.68146	**681.5**
09 December 2007	**435.6**	0.436	15	3	0.003	0	0	0.1	0	0	0.48058	**480.6**
10 December 2007	**446.1**	0.446	15	0	0	0	0	0.1	0	0	0.4461	**446.1**
11 December 2007	**372.8**	0.373	15	0.4	0.0004	0	0	0.1	0	0	0.37878	**378.8**
12 December 2007	**107.0**	0.107	15	0	0	0.138832102	0.000138832	0.1	1.38832E-05	0.01388321	0.106761752	**106.8**
13 December 2007	**193.3**	0.193	15	0	0	0.139726156	0.000139726	0.1	1.39726E-05	0.013972616	0.193040411	**193.0**
14 December 2007	**426.4**	0.426	15	0	0	0	0	0.1	0	0	0.4264	**426.4**

15 December 2007				0	0	0.152	0.000151907	0.1	1.51907E-05	0.015190708		
16 December 2007				0	0	0.335	0.000334837	0.1	3.34837E-05	0.033483735		
17 December 2007				0.2	0.0002	0.000	0	0.1	0	0		
18 December 2007				0	0	0.000	0	0.1	0	0		
19 December 2007				0	0	0.000	0	0.1	0	0		
20 December 2007				0	0	0.000	0	0.1	0	0		
21 December 2007				0.4	0.0004	0.000	0	0.1	0	0		
22 December 2007				2	0.002	0.000	0	0.1	0	0		
23 December 2007				0.4	0.0004	0.000	0	0.1	0	0		
24 December 2007				5.4	0.0054	0.000	0	0.1	0	0		
25 December 2007				1	0.001	0.000	0	0.1	0	0		
26 December 2007				0.6	0.0006	0.000	0	0.1	0	0		
27 December 2007				14.8	0.0148	0.000	0	0.1	0	0		
28 December 2007				1.6	0.0016	0.000	0	0.1	0	0		
29 December 2007				4.4	0.0044	0.000	0	0.1	0	0		
30 December 2007				0.2	0.0002	0.000	0	0.1	0	0		
31 December 2007				0.6	0.0006	0.056	5.56663E-05	0.1	5.56663E-06	0.005566627		
01 January 2008				0.2	0.0002	0.000	0	0.1	0	0		
02 January 2008				0	0	0.572	0.000572294	0.1	5.72294E-05	0.057229438		
03 January 2008				0	0	0.288	0.000287623	0.1	2.87623E-05	0.028762269		
04 January 2008	**435.8**	0.436	15	9	0.009	0	0	0.1	0	0	0.57082	**570.8**
05 January 2008	**196.2**	0.196	15	0.6	0.0006	0	0	0.1	0	0	0.20524	**205.2**
06 January 2008	**250.5**	0.250	15	6.4	0.0064	0	0	0.1	0	0	0.34647	**346.5**
07 January 2008	**383.8**	0.384	15	1.8	0.0018	0	0	0.1	0	0	0.41079	**410.8**
08 January 2008	**245.2**	0.245	15	13.2	0.0132	0	0	0.1	0	0	0.44319	**443.2**
09 January 2008	**196.4**	0.196	15	5.6	0.0056	0	0	0.1	0	0	0.28035	**280.4**
10 January 2008	**191.2**	0.191	15	8.4	0.0084	0	0	0.1	0	0	0.31718	**317.2**
11 January 2008	**190.4**	0.190	15	0.2	0.0002	0	0	0.1	0	0	0.19341	**193.4**
12 January 2008	**263.6**	0.264	15	5.2	0.0052	0	0	0.1	0	0	0.34156	**341.6**
13 January 2008	**385.9**	0.386	15	11.2	0.0112	0	0	0.1	0	0	0.55388	**553.9**
14 January 2008	**223.4**	0.223	15	2.2	0.0022	0	0	0.1	0	0	0.25641	**256.4**
15 January 2008	**297.7**	0.298	15	2	0.002	0	0	0.1	0	0	0.32766	**327.7**
16 January 2008	**334.0**	0.334	15	0	0	0	0	0.1	0	0	0.33396	**334.0**
17 January 2008	**299.9**	0.300	15	10	0.01	0	0	0.1	0	0	0.44986	**449.9**
18 January 2008	**234.6**	0.235	15	10.2	0.0102	0	0	0.1	0	0	0.38763	**387.6**
19 January 2008	**444.0**	0.444	15	13.2	0.0132	0	0	0.1	0	0	0.64196	**642.0**
20 January 2008	**698.5**	0.699	15	6	0.006	0	0	0.1	0	0	0.7885	**788.5**
21 January 2008	**828.0**	0.828	15	5.2	0.0052	0.156307585	0.000156308	0.1	1.56308E-05	0.015630759	0.905735539	**905.7**
22 January 2008	**440.7**	0.441	15	4.6	0.0046	0	0	0.1	0	0	0.50966	**509.7**
23 January 2008	**469.9**	0.470	15	3	0.003	0.111473156	0.000111473	0.1	1.11473E-05	0.011147316	0.51475279	**514.8**
24 January 2008	**298.5**	0.299	15	1	0.001	0	0	0.1	0	0	0.31354	**313.5**
25 January 2008	**182.2**	0.182	15	0	0	0.879372714	0.000879373	0.1	8.79373E-05	0.087937271	0.180840941	**180.8**
26 January 2008	**147.8**	0.148	15	0	0	0.613837807	0.000613838	0.1	6.13838E-05	0.061383781	0.146919243	**146.9**
27 January 2008	**78.9**	0.079	15	0	0	0.063228056	6.32281E-05	0.1	6.32281E-06	0.006322806	0.078775158	**78.8**
28 January 2008	**138.7**	0.139	15	0.4	0.0004	0	0	0.1	0	0	0.14471	**144.7**
29 January 2008	**130.6**	0.131	15	4	0.004	0	0	0.1	0	0	0.19057	**190.6**
30 January 2008	**192.5**	0.193	15	0.4	0.0004	0	0	0.1	0	0	0.1985	**198.5**
31 January 2008	**105.5**	0.105	15	10.4	0.0104	0.425377163	0.000425377	0.1	4.25377E-05	0.042537716	0.260851934	**260.9**
01 February 2008	**331.4**	0.331	15	1.8	0.0018	0	0	0.1	0	0	0.35839	**358.4**
02 February 2008	**736.3**	0.736	15	0.4	0.0004	0	0	0.1	0	0	0.74225	**742.3**
03 February 2008	**467.2**	0.467	15	9.2	0.0092	0	0	0.1	0	0	0.60517	**605.2**
04 February 2008	**539.1**	0.539	15	7.6	0.0076	0	0	0.1	0	0	0.65309	**653.1**
05 February 2008	**321.8**	0.322	15	4.6	0.0046	0	0	0.1	0	0	0.39078	**390.8**
06 February 2008	**400.8**	0.401	15	1.6	0.0016	0.123071395	0.000123071	0.1	1.23071E-05	0.01230714	0.424645393	**424.6**
07 February 2008	**287.4**	0.287	15	0.4	0.0004	0.322352444	0.000322352	0.1	3.22352E-05	0.032235244	0.292886471	**292.9**
08 February 2008	**428.1**	0.428	15	0.4	0.0004	0	0	0.1	0	0	0.43411	**434.1**
09 February 2008	**357.1**	0.357	15	0	0	0.100427611	0.000100428	0.1	1.00428E-05	0.010042761	0.356969359	**357.0**
10 February 2008	**82.5**	0.082	15	0.2	0.0002	0	0	0.1	0	0	0.08546	**85.5**

11 February 2008	**640.8**	0.641	15	0.2	0.0002	0	0	0.1	0	0	0.64377	**643.8**
12 February 2008	**239.9**	0.240	15	0	0	0	0	0.1	0	0	0.23994	**239.9**
13 February 2008	**382.2**	0.382	15	0.2	0.0002	0	0	0.1	0	0	0.38523	**385.2**
14 February 2008	**415.7**	0.416	15	0.2	0.0002	0.174862989	0.000174863	0.1	1.74863E-05	0.017486299	0.418447706	**418.4**
15 February 2008	**209.6**	0.210	15	0.2	0.0002	0.266160367	0.00026616	0.1	2.6616E-05	0.026616037	0.212160759	**212.2**
16 February 2008	**277.8**	0.278	15	0	0	0.126326918	0.000126327	0.1	1.26327E-05	0.012632692	0.27757051	**277.6**
17 February 2008	**398.7**	0.399	15	0	0	0	0	0.1	0	0	0.39866	**398.7**
18 February 2008	**439.3**	0.439	15	0.4	0.0004	0	0	0.1	0	0	0.44527	**445.3**
19 February 2008	**225.7**	0.226	15	0.4	0.0004	0.228168837	0.000228169	0.1	2.28169E-05	0.022816884	0.231337747	**231.3**
20 February 2008	**482.7**	0.483	15	0	0	0.05947244	5.94724E-05	0.1	5.94724E-06	0.005947244	0.482580791	**482.6**
21 February 2008	**331.4**	0.331	15	0.6	0.0006	0.505798164	0.000505798	0.1	5.05798E-05	0.050579816	0.339631303	**339.6**
22 February 2008	**338.2**	0.338	15	1	0.001	0.793523904	0.000793524	0.1	7.93524E-05	0.07935239	0.352019714	**352.0**
23 February 2008	**197.2**	0.197	15	0	0	0.43909627	0.000439096	0.1	4.39096E-05	0.043909627	0.196501356	**196.5**
24 February 2008	**34.0**	0.034	15	1.2	0.0012	0.242928614	0.000242929	0.1	2.42929E-05	0.024292861	0.051595607	**51.6**
25 February 2008	**176.8**	0.177	15	2.2	0.0022	0	0	0.1	0	0	0.20976	**209.8**
26 February 2008	**335.3**	0.335	15	0.2	0.0002	0.735460855	0.000735461	0.1	7.35461E-05	0.073546086	0.337216809	**337.2**
27 February 2008	**485.5**	0.485	15	0	0	0.352274127	0.000352274	0.1	3.52274E-05	0.035227413	0.484961589	**485.0**
28 February 2008	**385.4**	0.385	15	0	0	0.325746971	0.000325747	0.1	3.25747E-05	0.032574697	0.38491138	**384.9**
29 February 2008	**255.3**	0.255	15	7.4	0.0074	0.161839929	0.00016184	0.1	1.6184E-05	0.016183993	0.36600724	**366.0**
01 March 2008	**141.9**	0.142	15	0.8	0.0008	0.664090672	0.000664091	0.2	0.00013281 8	0.132818134	0.151887728	**151.9**
02 March 2008	**179.3**	0.179	15	1.2	0.0012	0.760901515	0.000760902	0.2	0.00015218	0.152180303	0.195017295	**195.0**
03 March 2008	**313.7**	0.314	15	1	0.001	0.067294122	6.72941E-05	0.2	1.34588E-05	0.013458824	0.328478118	**328.5**
04 March 2008	**319.1**	0.319	15	1.2	0.0012	0.530702241	0.000530702	0.2	0.00010614	0.106140448	0.335497893	**335.5**
05 March 2008	**213.7**	0.214	15	0	0	0.673783122	0.000673783	0.2	0.000134757	0.134756624	0.211688651	**211.7**
06 March 2008	**292.8**	0.293	15	3	0.003	0.782206337	0.000782206	0.2	0.000156441	0.156441267	0.335413381	**335.4**
07 March 2008	**247.7**	0.248	15	1.2	0.0012	0.480516638	0.000480517	0.2	9.61033E-05	0.096103328	0.26425845	**264.3**
08 March 2008	**337.8**	0.338	15	3.6	0.0036	0.774091831	0.000774092	0.2	0.000154818	0.154818366	0.389437725	**389.4**
09 March 2008	**224.6**	0.225	15	3.6	0.0036	0.571188597	0.000571189	0.2	0.000114238	0.114237719	0.276906434	**276.9**
10 March 2008	**449.4**	0.449	15	6.2	0.0062	0.406241456	0.000406241	0.2	8.12483E-05	0.081248291	0.541201276	**541.2**
11 March 2008	**363.7**	0.364	15	3	0.003	0.931108766	0.000931109	0.2	0.000186222	0.186221753	0.405896674	**405.9**
12 March 2008	**388.8**	0.389	15	7.6	0.0076	0.981215499	0.000981215	0.2	0.000196243	0.1962431	0.499896354	**499.9**
13 March 2008	**235.3**	0.235	15	2	0.002	0.302740269	0.00030274	0.2	6.05481E-05	0.060548054	0.264361779	**264.4**
14 March 2008	**350.9**	0.351	15	0.2	0.0002	0.421853082	0.000421853	0.2	8.43706E-05	0.084370616	0.352614441	**352.6**
15 March 2008	**307.8**	0.308	15	11.4	0.0114	0.050314979	5.0315E-05	0.2	1.0063E-05	0.010062996	0.478679055	**478.7**
16 March 2008	**424.9**	0.425	15	2.8	0.0028	0.565501122	0.000565501	0.3	0.00016965	0.169650337	0.464325245	**464.3**
17 March 2008	**216.6**	0.217	15	0	0	0.718629062	0.000718629	0.3	0.000215589	0.215588719	0.213396169	**213.4**
18 March 2008	**372.8**	0.373	15	0.2	0.0002	0.788845294	0.000788845	0.3	0.000236654	0.236653588	0.372210196	**372.2**
19 March 2008	**421.9**	0.422	15	0	0	0.854505453	0.000854505	0.3	0.000256352	0.256351636	0.418044725	**418.0**
20 March 2008	**254.7**	0.255	15	1.6	0.0016	0.379310559	0.000379311	0.3	0.000113793	0.113793168	0.276943102	**276.9**
21 March 2008	**193.4**	0.193	15	2	0.002	1.275198539	0.001275199	0.3	0.00038256	0.382559562	0.217641607	**217.6**
22 March 2008	**459.4**	0.459	15	0	0	1.190460716	0.001190461	0.3	0.000357138	0.357138215	0.454022927	**454.0**
23 March 2008	**153.9**	0.154	15	1	0.001	1.084014212	0.001084014	0.3	0.000325204	0.325204263	0.163991936	**164.0**
24 March 2008	**348.1**	0.348	15	1.8	0.0018	0.842488506	0.000842489	0.3	0.000252747	0.252746552	0.371328802	**371.3**
25 March 2008	**257.3**	0.257	15	1.8	0.0018	0.6549242	0.000654924	0.3	0.000196477	0.19647726	0.281332841	**281.3**
26 March 2008	**440.6**	0.441	15	0.6	0.0006	0.757235913	0.000757236	0.3	0.000227171	0.227170774	0.446162438	**446.2**
27 March 2008	**400.7**	0.401	15	2	0.002	1.418138016	0.001418138	0.3	0.000425441	0.425441405	0.424278379	**424.3**
28 March 2008	**171.1**	0.171	15	6.4	0.0064	0.779786284	0.000779786	0.3	0.000233936	0.233935885	0.263620962	**263.6**
29 March 2008	**318.9**	0.319	15	8.8	0.0088	0.025251996	2.5252E-05	0.3	7.5756E-06	0.007575599	0.450776366	**450.8**
30 March 2008	**492.5**	0.492	15	9.2	0.0092	1.051968098	0.001051968	0.3	0.00031559	0.315590429	0.625756144	**625.8**
31 March 2008	**588.4**	0.588	15	0.6	0.0006	1.169240567	0.001169241	0.3	0.000350772	0.35077217	0.592158417	**592.2**
01 April 2008	**470.2**	0.470	15	1	0.001	1.819427116	0.001819427	0.3	0.000545828	0.545828135	0.477032578	**477.0**
02 April 2008	**511.0**	0.511	15	1.2	0.0012	1.270776205	0.001270776	0.3	0.000381233	0.381232861	0.523261507	**523.3**
03 April 2008	**330.2**	0.330	15	0	0	1.913212681	0.001913213	0.3	0.000573964	0.573963804	0.321580543	**321.6**
04 April 2008	**205.1**	0.205	15	0.6	0.0006	1.101224106	0.001101224	0.3	0.000330367	0.330367232	0.209174492	**209.2**
05 April 2008	**283.8**	0.284	15	0.2	0.0002	1.26271131	0.001262711	0.3	0.000378813	0.378813393	0.281087799	**281.1**
06 April 2008	**368.5**	0.368	15	0.4	0.0004	1.03827959	0.00103828	0.3	0.000311484	0.311483877	0.369807742	**369.8**
07 April 2008	**633.7**	0.634	15	0.8	0.0008	0.90163201	0.000901632	0.3	0.00027049	0.270489603	0.641642656	**641.6**

