A Water Quality Survey of the River Ouseburn

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Abstract

The Ouseburn represents a typical urban tributary under stress from continuing urban development and an ever-changing climate. Sourced in the North of Newcastle-upon-Tyne, England, the river flows for 17.5km through agricultural and urban environments, covering a catchment of around $65km^2$. As the river passes between these different environments a water quality survey has been conducted to allow the implications of urbanisation on the Ouseburn to be understood, centring on the impacts of faecal pollution from under-performing storm overflows.

Through targeted sampling, laboratory analysis and the reviewing of long-term data an understanding of the current and long-term water quality situation in the Ouseburn has been gathered. Results provide strong evidence that point-source faecal pollution is occurring at two locations along the sampled stretch; Kingston Park Outfall, a previously identified malfunctioning storm overflow serving a mixed-use development in the upper limits of the catchment, and another location downstream. The effect of this pollution on a downstream bathing site has been analysed, concluding at high flows faecal contamination levels are unacceptable but generally pollution is heavily localised. From reviewing long-term water quality data faecal pollution has become significantly worsened despite lower rainfall levels indicative of further damage to the malfunctioning storm overflow. Potential solutions to combat the effects of the pollution have been analysed concluding soft-measures are a preferred option until an ecological impact assessment can be undergone to understand the impacts of the pollution to the aquatic and riparian environments where large-scale projects may become a necessity.

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List of Abbreviations

BB	Brunton Bridge
BOD	Biological Oxygen Demand
BWD	Bathing Water Directive
CFU	Coliform Units
COD	Chemical Oxygen Demand
CSOs	Combined Sewer Outfalls
DO	Dissolved Oxygen
DV	Dichromate Value
EA	Environment Agency
EUWTD	European Urban Wastewater Treatment Directive
FIO	Faecal Indicator Organisms
FWMA	Flood and Water Management Act
JD	Jesmond Dene
KPO	Kingston Park Outfall
LDF	Local Development Framework
MF	Membrane Filtration
MLSB	Membrane Lauryl Sulphate Broth
MTF	Multiple-Tube Fermentation
NCC	Newcastle City Council
NGP	Newcastle Great Park
NRBMP	Northumbria River Basin Management Plan
NWL	Northumbrian Water Limited
OCSG	Ouseburn Catchment Steering Group
RHF	Red House Farm
SB	Salters Bridge
SUDS	Sustainable Drainage Systems
TMB	Three Mile Bridge
TOC	Total Organic Carbon
UKPO	Upstream Kingston Park Outfall
WFD	Water Framework Directive

1. Introduction

1.1 Study Area

The Ouseburn is an urban tributary sourced near Callerton where it continues to flow 17.5km through Kingston Park, Newcastle Great Park, Gosforth and Jesmond Dene before discharging into the Tyne by way of the Ouseburn Valley. The catchment is approximately 65km^2 and comprises of both arable and urban land. Historically, the region has been susceptible to pollution mainly through poorly-practised agriculture, former land fill sites and mining. Mass urbanisation and increased efficiency in draining rural areas now poses a great threat to the ecological status of the Ouseburn.

New developments have led to land use changes, artificial drainage and the confinement of the river. The Ouseburn has become a typical peri-urban river through the regeneration of areas such as Kingston Park, a neighbouring mixed use development, and the new addition of Newcastle Great Park (Figure 1.1). Creeping impermeability has become a well-documented matter within urban expansions. A loss of natural water storage leads to an increase in run off rate and a dramatic increase in peak flow in surrounding water bodies, creating the potential for flooding. The risk of flooding becomes greater as developments spill onto the river's natural floodplains.

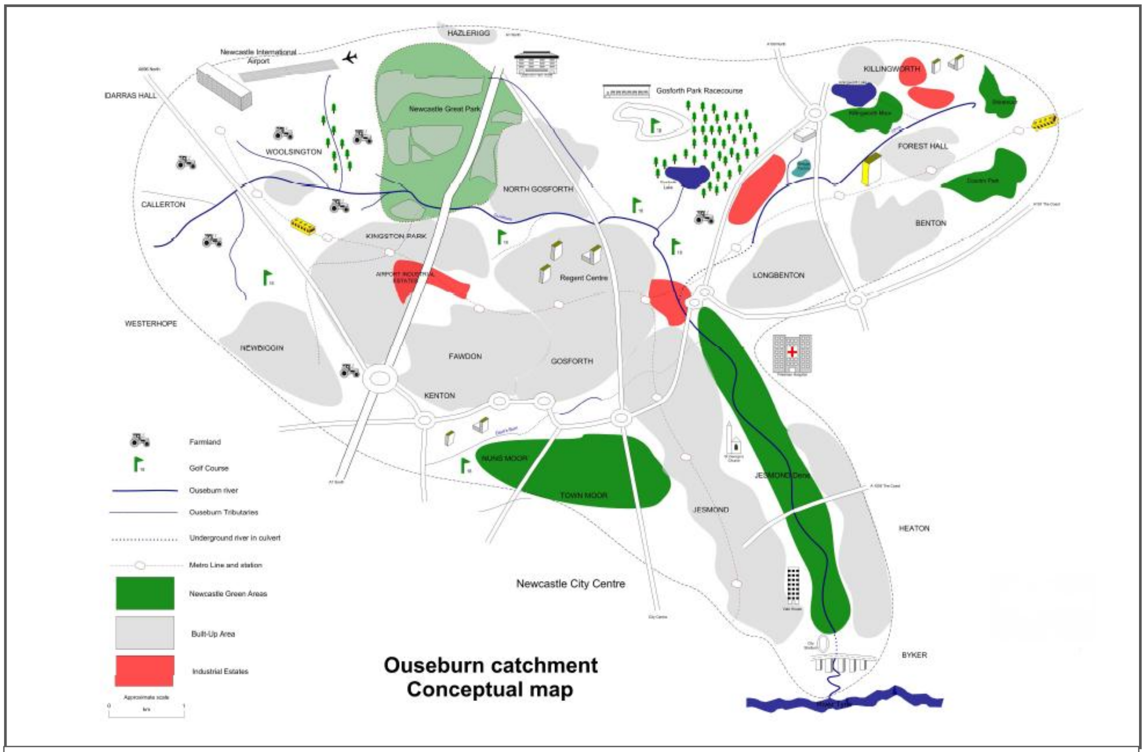


Figure 1.1: Ouseburn Catchment Conceptual Map (OCSG, 2009)

The upper reaches of the Ouseburn have been identified as an area at high risk from flooding. In June 2005, following an intense rainfall event, around 80 properties were affected by flooding from the combined sewer network (Newcastle City Council, 2008). Northumberian Water Ltd concluded that the Red House Farm Estate sewer was under capacity and the interaction between the river and the combined sewer overflow at Red House Farm was a contributing factor. An additional event in July 2007 showed that Kingston Park contributed 80% of the total flow of the river (Environmental Agency et al., 2009). The pressure exerted by urbanisation and creeping impermeability on the Ouseburn is paramount. The Northumbria Regional Flood and Coastal Committee were established by the Environmental Agency (EA) following the production of the recent Flood and Water Management Act 2010. The committee acknowledged the stress placed upon the Ouseburn with the contribution of £170,000 to address run-off from the Kingston Park estate and upstream rural areas (Hunt, 2009).

Jesmond Dene is an area of interest, in particular the implications of upstream pollution. The heavily modified Ouseburn dissects the steep-sided park where it often becomes a bathing spot for children in the summer months. The EA does not recognise it as a bathing water and the relevant standards are not enforced. Bathing waters are monitored weekly by the agency to detect the presence of pollution from sewage or livestock (Environmental Agency, 2011). Prior surveys have indicated that pollution is an issue in the Dene, predominantly at high flow, making the water course unsafe for bathing and unpleasant. Research shows the source of the pollution to be the Kingston Park Outfall. Jesmond Dene received a heritage lottery fund for the redevelopment of the park. The £6 million has been used for the creation of a new visitors centre with toilets, a petting zoo and landscaping with little attention paid to the monitoring and improving of the water in the Dene. Sampling will be continued in the area centring on faecal contamination.

The latest urban expansion along the Ouseburn is Newcastle Great Park which encompasses residential houses, commercial properties and community facilities. The development has implemented Sustainable Drainage Systems (SUDS) to manage surface water run-off from the site before discharging into the Ouseburn. SUDS are a novel approach to managing surface run-off aimed at overcoming the short-comings of the conventional approaches by mimicking natural drainage (National SUDS Working Group, 2004). They treat and control the impacts of run-off directly from the source. However, research indicates that the SUDS at Newcastle Great Park are not functioning correctly and are not being used to full capacity. The opportunity for a new river corridor, by tapping into the SUD network, has been extensively researched and can be seen to be beneficial to the Ouseburn in the '*Making Space for Water*

(2008)' project. The Newcastle Great Park estate appears to pose no threat to the status of the Ouseburn, but has caused concern to local residents. The concern stems from the flooding of 60 properties in September 2008 which was believed to be a direct result of the under performance of the SUDS (Northumbria Local Resilience Forum, 2008).

There exists a complex mesh of responsibilities within the Ouseburn catchment. Numerous stakeholders and shareholders interact with the river including Northumberland Water Ltd, Newcastle City Council, the EA, the public and the Ouseburn Catchment Steering Group, the latter of which drives for sustainable development in the region. Cooperation and clear communication between parties is crucial for the future success of the Ouseburn, particularly in accomplishing the challenges of the Water Framework Directive (WFD) and safe-guarding the future of Ouseburn inhabitants.

1.2 Policy

'*The WFD is a legally binding policy that provides a common framework for water management and protection throughout Europe'* (Kaika, 2003). The establishment of the framework added solidarity to a previously fractured policy structure, drawing together all aspects of water management in a common ground. The framework commits all European Member states to achieve a broad goal of '*good ecological and chemical status by 2015',* a process for local standards is defined within (Kallis and Butler, 2001).

Within the UK, the Department for Environment Food and Rural Affairs (DEFRA) spearheads a hierarchy that is responsible for the implementation of the WFD. The other parties include the EA, the Office of Water Services (OFWAT) and the Water Utilities. Great pressure is placed upon the utilities to strive for efficiency through innovation; combined with the current economic climate and the squeeze for profitability there is a barrier to the implementation of the WFD.

The implication of the WFD resonates in the Ouseburn; water quality analysis is conducted at a set of pre-determined sites identified in the Northumbria River Basin Management Plan (NRBMP). The analysis monitors the current status of the river, highlighting any failing's .The NRBMP was approved in 2009 and describes the actions required to improve the water environment over the next 20 years within the region. The Ouseburn presently has an overall score of 'good'. This project continues to align the goals of the WFD and NRBMP with the current status of the river through further targeted sampling. The WFD gives a standardised assessment method for which the water quality can be evaluated.

1.3 Water Quality

Urban runoff not only contributes to flooding but leads to reduced water quality through pollution from oil, grit and heavy metals. Previous studies suggest that point source pollution, as a result of urban runoff, occurs at Kingston Park Outfall due to outdated and damaged infrastructure. The continuation of monitoring contamination levels at the Kingston Park Outfall is at the heart of this project. The pollution has been shown to worsen at high flows causing the river to appear cloudy and have an unpleasant odour.

UK Climate Change Projections (2009) predict an increase of around 10 – 20% in winter precipitation within the Ouseburn catchment. In turn this leads to heavier more frequent precipitation and hence further urban runoff, meaning the risk of water pollution and floods become greater in the catchment. The monitoring of the present status of the river allows for an insight into the effects climate change could have on the future water quality of the Ouseburn.

Contamination of the Ouseburn came into the light of the media in recent times when a detergent spill foamed polluting the river. The spill originated from the Salters Bridge Outfall whose drainage system covers Benton Lane, Killingworth Village, Killingworth Moor and Forest Hall. Salters Bridge Outfall has been introduced as a new sampling station in this project.

Water quality is determined by physical, chemical and biological characteristics which are assessed against predetermined standards. Through strategic sampling and the conduction of laboratory tests this project provides a water quality survey of the Ouseburn, focused on the effect of Kingston Park Outfall on the faecal concentrations of the river but also identifying other present pollutants. The survey aims to identify specific areas where water quality is poor and align these with environmental water standards. The study supports previous research through the collation of long term quality data on the Ouseburn and the introduction of a one-off data set.

2. Aims & Objectives

2.1 Aim

Review a collation of three years of detailed long term water quality data on the Ouseburn, a typical peri-urban river, centring on faecal contamination. Generate original data through the continuation of targeted sampling for a further year, with the introduction of a new sampling post, and the inclusion of a one-off data set.

2.2 Objectives

- **To compose a review of relevant literature providing a background to the project.**
  Gather contextual information through the study of literature regarding water quality assessment, faecal indictor organisms, European and UK policy, environmental water standards and previous studies. Identify key shareholders and stakeholders in the Ouseburn catchment and the role which they play.

- **To review three years of detailed water quality data with the introduction of two new data sets.**
  Collate water quality data, focusing on faecal contamination, gathered from previous studies and align this with a continuation of sampling and a one-off faecal coliform data set.

- **To gather an understanding of the implications of faecal indicator organisms on the Ouseburn.**
  Through meetings and interviews with experts in the field, form an assessment of the consequences of faecal indicator organisms within the Ouseburn to support the findings of the literature review.

- **To produce a comprehensive sampling strategy for the continuation of sampling.**
  Formulate a structured plan to continue sampling at recognised stations with the introduction of a new sampling post at Salters Bridge Outfall. Learn the necessary laboratory skills to collect, analyse and interpret water samples, namely with respect to faecal indictor organisms.

- **To create an engaging summary report of major findings designed for public consumption.**
  Develop an informative appealing document with a summary of the conclusions of the report. It should be aesthetically pleasing but not shy on hard information and ultimately professional.

- **To compare results with environmental water standards.**
  Analyse findings against standards, such as the WFD to evaluate the true ecological and chemical status of the Ouseburn in greater detail.

- **To evaluate the implications of the conclusions with regards to the future of the Ouseburn.**
  Identify the sources of any threat to the overall water quality to the Ouseburn and offer up potential solutions and recommendations.

- **To write a summary document on water quality in the Ouseburn**
  Summarise all key findings in a professional document designed for local interest groups and wider dissemination.

3. Proposed Method Statement

Water quality is affected by a range of physical, chemical and biological variables. The quality will vary with weather conditions and the strategic sampling plan will incorporate this, providing a thorough analysis. The standardisation of results is critical and all assessments will be assessed in co-ordination with EA and WFD standards. A uniform approach allows for direct correlation between this study and previous surveys. The inclusion of a one-off faecal coliform count data set, carried out externally in Jesmond Dene, adds another dimension to the project.

3.1 Laboratory Tests

The following laboratory tests will be carried out to develop further knowledge into the water quality of the Ouseburn allowing conclusions to be drawn between previous studies and the unique data set. Laboratory training is essential to gather the necessary skills to implement the tests effectively and correctly. Preliminary testing under supervision will ensure the correct methods are followed.

3.1.1 Biological Oxygen Demand (BOD)

BOD is used by the EA to assess water quality standards in meeting the criteria of the WFD. The process allows for a prediction of the effects of pollution on the river, showing the amount of oxygen used by aerobic bacteria when decomposing under standard conditions. BOD is commonplace in wastewater treatment plants, providing an indication of the organic quality of the water.

Dissolved oxygen levels are particularly dependent on temperature, decreasing as temperature increases. To combat this two samples are collected, one of which is tested as soon as possible and the second incubated at room temperature (21^{o}C) for 5 days.

Unpolluted waters are said to give a result of 5mg/l or less. In 2009 the level of BOD in the Kingston Park Outfall was between 8-10mg/l from 3 samples (Ouseburn Catchment Steering Group, 2009). Previous studies over the past 3 years indicate a high level of BOD around the Kingston Park Outfall.

3.1.2 Chemical Oxygen Demand (COD)

COD is used to measure the amount of organic compounds in a sample. It indicates the amount of oxygen uptake by substances within the sample by way of a strong chemical oxidant. Results are the mass of oxygen consumed per litre of solution.

Normally COD values are higher than BOD results due to the less specific nature of the test; COD measures everything that can be chemically oxidised. COD can be placed into a ratio with BOD_5 (BOD_5/COD), giving a value between 0 and 1 where the greater the number the more biodegradable waste is present.

COD aids in the identification of toxic conditions in the watercourse. The test should be carried out prior to BOD to calculate the required volume of seeded dilution.

3.1.3 Enumeration of Bacteria (E. coli)

Testing for faecal bacteria is difficult and laborious. Therefore, a test for e-coli is carried out to indicate the presence of faecal bacteria that can be harmful to humans. E-coli are abundant in municipal waste due to their growth in human and animal intestines. A method of serial dilution of a sample which has passed through a membrane filter is recommended (Environment Agency, 2009). The filter is then placed in a solution allowing the growth of specific colonies which are counted after incubation. Aseptic techniques are essential due to the bacterial nature of the procedure.

Raw sewage is known to have a count of 10^6 CFU/100ml and the EA enforce a cap of 2000 CFU/100ml. The Ouseburn samples will be compared to these known standards as well as prior surveys. Previous research shows an excess of faecal contamination in the Ouseburn, particularly around the Kingston Park Outfall.

3.2 Gantt Chart

The proposed Gantt chart shows the method in which the project is anticipated to be managed. Following the production of the method statement and a more detailed sampling strategy, a more comprehensive plan can be manufactured.

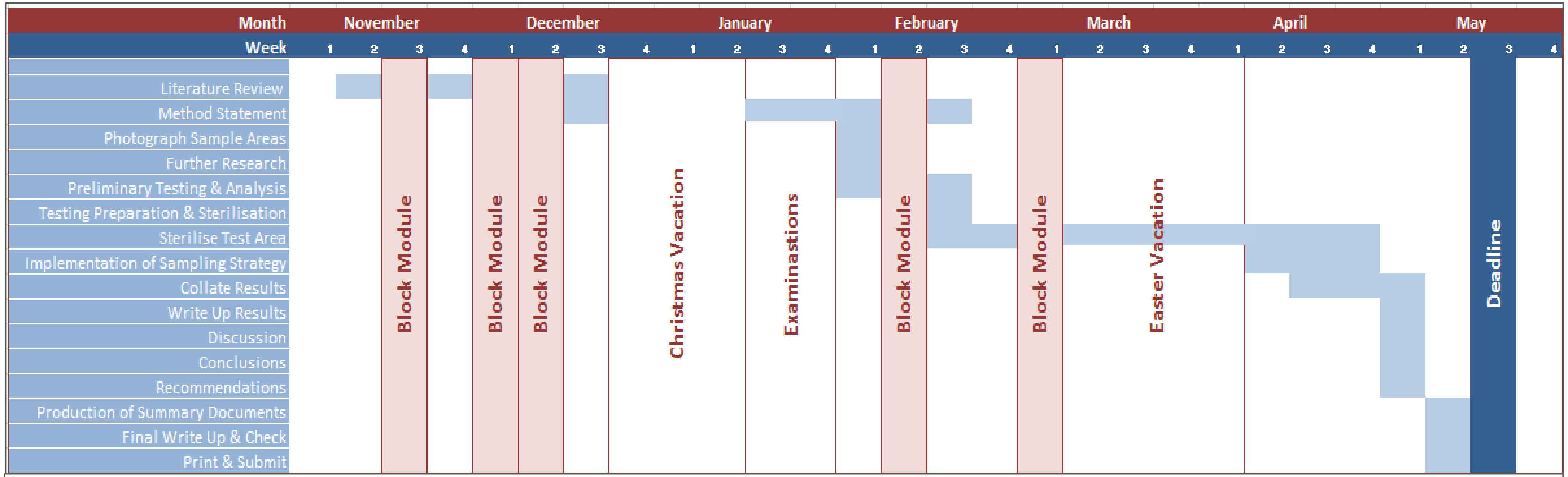


Figure 3.1: Provisional Gantt chart

3.3 Activity Description

Activity	Description
Photograph Sample Areas	This allows for an understanding to be developed of the sites that will be used for sampling. The sites will align with previous studies and the photographing of the sites allows for studying to be continued. It gives an insight into the potential barriers to sample collecting, allowing a solution to be produced.
Preliminary Testing & Analysis	The practising of laboratory techniques under supervision will ensure the correct method is undertaken and results are not compromised. This will also identify any immediate problems with the method statement and set a high standard for testing.
Test Preparation & Sterilisation	Cross-contamination is an issue when carrying out any environmental engineering experiment, therefore sterilisation is critical. Certain experiments, namely BOD levels, require a specific time delay hence good preparation is essential. Aseptic techniques should be used where required.
Implementation of Sampling Strategy	The sampling strategy will be outlined in the method statement. It will be constructed with the help of advice from experts in the field to ensure all factors are considered. The strategy must also comply with EA standards to provide a common framework for analysis.

Activity	Description
Analysis	To meet the objective of the creation of a summary document for wider dissemination; an accurate, relevant and representative analysis of the information gathered from the survey is critical. The success of the analysis is underpinned by consultation with stakeholders in the Ouseburn catchment; particularly regarding water quality, ensuring the success of wider dissemination.
Discussion, Conclusion & Recommendations	This will provide a large portion of the report and help to summarise the findings within a single section.
Production of Summary Documents	The summary documents are intended for wider dissemination, therefore sound planning is required to ensure success. It is important that there is appropriate input from the potential audience which influences the nature of the document. Therefore the identification and consultation of the target audience is critical, as is the foundation of relationships within this audience for technical assistance. The information can be systematically distributed in a variety of ways, including written information, electronic media and person-to-person communication. Information included in the document should be accurate, relevant and representative (Research Utilization Support and Help, 2001).

3.4 Sampling Stations

Figure 3.2: Sampling Station Locations (Google Maps, 2009)

Figure 3.2 shows the proposed sampling stations on a large scale. The method statement will contain a more detailed overview of sample locations including on-site photographs to be used as reference for future research. Sampling procedure will be carried out in accordance with EA Standards '*Practices and procedures for sampling' (2010b)*. The locations have been chosen to align with previous studies and allow for direct comparisons to be made with regards to long-term water quality in the Ouseburn.

Sample 1, located at Brunton Bridge, has been placed to identify the quality of the water entering the catchment. Sample points 2 and 3 are located upstream and downstream of Kingston Park Outfall to determine the effects of the outfall on water quality. Point 4 will help to identify the quantity of pollution entering the Ouseburn from A1 runoff. Salters Bridge Outfall has been added to the survey as pollution is also suspected to be entering the river at this point. Sample point 6, Jesmond Dene, has been chosen to continue the work of prior surveys.

4. Literature Review

'The quality of water, whether it is used for drinking, irrigation or recreational purposes, is significant for health in both developing and developed countries worldwide. Water quality can have a major impact on health, both through outbreaks of waterborne disease and by contributing to the background rates of disease' (World Health Organisation, 2001).

To allow the water quality of the Ouseburn to be effectively analysed and to meet the objectives of the project there is a requirement to gather an understanding of; the infrastructure previous studies identified to be deteriorating water quality in the catchment, the policy that dictates the standard of the Ouseburn's waters and the different ways stakeholders interact with the river. It is important to analyse the work of previous years on the water quality of the Ouseburn to detect potential gaps in prior research. The method statement includes a review of more technical and theoretical concepts relevant to laboratory experiments. The aim of this section is to provide background context to the study in three main areas; combined sewer overflows, policy and stakeholder analysis.

4.1 Combined Sewer Overflows (CSOs) & Misconnections

CSOs represent an issue at the forefront of the water industry; the inherited infrastructure of previous generations is outdated, inefficient and unsustainable. Combined sewers carry wastewater and surface runoff in the same pipes directly to wastewater treatment works, typically found in pre-1960 developments. Much of Newcastle's development occurred during the Industrial Revolution as population grew generating demand for housing; combined sewers are therefore present within the study catchment. Modern estates utilise a system separating the foul water from the rainfall, present in the more recent developments in the catchment.

The combined sewer system becomes vulnerable in periods of intense rainfall; overwhelmed by the amount of surface water the system requires a release to prevent water propagating up pipes and resurfacing. Urbanisation increases impermeability, increasing surface runoff and further exacerbating the situation. CSOs act as this release valve for the system, ensuring excess flow is acceptably discharged at managed sites. CSOs are therefore a critical part of water infrastructure, and a design necessity (Water UK, 2009). Regulation and management is critical to monitor the discharges into nearby watercourses and prevent environmental degradation, a role assumed by the Environment Agency (EA). Regulation allows discharge *'only as a result of rainfall or snowmelt*', therefore outfalls should not be discharging in times of no rainfall (Water UK, 2009).

Theoretically a well-managed and maintained CSO poses little threat to the water quality of receiving waters. If the outfall operates only in times of heavy rainfall, as specified by the EA, the foul water becomes substantially diluted prior to entering the watercourse where further dilution occurs. Other pollutants are associated with surface runoff, such as grits and oils, but this study targets faecal contamination. Biskupski (2011), Field (2010) and Willis (2009) conducted studies at times of low flow which demonstrated, through targeted sampling, pollution entered the Ouseburn from Kingston Park Outfall (KPO) regardless of rainfall quantity. KPO is not a CSO; it is a storm overflow behaving like a CSO suggested to be due to a misconnection or failing infrastructure.

'*A misconnection is where incorrect plumbing in your home causes waste water from your dishwasher, washing machine, sinks, baths and even your toilet being flushed directly into your local river instead of to the sewage treatment works (Connect Right, 2012).*' Misconnections are a pressing issue within the water industry, however identifying the source of misconnections is inherently difficult due to vast networks of infrastructure where responsibilities diverge from water companies to homeowners.

