Dissertation

Title How management practices carried out by Deane Golf Club may have an adverse effect upon water quality, specifically on the concentration levels of nitrate within an adjacent watercourse.

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How management practices carried out by Deane Golf Club may have an adverse effect upon water quality, specifically on the concentration levels of nitrate within an adjacent watercourse.

Logan Brigg, 2013

Bachelor of Science with Honours in Environmental Hazards.

I declare that the main text of this dissertation is no more than 10,000 words, and is all my own work.

Signed: ....

Contents

Appendix

Introduction

Water resources cover 70% of the world's surface area and provide habitable environments for all its flora and fauna (USGS, 2013). Additionally human life cannot survive without its water resources. It is imperative that we look to protect and improve the quality of water upon which we have an impact.

There have been numerous studies undertaken to investigate the effects of nitrate concentrations found within watercourses adjacent to agricultural land, particularly where slurry is intensively used (Zebarth et al, 1988,) or fertilisers regularly applied (Balogh & Anderson, 1992). In contrast, very few studies have examined nitrate effects upon other land uses in differing environs; in particular golf courses, and how management practices carried out, may possibly have an adverse effect upon water quality (Starr & DeRoo, 1981). Golf courses regularly receive "point source" pollution in the form of inorganic fertilisers in order to promote rapid growth.

Nitrate is a necessity for plant development; however it is highly soluble and easily lost to water through run-off and leaching, posing issues to water quality within river systems (Addiscott, 1996). Therefore as a result, The Environment Agency now considers nitrate as a potential water pollutant (Gaines, 1994). Between 1950-1985, the demand for protein and grain amplified as a result of the rapidly growing world population, leading to alternate management practices of agricultural land such as regular inorganic fertiliser treatment, as a consequence of rapid nitrate release after application. Within this thirty five year period, various research studies revealed a dramatic increase in the global use of fertilisers along with increased levels of nitrate in water supplies, especially in cultivated areas (Saull, 1990). Due to the similar trend between fertiliser treatment and nitrate concentrations, Academics often draw conclusion that the two correlate strongly and the vast majority of nitrate volume found to be present within river systems derives from fertiliser, as a consequence of their nitrogen base (Addiscott, 1996). However other atmospheric, environmental and geological sources provide nutrients and are repeatedly recycled through the soil, indicating fertilisers are not the only source of leached nitrate, combined with additional variables such as nitrate concentrations within differing fertilisers (Puri, 2002).

Although recent studies reveal an improvement of chemical and biological quality for rivers, a large percentage still exceed threshold levels established by the EU Directive of 50mg NO3/l (ADAS, 2007) .

This raises concerns with respect to the impact of nitrate and its potential links with serious health problems, encouraging more research into sources of contamination as well as looking at appropriate measures to minimise pollution of potable and recreational waters (Addiscott, 1996).

Chapter One: Hypothesis, Aims and Objectives

1.1. Hypothesis: The management practices carried out by Deane Golf Club will have an adverse effect upon the adjacent Water Course identified as the River Croal, specifically on the concentration levels of nitrate.

1.2. This Study intends to make use of previous findings related to the consequences of golf course management with respect to nitrate compound in adjacent/nearby water systems, in addition to physical and environmental factors influencing the rate and extent of the transfer of nitrate into the reference water body in order to establish whether or not Deane Golf Club has an adverse effect upon water quality, specifically in relation to measured concentration levels of nitrate.

The aims and objectives of this study are as follows:

- Collect toxicological data of the fertilisers' applied, volume of fertiliser spread, the time period in which the fertiliser is applied and the climatic conditions including various pertinent environmental factors such as precipitation levels and temperature in order to understand the role of climatic controls and fertiliser treatment on the transfer of nitrate in water systems.
- At pre-determined reference locations along a targeted length of the River Croal at staged intervals (pre, during and post fertiliser application) adjacent to Deane Golf Course, retrieve water samples, to undergo laboratory analysis to ultimately establish by comparison, their acceptability or otherwise to empirical threshold levels established by EU directives, and to reference sample results taken up and downstream of the stretch of Golf Course.
- Establish controlling mechanisms and their influence on the rate of transfer to the receptor.

Chapter Two: Literature Review

“Nitrate is not a new problem. Excessive concentrations were recorded in many domestic wells in a survey conducted 100 years ago. What is new is the public concern about nitrate” (quoted by Thomas M. Addiscott 1996)

Nitrogen represents approximately 78.09% of the atmosphere and is a necessary element for the continuity of life on Earth (Saha, 2008). However plants are unable to utilise nitrogen in its elemental form and therefore must made available in a reactive fixed form. This occurs by nitrogen bonding to hydrogen to form ammonium ions (NH4) and combining with oxygen to from nitrate ions (NO3) where they are then absorbed by plant roots; with the latter being the dominant form (Leatherwood, 2009). Nitrogen plays a vital role in maintaining a healthy, vigorous growth and is often applied to agricultural land in the form of fertilisers. Between 1950-1985, the demand for protein and grain amplified as a result of the rapidly growing world population, leading to the industrialisation of agricultural systems and alternate management practices such as regular inorganic fertiliser treatment, as a consequence of rapid nitrate release after application (Haygarth, 1997). The purpose of fertiliser application intends to rectify nutrient deficiencies and imbalances in flora and fauna therefore enhancing growth and product quality by (Mellor, 1995). It is estimated by Saull (1990) that within this 35 year period, the global use of inorganic fertilisers soared from 14 million tonnes to 125 million tonnes, an increase of almost 900%. However the greater the volume of fertiliser applied means the greater the risk of loss as plants receive more nitrate than they can efficiently uptake and is easily lost to water through run off and leaching as it highly soluble, potentially polluting river systems. As a result, The Environment Agency now considers nitrate as a potential water pollutant (Gaines, 1994). Polluted waters are defined as ‘surface freshwaters and ground waters with nitrate concentrations of greater than 50 mg/l’ (House of Commons, 2008). Direct field measurements confirm that high nitrate concentrations in waters originate from agricultural land. For example in England; Losses from agricultural land are estimated to account for 59% of the nitrate which enters surface waters (Hunt *et al.*, 2004). Due to the similar trend between fertiliser treatment and nitrate concentrations, Academics often draw conclusion that the two correlate strongly and the vast majority of nitrate volume found to be present within river systems derives from fertiliser as a consequence of their nitrogen base (Addiscott, 1996) . In 2000, it was estimated by Bio

Science Review that nitrogen fertiliser applied to agricultural land accounts for 100Tg of reactive nitrogen, annually (Fields, 2004).

The aforementioned facts and figures reinforce the statement made by John Aber, Vice President for Research and Public Service at the University of New Hampshire that ‘the nitrogen cycle has been altered more than any other basic element cycle’ as we as humans insert the majority of the continuous rise of compounds into the ecosystem, Possibly causing an adverse effect upon a number of factors such as biodiversity, water quality and human health (Fields, 2004).

Serious health problems such as methamoglobinaemia (blue-baby syndrome) and stomach cancer have been associated with the rise of nitrate concentrations in potable supplies. Methamoglobinaemia occurs when large quantities of nitrate are digested, converting into nitrite by microbes in the stomach. The nitrites then react with haemoglobin as it enters the blood stream to create methemoglobin (Heathwaite et al, 1993, p8). This enzyme greatly lessens the blood's ability to carry oxygen to the cells of the body causing what might be described as ‘chemical suffocation’ (Gustafson, 1993; Finley, 1990). . This is very common in infants under 6 months as they have a higher intestinal pH, promoting the conversion of nitrate to nitrite as well as containing foetal haemoglobin which more readily oxidizes nitrite to methemoglobin (Human Health, 2004).

Links associating nitrogen contaminated water supplies with regards to stomach cancer were suggested to have derived from N-nitroso compounds, which are carcinogenic with potential to initiate stomach cancer as stated by Preussman and Stewart (1984, p.406). N-nitroso is produced from the reaction of nitrite in the stomach with a secondary amine coming from the breakdown of meat or other protein. However, a study conducted at the Radcliffe Infirmary in Oxford located four study sites within the UK with two having a large percentage of stomach cancer rates in contrast to the two remaining areas with a low percentage. The hypothesis of the study is ‘that samples from the high-risk areas should contain more than those from the low-risk areas’. The study infact reveals, an adverse effect upon which the hypothesis is suggested, as concentration of nitrate in high risk populations were half that of the low risk populations; therefore significantly dismissing the link associated with stomach cancer and the rise of nitrate concentrations in potable supplies. It is evident from studies associated with

serious health problems that nitrate is not the root cause of conditions such as ‘blue baby syndrome’ but by nitrite, as it is converted in the stomach (Addiscott, 1996).
Not only does the increase of nitrate concentrations in water systems have a detrimental effect upon human health but can also be witnessed within the water systems themselves in the form of eutrophication. This occurs naturally from processes such as run-off from agricultural fields that receive point source pollution in the form of fertilisers, resulting in waterways being enriched in nitrogen and phosphorus, encouraging the growth of aquatic plants in excess causing numerous problems (Khan & Ansari, 2005). Examples of this are; narrowing waterways, anglers getting snagged and the propellers of boats getting caught (Addiscott, 1996). The excessive growth of algae due to nutrient enriched waters causes algae blooms. Not only is this an eye soar but one of the main hazards associated with excess blooms of algae is the subsequent decomposition on the river bed. The bacteria by which decomposes algae uses large amounts of oxygen resulting in anoxic conditions, possibly having an detrimental effect upon the ecological balance of the water system as fish and other organisms are starved of oxygen .This is known as the ‘dead zone’(Grant & Jickells, 1995, p.277).

Due to the multiple threats facing public health and the environment with regards to the level of nitrate present in water systems, as previously discussed, waters’ used for potable supply must have a nitrate concentration of less than 50 mg/l as stated by Drinking Water Directives to ensure human health is protected . In 1991 the nitrates directive was put into place with the main focus on ‘reducing water pollution caused or induced by nitrates from agricultural sources and preventing further such pollution’ (House of Commons, 2008). As a result, water draining from land adjacent to polluted waters are designated as Nitrate Vulnerable Zones (NVZ’s) as they may possibly aggravate matters. This is approximately 70% of land in England. Within NVZ’s, Statutory Management Requirements (SMR) are regulated, in particular SMR 4 states farmers must adopt management practices to minimize nitrate pollution. These are as follows: closed periods of organic and inorganic fertiliser application, spreading locations, spreading techniques, manure storage capacity and crop requirement (Defra, 2007). Studies undertaken by the Environment Agency between 1990-2005 reveal that a high number of rivers located in NVZ’s with a large catchment area have in fact declined in nitrate concentrations by up to 20% which is showed in the sampling data retrieved from River Trent. It is reported by the Environment Agency that 17% out of 7,300 river monitoring points surpass the threshold level of 50mg/l, in contrast with 83% that do not. However the Environment Agency states “ nitrate pollution has not changed significantly since the Directive came into force and that in some areas, particularly in the south and east of England, nitrate levels in groundwater have increased and are still rising” (House of Commons, 2008). In contrast, recent studies of Nitrate concentrations in surface waters between 1999 to 2005 reveal 28% of rivers exceeded nitrate threshold levels in 2005, compared with 32% in 2000 and 30% in 1999. This possibly indicates that Nitrate concentrations are decreasing within various regions or that the upward trend of recent decades is waning. Between 1990 and 2004 the percentage of rivers of ‘good’ biological quality in England decreased to 10% whereas rivers of ‘good’ chemical quality improved decreased to 19%. Despite the improvement of chemical and biological quality of rivers, a large percentage of rivers still exceed threshold levels established by EU directives of 50mg NO3/l (Enironment Angency, 2007). In light of the threshold levels established by EU directives of 50mg NO3/l The National Pig Association argues “there is no scientific justification from an environmental or human/animal health perspective for the level to be set at 50 mg/l” (House of Commons, 2008). In contrast, the recommended limit set by the Environmental Protection Agency for Waters used for potable supply in the United States is set at the maximum of 10 mg/l as a result of a 20 mg/l of nitrate being the lowest recorded concentration to result in health problems (Petrovic, 1990).

Although there are many problems associated with the use of nitrogen fertilisers, it does however reap a number of benefits. For example, within the March 2002 issue of the Swedish journal Ambio, Smil states “for at least a third of humanity in the world’s most populous countries the use of nitrogen fertilizers makes the difference between malnutrition and adequate diet” (Fields, 2004).

In order to prevent such nitrate losses, it must be ensured that very little nitrate is present in the soil at all times. However as some plants can efficiently uptake as much as 5 kg/ha of nitrate a day, it is vital that the soil contains a substantial supply of nitrate in order to promote growth. In contrast as the growth of the plant comes to a halt so does the uptake of nitrate. From this it is apparent that in fact, the main problem associated with such nitrate losses is untimely nitrate (nitrate present at the wrong time). This often occurs when the farmer applies nitrogen fertilisers to the soil when the plant is unable to utilise the nitrate present. However the timing of environmental factors such as rainfall events in relation to fertiliser applications during a period of growth will likely result in untimely nitrate as it is washed away before the crops have chance to utilise the released nitrogen (Addiscott, 1996) .

A study by Gaines (1994) was conducted with the purpose to determine the effect of soil texture on nitrate-nitrogen ($N0_3$-N) retention by comparing the $N0_3$-N retention of soils with varied sand, silt, clay, and organic matter. From this an understanding will be developed of which form of soil texture contributes the most and least NO_3N contamination through run off and leaching.

The study reveals 'during the seven days the samples were soaked in the 240ppm $N0_3$-N solution that sand (coarsest texture) absorbed the least amount of $N0_3$-N at 119 ppm followed by the Greensmix at 125 ppm, loamy sand at 149 ppm and sandy clay loam (finest texture) absorbed the most of $N0_3$-N at 176 ppm'. The study reveals soils such as clay and silt with a fine texture, absorb larger concentrations of N in contrast to coarse soils such as sand.
The results of soil texture affecting water permeability reveal that 'sand released more $N0_3$-N in the first 100 ml of soil percolates at 88%, 82% for the Greensmix, 71% for the loamy sand, and 62% for the sandy clay loam'. This indicates that the rate of percolation will be much faster in coarse soils such as sand when compared to finer soils.

It is evident from the results above that sand, since its $N0_3$-N retention level was low, would be the worst soil type for $N0_3$-N fertilizer application as it will leach from soil into the groundwater at a fast rate due to its poor structural development and relatively large pore size. As a consequence N is a significant groundwater pollutant when applied to sandy soils. In Contrast, leached nitrate from clay soils tend to contaminate surface waters as opposed to grouwndwaters due to their good structural development and reasonably small pore spaces. However, anaerobic conditions resulting from water logged conditions, often found in clay soils are likely to experience a considerable loss of nitrate through dentrification (Saull, 1990).

Nitrate levels fluctuate on a daily basis as a result of variations in the weather. As an outcome, various sites located within regions where the average concentrations of nitrate are lowest fail to meet the standards set by the EU directives. Higher concentrations tend to be present in dry areas when compared to wet areas. This is mainly due to the effect of dilution. As a consequence, Nitrate Vulnerable Zones tend to be located in drier and more arable regions (Roberts, 1987). Another factor in determining the quantity of N lost is land use. A study conducted by Lord *et al (2006)* reveal Nitrate concentrations on average were lower in areas under grass systems when compared to arable systems. The reason behind such a finding is that grassland is more prevalent in wetter areas therefore more water passes through the soil. As a result, this reduces the soil of Nitrate and dilutes concentrations even though the quantity of Nitrate leached is much higher.