08 April 2008	**545.4**	0.545	15	0	0	0.955649737	0.00095565	0.3	0.000286695	0.286694921	0.541049576	**541.0**
09 April 2008	**657.6**	0.658	15	0	0	1.439145029	0.001439145	0.3	0.000431744	0.431743509	0.651123847	**651.1**
10 April 2008	**447.8**	0.448	15	3.2	0.0032	1.134082295	0.001134082	0.3	0.000340225	0.340224689	0.49069663	**490.7**
11 April 2008	**401.4**	0.401	15	4.4	0.0044	1.142243654	0.001142244	0.3	0.000342673	0.342673096	0.462289904	**462.3**
12 April 2008	**628.8**	0.629	15	7.4	0.0074	0.150995594	0.000150996	0.3	4.52987E-05	0.045298678	0.73913052	**739.1**
13 April 2008	**454.3**	0.454	15	1.8	0.0018	1.060417469	0.001060417	0.3	0.000318125	0.318125241	0.476538121	**476.5**
14 April 2008	**277.1**	0.277	15	0	0	1.791089079	0.001791089	0.3	0.000537327	0.537326724	0.268990099	**269.0**
15 April 2008	**443.7**	0.444	15	0	0	1.418063753	0.001418064	0.3	0.000425419	0.425419126	0.437318713	**437.3**
16 April 2008	**557.3**	0.557	15	0	0	1.38154642	0.001381546	0.6	0.000828928	0.828927852	0.544876082	**544.9**
17 April 2008	**375.6**	0.376	15	0.6	0.0006	0.996914318	0.000996914	0.6	0.000598149	0.598148591	0.375617771	**375.6**
18 April 2008	**261.0**	0.261	15	0	0	1.04426347	0.001044263	0.6	0.000626558	0.626558082	0.251641629	**251.6**
19 April 2008	**106.6**	0.107	15	0	0	1.497303283	0.001497303	0.6	0.000898382	0.89838197	0.09316427	**93.2**
20 April 2008	**195.0**	0.195	15	1	0.001	0.615146459	0.000615146	0.6	0.000369088	0.369087876	0.204483682	**204.5**
21 April 2008	**689.4**	0.689	15	0.2	0.0002	1.296087062	0.001296087	0.6	0.000777652	0.777652237	0.680735216	**680.7**
22 April 2008	**504.5**	0.505	15	6.8	0.0068	2.159211677	0.002159212	0.6	0.001295527	1.295527006	0.587107095	**587.1**
23 April 2008	**410.8**	0.411	15	0.8	0.0008	1.714833327	0.001714833	0.6	0.0010289	1.028899996	0.4073765	**407.4**
24 April 2008	**492.9**	0.493	15	2	0.002	1.576359705	0.00157636	0.6	0.000945816	0.945815823	0.508672763	**508.7**
25 April 2008	**319.2**	0.319	15	0.8	0.0008	0.785848447	0.000785848	0.6	0.000471509	0.471509068	0.324107364	**324.1**
26 April 2008	**388.7**	0.389	15	0.6	0.0006	2.244201279	0.002244201	0.6	0.001346521	1.346520768	0.377462188	**377.5**
27 April 2008	**427.3**	0.427	15	5	0.005	2.232494928	0.002232495	0.6	0.001339497	1.339496957	0.482247546	**482.2**
28 April 2008	**635.5**	0.635	15	4.6	0.0046	1.311437491	0.001311437	0.6	0.000786862	0.786862495	0.692657063	**692.7**
29 April 2008	**503.9**	0.504	15	0	0	1.151514404	0.001151514	0.6	0.000690909	0.690908643	0.49355637	**493.6**
30 April 2008	**537.8**	0.538	15	0.2	0.0002	1.216805756	0.001216806	0.6	0.000730083	0.730083453	0.529838748	**529.8**
01 May 2008	**309.7**	0.310	15	0.2	0.0002	1.70950158	0.001709502	0.6	0.001025701	1.025700948	0.297314486	**297.3**
02 May 2008	**265.9**	0.266	15	3.8	0.0038	1.198147646	0.001198148	0.6	0.000718889	0.718888587	0.312146671	**312.1**
03 May 2008	**248.7**	0.249	15	2.2	0.0022	2.479389265	0.002479389	0.6	0.001487634	1.487633559	0.259415497	**259.4**
04 May 2008	**132.1**	0.132	15	3	0.003	2.336844892	0.002336845	0.6	0.001402107	1.402106935	0.156078396	**156.1**
05 May 2008	**687.2**	0.687	15	0	0	2.780709545	0.00278071	0.6	0.001668426	1.668425727	0.662173614	**662.2**
06 May 2008	**464.1**	0.464	15	0	0	2.787716505	0.002787717	0.6	0.00167263	1.672629903	0.438960551	**439.0**
07 May 2008	**212.9**	0.213	15	2.2	0.0022	2.875611427	0.002875611	0.6	0.001725367	1.725366856	0.219989497	**220.0**
08 May 2008	**391.9**	0.392	15	0.8	0.0008	3.227792877	0.003227793	0.6	0.001936676	1.936675726	0.374889864	**374.9**
09 May 2008	**257.9**	0.258	15	1.6	0.0016	0.546188484	0.000546188	0.6	0.000327713	0.327713091	0.276934304	**276.9**
10 May 2008	**369.5**	0.369	15	0.2	0.0002	1.077194187	0.001077194	0.6	0.000646317	0.646316512	0.362765252	**362.8**
11 May 2008	**407.2**	0.407	15	0	0	2.897237498	0.002897237	0.6	0.001738342	1.738342499	0.381074863	**381.1**
12 May 2008	**413.4**	0.413	15	0.4	0.0004	2.800751465	0.002800751	0.6	0.001680451	1.680450879	0.394233237	**394.2**
13 May 2008	**202.6**	0.203	15	0	0	2.553256828	0.002553257	0.6	0.001531954	1.531954097	0.179650689	**179.7**
14 May 2008	**508.8**	0.509	15	0	0	2.635917925	0.002635918	0.6	0.001581551	1.581550755	0.485046739	**485.0**
15 May 2008	**424.8**	0.425	15	0	0	2.163586105	0.002163586	0.6	0.001298152	1.298151663	0.405367725	**405.4**
16 May 2008	**268.2**	0.268	15	0	0	2.038395445	0.002038395	0.9	0.001834556	1.8345559	0.240661661	**240.7**
17 May 2008	**231.9**	0.232	15	0	0	1.720354671	0.001720355	0.9	0.001548319	1.548319204	0.208645212	**208.6**
18 May 2008	**241.6**	0.242	15	1	0.001	2.274893356	0.002274893	0.9	0.002047404	2.04740402	0.22588894	**225.9**
19 May 2008	**480.4**	0.480	15	0	0	2.404189561	0.00240419	0.9	0.002163771	2.163770605	0.447933441	**447.9**
20 May 2008	**417.2**	0.417	15	0	0	1.540682842	0.001540683	0.9	0.001386615	1.386614558	0.396400782	**396.4**
21 May 2008	**556.9**	0.557	15	2	0.002	2.926148552	0.002926149	0.9	0.002633534	2.633533697	0.547366995	**547.4**
22 May 2008	**437.8**	0.438	15	5	0.005	0.151276658	0.000151277	0.9	0.000136149	0.136148992	0.510797765	**510.8**
23 May 2008	**306.5**	0.306	15	0	0	2.25350885	0.002253509	0.9	0.002028158	2.028157965	0.276067631	**276.1**
24 May 2008	**339.8**	0.340	15	0	0	2.773761871	0.002773762	0.9	0.002496386	2.496385683	0.302394215	**302.4**
25 May 2008	**503.5**	0.503	15	0	0	3.279687022	0.003279687	0.9	0.002951718	2.95171832	0.459184225	**459.2**
26 May 2008	**476.2**	0.476	15	0	0	2.486529888	0.00248653	0.9	0.002237877	2.237876899	0.442591847	**442.6**
27 May 2008	**229.8**	0.230	15	1.2	0.0012	0.636552513	0.000636553	0.9	0.000572897	0.572897262	0.239246541	**239.2**
28 May 2008	**426.1**	0.426	15	0	0	0.83455497	0.000834555	0.9	0.000751099	0.75109473	0.414793508	**414.8**
29 May 2008	**324.5**	0.324	15	0	0	2.971391908	0.002971392	0.9	0.002674253	2.674252717	0.284366209	**284.4**
30 May 2008	**408.7**	0.409	15	0	0	2.168413644	0.002168414	0.9	0.001951572	1.95157228	0.379384205	**379.4**
31 May 2008	**352.5**	0.353	15	0.2	0.0002	3.469396657	0.0034694	0.9	0.00312246	3.122459691	0.308673105	**308.7**
01 June 2008	**335.1**	0.335	15	0	0	2.690798584	0.002690799	1.2	0.003228958	3.228958301	0.286655625	**286.7**
02 June 2008	**401.5**	0.401	15	1.8	0.0018	2.462041477	0.002462041	1.2	0.00295445	2.954449773	0.384153253	**384.2**
03 June 2008	**604.8**	0.605	15	0	0	3.371821546	0.003371822	1.2	0.004046186	4.046185856	0.544147212	**544.1**

04 June 2008	**446.8**	0.447	15	6.4	0.0064	0.319945259	0.000319945	1.2	0.000383934	0.383934311	0.537070985	**537.1**
05 June 2008	**335.2**	0.335	15	1	0.001	1.931068474	0.001931068	1.2	0.002317282	2.317282168	0.315430767	**315.4**
06 June 2008	**407.0**	0.407	15	0.8	0.0008	2.155393483	0.002155393	1.2	0.002586472	2.58647218	0.380192917	**380.2**
07 June 2008	**481.3**	0.481	15	0.2	0.0002	3.13922155	0.003139222	1.2	0.003767066	3.76706586	0.427764012	**427.8**
08 June 2008	**322.7**	0.323	15	0	0	2.190056878	0.002190057	1.2	0.002628068	2.628068254	0.283278976	**283.3**
09 June 2008	**628.5**	0.629	15	0	0	3.342007707	0.003342008	1.2	0.004010409	4.010409248	0.568363861	**568.4**
10 June 2008	**311.6**	0.312	15	0	0	3.821397095	0.003821397	1.2	0.004585677	4.585676514	0.242834852	**242.8**
11 June 2008	**379.2**	0.379	15	4.2	0.0042	1.3918638	0.001391864	1.2	0.001670237	1.670236559	0.417116452	**417.1**
12 June 2008	**403.2**	0.403	15	0	0	2.402147338	0.002402147	1.2	0.002882577	2.882576806	0.359921348	**359.9**

Site B

Reed Bed Water Balance

Date	Qi (l/d)	Qi (m3/d)	Area (m2)	Precip. (mm)	Precip. (m)	Hargreaves Et (mm/d)	Hargreaves Et (m/d)	K_c	Et_{reed} (m)	Et_{reed} (mm)	Qo (m3/d)	Qo (l/d)
03 Jul 06	64.7	0.065	4.05	0.0	0	4.016	0.00401582	0.7	0.002811074	2.811073822	0.053310151	53.3
04 Jul 06	100.7	0.101	4.05	0.0	0	3.879	0.00387941	0.7	0.002715587	2.715587086	0.089749372	89.7
05 Jul 06	91.9	0.092	4.05	0.0	0	3.892	0.003891604	0.7	0.002724123	2.724122709	0.080879803	80.9
06 Jul 06	80.9	0.081	4.05	0.0	0	4.235	0.004234667	0.7	0.002964267	2.96426695	0.068934719	68.9
07 Jul 06	79.8	0.080	4.05	0.0	0	3.570	0.003570158	0.7	0.002499111	2.499110936	0.069678601	69.7
08 Jul 06	128.8	0.129	4.05	12.4	0.0124	2.209	0.002209308	0.7	0.001546516	1.546515907	0.172776611	172.8
09 Jul 06	228.1	0.228	4.05	0.0	0	3.623	0.003623419	0.7	0.002536393	2.536393365	0.217870107	217.9
10 Jul 06	114.9	0.115	4.05	0.0	0	4.343	0.004342981	0.7	0.003040086	3.040086457	0.10254265	102.5
11 Jul 06	98.6	0.099	4.05	0.0	0	4.212	0.004211827	0.7	0.002948279	2.948278939	0.08666947	86.7
12 Jul 06	107.4	0.107	4.05	0.0	0	3.813	0.003812822	0.7	0.002668975	2.668975151	0.096635651	96.6
13 Jul 06	101.7	0.102	4.05	0.0	0	4.249	0.004248796	0.7	0.002974157	2.97415686	0.089699665	89.7
14 Jul 06	133.2	0.133	4.05	0.0	0	5.431	0.005431176	0.7	0.003801823	3.801823382	0.117840115	117.8
15 Jul 06	77.8	0.078	4.05	0.0	0	4.984	0.004984459	0.7	0.00348912	3.48912132	0.063674059	63.7
16 Jul 06	136.8	0.137	4.05	0.0	0	5.830	0.005829836	0.7	0.004080886	4.080885547	0.120272414	120.3
17 Jul 06	66.3	0.066	4.05	0.0	0	5.810	0.005810447	0.7	0.004067313	4.067312767	0.049789883	49.8
18 Jul 06	141.6	0.142	4.05	0.0	0	6.118	0.006118152	0.7	0.004282707	4.282706549	0.124300038	124.3
19 Jul 06	91.8	0.092	4.05	0.0	0	6.164	0.006164123	0.7	0.004314886	4.314885899	0.074294712	74.3
20 Jul 06	77.5	0.078	4.05	0.0	0	4.493	0.004493376	0.7	0.003145363	3.145362886	0.06478128	64.8
21 Jul 06	68.0	0.068	4.05	0.0	0	4.714	0.004714377	0.7	0.003300064	3.300063567	0.054607243	54.6
22 Jul 06	29.1	0.029	4.05	0.0	0	4.444	0.004443944	0.7	0.003110761	3.110761063	0.016471418	16.5
23 Jul 06	62.0	0.062	4.05	0.0	0	4.529	0.004528909	0.7	0.003170236	3.170236307	0.049148043	49.1
24 Jul 06	137.2	0.137	4.05	0.0	0	4.584	0.004583562	0.7	0.003208493	3.208493302	0.124233102	124.2
25 Jul 06	151.6	0.152	4.05	0.8	0.0008	5.295	0.005294576	0.7	0.003706203	3.706203079	0.139849878	139.8
26 Jul 06	115.3	0.115	4.05	0.0	0	4.380	0.004379858	0.7	0.003065901	3.065900837	0.102865602	102.9
27 Jul 06	128.5	0.129	4.05	0.0	0	4.602	0.004602096	0.7	0.003221467	3.221467484	0.115488057	115.5
28 Jul 06	124.1	0.124	4.05	0.0	0	3.644	0.003644033	0.7	0.002550823	2.550822779	0.113786668	113.8
29 Jul 06	245.2	0.245	4.05	14.8	0.0148	4.162	0.004162027	0.7	0.002913419	2.913418592	0.293383155	293.4
30 Jul 06	194.8	0.195	4.05	4.0	0.004	4.192	0.00419171	0.7	0.002934197	2.934197217	0.199114001	199.1
31 Jul 06	359.2	0.359	4.05	9.0	0.009	3.006	0.003006214	0.7	0.00210435	2.104350061	0.387169882	387.2
01 Aug 06	214.7	0.215	4.05	0.0	0	3.264	0.003263515	0.7	0.00228446	2.2844602	0.205495436	205.5
02 Aug 06	116.1	0.116	4.05	0.0	0	3.219	0.003219092	0.7	0.002253364	2.253364082	0.107011375	107.0
03 Aug 06	59.9	0.060	4.05	0.0	0	3.445	0.003445025	0.7	0.002411517	2.411517284	0.050083355	50.1
04 Aug 06	97.2	0.097	4.05	0.0	0	3.338	0.003338411	0.7	0.002336888	2.33688762	0.087720605	87.7
05 Aug 06	61.6	0.062	4.05	0.0	0	3.494	0.00349413	0.7	0.002445891	2.445891085	0.051654141	51.7
06 Aug 06	88.8	0.089	4.05	3.2	0.0032	2.989	0.002988583	0.7	0.002092008	2.092007866	0.093264868	93.3
07 Aug 06	118.6	0.119	4.05	0.0	0	3.347	0.003346824	0.7	0.002342777	2.34277657	0.109071755	109.1
08 Aug 06	124.1	0.124	4.05	0.0	0	3.446	0.003445687	0.7	0.002411981	2.411980908	0.114348977	114.3
09 Aug 06	43.6	0.044	4.05	0.2	0.0002	3.183	0.00318349	0.7	0.002228443	2.228443158	0.035389805	0.0
10 Aug 06	80.2	0.080	4.05	0.0	0	2.083	0.002082893	0.7	0.001458025	1.45802483	0.074322499	0.0
11 Aug 06	82.2	0.082	4.05	0.2	0.0002	2.517	0.002516918	0.7	0.001761843	1.761842631	0.075897037	0.0
12 Aug 06	104.9	0.105	4.05	0.0	0	2.718	0.002717962	0.7	0.001902574	1.902573572	0.097174577	0.0
13 Aug 06	207.3	0.207	4.05	0.0	0	2.867	0.002866964	0.7	0.002006875	2.006875062	0.199209656	199.2
14 Aug 06	197.2	0.197	4.05	0.0	0	2.275	0.00227536	0.7	0.001592752	1.592751678	0.190769356	190.8
15 Aug 06	397.9	0.398	4.05	13.0	0.013	1.713	0.001713353	0.7	0.001199347	1.199346776	0.445652646	445.7
16 Aug 06	274.3	0.274	4.05	1.2	0.0012	2.614	0.002614182	0.7	0.001829928	1.829927529	0.271761294	271.8
17 Aug 06	211.8	0.212	4.05	3.0	0.003	3.254	0.003253599	0.7	0.00227752	2.277519585	0.214681046	214.7
18 Aug 06	169.9	0.170	4.05	1.6	0.0016	3.134	0.003133577	0.7	0.002193504	2.193503923	0.167456309	167.5
19 Aug 06	246.4	0.246	4.05	11.8	0.0118	2.248	0.002247992	0.7	0.001573594	1.573594197	0.287799444	287.8
20 Aug 06	219.0	0.219	4.05	1.8	0.0018	2.995	0.002995308	0.7	0.002096715	2.096715336	0.217820803	217.8
21 Aug 06	129.2	0.129	4.05	0.6	0.0006	2.717	0.002716782	0.7	0.001901748	1.901747569	0.123975422	124.0
22 Aug 06	161.5	0.161	4.05	0.0	0	3.450	0.003449576	0.7	0.002414703	2.414703228	0.151672952	151.7
23 Aug 06	94.5	0.094	4.05	1.0	0.001	2.889	0.002888659	0.7	0.002022061	2.022061133	0.090338152	90.3
24 Aug 06	224.0	0.224	4.05	0.0	0	3.197	0.003196763	0.7	0.002237734	2.237733784	0.214917178	214.9
25 Aug 06	262.3	0.262	4.05	4.8	0.0048	2.714	0.002713903	0.7	0.001899732	1.899732382	0.274043584	274.0
26 Aug 06	64.5	0.065	4.05	0.0	0	2.451	0.002450561	0.7	0.001715393	1.715392976	0.057567658	57.6
27 Aug 06	151.0	0.151	4.05	4.4	0.0044	2.901	0.002901159	0.7	0.002030812	2.030811581	0.160600213	160.6
28 Aug 06	238.9	0.239	4.05	0.6	0.0006	2.568	0.002567532	0.7	0.001797273	1.797272555	0.234003546	234.0
29 Aug 06	244.0	0.244	4.05	0.2	0.0002	2.561	0.002561478	0.7	0.001793034	1.79303437	0.237515711	237.5
30 Aug 06	262.6	0.263	4.05	1.4	0.0014	2.554	0.002554254	0.7	0.001787977	1.787977456	0.260981191	261.0
31 Aug 06	244.5	0.244	4.05	5.0	0.005	1.875	0.001874698	0.7	0.001312288	1.312288492	0.259420232	259.4