Previous studies have conclusively shown high levels of faecal contamination discharging from KPO. Biskupski (2011) expanded the survey to consider the effects of Field's (2010) and Willis' (2009) previously well-established KPO faecal pollution on Jesmond Dene (JD), a downstream location used for recreational activites and bathing. Biskupski (2011) concluded there are '*unwanted negative effects on the water quality further downstream at Jesmond Dene'* as a result of the outfall. There are some criticisms of this study. Firstly the sampling regime used did not show conclusively KPO to be responsible for faecal contamination in JD. Sampling was concentrated heavily around KPO with a great distance prior to JD which was not sampled, where a number of outfalls are present which may be responsible for the pollution. A lack of data means that no entirely valid conclusions can be drawn about the relationship between KPO and JD from Biskupski's study. Another drawback of the study is the absence of long-term water quality data for the JD site, but as the survey has evolved so has the need for more sampling stations to build the body of evidence to prove pollution from KPO is occurring and affecting people. Biskupski (2011) added to the story of the Ouseburn's water quality by expanding beyond the two previous surveys catchments, but left behind a large un-sampled stretch of river. Salters Bridge (SB) has been included in this study as an initial step in bridging this gap.

Previous studies undeniably demonstrate the negative effects of KPO on the catchment, showing faecal pollution to be entering the watercourse. It is important that the body of evidence continues to grow adding greater value to the long-term analysis. A problem across all previous studies is the collection of samples solely in periods of low flow. While this allows for accurate comparisons across water quality investigations it also presents a gap in the research. CSOs operate in times of high flows, therefore to understand their implication on the water quality of the Ouseburn it is valuable to test at these times. The same is true of misconnections, at higher flows the system is placed under greater stress and the misconnection's implications become amplified. The March to April timeframe consistently used in previous studies to analyse the water quality has been shown to not represent these desirable higher flows due to a lack of rainfall. The inclusion of a unique data set gathered between October and November in this study presents an opportunity to expand the knowledge of contamination in the Ouseburn to outside of the low flow timeframe.

One of the most comprehensive areas of research on CSOs and under-performing storm overflows regards the development of solutions to correct the system. Combined sewers are inherently inefficient; mixing surface water, of a much higher quality, with foul water for combined treatment is more energy intensive than treating separately. Rainfall is of a high enough quality to have many applications such as garden watering or car washing. Unfortunately an outdated system has been inherited where it is not plausible, practically or financially, to eradicate combined sewers. Solutions primarily aim therefore at preventing polluting water entering the river system. Sustainable Drainage Systems (SUDS) are the most documented and well-established solution. Since the passing of the Flood and Water Management Act 2010 (FWMA) SUDS are a legal requirement on new developments to manage surface water runoff, becoming assets of the Local Authority after completion.

SUDS are present in the Upper Ouseburn study catchment as part of the Newcastle Great Park (NGP) development. Extensive research has made case for the inclusion of the NGP SUDS as storage capacity for the Ouseburn in times of flooding, primarily through the *'Making Space for Water'* project. Although research has consistently shown the benefits of a new river corridor little has been done to make this a reality. This area of research has become saturated and immobile; this study centres purely on water quality in the Ouseburn to build a greater knowledge of the current situation moving away from focusing on the operation of SUDS in the catchment.

4.2 Policy & Standards

Policy is a vital part of a surface water quality survey as it dictates the standards by which the watercourse can be compared and sets out the legal obligations of involved parties. Research informs policy makers to help shape policy; policy requires constant improvement and hence further research, creating a cycle. There is however another power that shapes the development of policy, public concern. The public plays a powerful role in the creation of policy; governments act if the public shows sufficient concern. '*Studies have found that the public learns a large amount about science through consuming mass media'* (Wilson, 1995). A well-informed public could perhaps be the greatest tool in improving the future water quality in the Ouseburn. The water quality surveys of Biskupski (2011), Field (2010) and Willis (2009) convincingly show on-going faecal pollution of the Ouseburn, but if the public is not presented with the information in an understandable manner little action can be achieved. '*Science is an encoded form of knowledge that requires translation in order to be understood'*, there is a requirement for scientific findings from the Ouseburn to be translated to the public, a role currently fulfilled by the Ouseburn Catchment Steering Group (OCSG) (Ungar, 2000) . A gap can appear between research and the public; this project aims to help bridge this gap with the production of a document which summarises the key findings of this project designed for public consumption. The OCSG continues on-going work with public engagement and consultation in the production of this document may be appropriate.

With regards to current policy which dictates water quality standards in UK Rivers, the previously discussed Water Framework Directive (WFD) tops the agenda. All previous studies have utilised the WFD as a benchmark to judge the chemical and ecological status of the river. The Ouseburn was previously rated as '*good*', achieving objectives set out by the directive (Biskupski, 2011). The WFD is aimed at a larger scale than the potential pollution from one misconnection on a relatively small catchment like the Ouseburn; the objectives fail to trickle down.

The EA monitor the water quality of the Ouseburn with regards to the WFD objectives from source to confluence through 5 sampling stations. The large expanse these stations cover does not allow the effects of localised point-source pollution to be recognised effectively. Callard (2008) evaluated the EA's ratings for the 5 sample points (Table 4.1), showing degradation in water quality between Brunton Bridge (BB) and Three Mile Bridge (TMB), spotting the need for concentrated sampling in the region to produce a detailed water quality surveying of the Upper Ouseburn. Table 4.1 shows the results of the EA General Quality Assessment of the Ouseburn between 2002 and 2006, while the Ouseburn is said to meet the standards over its entire catchment site by site it does not. The table shows water quality to be poor at the source, in the vicinity of the airport, and deteriorate further between BB and TMB, the location of KPO, which leaves the water body in poor condition through its remaining stretch. Biskupski (2011) identified JD as a bathing site and assumed that KPO was the cause of this degradation, suggested to be the case in Table 4.1. As previously discussed the large sampling distribution and the location of other outfalls in the stretch between KPO and JD makes it difficult to validate the relationship and this study will attempt to add further weight to this argument through the inclusion of SB as a sample point.

The EA modified its water quality criteria since Callard's (2008) study adopting a '*one out, all out'* policy following the implementation of the WFD strategy, moving away from General Quality Assessments and towards a tougher, more sophisticated methodology incorporating risk. Hence where previously the Ouseburn was designated an overall '*good*' status this may not be the case under new methodologies. These more stringent assessment criteria have led to a reduction in the amount of rivers meeting WFD objectives. The new methodology analyses the status of a river in three divisions; biological quality – an indicator of overall health, chemical quality – an indicator of organic pollution and nutrient status – an indication of pollution from agricultural practises. This project focuses on the chemical quality of the river aimed at identifying organic pollution. The Environment Agency's (2011) '*Method statement for the classification of surface water bodies v2.0'* provides an overview of the techniques and water quality parameters required to classify a water body in line with the WFD. As this study's primary focus is on faecal pollution in the Ouseburn it is impractical, irrelevant and time consuming to attempt to provide a classification of the river as a whole under this methodology but rather results should be analysed against typical levels, previous results and other standards using EA laboratory standards to present a solid case for organic pollution in the Ouseburn. The EA classifications are helpful and have been used to provide an overview of the current water quality in the river and identify points of interest requiring further investigations.

Table 4.1: General Quality Assessment of Ouseburn 2002-2006 (Callard, 2008)

From	To	Sample	km	2002	2003	2004	2005	2006
Source	Airport steam	Woolsington	3.8	C	D	D	D	D
Airport steam	Bent Hill	Brunton Bridge	2.2	C	C	C	C	B
Bent Hill	Great North Road	Three Mile Bridge	2	C	D	D	D	D
Great North Road	Castle Farm	Castle Farm	2.4	C	B	C	C	C
Castle Farm	Jesmond Dene	Jesmond Dene	1.8	C	B	C	C	C
Jesmond Dene	Tidal limit	Jesmond Dene	1	C	B	C	C	C
Tidal limit	Tyne	N/A	1	NA	NA	NA	NA	NA

Table 4.2: Classification for General Quality Assessment (Environment Agency, 2010a)

Classification	Description	
	Biological	Chemical
A - Very Good	Biology similar to that expected for an unpolluted river	All abstractions Very good salmon fisheries Cyprinid fisheries Natural ecosystem
B - Good	Biology is a little short of an unpolluted river	All abstractions Very good salmon fisheries Cyprinid fisheries Ecosystems at or close to natural
C -Fairly Good	Biology worse than expected for unpolluted river	Potable supply after advanced treatment Other abstractions Good cyprinid fisheries Natural ecosystems, or those corresponding to good cyprinid fisheries
D - Fair	A range of pollution tolerant species present	Potable supply after advanced treatment Other abstractions Fair cyprinid fisheries Impacted ecosystems
E - Poor	Biology restricted to pollution tolerant species	Low grade abstraction for industry Fish absent or sporadically present, vulnerable to pollution Impoverished ecosystems
F - Bad	Biology limited to a small number of species very tolerant of pollution	Very polluted rivers which may cause nuisance Severely restricted ecosystems

Another policy that resonates in the study catchment is the FWMA; a policy created to provide an overview of all flood and coastal erosion risks in the UK allowing a management strategy of local flooding to be developed. Surface water quality, not flooding, is the focus of this project but the FWMA has indirect positive effects on this. The key aspect of the policy which is relevant to a water quality survey of the Ouseburn regards the implementation of SUDS. One of the primary aims of the act is:

'To encourage the uptake of sustainable drainage systems by removing the automatic right to connect to sewers and providing for unitary and county councils to adopt SUDS for new developments and redevelopments (Ciria, 2010).'

By removing the automatic right to connect to existing sewer systems and encouraging the development of SUDS, the FWMA alleviates flooding from an overcapacity of current surface water drainage whilst also reducing the operation of CSOs and eradicating the creation of new misconnections preventing further degradation in the water quality of receiving waters. Within the catchment Kingston Park presents an example of a pre-FWMA development where connecting to the sewer network was an automatic right and NGP an example of a post-FWMA development where SUDS have been implemented to meet the requirements of the act. Previous investigations have explored the effectiveness of the SUDS with regards to their flood storing and water quality improving capabilities. This project's primary focus is on faecal contamination; it may be valuable to compare samples from an old-fashioned sewer connected development, Kingston Park, with that of a modern separate, NGP, especially as previous studies show KPO to be an example of a poorly connected sewer discharging faecal pollution. The effectiveness of the FWMA on receiving watercourses can then be observed.

Further policy regarding storm overflows is the European Urban Wastewater Treatment Directive (EUWTD). The directive spans a wide range of contemporary issues regarding wastewater treatment systems, not all directly relevant to the Ouseburn. The major implication of the EUWTD on the Ouseburn is summed up by the European Commission (2012) as:

'Ensuring that national authorities take measures to limit pollution of receiving waters from storm water overflows via collecting systems under unusual situations, such as heavy rain'

As previously discussed, the EA state regulation allowing discharge only as a direct result of heavy rain or snowmelt in line with the goals of the EUWTD. The EUWTD is a legally binding agreement between European Member States. While the EA has taken measures to limit the pollution from storm water overflows through the creation of consents to discharge, Biskupski

(2011), Field (2010) and Willis (2009) conclusively showed faecal pollution entering the system from KPO at times of low flow questioning the effectiveness of the present infrastructure which under EUWTD obligations should be designed to '*the best technical knowledge, not entailing excessive costs, regarding prevention of leaks and limitation of pollution of receiving waters due to storm water overflows'* (European Commission, 2012). The previous investigations have provided data that conflict with this legally binding agreement, it is important to consider the EUWTD when analysing potential point source pollution from storm water overflows in the catchment.

In review the policies discussed outline the legal obligations of involved parties, but it is important this review derives exact values than can be used as a comparative tool to indicate unacceptable levels of pollution in the river system, particularly focusing on faecal coliforms as other tests are supportive aids. Policy sets out long-term objectives on a European, National and District scale; the intention of this study is to survey water quality in the Ouseburn and analyse the current status of the river which by its nature is a localised issue not necessary transposed up to the scale of the WFD. To analyse the current status of the river is it important to provide direct values to compare results against providing a baseline by which to question data. Guidelines are usually categorised into three areas; guidelines for drinking water, agriculture and safe recreational environments, of which the Ouseburn falls into the latter.

Biskupski (2011) utilised the Bathing Water Directives (BWD) value of 2000 CFU/100ml to provide an indication of unacceptable levels of pollution at JD. The BWD is currently under review and the value of 2000 CFU/100ml is expected to be lowered to 500 CFU/100ml. JD is regularly used for bathing by youth in summer months hence the BWD is directly relevant at this location, but the remainder of the Ouseburn cannot realistically be categorised as a bathing water. Although the Ouseburn is not a recognised bathing water it is an easily accessible recreational area for the public and if levels are above those outlined in the BWD the river is not suitable for body contact and poses a potential threat to public health. Values of faecal coliforms should therefore benchmarked against BWD standards as while the river is not used for bathing along its entire stretch there is large potential for human interaction with the watercourse.

4.3 Stakeholders

An integral part of an analysis of a watercourse is understanding how stakeholders interact with the resource to discover the relevance of a study i.e. there would be no real need to analyse the faecal contamination in a river that nobody interacts with. It is vital to understand the needs and wants of all members involved to truly develop a sustainable catchment; avoiding a misalignment of goals. Stakeholder analysis allows an understanding of why a study is required and provides background context to the project, understanding where the project slots into the bigger picture.

The principle aim of the EA(2012) is '*to protect and improve the environment, and to promote sustainable development*'. The EA operates in a large variety of fields; flooding, drought, agriculture, fisheries, navigation, climate change and most importantly for this study water quality. As environmental regulators responsible for the implementation of the WFD the EA set the standards by which the Ouseburn's water quality can be analysed dictating the rules of the game, discussed in the Policy section of this review. The EA work alongside water utilities to identify and tackle CSOs and misconnections deemed to have large impacts on the aquatic and riparian environment; removing, improving or rebuilding over 6000 unacceptable overflows between 1989 and 2008 (Water UK, 2009). The EA are active in combatting faecal pollution from storm overflows through regulation and are committed to identifying unacceptable overflows which damage water quality, which previous studies demonstrate Kingston Park is.

Northumbrian Water Limited (NWL) is the water utility operating in the Ouseburn catchment, working under EA regulations to ensure there are no adverse effects on the environment from their water infrastructure. NWL provides water and sewerage services to the entire North East district; responsible for the maintenance and management of major water infrastructure such as CSOs, water and sewage mains and communication pipes. The main interaction between NWL and the Ouseburn comes from the operation of storm overflows which relieve by way of the river at times of high flow. NWL is responsible for identifying the misconnection in infrastructure that Biskupski (2011), Field (2010) and Willis (2009) deemed to be unacceptably polluting the watercourse. Initially a relationship can be drawn between EA and NWL; NWL owns the water infrastructure whilst the EA regulate the effect of that infrastructure on the environment.

Newcastle City Council (NCC) is the local authority in the catchment area; their main interaction with the Ouseburn stems from the Local Development Framework (LDF). The LDF outlines the spatial planning strategy within the region. Urban development increases surface impermeability, leading to not only more runoff but quicker runoff which stresses water infrastructure requiring more frequent operation of storm overflows than previous in turn polluting nearby watercourses. The NCC determines the spatial layout of developments around the Ouseburn and is therefore a key stakeholder, governing the future human stresses that will be placed on the watercourse and the layout of key infrastructure. The NCC is required to consult with the EA on the creation of the LDF. The importance of the EA within the Ouseburn continues to resonate, acting as an umbrella of regulation over major stakeholders.

As previously discussed public participation is critical to the future of the Ouseburn, the OCSG work to boost public understanding and stakeholder involvement. The OCSG (2009) mission statement states:

'A commitment to continuously improve water quality and ecological status, lower flood risk, increase access, recreation and amenity value whilst optimising economic/business activity, using an active public participation process'

The group creates a platform for dialogue aimed at removing boundaries between professional bodies, which can often be perceived as inaccessible and local residents. Stakeholder interaction is critical; professional bodies can learn from local knowledge and public concern and the public can empathise with and understand the constraints of professional bodies. This is the area where this study can be presented as an informative tool, adding purpose to the study. Dr Paul Quinn, Chairman of the OCSG, instigated the creation of the long-term water quality analysis of the Ouseburn driven from public concern for the current state of the Ouseburn.

On the whole this report fits into the stakeholder framework as a tool to help inform all involved stakeholders of the current quality status of the Ouseburn using the OCSG as a platform for presentation. The stakeholder analysis has identified the different responsibilities of the different parties that interact with the river.

4.4 Conclusions from Review

The major conclusions of the review are:

- All previous studies conclusively show faecal contamination to be occurring in the Ouseburn at low flows in the vicinity of Kingston Park Outfall indicative of a misconnected sewer or under-performing infrastructure. There is a need to continue to sample in this region to add further weight to this argument.

- Biskupski (2011) expanded the survey to examine the effect of KPO on the bathing waters of JD. The sample distribution however was highly spread; many other outfalls in the stretch may be responsible for the downstream pollution shown at JD. There is a need to increase sampling between KPO and the Dene to validate the relationship, this has been done by the inclusion of the SB sampling station.

- Sampling in previous studies took place in the March to April period, not indicative of high flows and hence the operation of storm overflows. The inclusion of a data set gathered between October and November will help to expand the research and give greater insight into the effect of storm overflows on the watercourse.

- A well-informed public have an important role to play in the future of the Ouseburn, public concern drives change. Science is an encoded form of knowledge and it is necessary to translate the findings of this report into an easily digested summary report for wider dissemination with potential collaboration with the OCSG.

- The major quantitative guideline relevant to the study is the BWD, particularly the value of 2000 CFU/100ml as a standard for faecal contamination.

- A complex mesh of responsibilities exists in the Ouseburn catchment; the EA have a large role in regulating the environmental damage on the river. The OCSG shows positive steps in reaching a collaborative approach to management of the Ouseburn, providing a platform for dialogue between professional bodies and the public. This report fits into the stakeholder framework as a tool to help inform all involved stakeholders of the current quality status of the Ouseburn using the OCSG as a platform for presentation.

5. Method Statement

The aim of this section is to provide details on the methodologies used in the gathering of primary data to allow the objectives of the project to be achieved. Where necessary a review of more technical and theoretical concepts relevant to laboratory experiments has been provided as background context. Laboratory procedures in this method statement have been derived from the Newcastle University School of Civil Engineering and Geosciences '*Standard Methods'* (2012).

5.1 Health & Safety

When working in the field or the laboratory a number of health and safety risks can arise. University Safety Policy must be adhered to at all times. Copies of health and safety documentation are available in Appendix 3.

For general laboratory work an induction is required, this provides the basic knowledge required to operate safely and efficiently in a biological laboratory environment. The induction includes an overview of the methods to be used in the study including a hard-copy of the *'Standard Methods'*. A copy of the *Environmental Engineering Laboratory Safety Policy* must be read, understood and signed.

Due to the biological nature of the study a *BioCOSHH Risk Assessment* is required to coordinate with University Regulations. A BioCOSHH is required by law for the possession or use of biological agents.

A risk assessment must also be carried out for working in the field and laboratory. These are more general, identifying hazards and then outlining the procedure to minimise its occurrence. Hard-copies of all health and safety documentation must be available at all times during experimenting, allowing persons who interact with the project in any way to understand the nature of the experiment and associated risks.

5.2 Sampling

5.2.1 Sampling Method

'The taking of a sample in the correct manner, using a suitable container, and transporting and storing it appropriately underpins any microbiological examination' (Environment Agency, 2010b). If an informed and suitable sampling procedure is not performed, any laboratory testing of that sample is rendered useless. The sampling method in this study has been created through consultations with laboratory technicians and under Environment Agency (EA) recommendations, ensuring the reliability and accuracy of results.

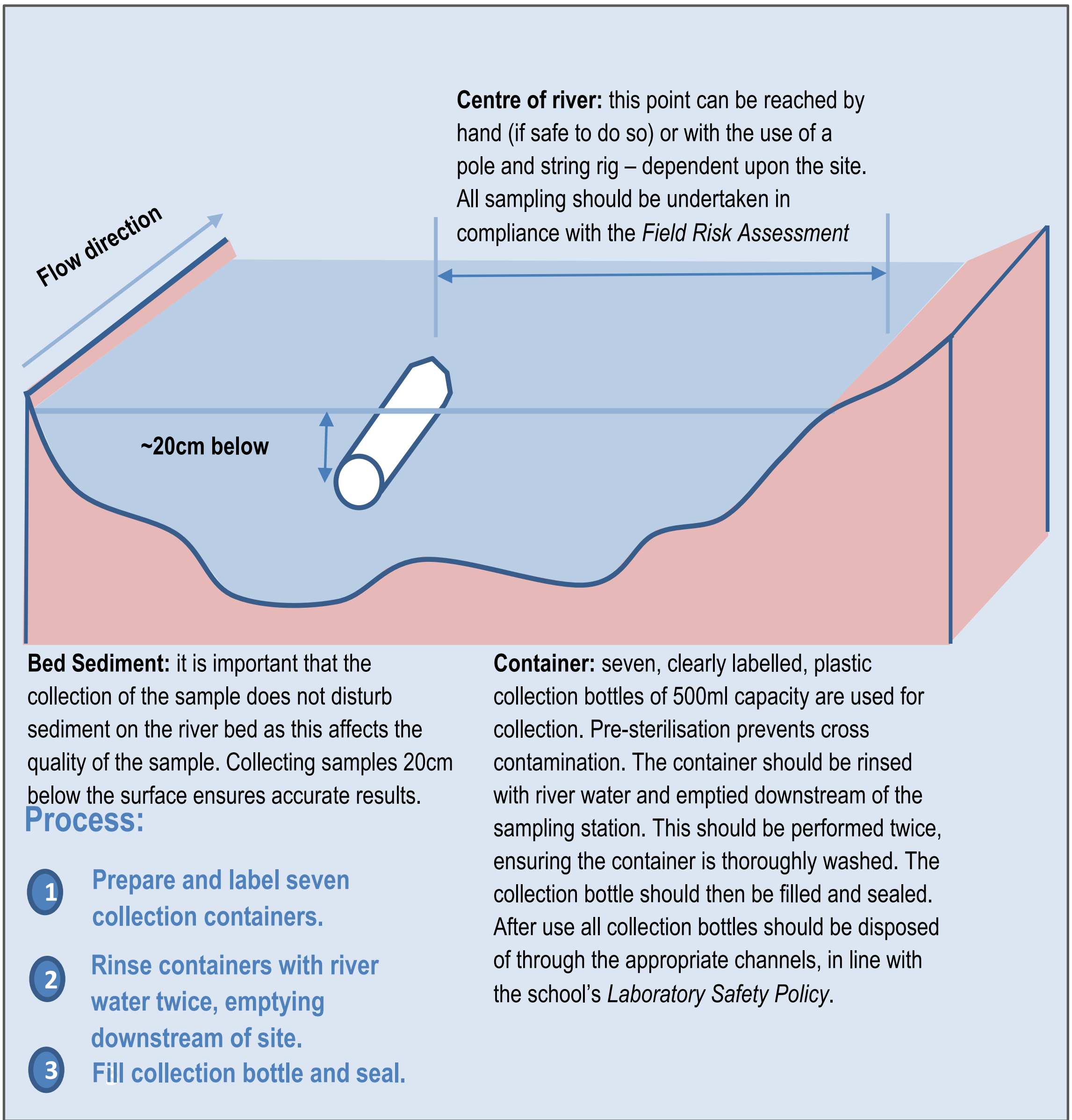


Figure 5.1: Sampling Methodology

Figure 5.1 shows the methodology used to ensure high quality samples. A sampling stick was also constructed to allow the middle of the river to be accessed safely and without disturbing bed sediment.

Samples should be tested within 24 hours of collection; if this is not possible samples should be stored in the laboratory cold room.

5.2.2 Sampling Stations

Sampling stations remained at the same locations specified in the proposed method statement (Figure 3.2). These stations where chosen to align with previous studies allowing a long-term analysis of the Ouseburn where possible. Taking samples across the length of the catchment highlights areas of concerns and allows for the identification of pollution sources. A more detailed description of each station is provided to ensure continuity in further studies and provide reasoning behind location choices.

1. Brunton Bridge

Aerial View

Site, facing upstream, low flow

This site represents the upstream boundary condition of the survey. The catchment upstream of the site is predominantly rural; allowing the influence of urbanisation on the Ouseburn to be seen by comparing the inflow quality with the other targeted sample sites. The EA also uses the site.

At low flow the river is rocky and shallow; care should be taken to not disturb the river bed as this will compromise sample quality. This site is also equipped with a flow gauge; this data can be used to see the effects of flow level on water quality.

2. Upstream Kingston Park

Aerial View

Site, facing downstream, low flow

This site has been used in previous studies to show the water quality shortly prior to Kingston Park Outfall (KPO), and hence deduce the effects it has on water quality. It has been used in the same way in this study.

At low flow the river is easily accessible and has a much greater water level than that of Brunton Bridge, making sampling relatively simple. Care should be taken at high flows as the water levels can be high; the broken reeds in centre of the river give an indication of how high the river can rise too.

3. Kingston Park Outfall

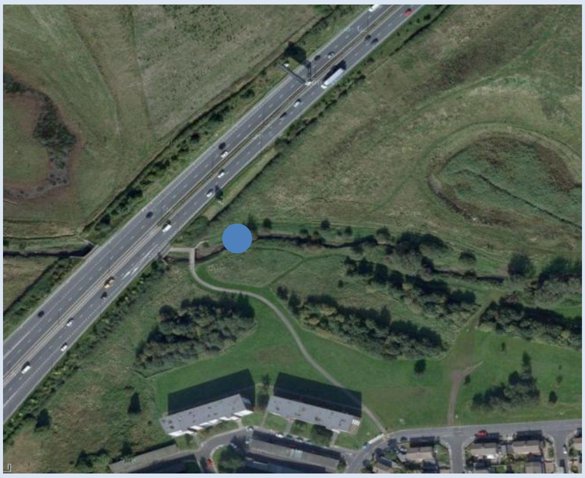
Aerial View

Kingston Park Outfall

Kingston Park is a development in the catchment which discharges into the Ouseburn by way of KPO. Previous studies have shown the strong link between pollution of the Ouseburn and KPO, this survey continues to test that connection through sampling around the outfall.