As nitrogen fertilisers are applied to steep slopes, gravity becomes a dominant force and as precipitation occurs nitrates are lost. Due to the slope there is very little time for the water to be evaporated from the surface or infiltrate into the soil, hence an increase in runoff and soil erosion, resulting in a large volume of nitrates reaching river system. Whereas on a gentle gradient the gravitational force has less of an impact, enabling nitrates to infiltrate the soil with the potential of being absorbed by plants. If the amount required to sustain maximum nutrient uptake by plants is exceeded, then unused nitrate is transferred to groundwater, slowing down the rate at which nitrate enters water systems (Ahmad, 1995)

The amount of nitrate travelling to a watercourse via overland flow and how much will infiltrate the soil is determined upon the relationship of rain fall intensity and infiltration capacity along with various other influences such as root density, toxicology of the fertilisers' applied, the volume of fertiliser spread and the time period in which the fertiliser is applied etc (Robinson 1956).

Harvest provides a reference point by which notable comparison of arable land may be derived during and post cultivation. Post cultivation renders any nitrate within soils, by definition, 'untimely nitrate'. A further reference medium is the equilibrium between rainfall and evaporation. During the summer months, the soil will dry via a process or transpiration and evaporation via the hydrological cycle. Conversely during the Autumn period, precipitation increases, overtaking the rate of evaporation increasing volumes of groundwater hence downward movement in turn, becoming a medium for nitrate movement. This would be an optimum period in which the study of nitrate losses could be quantified.

As the summer months pass the soil remains fairly warm in early autumn and as levels of precipitation increase, the soil becomes moist. As a consequence this provides optimum conditions for bacteria and small animals that occupy the soil, to produce nitrate and ammonium. However this is untimely nitrate, as precipitation is more frequent and the soil is bare, hence the increase of percolation of rain water through the soil for a period of up to four to six months, becoming a medium for nitrate movement as previously mentioned. The naturally occurring nitrate in the soil in autumn tends to account for a much larger quantity of the nitrate problem than the fertilisers applied in spring. A study conducted at the Brimstone Farm reveals that the transfer of nitrate-nitrogen at post harvest was approximately five times larger in comparison to the period of fertiliser treatment and harvest. This strongly opposes the conclusions made by many academics that the 'vast majority of nitrate volume found to be present within river systems derives from fertiliser'(Goss et al. 1993).

Golf courses are categorised as turf grass systems that are intensively managed with the potential to pollute the environment. The application of fertilisers tends to be confined to tees and greens, to which the vast majority of sandy soils are located on most golf courses. Therefore tees and greens are categorised as having the highest potential of nitrate leaching on golf courses. As a consequence this raises great concern with regards to nitrate in groundwater. In perspective, a typical 18 hole golf course ranging from 60 to 100 acres, only 2- 4 acres account for tees and greens. On a larger scale, a State such as New York with a total of 3081 million acres, consisting of roughly 1,000 golf courses; only 2,000 acres account for tees and greens in contrast to croplands which covers approximately 6 million acres. In light of these facts and figures the portion of golf courses having the highest potential for nitrate leaching represent an insignificant threat to the environment as a whole (Petrovic, 1990).

Chapter Three: Methodology

3.1. This Study intends to examine nitrate effects on the River Croal based upon management practices undertaken within the adjacent Deane Golf Course and how they may possibly have an adverse effect upon water quality, specifically in relation to measured concentration levels of nitrate, in addition to physical and environmental factors influencing the rate and extent on the transfer of nitrate into reference water bodies. The maintenance and development of high quality grass is essential to a golf course. As a consequence Golf courses regularly receive "point source" pollution in the form of inorganic fertilisers in order to promote rapid growth. As a result Reference data will be collated from the Green keeper, as to the toxicology of the fertilisers' applied, the volume of fertiliser spread and the time period in which the fertiliser is applied, in order to aid the understanding of how fertiliser treatment may have an affect upon the transfer of nitrate in water bodies. With this information made available it may be possible to predict the periods of the year for which the contamination of river systems is most likely to be apparent and ensure the sampling programme complies with this. However permission must be gained from the land owner to access land and retrieve water samples.

3.2. Sample sites: seven sample points are identified along a 1.9 kilometre stretch of the River Croal (5 sample points are allocated along the stretch on the golf course and a sample point upstream and downstream of the golf course to provide comparison). Each location differs in topography, adjacent vegetation cover and distance from the golf course in order to present a variation in results. The collection of samples took place over a period of seven months (August-January) with a sample collection frequency of two per calendar month (middle and end). On the days of sampling it is vital to collect the all the data in one day as rivers will change in response to rainfall events with the potential of providing false negative or false positive results.

Individual properties will be investigated by using specific methods and apparatus. For example:

3.2.1. To further validate readings, the velocity was recorded at each location at regular intervals across the channel. This was done by using the flow meter provided by The University of Central Lancashire. The velocity of the river is measured approximately at a depth of 60% from the surface water with the propeller fully submerged and facing upstream. For an accurate velocity reading, the operative must stand downstream to avoid a disturbance of the rivers flow. At each point, distance from the bank, water depth and velocity should was recorded. Several readings are taken from each location with a measurement time of one minute at the end of which the number of the rotations the propeller made is provided by the Geopack Merter (River Velocity, 2006). Then an average is calculated using an equation.

For example: $V\ (m/s^{-1}) = 0.000854C + 0.05$

3.2.2. The level of precipitation plays a vital role in assessing result trends of levels of nitrate retrieved within water course samples. Precipitation levels were recorded on a daily basis over the investigation period from recognised internet based meteorological sources (www.Metcheck.com). This data has been collated at twice monthly intervals prior to sample retrieval in order to provide pertinent reference (Appendix **I**). By the study of precipitation, a considered opinion maybe derived with respect to the level of nitrates recorded with samples retrieved in relation to infiltration rates and run off with combined geological data into surface waters. Additionally it is recognised that rainwater contains levels of nitrates which may lead to false positive or negative nitrate results which may be investigated.

3.2.3. To ensure safety, work will not be conducted in a river which is too deep or fast flowing. As there is a potential risk of falling into the water when collecting samples an appropriate buoyancy aid will be worn at all times. Appropriate warm, waterproof clothing and suitable footwear will be worn to lower potential risks from occurring such as slips, trips, and falls. When collecting samples from the water course plastic gloves are necessarily, as some rivers may carry diseases such as Weil's disease or leptospirosis. The application for safety and ethical approval along with the Risk Assessment form can be seen in Appendix **II**.

3.2.4. Before retrieving three 75ml samples of course water from each location, each sample vessel is purged three times in order to remove any impurities with the potential to affect the results. The sample bottles used were made from glass as recommended by The World Meteorological Organization (WMO,1988, p.75) to be the most suitable for nitrate collection. The method of extraction was to inundate the sample bottle until it was full, where then the lid was instantly secured. The samples were clearly labelled identifying the area to which they represent on the river along with the date, time and any factors in which may have been present, with the possibility of impeding the results. Each sample is stored in a cool box to preserve its natural temperature where it is then transported to the laboratory and stored in the fridge at a temperature of 1-4°C as s advised by Bartram et al,(1996, p.75).

3.2.5. pH levels are required to determine the acidity or alkalinity of the river system at each of the seven locations. Electrodes are placed in potassium chloride solution to neutralise the reading. The electrodes were lowered into each of the three beakers for the seven locations and left to settle for one minute before taking a reading. The mean of each location was worked out and was used as the final figure (Estuarine Science, 2007).

The samples were analysed at UCLan Analytical Unit using a Dionex machine. The Dionex can be used to analyse concentrations of nutrients in the water samples. Twenty millilitres of sample water is injected into the machine. This was repeated for each study site over the six months of collection. The Dionex reads the results in mg/l with a time delay of four to 5 minutes and produces graphs revealing specific concentrations of nitrate, chloride, and sulphate. Examples of the graphs produced by the Dionex can be seen within Appendix **III.**

Chapter Four: Study Site

4.1. Deane Golf Club is situated approximately 3.11 km South West of Bolton Town Centre, in the county of Greater Manchester, England. Measuring 5652 yards over eighteen holes, the highest point of the Golf Course is recorded at 135 metres, with the lowest recorded at 108 metres above Ordnance datum. A 1.4 kilometre stretch of the Golf course nestles along the valley of the River Croal, a tributary of the River Irwell (Deane Golf Club, 2013). The River Croal flows eastwards through Bolton for approximately 16 km rising at the confluence of Middle Brook and Deane Church Brook (River Croal, 2010) .

4.2. Brown (2013), Head Green Keeper of Deane Golf Course states that the practice of fertiliser application undertaken at Deane Golf Club generally take place between May-October, receiving 162 kg of nitrate annually. The application of fertilisers is confined to greens and tees which receive two summer feeds in May and July and one winter feed in October. However due to extensive work regarding the landscaping of the golf course through the summer (June-August), the application of fertilisers in July was avoided due to a high risk of leaching and as a consequence the fertiliser applications altered. The treatment of which the golf course received over the study period, are shown the table below;

	Greens	tees
15th September	Fertiliser used: Angus 8% nitrate 4% potassium 2kg to each green total of 36 kg	Fertiliser used: Angus 8% nitrate 4% potassium 1kg to each tee total of 18 kg
15th November	Fertiliser used: Angus 3% nitrate 22% potassium 2kg to each green Total of 36kg	Fertiliser used: Angus 3% nitrate 22% potassium 1kg to each tee Total of 18 kg

Table. (1): Fertiliser application over the study period.

4.3. August 15: Due to a relatively small quantity of rainfall at the start of August, the water level was low at a depth of approximately 50 cm and the river was slow-moving.

August 30: The flow of river is fairly fast as the level of precipitation increased dramatically leading up to the day of the study.

September 15: the general view of the area is that the river is fast flowing. The fast flowing river would make sense of the precipitation levels from the previous days prior the investigation.

September 30: The River is fast flowing and flooded in some areas with water inundating the golf course; in particular Hole 14 .The weather was rather cloudy, unsettled and breezy with showers tending to merge into longer spells of rain. The rain was moderate to heavy at times.

October 15: as a consequence of 24.1 mm of rainfall on the night of October 11th the river is fast flowing and approximately 130 cm deep.

October 30: The river is very shallow, approximately 40cm and is slow flowing.

November 15: Due to very little rainfall leading up to the day of sampling the river was slow flowing. and shallow. On the day of the study the weather was dry with clear skies with very little wind.

November 30: the depth of the river was approximately 60 cm and the river was fairly slow flowing.

December 15: Due to a relatively small quantity of rainfall at the start of December the water level was low and the river was slow-moving

January 15: On the day of the study the weather was wet, with a brief light fall of rain. As result of very little precipitation the river was very shallow and slow flowing.

January 31: Throughout the month of January, the weather reached subzero conditions with temperatures ranging from -3 to -12^{oc}. Due to substantial levels of rain and snowfall leading up to the study the river was fast flowing and flooded in some areas, obstructing the concrete walk way present to the north of the river .

4.4. The general superficial geology of the river channel study area is one of Alluvium deposits, comprising of Clays, Silts, Sand and Gravels. Deposits formed up to 2 million years ago in the Quaternary Period. Immediately adjacent to the study areas beyond and underlying the reference site, the superficial deposits recorded comprise of Till (Clays), Devensian-Diamicton Superficial Deposits formed up to 2 million years ago in the Quaternary Period.

The solid geology for they study area comprises of Pennine Lower Coal Measures Formation - Mudstone, Siltstone and Sandstone; Sedimentary Bedrock formed approximately 314 to 316 million years ago in the Carboniferous Period.

4.5. The immediate soil characterisation is identified as Suburban, deep clay to sandy loam originating from Riverine Clay and Floodplain Sands and Gravel parent material with no recorded pH data. Within the reference site and the residential surrounding areas to the north soil classification is one of Suburban, deep Loam to Clayey Loam originating from glacial till parent material (British Geological Survey, 2008).

4.6. Sample Location Sites.

Fig. (1): Aerial view of locations 1 & 2. Source: Google Earth 2013

Fig. (2): Location 1, Ground view.

To the North the River Croal is bounded by masonry retaining structures of residential dwellings at a height of approximately 2 meters. The channel width is 5.314 meters.

Fig. (3): Location 2, Ground view.

The cross section of the south bank indicates moderate soil cover with underlying superficial Clay deposits. Mature tree growth and dense vegetation foliage; including invasive plants such as Japanese Knotweed cover the steeply convex slope. The channel width is 3.755 metres.

Fig. (4): Surface water discharge from the housing estate, between Locations 1& 2.

Fig. (5): Surface water discharge from Beaumont Road Bridge, approximately 25 yards east of Location 1.

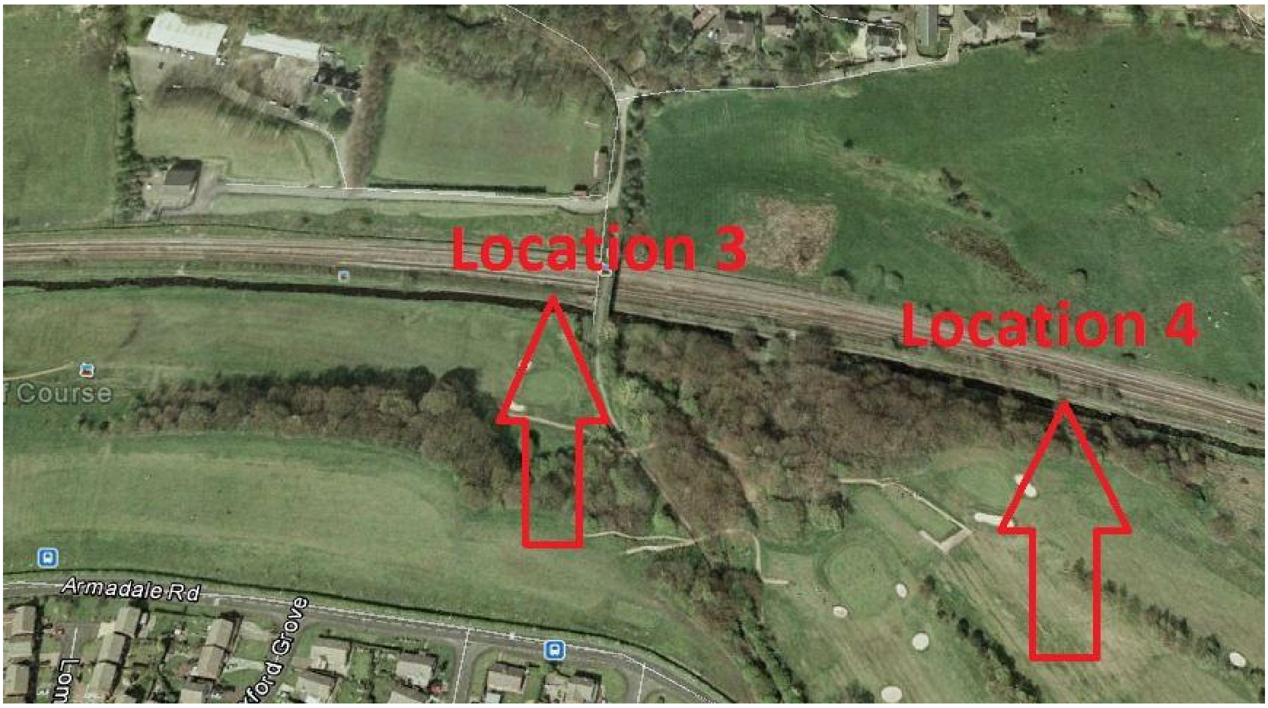

Fig. (6): Aerial view of locations 3 & 4. Source: Google Earth 2013.

Fig. (7): Location 3, Ground view.

Tall, mixed bank side vegetation runs along the south bank. The land adjacent to the River Croal is a landscaped golf course which is relatively flat. However beyond the south fairway edge a steeply convex slope is heavily wooded with sparse foliage/vegetation cover. The width of the channel is 6.62 meters. The distance from the River Croal to the green is approximately 37.31 metres.

Fig. (8): Surface water discharge between locations 2 & 3, presumably from the housing development, south of the Golf course.

Fig. (9): The South bank, approximately 30 yards to the west of location 3, shows evidence of erosion and sand superficial deposits.

Fig. (10): Land drainage into the River Croal from the golf course. Leading up to Location 3, land drains occur at 30 yard intervals along the stretch of Hole 14, a distance of 368 meters.