01 Sep 06	**228.8**	**0.229**	4.05	0.8	0.0008	2.978	0.002978033	0.5	0.001489017	1.489016604	0.226011983	**226.0**
02 Sep 06	**2.0**	**0.002**	4.05	26.4	0.0264	2.669	0.00266949	0.5	0.001334745	1.334744992	0.103509283	**103.5**
03 Sep 06	**0.0**	**0.000**	4.05	1.0	0.001	2.552	0.00255209	0.5	0.001276045	1.276044852	-0.001117982	**0.0**
04 Sep 06	**34.5**	**0.034**	4.05	9.8	0.0098	2.057	0.002057304	0.5	0.001028652	1.02865177	0.07000896	**70.0**
05 Sep 06	**170.9**	**0.171**	4.05	0.2	0.0002	2.091	0.002091215	0.5	0.001045608	1.045607618	0.167432789	**167.4**
06 Sep 06	**118.6**	**0.119**	4.05	1.2	0.0012	2.481	0.002480648	0.5	0.001240324	1.240324132	0.118396687	**118.4**
07 Sep 06	**148.8**	**0.149**	4.05	0.0	0	2.236	0.002235695	0.5	0.001117848	1.117847706	0.144242717	**144.2**
08 Sep 06	**122.8**	**0.123**	4.05	0.0	0	2.511	0.002510706	0.5	0.001255353	1.255352921	0.117750821	**117.8**
09 Sep 06	**68.8**	**0.069**	4.05	0.2	0.0002	2.813	0.002812975	0.5	0.001406487	1.406487485	0.063941226	**63.9**
10 Sep 06	**181.0**	**0.181**	4.05	0.0	0	2.656	0.002655575	0.5	0.001327787	1.327787412	0.175597461	**175.6**
11 Sep 06	**385.0**	**0.385**	4.05	21.0	0.021	2.363	0.002363156	0.5	0.001181578	1.181577996	0.465299609	**465.3**
12 Sep 06	**270.0**	**0.270**	4.05	3.0	0.003	1.551	0.001551158	0.5	0.000775579	0.775579116	0.279046405	**279.0**
13 Sep 06	**122.3**	**0.122**	4.05	8.2	0.0082	2.118	0.002118343	0.5	0.001059171	1.05917134	0.151185356	**151.2**
14 Sep 06	**144.9**	**0.145**	4.05	0.2	0.0002	1.817	0.001816814	0.5	0.000908407	0.908407067	0.142053451	**142.1**
15 Sep 06	**22.4**	**0.022**	4.05	0.0	0	2.302	0.002302389	0.5	0.001151194	1.151194445	0.017710162	**17.7**
16 Sep 06	**84.4**	**0.084**	4.05	0.0	0	2.627	0.002627427	0.5	0.001313714	1.313713677	0.07903946	**79.0**
17 Sep 06	**140.1**	**0.140**	4.05	1.2	0.0012	2.627	0.002626637	0.5	0.001313318	1.313318392	0.139618561	**139.6**
18 Sep 06	**154.3**	**0.154**	4.05	5.2	0.0052	2.094	0.002093879	0.5	0.001046939	1.046939451	0.171147395	**171.1**
19 Sep 06	**143.1**	**0.143**	4.05	0.0	0	1.860	0.001860051	0.5	0.000930025	0.930025337	0.139303397	**139.3**
20 Sep 06	**169.0**	**0.169**	4.05	26.6	0.0266	1.984	0.001984489	0.5	0.000992245	0.992244633	0.272716409	**272.7**
21 Sep 06	**179.1**	**0.179**	4.05	6.6	0.0066	1.485	0.001485335	0.5	0.000742667	0.742667296	0.202844697	**202.8**
22 Sep 06	**37.3**	**0.037**	4.05	1.4	0.0014	2.279	0.002278998	0.5	0.001139499	1.139499192	0.038390028	**38.4**
23 Sep 06	**31.6**	**0.032**	4.05	2.4	0.0024	1.956	0.001955922	0.5	0.000977961	0.977961057	0.037394258	**37.4**
24 Sep 06	**80.1**	**0.080**	4.05	5.4	0.0054	1.808	0.001808379	0.5	0.00090419	0.904189743	0.098293032	**98.3**
25 Sep 06	**57.3**	**0.057**	4.05	7.0	0.007	2.005	0.00200498	0.5	0.00100249	1.002489824	0.081574916	**81.6**
26 Sep 06	**5.4**	**0.005**	4.05	0.2	0.0002	1.845	0.001844714	0.5	0.000922357	0.922356909	0.002489455	**2.5**
27 Sep 06	**57.9**	**0.058**	4.05	13.6	0.0136	1.876	0.001875631	0.5	0.000937816	0.937815676	0.109136847	**109.1**
28 Sep 06	**3.7**	**0.004**	4.05	0.0	0	1.409	0.001409174	0.5	0.000704587	0.704587029	0.000851423	**0.9**
29 Sep 06	**34.1**	**0.034**	4.05	2.6	0.0026	1.381	0.001380638	0.5	0.000690319	0.690319027	0.041791708	**41.8**
30 Sep 06	**36.5**	**0.036**	4.05	5.6	0.0056	1.769	0.001768946	0.5	0.000884473	0.884472843	0.055577885	**55.6**
01 Oct 06	**146.9**	**0.147**	4.05	25.8	0.0258	1.491	0.001491078	0.3	0.000447323	0.447323271	0.249595841	**249.6**
02 Oct 06	**165.9**	**0.166**	4.05	0.2	0.0002	1.669	0.001668648	0.3	0.000500594	0.500594357	0.164652593	**164.7**
03 Oct 06	**155.3**	**0.155**	4.05	0.0	0	1.467	0.001467483	0.3	0.000440245	0.440244917	0.153542008	**153.5**
04 Oct 06	**132.2**	**0.132**	4.05	2.4	0.0024	1.446	0.001445817	0.3	0.000433745	0.433745129	0.140203332	**140.2**
05 Oct 06	**91.2**	**0.091**	4.05	8.8	0.0088	1.670	0.001669525	0.3	0.000500857	0.500857395	0.124811528	**124.8**
06 Oct 06	**127.4**	**0.127**	4.05	1.0	0.001	1.417	0.001416662	0.3	0.000424998	0.424998493	0.129723756	**129.7**
07 Oct 06	**125.5**	**0.126**	4.05	0.0	0	1.366	0.001365897	0.3	0.000409769	0.409769145	0.123882935	**123.9**
08 Oct 06	**125.3**	**0.125**	4.05	28.0	0.028	1.384	0.001383795	0.3	0.000415138	0.415138471	0.236976189	**237.0**
09 Oct 06	**175.6**	**0.176**	4.05	3.8	0.0038	1.032	0.001032478	0.3	0.000309743	0.30974326	0.18969554	**189.7**
10 Oct 06	**119.0**	**0.119**	4.05	8.6	0.0086	1.434	0.001434407	0.3	0.000430322	0.430322025	0.152074696	**152.1**
11 Oct 06	**184.5**	**0.185**	4.05	20.4	0.0204	1.541	0.001540821	0.3	0.000462246	0.462246256	0.265285403	**265.3**
12 Oct 06	**138.7**	**0.139**	4.05	0.2	0.0002	1.244	0.001243789	0.3	0.000373137	0.373136619	0.137951297	**138.0**
13 Oct 06	**103.5**	**0.103**	4.05	0.2	0.0002	1.289	0.001289038	0.3	0.000386711	0.3867113	0.102698819	**102.7**
14 Oct 06	**214.0**	**0.214**	4.05	0.0	0	1.319	0.001318929	0.3	0.000395679	0.395678713	0.212432501	**212.4**
15 Oct 06	**162.5**	**0.162**	4.05	0.0	0	1.280	0.001279733	0.3	0.00038392	0.383919919	0.160895124	**160.9**
16 Oct 06	**120.7**	**0.121**	4.05	0.6	0.0006	1.058	0.001057973	0.3	0.000317392	0.317391967	0.121842063	**121.8**
17 Oct 06	**175.3**	**0.175**	4.05	12.0	0.012	1.041	0.001040949	0.3	0.000312285	0.312284618	0.222610247	**222.6**
18 Oct 06	**154.6**	**0.155**	4.05	0.0	0	0.979	0.00097949	0.3	0.000293847	0.293846879	0.15342242	**153.4**
19 Oct 06	**209.0**	**0.209**	4.05	14.4	0.0144	1.145	0.001144939	0.3	0.000343482	0.343481824	0.265976399	**266.0**
20 Oct 06	**96.5**	**0.096**	4.05	0.2	0.0002	0.919	0.000918924	0.3	0.000275677	0.275677075	0.096166008	**96.2**
21 Oct 06	**189.7**	**0.190**	4.05	13.8	0.0138	1.223	0.001223253	0.3	0.000366976	0.366976043	0.244071247	**244.1**
22 Oct 06	**171.4**	**0.171**	4.05	0.2	0.0002	0.987	0.000986653	0.3	0.000295996	0.295995938	0.171038716	**171.0**
23 Oct 06	**161.0**	**0.161**	4.05	0.0	0	0.879	0.000879138	0.3	0.000263742	0.263741526	0.159956847	**160.0**
24 Oct 06	**192.2**	**0.192**	4.05	0.0	0	1.045	0.001044536	0.3	0.000313361	0.313360818	0.190963389	**191.0**

25 Oct 06	**671.5**	**0.671**	4.05	57.6	0.0576	1.058	0.001058175	0.3	0.000317452	0.317452419	0.903454318	**903.5**
26 Oct 06	**141.2**	**0.141**	4.05	1.6	0.0016	0.963	0.000962814	0.3	0.000288844	0.288844325	0.14652768	**146.5**
27 Oct 06	**184.1**	**0.184**	4.05	1.6	0.0016	0.953	0.000952912	0.3	0.000285874	0.285873681	0.189432212	**189.4**
28 Oct 06	**118.8**	**0.119**	4.05	1.0	0.001	0.865	0.000865409	0.3	0.000259623	0.259622646	0.121843528	**121.8**
29 Oct 06	**73.0**	**0.073**	4.05	0.0	0	0.797	0.000797231	0.3	0.000239169	0.239169213	0.071991365	**72.0**
30 Oct 06	**190.5**	**0.191**	4.05	0.2	0.0002	0.822	0.000822461	0.3	0.000246738	0.246738294	0.19033321	**190.3**
31 Oct 06	**66.5**	**0.067**	4.05	0.0	0	0.710	0.000709728	0.3	0.000212918	0.212918323	0.065685181	**65.7**
01 Nov 06	**34.5**	**0.034**	4.05	0.0	0	0.789	0.00078925	0.1	7.8925E-05	0.078924993	0.034165354	**34.2**
02 Nov 06	**8.8**	**0.009**	4.05	0.0	0	0.696	0.00069563	0.1	6.9563E-05	0.069562956	0.00855327	**8.6**
03 Nov 06				0.0	0	0.754	0.000754448	0.1	7.54448E-05	0.075444779		
04 Nov 06				0.0	0	0.792	0.000791785	0.1	7.91785E-05	0.079178522		
05 Nov 06				0.2	0.0002	0.811	0.000810818	0.1	8.10818E-05	0.08108183		
06 Nov 06				0.2	0.0002	0.719	0.000719283	0.1	7.19283E-05	0.071928342		
07 Nov 06				0.2	0.0002	0.754	0.000753623	0.1	7.53623E-05	0.07536232		
08 Nov 06				1.8	0.0018	0.559	0.000558879	0.1	5.58879E-05	0.055887878		
09 Nov 06				0.0	0	0.669	0.000669295	0.1	6.69295E-05	0.066929478		
10 Nov 06				5.0	0.005	0.637	0.000636907	0.1	6.36907E-05	0.06369065		
11 Nov 06				0.2	0.0002	0.708	0.000707995	0.1	7.07995E-05	0.070799532		
12 Nov 06				0.2	0.0002	0.564	0.000564448	0.1	5.64448E-05	0.056444761		
13 Nov 06				0.8	0.0008	0.519	0.000519	0.1	5.19E-05	0.051900044		
14 Nov 06				0.2	0.0002	0.517	0.000517264	0.1	5.17264E-05	0.051726422		
15 Nov 06				39.8	0.0398	0.326	0.000326442	0.1	3.26442E-05	0.032644191		
16 Nov 06				3.8	0.0038	0.317	0.000317488	0.1	3.17488E-05	0.031748768		
17 Nov 06				1.4	0.0014	0.376	0.000375603	0.1	3.75603E-05	0.037560265		
18 Nov 06				0.8	0.0008	0.381	0.000381496	0.1	3.81496E-05	0.038149579		
19 Nov 06				1.0	0.001	0.361	0.000361386	0.1	3.61386E-05	0.036138646		
20 Nov 06				1.0	0.001	0.597	0.000596985	0.1	5.96985E-05	0.059698532		
21 Nov 06				0.6	0.0006	0.409	0.000408867	0.1	4.08867E-05	0.04088671		
22 Nov 06				0.4	0.0004	0.394	0.000394412	0.1	3.94412E-05	0.039441225		
23 Nov 06				1.8	0.0018	0.460	0.000459559	0.1	4.59559E-05	0.045955872		
24 Nov 06				14.0	0.014	0.475	0.000475092	0.1	4.75092E-05	0.047509163		
25 Nov 06				0.0	0	0.465	0.000465443	0.1	4.65443E-05	0.046544301		
26 Nov 06				8.0	0.008	0.397	0.000396992	0.1	3.96992E-05	0.039699192		
27 Nov 06				16.4	0.0164	0.484	0.000484297	0.1	4.84297E-05	0.048429693		
28 Nov 06	**157.1**	**0.157**	4.05	1.4	0.0014	0.387	0.000387047	0.1	3.87047E-05	0.038704684	0.162638523	**162.6**
29 Nov 06	**86.5**	**0.086**	4.05	0.4	0.0004	0.410	0.000410463	0.1	4.10463E-05	0.041046345	0.087951262	**88.0**
30 Nov 06	**678.7**	**0.679**	4.05	38.6	0.0386	0.458	0.000458294	0.1	4.58294E-05	0.045829383	0.834871891	**834.9**
01 Dec 06	**333.3**	**0.333**	4.05	3.6	0.0036	0.276	0.000276433	0.1	2.76433E-05	0.027643314	0.347775545	**347.8**
02 Dec 06	**163.2**	**0.163**	4.05	12.6	0.0126	0.467	0.000467355	0.1	4.67355E-05	0.046735515	0.214003221	**214.0**
03 Dec 06	**482.6**			17.0	0.017	0.410	0.000409518	0.1	4.09518E-05	0.04095179		
04 Dec 06	**253.8**	**0.254**	4.05	6.4	0.0064	0.417	0.000417284	0.1	4.17284E-05	0.041728377	0.2795435	**279.5**
05 Dec 06	**228.1**	**0.228**	4.05	7.0	0.007	0.443	0.000442999	0.1	4.42999E-05	0.044299895	0.256313085	**256.3**
06 Dec 06	**207.1**	**0.207**	4.05	5.0	0.005	0.336	0.000335777	0.1	3.35777E-05	0.033577731	0.22716651	**227.2**
07 Dec 06	**239.5**	**0.240**	4.05	4.0	0.004	0.334	0.00033441	0.1	3.3441E-05	0.033440994	0.255607064	**255.6**
08 Dec 06	**242.8**	**0.243**	4.05	0.0	0	0.301	0.000300824	0.1	3.00824E-05	0.030082423	0.242698166	**242.7**
09 Dec 06	**149.9**	**0.150**	4.05	0.0	0	0.301	0.000301397	0.1	3.01397E-05	0.030139682	0.149787934	**149.8**
10 Dec 06	**204.8**	**0.205**	4.05	11.6	0.0116	0.259	0.000259118	0.1	2.59118E-05	0.025911824	0.251647557	**251.6**
11 Dec 06	**263.9**	**0.264**	4.05	5.0	0.005	0.423	0.000423092	0.1	4.23092E-05	0.042309247	0.283988648	**284.0**
12 Dec 06	**209.6**	**0.210**	4.05	5.8	0.0058	0.424	0.000424026	0.1	4.24026E-05	0.042402624	0.232935769	**232.9**
13 Dec 06	**164.3**	**0.164**	4.05	0.2	0.0002	0.356	0.000355902	0.1	3.55902E-05	0.035590179	0.16496836	**165.0**
14 Dec 06	**116.4**	**0.116**	4.05	0.2	0.0002	0.385	0.000385352	0.1	3.85352E-05	0.038535206	0.117076432	**117.1**
15 Dec 06	**269.0**	**0.269**	4.05	13.4	0.0134	0.386	0.000386148	0.1	3.86148E-05	0.038614804	0.32315361	**323.2**
16 Dec 06	**94.6**	**0.095**	4.05	0.4	0.0004	0.288	0.000288183	0.1	2.88183E-05	0.028818321	0.096123286	**96.1**
17 Dec 06	**163.4**	**0.163**	4.05	0.4	0.0004	0.294	0.000294415	0.1	2.94415E-05	0.029441535	0.164948262	**164.9**
18 Dec 06	**124.3**	**0.124**	4.05	0.0	0	0.255	0.000254543	0.1	2.54543E-05	0.025454297	0.12415691	**124.2**
19 Dec 06	**146.5**	**0.146**	4.05	0.2	0.0002	0.202	0.000202469	0.1	2.02469E-05	0.020246918	0.147218	**147.2**