The sample is taken downstream of the outfall to highlight the effects of the discharge when mixed with the normal flow; this also aligns with previous studies.

4. A1 Outfall



Aerial View

A1 Outfall

The A1 outfall has been considered to evaluate whether runoff from the road is having negative impacts on water quality within the river. Various pollutants are associated with rainwater or snowmelt that washes off roads and into nearby water courses; water can come into contact with dirt, antifreeze, engine oil and a host of other contaminants. While these are not specifically being targeted in the experiments conducted in this survey the outfall is a site of interest with regards to water quality in the Ouseburn.

5. Red House Farm Outfall

Aerial View

Red House Farm Outfall

Red House Farm is a relatively new urban development whose runoff discharges into the Ouseburn by way of the Red House Farm Outfall. Due to the combined sewer system in operation in the region it is important to monitor the water quality of this discharge; therefore it has been included in this survey like the studies before this.

The site is particularly steep and care should be taken when collecting the sample, no unnecessary risks should be taken in the collection of samples.

6. Salters Bridge

Aerial View

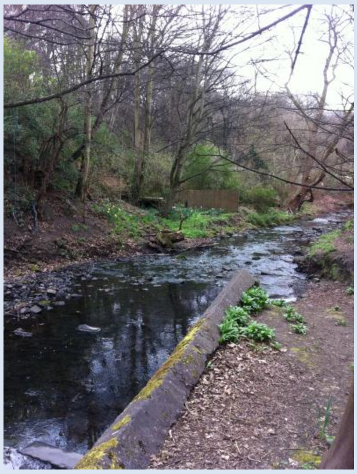
Site, facing downstream, low flow

This site has been added to the study dye to gaps in prior research. Another benefit of adding this station is that it provides an intermittent point between Red House Farm and Jesmond Dene (JD) which would otherwise be some distance, adding further detail to the survey.

The river widens at this point and flow can be reasonably high, care should be taken due to the steep banks in this area.

7. Jesmond Dene

Aerial View



Site, facing downstream, low flow

JD marks the lower boundary of the catchment; observations at this site will allow the effects of upstream pollution to be understood. Access to the site is safe and easy. As previously explained the JD Park has recently undergone a period of development and is a recreational area for locals and visitors. The water quality of this site is therefore important due to many people interacting with the river, particularly in summer months when it regularly becomes a bathing spot. Testing in this area will identify if bathing water standards are currently being met.

5.3 Enumeration of Bacteria (E-coli)

5.3.1 Overview

Coliforms have been broadly used as an indicator of water quality, historically leading to changes in public health policy. E. coli is the widely preferred index of faecal contamination, if E. coli is present there is faecal contamination of some sort. E. coli is a thermotolerant coliform species specifically of faecal origin; its presence in water is an indicator of faecal contamination (Dufour et al., 2003). E. coli is present in human and animal intestines and abundant in faeces, the presence of E. coli is a critical parameter in assessing water quality.

Due to rapid urbanisation water infrastructure in the catchment places stress upon the Ouseburn, particularly storm overflows. Previous water quality surveys show that quality around outfalls, namely KPO, is high in faecal contamination. The presence of E. coli in samples aids in highlighting point sources of faecal pollution along the river.

As the Ouseburn meanders through sub-urban Newcastle it becomes a recreational spot for walkers and bathers, it is therefore vital the water is not harmful to human health or repugnant. High levels of E. coli can be indicative of health hazards and unpleasant odours and aesthetics. This procedure will provide evidence of whether the river is below requirements of the Water Framework Directive (WFD) or a threat to human health.

Laboratory methods within this study are co-ordinated with the Environmental Agency's (2009) *'The Microbiology of Drinking Water'* series such that comparisons between primary data and WFD targets can be drawn. This ensures a high quality of method and provides a clear standard to abide by. The method chosen for the identification of faecal contamination is Membrane Filtration (MF) to isolate and cultivate E. coli on a Membrane Lauryl Sulphate Broth (MLSB) medium at a temperature of 44^{o}C for 18 hours. International standards ISO 9308-1 and ISO 9308-2 also outline this procedure. The method is divided into two main aspects, a serial dilution and a MF process.

The MF technique is fully accepted and approved as a procedure for monitoring microbial quality (Rompré et al., 2002). There are limitations to the method. Nutrient-rich environments may encourage growth of some species of thermotolerant coliforms other than E. coli (Bartram and Ballance, 1996). Excessive crowding from background coliforms can interfere with E. coli growth. Any pink colonies should be noted in results but not counted. Common sense can be used to evaluate whether their growth has crowded E. coli growth, if necessary a repeat test should be performed. Turbid and high sediment waters can also accumulate deposit on the membrane inhibiting growth. Preliminary testing shows this should not be problematic for this survey; the outlined sampling methods do not disturb bed sediment and turbidity is not high enough within the catchment.

MF assumes all cultivated yellow colonies are E. coli producing a presumptive count, expressed as presumptive E. coli count per 100ml. Verification methods are available to find the exact nature of grown colonies, but the E. coli assumption is appropriate as more than 95% of bacteria isolated at 44^{o}C are the gut organism E. coli (Bartram and Ballance, 1996). MF is relatively simple and inexpensive but laborious. Due to the biological nature of the test good laboratory practice is crucial. As experience of the method grows quality and efficiency improves. Inductions and preliminary testing are required to understand the method and improve laboratory techniques.

The most common alternative to MF is the Multiple-Tube Fermentation (MTF) technique, semi-quantitative in nature. This produces a statistical estimate of mean coliforms in the sample and precision of the estimation is low (Rompré et al., 2002). The MF method has been adopted as opposed to MTF due to its greater accuracy, quantitative outcomes and shorter time period. The MTF could be useful if waters are too turbid for the MF method.

5.3.2 Apparatus

48 x Petri Dishes

48 x Small Glass Vials

48 x Membrane Filters (0.45µm)

250ml x MLSB

500ml x Ringer's Solution

Sterile Pipette Tips (5ml and 10ml) & Relative Pipettes

7 x Filtration Units

1 x Vacuum Pump

1 x Bunsen Burner & Heatproof Matt

1 x Spatula

1 x Forceps

5.3.3 Preparation

Testing must occur within 24 hours of collecting the sample; preparation work must be carried out prior to sampling to ensure the process runs smoothly. The preparation involves the making of Ringer's solution, used to disperse bacteria evenly on the membrane filters, and MLSB, the media for bacteria to grow upon.

Ringer's is an isotonic solution; the rate of water diffusion is the same in all directions and hence the cell will neither gain nor lose water. This prevents the e-coli cells from swelling and ultimately bursting, a process known as cytolysis. The ability to leave bacteria undamaged allows the solution to be used to spread the bacteria across the membrane and as a diluting agent in the serial dilution process. A guide to how to manufacture Ringer's is included in Figure 5.3.

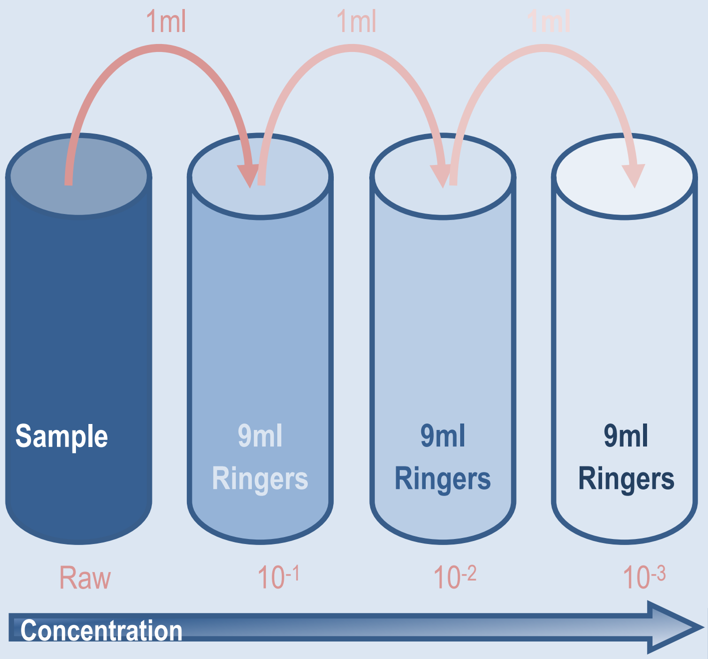
Figure 5.2: Autoclaving preparation

MLSB is a membrane filtration medium for the enumeration of coliform organisms and E-coli in water samples (MAST, 2012). Instructions on how to create the media are available on the side of the product packaging, 76.2g of MLSB powder should be dissolved in 1 litre of distilled water. This should be poured into labelled bottles and sterilised in the autoclave for 10 minutes at 115°C. The broth can be stored for a month in a cold room, however it is advised to be used as soon as possible and fresh batches made for each sampling trip. Other cultivating medium exist but MLSB is a simple, inexpensive cultural medium widely accepted in literature.

Due to the biological nature of cultivating bacteria and to ensure only e-coli is grown sterilisation is a key component of this method, preventing cross-contamination. Autoclaving of Ringer's solution, pipette tips, MLSB and filtration units guarantees sterilisation. Other equipment, such as petri dishes and membrane filters, are sterilised in production and do not require autoclaving. An induction to the autoclave is necessary and risk assessments should always be adhered to.

5.3.4 Serial Dilution

Serial dilution is the stepped dilution of the raw water sample with a constant dilution factor to provide a more accurate result. Through diluting the sample more manageable results are created, if dilution was not used isolated e-coli would be too numerous to accurately count. EA standards stipulate a maximum count of 100 coliforms per membrane filter, which would be unachievable without serial dilution (Environment Agency, 2009). Aseptic techniques should be used throughout; flaming vials upon opening and closing to prevent cross-contamination. Figure 5.3 summarises the serial dilution technique.



Ringer's: Ringer's solution must be made prior to the conduction of the experiment. To do this fill a 1 litre flask with deionised water, add a quarter strength Ringer pill and wait 20 minutes until dissolved. Once dissolved, pipette 9ml of the solution into bottles which should then be sealed and placed in the autoclave for 10 minutes at 115^{o}C.

Process:

1. Prepare Ringer's solution and lab environment.
2. Follow through serial dilution technique, labelling correctly.

Technique: Using a fresh sterile pipette transfer 1ml of sample water to the first 9ml Ringer's solution and mix. This creates the first diluted sample, which should consequently be labelled 10^{-1} to prevent confusion. With the use of a new sterile pipette, transfer 1ml of the previous diluted sample (10^{-1}) and add this to the next bottle of Ringer's solution, creating a more diluted sample (10^{-2}). Repeat this stage again to obtain the 10^{-3} dilution. Duplicates of each dilution should be made to further improve accuracy, alongside blanks to verify method.

Figure 5.3: Serial Dilution Methodology

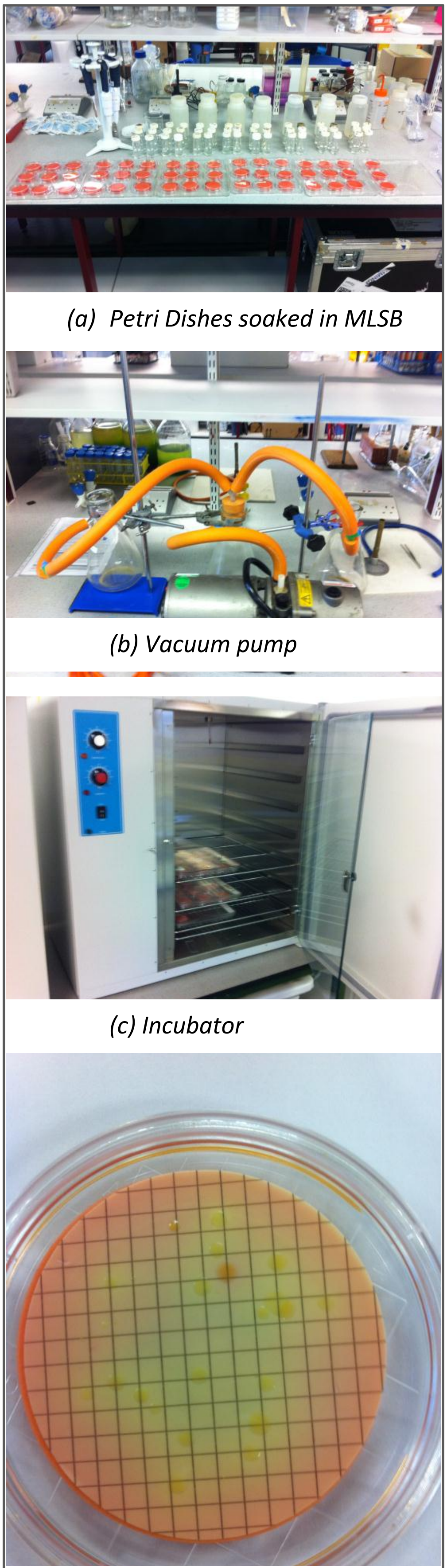
5.3.5 Membrane Filtration

The next phase of this method involves the MF of the dilutions to isolate and cultivate the E. coli, allowing for the count to be made and ultimately determine the extent of faecal contamination in the Ouseburn.

Firstly petri dishes should be removed from packaging and appropriately labelled on their underside, preventing confusion between samples. Aseptic techniques should be used to remove a membrane pad from packaging, leaving the gridded membrane in sleeve until needed. The pads require soaking in MLSB to provide an environment for bacterial growth; this requires 2.5ml of MLSB. After 20 minutes any excess should be discarded to prevent confluent growth.

After soaking the pads the 0.45µm gridded membrane filters should be removed and placed upon the filtration unit. The weakest dilution is then poured over the membrane and the vacuum pump switched on, dispersing the sample evenly over the membrane preventing the clustering of bacteria. The membrane should then be placed into the correct petri dish and repeat until all dilutions for one sample are complete. The filtration unit should be changed for each sample to prevent contamination, by starting at the weakest dilution there is no need to change unit for each dilution.

Once completed for all dilutions the petri dishes should be placed in labelled trays and incubated at 44°C for 18 hours. When returning to count the E. coli the trays should be left for 15 minutes at



(a) Petri Dishes soaked in MLSB

(b) Vacuum pump

(c) Incubator

(d) Results

Figure 5.4: MF Method

room temperature as some colours may change. All yellow colonies are counted irrespective of size; pink colonies should also be noted as they may have interfered with growth.

As recommended by the Environment Agency (2009) the ideal count range to remain accurate on a single membrane is between 10 and 100 colonies, plates within this range are preferred results.

5.3.6 Preliminary Results

The number of presumptive E. coli is widely expressed as the number of colonies per 100ml of sample. It is important to take into account any dilution factor, the equation required to calculate results is given by:

$$Coliform\ Units\ per\ 100ml = \frac{Number\ of\ colonies \times 100\ \times dilution}{Volume\ of\ sample\ filtered}$$

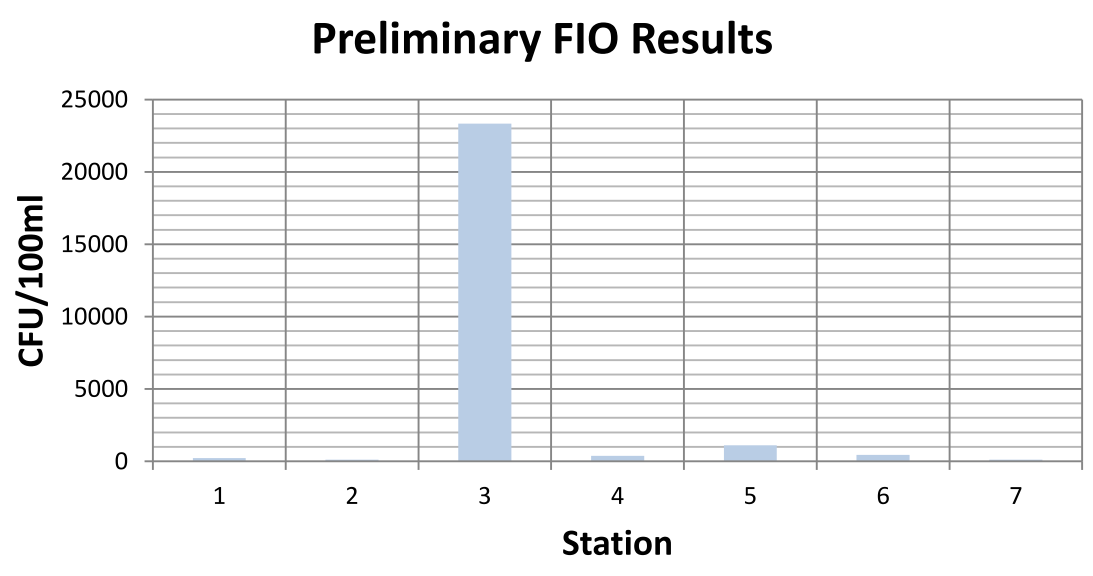


Figure 5.5: Preliminary FIO Results, 22/02/2012

Figure 5.5 shows a large rise in faecal contamination at Kingston Park Outfall, due to the preliminary nature of these results they will not be considered in the overall outcome of this report.

Table 5.1: Preliminary FIO Results, 22/02/2012

Date	22/02/2012							
Flow	Low							
Station		1	2	3	4	5	6	7
CFU/100ml		222	111	23333	389	1111	444	111

5.4 Chemical Oxygen Demand (COD)

5.4.1 Overview

Before introducing the procedure used in this study to determine organic content of water samples, the concept of dissolved oxygen (DO) is described to provide background context. Oxygen demand gives an indication of the health of a stream and its ability to support a balanced aquatic ecosystem. Oxygen is transferred from the atmosphere across the air/water interface; the amount is dependent upon how much oxygen can be solubilized in water (Kiely, 1998). There is a source and sink balance within the system; aquatic animals, decomposition and chemical reactions consume DO and the atmosphere and plants replenish stocks. This balance can be shifted by an increase in oxygen-consuming sources, such as microbial activity from the discharging of organic waste into the stream or storm water runoff from both urban and agricultural environments, resulting in an oxygen deficit. Equally oxygen abundance can lead to eutrophication through excessive photosynthesis. Oxygen demand indicates which direction the balance has been pushed, a high demand is indicative of organic pollution. It is an important parameter when assessing the quality of a water course; it provides an indication of the ecological status of the river and can identify toxic conditions. Oxygen demand testing, alongside the MF method, will identify areas of organic pollution within the Ouseburn.

There are numerous methods used to calculate oxygen demand, this study calculates COD. Biological Oxygen Demand (BOD) originally formed part of the surveys methodology but has been abandoned in favour of COD for various reasons. The major factor is time. After consultations with laboratory technicians and previous studies BOD was identified as a time consuming process. While BOD is more accurate than COD, due to the nature of the experiment, by not spending time on 5 day BOD procedures more sampling can be done and the scope of the study increased. COD is a relatively quick test involving less sample manipulation meaning that all laboratory tests can be carried out within 24 hours of sample collection and more trips can be generated.

The COD test measures the total organic carbon, determining the amount of oxygen required to oxidise organics in the water. The primary difference between BOD and COD testing is in this oxidation technique, COD uses a strong chemical oxidant whilst BOD uses micro-organisms. While this improves speed the less specific nature of the test, oxidising total organics, leads to the COD levels being higher than BOD. BOD testing reveals the rates of biodegradation of organic pollutants, differentiating unstable from stable organic matter, but with a sacrifice of time. For the purpose of this study COD testing was adopted allowing a more comprehensive data set to be gathered. Conversion factors are available with BOD_5 roughly equal to 0.6COD; this does however require calibration to be representative of the study area.

The adopted technique is a closed reflux method where COD levels are calculated through titration using ferrous ammonium sulphate, Standard Methods (1997) are available. The closed reflux method is suitable for a COD range of 0 – 600 mg/l in a 2ml sample. Higher ranges can be covered by appropriate dilution. The open reflux method is aimed at solid samples or samples with a high concentration of solids, preliminary studies show this is not the case in the Ouseburn.

Titration accuracy is highly dependent on the competency of the tester, requiring slow release of the burette's contents. The titration aspect of this procedure is the main source of error through misreading the burette or releasing contents of the burette too quickly. The tipping point of the Ferroin indicator is highly sensitive, often governed by a single drop, requiring practice and precision. A laboratory induction and preliminary testing are needed to improve competency prior to official sampling. Chemicals used in the process are harmful and risk assessments should always be adhered to.

5.4.2 Apparatus

All equipment for the COD experiment is located in COD stations within the laboratory. The following apparatus is required for the completion of the procedure:

- 16 x Clean, dry COD reaction tubes (duplicates per sample and two blanks)
- 1 x Reactor Block
- 32ml x 0.075N Potassium Dichromate (digestion solution)
- 56ml x Sulphuric Acid/Silver Sulphate solution
- 1 x Burette
- 16 x 100ml Conical Flasks
- 0.025N Ferrous Ammonium Sulphate (sufficient for titration)
- Ferroin Indicator

Figure 5.6: COD station

5.4.3 Procedure

As previously stated the procedure is relatively quick, but dependent on highly competent laboratory skills. The following steps outline the method, also available in the School's '*Standard Methods'* (2012) provided upon induction:

(1) Preheat reactor block to the pre-set temperature (150^{o}C) for 1 hour.

(2) Pipette 2ml sample into clean, dry reaction tube.

(3) Using auto-dispenser add 2ml 0.075N potassium dichromate (digestion solution).

(4) Potassium dichromate and sulphuric acid/silver sulphate produce a highly exothermic reaction. Dispense 3.5ml sulphuric acid/silver sulphate down the side of the reaction tube so that an acid layer is formed at the bottom of the tube, preventing the handling of hot tubes.

(5) Cap the tube and holding the cap invert several times until mixed, avoided touching the glass. Place reaction tube in reaction block for 2 hours.

(6) Remove from block and cool. Transfer contents of each tube to a 100ml conical flask and titrate with 0.025N ferrous ammonium sulphate using ferroin indicator, blue-green to red-brown.

To improve accuracy the coloured liquid is kept as reference for other tests, ensuring continuity. The inclusion of blanks is necessary to calculate COD; this should be refluxed and titrated in the same manner. Duplicates are used to reduce the effects of error.

5.4.4 Preliminary Results

Through the closed reflux method COD is expressed mg/l as a dichromate value (DV). The following equation determines COD levels:

$$\boldsymbol{mg/l\ D.V\ =\frac{(a-b)c\ \times 8000}{ml\ sample}}$$

Where: a = titration for blank

b= titration for sample

c = normality of ferrous ammonium sulphate

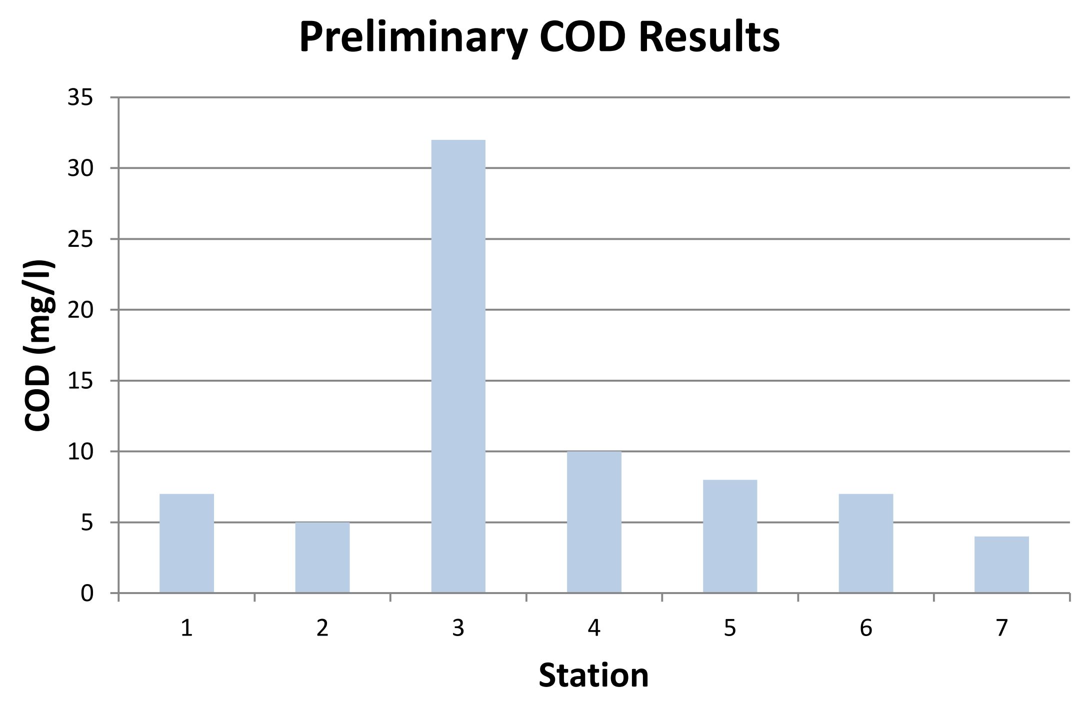


Figure 5.7: Preliminary COD Results, 22/02/2012

Table 5.2: Preliminary COD Results, 22/02/2012

Date	22/02/2012						
Flow	Low						
Station	1	2	3	4	5	6	7
COD (mg/l)	7	5	32	10	8	7	4

Figure 5.7 shows a rise similar to that demonstrated in the FIO results at the KPO followed by a steady decline in COD down to JD levels.