Fig. (11): Location 4, Ground View.

Mature tree growth and sparse vegetation foliage cover the steeply convex south bank. The channel width is 5.084 meters

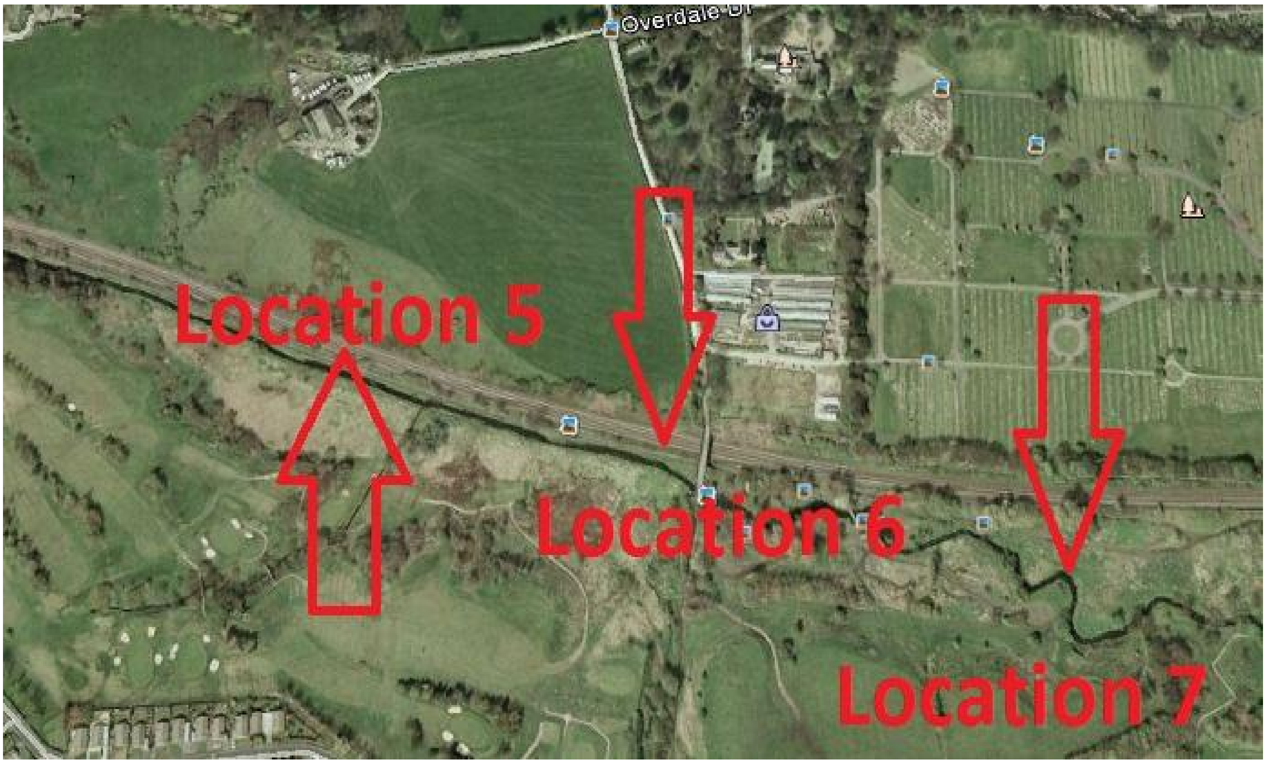

Fig. (12): Aerial view of Locations 5, 6 & 7. Source: Google Earth 2013

Fig. (13): Location 5, Ground View.

The land adjacent is relatively flat and heavily covered by dense tall, bank side vegetation with mixed deciduous woodland. The distance from the green is approximately 37.31 metres with a measurement of the channel width at 6.786 meters.

Fig. (14): A surface water feature, discharging from the golf course, between locations 5 & 6.

Fig. (15): Location 6, Ground view.

It is evident that infilled material has been deposited within the river course which narrows the river channel. The width of the river channel is 3.496. Shrub land is present to the south of the bank and is relatively flat with mixed deciduous woodland. Within the golf course a moderate slope is present with a Conifer with small cylindrical needles encircling the branch; identified as spruce and is approximately 65 ft. The distance on the river Croal to the tee is 22.64 metres.

Fig. (16): Location 7, Ground View.

As shown above, a meander of the river channel is present with deep fast flowing water towards the North of the bank where undercutting has taken place to a great extent over time. Moving towards the South bank, the river flow became relatively gentle and shallow with very little undercutting of the bank. The north and south banks are relatively flat with dense, vegetation cover (weeds and shrubs) and moderate woodland. The width of the River channel is 7.638.

Chapter Five: Results

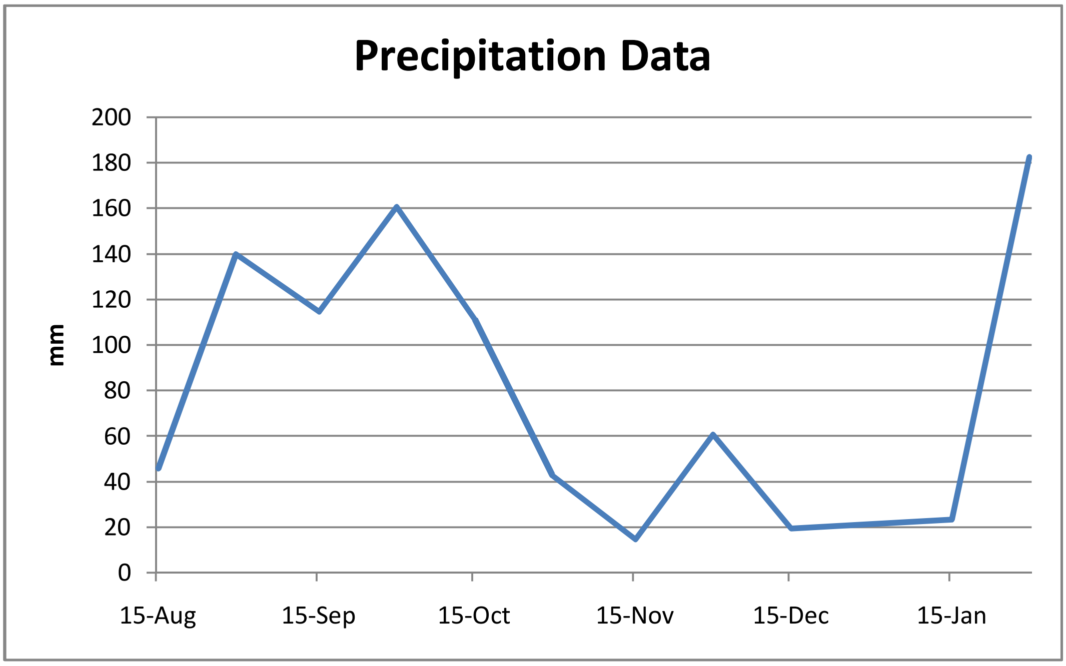

Fig. (17): Precipitation Data, August 2012-January 2013.

5.1. From the data represented in figure17, the graph reveals a large increase of precipitation of up to 93.97mm between 15th -30th August. This is represented by a steep rising limb. Precipitation levels drop significantly between 30th September and 15th November by 145.94mm. As shown in the graph, rainfall total is recorded at its lowest level of 14.7mm on 15th November. Between 15th December and 15th January precipitation remains relatively constant varying from 19.6-23.34mm , however the graph peaks on 30th January reaching the highest recorded rainfall of 182.45mm.

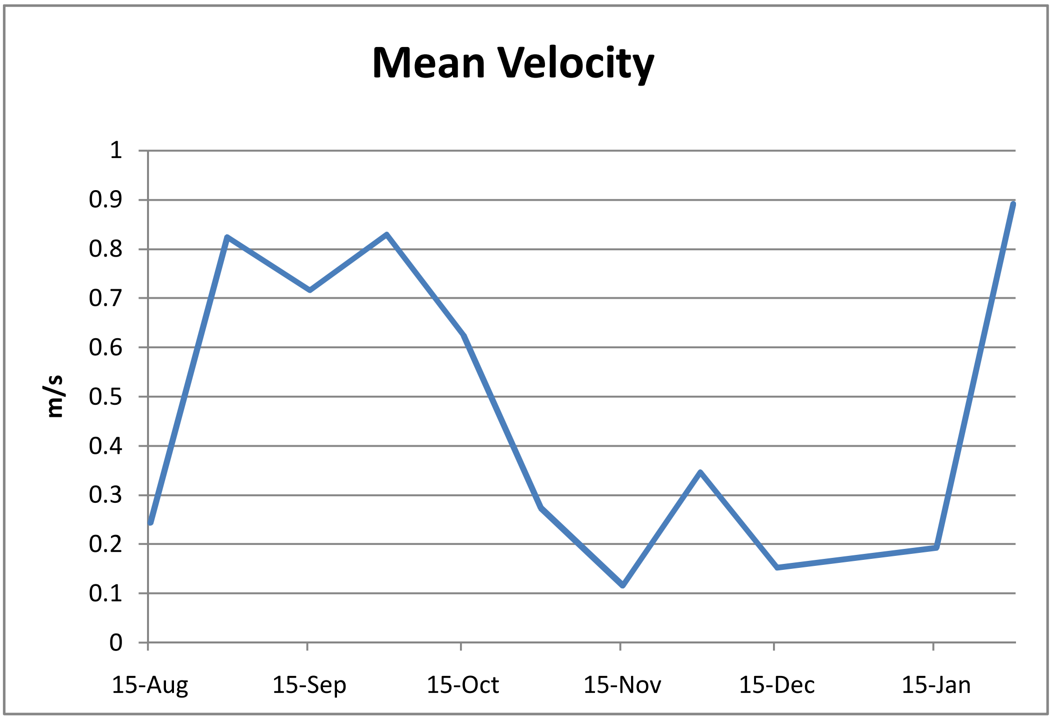

Fig. (18): Mean Velocity, August 2012-January 2013.

5.2. As can be seen from figure 18, there is a steep rising limb between 15th- 30th August, with the mean velocity reaching 0.824m/s. The fluctuation between 30th August-30th September is minimal, as represented in the graph by a gentle falling limb followed by an equally gentle rising limb. The mean velocity drops steeply between 30th September-15th November, by 0.712m/s. As shown above, the mean velocity is recorded at its lowest of 0.116m/s on 15th November. Between the 15th December-15th January, the velocity is fairly constant with a slight increase of 0.041m/s. The velocity drastically ascends on 30th January, recorded at its highest velocity of 0.891m/s.

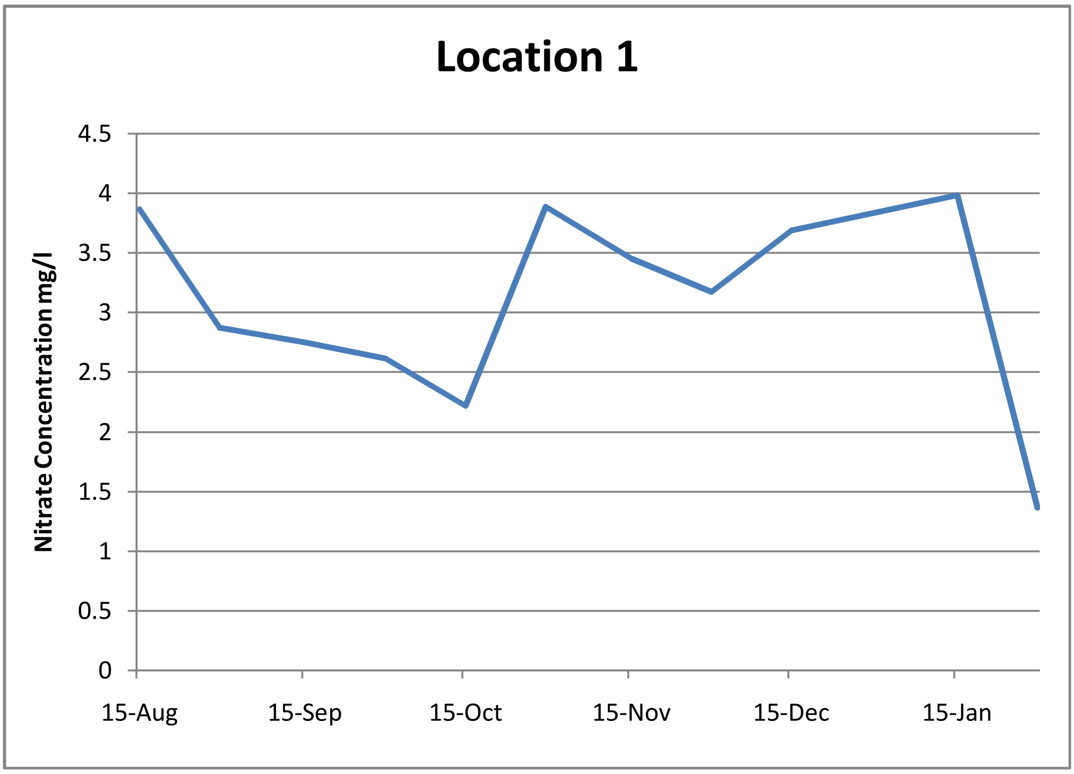

Fig. (19): Nitrate Concentration, Location 1, August 2012-January 2013.

5.3. Figure 19 shows a gradual decrease within nitrate concentrations between 15th August-15th October by 1.647mg/l. Between the 15th-30th November, there is a very sharp rising limb, with the nitrate concentration reaching 3.888mg/l. The fluctuation between 30th October-15th January is minimal, as represented in the graph by a gentle falling limb followed by an equally gentle rising limb, ranging from 3.176mg/l to 3.985mg/l. The lowest level of nitrate concentration is recorded at 1.365mg/l on the 30th January. This corresponds with the steep falling limb shown in figure 3.

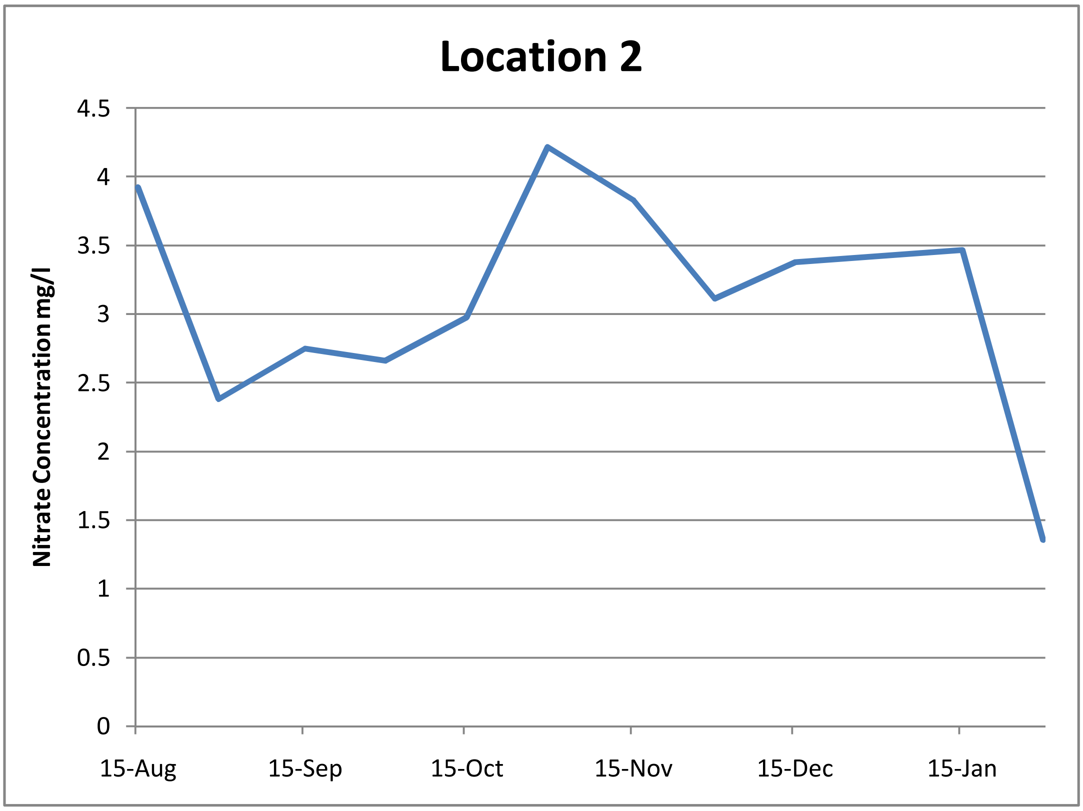

Fig. (20): Nitrate Concentration, Location 2, August 2012-January 2013.