20 Dec 06	**162.7**	**0.163**	4.05	0.2	0.0002	0.229	0.000228763	0.1	2.28763E-05	0.022876299	0.163452351	**163.5**
21 Dec 06	**119.7**	**0.120**	4.05	0.0	0	0.207	0.00020726	0.1	2.0726E-05	0.020726015	0.11961606	**119.6**
22 Dec 06	**174.4**	**0.174**	4.05	0.2	0.0002	0.327	0.000326671	0.1	3.26671E-05	0.032667148	0.175097698	**175.1**
23 Dec 06	**153.6**	**0.154**	4.05	0.2	0.0002	0.271	0.000270519	0.1	2.70519E-05	0.027051948	0.15431544	**154.3**
24 Dec 06	**150.3**	**0.150**	4.05	0.0	0	0.283	0.00028315	0.1	2.8315E-05	0.028315037	0.150222824	**150.2**
25 Dec 06	**188.5**	**0.189**	4.05	0.4	0.0004	0.193	0.000192536	0.1	1.92536E-05	0.019253647	0.190069523	**190.1**
26 Dec 06	**165.3**	**0.165**	4.05	0.4	0.0004	0.212	0.00021247	0.1	2.1247E-05	0.021246961	0.16683395	**166.8**
27 Dec 06	**269.2**	**0.269**	4.05	13.0	0.013	0.187	0.000187111	0.1	1.87111E-05	0.01871115	0.32175672	**321.8**
28 Dec 06	**267.2**	**0.267**	4.05	2.4	0.0024	0.250	0.000250485	0.1	2.50485E-05	0.025048527	0.276806053	**276.8**
29 Dec 06	**393.2**	**0.393**	4.05	26.0	0.026	0.319	0.000318516	0.1	3.18516E-05	0.031851578	0.498328501	**498.3**
30 Dec 06	**232.7**	**0.233**	4.05	1.2	0.0012	0.395	0.000395423	0.1	3.95423E-05	0.039542258	0.237402354	**237.4**
31 Dec 06	**191.8**	**0.192**	4.05	6.2	0.0062	0.279	0.000278734	0.1	2.78734E-05	0.027873379	0.216802113	**216.8**
01 Jan 07	**157.7**	**0.158**	4.05	2.0	0.002	0.397	0.000396549	0.1	3.96549E-05	0.039654922	0.165686898	**165.7**
02 Jan 07	**147.5**	**0.147**	4.05	0.2	0.0002	0.206	0.000205809	0.1	2.05809E-05	0.020580913	0.148214147	**148.2**
03 Jan 07	**125.7**	**0.126**	4.05	4.0	0.004	0.293	0.000292551	0.1	2.92551E-05	0.029255093	0.141766517	**141.8**
04 Jan 07	**128.7**	**0.129**	4.05	0.0	0	0.347	0.000347062	0.1	3.47062E-05	0.034706209	0.12853694	**128.5**
05 Jan 07	**143.4**	**0.143**	4.05	0.2	0.0002	0.244	0.000243797	0.1	2.43797E-05	0.024379745	0.144066262	**144.1**
06 Jan 07	**176.4**	**0.176**	4.05	5.2	0.0052	0.326	0.00032576	0.1	3.2576E-05	0.032575964	0.197343067	**197.3**
07 Jan 07	**176.4**	**0.176**	4.05	4.8	0.0048	0.313	0.00031305	0.1	3.1305E-05	0.031304999	0.195728215	**195.7**
08 Jan 07	**248.5**	**0.249**	4.05	6.0	0.006	0.378	0.000378164	0.1	3.78164E-05	0.037816377	0.272666844	**272.7**
09 Jan 07	**179.8**	**0.180**	4.05	3.2	0.0032	0.488	0.000487633	0.1	4.87633E-05	0.048763281	0.192597509	**192.6**
10 Jan 07	**94.9**	**0.095**	4.05	4.6	0.0046	0.425	0.000425	0.1	4.25E-05	0.042500018	0.113362875	**113.4**
11 Jan 07	**203.5**	**0.203**	4.05	7.4	0.0074	0.305	0.000305145	0.1	3.05145E-05	0.030514542	0.233336416	**233.3**
12 Jan 07	**104.6**	**0.105**	4.05	0.2	0.0002	0.389	0.000389091	0.1	3.89091E-05	0.038909109	0.105247418	**105.2**
13 Jan 07	**126.1**	**0.126**	4.05	1.2	0.0012	0.430	0.00042991	0.1	4.2991E-05	0.042990976	0.130798387	**130.8**
14 Jan 07	**144.6**	**0.145**	4.05	0.0	0	0.490	0.000489935	0.1	4.89935E-05	0.048993541	0.144439076	**144.4**
15 Jan 07	**83.5**	**0.084**	4.05	2.2	0.0022	0.414	0.000414479	0.1	4.14479E-05	0.041447943	0.092247136	**92.2**
16 Jan 07	**270.0**	**0.270**	4.05	3.2	0.0032	0.440	0.000440491	0.1	4.40491E-05	0.044049071	0.282819101	**282.8**
17 Jan 07	**83.4**	**0.083**	4.05	2.0	0.002	0.413	0.000413355	0.1	4.13355E-05	0.041335492	0.091295091	**91.3**
18 Jan 07	**333.9**	**0.334**	4.05	15.6	0.0156	0.392	0.000391534	0.1	3.91534E-05	0.03915337	0.396898929	**396.9**
19 Jan 07	**184.7**	**0.185**	4.05	1.0	0.001	0.512	0.000511617	0.1	5.11617E-05	0.051161722	0.188522795	**188.5**
20 Jan 07	**172.4**	**0.172**	4.05	2.6	0.0026	0.523	0.000522731	0.1	5.22731E-05	0.052273058	0.182743294	**182.7**
21 Jan 07	**224.6**	**0.225**	4.05	1.4	0.0014	0.457	0.000456992	0.1	4.56992E-05	0.045699245	0.230064918	**230.1**
22 Jan 07	**258.4**	**0.258**	4.05	5.6	0.0056	0.368	0.000368159	0.1	3.68159E-05	0.036815943	0.280883395	**280.9**
23 Jan 07	**250.5**	**0.251**	4.05	0.2	0.0002	0.370	0.000369818	0.1	3.69818E-05	0.036981814	0.251175224	**251.2**
24 Jan 07	**66.1**	**0.066**	4.05	0.0	0	0.422	0.00042182	0.1	4.2182E-05	0.042181957	0.065949163	**65.9**
25 Jan 07	**215.7**	**0.216**	4.05	0.0	0	0.438	0.000438421	0.1	4.38421E-05	0.04384213	0.215567439	**215.6**
26 Jan 07	**175.3**	**0.175**	4.05	0.0	0	0.446	0.000446372	0.1	4.46372E-05	0.044637194	0.175094219	**175.1**
27 Jan 07	**202.6**	**0.203**	4.05	0.0	0	0.257	0.000256998	0.1	2.56998E-05	0.025699849	0.202530916	**202.5**
28 Jan 07	**218.7**	**0.219**	4.05	0.0	0	0.409	0.000409459	0.1	4.09459E-05	0.040945936	0.218571669	**218.6**
29 Jan 07	**267.6**	**0.268**	4.05	0.0	0	0.313	0.00031302	0.1	3.1302E-05	0.03130203	0.267488227	**267.5**
30 Jan 07	**258.6**	**0.259**	4.05	0.0	0	0.500	0.00049969	0.1	4.9969E-05	0.049968981	0.258435126	**258.4**
31 Jan 07	**138.7**	**0.139**	4.05	0.0	0	0.524	0.000524212	0.1	5.24212E-05	0.052421236	0.138440194	**138.4**
01 Feb 07	**170.3**	**0.170**	4.05	0.0	0	0.388	0.000387569	0.1	3.87569E-05	0.038756908	0.170130535	**170.1**
02 Feb 07	**299.0**	**0.299**	4.05	0.2	0.0002	0.644	0.000643737	0.1	6.43737E-05	0.06437373	0.299514286	**299.5**
03 Feb 07	**120.4**	**0.120**	4.05	0.2	0.0002	0.249	0.000249369	0.1	2.49369E-05	0.024936946	0.121121505	**121.1**
04 Feb 07	**152.8**	**0.153**	4.05	0.2	0.0002	0.164	0.000163937	0.1	1.63937E-05	0.0163937	0.153503606	**153.5**
05 Feb 07	**258.2**	**0.258**	4.05	0.0	0	0.189	0.000189141	0.1	1.89141E-05	0.018914091	0.258133398	**258.1**
06 Feb 07	**249.1**	**0.249**	4.05	0.0	0	0.174	0.000174379	0.1	1.74379E-05	0.017437948	0.249019376	**249.0**
07 Feb 07	**182.0**	**0.182**	4.05	1.0	0.001	0.155	0.000155079	0.1	1.55079E-05	0.015507927	0.185959693	**186.0**
08 Feb 07	**580.7**	**0.581**	4.05	14.2	0.0142	0.141	0.000141279	0.1	1.41279E-05	0.01412792	0.638140282	**638.1**
09 Feb 07	**496.3**	**0.496**	4.05	4.6	0.0046	0.225	0.000224755	0.1	2.24755E-05	0.022475519	0.514866474	**514.9**
10 Feb 07	**501.0**	**0.501**	4.05	8.8	0.0088	0.155	0.000154541	0.1	1.54541E-05	0.015454082	0.536607411	**536.6**
11 Feb 07	**298.7**	**0.299**	4.05	4.4	0.0044	0.245	0.000244894	0.1	2.44894E-05	0.024489442	0.316400818	**316.4**
12 Feb 07	**288.6**	**0.289**	4.05	4.0	0.004	0.208	0.000208107	0.1	2.08107E-05	0.020810671	0.304678217	**304.7**
13 Feb 07	**369.9**	**0.370**	4.05	6.0	0.006	0.232	0.000231543	0.1	2.31543E-05	0.023154288	0.394136225	**394.1**

14 Feb 07	**240.4**	**0.240**	4.05	0.0	0	0.250	0.000250098	0.1	2.50098E-05	0.025009783	0.24029621	**240.3**
15 Feb 07	**301.0**	**0.301**	4.05	6.4	0.0064	0.211	0.000211337	0.1	2.11337E-05	0.021133707	0.326794408	**326.8**
16 Feb 07	**191.0**	**0.191**	4.05	0.4	0.0004	0.244	0.000244375	0.1	2.44375E-05	0.024437465	0.192471028	**192.5**
17 Feb 07	**199.1**	**0.199**	4.05	0.0	0	0.303	0.000302701	0.1	3.02701E-05	0.030270108	0.198949906	**198.9**
18 Feb 07	**235.8**	**0.236**	4.05	0.2	0.0002	0.266	0.000265973	0.1	2.65973E-05	0.026597274	0.236539781	**236.5**
19 Feb 07	**373.2**	**0.373**	4.05	12.0	0.012	0.199	0.000199038	0.1	1.99038E-05	0.01990381	0.42172689	**421.7**
20 Feb 07	**334.3**	**0.334**	4.05	1.6	0.0016	0.338	0.000337627	0.1	3.37627E-05	0.033762735	0.340648261	**340.6**
21 Feb 07	**250.9**	**0.251**	4.05	11.0	0.011	0.283	0.000282788	0.1	2.82788E-05	0.028278783	0.295377971	**295.4**
22 Feb 07	**209.2**	**0.209**	4.05	6.2	0.0062	0.306	0.000306391	0.1	3.06391E-05	0.030639074	0.234175912	**234.2**
23 Feb 07	**155.0**	**0.155**	4.05	5.2	0.0052	0.267	0.000266705	0.1	2.66705E-05	0.026670535	0.175991984	**176.0**
24 Feb 07	**368.6**	**0.369**	4.05	1.4	0.0014	0.286	0.000285894	0.1	2.85894E-05	0.028589388	0.374201713	**374.2**
25 Feb 07	**197.4**	**0.197**	4.05	0.0	0	0.299	0.000298771	0.1	2.98771E-05	0.029877124	0.197241498	**197.2**
26 Feb 07	**169.1**	**0.169**	4.05	3.8	0.0038	0.283	0.000282773	0.1	2.82773E-05	0.028277302	0.184422977	**184.4**
27 Feb 07	**281.6**	**0.282**	4.05	6.6	0.0066	0.359	0.000359105	0.1	3.59105E-05	0.035910474	0.308164563	**308.2**
28 Feb 07	**352.4**	**0.352**	4.05	2.6	0.0026	0.353	0.000352813	0.1	3.52813E-05	0.035281295	0.362789611	**362.8**
01 Mar 07	**206.8**	**0.207**	4.05	0.0	0	0.358	0.000357897	0.3	0.000107369	0.107369179	0.206332655	**206.3**
02 Mar 07	**322.8**	**0.323**	4.05	29.2	0.0292	0.298	0.00029843	0.3	8.9529E-05	0.089528964	0.440659908	**440.7**
03 Mar 07	**160.7**	**0.161**	4.05	2.0	0.002	0.434	0.000433994	0.3	0.000130198	0.130198213	0.168312697	**168.3**
04 Mar 07	**252.2**	**0.252**	4.05	18.8	0.0188	0.396	0.000396003	0.3	0.000118801	0.118801037	0.327883856	**327.9**
05 Mar 07	**219.5**	**0.219**	4.05	20.6	0.0206	0.313	0.000313171	0.3	9.39513E-05	0.093951257	0.302499497	**302.5**
06 Mar 07	**192.8**	**0.193**	4.05	3.6	0.0036	0.439	0.000438573	0.3	0.000131572	0.131571948	0.206849634	**206.8**
07 Mar 07	**124.4**	**0.124**	4.05	0.2	0.0002	0.414	0.000413867	0.3	0.00012416	0.124160105	0.124709652	**124.7**
08 Mar 07	**79.5**	**0.080**	4.05	3.8	0.0038	0.410	0.000410163	0.3	0.000123049	0.123048993	0.094406652	**94.4**
09 Mar 07	**48.6**	**0.049**	4.05	0.0	0	0.491	0.000491055	0.3	0.000147316	0.147316396	0.047995869	**48.0**
10 Mar 07	**0.6**	**0.001**	4.05	0.0	0	0.466	0.000465622	0.3	0.000139687	0.139686536	4.26953E-06	**0.0**
11 Mar 07	**79.7**	**0.080**	4.05	1.0	0.001	0.342	0.000341777	0.3	0.000102533	0.102533013	0.083292241	**83.3**
12 Mar 07	**40.2**	**0.040**	4.05	2.2	0.0022	0.472	0.000472494	0.3	0.000141748	0.141748296	0.048520919	**48.5**
13 Mar 07	**41.3**	**0.041**	4.05	0	0	0.550	0.000549676	0.3	0.000164903	0.164902788	0.040657144	**40.7**
14 Mar 07	**7.6**	**0.008**	4.05	0	0	0.462	0.00046222	0.3	0.000138666	0.138665929	0.006990903	**7.0**
15 Mar 07	**21.5**	**0.022**	4.05	0	0	0.474	0.000474051	0.3	0.000142215	0.142215428	0.020941528	**20.9**
16 Mar 07	**37.2**	**0.037**	4.05	0.8	0.0008	0.379	0.000378955	0.3	0.000113687	0.11368652	0.03997207	**40.0**
17 Mar 07	**89.3**	**0.089**	4.05	0.6	0.0006	0.412	0.000412139	0.3	0.000123642	0.123641633	0.091276751	**91.3**
18 Mar 07	**61.3**	**0.061**	4.05	2.6	0.0026	0.522	0.00052166	0.3	0.000156498	0.156497939	0.071171183	**71.2**
19 Mar 07	**125.0**	**0.125**	4.05	1.4	0.0014	0.536	0.000536015	0.3	0.000160805	0.160804579	0.129991241	**130.0**
20 Mar 07	**84.1**	**0.084**	4.05	0	0	0.476	0.00047556	0.3	0.000142668	0.142667851	0.083497195	**83.5**
21 Mar 07	**74.8**	**0.075**	4.05	5	0.005	0.396	0.000395755	0.3	0.000118727	0.118726631	0.094581657	**94.6**
22 Mar 07	**31.8**	**0.032**	4.05	0.8	0.0008	0.467	0.00046701	0.3	0.000140103	0.140103103	0.034450082	**34.5**
23 Mar 07	**38.3**	**0.038**	4.05	0	0	0.574	0.000573924	0.3	0.000172177	0.172177212	0.037635182	**37.6**
24 Mar 07	**51.7**	**0.052**	4.05	0	0	0.655	0.000654569	0.3	0.000196371	0.196370748	0.050932198	**50.9**
25 Mar 07	**53.0**	**0.053**	4.05	0	0	0.512	0.000512365	0.3	0.00015371	0.153709589	0.052387476	**52.4**
26 Mar 07	**27.2**	**0.027**	4.05	0	0	0.606	0.00060605	0.3	0.000181815	0.181814909	0.02648115	**26.5**
27 Mar 07	**154.0**	**0.154**	4.05	0	0	0.608	0.000608472	0.3	0.000182542	0.182541581	0.153303207	**153.3**
28 Mar 07	**91.8**	**0.092**	4.05	0.6	0.0006	0.600	0.000600083	0.3	0.000180025	0.180024881	0.093470899	**93.5**
29 Mar 07	**93.9**	**0.094**	4.05	3.2	0.0032	0.520	0.000520319	0.3	0.000156096	0.156095563	0.106235313	**106.2**
30 Mar 07	**161.9**	**0.162**	4.05	0	0	0.471	0.000471477	0.3	0.000141443	0.14144297	0.161307156	**161.3**
31 Mar 07	**148.6**	**0.149**	4.05	0	0	0.577	0.000577342	0.3	0.000173203	0.173202541	0.14792603	**147.9**
01 Apr 07	**217.5**	**0.217**	4.05	0	0	0.637	0.000636608	0.3	0.000190983	0.19098251	0.216681521	**216.7**
02 Apr 07	**135.8**	**0.136**	4.05	0	0	0.739	0.000738787	0.3	0.000221636	0.221636095	0.134904874	**134.9**
03 Apr 07	**172.1**	**0.172**	4.05	0	0	0.628	0.000627587	0.3	0.000188276	0.188276226	0.171377481	**171.4**
04 Apr 07	**175.8**	**0.176**	4.05	0	0	0.819	0.000819041	0.3	0.000245712	0.245712268	0.174849865	**174.8**
05 Apr 07	**172.9**	**0.173**	4.05	0	0	0.874	0.000874023	0.3	0.000262207	0.262206916	0.171790562	**171.8**
06 Apr 07	**71.7**	**0.072**	4.05	0	0	0.832	0.000832289	0.3	0.000249687	0.249686799	0.070666268	**70.7**
07 Apr 07	**27.5**	**0.028**	4.05	0	0	0.941	0.000941005	0.3	0.000282301	0.282301494	0.026359179	**26.4**