5.5 Total Organic Carbon (TOC)

5.5.1 Overview

TOC is a non-specific indicator of water quality and generally used to support further testing, namely COD. TOC is the amount of dissolved organic substances in the water sample that contain carbon and is not specific in nature. While TOC does not explicitly classify organic contaminants it detects their presence. TOC helps in identifying the health of a stream, used in coordination with faecal indicator organisms and COD testing to enhance the body of evidence for pollution in the Ouseburn.

Organic carbon is naturally present in all water courses from a variety sources, such as destabilising plant life and dead animal matter, and makes part of essential biogeochemical processes. Alterations to the cycle through chemical organic pollution pressurises the system affecting aquatic life through lowered oxygen levels, damaging the riparian and aquatic ecosystems. Organic pollutants such as nitrates and phosphates from poor agricultural practices impact TOC levels greatly; causing algae blooms which rapidly consume oxygen supply. These blooms eventually reach unsustainable levels, dying and depositing large amounts of organic carbon. Organic carbon is natural and vital for river ecosystems; human intervention within this cycle tips a delicate balance and this is where the problem lies.

High TOC levels are indicative of organic pollution where further testing identifies the nature of the pollutant. The concentration of organic carbon present in surface water is generally less than 10mg/l, except where high concentrations of municipal waste is present (Bartram and Ballance, 1996).

TOC forms the outer boundary of a theoretical BOD/COD/TOC relationship; TOC measures all carbon as CO^2, and therefore inorganic carbon, while BOD and COD tests determine the amount of oxygen required for oxidation (Kiely, 1998). TOC is a rapid measurement for determining the organic content of water and wastewater. Empirical relationships can be derived between TOC and COD, if relative concentrations do not differ greatly, meaning TOC can be used to quickly estimate a COD value. As COD is in turn related to BOD the relationship can be expanded.

5.5.2 Procedure

A specialised TOC measurement unit is used to automatically measure levels of total carbon and inorganic carbon where TOC represents the difference. The use of automatic measurement units provides a simple, consistent and accurate method avoiding human error and guaranteeing quality.

The unit in this study is the Shimadzu TOC-5050A, using catalytically aided combustion oxidation and pre-acidification to calculate total and inorganic carbon respectively.

The procedure is simple due to its automatic nature; operation of the unit however should be left to laboratory technicians. Tubes required for the procedure are specific to the machine.

(1) Syringe 7ml of sample through a 2mm filter into the correct tube, labelling correctly throughout.

(2) Create duplicates of each sample to provide a better representation and increase accuracy.

(3) Place samples into correct slots and run machine.

Figure 5.8: Shimadzu TOC-5050A

5.5.3 Preliminary Results

Prelimary samples were taken at low flow after a few days without rainfall. Duplicates of samples were made and an average calculated.

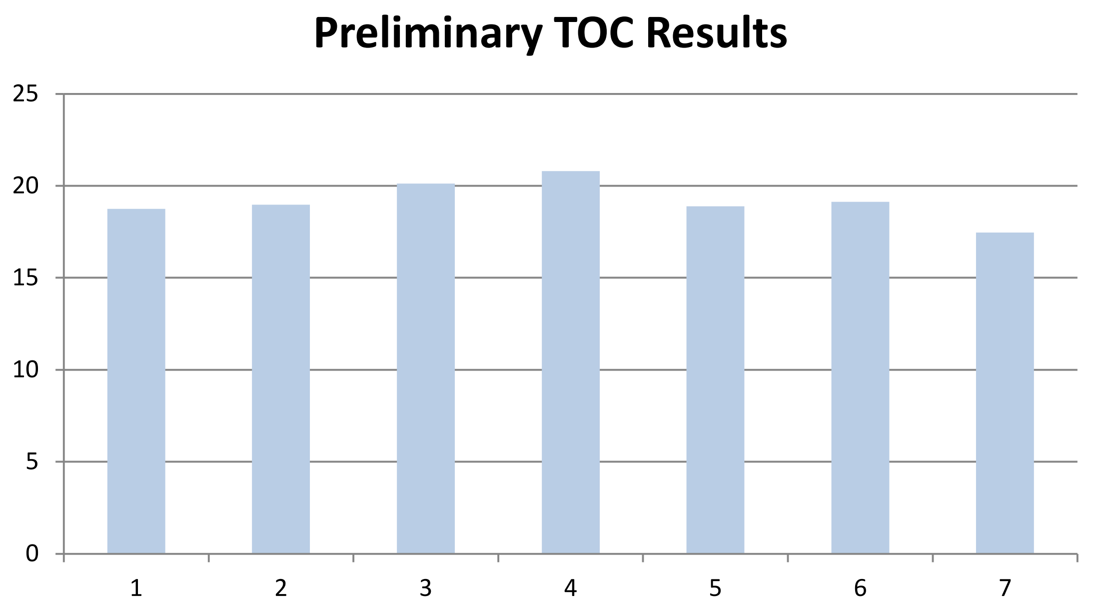


Figure 5.9: Preliminary TOC Results, 22/02/2012

Table 5.3: Preliminary TOC Results, 22/02/2012

Date	22/02/2012						
Flow	Low						
Station	1	2	3	4	5	6	7
TOC (mg/l)	18.75	18.97	20.13	20.795	18.89	19.125	17.465

Preliminary results show high TOC levels entering the catchment potentially due to organic pollution from agricultural regions upstream. Levels within the study area rise to a peak in the A1 and KPO region.

6. Results

6.1 Introduction

This section presents data gathered from this study combined with that from previous studies in a clear summarised manner aimed at producing a long-term water quality analysis of the Ouseburn. Comprehensive lists of raw data are available in Appendix 2, should these be required for further research. Conclusions will be drawn from these Results in the Discussion.

Results generated in this study were taken over a month period from 02/03/2012 to 01/04/2012. Preliminary testing improved laboratory techniques increasing the reliability of results and ensuring the analysis adhered to Environmental Agency (EA) standards. The standardisation of results allows for direct comparison with previous studies and water quality policy which is fundamental for long-term water quality analysis. Results generated in this study, and previous studies, have improved accuracy and reliability through standardisation.

Through the selection of identical laboratory techniques, water quality parameters are consistent with previous studies. This investigation includes a new sample station, Salters Bridge (SB), to increase the body of evidence for pollution in the Ouseburn. Due to the unique inclusion of SB no comparison can be made on a long-term scale at the site but the data does add a new dimension to the survey. Available long-term water quality data for the Ouseburn dates back to 2009; as studies have evolved new stations have been included to develop the water quality analysis. Certain sampling sites therefore do not have full data records for the three year period and comparisons are made were possible; the inclusion of Kingston Park Outfall (KPO) is constant throughout. Utilising photos of sampling from previous investigations to identify the sampling locations in this survey ensures dependable comparisons can be made.

The gathered data from this study falls into two clear sectors; high flows and low flows. The majority of results compiled in the research are at times of low flow where no significant weather has led to increased urban runoff or sewer overflow which are thought to further deteriorate water quality. The low flow period lies between 20/03/2012 and 01/04/2012; river levels were estimated to be around 20cm at this time. The higher flow period occurred on the 02/03/2012 and 08/03/2012 trips, the river was deemed to be at high flow through visible inspection. There are therefore four sets of low flow data and two sets at high flow for all parameters; the low flow analysis is inherently more reliable than the high flow due to this. The high flow data should be used with awareness of this comparative limitation but it is still valid, accurate and reliable information. All previous studies have taken place during periods of prolonged low flow and therefore all long-term analysis is using low flow data.

The unique data set of faecal indicator organisms (FIOS) was gathered by first year undergraduate students between October and November over a three year period at the Crag Hall sampling site. This data set is inherently less reliable due to the lack of technical ability of first year students in a reasonably complex procedure where the prevention of cross-contamination is vital. The record should therefore be used with caution, but the vast quantity of data means it is a valuable record and can provide a greater insight into water quality in the Ouseburn at a previously unsampled time of year.

Preliminary results showed deterioration in water quality at KPO and the new SB site indicative of sewer outfall pollution. The results from further sampling confirm this and are presented in this section. Throughout this section **red** is used as an indicator of **high flow** data, **purple low flow** and **green annual averages**. The stations are numbered as below:

1. Brunton Bridge (BB)
2. Upstream of Kingston Park Outfall (UKPO)
3. Downstream of Kingston Park Outfall (KPO)
4. A1 Outfall
5. Red House Farm (RHF)
6. Salters Bridge (SB)
7. Jesmond Dene (JD)

6.2 Enumeration of Bacteria (E. coli) Results

Figure 6.1 shows the CFU/100ml at both high flow and low flow. Figure 6.2 gives a clearer view of the faecal contamination at low flow. The results are the mean of two plate counts which are within the recommended EA range (10-100 coliforms per plate). Range bars have been included to identify any points where this mean may be misrepresentative.

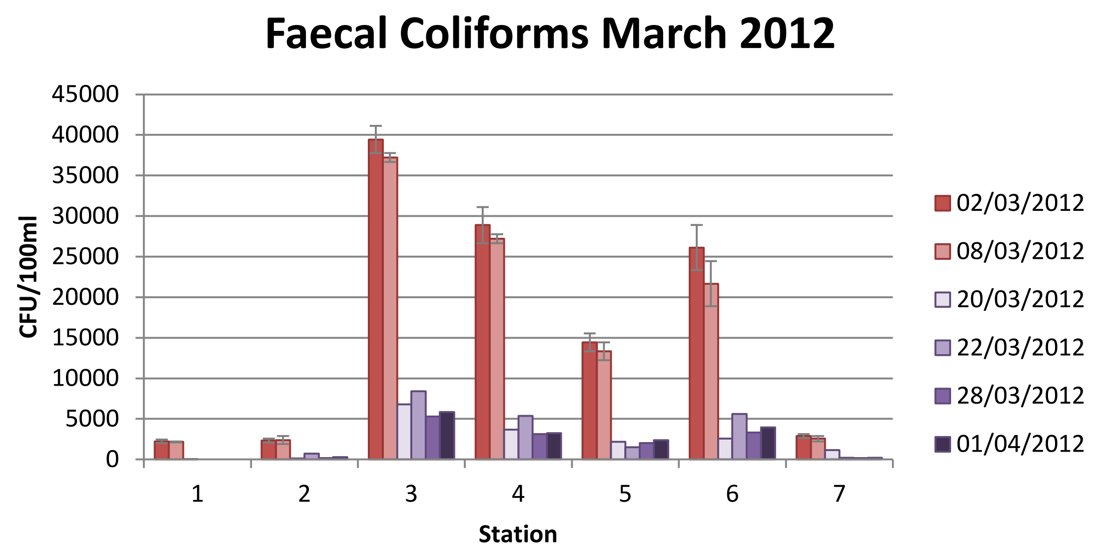


Figure 6.1: Graph of High and Low Flow Faecal Coliforms from March 2012

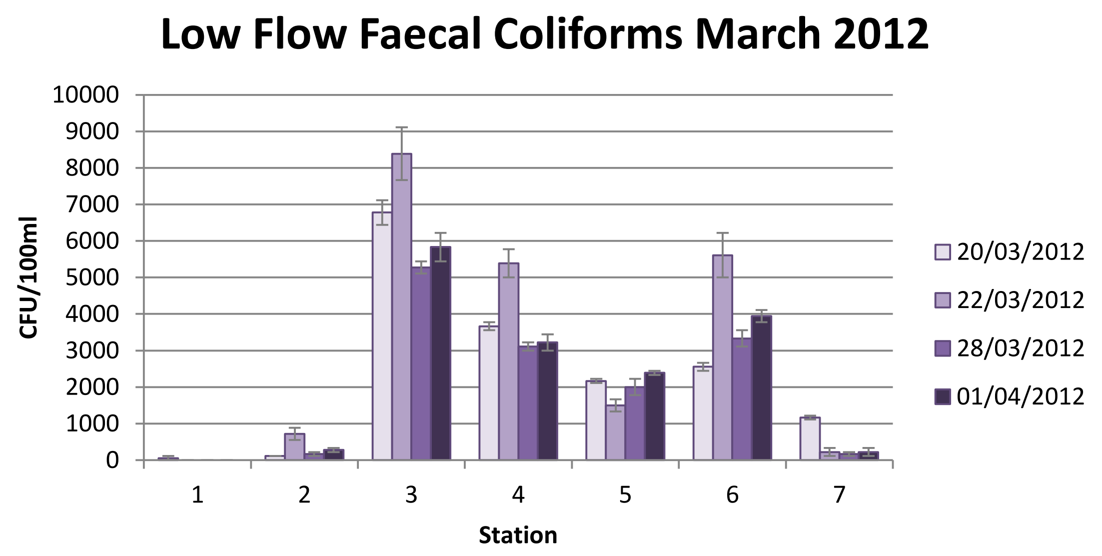


Figure 6.2: Graph of Low Flow Faecal Coliforms from March 2012

The graphs show faecal contamination spiking at KPO, diluting as the river passes by RHF and rising again at SB before returning to original levels at JD. While the trend varies in magnitude it is constant through all sampling trips. High flow data shows the same trend but amplified further. The figures show a large increase in faecal contamination as the river moves from a rural to an urban environment. The value of faecal contamination reaches exceptional levels at a maximum of around 40000 CFU/100ml at high flow and 8500 CFU/100ml at low flow. Values of CFU/100ml for each station on each trip are available in Table 6.1.

Table 6.1: CFU/100ml Values from March 2012

	Station						
	1	2	3	4	5	6	7
02/03/2012	2222	2333	39444	28889	14444	26111	2889
08/03/2012	2167	2389	37222	27222	13333	21667	2556
20/03/2012	56	111	6778	3667	2167	2556	1167
22/03/2012	0	722	8389	5389	1500	5611	222
28/03/2012	0	167	5278	3111	2000	3333	167
01/04/2012	0	278	5833	3222	2389	3944	222
	CFU/100ml						

Figures 6.3 and 6.4 have been included to show the average high and low flow CFU/100ml in the Ouseburn. These graphs give a clearer representation of the discussed trend.

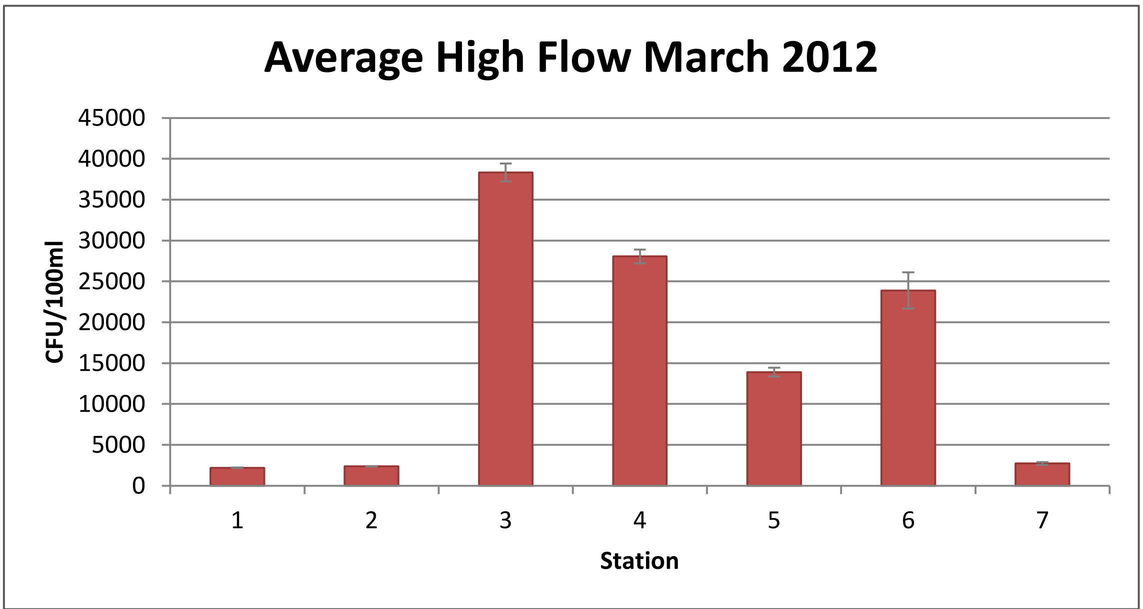


Figure 6.3: Graph of Average High Flow CFU/100ml from March 2012

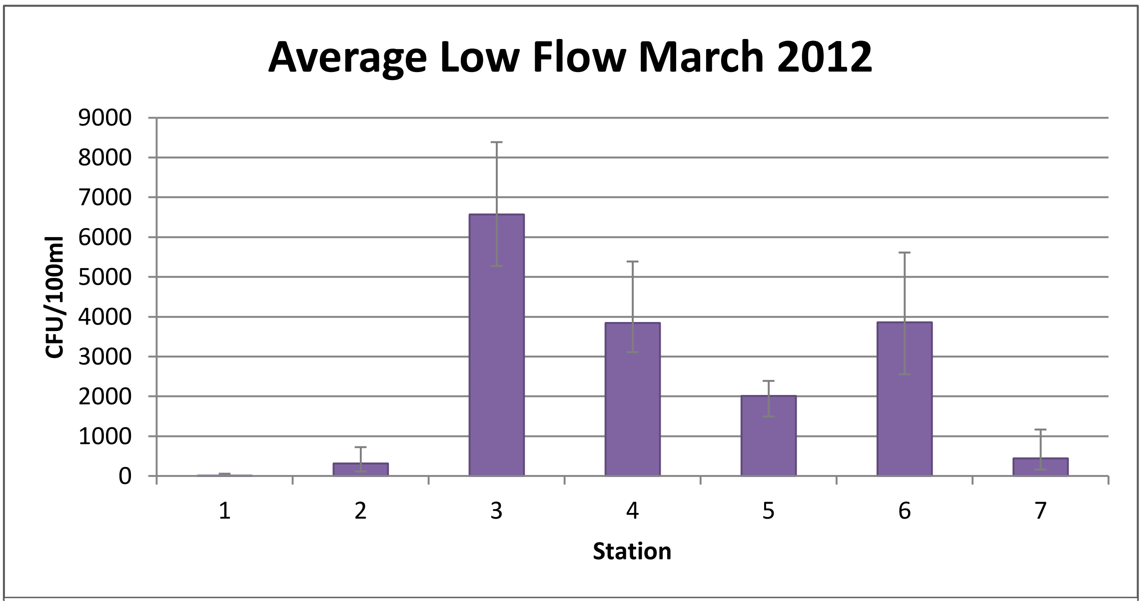


Figure 6.4: Graph of Average Low Flow CFU/100ml from March 2012

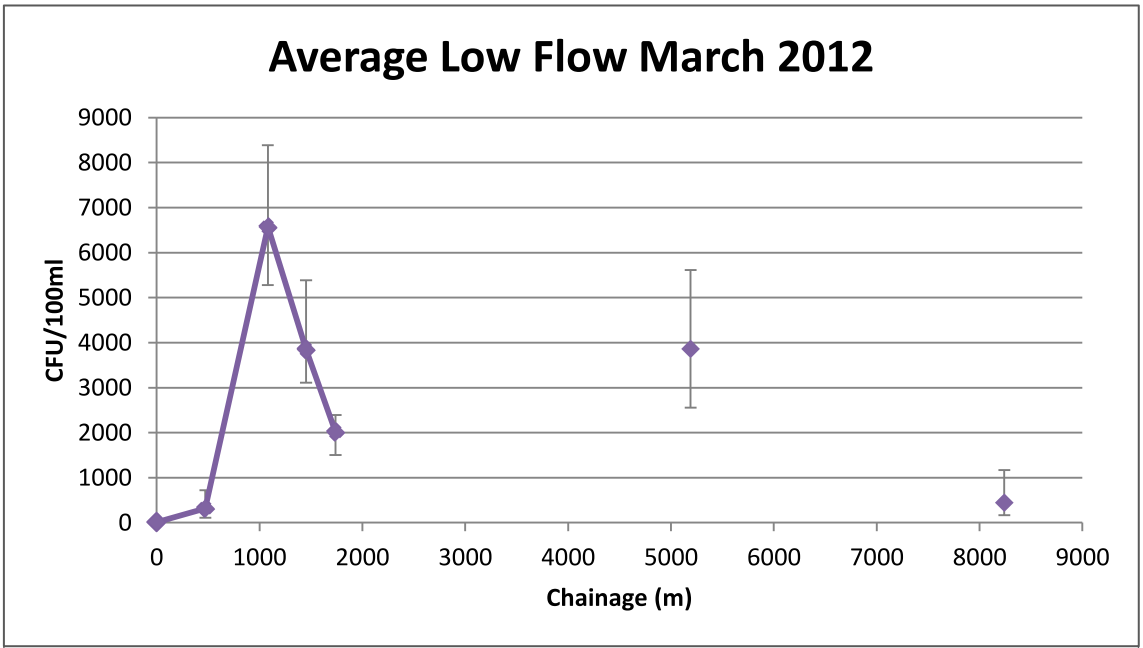


Figure 6.5: FIO Sample Distribution Graph from March 2012

Figure 6.5 shows the dispersal of samples relative to CFU/100ml. The graph shows the clear rise and decline in faecal contamination around KPO. The concentrated sampling around Kingston Park Outfall validates the observed relationship; this relationship is likely to not be linear but this has been as a representation tool. Sampling after this becomes sparse. SB shows a rise in faecal coliforms over a large distance meaning there is an increase in that stretch of river at some point. However it is not possible to deduce whether faecal conditions at SB are on a rise or a decline. Similarly contamination could rise again before falling at JD. The ability to pinpoint pollution becomes impossible as the samples become further dispersed due to the unknown shape of the graph. Ideally several sampling stations would be included to add greater shape to the graph as there are regions which cannot be predicted.

Table 6.2 shows the average values of CFU/100ml for March 2012 at high and low flow represented in Figure 6.3, 6.4 and 6.5.

Table 6.2: CFU/100ml Average Values from March 2012

Station						
1	2	3	4	5	6	7
2194	2361	38333	28056	13889	23889	2722
14	319	6569	3847	2014	3861	444

Figure 6.6 shows faecal contamination results over a three year period at the sample stations. Values are given in Table 6.3.

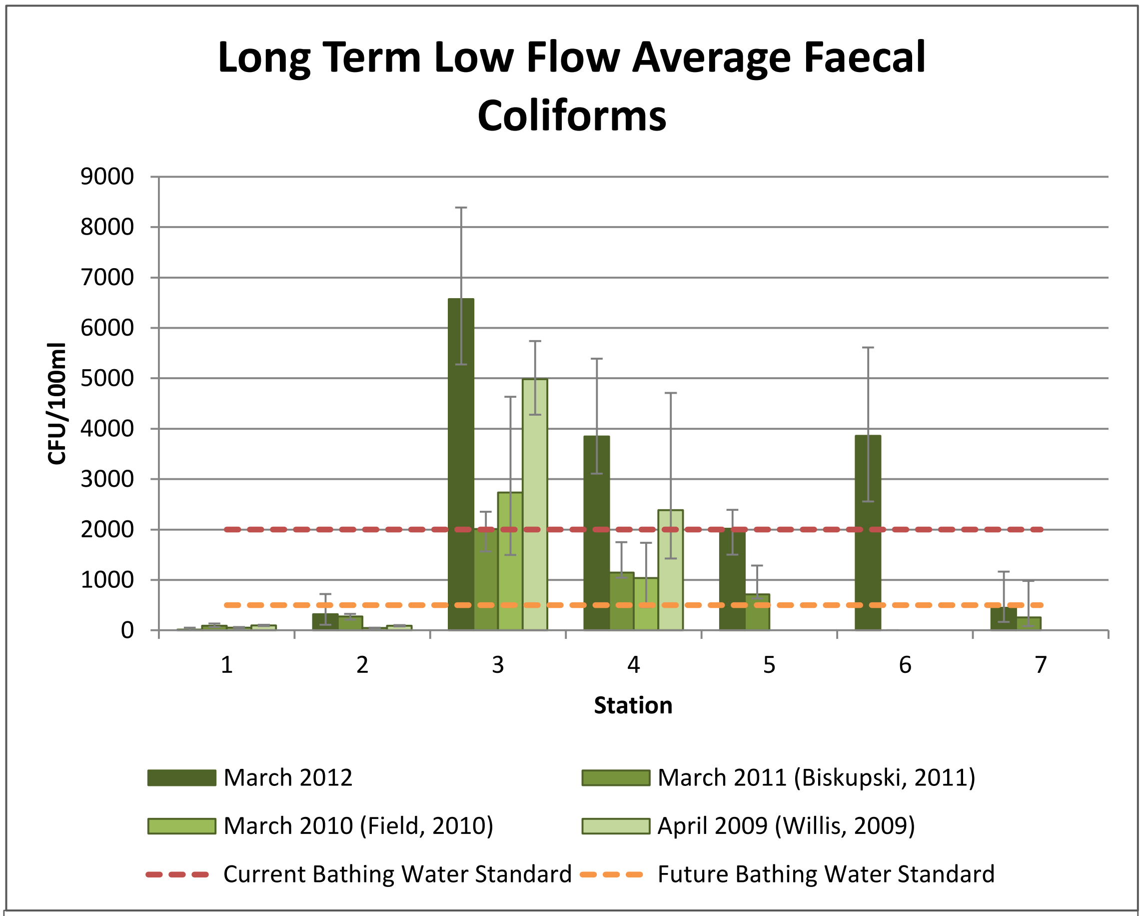


Figure 6.6: Graph of Long Term Average Low Flow CFU/100ml

Table 6.3: Long Term Average Low Flow CFU/100ml

	Station						
	1	2	3	4	5	6	7
March 2012	14	319	6569	3847	2014	3861	444
March 2011 (Biskupski, 2011)	89	273	2009	1146	714	-	256
March 2010 (Field, 2010)	55	47	2737	1036	-	-	-
April 2009 (Willis, 2009)	97	90	4983	2385	-	-	-
	CFU/100ml						

The graph shows a consistent spike at KPO over the three year period. The magnitude of the results varies, with 2012 being the greatest and 2011 the lowest. The graph shows levels to be low at BB and UKPO; showing the water entering from the rural region of the Ouseburn is not affecting the faecal concentrations of the river. After the KPO spike previous results show a dissipation of faecal contamination. This study differs by showing a rise at SB before declining down to JD levels which are consistent with Biskupski's findings. The long term trend shows a reduction in faecal contaminants year upon year until 2012 where the average has dramatically increased.