As shown in figure 20, there is a relatively sharp decrease between 15th August-30th August of 1.543mg/l. Little fluctuations occur between 30th August-15th October, ranging from 2.378mg/l to 2.972mg/l, stating an increase of 0.594mg/l. At 30th October, nitrate concentration reaches its peak of 4.216mg/l, followed by a reasonably gentle decrease up to 30th November. Between 30th November -15th January, the nitrate concentration remains relatively steady. The nitrate concentration steeply descends by 2.113mg/l on 30th January, with the lowest reading of 1.354mg/l.

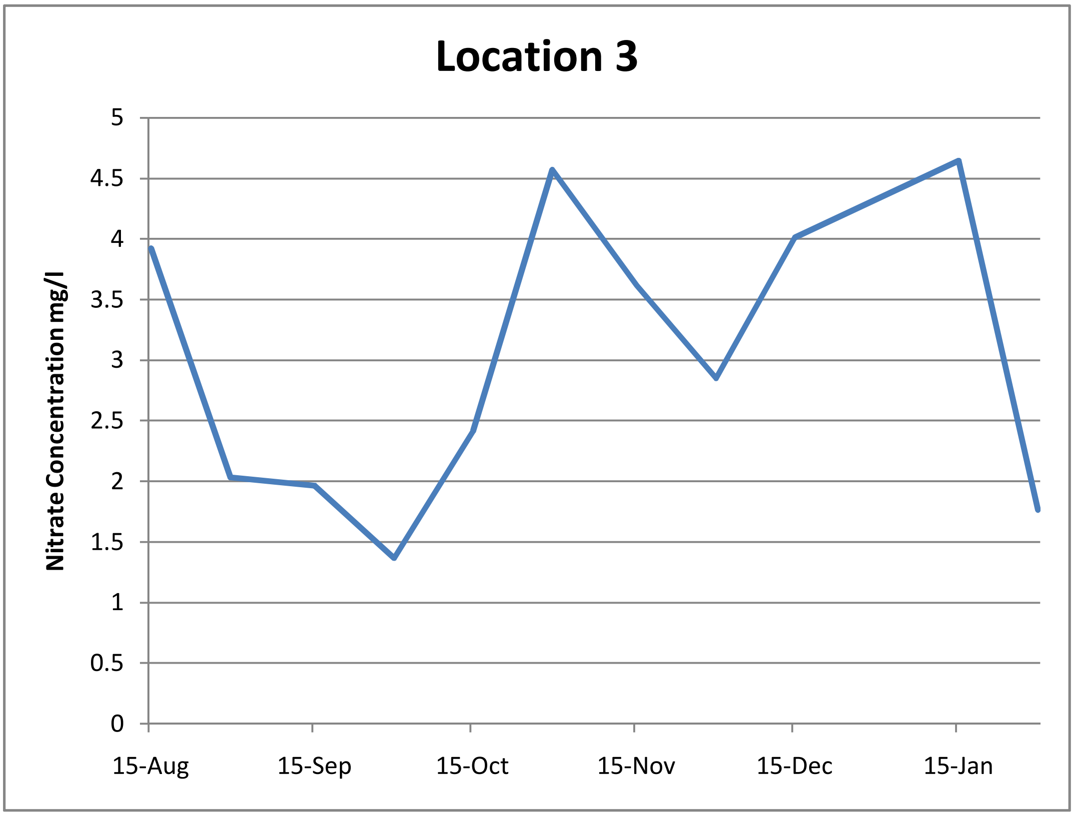

Fig. (21): Nitrate Concentration, Location 3, August 2012-January 2013.

Figure 21 reveals relatively large fluctuations throughout the study period. A sharp falling limb occurs between 15th -30th August, a decrease of 1.886mg/l. Between 30th August -30th September, the concentration of nitrate gently decreases to its lowest point of 1.37mg/l. In contrast, there is a significant rising limb from 30th September-30th October, with an increase of 3.2mg/l. Fluctuation occurs between 30th October-15th January, as represented in the graph by a gentle falling limb followed by an equally gentle rising limb, ranging from 2.854 to 4.645mg/l. On the 30th January, nitrate concentration drops dramatically by 2.881mg/l.

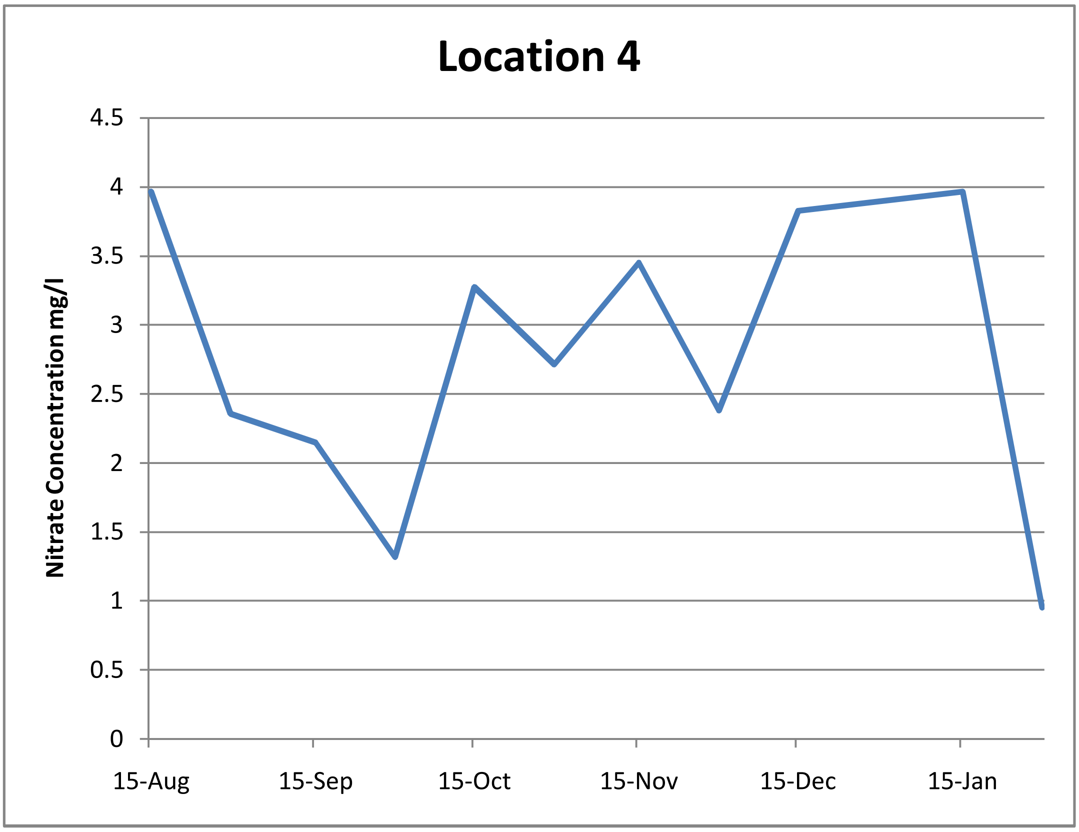

Fig. (22): Nitrate Concentration, Location 4, August 2012-January 2013.

From the results obtained in figure 22, the graph reveals a significant decline in nitrate concentration of 2.643mg/l between 15th August-30th September. Regular fluctuations occur between 30th September- 15th December, varying between 1.321 and 3.823mg/l. During a period ranging from 15th December -15th January shows a relatively constant level of nitrate concentration. The highest recorded nitrate concentration of 3.964mg/l occurs on 15th August and 15th January. Between 15th-30th January there is a drastic drop of over 75%, this is represented by a steep falling limb to its lowest recorded nitrate concentration of 0.953mg/l.

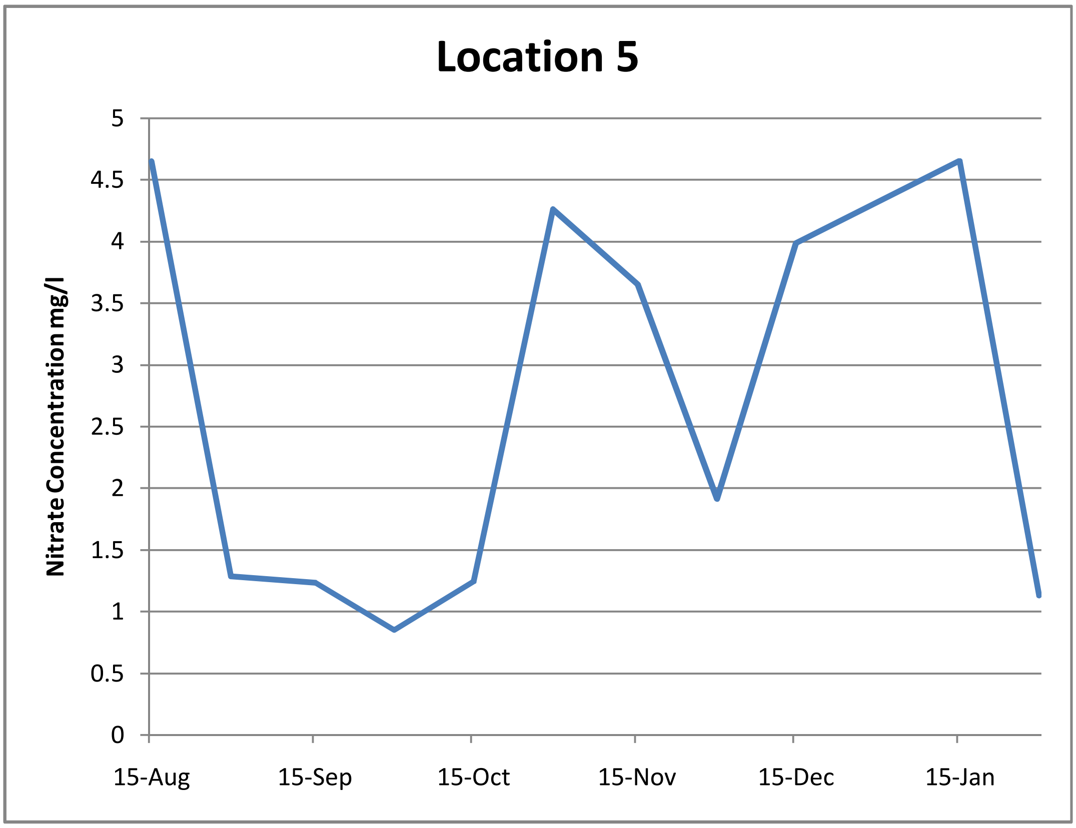

Fig. (23): Nitrate Concentration, Location 5, August 2012-January 2013.

In figure 23, nitrate concentration decreases severely between 15th-30th August by 3.367mg/l. Between 30th August-30th September, nitrate concentration gradually declines to its lowest recorded figure of 0.851mg/l. This is followed by a significant sharp rise of 70% from 15th-30th October. Between 30th October- 15th January the level falls by an order of 2.23 before returning to the highest recorded level of 4.653 mg/l. Nitrate concentration drops dramatically between 15th-30th January by 3.524mg/l, this is represented in the graph by a steep falling limb.

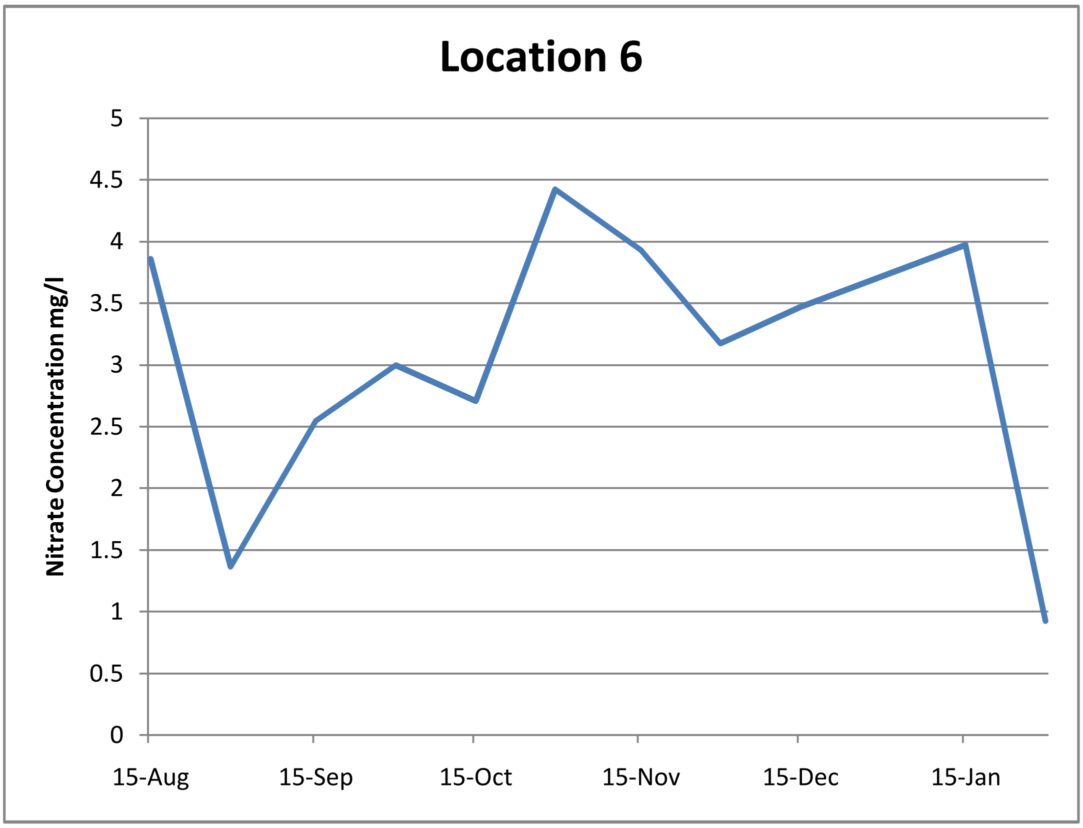

Fig. (24): Nitrate Concentration, Location 6, August 2012-January 2013.

Results shown in figure 24 illustrate a relatively sharp decrease of 65% between 15th-30th August. Following this, a gentle incline, reaching a nitrate concentration of 2.996mg/l on 30th September. The highest recorded level of nitrate concentration revealed on 30th October is 4.423mg/l, almost 80% higher than the lowest figure documented on 30th January. The readings on 15th November and 15th January are similar with a difference of only 0.041 whilst the intermediate reading on 30th November has a slight dip of approximately 20%.