08 Apr 07	**110.6**	**0.111**	4.05	0	0	0.858	0.000858419	0.3	0.000257526	0.257525739	0.109537021	**109.5**
09 Apr 07	**146.6**	**0.147**	4.05	0	0	0.755	0.000755395	0.3	0.000226619	0.226618596	0.145714695	**145.7**
10 Apr 07	**105.2**	**0.105**	4.05	0	0	0.675	0.000674949	0.3	0.000202485	0.202484643	0.104344937	**104.3**
11 Apr 07	**162.2**	**0.162**	4.05	0	0	0.904	0.000904158	0.3	0.000271247	0.271247341	0.161066448	**161.1**
12 Apr 07	**143.5**	**0.143**	4.05	0	0	1.126	0.0011257	0.3	0.00033771	0.337709872	0.142129775	**142.1**
13 Apr 07	**171.0**	**0.171**	4.05	0	0	1.018	0.001018283	0.3	0.000305485	0.305484752	0.169762787	**169.8**
14 Apr 07	**144.8**	**0.145**	4.05	0	0	1.115	0.001114967	0.3	0.00033449	0.334490081	0.143425315	**143.4**
15 Apr 07	**165.7**	**0.166**	4.05	0	0	0.864	0.000863667	0.3	0.0002591	0.259100008	0.164678145	**164.7**
16 Apr 07	**180.8**	**0.181**	4.05	0	0	0.845	0.000844501	0.3	0.00025335	0.253350207	0.179806432	**179.8**
17 Apr 07	**170.9**	**0.171**	4.05	0	0	0.824	0.000824434	0.3	0.00024733	0.247330163	0.169855813	**169.9**
18 Apr 07	**108.0**	**0.108**	4.05	0	0	0.949	0.000949167	0.3	0.00028475	0.284750148	0.106861762	**106.9**
19 Apr 07	**178.0**	**0.178**	4.05	0	0	1.009	0.001008699	0.3	0.00030261	0.302609779	0.17675693	**176.8**
20 Apr 07	**103.6**	**0.104**	4.05	0	0	1.001	0.001001005	0.3	0.000300302	0.300301563	0.102381279	**102.4**
21 Apr 07	**3.4**	**0.003**	4.05	0	0	0.889	0.000888718	0.3	0.000266615	0.266615303	0.002340208	**2.3**
22 Apr 07	**1.9**	**0.002**	4.05	2.2	0.0022	0.986	0.000985858	0.3	0.000295757	0.295757437	0.009564682	**9.6**
23 Apr 07	**6.1**	**0.006**	4.05	8.2	0.0082	0.647	0.000647171	0.3	0.000194151	0.194151213	0.038551188	**38.6**
24 Apr 07	**59.3**	**0.059**	4.05	13.8	0.0138	0.855	0.000854872	0.3	0.000256462	0.256461504	0.114131331	**114.1**
25 Apr 07	**178.3**	**0.178**	4.05	1.6	0.0016	1.007	0.001007113	0.3	0.000302134	0.302134015	0.183523857	**183.5**
26 Apr 07	**113.0**	**0.113**	4.05	0	0	1.044	0.001044191	0.3	0.000313257	0.31325728	0.111733808	**111.7**
27 Apr 07	**120.8**	**0.121**	4.05	0.8	0.0008	0.853	0.000853138	0.3	0.000255941	0.255941304	0.123043438	**123.0**
28 Apr 07	**308.9**	**0.309**	4.05	0	0	0.996	0.000996097	0.3	0.000298829	0.298828971	0.307729743	**307.7**
29 Apr 07	**298.5**	**0.299**	4.05	0	0	1.023	0.001022819	0.3	0.000306846	0.306845816	0.297294774	**297.3**
30 Apr 07	**237.3**	**0.237**	4.05	0.8	0.0008	0.968	0.000968363	0.3	0.000290509	0.29050895	0.239325939	**239.3**
01 May 07	**268.5**	**0.268**	4.05	0	0	1.055	0.00105464	0.5	0.00052732	0.527319907	0.266334354	**266.3**
02 May 07	**121.7**	**0.122**	4.05	0	0	1.131	0.001130886	0.5	0.000565443	0.565442868	0.119404956	**119.4**
03 May 07	**87.1**	**0.087**	4.05	0	0	1.312	0.001311744	0.5	0.000655872	0.655872242	0.084411217	**84.4**
04 May 07	**87.4**	**0.087**	4.05	0	0	1.405	0.001404774	0.5	0.000702387	0.702387152	0.084507832	**84.5**
05 May 07	**69.8**	**0.070**	4.05	0	0	1.879	0.001878613	0.5	0.000939306	0.939306342	0.066020809	**66.0**
06 May 07	**94.1**	**0.094**	4.05	0	0	0.937	0.000937462	0.5	0.000468731	0.468730829	0.09215164	**92.2**
07 May 07	**138.4**	**0.138**	4.05	2.4	0.0024	1.171	0.00117065	0.5	0.000585325	0.58532516	0.145716933	**145.7**
08 May 07	**225.2**	**0.225**	4.05	0.2	0.0002	0.924	0.000923509	0.5	0.000461754	0.461754398	0.224089895	**224.1**
09 May 07	**225.2**	**0.225**	4.05	2.4	0.0024	1.172	0.001172481	0.5	0.000586241	0.586240563	0.232495726	**232.5**
10 May 07	**206.3**	**0.206**	4.05	0	0	0.992	0.000991701	0.5	0.000495851	0.495850707	0.204331805	**204.3**
11 May 07	**319.8**	**0.320**	4.05	8.8	0.0088	1.176	0.001176034	0.5	0.000588017	0.588016862	0.353028532	**353.0**
12 May 07	**227.9**	**0.228**	4.05	0.6	0.0006	0.964	0.000963502	0.5	0.000481751	0.481750926	0.228336409	**228.3**
13 May 07	**246.1**	**0.246**	4.05	0.8	0.0008	1.182	0.001181846	0.5	0.000590923	0.590922823	0.246944263	**246.9**
14 May 07	**150.1**	**0.150**	4.05	0.4	0.0004	0.887	0.00088717	0.5	0.000443585	0.443585009	0.149875981	**149.9**
15 May 07	**352.7**	**0.353**	4.05	2.6	0.0026	0.763	0.000763339	0.5	0.000381669	0.381669437	0.361671739	**361.7**
16 May 07	**186.2**	**0.186**	4.05	2	0.002	1.192	0.001192349	0.5	0.000596174	0.596174343	0.191932994	**191.9**
17 May 07	**175.8**	**0.176**	4.05	0	0	1.276	0.00127617	0.5	0.000638085	0.638084924	0.173260756	**173.3**
18 May 07	**6.4**	**0.006**	4.05	0.8	0.0008	1.331	0.001330527	0.5	0.000665264	0.66526374	0.006958182	**7.0**
19 May 07	**5.0**	**0.005**	4.05	0.6	0.0006	1.327	0.001327413	0.5	0.000663707	0.663706673	0.004729488	**4.7**
20 May 07	**39.5**	**0.039**	4.05	0	0	1.417	0.001416872	0.5	0.000708436	0.708436018	0.036603334	**36.6**
21 May 07	**162.6**	**0.163**	4.05	0	0	1.270	0.001270041	0.5	0.00063502	0.635020293	0.160020668	**160.0**
22 May 07	**351.5**	**0.352**	4.05	0	0	1.109	0.001108532	0.5	0.000554266	0.554265863	0.349302723	**349.3**
23 May 07	**187.4**	**0.187**	4.05	0.6	0.0006	1.151	0.001151079	0.5	0.00057554	0.575539644	0.187486564	**187.5**
24 May 07	**93.5**	**0.093**	4.05	0	0	1.193	0.001193452	0.5	0.000596726	0.596725969	0.09106326	**91.1**
25 May 07	**5.4**	**0.005**	4.05	0	0	1.417	0.001416812	0.5	0.000708406	0.708406037	0.002545956	**2.5**
26 May 07	**145.5**	**0.145**	4.05	11.2	0.0112	1.443	0.001443034	0.5	0.000721517	0.721517076	0.187930356	**187.9**
27 May 07	**622.2**	**0.622**	4.05	9.4	0.0094	1.146	0.001145657	0.5	0.000572828	0.572828466	0.657905045	**657.9**
28 May 07	**167.6**	**0.168**	4.05	1.4	0.0014	1.603	0.00160285	0.5	0.000801425	0.801424763	0.17000423	**170.0**
29 May 07	**23.8**	**0.024**	4.05	0	0	1.478	0.00147813	0.5	0.000739065	0.73906511	0.020804286	**20.8**
30 May 07	**18.1**	**0.018**	4.05	0.6	0.0006	0.745	0.000744522	0.5	0.000372261	0.372261101	0.019019843	**19.0**
31 May 07	**165.3**	**0.165**	4.05	0.2	0.0002	0.843	0.000843326	0.5	0.000421663	0.421662902	0.164402265	**164.4**
01 Jun 07	**280.2**	**0.280**	4.05	0.4	0.0004	1.204	0.001203697	0.7	0.000842588	0.842587707	0.27836252	**278.4**
02 Jun 07	**132.1**	**0.132**	4.05	1	0.001	1.350	0.001350428	0.7	0.000945299	0.945299404	0.132319037	**132.3**
03 Jun 07	**251.8**	**0.252**	4.05	1.4	0.0014	1.433	0.001433351	0.7	0.001003346	1.003345902	0.253403949	**253.4**
04 Jun 07	**144.6**	**0.145**	4.05	1.2	0.0012	1.430	0.001430472	0.7	0.00100133	1.001330268	0.145442112	**145.4**