The next record considered is the faecal contamination results gathered from the Crag Hall site over a three year period between October and November by first year undergraduate students. As previously discussed these results are of questionable accuracy due to the complex micro-biological nature of testing and the lack of technical ability of first year students. Therefore it is necessary to carry out a statistical analysis of the data to identify errors in the data due to incompetence.

Firstly it is important to disregard any data deemed to be a result of human error. Figure 6.7 and 6.8 show the distribution of the raw data, one through a frequency distribution and the other a scatter plot. The frequency distribution shows the data to be correlated into three main sets; one at both the high and low end of the spectrum and a central cluster. The central cluster represents the expected results from the survey, with a range of around 3000-6000 CFU/100ml, but it necessary to add statistical weight to this observation. This was done using standard deviations from the mean. Due to the high likelihood of human error, data outside of one standard deviation from the mean was disregarded, creating Figure 6.9 and 6.10.

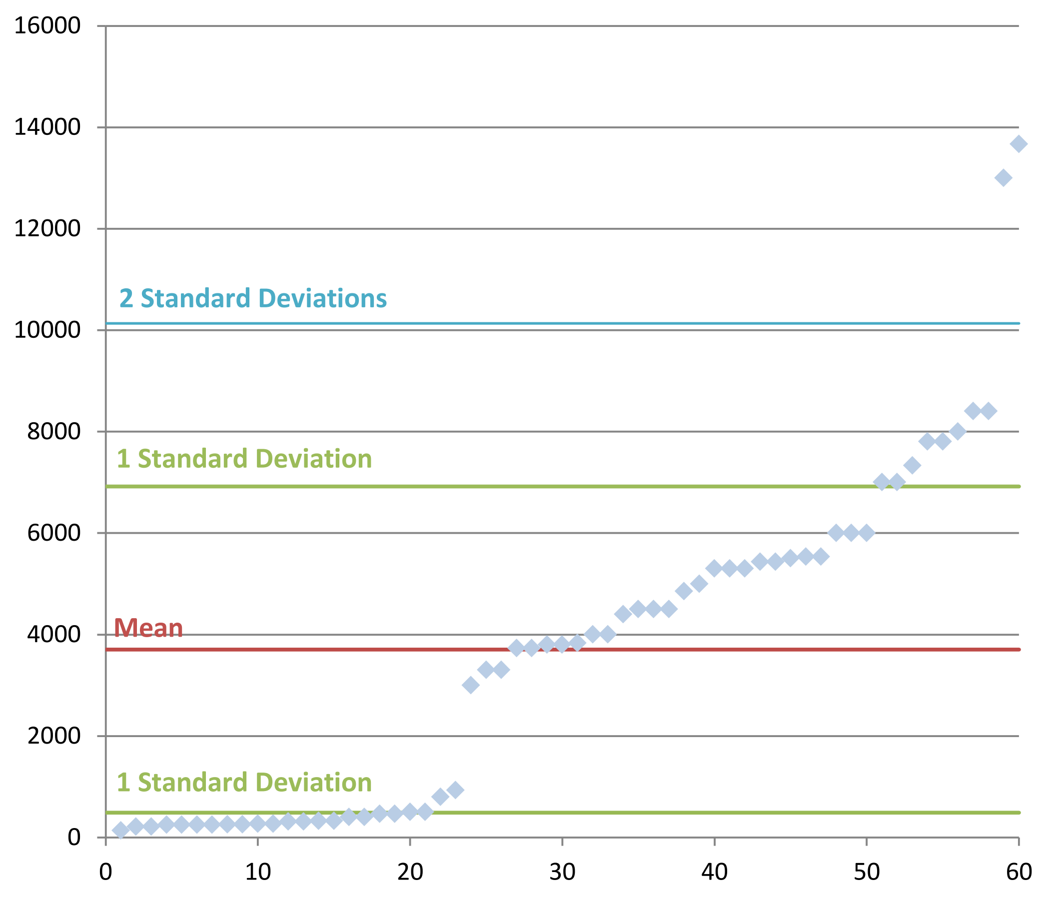


Figure 6.7: Diagnostic Plot of 1st year FIO October-November, Crag Hall

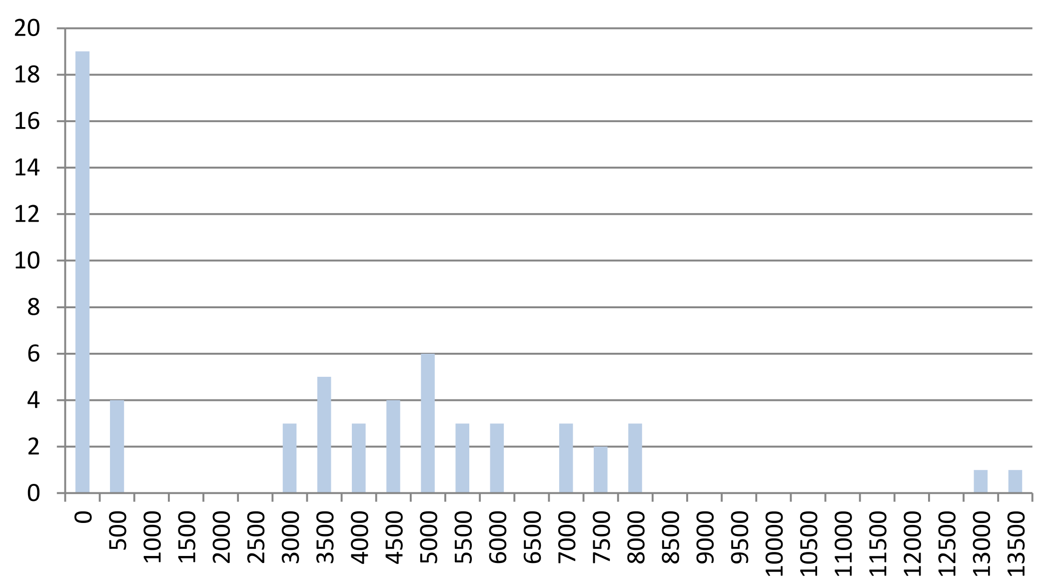


Figure 6.8: Frequency Distribution of 1st year FIO October-November, Crag Hall

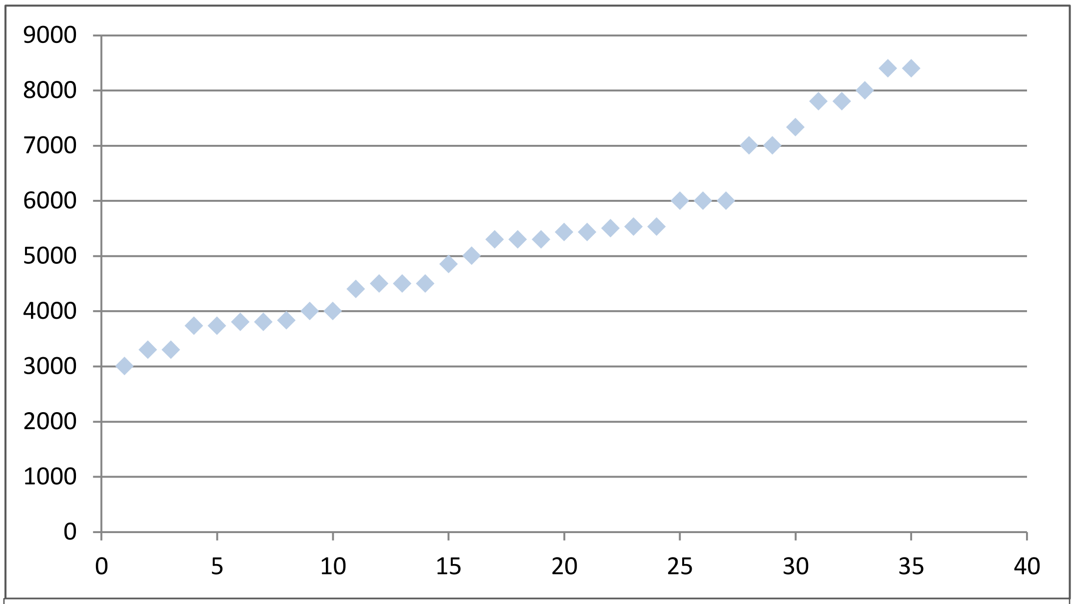


Figure 6.9: Scatter Plot of altered 1st year FIO October-November, Crag Hall

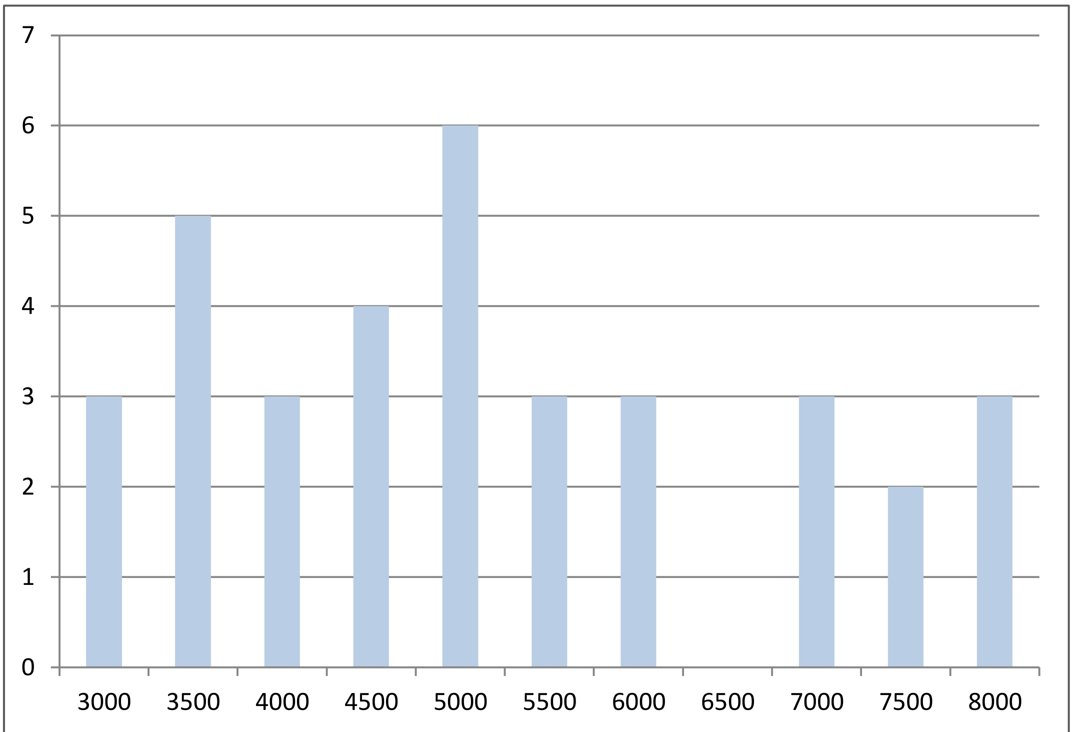


Figure 6.10: Frequency Distribution of altered 1st year FIO October-November, Crag Hall

Figure 6.9 and 6.10 show plots derived following the removal of results outside of one standard deviation believed to be caused by human error and a lack of technical ability. The frequency plot demonstrates a normal ‘bell-shaped’ distribution shifted slightly to the left peaking in the 5,000 CFU/100ml region of the plot. The removal of the errors results in a change of the mean value. The mean value of faecal pollution observed at the Crag Hall site in the October to November timeframe over the three year period is 5780 CFU/100ml.

6.3 Total Organic Carbon (TOC) Results

Figure 6.11 shows the TOC levels gathered from the March 2012 study at times of high and low flow. TOC results are reliable due to the use of calibrated machinery to accurately measure levels; hence no range bars are included in Figure 6.1.

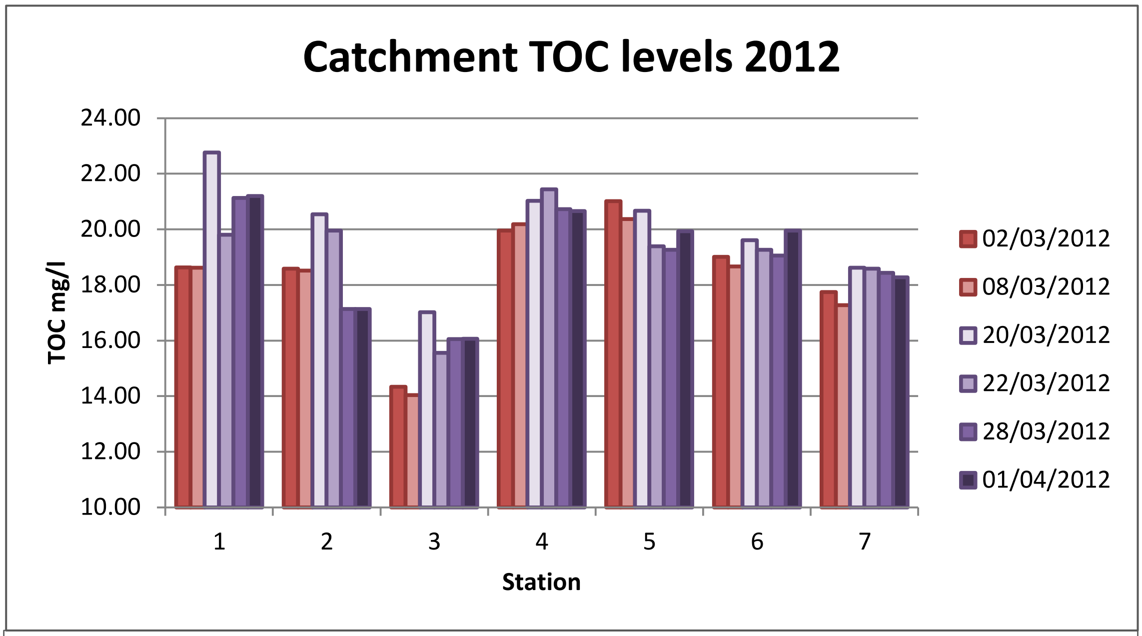


Figure 6.11: Graph of High and Low Flow TOC from March 2012

The graph shows a repeated trend through all sampling trips. TOC levels start high in the preliminary stations, dip at KPO and rise again at RHF before declining to JD. The trend varies slightly in magnitude dependent upon the sample date; however the KPO dip is present in all. For the most part higher flows have lower TOC levels than lower flows. Overall the results show a constant pattern at both low and high flow with little internal variance. Table 6.4 shows the values produced from the study, the consistency of results is shown at each sample site over the month period.

Table 6.4: TOC (mg/l) levels from March 2012

	Station						
	1	2	3	4	5	6	7
02/03/2012	18.64	18.59	14.34	19.95	21.02	19.02	17.74
08/03/2012	18.62	18.52	14.04	20.19	20.37	18.67	17.27
20/03/2012	22.77	20.54	17.02	21.03	20.67	19.61	18.62
22/03/2012	19.81	19.96	15.56	21.45	19.40	19.27	18.58
28/03/2012	21.14	17.13	16.05	20.73	19.26	19.06	18.44
01/04/2012	21.20	17.14	16.07	20.66	19.93	19.95	18.28

Figure 6.12 shows the overall average TOC levels alongside average levels at low and high flow during March 2012. The average has been used to identify the trend clearly. Range bars show how representative the mean is of the gathered samples. These bars also provide an indication of the consistency of results at individual sites; ranges tend to be small showing uniformity in results with the exceptions of BB and UKPO which show large variances at low flows. Average values are displayed in Table 6.5.

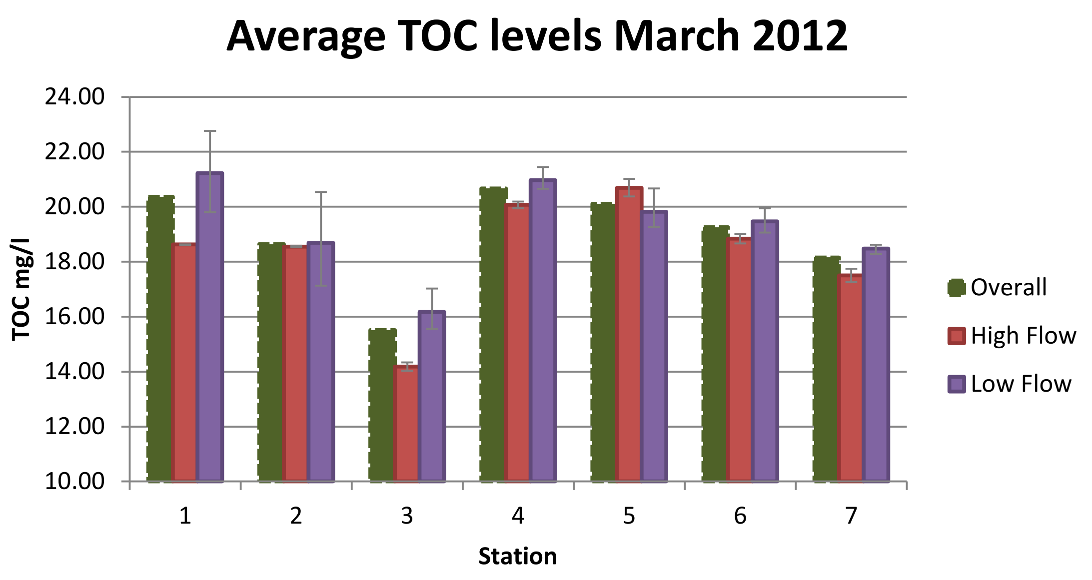


Figure 6.12: Graph of Average TOC levels from March 2012

Table 6.5: TOC Average Values from March 2012

	Station						
	1	2	3	4	5	6	7
Overall Average	20.36	18.64	15.51	20.67	20.11	19.26	18.16
High Flow	18.63	18.55	14.19	20.07	20.69	18.84	17.51
Low Flow	21.23	18.69	16.17	20.96	19.81	19.47	18.48
	TOC mg/l						

Figure 6.13 shows the low flow TOC average plotted against sample station chainage. Adding scale to the graph allows the dispersal of sample points to be clearly visualised and can validate previously identified relationships. The relationship is again unlikely to be linear but this has been used as a visualisation tool, as the samples become more dispersed the relationship cannot be accurately identified. The concentrated sampling around KPO adds confidence to the observed dip.

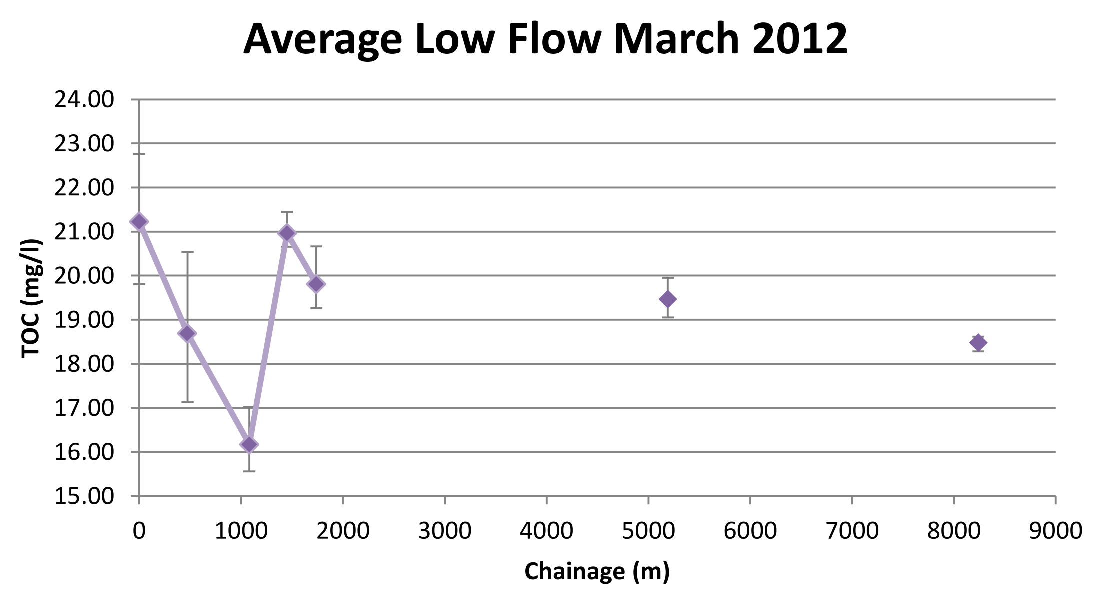


Figure 6.13: TOC Sample Distribution Graph from March 2012

Figure 6.14 compares the TOC levels gathered from this study with the previous three years to provide a long-term analysis.

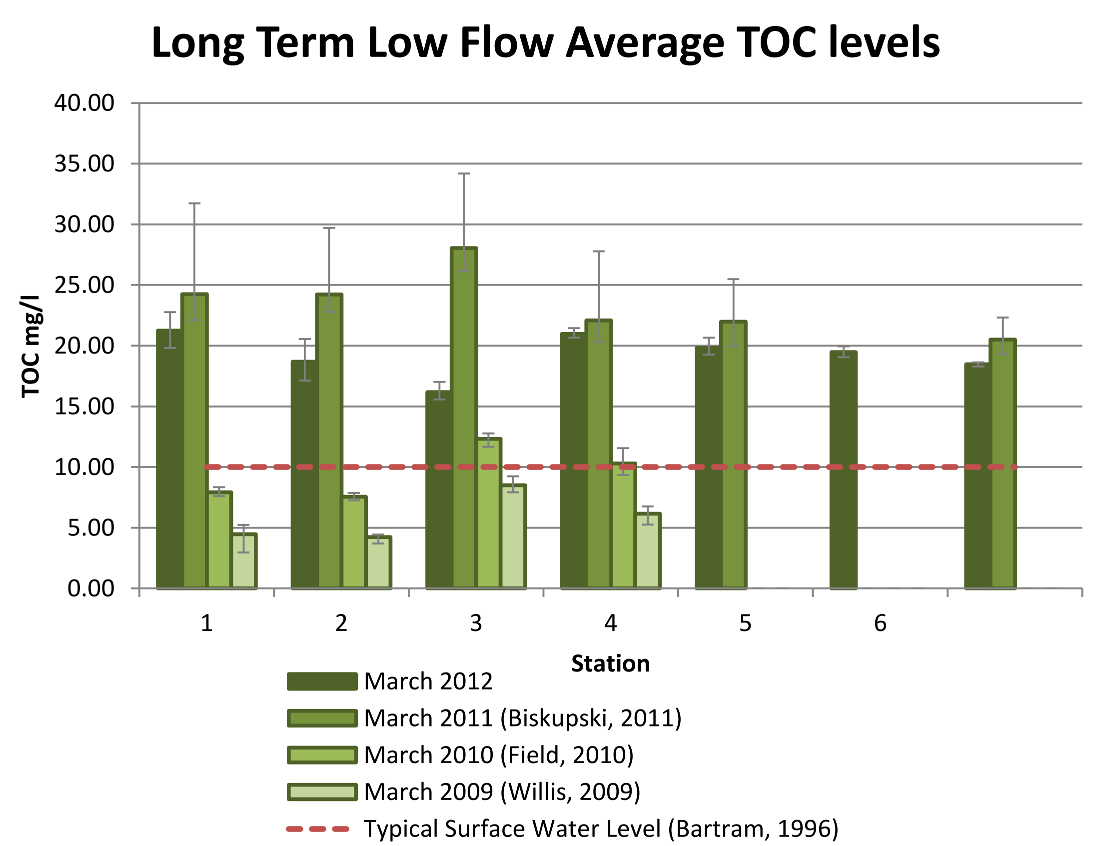


Figure 6.14: Graph of Long Term Average Low Flow TOC levels

Table 6.6: Long Term Average Low Flow TOC levels

	Station						
	1	2	3	4	5	6	7
March 2012	21.2	18.7	16.2	21.0	19.8	19.5	18.5
March 2011 (Biskupski, 2011)	24.2	24.23	28.04	22.09	21.97	-	20.49
March 2010 (Field, 2010)	7.92	7.538	12.315	10.305	-	-	-
April 2009 (Willis, 2009)	4.47	4.22	8.49	6.16	-	-	-
	TOC (mg/l)						

When observing TOC levels on a long term scale the 'KPO dip' identified in March 2012 is not present in any previous survey, in fact the opposite is true levels rise at the outfall in all prior studies. Range bars show that the mean is mostly representative of the gathered results with the exception of March 2011 where a large range shows the mean to be slightly misleading. March 2011 shows the greatest magnitude of TOC, 2010 and 2009 show reasonably low levels of TOC compared to typical levels. Levels have increased year on year, most steeply between 2010 and 2011. This year shows a slight decrease in TOC from 2011 but considerably higher levels than the 2009-2010 period. The long term trend shows a rise in TOC levels at KPO. Due to the use of calibrated machinery to accurately and reliably calculate TOC levels it is peculiar that March 2012 contradicts previous trend. Samples were collected and analysed in the same manner and at the same time of year as previous studies, it would therefore be expected that results follow a similar trend but this is not the case.