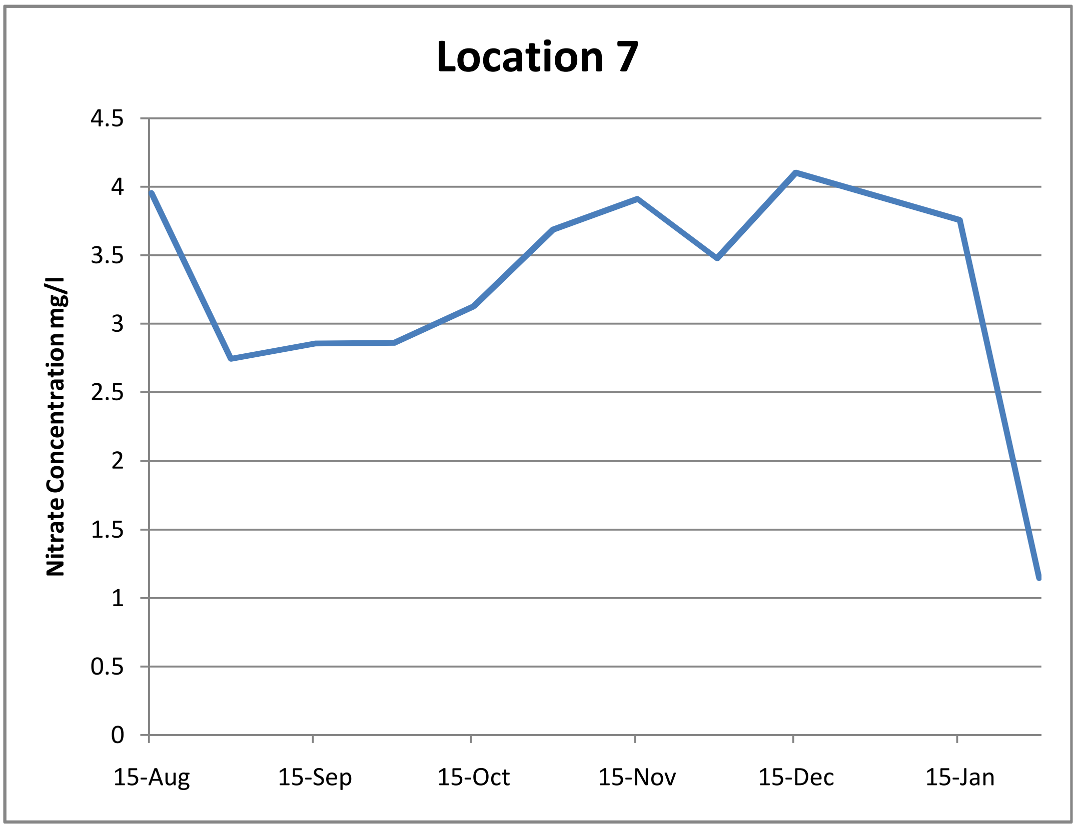

Fig. (25): Nitrate Concentration, Location 7, August 2012-January 2013.

Figure 25 reveals a moderate drop between 15th-30th August of 1.208mg/l. This is followed by a gradual increase between 30th August and 15th November, with nitrate concentrations ranging from 2.745-3.91mg/l. The readings on 15th November and 15th December are similar with a small difference of only 0.191 whilst the intermediate reading on 30th November has a slight decrease of approximately 15%. The highest recorded nitrate concentration is shown on 15th December at 4.101mg/l, in contrast to the lowest recording of 1.146mg/l on 30th January, a decrease of approximately 72%. This is represented on the graph by a steep falling limb.

	Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7
15/08/12	6.64	6.67	6.52	6.66	6.64	6.74	6.67
30/08/12	6.67	6.62	6.68	6.64	6.68	6.58	6.54
15/09/12	6.35	6.56	6.48	***7.24***	6.75	6.58	6.65
30/09/12	6.47	6.51	6.55	6.64	6.85	6.48	6.55
15/10/12	6.45	6.67	6.67	6.85	6.71	6.78	6.86
30/10/12	6.58	6.49	6.53	6.49	6.48	6.49	6.58
15/11/12	6.56	6.55	6.66	6.54	6.74	6.87	6.74
30/11/12	6.92	6.81	6.97	6.78	7.01	6.84	7.01
15/12/12	7.15	7.08	6.99	7.11	6.97	7.28	6.87
15/01/13	6.68	6.98	7.03	6.88	7.12	7.34	7.33
30/01/13	7.18	7.33	7.12	7.26	7.25	6.99	7.28

Table. (2): Results of pH analysis, August 2012-January 2013.

5.4. The pH values range from 6.45 (highlighted red) to 7.34 (highlighted green). This indicates slightly acidic to neutral conditions to exist within the water course over the period of monitoring. In general, initial values were recorded at "slightly" acidic levels up to and including the monitoring visit undertaken on 15th November 2012. Thereafter, an increased value trend is noticeable, whereby levels are recorded marginally above and below pH 7 (neutral). An anomalous result recorded at Location 4 on 15th September 2012 of 7.24 (bold italics) is postulated as analytical error.

Chapter Six: Discussion

6.1. Data collected from the River Croal will be examined in great deal with respect to the toxicology of the fertiliser applied, the volume of fertiliser spread and the time period in which the fertiliser is applied, along with the management practices carried out by Deane Golf Club and climatic conditions with the potential to have an effect upon the results obtained.

6.2. The results obtained from the subject length of the River Croal ranged between 0.851mg/l and 4.653mg/l, which are significantly lower than the 50mg NO3/l threshold established by the EU Directives. Based upon the aforementioned figures the application of fertilisers does not pose a contamination risk to the River Croal. However in order to see whether there is any effect upon nitrate levels, it will be beneficial to compare the results recorded from the River Croal to the national average of surface water in the UK. The UK national average ranges from 5mg/l - 18mg/l (Organization, 2011), which is still higher than the highest result obtained from the River Croal.

6.2.1. It would be expected that the average nitrate concentration of Locations 1 & 2 would relatively be lower in comparison to locations along the stretch of the golf course as they are close to areas in which receive point source pollution in the form of fertiliser treatment, therefore it would be expected to find and increase in nitrates found in the River Croal at these particular locations within a rural setting. However at both positions, the average nitrate concentrations are in fact higher. A possible reason for such anomalies could be due to Locations 1 & 2 being located with an urban environment therefore outside influences such as outfalls from housing estates and Beaumont Road Bridge along with additional factors such as road salts through the winter period may have an adverse effect upon the results obtained. However outfalls only occur between Locations 1 & 2 possibly explaining why the average is higher at Location 2 in comparison to Location 1. From the surrounding area there is no possible explanation as to why Location 1 obtains the third highest result as there are no visual features with the potential to affect the result collated. The South Bank at Location 2 reveals moderate soil cover with underlying superficial Clay deposits. As a consequence it would be expected that the nitrate resulted collected would in fact be lower as a study by Gaines reveals soils such as clay and silt with a fine texture absorb larger concentrations of N in contrast to coarse soils such sand.

6.2.2. Evidence from a previous study conducted by Gaines (1994) with the purpose to determine the effect of soil texture on nitrate-nitrogen retention, reveals sand as the worst soil type for N03-N fertiliser application; as it leaches from the soil into the groundwater at a much faster rate due to its poor structural development and relatively large pore space in contrast to clay. This indicates that the highest mean nitrate concentration should be identified at location 3 as figure 9 illustrates sand superficial deposits along the South bank. However this was not the case. A possible factor in determining the quantity of N lost is land use. A study conducted by Lord et al reveal that nitrate concentrations on average are lower in areas under grass systems when compared to arable systems. The reason behind this finding is that grassland is more prevalent in wetter areas therefore more water passes through the soil. As a consequence, this reduces the soil of nitrate and dilutes concentrations even though the quantity of nitrate lost is much higher. This may explain why the mean average nitrate concentration of location 3 is lower than expected as the land adjacent to the river Croal is a landscaped golf course. The fairway adjacent to the River Croal is relatively flat, enabling nitrate to infiltrate the soil with the potential of being absorbed by plant roots, hence an intermediate reading from Location 3. If the amount required to sustain the maximum nutrient uptake by plants is exceeded, then unused nitrate is transferred to groundwater. However the rate at which this occurs depends on a number of factors. Mestrovic (1990) states 'leaching of fertiliser N applied to turf grass has been shown to be highly influenced by soil texture, N source, rate and timing, and irrigation/rainfall'. Eberth (1998) states the 'downward movement of water is enhanced under conditions of high precipitation and or irrigation on coarse textured soils'. Since the superficial soil of Location 3 is coarse sand combined with the availability of large volumes of water as a transport mechanism, suggesting the rate of nitrate transfer to the groundwater will be rapid. However if the water table is not in hydraulic continuity with the water coarse, the rate at which nitrate enters the water system is reduced possibly explaining the mean recorded nitrate concentration at Location 3 of 3.015 mg/l.

6.2.3. An anomaly occurs at Location 4 on 30th October of 2.715 mg/l. When compared to other Locations on the same date, this is a significant drop with respect to the results collated. Rainfall data for 30th October is recorded at 42.8 mm which is relatively low when compared to the highest recorded level of 182.45 mm. In light of the figures aforementioned, it would be expected that the recording at Location 4 would presumably be higher due to the lack of rainfall acting as a diluting. A possible explanation for the anomaly is the topography of

Location 4: mature tree growth along with sparse vegetation foliage cover. Nitrate present in the soil layers at this particular location will have an increased chance of absorption when compared to an area where the soil is bare. However if this was the case, why would location 2 with similar topography be significantly higher with a recording of 4.216 mg/l on the same date? Proving this to be a null hypothesis. However between Locations 2 and 3, land drains discharging into the River Croal which appears to be from the golf course at 30 yard intervals possibly having an adverse effect upon the results collated on the 30th October at location 4. The mean average nitrate concentration at Location 4 drops by 0.265 mg/l in comparison with Location 3. This is expected as the superficial soil is deep loam to clayey loam. A study by Gaines (1994) reveals soils such as clay and silt with a fine texture absorb larger concentrations of N in contrast to coarse soils such sand possibly explain the lowest result obtained on the 30th October. In contrast results of soil texture affecting water permeability reveal the rate of percolation of N is much faster in coarse soils when compared to finer soils. Due to the good structural development and reasonably small pore spaces clay soils are likely to contaminate surface waters opposed to groundwater. However due to very little rainfall, the amount of nitrate leached from the soil is small or the amount of nitrate present in the soil at this particular time is minimal.

6.2.4. The mean average nitrate concentration of Location 5 is recorded at its lowest. However three readings are in excess of 4mg/l, with the highest recorded reading of 4.653mg/l on the 15th August and 15th January. In contrast Location 5, records the lowest reading of 0.851mg/l on 30th September. A viable explanation for the result obtained of 4.653mg/l is that a farm exists directly north of Location 5 with worked agricultural land and a gradient of 1 in 11. There is a possibility that the agricultural fields receive point source pollution in the form of fertilisers with the potential of excess nitrate leaching into the River Croal, having an impact upon the results obtained. The three results in excess of 4mg/l are recorded on days with very little rainfall as would be expected however the highest recorded readings on both dates previously mentioned are significantly higher when in comparison to the other locations except for Location 3 on 15th January. A reason behind this finding is that Location 3 is approximately 37.31 metres away from a green which receives point source pollution in the form of fertilisers. The second highest day of recorded rainfall on 30th September, may possibly explain the lowest result recorded of 0.851mg/l. This is mainly due to the effect of dilution. However in comparison to the readings of other locations on the same date it appears to be significantly lower. The reason behind this could possibly be the distance from an area which receives fertiliser applications (greens/tees) to the River Croal, as it is the furthest distance out of the locations along the stretch of the course. The distance between Location 5 to a green area is approximately 68m, therefore reducing the time and quantity of nitrate entering the River Croal via leaching and run-off? The land adjacent is relatively flat enabling nitrate to infiltrate the soil with the potential of being absorbed by the roots of the dense tall, bank side vegetation, hence the lowest reading.

6.2.5. Due to similar topography at Locations 5 & 6 it would be expected that the average nitrate concentrations would in fact be fairly similar. However this was not the case as Location 6 is closest to an area (tee) which receives point source pollution in the form of fertilisers with respect to all of the locations along the stretch of the golf course; hence an increase of 0.408mg/l. The distance from the tee to the River Croal is approximately 22.64m, therefore increasing the time and quantity of nitrate entering the River Croal via leaching and run-off. From this information, it would be expected that the mean average nitrate concentration of Location 6 would in fact record the highest. However due to dense tall, bank side vegetation, nitrate has the potential of being absorbed therefore reducing the amount of nitrate entering the water system. Between Locations 5 & 6, a surface water feature discharges from the golf course into the River Croal, potentially affecting the results collated. The increase in nitrate levels at this location could be attributable to an increase level of nitrate discharged into the tributary from point sources of fertiliser application within the golf course. Conversely it could be postulated via natural attenuation that any levels of nitrate found within the tributary would in fact be diminished dependent upon velocity and rainfall.

6.2.6. Unexpectedly, Location 7 situated beyond the stretch of the golf course recorded the highest mean nitrate concentration with a result of 3.238mg/l. Initially, Location 7 would be expected to obtain a lower average nitrate concentration in comparison to the locations situated along the stretch of the golf course, as they are closer to areas which receive point source pollution in the form of fertiliser treatment. However this was not the case. A viable explanation for the result obtained is that a graveyard is directly north of Location 7 with a possibility of management practices carried out with the potential to affect the results obtained at this particular location. The gradient of the grave yard is 1 in 16, potentially increasing the rate of run-off and leaching of nitrate into the River Croal. A meander of the river channel is present and the channel width is general wider. This is because the swing of the flow that has been induced by the riffles directs the maximum velocity towards one of the banks, in this instance the North bank and results in erosion. As the water samples were collected from the North bank, nitrates carried within the water system will be carried towards the surface due to the fast flow of the river as opposed to a slow moving river where nitrates are carried closer to the bed, possibly explaining the highest average nitrate result obtained at Location 7?

6.3. The relationship between precipitation levels and nitrate concentrations correspond in most cases, as expected. The rainfall data reveals the highest recorded rainfall of 182.45mm leading up to 30th January from the 15th January, this concurs with the dip in nitrate concentrations found on the 30th January. This is mainly due to the effect of dilution. In contrast the less rainfall recorded, the higher the nitrate concentration. An example of this can be seen on the 15th January with a recording of 23.34 mm along with the highest recorded nitrate concentration of 4.653mg/l at location 5.

6.4. Angus (Fertiliser) is applied to greens and tees on 15th September and 15th November. Due to the increased rate of nitrate addition to the golf course it would be expected that the amount of leached nitrate would in fact increase significantly. However this does not seem to be the case in September. This would suggest optimum fertiliser application or the large amount of rainfall in September reduces the soil of nitrate and dilutes concentrations even though the quantity of nitrate lost is much higher. In general the recordings of nitrate concentrations are higher in November when compared to September even though the content of nitrate is lower by 5%. A possible explanation for this finding is the amount of rainfall recorded when in comparison to September, a difference of 199.99mm. This is a significant difference; therefore the lack of rainfall will cause very little dilution. Backing up the statement made by Roberts (1987) that ' higher concentrations tend to be in dry areas when compared to wet areas'.

Chapter Seven: Conclusion

The aim of this investigation was to establish whether the management practices employed by Deane Golf Club have an adverse effect with respect to the levels of nitrate found to be contained with the adjacent River Croal secondary water course.

It is clearly demonstrated by production of investigation data and monitoring results that the practices of fertiliser application employed to adjacent tee and green areas do not significantly contribute to the level of nitrate content present within the water system. It has been demonstrated that the ability of surface water run-off from the Golf Course is present via a system of land drainage discharge, surface water run-off in an isolated incident of flooding (30th September) and a natural leaching process. Throughout the investigation, levels of nitrate did not exceed 8% of the recognised contamination threshold of Freshwater with respect to nitrate in relation to the legislative EU Directive.

In summary, one justification of the findings may be the 'optimum' fertiliser application to target areas. Whilst this is plausible, the degree of measured application based upon such practices by personnel is unlikely.

A more considered opinion based upon the comparison of analytical and physical data retrieved would be that the major influencing factor is that of precipitation. The general trend of results highlights the fluctuation of nitrate levels is conversely related to the level of precipitation.

Velocity of the water course is also directly proportionate to the level of precipitation. This could offer further mitigation in that any nitrates present within the water body would be transported from the location sites at an increased rate and the increased water levels act as a dilutant to the contaminant.

The varied geological and vegetation environs contribute to the results, however in contradiction to the expected reasoning developed.