05 Jun 07	**178.3**	**0.178**	4.05	0.4	0.0004	1.723	0.001722659	0.7	0.001205861	1.20586119	0.175003762	**175.0**
06 Jun 07	**68.4**	**0.068**	4.05	0	0	1.794	0.001793573	0.7	0.001255501	1.255500751	0.063315222	**63.3**
07 Jun 07	**22.9**	**0.023**	4.05	0	0	1.695	0.001694616	0.7	0.001186231	1.186231352	0.018138263	**18.1**
08 Jun 07	**81.5**	**0.082**	4.05	0	0	1.567	0.001566624	0.7	0.001096637	1.096636832	0.077068621	**77.1**
09 Jun 07	**102.5**	**0.102**	4.05	0	0	1.571	0.001571317	0.7	0.001099922	1.099921961	0.098002816	**98.0**
10 Jun 07	**51.7**	**0.052**	4.05	0	0	1.363	0.001363101	0.7	0.00095417	0.954170388	0.04786311	**47.9**
11 Jun 07	**164.3**	**0.164**	4.05	0	0	0.793	0.000792525	0.7	0.000554768	0.554767579	0.162055691	**162.1**
12 Jun 07	**228.1**	**0.228**	4.05	0	0	0.572	0.000571947	0.7	0.000400363	0.400363173	0.226521029	**226.5**
13 Jun 07	**139.8**	**0.140**	4.05	0	0	0.831	0.000831098	0.7	0.000581769	0.581768805	0.137436336	**137.4**
14 Jun 07	**190.8**	**0.191**	4.05	0	0	1.112	0.0011123	0.7	0.00077861	0.778609748	0.187654131	**187.7**
15 Jun 07	**156.6**	**0.157**	4.05	24.4	0.0244	1.221	0.001221376	0.7	0.000854963	0.854963001	0.2519649	**252.0**
16 Jun 07	**229.7**	**0.230**	4.05	3.6	0.0036	1.066	0.001065943	0.7	0.00074616	0.746159938	0.241268052	**241.3**
17 Jun 07	**117.3**	**0.117**	4.05	0.2	0.0002	1.391	0.001390585	0.7	0.00097341	0.973409729	0.114145191	**114.1**
18 Jun 07	**82.1**	**0.082**	4.05	0	0	1.143	0.001142987	0.7	0.000800091	0.800090619	0.078839633	**78.8**
19 Jun 07	**377.5**	**0.377**	4.05	22.6	0.0226	1.291	0.00129113	0.7	0.000903791	0.90379078	0.465352147	**465.4**
20 Jun 07	**263.8**	**0.264**	4.05	5.6	0.0056	1.285	0.001285436	0.7	0.000899805	0.899804987	0.28280329	**282.8**
21 Jun 07	**221.9**	**0.222**	4.05	11.6	0.0116	1.152	0.001151553	0.7	0.000806087	0.806087074	0.265587847	**265.6**
22 Jun 07	**147.8**	**0.148**	4.05	3.2	0.0032	1.008	0.001008152	0.7	0.000705706	0.705706378	0.157874389	**157.9**
23 Jun 07	**183.1**	**0.183**	4.05	1.4	0.0014	1.331	0.001330754	0.7	0.000931528	0.931528012	0.185009812	**185.0**
24 Jun 07	**270.5**	**0.270**	4.05	10.6	0.0106	1.508	0.001508192	0.7	0.001055734	1.055734175	0.309119277	**309.1**
25 Jun 07	**155.2**	**0.155**	4.05	1.2	0.0012	1.113	0.001112955	0.7	0.000779068	0.779068292	0.156887273	**156.9**
26 Jun 07	**267.2**	**0.267**	4.05	0.8	0.0008	1.313	0.001313002	0.7	0.000919101	0.919101491	0.266705139	**266.7**
27 Jun 07	**130.7**	**0.131**	4.05	0.6	0.0006	1.378	0.001377542	0.7	0.00096428	0.96427965	0.129197167	**129.2**
28 Jun 07	**150.5**	**0.150**	4.05	0.4	0.0004	1.582	0.001582362	0.7	0.001107654	1.107653613	0.147614003	**147.6**
29 Jun 07	**158.2**	**0.158**	4.05	0.2	0.0002	1.476	0.001475717	0.7	0.001033002	1.033001847	0.154801343	**154.8**
30 Jun 07	**205.5**	**0.205**	4.05	0.4	0.0004	1.221	0.001221277	0.7	0.000854894	0.854893681	0.203642681	**203.6**
01 Jul 07	**204.2**	**0.204**	4.05	0.8	0.0008	1.227	0.00122741	0.7	0.000859187	0.859187297	0.203962791	**204.0**
02 Jul 07	**251.5**	**0.252**	4.05	0.8	0.0008	1.476	0.001475717	0.7	0.001033002	1.033001847	0.250568843	**250.6**
03 Jul 07	**223.6**	**0.224**	4.05	0.4	0.0004	1.221	0.001221277	0.7	0.000854894	0.854893681	0.221740181	**221.7**
04 Jul 07	**150.3**	**0.150**	4.05	0.4	0.0004	1.227	0.00122741	0.7	0.000859187	0.859187297	0.148477791	**148.5**
05 Jul 07	**150.3**	**0.150**	4.05	0.4	0.0004	1.262	0.00126218	0.7	0.000883526	0.883526071	0.148379219	**148.4**
06 Jul 07	**160.2**	**0.160**	4.05	0.2	0.0002	1.551	0.001551345	0.7	0.001085942	1.085941836	0.156581936	**156.6**
07 Jul 07	**75.5**	**0.076**	4.05	0.4	0.0004	1.692	0.001691936	0.7	0.001184356	1.184355507	0.07234836	**72.3**
08 Jul 07	**155.3**	**0.155**	4.05	0	0	1.632	0.001632176	0.7	0.001142523	1.142523289	0.150697781	**150.7**
09 Jul 07	**116.1**	**0.116**	4.05	0.2	0.0002	1.064	0.001063699	0.7	0.000744589	0.744589257	0.113931914	**113.9**
10 Jul 07	**268.6**	**0.269**	4.05	0	0	1.421	0.001421092	0.7	0.000994765	0.994764554	0.264583704	**264.6**
11 Jul 07	**166.4**	**0.166**	4.05	0	0	1.892	0.001892301	0.7	0.00132461	1.3246104	0.161075328	**161.1**
12 Jul 07	**118.8**	**0.119**	4.05	0	0	2.097	0.002096542	0.7	0.00146758	1.467579549	0.112901303	**112.9**
13 Jul 07	**163.4**	**0.163**	4.05	0	0	0.805	0.000805184	0.7	0.000563629	0.563628642	0.161164804	**161.2**
14 Jul 07	**96.3**	**0.096**	4.05	0	0	1.818	0.001818393	0.7	0.001272875	1.272874843	0.091174857	**91.2**
15 Jul 07	**101.3**	**0.101**	4.05	3.2	0.0032	1.770	0.001770281	0.7	0.001239197	1.239196717	0.109258753	**109.3**
16 Jul 07	**185.5**	**0.186**	4.05	5.8	0.0058	2.235	0.002235074	0.7	0.001564552	1.564551895	0.202688565	**202.7**
17 Jul 07	**222.4**	**0.222**	4.05	3.6	0.0036	1.740	0.001740411	0.7	0.001218288	1.218287967	0.232088434	**232.1**
18 Jul 07	**129.8**	**0.130**	4.05	2.8	0.0028	2.369	0.002369368	0.7	0.001658558	1.658557855	0.134440341	**134.4**
19 Jul 07	**198.1**	**0.198**	4.05	0.6	0.0006	1.627	0.001627057	0.7	0.00113894	1.138940014	0.195892293	**195.9**
20 Jul 07	**177.1**	**0.177**	4.05	8.4	0.0084	0.908	0.000908276	0.7	0.000635793	0.635793352	0.208572537	**208.6**
21 Jul 07	**35.9**	**0.036**	4.05	2.2	0.0022	0.975	0.000974661	0.7	0.000682262	0.682262359	0.042056837	**42.1**
22 Jul 07	**122.6**	**0.123**	4.05	2.8	0.0028	1.234	0.001234092	0.7	0.000863865	0.86386473	0.130391348	**130.4**
23 Jul 07	**303.2**	**0.303**	4.05	1	0.001	1.364	0.001364358	0.7	0.00095505	0.955050429	0.303422046	**303.4**
24 Jul 07	**205.9**	**0.206**	4.05	0	0	1.256	0.001255859	0.7	0.000879102	0.879101627	0.202352138	**202.4**
25 Jul 07	**115.7**	**0.116**	4.05	0	0	1.431	0.001430528	0.7	0.00100137	1.001369712	0.111654453	**111.7**
26 Jul 07	**41.8**	**0.042**	4.05	0	0	1.446	0.001446023	0.7	0.001012216	1.012215782	0.037653026	**37.7**
27 Jul 07	**82.7**	**0.083**	4.05	0	0	1.438	0.001438133	0.7	0.001006693	1.006693053	0.078572893	**78.6**
28 Jul 07	**226.3**	**0.226**	4.05	0	0	1.142	0.001141956	0.7	0.00079937	0.799369531	0.223052553	**223.1**
29 Jul 07	**266.5**	**0.266**	4.05	0	0	1.442	0.001442088	0.7	0.001009462	1.009461853	0.262386679	**262.4**
30 Jul 07	**228.6**	**0.229**	4.05	0.2	0.0002	1.405	0.001404626	0.7	0.000983238	0.983237853	0.225397887	**225.4**
31 Jul 07	**236.6**	**0.237**	4.05	0.2	0.0002	1.398	0.001397719	0.7	0.000978403	0.978403324	0.233397467	**233.4**
01 Aug 07	**138.2**	**0.138**	4.05	0	0	1.174	0.001174435	0.7	0.000822105	0.822104761	0.134866304	**134.9**

02 Aug 07				1.2	0.0012	1.265	0.00126523	0.7	0.000885661	0.885660798		
03 Aug 07				2.8	0.0028	1.252	0.001252237	0.7	0.000876566	0.876565957		
04 Aug 07				0	0	1.274	0.001273774	0.7	0.000891641	0.891641459		
05 Aug 07				0	0	0.820	0.000819682	0.7	0.000573777	0.573777306		
06 Aug 07				3.4	0.0034	1.357	0.001357301	0.7	0.000950111	0.950110983		
07 Aug 07				4.8	0.0048	1.215	0.001215483	0.7	0.000850838	0.850837994		
08 Aug 07				1.8	0.0018	1.324	0.001324396	0.7	0.000927077	0.92707702		
09 Aug 07				2.8	0.0028	1.068	0.001068263	0.7	0.000747784	0.747784316		
10 Aug 07				0.2	0.0002	0.986	0.000985764	0.7	0.000690035	0.69003461		
11 Aug 07				2.2	0.0022	0.790	0.000790383	0.7	0.000553268	0.553268184		
12 Aug 07				8.8	0.0088	1.268	0.001268067	0.7	0.000887647	0.887647141		
13 Aug 07				0.6	0.0006	1.106	0.001105567	0.7	0.000773897	0.773896723		
14 Aug 07				27.4	0.0274	0.880	0.000880184	0.7	0.000616128	0.616128458		
15 Aug 07				14	0.014	1.179	0.001179438	0.7	0.000825606	0.825606352		
16 Aug 07				0	0	1.171	0.001170882	0.7	0.000819618	0.819617657		
17 Aug 07				4	0.004	0.915	0.000914628	0.7	0.00064024	0.640239823		
18 Aug 07				11.2	0.0112	0.863	0.000863074	0.7	0.000604152	0.604151867		
19 Aug 07				0	0	0.879	0.000879386	0.7	0.00061557	0.615570284		
20 Aug 07				12.4	0.0124	0.987	0.000987163	0.7	0.000691014	0.691014252		
21 Aug 07	**134.1**	**0.134**	4.05	0.4	0.0004	0.989	0.000988782	0.7	0.000692147	0.692147428	0.13293445	**132.9**
22 Aug 07	**114.6**	**0.115**	4.05	0	0	1.135	0.001134542	0.7	0.000794179	0.794179409	0.111353573	**111.4**
23 Aug 07	**144.8**	**0.145**	4.05	0	0	0.929	0.000928666	0.7	0.000650066	0.650065883	0.142147233	**142.1**
24 Aug 07	**67.3**	**0.067**	4.05	0	0	1.104	0.001104472	0.7	0.000773131	0.773130506	0.064128821	**64.1**
25 Aug 07	**19.8**	**0.020**	4.05	0	0	0.931	0.000931138	0.7	0.000651796	0.651796309	0.017167725	**17.2**
26 Aug 07	**72.2**	**0.072**	4.05	0	0	1.085	0.00108459	0.7	0.000759213	0.759212963	0.069172687	**69.2**
27 Aug 07	**116.1**	**0.116**	4.05	0	0	0.947	0.000947403	0.7	0.000663182	0.663181957	0.113451613	**113.5**
28 Aug 07	**126.4**	**0.126**	4.05	0	0	0.943	0.00094289	0.7	0.000660023	0.660022809	0.123724408	**123.7**
29 Aug 07	**99.5**	**0.099**	4.05	0	0	0.890	0.000890455	0.7	0.000623319	0.623318648	0.096940559	**96.9**
30 Aug 07	**113.4**	**0.113**	4.05	0	0	0.825	0.000824894	0.7	0.000577426	0.57742598	0.111091425	**111.1**
31 Aug 07	**116.0**	**0.116**	4.05	0	0	0.713	0.000713473	0.7	0.000499431	0.499431081	0.113972304	**114.0**
01 Sep 07	**97.0**	**0.097**	4.05	0	0	0.837	0.000837476	0.5	0.000418738	0.418738077	0.095346611	**95.3**
02 Sep 07	**34.5**	**0.034**	4.05	1.6	0.0016	0.867	0.000866642	0.5	0.000433321	0.433320989	0.03921005	**39.2**
03 Sep 07	**146.9**	**0.147**	4.05	0	0	0.940	0.000939762	0.5	0.000469881	0.4698812	0.145014481	**145.0**
04 Sep 07	**161.7**	**0.162**	4.05	0	0	0.814	0.00081398	0.5	0.00040699	0.406990047	0.16008919	**160.1**
05 Sep 07	**100.3**	**0.100**	4.05	0	0	0.806	0.00080585	0.5	0.000402925	0.402925146	0.098688153	**98.7**
06 Sep 07	**123.3**	**0.123**	4.05	0	0	0.902	0.000901984	0.5	0.000450992	0.450991897	0.121435983	**121.4**
07 Sep 07	**112.3**	**0.112**	4.05	0	0	0.981	0.000980983	0.5	0.000490491	0.490491457	0.11030351	**110.3**
08 Sep 07	**79.4**	**0.079**	4.05	0	0	0.708	0.000707598	0.5	0.000353799	0.353798905	0.077939614	**77.9**
09 Sep 07	**143.2**	**0.143**	4.05	0	0	0.613	0.000613478	0.5	0.000306739	0.306738796	0.141970208	**142.0**
10 Sep 07	**156.0**	**0.156**	4.05	0	0	0.766	0.000765565	0.5	0.000382783	0.382782661	0.15448723	**154.5**
11 Sep 07	**116.1**	**0.116**	4.05	0	0	0.714	0.000713629	0.5	0.000356815	0.356814564	0.114692401	**114.7**
12 Sep 07	**136.1**	**0.136**	4.05	0	0	0.646	0.000646264	0.5	0.000323132	0.323131888	0.134778816	**134.8**
13 Sep 07	**131.1**	**0.131**	4.05	0	0	0.709	0.000708694	0.5	0.000354347	0.354347231	0.129664894	**129.7**
14 Sep 07	**166.3**	**0.166**	4.05	0.2	0.0002	0.809	0.000808619	0.5	0.00040431	0.40430961	0.165470046	**165.5**
15 Sep 07	**108.6**	**0.109**	4.05	0	0	0.782	0.000781765	0.5	0.000390882	0.390882362	0.107001926	**107.0**
16 Sep 07	**133.0**	**0.133**	4.05	1	0.001	0.748	0.000747677	0.5	0.000373839	0.373838648	0.135488453	**135.5**
17 Sep 07	**81.9**	**0.082**	4.05	0.2	0.0002	0.704	0.000703739	0.5	0.000351869	0.351869336	0.081322429	**81.3**
18 Sep 07	**154.2**	**0.154**	4.05	0	0	0.595	0.00059494	0.5	0.00029747	0.297470004	0.152980246	**153.0**
19 Sep 07	**95.0**	**0.095**	4.05	4.2	0.0042	0.650	0.00065047	0.5	0.000325235	0.325235094	0.110740298	**110.7**
20 Sep 07	**113.0**	**0.113**	4.05	1.2	0.0012	0.620	0.000620459	0.5	0.000310229	0.310229279	0.116606071	**116.6**
21 Sep 07	**178.6**	**0.179**	4.05	25.2	0.0252	0.618	0.000618013	0.5	0.000309007	0.309006622	0.279361023	**279.4**
22 Sep 07	**150.5**	**0.150**	4.05	0	0	0.637	0.000637343	0.5	0.000318671	0.318671342	0.149189381	**149.2**
23 Sep 07	**200.2**	**0.200**	4.05	7.8	0.0078	0.663	0.000662827	0.5	0.000331413	0.331413458	0.230460275	**230.5**
24 Sep 07	**91.6**	**0.092**	4.05	3.8	0.0038	0.607	0.000606671	0.5	0.000303335	0.303335339	0.105788992	**105.8**
25 Sep 07	**80.4**	**0.080**	4.05	0	0	0.589	0.000588617	0.5	0.000294308	0.294308413	0.079178051	**79.2**
26 Sep 07	**75.8**	**0.076**	4.05	0	0	0.555	0.000554653	0.5	0.000277327	0.277326606	0.074686827	**74.7**