6.4 Chemical Oxygen Demand (COD) Results

Figure 6.15 shows the COD levels gathered from the March 2012 study at times of high and low flow. COD results are less reliable than TOC results due to the sensitive nature of the titration procedure and the need for high technical capability. The results in this section are therefore of questionable accuracy and may be suspect to human error.

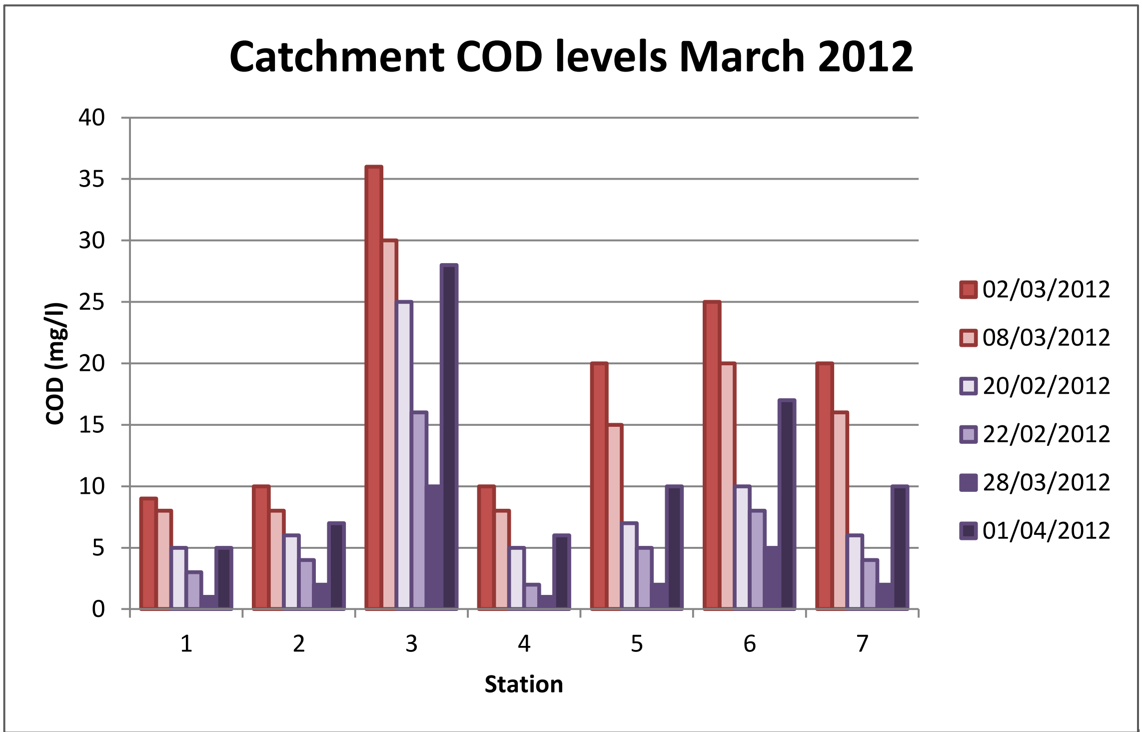


Figure 6.15: Graph of High and Low Flow COD levels from March 2012

The graph shows a consistent trend on all sampling trips; levels enter the system comparatively low before reaching a catchment maximum at KPO. The levels reduce at the A1 Outfall and begin to steadily rise to another peak at SB before dropping to JD levels. The relationship is present in all sampling trips although varies in magnitude across the sampling period. Higher flows correspond to a higher COD. Table 6.7 shows the exact values gathered in the study.

Table 6.7: COD levels (mg/l) Values from March 2012

	Station						
	1	2	3	4	5	6	7
02/03/2012	9	10	36	10	20	25	20
08/03/2012	8	8	30	8	15	20	16
20/03/2012	5	6	25	5	7	10	6
22/03/2012	3	4	16	2	5	8	4
28/03/2012	1	2	10	1	2	5	2
01/04/2012	5	7	28	6	10	17	10
	COD (mg/l)						

Figure 6.16 shows the average COD levels at high and low flow to allow the discussed trend to be clearly visualised and a long-term analysis made. Range bars have been used to show the accuracy of the mean. The range at high flows is relatively low due to fewer sampling trips occurring at these times. Low flows exhibit a large range of COD levels; this is important when considering long term averages as the mean may be misrepresentative of catchment characteristics. Table 6.8 gives the calculated average values.

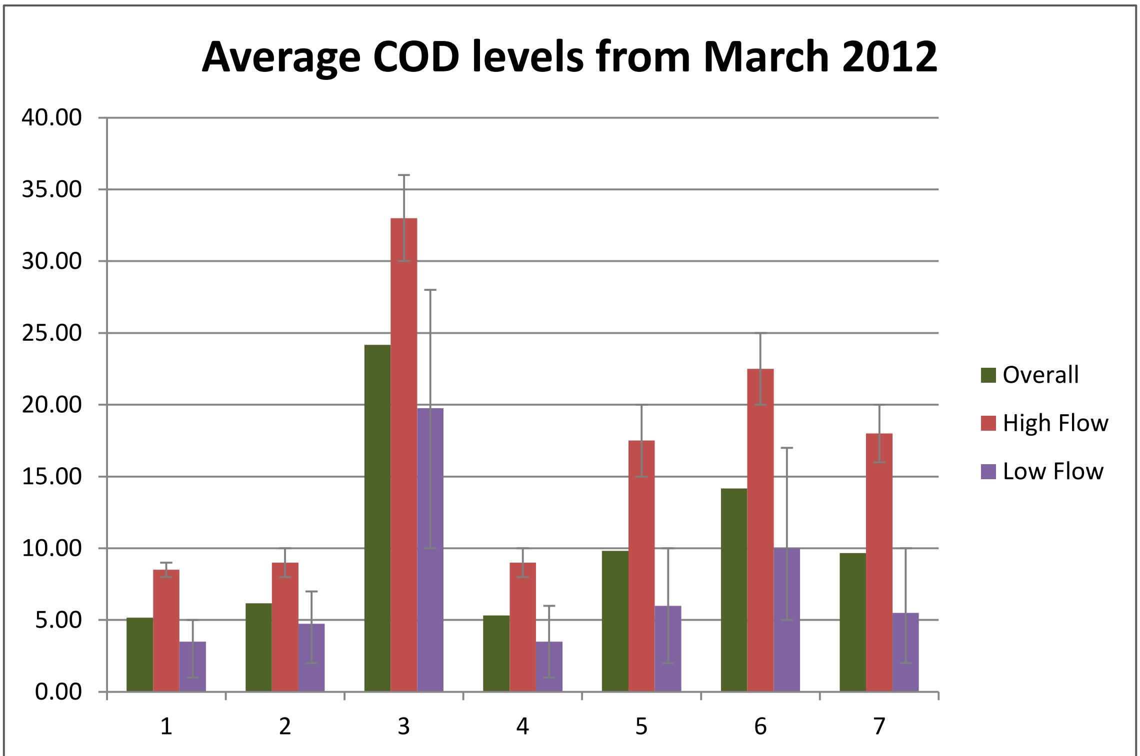


Figure 6.16: Graph of Average COD levels from March 2012

Table 6.8: COD Average Values from March 2012

	Station						
	1	2	3	4	5	6	7
Overall Average	5.17	6.17	24.17	5.33	9.83	14.17	9.67
High Flow	8.50	9.00	33.00	9.00	17.50	22.50	18.00
Low Flow	3.50	4.75	19.75	3.50	6.00	10.00	5.50
	COD mg/l						

Figure 6.17 shows the identified oxygen demand relationship compared to their distribution within the sample catchment, adding scale to the previously identified trend. As in previous results sampling is sparse after RHF and the relationship becomes less identifiable. The concentrated sampling around the KPO allows the relationship to be visualised more confidently. The graph shows a sudden, sharp increase in COD at KPO over a short distance. There is an increase in COD between RHF and SB but due to a lack of sampling data is not possible to identify the nature of the relationship in this region.

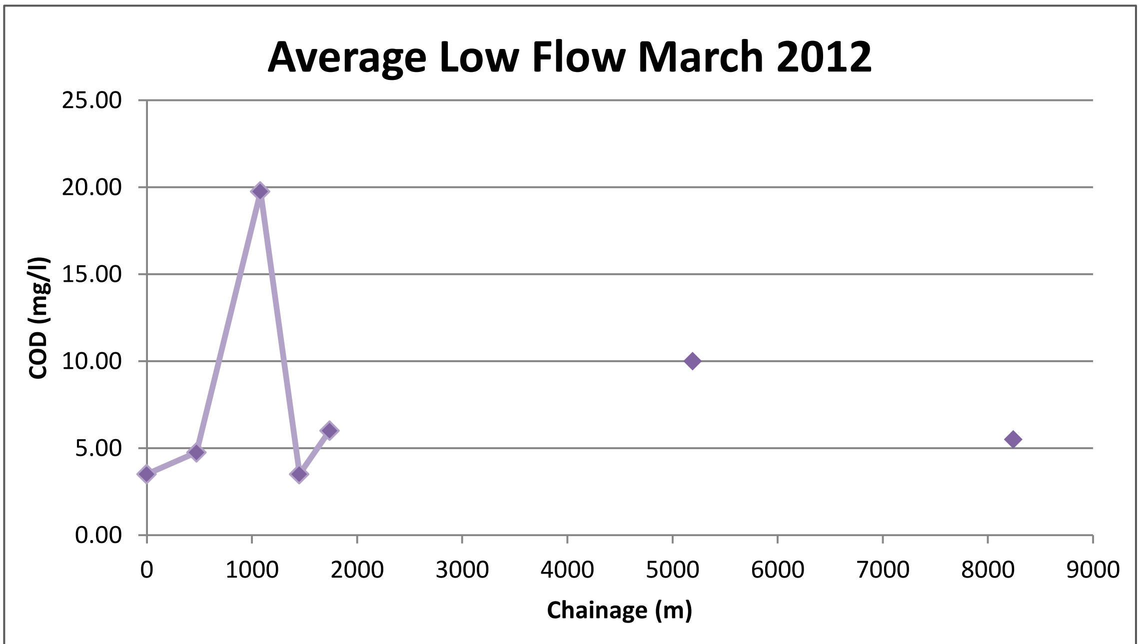


Figure 6.17: COD Sample Distribution Graph from March 2012

Long-term COD data is relatively sparse due to the evolution of the project and the inclusion of new sampling points. The COD test was not included in the 2011 study, where a BOD test was preferred. Figure 6.18 shows the long term low flow average COD levels due to a lack of high flow data in previous studies. Range bars shows a lack of confidence in the results of 2012 and the majority of previous results to be reasonably reliable. A rise in COD levels at KPO is present in all studies which adds weight to the gathered data. The absence of COD data after the A1 outfall means no long-term trend can be identified in this region. Levels increased over the 2009-2010 period but are shown to drop in 2012. The lack of data from 2011 makes it difficult to identify the overall long term trend as a gap appears. Precise values are given in Table 6.9.

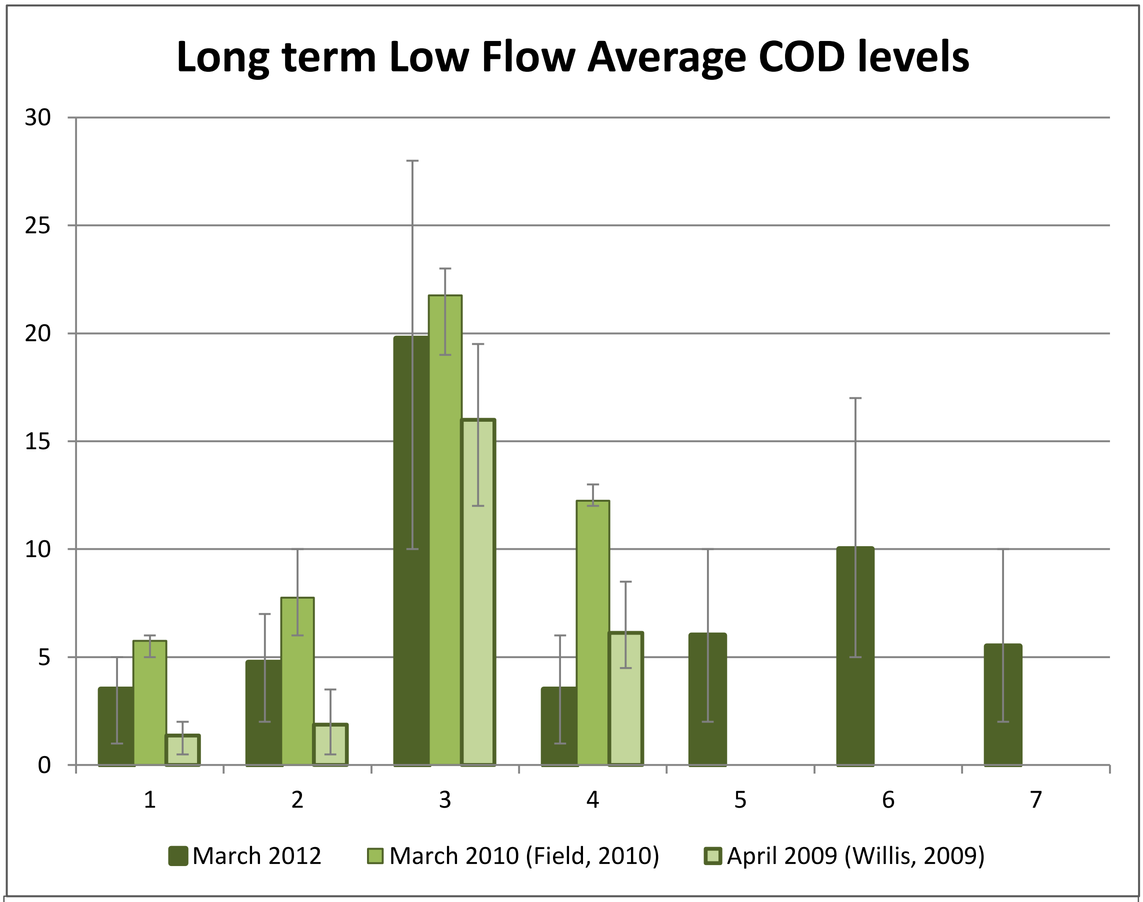


Figure 6.18: Graph of Long Term Average Low Flow COD levels

Table 6.9: Long Term Average Low Flow COD levels

	Station						
	1	2	3	4	5	6	7
March 2012	3.5	4.8	19.8	3.5	6.0	10.0	5.5
March 2010 (Field, 2010)	5.75	7.75	21.75	12.25	-	-	-
April 2009 (Willis, 2009)	1.37	1.875	16	6.125	-	-	-
	COD (mg/l)						

7. Discussion

The results gathered provide evidence demonstrating point source faecal pollution is occurring at Kingston Park Outfall (KPO) and at another location downstream. The high levels of faecal pollution shown can have potentially drastic effects on the aquatic and riparian environment; damaging wildlife and biodiversity, causing a foul smell and unsightly debris to enter the river, some of which are already noticeable upon arrival at the Ouseburn.

Table 7.1 shows the EA assessment of the Ouseburn between 2002 and 2006, displaying degradation occurring between Brunton Bridge (BB) and Three Mile Bridge (TMB) since 2003 after which the river's quality is significantly reduced. Studies investigated the region in an attempt to identify the source of the pollution in this stretch. Previous studies and this study conclusively show that in the stretch from BB to TMB, KPO is responsible for the degradation in water quality, demonstrating vast quantities of faecal matter entering the watercourse.

Table 7.1: General Quality Assessment of Ouseburn 2002-2006 (Callard, 2008)

From	To	Sample	km	2002	2003	2004	2005	2006
Source	Airport steam	Woolsington	3.8	C	D	D	D	D
Airport steam	Bent Hill	Brunton Bridge	2.2	C	C	C	C	B
Bent Hill	Great North Road	Three Mile Bridge	2	C	D	D	D	D
Great North Road	Castle Farm	Castle Farm	2.4	C	B	C	C	C
Castle Farm	Jesmond Dene	Jesmond Dene	1.8	C	B	C	C	C
Jesmond Dene	Tidal limit	Jesmond Dene	1	C	B	C	C	C
Tidal limit	Tyne	N/A	1	NA	NA	NA	NA	NA

However, previous surveys presumed the pollution identified at KPO was responsible for the decline in water quality in the remaining stretch of river. This study irrefutably shows faecal pollution levels rise again in the Red House Farm (RHF) to Salters Bridge (SB) region of the catchment, after KPO, indicative of another source of pollution. Due to the sparse dispersal of the sampling stations neither the location of the pollution or its true magnitude can be defined, but it is clear there is a definite rise. This provides a valuable insight into an unexplored region of the Ouseburn, previously assumed to be inactive with regards to pollution. Further sampling within the stretch could lead to the identification of the location and magnitude of this new pollution source in the Ouseburn.

Biskupski (2011), as well as others, based his study upon the assumption that KPO was the sole contributor to pollution in the Ouseburn, examining the effects of the outfall's pollution on Jesmond Dene (JD). The sampling regime designed by Biskupski used this assumption to justify the gulf between sampling at RHF and JD, presuming inactivity in the vast expanse. However the unexplored region is host to numerous storm overflows, all of which have potential to contribute faecal pollution to the Ouseburn prior to JD. Biskupski (2011) stated his results showed '*that there is only one main source of pollution in the Ouseburn, after the main influx of pollution at Kingston Park outlet; E-coli, BOD and TOC levels fall.'* Biskupski's conclusion that KPO is the only source of pollution in the Ouseburn has been discovered to be inaccurate in this study through the introduction of the SB sampling station. The rise in pollution in the RHF to SB stretch suggests that pollution levels at the Dene are the result of another source, potentially in combination with residual pollution from KPO.

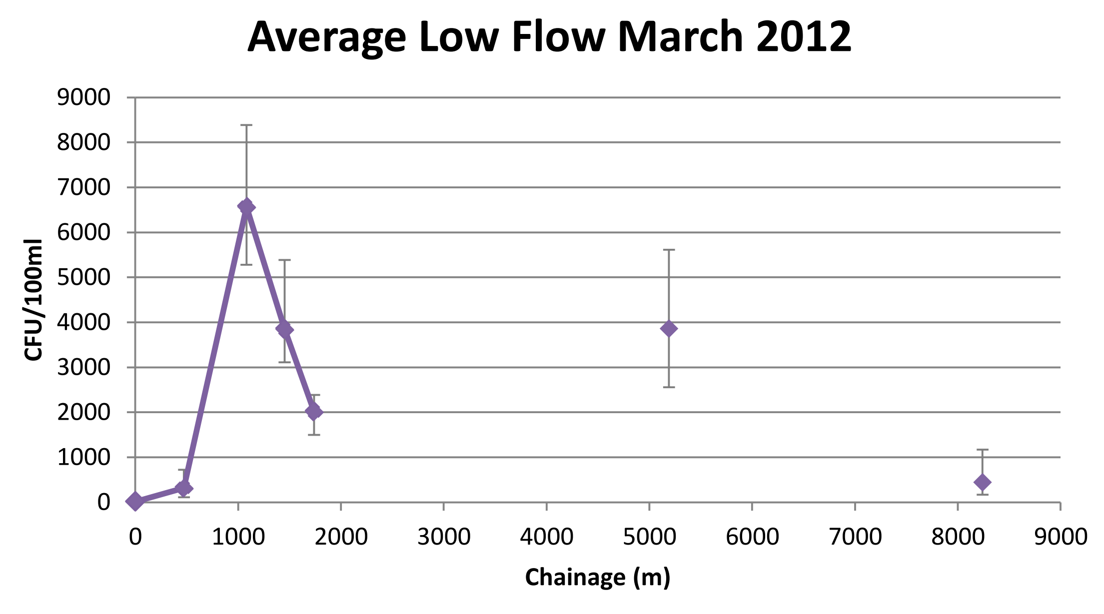


Figure 7.1: FIO Sample Distribution Graph from March 2012

Figure 7.1 supports this theory, showing the average CFU/100ml at low flow with regards to the distribution of samples in the catchment. The range bars show that across all samples there is a rise between RHF and SB. The effects of pollution at KPO are shown to be relatively localised within the system becoming quickly diluted, creating a spike which quickly declines. It is worth noting these results are at a time of low flow, indicative of lower pollution levels. The results demonstrate that where previous studies presumed KPO to be responsible for the decline in water quality downstream this is not the case, the effects are highly localised within a small region. There is another factor in play.

Drawing comparisons between this study and previous studies allows for an examination of how water quality in the Ouseburn is changing under growing pressures from urban development. The studies used for comparison were completed by Biskupski (2011), Field (2010) and Willis (2009).

As the survey has evolved the study catchment has expanded to explore new hypothesis and hence not all sampling stations are present in all surveys. Some stations are however consistent, which have been used to make comparisons.

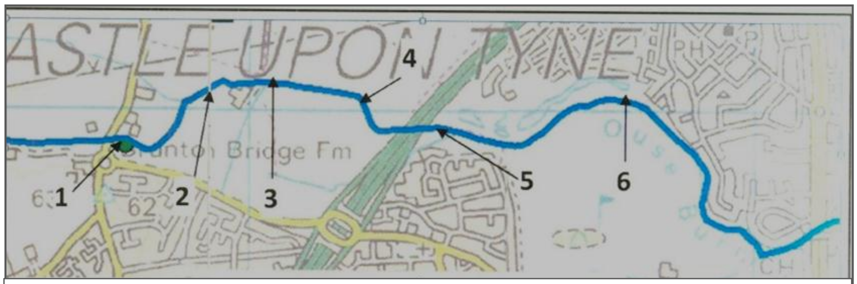


Figure 7.2: Willis' Sampling Distribution (Willis, 2009)

Figure 7.3: Field's Sampling Distribution (Field, 2010)

Figure 7.4: Biskupski's Sampling Distribution (Biskupski, 2011)

Figures 7.2, 7.3 and 7.4 show the distribution of the sampling stations in the previous studies. A comparison can only be realistically and reliably made over the BB to A1 outfall stretch of the river as these are consistent across all surveys. The station numbers used in this discussion are the numbers given to the stations throughout this study; previous survey numbering has been translated to fit into this structure.

The majority of results gathered across all studies, including this one, have taken place at times of low flow. There is an ideal relationship between faecal contamination from storm overflows and rainfall; less rainfall leads to less surface runoff and hence less pollution. Higher flow results from this study show this relationship to be true, demonstrating significantly higher faecal pollution than times of low flow. In this project the flow state of the river was graded visibly and 'high flows' are those flows which are higher relative to others within the study, as a result high flows in this study are certainly not as high as those associated with winter or autumn. While high flow results show considerably higher levels of pollution, reaching exceptional levels of 40,000 CFU/100ml, there exist only two sampling trips to represent this period resulting in a lack of reliability. For long-term comparison it is necessary to use the derived low flow averages due to the consistent low flow conditions of previous studies.

Faecal contamination is at the centre of this project; it is valuable to compare the pollution levels identified in this investigation with those of others. Table 7.2 shows that concentrations had been reducing since Willis' (2009) study. Previous studies placed this down to the variance in precipitation across the different study periods leading to less pollution due to less surface runoff. The results of this year show a dramatic increase across the majority of stations, with exception at BB which demonstrates a large reduction. March 2012 exhibits the highest faecal contamination in the history of the study. All studies show conclusively the pressure of urbanisation on the catchment; contamination levels income low from the agricultural upstream region but upon passing through the urbanised area of Kingston Park rise sharply.

Table 7.2: Long Term Average Low Flow CFU/100ml

	Station			
	1	2	3	4
March 2012	14	319	6569	3847
March 2011 (Biskupski, 2011)	89	273	2009	1146
March 2010 (Field, 2010)	55	47	2737	1036
April 2009 (Willis, 2009)	97	90	4983	2385
	CFU/100ml			

As shown in the results section the Total Organic Carbon (TOC) results gathered from this year's study contradict previous year trends (Figure 6.14). There should be an observable relationship between TOC and Chemical Oxygen Demand (COD) which does not seem present; in fact the inverse relationship to expected is exhibited. TOC is measured using calibrated machinery whilst COD uses a titration method prone to human error, making TOC results inherently more reliable than COD. However COD levels peak at KPO as would be expected in coordination with the faecal concentration rise. TOC levels demonstrate the inverse, dipping at KPO. TOC is technically more accurate than COD, but COD exhibits the expected relationship with faecal contamination while TOC does not. These results are believed to have a source of error within, or an unidentifiable external factor affecting their outcome, and therefore have not been included in the long-term analysis as their reliability is questionable. This does not affect the overall outcome of the project, as faecal plate count results are reliable and the main focus of the survey.

Precipitation levels are theoretically linked to the amount of faecal pollution and have been used as an explanation by others for long-term variance in contamination levels; as rainfall increases so does surface runoff and hence more pollution enters the river either through combined sewer outfalls or under-performing storm overflows. Therefore as monthly precipitation increases, it would be expected to see relative increases in faecal contamination at Kingston Park for that month. The 2009-2011 period exhibited this relationship showing faecal contamination to decline with rainfall, and vice versa (Table 7.3). However while this year has shown an increase in precipitation the increase in faecal pollution demonstrated is disproportionate compared to previous studies. Faecal contamination is significantly higher than that of 2009 but precipitation significantly lower. Averages are inherently prone to distortion; using the total monthly precipitation may lead to a misrepresentation as it is not known when exactly the rainfall fell during the study window. In fact faecal contamination results suggest the majority of rainfall fell within the first week of March when the river was observed to be at higher flows, hence using the average CFU/100ml may be misrepresentative but without more accurate precipitation data it would be speculative to assume the relationship between faecal contamination and flow is present. The precipitation levels were also measured at Durham, a significant distance away from the Ouseburn, meaning they may not be fully representative. Still this would not account for the vast difference displayed in the relationship. Perhaps a reason for this large rise is the previously identified damaged infrastructure becoming worsened by further urbanisation and more extreme winter runoffs placing stress on existing weaknesses leading to further failure, this is difficult to prove without validation from further monitoring. It is clear however there is change in the Ouseburn at Kingston Park this year; contamination is much worse at considerably lower flows.