Research has identified that in some quarters, an un-educated understanding that the increased level of nitrate contamination within water courses is directly attributable to fertiliser application based upon its more frequent use and increased toxicity. This study has established that environmental and geological factors greatly influence to nitrate levels found within surface water courses.

Chapter Eight: Limitations

Upon reflection of the results of the studies undertaken, several revised factors may take account for the discrepancies and anomalies highlighted within the context of the results and discussion contained within this document. The most glaring benefit to assist this study would be to conduct the investigation over a prolonged time period, for example a full year as opposed to six months. As a consequence, fluctuations of weather patterns would almost certainly become apparent, and as a result, a more considered approach could be adopted with respect to their influence of nitrate level.

It may be possible that surrounding environs with respect to the chosen reference locations may have received point source pollution in the form of fertilisers, therefore potentially impacting the results obtained. Consequently, a true representation may have not been given with respect to the effect of fertiliser's application as a management practice carried out by Deane Golf Course.

Reference sample results taken up and downstream of the stretch of Golf Course were manipulated by outside influences such as surface water discharge from housing estates and roads, therefore a baseline was not provided from which the levels of nitrate could be measured against.

Samples were retrieved from the North Bank only due to access restrictions to the South Bank such as private land ownership, steep sloping landscape and the operational use of the Golf Course. If samples were retrieved across the width of the channel, a greater representation of the whole water body could have been gained with respect to nitrate levels contained therein.

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Appendix I

August
1st 0 0 0
2nd 0 0.1 0.2
3rd 0.5 0.1 0.4
4th 0 0 0
5th 0 0 0
6th 0.2 0 0
7th 0.1 0.2 0.1
8th 0.3 1.4 0.1
9th 0 0 0
10th 0 0 0
11th 8.8 1.9 1
12th 0 0 0
13th 0 0 0
14th 0.2 0.8 0
15th 0.3 0.2 0
16th 0 0 0
17th 0 0 0.3
17th 0 5 0
18th 3.5 0 0

19th 0.1 3.3 26.1
20th 10.8 0.4 0
21st 0.2 0 0
22nd 0 1.2 2
23rd 0 0.5 0. 8
24th 0.1 4.2 2.4
25th 4.6 0.7 0.2
26th 0.1 0.2 13.8
27th 0.1 0.2 0.1
28th 3.3 0.8 0.2
29th 0.2 2.5 2.3
30th 0.7 0.2 0
31st 0.6 0.5 0

September

1st 0.2 0.8 0
2nd 0.3 0.2 0
3rd 0 0 0
4th 0 0 0.3
5th 0 0 0.1
6th 0.2 6.5 7.6
6th 3.1 7.4 0
8th 0 0.5 20.9
9th 0 0.5 0.4

10th 0 0 .1 1
11th 0   0   0
12th 0 6.4 5
13th 0 0.3 13.9
14th 0 0   0.2
15th 6.7 6.8 9.6
16th 5.2 7.6 3.4
17th 0 5 0
18th 3.5 0 0

19th 0.1 3.3 26.1
20th 10.8 0.4 0
21st 0.2 0 0
22nd 0 1.2   2
23rd 0 0.5   0. 8
24th 0.1 4.2   2.4
25th 4.6 0.7 0.2
26th 0.1 0.2 13.8
27th 0.1 0.2 0.1
28th 3.3 0.8 0.2
29th 0.2 2.5 2.3
30th 0.7   0.2 0
0.6 0.5 0

October
1st 0.7 1.4 1.7
2nd 0.5 0.6 0.1
3rd 0.2 0.3 0
4th 0.3 2.5 0

5th morning 0.2
Afternoon 0.3
Evening   0

6th   0.1 0.2 0
7th 0 0 0
8th 0 0 0
9th 0 0 0
10th 0.1 0.2 0
11th 2.5 3.8 24.1
12th 0   0.2 0.1
13th 0.3 1.4 2.7
14th 1.2 0.8 4.3
15th 1.1 0.9 5.6
16th 0.5 3.3 0.2
17th 5.1 2.4   1.8
18th 0 0.6 0.9

19th 0 0 0
20th 0 0.2 0
21st 0 5.3 9.4
22nd 1.1 0.8 0.5
23rd 0.3 0.7 0
24th 0.5 0.3 0.5
25th 0.1 0.2 0
26th 0 0 0
27th 0 0 2
28th 2.1 6.3 2.2
29th 0.7 0.4 0
30th 0.3 1 0.2
31st 1 4 14.5

November
1st 0.7 1.4 1.7
2nd 0.5 0.6 0.1
3rd 0.2 0.3 0
4th 0.3 2.5 0
5th 0 0 0
6th 0 0.4 0
7th 0.2 1 0.1
8th 0.2 03 0
9th 0.3 0.2 0.2
10th 0 0 0
11th 0 0 0
12th 2.8 0.4 0.2
13th 0 0 0
14th 0 0 0
15th 0 0 0.1
16th 0.3 0.2 0.5
17th 0.2 0.2 0
18th 0.5 0.2 2.1
19th 5.5 3.4 0
20th 12.1 10.2 0.7
21st 0 0 0
22nd 0 0 0.1
23rd 9.1 11.9 0.2
24th 0 0 0.7
25th 0.3 0.2 0.5
26th 2.8 0.8 7.7
27th 5.9 1.2 0.3
28th 0 0 0
29th 0 0 0
30th 0.4 0 2.2

December
1st 0 0 0
2nd 0 0 5.4
3rd 3.2 0 0.2
4th 0.6 0.5 0.4

5th 0 0 0
6th 0 0 2.8
7th 1.7 0.2 0.2
8th 0 0 0
9th 0 0 0
10th 0 0 0
11th 0 0 0
12th 0 0 0.4
13th 0.5 0 0
14th 0.1 0.5 2.9
15th 0 0 0
16th 0 0 0.2
17th 0.4 0.4 0.2
18th 0 0 0
19th 0.1 3.3 26.1
20th 10.8 0.4 0
21st 0.2 0 0
22nd 0 1.2 2
23rd 0 0.5 0. 8
24th 0.1 4.2 2.4
25th 4.6 0.7 0.2
26th 0.1 0.2 13.8
27th 0.1 0.2 0.1
28th 3.3 0.8 0.2
29th 0.2 2.5 2.3
30th 0.7 0.2 0
31st 0.6 0.5 0

January
1st 0 0 0
2nd 0 0.1 0.2
3rd 0.5 0.1 0.4
4th 0 0 0
5th 0 0 0
6th 0.2 0 0
7th 0.1 0.2 0.1
8th 0.3 1.4 0.1
9th 0 0 0
10th 0 0 0
11th 8.8 1.9 1
12th 0 0 0
13th 0 0 0
14th 0.2 0.8 0
15th 0.3 0.2 0
16th 0 0 0
17th 0 0 0.3
18th 0 0 0.1
19th 0.2 6.5 7.6
20th 3.1 7.4 0
21st 0 0.5 20.9
22nd 0 0.5 0.4

23rd 0 0 .1 1
24th 0 0 0
25th 0 6.4 5
26th 0 0.3 13.9
27th 0 0 0.2
28th 2.2 10.7 0.5
29th 3.2 3.8 1.8
30th 20 0 0
31st 1.3 0.2 0.3

Appendix II

Application for safety and ethical approval for all projects

School of Built and Natural Environment

All undergraduate, postgraduate, commercial and research projects need ethical approval. No field work, experimentation or work with participants can start until approval is granted. The questions below should be completed by the Principal Investigator or supervisor of the proposed project. Where projects involve students, the Principal Investigator is always the supervisor and never the student.

For **undergraduate** and **postgraduate taught** projects: use the questions to identify whether the project should be referred to the relevant Ethics Committee.

- If you answer “No” to questions, then do not apply for approval.
- If you answer “Yes” to any of the questions, please discuss them with your supervisor. If your supervisor is confident that you can follow standard forms, protocols or approaches, then your supervisor can approve your application. If your supervisor is not, then the application should be sent for approval.

For **research, commercial and other** projects: use the questions to help compile suitable evidence to support your application.

- If you answer “No” to questions, then your application is likely to be approved quickly.
- If you answer “Yes” to **any** of the questions, please provide evidence relating to the management of the activity. If your approach seems appropriate, then your application is

1 Project synopsis Approver: Cmte number:

1.1 Title	How management practices carried out by Deane Golf Club have an adverse effect upon water quality, specifically on the concentration levels of nitrate.									
1.2 Project type	Original research		Research degree		PG taught		UG taught		Commercial	
1.3 Short description in layman's terms [no acronyms or jargon]	Fertilisers are often applied to golf courses to increase the growth of grass as well as stumping the development weeds. This essay aims to investigate how the compound of nitrate may possibly have an effect on water quality.									
1.4 Dates	Start March 2012	End April 2013								
1.5 School of …..	Built and Natural Environment									

2 Participants

2.1 Project supervisor /principal investigator: name, position and original signature	Project supervisor: Jo Dawson Principle Investigator : Logan Brigg
2.2 Co-workers: names and positions [eg student]	

3 External collaborators
3.1 List external collaborating bodies
3.2 Provide evidence of any ethical approvals obtained [or needed] by external collaborators
3.3 Indicate whether confidentiality agreements have been or will be completed

Read any associated procedures and guidance or follow any associated checklist, and delete, Yes or No, for each characteristic in A) to F) below.

If you respond **No**, then in your judgment you believe that the characteristic is irrelevant to the activity.

If you respond **Yes**, then you should **provide relevant documentation** [including risk assessments] with the application, and cross-reference to it, eg A2 or B9. **Use reference numbers of standard** forms, protocols and approaches and risk assessments where they exist.

A) Does the activity involve field work or travel to unfamiliar places? If Yes:	A) Yes/No
1. Does the activity involve field work or leaving the campus [eg overseas]?	1. Yes/No
2. Does the field work involve a 'party' of participants or lone working ?	2. Yes/No
3. Does the activity involve children visiting from schools?	3. Yes/No
B) Does the activity involve humans other than the investigators? If Yes:	B) Yes/No
1. Will the activity involve any external organisation for which separate and specific ethics clearance is required (e.g. NHS; school; any criminal justice agencies including the Police, CPS, Prison Service)? – start this now [CRB clearance process at Loughborough; Uclan contact Carole Knight]	1. Yes/No
2. Does the activity involve participants who are unable to give their informed consent (e.g. children, people with severe learning disabilities, unconscious patients etc.) or who may not be able to give valid consent (e.g. people experiencing mental health difficulties)?	2. Yes/No
3. Does the activity require participants to give informed consent? [consent guidance at City U]	3. Yes/No

4. Does the activity raise issues involving the potential abuse or misuse of power and authority which might compromise the validity of participants' consent (e.g. relationships of line management or training)?	4. Yes/[✓ No]
5. Is there a potential risk arising from the project of physical, social, emotional or psychological harm to the researchers or participants?	5. [✓ Yes]/No
6. Does the activity involve the researchers and/or participants in the potential disclosure of any information relating to illegal activities; the observation of illegal activities; or the possession, viewing or storage (whether in hard copy of electronic format) which may be illegal?	6. Yes/[✓ No]
7. Will deception of the participant be necessary during the activity?	7. Yes/[✓ No]
8. Does the activity (e.g. art) aim to shock or offend?	8. Yes/[✓ No]
9. Will the activity involve invasion of privacy or access to confidential information about people without their permission?	9. Yes/[✓ No]
10. Does the activity involve medical research with humans, clinical trials or use human tissue samples or body fluids?	10. Yes/[✓ No]
11. Does the activity involve excavation and study of human remains?	11. Yes/[✓ No]
C) Does the activity involve animals and other forms of life? If Yes:	C) Yes/[✓ No]
1. Does the activity involve scientific procedures being applied to a vertebrate animal (other than humans) or an octopus?	1. Yes/[✓ No]
2. Does the activity involve work with micro-organisms?	2. Yes/[✓ No]
3. Does the activity involve genetic modification?	3. Yes/[✓ No]
4. Does the activity involve collection of rare plants?	4. Yes/[✓ No]
D) Does the activity involve data about human subjects? If Yes:	D) Yes/[✓ No]
1. After using the data protection compliance checklist, have you any data protection requirements?	1. Yes/[✓ No]
2. After answering the data protection security processing questions, have you any security requirements? [Data storage] [keep raw data for 5 years]	2. Yes/[✓ No]
E) Does the activity involve hazardous substances? If Yes:	E) [✓ Yes]/No
1. Does the activity involve substances injurious to human or animal health or to the environment? Substances must be disposed properly.	1. [✓ Yes]/No
2. Does the activity involve igniting, exploding, heating or freezing substances?	2. Yes/[✓ No]
F) Other activities:	F)
1. Does the activity relate to military equipment, weapons or the Defence Industry?	1. Yes/[✓ No]
2. Are you aware of any ethical concerns about the company/ organisation, e.g. its product has a harmful effect on humans, animals or the environment; it has a record of supporting repressive regimes; does it have ethical practices for its workers and for the safe disposal of products?	2. Yes/[✓ No]
Note: in all cases funding should not be accepted from tobacco-related industries	

If you respond **Yes**, then you should **provide relevant documentation** [including risk assessments] with the application, and cross-reference to it, eg A2 or B9. **Use reference numbers of standard** forms, protocols and approaches and risk assessments where they exist.

These standard forms are being followed [cross reference to the characteristic, eg A2]:

A1 See Risk Assessment
A2 See Risk Assessment
B5 See Risk Assessment
E1 See Risk Assessment

Health, Safety and Environment Section

RISK ASSESSMENT FORM

University of Central Lancashire

Risk Assessment For

Service / Faculty / Dept: SBNE

Location of Activity: Deane Golf Club

Activity: How management practices carried out by Deane Golf Club have an adverse effect upon water quality, specifically on the concentration levels of nitrate within an djacent watercourse (Middlebrook)

REF:

Assessment Undertaken By

Name: Logan Brigg

Date: 12/12/12

Signed by Head of Dept / equivalent

Date 12/02/13

Assessment Reviewed

Name:

Date:

List significant hazards here:	List groups of people who are at risk:	List existing controls, or refer to safety procedures etc.	For risks, which are not adequately controlled, list the action needed.	Remaining level of risk: high, med or low
A1) Transportation (Car)	L.Brigg	Contact details for insurance and breakdown/ recovery services. Mobile phone (ensure charged)		Low
A2) Lone working	L.Brigg	Avoid lone working where possible especially if it is in an unfamiliar area. Always carry fully charged mobile phone. Location information given to a friend/ family member along with estimated time of return.		Low
B5) Slips, trips and falls when collecting samples	L.Brigg	Use of appropriate clothing and footwear. Mobile phone to contact emergency services. Take into account environment and the kind of Clothing and Footwear required. To avoid leaning over the bank and falling in the water course, water samples will be collected using a hand held baler.		Low

http://www.uclan.ac.uk/other/hseo/risk/coshh.htm

B5) Personal Security	L.Brigg	Mobile phone number and information given to a friend/ family member as to the location of the study and estimated time of arrival.		Low
B5) Weather	L.Brigg	Avoid Skin exposure even if some cloud cover and use high factor sun block. Stop work if conditions begin to create significant increases in risk. Carry suitable clothing for change in conditions. Be aware of signs of hypothermia and/ or sun stroke. Avoid collecting samples during a heavy rainfall period as the river may flood unexpectedly.		Low
E1) Hazardous Substances	L.Brigg	Nitrate is only toxic to humans when consumed. Wear appropriate clothing to avoid direct contact with pure nitrate.	The chances of direct contact with pure nitrate are extremely low as the water course dilutes concentration levels. However Personal Protective clothing will be worn at all times.	Low
Falling into water Drowning Hypothermia Physical injuries due to slips, trips & falls	L.Brigg	• Never work alone near to fast flowing and/or deep water; • Never enter a flooded/fast flowing water course. (NOTE – fast flowing water above knee height is likely to knock a person off their feet.); • Only persons who can swim should enter a water course; • Carry a mobile phone (in a waterproof bag) so that emergency assistance can be summoned if required; • Wear an appropriate buoyancy aid if there is any risk of falling into the		

http://www.uclan.ac.uk/other/hseo/risk/coshh.htm

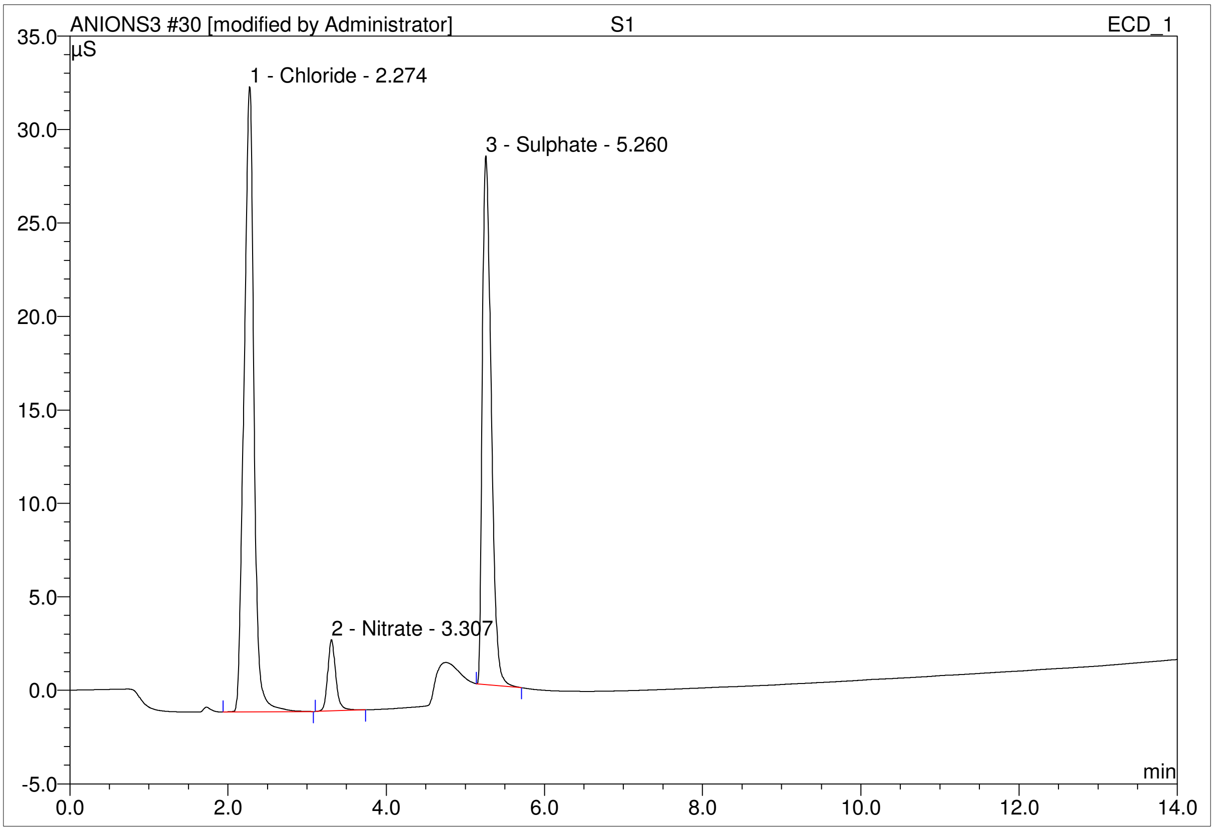
		water. Instruction in safe use should be given by a member of staff; • Avoid areas with significant downstream hazards such as weirs and waterfalls. Edge protection or grablines may be required to prevent falls into water or being swept downstream; • Ensure equipment is available to help a person get out of the water (e.g. a throwline, public safety equipment). Where public safety equipment is available, these should be checked prior to use to ensure they are in good order; • Always leave details of the time and location you plan to visit with the School Office. (see Field Trip Guidance); • Assess the local weather forecast for the time of the planned activity. Postpone activity if extreme weather or flooding is expected; • Research expected water level changes for before and during the activity (e.g. tidal changes and heavy rainfall), ensure there is enough time to carry out the planned activity. Research how high the tide will reach and whether there are any strong local currents. Check if area may be cut off or submerged by a sudden wave or quick rise in the tide level. NOTE: The tide may advance more quickly than you can retreat;		

		• Assess suitability of access and egress routes, banks, crossings and waterside access/egress points etc. (Find some gradually sloping land and check that the bank is not slippery and there is no deep mud/vegetation). Plan an alternative route if any areas may become unsafe or flooded; • Wear suitable warm waterproof clothing and footwear. Take dry spare clothing and leave away from the water or place in a suitable dry bag; • Check for underwater hazards (rocks/roots can trap feet, rusty pieces of metal which can cut etc.). Wear footwear at all times when in the water. (NOTE: Wellington boots may fill with water and make it difficult to reach safety); • A qualified first aider should be present.		

Appendix III

30 S1

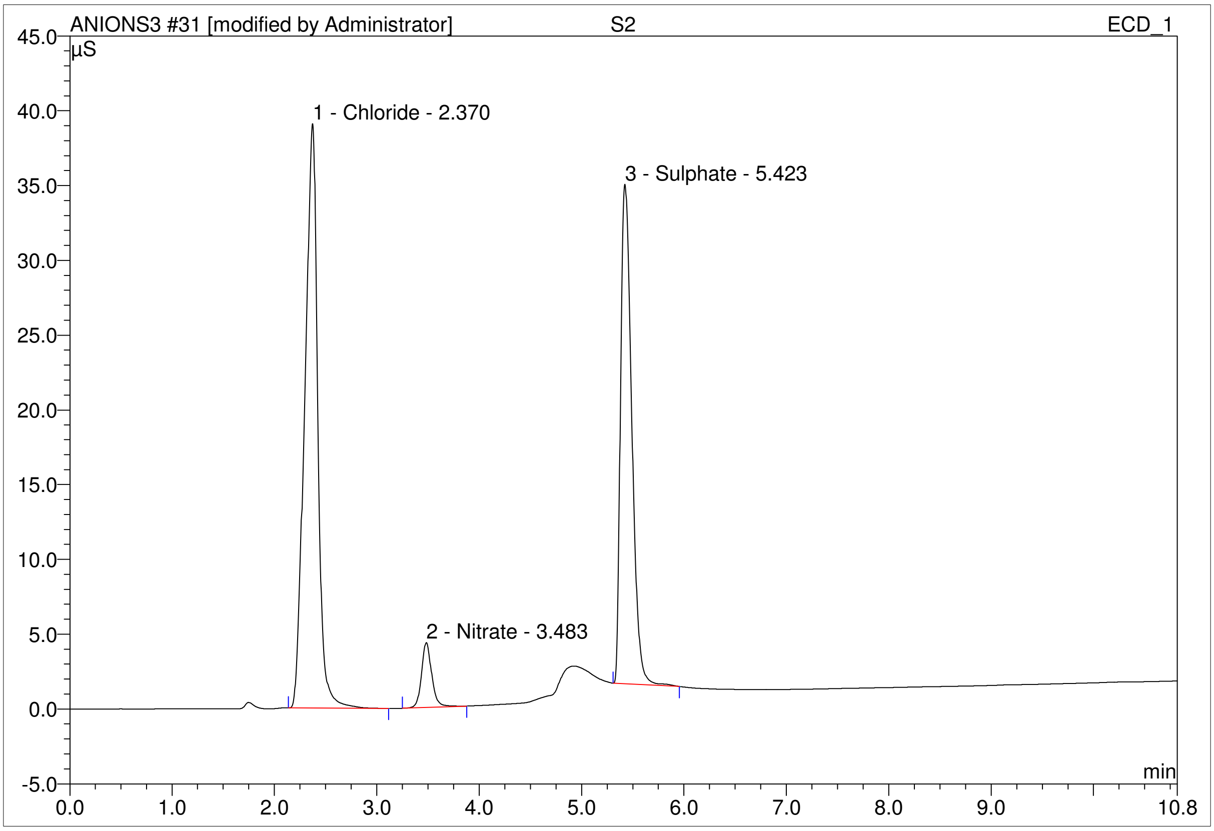
Sample Name:	**S1**	*Injection Volume:*	**20.0**
Vial Number:	**155**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 13:50**	*Sample Weight:*	**1.0000**
Run Time (min):	**14.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.27	Chloride	33.450	4.825	53.90	20.774	BMB
2	3.31	Nitrate	3.814	0.451	5.04	3.455	BMB
3	5.26	Sulphate	28.286	3.675	41.06	22.516	BMB*
Total:			65.550	8.952	100.00	46.745	

31 S2

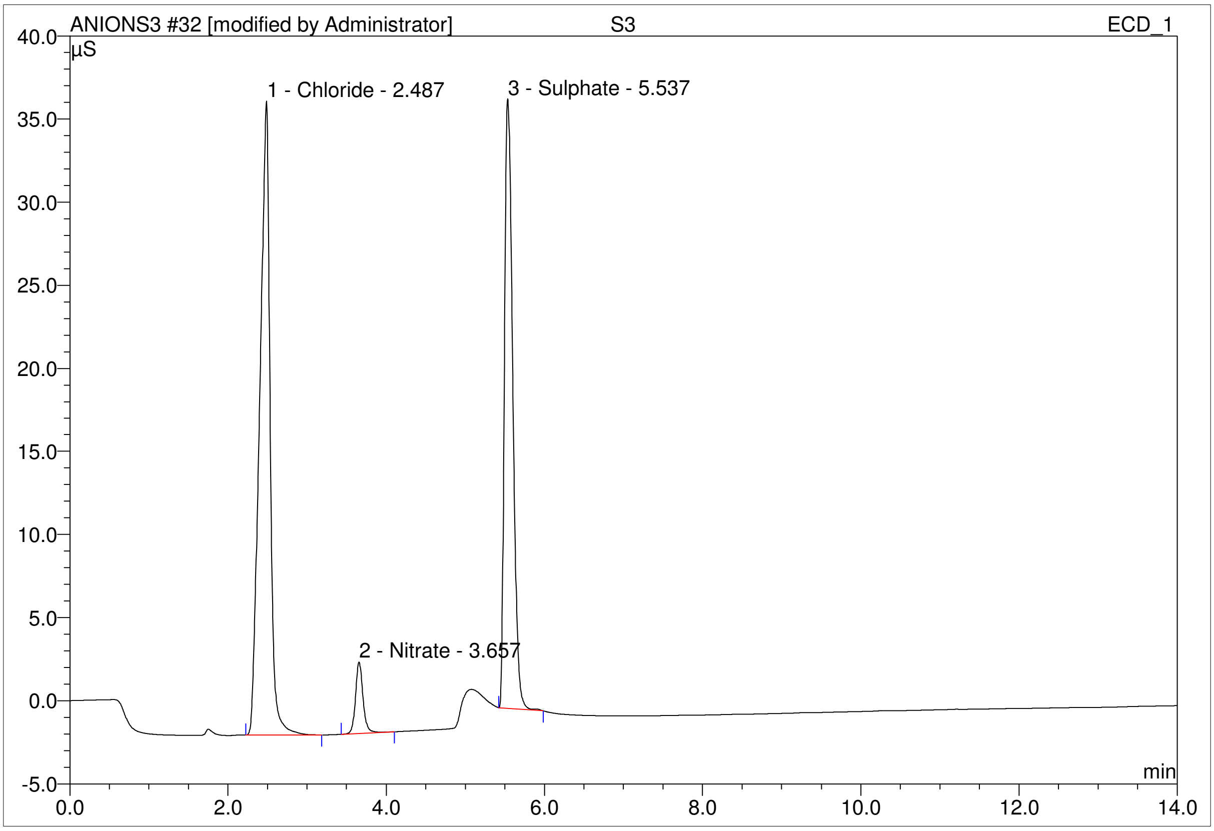
Sample Name:	**S2**	*Injection Volume:*	**20.0**
Vial Number:	**156**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 14:05**	*Sample Weight:*	**1.0000**
Run Time (min):	**10.82**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.37	Chloride	39.071	5.746	54.61	24.738	BMB
2	3.48	Nitrate	4.335	0.499	4.75	3.823	BMB
3	5.42	Sulphate	33.398	4.276	40.64	26.197	BMB*
Total:			76.804	10.521	100.00	54.758	

32 S3

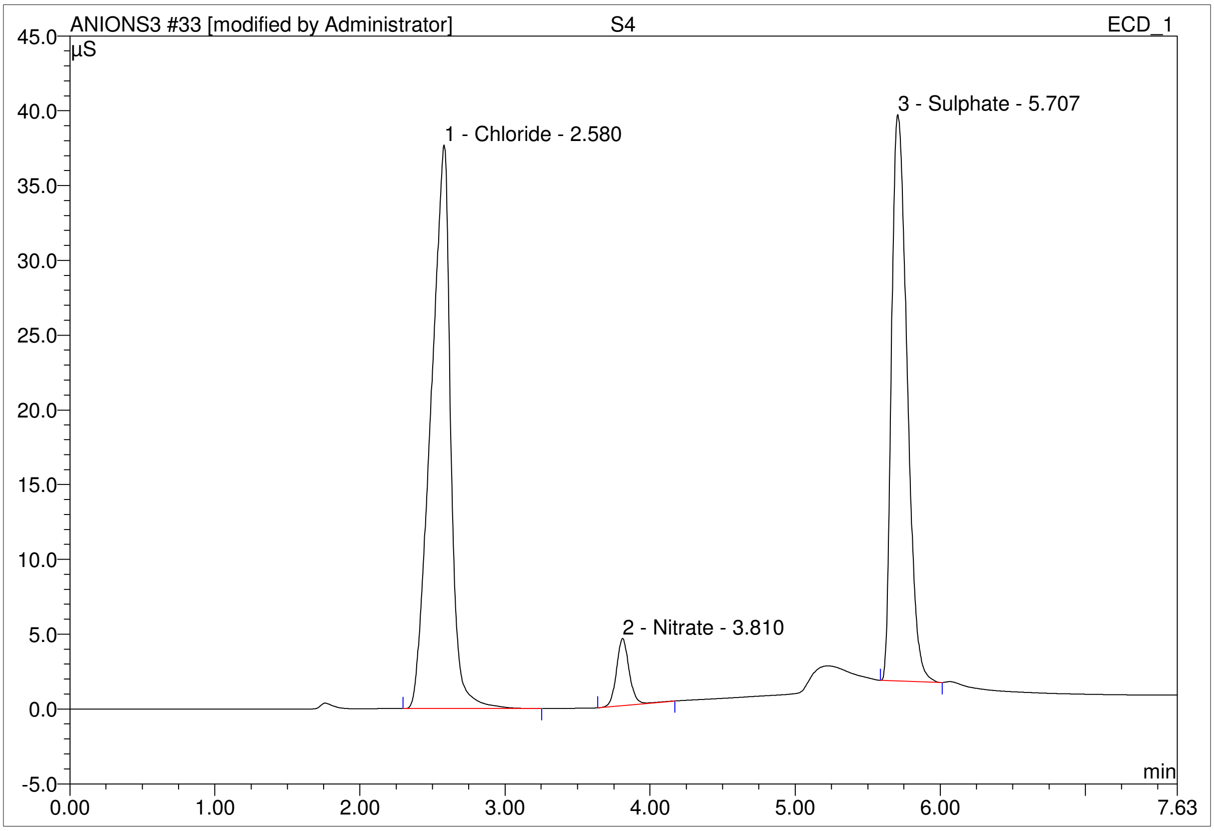
Sample Name:	**S3**	*Injection Volume:*	**20.0**
Vial Number:	**157**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 14:20**	*Sample Weight:*	**1.0000**
Run Time (min):	**14.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.49	Chloride	38.141	5.770	53.85	24.844	BMB
2	3.66	Nitrate	4.308	0.472	4.41	3.616	BMB
3	5.54	Sulphate	36.677	4.472	41.74	27.399	BMB*
Total:			79.126	10.715	100.00	55.858	