27 Sep 07	**100.0**	**0.100**	4.05	0	0	0.531	0.000531266	0.5	0.000265633	0.265632866	0.098959187	**99.0**
28 Sep 07	**108.0**	**0.108**	4.05	1.4	0.0014	0.477	0.000477137	0.5	0.000238569	0.238568527	0.112718797	**112.7**
29 Sep 07	**124.3**	**0.124**	4.05	0.6	0.0006	0.421	0.00042108	0.5	0.00021054	0.21053983	0.125837314	**125.8**
30 Sep 07	**178.6**	**0.179**	4.05	0.4	0.0004	0.598	0.000598317	0.5	0.000299158	0.299158456	0.178960908	**179.0**
01 Oct 07	**131.8**	**0.132**	4.05	0.4	0.0004	0.529	0.000528668	0.3	0.0001586	0.158600276	0.132790169	**132.8**
02 Oct 07	**117.3**	**0.117**	4.05	2	0.002	0.443	0.00044268	0.3	0.000132804	0.132803877	0.124839644	**124.8**
03 Oct 07	**133.8**	**0.134**	4.05	6.4	0.0064	0.499	0.000498931	0.3	0.000149679	0.149679327	0.159121299	**159.1**
04 Oct 07	**147.3**	**0.147**	4.05	0	0	0.602	0.000602423	0.3	0.000180727	0.180726936	0.146613056	**146.6**
05 Oct 07	**127.8**	**0.128**	4.05	0	0	0.545	0.000544732	0.3	0.00016342	0.163419552	0.127160651	**127.2**
06 Oct 07	**143.6**	**0.144**	4.05	0.2	0.0002	0.524	0.000524072	0.3	0.000157222	0.157221628	0.143813252	**143.8**
07 Oct 07	**107.2**	**0.107**	4.05	0	0	0.495	0.000494817	0.3	0.000148445	0.148445121	0.106558797	**106.6**
08 Oct 07	**107.7**	**0.108**	4.05	1.4	0.0014	0.417	0.000417183	0.3	0.000125155	0.125154878	0.112893123	**112.9**
09 Oct 07	**148.3**	**0.148**	4.05	5.8	0.0058	0.499	0.000499279	0.3	0.000149784	0.149783703	0.171225876	**171.2**
10 Oct 07	**136.8**	**0.137**	4.05	0	0	0.478	0.000477718	0.3	0.000143315	0.143315366	0.136219573	**136.2**
11 Oct 07	**76.4**	**0.076**	4.05	0	0	0.327	0.00032658	0.3	9.79739E-05	0.097973927	0.075983206	**76.0**
12 Oct 07	**123.4**	**0.123**	4.05	0.4	0.0004	0.321	0.000320667	0.3	9.62E-05	0.09620001	0.12463539	**124.6**
13 Oct 07	**102.7**	**0.103**	4.05	0	0	0.407	0.000407379	0.3	0.000122214	0.122213659	0.102247535	**102.2**
14 Oct 07	**194.2**	**0.194**	4.05	0	0	0.404	0.000404284	0.3	0.000121285	0.121285292	0.193736295	**193.7**
15 Oct 07	**88.2**	**0.088**	4.05	0.2	0.0002	0.430	0.000430401	0.3	0.00012912	0.129120343	0.088494563	**88.5**
16 Oct 07	**99.9**	**0.100**	4.05	2	0.002	0.445	0.000445407	0.3	0.000133622	0.133622209	0.10745133	**107.5**
17 Oct 07	**125.4**	**0.125**	4.05	0	0	0.382	0.00038227	0.3	0.000114681	0.114680876	0.124935542	**124.9**
18 Oct 07	**104.6**	**0.105**	4.05	0	0	0.416	0.000416188	0.3	0.000124856	0.12485626	0.104089332	**104.1**
19 Oct 07	**75.8**	**0.076**	4.05	0	0	0.333	0.000332508	0.3	9.97525E-05	0.099752462	0.075406003	**75.4**
20 Oct 07	**15.5**	**0.016**	4.05	0	0	0.322	0.000321537	0.3	9.64612E-05	0.096461202	0.015141832	**15.1**
21 Oct 07	**70.1**	**0.070**	4.05	0.2	0.0002	0.238	0.000237861	0.3	7.13583E-05	0.071358323	0.070630999	**70.6**
22 Oct 07	**21.8**	**0.022**	4.05	0.6	0.0006	0.205	0.000204683	0.3	6.14049E-05	0.061404943	0.02398381	**24.0**
23 Oct 07	**6.7**	**0.007**	4.05	0	0	0.358	0.000357845	0.3	0.000107353	0.107353434	0.006262719	**6.3**
24 Oct 07	**19.7**	**0.020**	4.05	0.2	0.0002	0.402	0.000401839	0.3	0.000120552	0.120551596	0.019986766	**20.0**
25 Oct 07	**11.0**	**0.011**	4.05	0	0	0.372	0.000372185	0.3	0.000111656	0.111655545	0.010520295	**10.5**
26 Oct 07	**16.2**	**0.016**	4.05	1.8	0.0018	0.280	0.000279551	0.3	8.38652E-05	0.083865153	0.023195346	**23.2**
27 Oct 07	**9.7**	**0.010**	4.05	0	0	0.310	0.00030954	0.3	9.2862E-05	0.092861995	0.009313909	**9.3**
28 Oct 07	**49.2**	**0.049**	4.05	5.4	0.0054	0.332	0.000331929	0.3	9.95788E-05	0.09957875	0.070629206	**70.6**
29 Oct 07	**99.2**	**0.099**	4.05	0.2	0.0002	0.289	0.000288935	0.3	8.66806E-05	0.086680605	0.099638944	**99.6**
30 Oct 07	**160.9**	**0.161**	4.05	0	0	0.241	0.000241016	0.3	7.23047E-05	0.072304654	0.160589666	**160.6**
31 Oct 07	**89.2**	**0.089**	4.05	0	0	0.189	0.000188841	0.3	5.66522E-05	0.056652218	0.088975559	**89.0**
01 Nov 07	**68.0**	**0.068**	4.05	0	0	0.212	0.000211995	0.1	2.11995E-05	0.021199464	0.067886642	**67.9**
02 Nov 07	**84.6**	**0.085**	4.05	0	0	0.248	0.000247682	0.1	2.47682E-05	0.024768217	0.084544689	**84.5**
03 Nov 07	**73.2**	**0.073**	4.05	0.2	0.0002	0.197	0.000196869	0.1	1.96869E-05	0.019686859	0.073975268	**74.0**
04 Nov 07	**156.0**	**0.156**	4.05	0	0	0.177	0.000176833	0.1	1.76833E-05	0.017683327	0.155965883	**156.0**
05 Nov 07	**127.1**	**0.127**	4.05	0	0	0.198	0.000198148	0.1	1.98148E-05	0.019814801	0.12702975	**127.0**
06 Nov 07	**87.1**	**0.087**	4.05	0	0	0.236	0.000236433	0.1	2.36433E-05	0.023643332	0.086971745	**87.0**
07 Nov 07	**139.7**	**0.140**	4.05	0	0	0.203	0.000203381	0.1	2.03381E-05	0.020338122	0.139567631	**139.6**
08 Nov 07	**110.0**	**0.110**	4.05	0.8	0.0008	0.226	0.000226334	0.1	2.26334E-05	0.022633407	0.113158335	**113.2**
09 Nov 07	**137.7**	**0.138**	4.05	0	0	0.206	0.000206443	0.1	2.06443E-05	0.020644267	0.137571391	**137.6**
10 Nov 07	**73.2**	**0.073**	4.05	0	0	0.168	0.000168304	0.1	1.68304E-05	0.016830362	0.073176837	**73.2**
11 Nov 07	**117.4**	**0.117**	4.05	0.8	0.0008	0.20	0.000203374	0.1	2.03374E-05	0.020337387	0.120577634	**120.6**
12 Nov 07	**100.3**	**0.100**	4.05	0	0	0.19	0.000186609	0.1	1.86609E-05	0.018660892	0.100244423	**100.2**
13 Nov 07	**196.2**	**0.196**	4.05	0	0	0.15	0.000154604	0.1	1.54604E-05	0.015460435	0.196159885	**196.2**
14 Nov 07	**126.1**	**0.126**	4.05	5.4	0.0054	0.15	0.000150484	0.1	1.50484E-05	0.015048438	0.147921554	**147.9**
15 Nov 07	**143.6**	**0.144**	4.05	1.6	0.0016	0.12	0.000116614	0.1	1.16614E-05	0.011661402	0.150072771	**150.1**
16 Nov 07	**162.6**	**0.163**	4.05	0	0	0.14	0.000140415	0.1	1.40415E-05	0.014041509	0.162535632	**162.5**
17 Nov 07	**155.6**	**0.156**	4.05	24	0.024	0.12	0.000120205	0.1	1.20205E-05	0.012020537	0.252761317	**252.8**
18 Nov 07	**219.0**	**0.219**	4.05	7.4	0.0074	0.11	0.000111174	0.1	1.11174E-05	0.011117433	0.248947474	**248.9**
19 Nov 07	**122.6**	**0.123**	4.05	9.8	0.0098	0.13	0.000128637	0.1	1.28637E-05	0.012863676	0.162187902	**162.2**
20 Nov 07	**135.4**	**0.135**	4.05	3.6	0.0036	0.16	0.000158083	0.1	1.58083E-05	0.015808317	0.149890976	**149.9**
21 Nov 07	**109.9**	**0.110**	4.05	1.4	0.0014	0.14	0.000140588	0.1	1.40588E-05	0.014058785	0.115480562	**115.5**

22 Nov 07	**84.9**	**0.085**	4.05	0	0	0.16	0.000160374	0.1	1.60374E-05	0.016037439	0.084865048	**84.9**
23 Nov 07	**148.8**	**0.149**	4.05	0.2	0.0002	0.13	0.000128201	0.1	1.28201E-05	0.012820136	0.149528078	**149.5**
24 Nov 07	**145.9**	**0.146**	4.05	0.8	0.0008	0.14	0.000137993	0.1	1.37993E-05	0.013799303	0.149104113	**149.1**
25 Nov 07	**117.4**	**0.117**	4.05	0	0	0.12	0.00012369	0.1	1.2369E-05	0.012369002	0.117369906	**117.4**
26 Nov 07	**177.8**	**0.178**	4.05	0	0	0.13	0.00013097	0.1	1.3097E-05	0.013097019	0.177786957	**177.8**
27 Nov 07	**165.0**	**0.165**	4.05	0	0	0.11	0.000106146	0.1	1.06146E-05	0.010614602	0.164972011	**165.0**
28 Nov 07	**99.2**	**0.099**	4.05	4.4	0.0044	0.12	0.000124868	0.1	1.24868E-05	0.012486801	0.116949428	**116.9**
29 Nov 07	**83.6**	**0.084**	4.05	1.2	0.0012	0.13	0.000132658	0.1	1.32658E-05	0.013265775	0.088453774	**88.5**
30 Nov 07	**118.6**	**0.119**	4.05	1.6	0.0016	0.15	0.000153195	0.1	1.53195E-05	0.015319481	0.124977956	**125.0**
01 Dec 07	**93.6**	**0.094**	4.05	1.4	0.0014	0.13	0.000130292	0.1	1.30292E-05	0.013029241	0.099239732	**99.2**
02 Dec 07	**179.1**	**0.179**	4.05	4.2	0.0042	0.13	0.000132195	0.1	1.32195E-05	0.013219452	0.196078961	**196.1**
03 Dec 07	**167.3**	**0.167**	4.05	0	0	0.12	0.000115368	0.1	1.15368E-05	0.011536838	0.167248276	**167.2**
04 Dec 07	**174.3**	**0.174**	4.05	3.2	0.0032	0.13	0.000127084	0.1	1.27084E-05	0.012708414	0.187186031	**187.2**
05 Dec 07	**139.9**	**0.140**	4.05	2.2	0.0022	0.12	0.000123852	0.1	1.23852E-05	0.012385215	0.14879484	**148.8**
06 Dec 07	**211.3**	**0.211**	4.05	15.2	0.0152	0.15	0.000145521	0.1	1.45521E-05	0.014552097	0.272828564	**272.8**
07 Dec 07	**164.6**	**0.165**	4.05	1.6	0.0016	0.12	0.000115014	0.1	1.15014E-05	0.011501367	0.171020919	**171.0**
08 Dec 07	**252.7**	**0.253**	4.05	23.4	0.0234	0.14	0.000135781	0.1	1.35781E-05	0.013578095	0.347367509	**347.4**
09 Dec 07	**208.9**	**0.209**	4.05	0.6	0.0006	0.11	0.000110077	0.1	1.10077E-05	0.011007699	0.211290419	**211.3**
10 Dec 07	**237.8**	**0.238**	4.05	0	0	0.11	0.000106666	0.1	1.06666E-05	0.010666571	0.2377893	**237.8**
11 Dec 07	**138.9**	**0.139**	4.05	0.2	0.0002	0.09	9.43288E-05	0.1	9.43288E-06	0.009432877	0.139709297	**139.7**
12 Dec 07	**99.2**	**0.099**	4.05	0	0	0.10	9.69374E-05	0.1	9.69374E-06	0.009693739	0.09914074	**99.1**
13 Dec 07	**136.7**	**0.137**	4.05	0	0	0.10	9.51657E-05	0.1	9.51657E-06	0.009516569	0.136618958	**136.6**
14 Dec 07	**300.1**	**0.300**	4.05	0	0	0.12	0.000122593	0.1	1.22593E-05	0.01225925	0.30005535	**300.1**
15 Dec 07				0	0	0.09	9.41591E-05	0.1	9.41591E-06	0.009415909		
16 Dec 07				0	0	0.09	9.46634E-05	0.1	9.46634E-06	0.009466344		
17 Dec 07				0	0	0.15	0.000150372	0.1	1.50372E-05	0.01503718		
18 Dec 07				0	0	0.13	0.000127787	0.1	1.27787E-05	0.012778684		
19 Dec 07				0	0	0.15	0.000152595	0.1	1.52595E-05	0.015259492		
20 Dec 07				0	0	0.14	0.000143281	0.1	1.43281E-05	0.014328129		
21 Dec 07				0.2	0.0002	0.14	0.000144369	0.1	1.44369E-05	0.014436908		
22 Dec 07				3.2	0.0032	0.15	0.000147158	0.1	1.47158E-05	0.014715766		
23 Dec 07				0.2	0.0002	0.14	0.000135562	0.1	1.35562E-05	0.013556156		
24 Dec 07				3.4	0.0034	0.14	0.000140857	0.1	1.40857E-05	0.014085696		
25 Dec 07				0.4	0.0004	0.13	0.000126459	0.1	1.26459E-05	0.012645851		
26 Dec 07				0	0	0.14	0.000139688	0.1	1.39688E-05	0.01396884		
27 Dec 07				6	0.006	0.12	0.0001157	0.1	1.157E-05	0.011569999		
28 Dec 07				7.4	0.0074	0.16	0.000161669	0.1	1.61669E-05	0.016166902		
29 Dec 07				0.8	0.0008	0.15	0.000152025	0.1	1.52025E-05	0.015202511		
30 Dec 07				0.6	0.0006	0.13	0.000128846	0.1	1.28846E-05	0.012884606		
31 Dec 07				1.4	0.0014	0.11	0.000107237	0.1	1.07237E-05	0.010723698		
01 Jan 08				2.2	0.0022	0.12	0.000118937	0.1	1.18937E-05	0.011893729		
02 Jan 08				0	0	0.11	0.00010857	0.1	1.0857E-05	0.010857045		
03 Jan 08				0	0	0.12	0.000117152	0.1	1.17152E-05	0.011715214		
04 Jan 08				9.6	0.0096	0.13	0.000126955	0.1	1.26955E-05	0.012695486		
05 Jan 08				2.4	0.0024	0.14	0.000140683	0.1	1.40683E-05	0.014068284		
06 Jan 08				10.2	0.0102	0.13	0.000127965	0.1	1.27965E-05	0.012796471		
07 Jan 08				2	0.002	0.15	0.000150202	0.1	1.50202E-05	0.015020165		
08 Jan 08				12.2	0.0122	0.17	0.000169724	0.1	1.69724E-05	0.016972382		
09 Jan 08				16.2	0.0162	0.14	0.000137142	0.1	1.37142E-05	0.013714164		
10 Jan 08				16.4	0.0164	0.15	0.000147585	0.1	1.47585E-05	0.014758476		
11 Jan 08				0	0	0.14	0.000137546	0.1	1.37546E-05	0.013754619		
12 Jan 08				12.8	0.0128	0.15	0.000145826	0.1	1.45826E-05	0.014582561		
13 Jan 08				14.6	0.0146	0.14	0.000141939	0.1	1.41939E-05	0.014193873		
14 Jan 08				3.6	0.0036	0.16	0.000155339	0.1	1.55339E-05	0.015533922		
15 Jan 08				2.8	0.0028	0.15	0.000148688	0.1	1.48688E-05	0.01486885		

16 Jan 08				0.6	0.0006	0.13	0.000134538	0.1	1.34538E-05	0.01345375		
17 Jan 08				8.8	0.0088	0.19	0.000190392	0.1	1.90392E-05	0.019039217		
18 Jan 08				11.4	0.0114	0.20	0.000195034	0.1	1.95034E-05	0.019503357		
19 Jan 08				6	0.006	0.15	0.000145922	0.1	1.45922E-05	0.014592226		
20 Jan 08				3.4	0.0034	0.15	0.000153731	0.1	1.53731E-05	0.015373083		
21 Jan 08				1.2	0.0012	0.22	0.00021663	0.1	2.1663E-05	0.02166297		
22 Jan 08				0.4	0.0004	0.17	0.000168987	0.1	1.68987E-05	0.016898651		
23 Jan 08				0.4	0.0004	0.20	0.00019818	0.1	1.9818E-05	0.019818002		
24 Jan 08				0	0	0.21	0.000205955	0.1	2.05955E-05	0.02059547		
25 Jan 08				0.2	0.0002	0.18	0.000178476	0.1	1.78476E-05	0.017847643		
26 Jan 08				0.2	0.0002	0.17	0.000174188	0.1	1.74188E-05	0.017418832		
27 Jan 08				0	0	0.26	0.000258267	0.1	2.58267E-05	0.025826708		
28 Jan 08				0	0	0.23	0.00022764	0.1	2.2764E-05	0.022764007		
29 Jan 08				0.2	0.0002	0.22	0.000221272	0.1	2.21272E-05	0.022127242		
30 Jan 08				0	0	0.18	0.000183795	0.1	1.83795E-05	0.018379548		
31 Jan 08				0	0	0.26	0.000258318	0.1	2.58318E-05	0.025831848		
01 Feb 08				0	0	0.17	0.000171367	0.1	1.71367E-05	0.01713674		
02 Feb 08				8	0.008	0.18	0.000177681	0.1	1.77681E-05	0.017768051		
03 Feb 08				5.4	0.0054	0.23	0.000234943	0.1	2.34943E-05	0.02349434		
04 Feb 08				3.6	0.0036	0.26	0.000260007	0.1	2.60007E-05	0.026000677		
05 Feb 08				6.6	0.0066	0.27	0.000268328	0.1	2.68328E-05	0.026832761		
06 Feb 08				0.8	0.0008	0.28	0.000276577	0.1	2.76577E-05	0.027657719		
07 Feb 08				3.2	0.0032	0.25	0.00025388	0.1	2.5388E-05	0.02538804		
08 Feb 08				1.2	0.0012	0.21	0.000213823	0.1	2.13823E-05	0.021382342		
09 Feb 08				0.2	0.0002	0.29	0.000285722	0.1	2.85722E-05	0.028572164		
10 Feb 08				0	0	0.27	0.000265441	0.1	2.65441E-05	0.026544138		
11 Feb 08				0.2	0.0002	0.35	0.000354776	0.1	3.54776E-05	0.035477586		
12 Feb 08				0.2	0.0002	0.44	0.000440841	0.1	4.40841E-05	0.044084079		
13 Feb 08				0	0	0.34	0.00033926	0.1	3.3926E-05	0.033926011		
14 Feb 08				0	0	0.24	0.000236613	0.1	2.36613E-05	0.023661318		
15 Feb 08				0	0	0.25	0.000252856	0.1	2.52856E-05	0.02528564		
16 Feb 08				0.4	0.0004	0.32	0.000319364	0.1	3.19364E-05	0.031936427		
17 Feb 08				0.6	0.0006	0.26	0.000261499	0.1	2.61499E-05	0.026149862		
18 Feb 08				0.2	0.0002	0.33	0.000326523	0.1	3.26523E-05	0.03265229		
19 Feb 08				0.4	0.0004	0.28	0.000282726	0.1	2.82726E-05	0.028272553		
20 Feb 08				0	0	0.28	0.000279102	0.1	2.79102E-05	0.027910181		
21 Feb 08				0	0	0.31	0.000311356	0.1	3.11356E-05	0.031135649		
22 Feb 08				0	0	0.35	0.000354349	0.1	3.54349E-05	0.035434933		
23 Feb 08				0	0	0.34	0.00034076	0.1	3.4076E-05	0.034076003		
24 Feb 08				0.6	0.0006	0.41	0.000409659	0.1	4.09659E-05	0.040965897		
25 Feb 08				0.4	0.0004	0.33	0.000326544	0.1	3.26544E-05	0.03265436		
26 Feb 08				0.4	0.0004	0.42	0.000424167	0.1	4.24167E-05	0.042416728		
27 Feb 08				0	0	0.41	0.000410184	0.1	4.10184E-05	0.041018353		
28 Feb 08				0	0	0.37	0.000373496	0.1	3.73496E-05	0.037349556		
29 Feb 08				0	0	0.39	0.000391885	0.1	3.91885E-05	0.039188454		
01 Mar 08				0.4	0.0004	0.40	0.000404918	0.3	0.000121475	0.121475267		
02 Mar 08				0.6	0.0006	0.43	0.000431075	0.3	0.000129323	0.129322641		
03 Mar 08				1	0.001	0.33	0.000330908	0.3	9.92725E-05	0.099272493		
04 Mar 08				0	0	0.48	0.000479809	0.3	0.000143943	0.143942646		
05 Mar 08				0	0	0.31	0.000313866	0.3	9.41597E-05	0.094159653		
06 Mar 08				1.6	0.0016	0.42	0.000423175	0.3	0.000126952	0.126952411		
07 Mar 08				1	0.001	0.43	0.000431763	0.3	0.000129529	0.129528786		
08 Mar 08				0.8	0.0008	0.47	0.000465705	0.3	0.000139712	0.139711649		
09 Mar 08				3.2	0.0032	0.51	0.000514747	0.3	0.000154424	0.154424036		