Table 7.3: Long Term Precipitation Data, March to April (MET Office, 2012)

Year	Month	Total Precipitation (mm)	Average CFU/100ml at Kingston Park
2009	April	36.8	4983
2010*	April	12.4	2737
2011*	April	7.2	2009
2012	March	15.0 (*Provisional*)	6569

*Some sampling took place in March but this was majorly in the preliminary phases of the project and the majority of the data was gathered within the MET Office April timeframe.

Data available at: http://www.metoffice.gov.uk/climate/uk/stationdata/durhamdata.txt

As previously discussed the majority of the results analysed were observed at times of low flow indicative of lower pollution, but the faecal contamination data set gathered by first year undergraduates was collected in the higher flow October to November timeframe. A useful comparison can therefore be made regarding the effects of flow on pollution levels. The sampling station used in the gathering of this data was Crag Hall, which lies south of SB in the vicinity of JD. Biskupski's (2011) data is the only year available for comparison at the Dene within the 2009 to 2011 timeframe. The data set is not as useful as initially perceived; a lack of details about sampling dates meant the data had to be treated as a bulk period rather than yearly which would be more valuable. The only meaningful result that could be gathered from the set is the mean faecal contamination value of 5,780 CFU/100ml over the three year period due to this lack of detail.

Table 7.4 shows the precipitation levels in the months where sampling took place by the first year students. While it is not possible to differentiate the results yearly for a more comprehensive comparison it is clearly visible that Table 7.4 shows greater precipitation over the three year period in this timeframe than the March to April window, hence the gathered results are at significantly higher flows. 2011 represents a particularly dry year, shown in both Table 7.3 and 7.4, which could potentially affect the comparison between Biskupski's study and the first year data set due to Biskupski's average lying solely in this dry period and the other incorporating the two wetter years. It is still visible that the October to November timeframe is consistently wetter than the March to April window, even in the dry year of 2011, so some conclusions can be drawn although vague due to the data limitations.

Table 7.4: Long Term Precipitation Data, October to November (MET Office, 2012)

Year	Month	Total Precipitation (mm)
2009	October	46.2
	November	146.6
2010	October	62.2
	November	157.3
2011	October	53.8
	November	27.2

Data available at: http://www.metoffice.gov.uk/climate/uk/stationdata/durhamdata.txt

Table 7.5 shows a comparison of faecal contamination across the two different flow phases. Whilst samples were not collected at the exact same location the stations are relatively close and there is no water infrastructure between the two suspected to be polluting the river. Therefore a conclusion can be made on the effects of flow on the water quality in JD. Table 7.5 reiterates that at high flows faecal pollution in the Ouseburn is substantially higher than at lower flows. This verifies the observed relationship within the faecal contamination data gathered this year, which was previously of questionable accuracy due to only two available 'higher' flow data sets. This flow relationship is indicative of pollution from malfunctioning storm overflows, as rainfall increases storm overflows are operated and pollute receiving waters. Once again the pressures of urbanisation on the Ouseburn resonate throughout.

Table 7.5: High and Low Flow Faecal Contamination Comparison at Jesmond Dene

Years	Timeframe	Flow	Average CFU/100ml	Station
2009-2011	October - November	High	5,780	Crag Hall
2011 (Biskupski, 2011)	March - April	Low	256	Jesmond Dene

As discovered in the literature review in summer months the Dene becomes a bathing water for children and should meet standards of the Bathing Water Directive (BWD); it is not currently legally obliged to do so as it is not a recognised bathing site. Current standards regarding faecal contamination in the BWD state levels above 2000 CFU/100ml as incompliant and are set to reduce to 500 CFU/100ml in the near future. Table 7.5 indicates that at times of low flow the levels even comply with the more stringent standards of the future but at higher flows the level of pollution is nearly three times the acceptable level. However it is unlikely that bathing will be occurring in the river at these higher flows and hence pollution in the Dene is currently not a major risk to public health, but as the climate continues to change and further urbanisation higher flows will be a more frequent occurrence creating a larger risk.

A main issue is that the Ouseburn is an easily accessible watercourse used by the local residents as a recreational area for walking and relaxing with a large potential for human interaction. The identified faecal pollution from storm overflows not only poses a potential threat to health but leads to unsightly debris and a foul smell in the river which damages the experience of the public using the riparian environment for recreational activities.

Previous studies have attempted to design engineering solutions, such as reed beds, to increase water quality in the Ouseburn; treating Kingston Park's polluting waters prior to entering the river. The ideal solution would be to identify the weakness in the system that is leading to this localised pollution. KPO provides a sewer relief point for a vast area and to identify and repair a single flaw in such a complex network is expensive, disruptive and impractical. This is the reason previous studies opted to design reed beds, cleansing the water prior to interacting with the river. However previous studies assumed that the degradation at Kingston Park was responsible for the downstream degradation which has been shown to not be the case in this study (Figure 7.1), although it may be the case at higher flows. In fact the effects of Kingston Park have been shown to be highly localised, begging the question as to whether large-scale engineering solutions should be carried out at all. Naturally it is unacceptable to have sewage entering a watercourse that is frequented by locals as a walking spot but it is unrealistic, both financially and spatially, to implement a 40,000 m^2 reed bed in an urban environment where degradation occurs for only 700m of the river, after which levels become acceptable for human interaction again. It is unrealistic to implement the reed system due to these financial and spatial constraints, it may however be necessary to meet the '*one out, all out'* standards of the EA with regards to the WFD.

The public's major concern is the debris and smell in the river and the knock-on effects of pollution on biodiversity and wildlife. The best solution currently is likely to be to implement a finer screen on KPO to prevent debris from entering the watercourse. The banks in the area are steep and high meaning walkers are not directly adjacent to the river and the smell is not particularly noticeable. There is potential to place a fence along the 700m stretch to prevent the public accessing the river, but this is not recommended as it would ruin the environment and the public's experience of the Ouseburn whilst adding no real value. Perhaps signposts could be placed in the vicinity of the river informing the public of the dangers.

One bonus of implementing the reed bed system is the enhancement of water quality would increase biodiversity and wildlife in the region. However as previously stated the effects on water quality are shown to be localised with quality returning to standard levels shortly afterward (Figure 7.1). There is a risk that although the river quickly returns to acceptable levels with regards to faecal contamination, the small stretch of intense pollution may have detrimental knock-on effects to downstream biodiversity and ecology, providing weight to the argument for an engineering solution. Rivers by their very nature are a complex system where upstream conditions can vastly impact those downstream. To truly understand the effects of the pollution on downstream biodiversity it is necessary to carry out an ecological impact assessment, outside the scope of this project. It is important the public are engaged in the solution-making process to ensure they are aware of the constraints and responsibilities of professional bodies operating in the region and the relative scale of the issue.

The on-going pollution situation in the Ouseburn is likely to become worsened by further urbanisation in combination with an ever-changing climate; as developments continue to utilise the Ouseburn as a stress-relief in more frequent times of heavy rainfall, contamination will continue to worsen. There is a risk that the damaged infrastructure identified at the KPO will become overwhelmed and deteriorate further as a result of creeping impermeability, increasing surface runoff, and climate change, increasing more extreme precipitation events. In fact this year may already show the first signs of further damage to the system; demonstrating much higher pollution levels at much lower flows than previously, perhaps due to a weakening in the infrastructure. The Flood and Water Management Act however presents a positive picture regarding the effects of future urbanisation on sub-urban rivers like the Ouseburn, making the sustainable management of drainage a legal obligation and easing human induced pressures.

The major concern from the milieu explored in this project is the discovery of the rise in pollution between RHF and SB, the true magnitude and precise location of which is not known. Levels have potential to rise much higher in the unexplored region. This new pollution source could also have more direct effects on public health due to its proximity to the Dene compared to Kingston Park. The source may be in an easily accessible part of the river and further investigation is necessary to identify the cause of this rise in pollution and examine its effect on the public and river ecology.

8. Conclusions

The review of literature within the study field allowed not only for the identification of gaps in prior research but provided contextual background to the study and a field-specific knowledge base. Knowledge gathered from researching the literature review in coordination with laboratory technician consultations informed a structured sampling methodology after which inductions led to the development of the necessary laboratory skills to collect, analyse and interpret samples accurately and efficiently.

The literature review led to the identification of the environmental water standards by which the Ouseburn's waters can be benchmarked. The review concluded that the Water Framework Directive fails to truly resonate in a relatively small catchment such as the Ouseburn and the relevant comparative standard was the Bathing Water Directive, due to the high potential for human interaction in the catchment. Pollution in Jesmond Dene at low flows is acceptable by Bathing Water Standards, but is significantly greater than acceptable levels at high flows. Risk to public health is low as during high flows it is inherently less likely waters will be used for bathing.

The reviewed data provides irrefutable evidence to demonstrate faecal pollution is occurring in the Ouseburn as a direct result of discharge from Kingston Park Outfall (KPO) and another location downstream. Where previous studies assumed KPO to be responsible for downstream degradation this has been shown to be incorrect, there is another source of faecal pollution located between Red House Farm and Salters Bridge which is contributing to downstream contamination levels. Faecal pollution from KPO has in fact been shown to be highly localised within a 700m stretch of the river; the impact of this on river ecology is currently unknown without the production of an ecological impact assessment.

The faecal contamination reported in this investigation exhibits the highest levels of pollution in the history of the study. Previously contamination had been correlated to precipitation levels, but this study demonstrates significantly higher levels of pollution in times of significantly less rainfall. It is theorised that this is due to previously identified damaged infrastructure becoming worsened. The pollution faced by the Ouseburn is believed to be under threat by further urbanisation in combination with an ever-changing climate in the future. There is a risk that identified under-performing infrastructure will become overwhelmed and deteriorate further.

The inclusion of a high flow data set gathered over a three year period between October and November was not as useful as first perceived due to a lack of details about sampling dates, resulting in the data being treated as a less specific three year period rather than year by year. The set did however show pollution in the Ouseburn to be related to flow showing higher flows to exhibit higher pollution levels, indicative of pollution from malfunctioning storm overflows. The pressures of urbanisation on the Ouseburn resonate throughout the study

Previous studies opted to design large-scale engineering solutions, such as reed beds. The approach towards SUDS outlined in this study was that these should only be created after an ecological impact assessment demonstrates that there is a case to do so, due to the localised nature of the pollution. This project has recommended the implementation of more soft approaches, such as signposts and finer screens on storm outlets, until the downstream consequences of the localised faecal pollution are understood.

The literature review identified the need for the project findings to be summarised and translated into an easily digestible report used as a public engagement tool. However it was perhaps optimistic to expect the production of this document within the given timeframe due to the extensive amount of time spent on collecting and analysing water samples.

9. Recommendations

9.1 A New Source of Pollution

The data gathered in the study concluded that Kingston Park Outfall (KPO) is not the sole source of faecal pollution in the Ouseburn deteriorating water quality; another pollution source lies downstream between the Red House Farm and Salters Bridge (SB) sampling stations. The precise magnitude and location of this pollution source is unknown due to the speculative nature of the inclusion of SB. An opportunity therefore arises to concentrate sampling in this region to characterise this new pollution source and its impacts on both the public and environment. This is highly recommended as the source is in much closer proximity to the bathing waters of Jesmond Dene and has great potential to have detrimental effects on public health.

9.2 Damaged Kingston Park Infrastructure

KPO has been proven time and again to be polluting the Ouseburn's waters through either damaged infrastructure or a misconnection. This project has demonstrated that the situation has changed with regards to damage this year; pollution is considerably higher at significantly lower precipitation levels, thought to be caused by further damage. Continued monitoring of the outlet is essential to build a body evidence to validate this observed damage change. With regards to the forming of solutions to combat this damaged infrastructure there is a need to conduct an ecological impact assessment to understand the implications of the localised pollution on biodiversity and wildlife showing the need for change.

9.3 Autumn & Winter Sampling

This survey took an initial step towards bridging the gap between low and high flow studies of the Ouseburn with the inclusion of the unique October to November dataset. As discussed this record was of debatable use due to a lack of detail regarding sampling trip dates. A relationship was observed but of questionable accuracy; higher flows exhibit higher levels of pollution. Sampling in the wetter months is highly recommended to further validate this relationship and add a new dimension to the Ouseburn water quality story.

9.4 Ouseburn Catchment Steering Group (OCSG)

The literature review in this project identified the importance of public engagement in changing the future of the Ouseburn; professional bodies will act if sufficient public concern is generated. There is a need for projects on the Ouseburn to be translated and communicated to the public; the OCSG presents a platform to make this a possibility. Future projects should be carried out in full co-ordination with the OCSG to add real value to investigations.

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Appendix 1

Project Management Statement

Figure A1.1 and A1.2 allow for a comparison between the provisional management structure and the actual events. The major shift was due to the time required for sampling and laboratory analysis, which was much greater than initially projected following consultations with laboratory technicians. There were many sacrifices to be made within the project; for example the production of a summary document was abandoned in favour of generating more sampling trips to build the body of evidence to support this thesis.

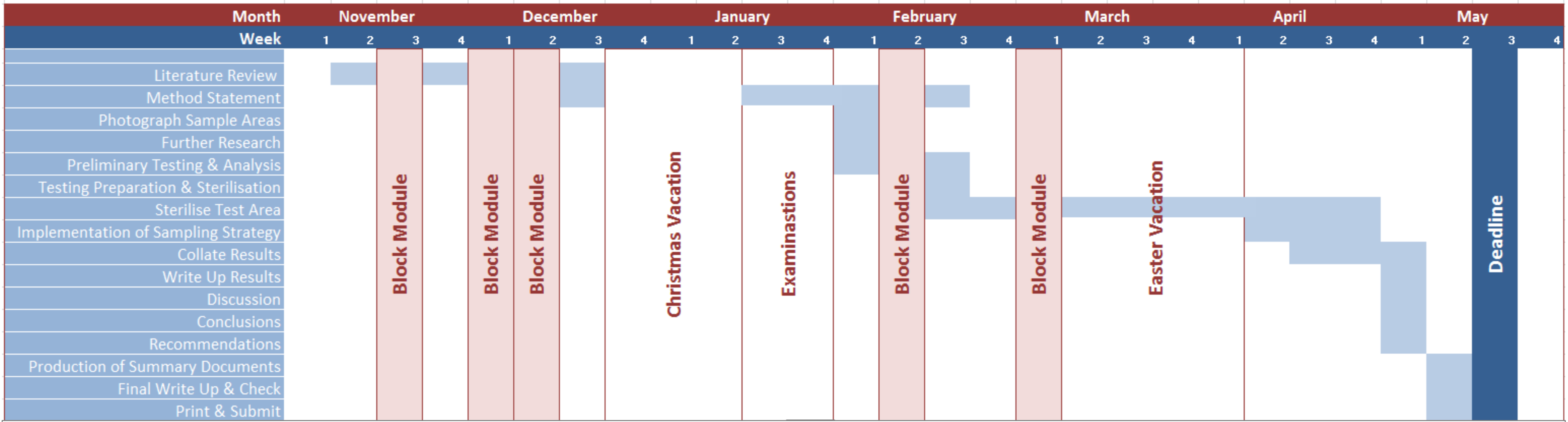

Figure A1.1: Provisional Gantt chart

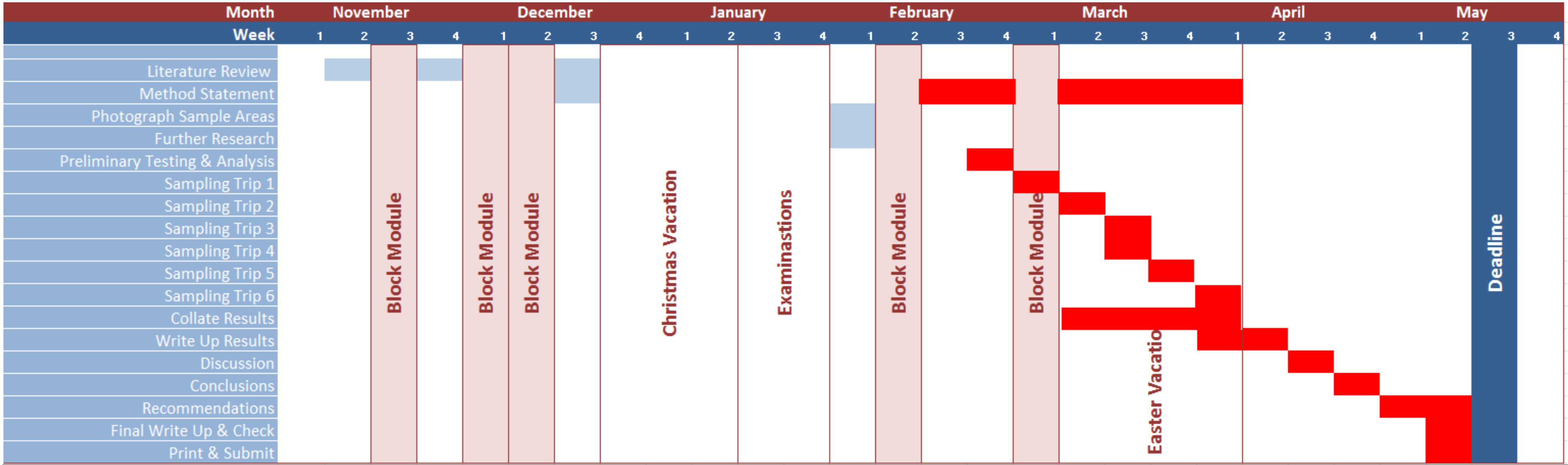

Figure A1.2: Actual Gantt chart

Appendix 2

Project Specific Information

A2.1 Enumeration of Bacteria Raw Data

02/03/2012

	1		2		3		4		5		6		7	
-1	22	18	19	23	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	24	28
-2	2	1	1	2	37	34	24	28	14	12	26	21	5	3
-3	0	0	0	0	5	6	2	1	1	0	0	0	0	0

	1		2		3		4		5		6		7	
-1	2444	2000	2111	2556	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	2667	3111
-2	2222	1111	1111	2222	41111	37778	26667	31111	15556	13333	28889	23333	5556	3333
-3	0	0	0	0	50000	60000	20000	10000	10000	0	0	0	0	0
CFU/100ml	2222		2333		39444		28889		14444		26111		2889	

08/03/2012

	1		2		3		4		5		6		7	
-1	20	19	17	26	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	20	26
-2	3	0	1	5	33	34	25	24	11	13	22	17	1	6
-3	0	0	0	0	3	2	3	1	3	2	2	1	0	0

	1		2		3		4		5		6		7	
-1	2222	2111	1889	2889	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	2222	2889
-2	3333	0	1111	5556	36667	37778	27778	26667	12222	14444	24444	18889	1111	6667
-3	0	0	0	0	30000	20000	30000	10000	30000	20000	20000	10000	0	0
CFU/100ml	2167		2389		37222		27222		13333		21667		2556	

20/03/2012

	1		2		3		4		5		6		7	
-1	1	0	1	1	58	64	32	34	19	20	24	22	10	11
-2	0	0	1	0	2	4	2	3	2	1	1	2	0	1
-3	0	0	0	0	0	1	0	0	0	0	0	0	0	0

	1		2		3		4		5		6		7	
-1	111	0	111	111	6444	7111	3556	3778	2111	2222	2667	2444	1111	1222
-2	0	0	1111	0	2222	4444	2222	3333	2222	1111	1111	2222	0	1111
-3	0	0	0	0	0	10000	0	0	0	0	0	0	0	0
CFU/100ml	56		111		6778		3667		2167		2556		1167	

22/03/2012

	1		2		3		4		5		6		7	
-1	0	0	8	5	82	69	45	52	15	12	56	45	3	1
-2	0	0	0	0	8	8	6	7	1	1	5	4	1	0
-3	0	0	0	0	0	0	0	1	0	0	0	0	0	0

	1		2		3		4		5		6		7	
-1	0	0	889	556	9111	7667	5000	5778	1667	1333	6222	5000	333	111
-2	0	0	0	0	8889	8889	6667	7778	1111	1111	5556	4444	1111	0
-3	0	0	0	0	0	0	0	10000	0	0	0	0	0	0
CFU/100ml	0		722		8389		5389		1500		5611		222	

28/03/2012

	1	2		3		4		5		6		7	
-1	0 0	1	2	49	46	27	29	20	16	32	28	2	1
-2	0 0	1	1	5	2	2	1	1	2	4	5	0	1
-3	0 0	0	0	0	2	1	0	0	1	0	0	0	0

	1	2		3		4		5		6		7	
-1	0 0	111	222	5444	5111	3000	3222	2222	1778	3556	3111	222	111
-2	0 0	1111	1111	5556	2222	2222	1111	1111	2222	4444	5556	0	1111
-3	0 0	0	0	0	20000	10000	0	0	10000	0	0	0	0
CFU/100ml	0	167		5278		3111		2000		3333		167	

01/04/2012

	1	2		3		4		5		6		7	
-1	0 0	2	3	56	49	31	27	22	21	34	37	3	1
-2	0 0	1	1	6	3	1	2	1	1	4	6	1	0
-3	0 0	0	0	1	0	0	0	0	0	1	0	0	0

	1	2		3		4		5		6		7	
-1	0 0	222	333	6222	5444	3444	3000	2444	2333	3778	4111	333	111
-2	0 0	1111	1111	6667	3333	1111	2222	1111	1111	4444	6667	1111	0
-3	0 0	0	0	10000	0	0	0	0	0	10000	0	0	0
CFU/100ml	0	278		5833		3222		2389		3944		222	

A2.2 Total Organic Carbon Raw Data

Date:	22/02/2012		mg/l TC	IC	TOC	Average TOC
	Blank	0	0.00	0.00	0.00	
		0	0.00	0.00	0.00	
	Brunton Bridge	1	60.74	41.49	19.25	
		1	59.35	41.10	18.25	18.75
	Upstream Kingston Park	2	60.60	40.81	19.79	
		2	59.39	41.24	18.15	18.97
	Kingston Park Outfall	3	43.44	23.55	19.89	
		3	43.91	23.54	20.37	20.13
	A1 Outfall	4	65.42	44.57	20.85	
		4	65.28	44.54	20.74	20.795
	Red House Farm	5	56.29	38.26	18.03	
		5	58.09	38.34	19.75	18.89
	Salters Bridge	6	57.87	38.74	19.13	
		6	57.81	38.69	19.12	19.125
	Jesmond Dene	7	53.74	36.16	17.58	
		7	53.89	36.54	17.35	17.465

Date:	02/03/2012		mg/l TC	IC	TOC	Average TOC
	Blank	0	0.00	0.00	0.00	
		0	0.00	0.00	0.00	
	Brunton Bridge	1	57.32	38.21	19.11	
		1	57.11	38.95	18.16	18.635
	Upstream Kingston Park	2	58.52	39.30	19.22	
		2	57.05	39.10	17.95	18.585
	Kingston Park Outfall	3	39.51	25.30	14.21	
		3	39.26	24.80	14.46	14.335
	A1 Outfall	4	67.21	47.12	20.09	
		4	67.02	47.21	19.81	19.95
	Red House Farm	5	59.83	38.72	21.11	
		5	59.72	38.80	20.92	21.015
	Salters Bridge	6	55.35	36.28	19.07	
		6	55.02	36.06	18.96	19.015
	Jesmond Dene	7	49.22	31.23	17.99	
		7	49.03	31.54	17.49	17.74

Date: 08/03/2012			mg/l			
			TC	IC	TOC	
		0	0.00	0.00	0.00	
	Blank	0	0.00	0.00	0.00	Average TOC
		1	58.24	39.00	19.24	
	Brunton Bridge	1	56.99	39.00	17.99	18.615
	Upstream Kingston Park	2	58.22	39.06	19.16	
		2	56.97	39.09	17.88	18.52
		3	39.39	25.31	14.08	
	Kingston Park Outfall	3	39.39	25.40	13.99	14.035
		4	67.07	47.02	20.05	
	A1 Outfall	4	66.87	56.55	20.32	20.185
		5	59.78	37.66	22.12	
	Red House Farm	5	56.54	37.92	18.62	20.37
		6	55.39	36.38	19.01	
	Salters Bridge	6	54.91	36.59	18.32	18.665
		7	49.50	31.99	17.51	
	Jesmond Dene	7	48.88	31.85	17.03	17.27

Date: 20/03/2012			mg/l			
			TC	IC	TOC	
		0	0.00	0.00	0.00	
	Blank	0	0.00	0.00	0.00	Average TOC
		1	67.33	41.70	25.63	
	Brunton Bridge	1	61.73	41.83	19.90	22.765
	Upstream Kingston Park	2	63.91	43.05	20.86	
		2	63.40	43.18	20.22	20.54
		3	41.00	23.43	17.57	
	Kingston Park Outfall	3	39.16	22.69	16.47	17.02
		4	70.18	48.60	21.58	
	A1 Outfall	4	68.62	48.15	20.47	21.025
		5	60.12	38.80	21.32	
	Red House Farm	5	59.94	39.93	20.01	20.665
		6	57.51	37.14	20.37	
	Salters Bridge	6	56.53	37.69	18.84	19.605
		7	54.32	34.95	19.37	
	Jesmond Dene	7	52.96	35.09	17.87	18.62