33 S4

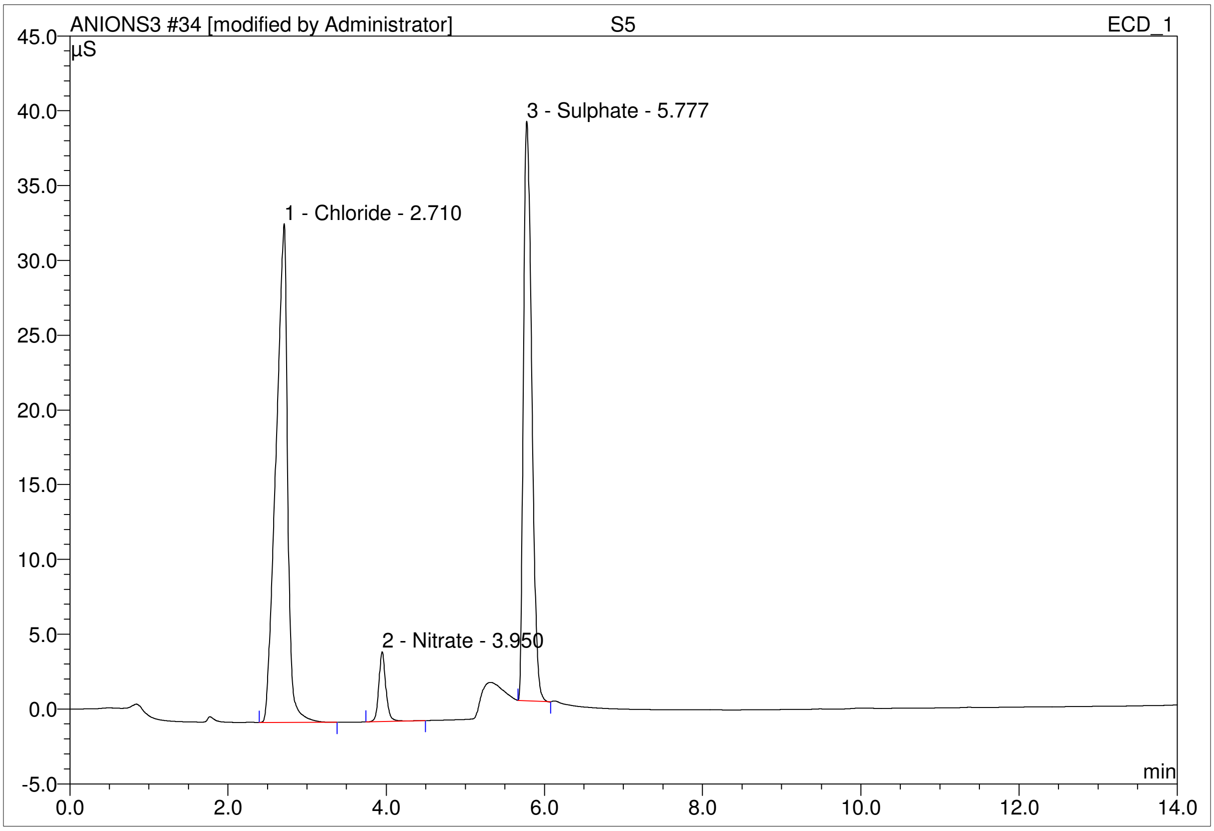
Sample Name:	**S4**	*Injection Volume:*	**20.0**
Vial Number:	**158**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 14:36**	*Sample Weight:*	**1.0000**
Run Time (min):	**7.63**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.58	Chloride	37.681	5.932	53.35	25.539	BMB
2	3.81	Nitrate	4.484	0.451	4.05	3.449	BMB*
3	5.71	Sulphate	37.874	4.736	42.60	29.015	BMB*
Total:			80.040	11.119	100.00	58.003	

34 S5

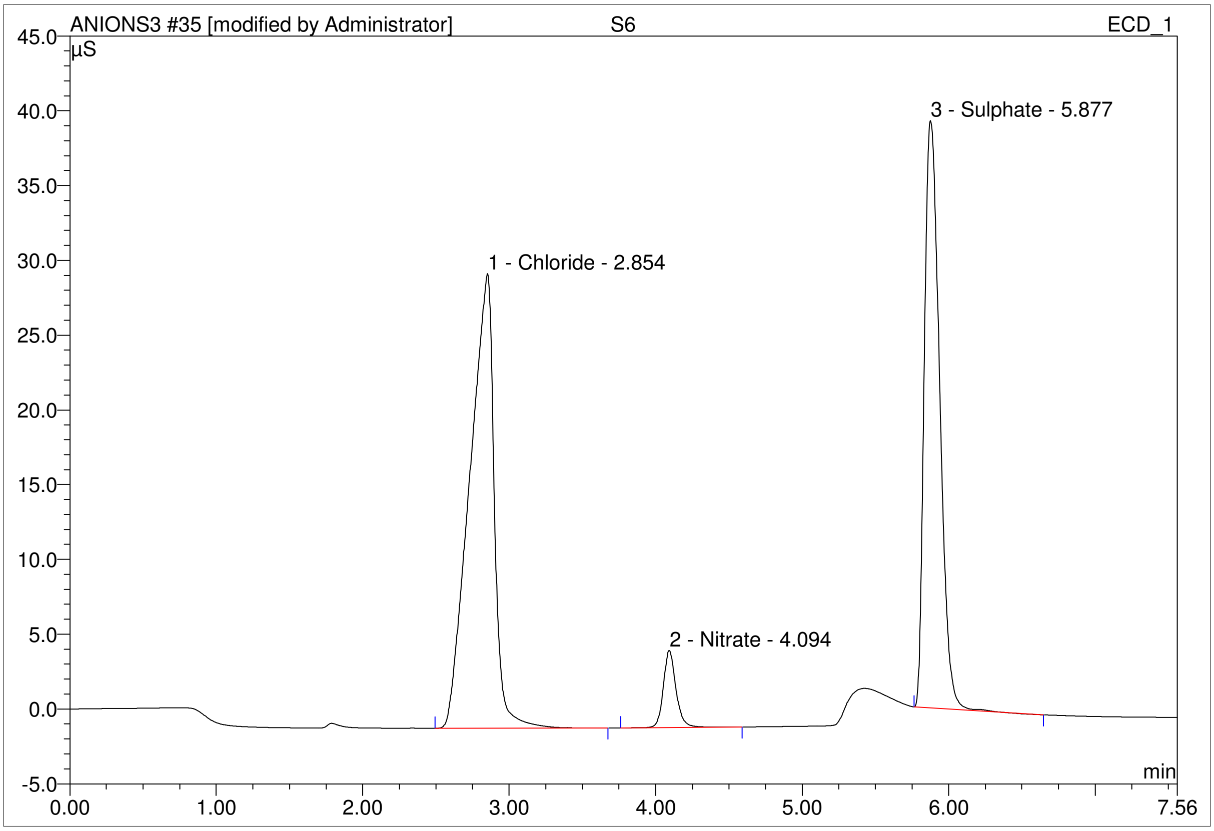
Sample Name:	**S5**	*Injection Volume:*	**20.0**
Vial Number:	**159**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 14:55**	*Sample Weight:*	**1.0000**
Run Time (min):	**14.00**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.71	Chloride	33.352	5.682	52.19	24.463	BMB
2	3.95	Nitrate	4.666	0.478	4.39	3.658	BMB
3	5.78	Sulphate	38.746	4.728	43.42	28.962	BMB*
Total:			76.764	10.887	100.00	57.083	

35 S6

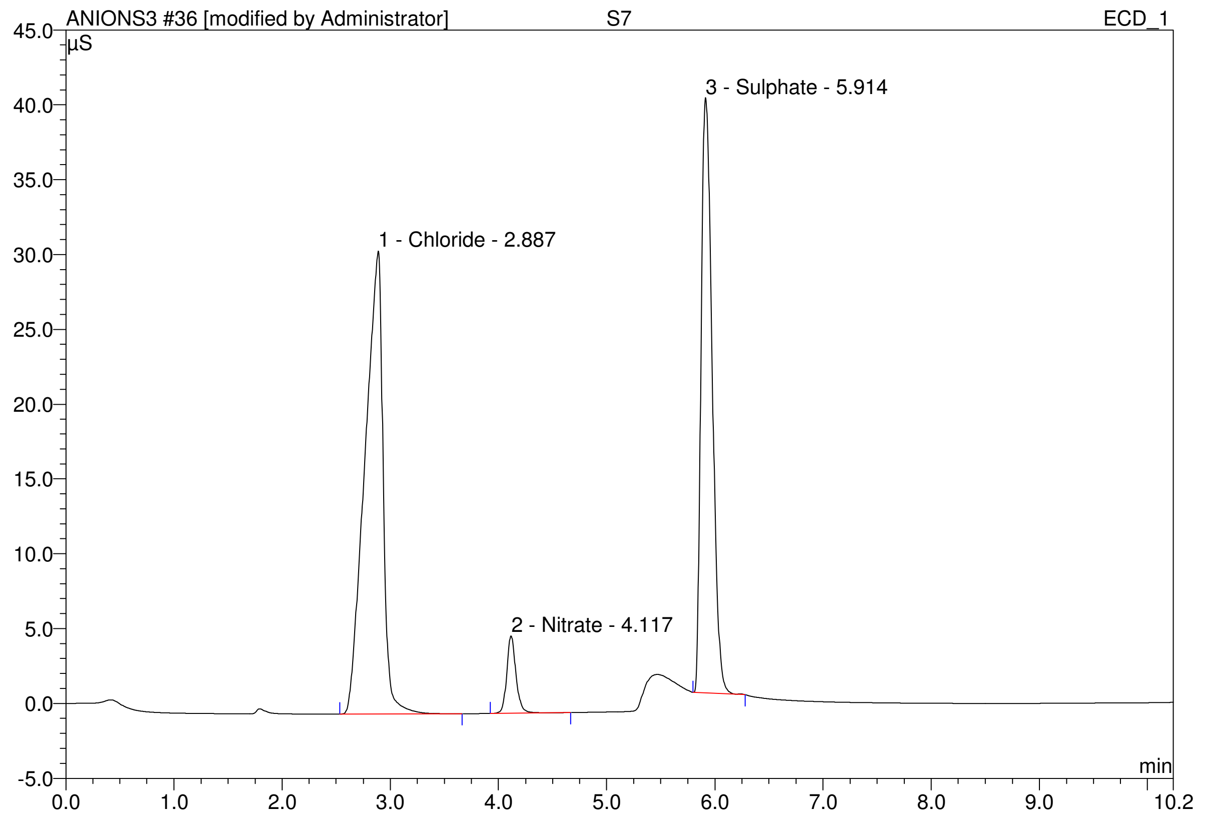
Sample Name:	**S6**	*Injection Volume:*	**20.0**
Vial Number:	**160**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 15:10**	*Sample Weight:*	**1.0000**
Run Time (min):	**7.56**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.85	Chloride	30.400	5.908	52.77	25.439	BMB
2	4.09	Nitrate	5.155	0.514	4.59	3.933	BMB
3	5.88	Sulphate	39.272	4.775	42.64	29.253	BMB*
Total:			74.827	11.197	100.00	58.625	

36 S7

Sample Name:	**S7**	*Injection Volume:*	**20.0**
Vial Number:	**161**	*Channel:*	**ECD_1**
Sample Type:	**unknown**	*Wavelength:*	**n.a.**
Control Program:	**Anions-manual-a**	*Bandwidth:*	**n.a.**
Quantif. Method:	**Anions3**	*Dilution Factor:*	**1.0000**
Recording Time:	**22/11/2012 15:19**	*Sample Weight:*	**1.0000**
Run Time (min):	**10.24**	*Sample Amount:*	**1.0000**



No.	Ret.Time min	Peak Name	Height µS	Area µS*min	Rel.Area %	Amount	Type
1	2.89	Chloride	30.928	6.020	53.41	25.920	BMB
2	4.12	Nitrate	5.168	0.511	4.53	3.910	BMB
3	5.91	Sulphate	39.770	4.740	42.05	29.038	BMB*
Total:			75.866	11.271	100.00	58.868	

15-Aug	3.867	15-Aug	3.921	15-Aug	3.922
30-Aug	2.874	30-Aug	2.378	30-Aug	2.036
15-Sep	2.748	15-Sep	2.747	15-Sep	1.967
30-Sep	2.618	30-Sep	2.661	30-Sep	1.37
15-Oct	2.22	15-Oct	2.972	15-Oct	2.415
30-Oct	3.888	30-Oct	4.216	30-Oct	4.57
15-Nov	3.455	15-Nov	3.828	15-Nov	3.616
30-Nov	3.176	30-Nov	3.113	30-Nov	2.854
15-Dec	3.691	15-Dec	3.375	15-Dec	4.012
15-Jan	3.985	15-Jan	3.467	15-Jan	4.645
30-Jan	1.365	30-Jan	1.354	30-Jan	1.764
	1		2		3
	3.08		3.093		3.015

rainfall				velocity	
	15-Aug	45.78	15-Aug	0.244	
	30-Aug	139.75	30-Aug	0.824	
	15-Sep	114.65	15-Sep	0.715	
	30-Sep	160.64	30-Sep	0.828	
	15-Oct	111.1	15-Oct	0.625	
	30-Oct	42.8	30-Oct	0.273	
	15-Nov	14.7	15-Nov	0.116	
	30-Nov	60.6	30-Nov	0.346	
	15-Dec	19.6	15-Dec	0.152	15 nov= po
	15-Jan	23.34	15-Jan	0.193	
	30-Jan	182.45	30-Jan	0.891	

ph

	15-Aug	6.64	6.67	6.52	6.66
	30-Aug	6.67	6.62	6.68	6.64
	15-Sep	6.35	6.56	6.48	7.24
	30-Sep	6.47	6.51	6.55	6.64
	15-Oct	6.45	6.67	6.67	6.85
	30-Oct	6.58	6.49	6.53	6.49
	15-Nov	6.56	6.55	6.66	6.54
	30-Nov	6.92	6.81	6.97	6.78
	15-Dec	7.15	7.08	6.99	7.11
	15-Jan	6.68	6.98	7.03	6.88
	30-Jan	7.18	7.33	7.12	7.26

15-Aug	3.964	15-Aug	4.653	15-Aug	3.859
30-Aug	2.358	30-Aug	1.286	30-Aug	1.365
15-Sep	2.147	15-Sep	1.237	15-Sep	2.548
30-Sep	1.321	30-Sep	0.851	30-Sep	2.996
15-Oct	3.275	15-Oct	1.243	15-Oct	2.709
30-Oct	2.715	30-Oct	4.264	30-Oct	4.423
15-Nov	3.449	15-Nov	3.658	15-Nov	3.933
30-Nov	2.378	30-Nov	1.916	30-Nov	3.172
15-Dec	3.823	15-Dec	3.985	15-Dec	3.469
15-Jan	3.964	15-Jan	4.653	15-Jan	3.974
30-Jan	0.953	30-Jan	1.129	30-Jan	0.925
	4		5		6
	2.75		2.625		3.033

tassium so should increase ph

6.64	6.74	6.67
6.68	6.58	6.54
6.75	6.58	6.65
6.85	6.48	6.55
6.71	6.78	6.86
6.48	6.49	6.58
6.74	6.87	6.74
7.01	6.84	7.01
6.97	7.28	6.87
7.12	7.34	7.33
7.25	6.99	7.28

15-Aug	3.953
30-Aug	2.745
15-Sep	2.856
30-Sep	2.863
15-Oct	3.127
30-Oct	3.686
15-Nov	3.91
30-Nov	3.476
15-Dec	4.101
15-Jan	3.756
30-Jan	1.146
	7
	3.238