10 Mar 08				17.6	0.0176	0.47	0.00047312	0.3	0.000141936	0.141936044		
11 Mar 08				1.2	0.0012	0.57	0.000571034	0.3	0.00017131	0.171310229		
12 Mar 08	**30.1**	**0.030**	4.05	1.2	0.0012	0.51	0.000507904	0.3	0.000152371	0.15237108	0.034350589	**34.4**
13 Mar 08	**99.4**	**0.099**	4.05	0	0	0.49	0.000488384	0.3	0.000146515	0.146515223	0.098791229	**98.8**
14 Mar 08	**98.5**	**0.099**	4.05	0.4	0.0004	0.39	0.000392736	0.3	0.000117821	0.117820941	0.099650517	**99.7**
15 Mar 08	**93.2**	**0.093**	4.05	7.6	0.0076	0.35	0.000346744	0.3	0.000104023	0.104023341	0.123604859	**123.6**
16 Mar 08	**75.4**	**0.075**	4.05	6.8	0.0068	0.42	0.00041771	0.3	0.000125313	0.125312992	0.102447867	**102.4**
17 Mar 08	**33.3**	**0.033**	4.05	0	0	0.51	0.000505486	0.3	0.000151646	0.151645767	0.032708912	**32.7**
18 Mar 08	**35.7**	**0.036**	4.05	0	0	0.49	0.000488296	0.3	0.000146489	0.146488872	0.035068259	**35.1**
19 Mar 08	**15.5**	**0.015**	4.05	0	0	0.54	0.00054336	0.3	0.000163008	0.163008012	0.014832125	**14.8**
20 Mar 08	**10.8**	**0.011**	4.05	0.2	0.0002	0.41	0.000405901	0.3	0.00012177	0.121770175	0.011132215	**11.1**
21 Mar 08	**18.4**	**0.018**	4.05	0.8	0.0008	0.60	0.000596627	0.3	0.000178988	0.178988048	0.020930483	**20.9**
22 Mar 08	**8.6**	**0.009**	4.05	0	0	0.48	0.000479859	0.3	0.000143958	0.143957791	0.007966971	**8.0**
23 Mar 08	**43.6**	**0.044**	4.05	1	0.001	0.47	0.000469772	0.3	0.000140932	0.140931528	0.047033073	**47.0**
24 Mar 08	**92.7**	**0.093**	4.05	0	0	0.50	0.000501998	0.3	0.000150599	0.150599253	0.092051611	**92.1**
25 Mar 08	**79.5**	**0.080**	4.05	0.6	0.0006	0.58	0.000580553	0.3	0.000174166	0.174165827	0.081232321	**81.2**
26 Mar 08	**63.1**	**0.063**	4.05	0.6	0.0006	0.66	0.000662441	0.3	0.000198732	0.198732307	0.064763596	**64.8**
27 Mar 08	**92.4**	**0.092**	4.05	1.8	0.0018	0.62	0.00061815	0.3	0.000185445	0.185444999	0.098908179	**98.9**
28 Mar 08	**65.2**	**0.065**	4.05	13	0.013	0.68	0.00068421	0.3	0.000205263	0.205263029	0.1170033	**117.0**
29 Mar 08	**99.1**	**0.099**	4.05	6.2	0.0062	0.66	0.000655874	0.3	0.000196762	0.196762306	0.12340542	**123.4**
30 Mar 08	**136.8**	**0.137**	4.05	1	0.001	0.62	0.000620069	0.3	0.000186021	0.186020711	0.140096616	**140.1**
31 Mar 08	**112.2**	**0.112**	4.05	9.6	0.0096	0.60	0.00060304	0.3	0.000180912	0.180911983	0.15039346	**150.4**
01 Apr 08	**81.8**	**0.082**	4.05	1.2	0.0012	0.72	0.000721996	0.3	0.000216599	0.216598722	0.085755852	**85.8**
02 Apr 08	**75.9**	**0.076**	4.05	0.2	0.0002	0.64	0.000637927	0.3	0.000191378	0.191378215	0.075888764	**75.9**
03 Apr 08	**74.8**	**0.075**	4.05	0	0	0.71	0.000705322	0.3	0.000211597	0.211596709	0.073900726	**73.9**
04 Apr 08	**51.3**	**0.051**	4.05	0	0	0.73	0.000732053	0.3	0.000219616	0.219615978	0.050410555	**50.4**
05 Apr 08	**81.3**	**0.081**	4.05	0.4	0.0004	0.68	0.000678497	0.3	0.000203549	0.203549197	0.082130241	**82.1**
06 Apr 08	**125.8**	**0.126**	4.05	0.6	0.0006	0.72	0.000723041	0.3	0.000216912	0.21691238	0.127389966	**127.4**
07 Apr 08	**58.8**	**0.059**	4.05	2.6	0.0026	0.72	0.000720917	0.3	0.000216275	0.21627515	0.068407932	**68.4**
08 Apr 08	**83.5**	**0.084**	4.05	0	0	0.58	0.000583376	0.3	0.000175013	0.175012814	0.082818121	**82.8**
09 Apr 08	**57.2**	**0.057**	4.05	0	0	0.69	0.000690337	0.3	0.000207101	0.207101024	0.056380472	**56.4**
10 Apr 08	**69.9**	**0.070**	4.05	5	0.005	0.78	0.000775094	0.3	0.000232528	0.232528226	0.089242876	**89.2**
11 Apr 08	**49.7**	**0.050**	4.05	4	0.004	0.73	0.000726973	0.3	0.000218092	0.218091992	0.065049227	**65.0**
12 Apr 08	**11.8**	**0.012**	4.05	1.4	0.0014	0.62	0.000622941	0.3	0.000186882	0.186882175	0.016751589	**16.8**
13 Apr 08	**28.5**	**0.029**	4.05	2	0.002	0.80	0.000803262	0.3	0.000240979	0.240978559	0.035624037	**35.6**
14 Apr 08	**108.1**	**0.108**	4.05	0.2	0.0002	0.78	0.000784531	0.3	0.000235359	0.235359409	0.107937564	**107.9**
15 Apr 08	**109.0**	**0.109**	4.05	0	0	0.82	0.000818797	0.3	0.000245639	0.245639135	0.107962854	**108.0**
16 Apr 08	**61.8**	**0.062**	4.05	0	0	0.71	0.000709173	0.3	0.000212752	0.212751875	0.060961432	**61.0**
17 Apr 08	**45.6**	**0.046**	4.05	0	0	0.58	0.000576665	0.3	0.000172999	0.172999495	0.044899352	**44.9**
18 Apr 08	**51.7**	**0.052**	4.05	0	0	0.52	0.000516685	0.3	0.000155005	0.155005435	0.051099728	**51.1**
19 Apr 08	**69.3**	**0.069**	4.05	2.6	0.0026	0.46	0.000464527	0.3	0.000139358	0.139358202	0.079242522	**79.2**
20 Apr 08	**75.2**	**0.075**	4.05	0	0	0.35	0.000348861	0.3	0.000104658	0.104658229	0.074772288	**74.8**
21 Apr 08	**53.9**	**0.054**	4.05	0	0	0.60	0.000596874	0.3	0.000179062	0.179062306	0.053205567	**53.2**
22 Apr 08	**51.5**	**0.052**	4.05	4.2	0.0042	0.85	0.000847395	0.3	0.000254218	0.254218387	0.067499646	**67.5**
23 Apr 08	**47.1**	**0.047**	4.05	0.4	0.0004	0.85	0.000849517	0.3	0.000254855	0.254854981	0.047722453	**47.7**
24 Apr 08	**40.3**	**0.040**	4.05	7.6	0.0076	1.03	0.001032853	0.3	0.000309856	0.30985601	0.069863545	**69.9**
25 Apr 08	**31.8**	**0.032**	4.05	2.8	0.0028	0.67	0.000669027	0.3	0.000200708	0.200708194	0.042315593	**42.3**
26 Apr 08	**36.4**	**0.036**	4.05	6	0.006	0.79	0.00078873	0.3	0.000236619	0.23661908	0.059734	**59.7**
27 Apr 08	**112.5**	**0.112**	4.05	2.2	0.0022	0.96	0.000962031	0.3	0.000288609	0.288609193	0.120206517	**120.2**
28 Apr 08	**87.0**	**0.087**	4.05	1.2	0.0012	0.80	0.000803132	0.3	0.000240939	0.240939478	0.09091881	**90.9**
29 Apr 08	**73.0**	**0.073**	4.05	0	0	0.82	0.000823729	0.3	0.000247119	0.247118629	0.072003016	**72.0**
30 Apr 08	**54.2**	**0.054**	4.05	0	0	0.75	0.000746285	0.3	0.000223886	0.223885514	0.053243264	**53.2**
01 May 08	**74.8**	**0.075**	4.05	0.6	0.0006	0.89	0.000886761	0.5	0.000443381	0.443380636	0.075392001	**75.4**
02 May 08	**57.4**	**0.057**	4.05	0.4	0.0004	0.96	0.000962752	0.5	0.000481376	0.481376204	0.057108888	**57.1**
03 May 08	**22.8**	**0.023**	4.05	0.4	0.0004	0.82	0.000820647	0.5	0.000410324	0.410323597	0.022758189	**22.8**
04 May 08	**19.7**	**0.020**	4.05	2.4	0.0024	1.05	0.001045709	0.5	0.000522855	0.522854718	0.027333208	**27.3**
05 May 08	**27.0**	**0.027**	4.05	0	0	1.09	0.00109162	0.5	0.00054581	0.54581022	0.024754853	**24.8**

06 May 08	**25.9**	**0.026**	4.05	0	0	1.06	0.001064701	0.5	0.000532351	0.532350525	0.023713211	**23.7**
07 May 08	**61.8**	**0.062**	4.05	0	0	1.21	0.001209634	0.5	0.000604817	0.604817162	0.059373567	**59.4**
08 May 08	**64.0**	**0.064**	4.05	0	0	1.09	0.001094856	0.5	0.000547428	0.547428248	0.0617983	**61.8**
09 May 08	**85.1**	**0.085**	4.05	0.8	0.0008	0.69	0.000687561	0.5	0.00034378	0.343780417	0.086920189	**86.9**
10 May 08	**64.3**	**0.064**	4.05	6	0.006	0.66	0.000655655	0.5	0.000327827	0.327827358	0.087239799	**87.2**
11 May 08	**99.6**	**0.100**	4.05	0	0	1.03	0.00103334	0.5	0.00051667	0.516670137	0.097514986	**97.5**
12 May 08	**63.1**	**0.063**	4.05	0	0	0.97	0.000973792	0.5	0.000486896	0.486896228	0.06115557	**61.2**
13 May 08	**83.9**	**0.084**	4.05	0	0	0.86	0.000856866	0.5	0.000428433	0.428433136	0.082197346	**82.2**
14 May 08	**79.4**	**0.079**	4.05	0	0	0.86	0.000864147	0.5	0.000432073	0.432073417	0.077622603	**77.6**
15 May 08	**91.5**	**0.091**	4.05	0	0	0.89	0.000885552	0.5	0.000442776	0.442776051	0.089691757	**89.7**
16 May 08	**79.4**	**0.079**	4.05	0	0	0.95	0.000952001	0.5	0.000476	0.476000342	0.077444699	**77.4**
17 May 08	**51.3**	**0.051**	4.05	0	0	0.80	0.000803936	0.5	0.000401968	0.401968054	0.049672029	**49.7**
18 May 08	**110.0**	**0.110**	4.05	1.2	0.0012	0.79	0.000789455	0.5	0.000394728	0.394727679	0.113271353	**113.3**
19 May 08	**107.9**	**0.108**	4.05	0	0	0.94	0.000937278	0.5	0.000468639	0.468638904	0.105974512	**106.0**
20 May 08	**98.6**	**0.099**	4.05	0	0	0.81	0.000809743	0.5	0.000404871	0.404871364	0.096970271	**97.0**
21 May 08	**85.2**	**0.085**	4.05	0.2	0.0002	0.79	0.00078822	0.5	0.00039411	0.394110217	0.084428854	**84.4**
22 May 08	**114.3**	**0.114**	4.05	9.4	0.0094	0.59	0.000585081	0.5	0.00029254	0.292540378	0.151170211	**151.2**
23 May 08	**62.4**	**0.062**	4.05	0.6	0.0006	0.89	0.000892561	0.5	0.00044628	0.446280286	0.063037565	**63.0**
24 May 08	**97.0**	**0.097**	4.05	0.2	0.0002	0.84	0.000840313	0.5	0.000420156	0.420156284	0.096150867	**96.2**
25 May 08	**103.0**	**0.103**	4.05	6	0.006	0.90	0.000904058	0.5	0.000452029	0.45202899	0.125496783	**125.5**
26 May 08	**89.1**	**0.089**	4.05	5	0.005	0.84	0.000841067	0.5	0.000420533	0.420533291	0.10760934	**107.6**
27 May 08	**97.8**	**0.098**	4.05	5.8	0.0058	0.55	0.000554571	0.5	0.000277285	0.277285386	0.120121994	**120.1**
28 May 08	**98.8**	**0.099**	4.05	0	0	0.62	0.000621853	0.5	0.000310927	0.310926655	0.097493247	**97.5**
29 May 08	**48.9**	**0.049**	4.05	0	0	1.15	0.001147589	0.5	0.000573795	0.573794553	0.046553632	**46.6**
30 May 08	**54.9**	**0.055**	4.05	0.4	0.0004	0.98	0.000984077	0.5	0.000492038	0.492038423	0.054489744	**54.5**
31 May 08				0	0	1.28	0.001280563	0.5	0.000640281	0.640281437		
01 Jun 08				0	0	1.14	0.001140087	0.7	0.000798061	0.798061174		
02 Jun 08				0	0	1.10	0.001104756	0.7	0.000773329	0.773329077		
03 Jun 08				0	0	1.12	0.001122114	0.7	0.00078548	0.785479737		
04 Jun 08				10.4	0.0104	0.82	0.000815075	0.7	0.000570553	0.570552639		
05 Jun 08				2	0.002	0.86	0.00086259	0.7	0.000603813	0.603812924		
06 Jun 08				0.4	0.0004	1.10	0.001104232	0.7	0.000772963	0.772962665		
07 Jun 08				0	0	1.24	0.001243794	0.7	0.000870656	0.870655652		
08 Jun 08				0	0	0.97	0.000974343	0.7	0.00068204	0.682040086		
09 Jun 08				0	0	0.98	0.000983719	0.7	0.000688603	0.688603183		
10 Jun 08				0	0	1.03	0.001025592	0.7	0.000717915	0.717914745		
11 Jun 08				4.8	0.0048	0.72	0.000717535	0.7	0.000502274	0.502274397		
12 Jun 08				0.2	0.0002	0.94	0.000937478	0.7	0.000656234	0.656234276		
13 Jun 08					0	1.151514404	0.001151514	0.7	0.00080606	0.806060083		
14 Jun 08					0	1.216805756	0.001216806	0.7	0.000851764	0.851764029		
15 Jun 08	**152.0**	**0.152**	4.05		0	1.70950158	0.001709502	0.7	0.001196651	1.196651106	0.147201063	**147.2**
16 Jun 08	**99.2**	**0.099**	4.05		0	1.198147646	0.001198148	0.7	0.000838703	0.838703352	0.095783251	**95.8**
17 Jun 08	**119.7**	**0.120**	4.05		0	2.479389265	0.002479389	0.7	0.001735572	1.735572486	0.112670931	**112.7**
18 Jun 08	**151.9**	**0.152**	4.05		0	2.336844892	0.002336845	0.7	0.001635791	1.635791424	0.145280045	**145.3**
19 Jun 08	**226.1**	**0.226**	4.05		0	2.780709545	0.00278071	0.7	0.001946497	1.946496682	0.218264188	**218.3**
20 Jun 08	**81.5**	**0.082**	4.05		0	2.787716505	0.002787717	0.7	0.001951402	1.951401554	0.073606824	**73.6**
21 Jun 08	**466.1**	**0.466**	4.05		0	2.875611427	0.002875611	0.7	0.002012928	2.012927999	0.457965142	**458.0**
22 Jun 08	**272.5**	**0.272**	4.05		0	3.227792877	0.003227793	0.7	0.002259455	2.259455014	0.263309207	**263.3**
23 Jun 08	**128.8**	**0.129**	4.05		0	0.546188484	0.000546188	0.7	0.000382332	0.382331939	0.127271556	**127.3**