Date:	22/03/2012		TC (mg/l)	IC (mg/l)	TOC (mg/l)	Average TOC
	Blank	0	0.00	0.00	0.00	
		0	0.00	0.00	0.00	
	Brunton Bridge	1	61.39	41.49	19.90	
		1	61.53	41.81	19.72	19.81
	Upstream Kingston Park	2	62.52	43.01	19.51	
		2	63.31	42.91	20.40	19.955
	Kingston Park Outfall	3	39.12	22.84	16.28	
		3	37.70	22.86	14.84	15.56
	A1 Outfall	4	69.85	48.29	21.56	
		4	69.35	48.02	21.33	21.445
	Red House Farm	5	59.18	39.28	19.30	
		5	58.71	39.22	19.49	19.395
	Salters Bridge	6	55.92	36.35	19.57	
		6	56.08	37.12	18.96	19.265
	Jesmond Dene	7	55.05	35.98	19.07	
		7	54.16	36.07	18.09	18.58

Date:	28/03/2012		TC (mg/l)	IC (mg/l)	TOC (mg/l)	Average TOC
	Blank	0	0.00	0.00	0.00	
		0	0.00	0.00	0.00	
	Brunton Bridge	1	61.78	40.49	21.29	
		1	61.63	40.65	20.98	21.135
	Upstream Kingston Park	2	61.46	44.54	16.92	
		2	62.25	44.91	17.34	17.13
	Kingston Park Outfall	3	38.41	22.42	15.99	
		3	38.67	22.56	16.11	16.05
	A1 Outfall	4	68.95	48.29	20.66	
		4	69.03	48.24	20.79	20.725
	Red House Farm	5	58.17	39.56	18.61	
		5	58.89	38.98	19.91	19.26
	Salters Bridge	6	56.02	36.24	19.78	
		6	55.97	37.64	18.33	19.055
	Jesmond Dene	7	54.89	36.03	18.86	
		7	53.99	35.97	18.02	18.44

			mg/l			
Date: 01/04/2012			TC	IC	TOC	
Blank		0	0.00	0.00	0.00	
		0	0.00	0.00	0.00	Average TOC
Brunton Bridge		1	61.86	40.52	21.34	
		1	61.93	40.88	21.05	21.195
Upstream Kingston Park		2	61.61	44.52	17.09	
		2	61.99	44.81	17.18	17.135
Kingston Park Outfall		3	38.55	22.49	16.06	
		3	38.60	22.53	16.07	16.065
A1 Outfall		4	69.01	48.36	20.65	
		4	69.09	48.42	20.67	20.66
Red House Farm		5	58.23	38.20	20.03	
		5	58.76	38.93	19.83	19.93
Salters Bridge		6	56.11	36.22	19.89	
		6	56.02	36.01	20.01	19.95
Jesmond Dene		7	54.55	35.99	18.56	
		7	54.02	36.02	18.00	18.28

A2.3 Chemical Oxygen Demand Raw Data

Average Titration Values

		Date					
		2	**8**	**20**	**22**	**28**	**1**
Station	1	5.91	6.02	6.05	6.07	6.19	5.85
	2	5.9	6.02	6.04	6.06	6.18	5.83
	3	5.64	5.8	5.85	5.94	6.1	5.62
	4	5.9	6.02	6.05	6.08	6.19	5.84
	5	5.8	5.95	6.03	6.05	6.18	5.8
	6	5.75	5.9	6	6.02	6.15	5.73
	7	5.8	5.94	6.04	6.06	6.18	5.8

COD levels (mg/l)

		Date					
		2	**8**	**20**	**22**	**28**	**1**
Station	1	9	8	5	3	1	5
	2	10	8	6	4	2	7
	3	36	30	25	16	10	28
	4	10	8	5	2	1	6
	5	20	15	7	5	2	10
	6	25	20	10	8	5	17
	7	20	16	6	4	2	10

A2.4 First Year Data Set

			CFU/100ml	Difference from mean squared
19	Over 1 Deviation	1	136.7	12731182.99
		2	213	12192515.93
		3	213	12192515.93
		4	246.7	11958305.76
		5	247	11956231
		6	247	11956231
		7	247	11956231
		8	253	11914773.66
		9	253	11914773.66
		10	270	11797702.2
		11	270	11797702.2
		12	310	11524519.93
		13	310	11524519.93
		14	323	11436424.7
		15	323	11436424.7
		16	400	10921559.83
		17	400	10921559.83
		18	463	10509126.76
		19	463.3	10507181.79
31	Inside 1 Deviation	20	500	10270604.17
		21	500	10270604.17
		22	800	8437737.166
		23	933	7682755.129
		24	3000	496712.4991
		25	3300	163845.4991
		26	3300	163845.4991
		27	3730	636.1324694
		28	3730	636.1324694
		29	3800	9067.165803
		30	3800	9067.165803
		31	3830	15680.4658
		32	4000	87155.83247
		33	4000	87155.83247
		34	4400	483333.1658
		35	4500	632377.4991
		36	4500	632377.4991
		37	4500	632377.4991
		38	4850	1311532.666
		39	5000	1677599.166
		40	5300	2544732.166
		41	5300	2544732.166
		42	5300	2544732.166
		43	5433	2986750.129

			CFU/100ml	Difference from mean squared
		44	5433	2986750.129
		45	5500	3222820.832
		46	5530	3331434.132
		47	5530	3331434.132
		48	6000	5268042.499
		49	6000	5268042.499
		50	6000	5268042.499
8	Over 1 Deviation	51	7000	10858485.83
		52	7000	10858485.83
		53	7333	13163992.46
		54	7800	16770840.5
		55	7800	16770840.5
		56	8000	18448929.17
		57	8400	22045106.5
		58	8400	22045106.5
	Outliers	59	13000	86401145.83
		60	13666	99225937.09

Appendix 3

Risk Assessments

A3.1 Field Work

Newcastle University Risk Assessment	
Title of project or activity	**Project**: *A Water Quality Survey of the River Ouseburn* **Activity:** *Field Work*
Responsible Person / Manager	**Supervisor:** DR PAUL QUINN **Researcher:** MATTHEW RENNIE
School	SCHOOL OF CIVIL ENGINEERING & GEOSCIENCES, NEWCASTLE UNIVERSITY
Date of assessment	06/02/2012
Location of work **(Buildings and room numbers)**	Sampling from the river Ouseburn, Newcastle Upon Tyne.
Introduction	
The following risk assessment and guidance has been developed to assess the hazardous activities, risks and identify appropriate prevention and control measures. A simple implementation check is provided to assist schools in demonstrating that the control measures are being implemented. Please identify when they have been implemented.	
Activities with Hazardous Potential and Significant Risks	
These are contained within the shaded area. The first shaded area in the assessment identifies the hazard or hazardous activity and the second identifies the risks imposed by that activity.	
Preventative and Protective Measures to Avoid or Reduce Risks to an Acceptable Level	
These are contained within the un-shaded areas. This section identifies the control measures required and may require schools to choose options or carry out additional risk assessments.	
Help and Support	
Safety Office Occupational Health Service	Schools must visit the University Safety Office website. The website contains a wide range of guidance to assist schools to manage health and safety effectively including University Safety Policies and Supplements, Safety Guidance, Training, Forms, etc.

Hazard 1	Access to river	Implemented	Date
Risks	There is a risk of falling into, or around, the river when collecting the samples, especially at high flows; this is a reasonably high risk. Presents a risk to the person collecting the sampling.		
Control Measures	Sampling should never be carried out alone. Visiting the sample points prior to sampling will allow for the collector to identify any possible risks and provide specific solutions to the problem – i.e. steep banks may make it hard to access the river and another sampling technique (bucket and string) method may be required. Suitable footwear should be worn if required.		

Hazard 2	Traffic	Implemented	Date
Risks	The sampling sites are in an urban area and hence there is a risk to personal safety, however the river is mainly located away from roads and the risk is generally low apart from some sampling stations (i.e. Brunton Bridge). Presents a risk to the team carrying out the fieldwork.		
Control Measures	General vigilance and awareness of traffic dangers should provide sufficient solution to the risk. High visibility clothing may be worn to alert drivers to your presence.		
Hazard 3	Infection	Implemented	Date
Risks	When collecting the samples, there is a risk of infections from the raw river water entering the person through open wounds or the mouth. This could result in illness. Presents a risk to the person collecting the sampling.		
Control Measures	Cover all open wounds/broken skin prior to sampling by plasters or gloves. Wash hands both prior and after sampling.		
Hazard 4	Severe Weather	Implemented	Date
Risks	There is a risk of severe weather, namely rain events, which could make the river banks more dangerous and threaten personal safety.		
Control Measures	When planning field trips it is important to be aware of the weather, in addition to weather forecasts. Information about potential local flooding can be obtained from the Environment Agency website. Prior to trips weather reports should be checked to ensure safety and avoid times of severe weather. Appropriate clothing should be worn at all times.		
Hazard 5	Transport between stations	Implemented	Date
Risks	Road traffic accidents arising from drivers lack of competence, drivers fatigue or loss of concentration or the state of the vehicle. Presents a risk to the driver, passenger, other road users and pedestrians.		
Control Measures	General vigilance and awareness of the Highway Code will allow this risk to be controlled.		
Hazard 6		Implemented	Date
Risks			
Control Measures			
	Emergency Procedures	Implemented	Date
Risks	It is important to be able to communicate in an emergency, so a mobile phone or a VHF radio is important. Check the reception prior to sampling, however, because it can vary in remote areas. Do not sample alone, as others can help in an emergency.		
Control Measures			

Hazards	**Additional Control Measures Required (List and Implement)**	Implemented	Date	N/A
Risks				
Control Measures				

Assessor		
Name	**Signature**	**Date**
Matthew Rennie		
Responsible Person / Manager		
Name	**Signature**	**Date**
Paul Quinn		

A3.2 Laboratory Work

Newcastle University Risk Assessment	
Title of project or activity	**Project**: *A Water Quality Survey of the River Ouseburn* **Activity:** *Laboratory Work – Total Organic Carbon, Chemical Oxygen Demand & Enumeration of Bacteria.*
Responsible Person / Manager	DR PAUL QUINN
School	SCHOOL OF CIVIL ENGINEERING & GEOSCIENCES, NEWCASTLE UNIVERSITY
Date of assessment	06/02/2012
Location of work **(Buildings and room numbers)**	ENVIRONMENTAL ENGINEERING TEACHING LAB, 1ST FLOOR, CASSIE BUILDING (UNIVERSITY MAP REF: 49)
Introduction	
The following risk assessment and guidance has been developed to assess the hazardous activities, risks and identify appropriate prevention and control measures. A simple implementation check is provided to assist schools in demonstrating that the control measures are being implemented. Please identify when they have been implemented.	
Activities with Hazardous Potential and Significant Risks	
These are contained within the shaded area. The first shaded area in the assessment identifies the hazard or hazardous activity and the second identifies the risks imposed by that activity.	
Preventative and Protective Measures to Avoid or Reduce Risks to an Acceptable Level	
These are contained within the un-shaded areas. This section identifies the control measures required and may require schools to choose options or carry out additional risk assessments.	
Help and Support	
Safety Office Occupational Health Service	Schools must visit the University Safety Office website. The website contains a wide range of guidance to assist schools to manage health and safety effectively including University Safety Policies and Supplements, Safety Guidance, Training, Forms, etc.

Hazard 1	Aseptic technique – requires the use of Bunsen burner	Implemented	Date
Risks	Burning oneself/others on the flame of the burner. Knocking over of the Bunsen burner.		
Control Measures	While the blue flame is required to gain the heat needed for sterilisation when it is not being used it should be always placed on the orange flame, making it more visible to everyone in the lab. Use of a fire proof mat is essential to prevent marking of the laboratory surfaces, or worse.		
Hazard 2	Eye/Hand/Clothes contamination	Implemented	Date
Risks	Risk of sample water or other chemicals used in the experiment causing harm.		
Control Measures	Use of personal protective equipment, more specifically goggles, gloves and laboratory coats, will help to prevent this. In the event of an incident, eyewash is available within the laboratory alongside other cleansing products.		
Hazard 3	Consumption of raw water sample	Implemented	Date

Risks	Risk of consuming raw river water sample which could lead to illness, due to the nature of the experiment.		
Control Measures	Washing hands upon entering and leaving the laboratory will help to prevent contamination both entering and exiting the room. No use of mobile phones within the lab as these could then carry microorganisms upon exiting, which may come into contact with the mouth. No food or drink to be consumed within the lab.		
Hazard 4	Contamination to outside world	Implemented	Date
Risks	Microorganisms, bacteria etc... on clothing, books and other objects leaving the laboratory on one's person.		
Control Measures	All personal belongings should never enter the laboratory, and should be stored in the locker provided. Use of PPE, glasses, gloves and lab coats will help to prevent contamination. Thorough washing of hands upon arrival and leaving.		
Hazard 5	Sharps, Slides and Pipette Tips	Implemented	Date
Risks	Pipette Tips <1ml can be extremely sharp, and pose the risk of cutting laboratory users – they also may contain a biological risk.		
Control Measures	Sharps, slides and pipette tips must be disposed of in the distinctive yellow sharps boxes placed around the laboratories. No unguarded sharps are to be left anywhere. It is essential that all contaminated laboratory materials are sterilised before disposal, and all disposable waste is incinerated.		
Hazard 6	Use of the Autoclave	Implemented	Date
Risks	Burns by touching hot contents of autoclave or metal parts of autoclave. Trauma injury by opening of door/lid whilst vessel is still at high temperature and under pressure.		
Control Measures	Must receive instruction from a member of staff before using the autoclave; and the autoclave is to be serviced and checked at 6 month intervals.		
	Emergency Procedures	Implemented	Date
Risks	Emergency procedures are outlined in the Environmental Engineering Laboratory Safety Policy. Methods will be aligned with the School of Civil Engineering and Geosciences' *Environmental Engineering Laboratory Methods*.		
Control Measures	Align experiments with the school's safety policy and laboratory methods.		
Hazards	**Additional Control Measures Required (List and Implement)**	Implemented	Date N/A
Risks	Do not go into the laboratory unless necessary. Keep the door shut. Disinfect the bench at the beginning and end of each day.		

	Clean up spillages vigilantly. Ensure that disinfectant is available. See BioCOSHH for analysis of biological risks associated with working with river water.		
Control Measures			
Assessor			
Name		**Signature**	**Date**
Matthew Rennie			
Responsible Person / Manager			
Name		**Signature**	**Date**
Paul Quinn			

A3.3 BioCOSHH

Newcastle University Microbiological Hazards and Genetic Modification Safety Advisory Sub-Committee BioCOSHH Risk Assessment

A BioCOSHH risk assessment is required for work with biological agents and hazards. The form should be completed electronically and signed by the principal investigator. Hazard Group 2 and 3 biological agents and hazards must be registered using the Pathogen Registration form and the BioCOSHH form sent by email to the University Biological Safety Officer. The possession or use of any Hazard Group 3 biological agent or the Hazard Group 2 biological agents *Bordetella pertussis*, *Corynebacterium diphtheriae* and *Neisseria meningitidis* requires permission from the University Biological Safety Officer. Guidance on completing this form is provided in the BioCOSHH Risk Assessment section of the Safety Office website.

Title of project	A WATER QUALITY SURVEY OF THE RIVER OUSEBURN
Principal investigator / Responsible person	**Supervisor:** DR PAUL QUINN **Researcher:** MATTHEW RENNIE
School	SCHOOL OF CIVIL ENGINEERING & GEOSCIENCES, NEWCASTLE UNIVERSITY
Date of assessment	03/02/2012
Location of work **(Buildings and room numbers)**	ENVIRONMENTAL ENGINEERING TEACHING LAB, 1ST FLOOR, CASSIE BUILDING (UNIVERSITY MAP REF: 49)

Section 1 Project or Activity

1.1: Brief description of project or activity
This project continues to review long-term water quality data in the River Ouseburn, centring on faecal contamination. Laboratory testing will be in the nature of Faecal Indicator Organisms (FIOs), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) experiments – a general risk assessment is provided for both laboratory and field work. Methods will be aligned with the School of Civil Engineering and Geosciences' *Environmental Engineering Laboratory Method.* This BioCOSHH risk assessment centres on the associated biological hazards of working with raw river water. The study area employs a combined sewer system, and during periods of high precipitation it is thought that raw sewage

may be entering the water course. Therefore the following must be considered a hazard to the researcher: **Bacteria***: E-coli, shigella, typhoid fever, and salmonella.* Whilst some of these may seem extreme for the study area, they are worth bearing in mind as they can cause diarrhoea, fever, cramps and various other illnesses. **Funguses:** *Aspergillus and other funguses often grow in compost.* These can lead to allergic symptoms, i.e. runny nose. **Parasites:** *Cryptosporidium and giardia lamblia.* This may cause diarrhoea, or even nausea and slight fever. *Roundworm.* This can appear symptomless, but may cough and have trouble breathing. **Viruses:** *Hepatitis A.* This can cause liver disease, but the risk of this is very small and may be greater depending upon the community in which the study is orientated. The Electronic Library of Construction Occupational Safety and Health (elCOSH) provides further details on working with water that may contain sewage at: http://www.elcosh.org/en/document/302/d000283/hazard-alert-biological-hazards-in-sewage-and-wastewater-treatment-plants.html

Section 2 Hazards

2.1: Biological agents or hazards	
Pathogens (ACDP/DEFRA Hazard Group 1)	N/A
Pathogens (ACDP/DEFRA Hazard Group 2)	*Escherichia coli, Salmonella, Shigella, Hepatitis A, Cryptosporidium, Giardia lamblia, Aspergillus.*
Pathogens (ACDP/DEFRA Hazard Group 3)	N/A
Toxins	N/A
Carcinogens	N/A
Allergens	N/A
Human primary or continuous cell cultures	N/A
Animal primary or continuous cell cultures	N/A
Human cells or tissues	N/A

Animal cells or tissues	N/A
Human blood	N/A
Patient contact	N/A
Animals	N/A
Plants	N/A
Soils	N/A
Other biological hazards	N/A

Section 3 Risks

3.1: Human diseases, illnesses or conditions associated with biological agents or hazards	
Bacteria*: E-coli, shigella, typhoid fever, and salmonella.* Whilst some of these may seem extreme for the study area, they are worth bearing in mind as they can cause diarrhoea, fever, cramps and various other illnesses. **Funguses:** *Aspergillus and other funguses often grow in compost.* These can lead to allergic symptoms, i.e. runny nose. **Parasites:** *Cryptosporidium and giardia lamblia.* This may cause diarrhoea, or even nausea and slight fever. *Roundworm.* This can appear symptomless, but may cough and have trouble breathing. **Viruses:** *Hepatitis A.* This can cause liver disease, but the risk of this is very small and may be greater depending upon the community in which the study is orientated.	
3.2: Potential routes of exposure	
Inhalation ☐ **Ingestion** ☑ **Injection** ☐ **Absorption** ☐ **Other** ☑	**Select all that apply**
Possibility of exposure through the eye by spillage may cause damage to the eye. Exposure may result from direct contact with the laboratory culture. Due to the nature of the exposure route it is likely that symptoms with be the expected ones.	
3.3: Use of biological agents or hazards	
Small scale ☑ Medium scale ☐ Large scale ☐ Fieldwork ☑ Animals ☐ Plants ☐ Other ☐	Select all that apply
Fieldwork is within the local area and hence may lead to exposure to endogenous biological agents. Environmental samples can contain pathogenic organisms which can be either unintentionally or purposely cultivated. Culture conditions will influence selection and survival. Microorganisms isolated from the environment should be treated as pathogenic until shown to be otherwise.	

3.4: Frequency of use	
Daily ☐ Week ☐ Monthly ☐ Other ☑	Select one
Fortnightly	
3.5: Maximum amount or concentration used	
Negligible ☐ Low ☐ Medium ☑ High ☐	Select one
Previous studies show E-coli levels in the river to be around 2000 CFU/100ml at one particular station, but have been as high as 5000 CFU/100ml.	
3.6: Levels of infectious aerosols	
Negligible ☑ Low ☐ Medium ☐ High ☐	Select one
3.7: Potential for exposure to biological agents or hazards	
Negligible ☐ Low ☑ Medium ☐ High ☐	Select one
3.8: Who might be at risk **(*Contact the University Occupational Health Service)**	
Staff ☑ Students ☑ Visitors ☐ Public ☐ Young people (<18yrs) ☐ *New and expectant mothers ☐ Other ☐	
Directly other people using the lab, who may be unaware of the experiment, may be at risk from contamination. There is a risk of indirectly affecting maintenance staff (cleaners, porters etc.).	

3.9: Assessment of risk to human health **(Prior to use of controls)**		
Level of risk	**Effectively zero** ☐ **Low** ☐ **Medium/low** ☑ **Medium** ☐ **High** ☐	Select one
3.10: Assessment of risk to environment **(Prior to use of controls)**		
Level of risk	**Effectively zero** ☐ **Low** ☑ **Medium/low** ☐ **Medium** ☐ **High** ☐	Select one

Section 4 Controls to Reduce Risks as Low as Possible

4.1: Containment

Laboratory ☑ Animal facility ☐ Plant facility ☐ Other ☐	Select all that apply
All equipment to be left in the lab should be clearly labelled, sterilised and sealed to ensure other lab users are aware of what is contained within.	
4.2: Containment level	
Containment level (CL 1) ☐ Containment level (CL 2) ☑ Containment level (CL 3) ☐	Select one
Working with hazard group 2 (HG 2) biological agents.	
4.3: Microbiological safety cabinets (MSC)	
Class 1 ☐ Class 2 ☑ Class 3 ☐ Other ☐	Select all that apply
4.4: Other controls	
Sharps: Sharps, slides and pipette tips must be disposed of in the distinctive yellow sharps boxes placed around the lab. **Disposal:** It is essential that all contaminated laboratory materials are sterilised before disposal, and all disposable waste is incinerated. **Hygiene:** Washing hands upon entering and leaving the lab will help to prevent contamination both entering and exiting the room. No food or drink should be consumed within the lab, nor should mobile phones be used. All personal belongings should never enter the laboratory, and should be stored within the provided locker. PPE should be used to protect eyes, open cuts and clothing transference. **General Points**: Do not enter the laboratory unless entirely necessary. Keep the door shut. Disinfect the bench at the beginning and end of each session. Clean up spillages vigilantly. Ensure disinfectant is available. For further practical risks with the project see individual laboratory and field risk assessments. All laboratory work will be carried out in accordance with the school's *Safety Policy*.	
4.5: Storage of biological agents or hazards	
There is no real need for ventilation or security. Storage units will be clearly labelled and sealed to prevent other lab users from interacting with them, minimising the risk. The amount of sample will initially be around 500ml per station, and with 7 stations this is 3.5l of sample. They should be kept aside in a safe environment, to minimise interaction with other members of the laboratory.	

4.6: Transport of biological agents or hazards	
The samples will be collected in seven plastic collection bottles, rinsed with distilled water to prevent cross contamination. These will then be tightly sealed and transported back to the laboratory by car.	
4.7: Inactivation of biological agents or hazards	
Disinfection ☑ Autoclave ☑ Fumigation ☐ Incineration ☑ Other ☐	
Sharps: must be disposed of in the distinctive yellow sharps boxes placed around the lab and disposed of by the technical staff. **Contaminated disposable waste**: should be placed in special tins or autoclave bags. They will then be autoclaved and finally incinerated before disposal. **Contaminated non-disposables**: should be placed in the specially marked buckets and autoclaved. Only then can they be passed to the wash room. **Contaminated glass pipettes**: should be submerged in an appropriately sized discard jar filled with 1% Vikron (disinfectant) and allowed to stand overnight and then passed to the wash room. **Broken glass:** must be placed in the contaminated broken glass bucket, which will then be autoclaved.	
4.8: Personal protective equipment (PPE)	
Lab coat ☑ Lab gown ☐ Surgical scrubs ☐ Disposable clothing ☐ Apron ☐ Spectacles ☐ Goggles ☑ Face shield ☐ Gloves ☑ Special headwear ☐ Special footwear ☐ Other ☐	Select all that apply
These should be worn at all times in the laboratory.	
4.9: Respiratory protective equipment (RPE)	
Disposable mask ☐ Filter mask ☐ Half face respirator ☐ Full face respirator ☐ Powered respirator ☐ Breathing apparatus ☐ Other ☐	Select all that apply
N/A	
4.10: Health surveillance or immunisation **(If you need advice contact the University Occupational Health Service)**	
N/A	
4.11: Instruction, training and supervision	
To work safely within the university laboratory all users must abide by the lab's *Safety Policy* and have completed a full induction to the lab.	
4.12: HSE consent or DEFRA licence	
N/A	

Section 5 Emergency Procedures

5.1: Emergency procedures		
In an emergency regarding contamination to skin, eyes and mouth thorough washing with water should be carried out. Help should be sought where required from first aiders, GP or hospital. The incident and biological agents or hazards to medical staff and provide them with a copy of the BioCOSHH.		
5.2: Emergency contacts		
Name	Position	Telephone
Dr Paul Quinn	Principal Investigator	+44 (0) 191 222 5773

Section 6 Approval

6.1: Assessor		
Name	Signature	Date
Matthew Rennie		
6.2: Principal investigator / Responsible person		
Name	Signature	Date
Paul Quinn		

Risk Estimation Matrix

Severity of harm	**Likelihood of harm**			
	High	**Medium**	**Low**	**Negligible**

Severe				
Moderate				
Minor			**Low**	
Negligible				