EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Dee Estuary

2013

Cover photo: Shellfish landing point at Thurstaston

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STATEMENT OF USE: This report provides a sanitary survey relevant to bivalve mollusc beds in the Dee estuary, as required under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption. It provides an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency		
Local Enforcement Authorities		
IFCA/Welsh Government		
Water company		

DISSEMINATION: Food Standards Agency, Flintshire Council, Wirral Council, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2013. Sanitary survey of the Dee estuary. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of EC Regulation No. 854/2004.

CONTENTS

1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

Filter feeding, bivalve molluscan shellfish (e.g. mussels, clams, oysters) retain and accumulate a variety of microorganisms from their natural environments. Since filter feeding promotes retention and accumulation of these microorganisms, the microbiological safety of bivalves for human consumption depends heavily on the quality of the waters from which they are taken.

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. Infectious disease outbreaks are more likely to occur in coastal areas, where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and/or animal origin.

In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007)

The risk of contamination of bivalve molluscs with pathogens is assessed through the microbiological monitoring of bivalves. This assessment results in the classification of BMPAs, which determines the level of treatment (e.g. purification, relaying, cooking) required before human consumption of bivalves (Lee and Younger, 2002).

Under EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of BMPAs and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The Centre for Environment, Fisheries & Aquaculture Science (Cefas) is performing sanitary surveys for new BMPAs in England and Wales, on behalf of the Food Standards Agency (FSA). The purposes of the sanitary surveys are to demonstrate compliance with the requirements stated in Annex II (Chapter II paragraph 6) of EC Regulation 854/2004, whereby ‘if the competent authority decides in principle to classify a production or relay area it must:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;

(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;

(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; and

(d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.'

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as an indicator of microbiological contamination in bivalves. This bacterium is present in animal and human faeces in large numbers and is therefore indicative of contamination of faecal origin.

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and improve analysis of their effects on shellfish hygiene. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents the information relevant to undertake a sanitary survey for cockles (*Cerastoderma edule*) and mussels (*Mytilus* spp.) within the Dee estuary. A sanitary survey has already been undertaken for parts of the eastern side of the estuary (CEFAS, 2009) but the sampling plan for this requires some revision, and the more extensive shellfish beds in the western parts of the estuary were not considered in the survey. The area was prioritised for survey in 2012-13 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2 AREA DESCRIPTION

The Dee Estuary is situated between the Flintshire coast of north-east Wales and the Wirral peninsula in Cheshire, north-west coast of England. The national boundary runs through the middle of the estuary. The location of estuary and the extent of its catchment are shown in Figure 1.1.

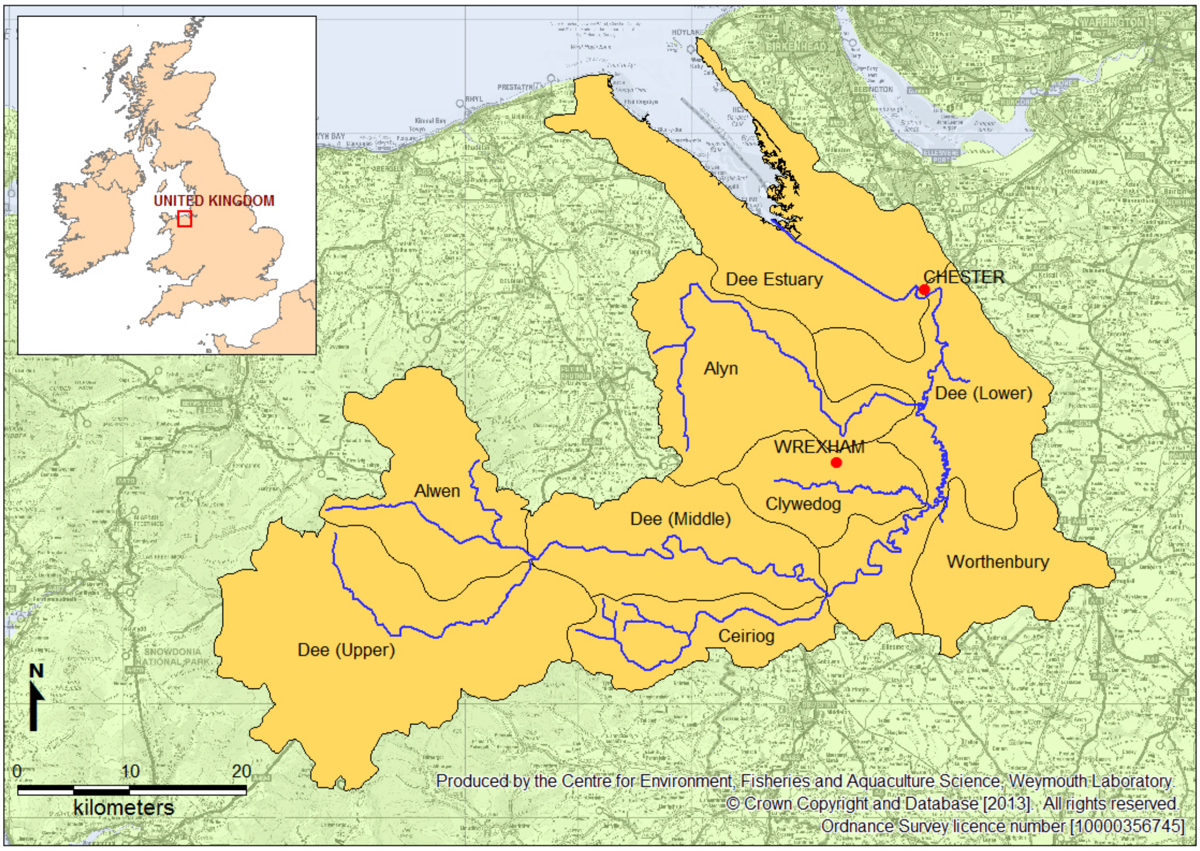

Figure 1.1 Location of the Dee Estuary and its river catchments.

The River Dee is 110km in length from its source in Snowdonia National Park through to its mouth in Liverpool Bay. It becomes tidal at Chester weir, then passes through a lengthy canalised section before opening out into a funnel shaped estuary. It is one of the largest UK estuaries supporting a wide range of habitats and species. It has extensive intertidal areas comprising mainly of mudflats, sandflats and saltmarsh bisected by the river channel. The estuary supports significant population of cockles, and, to a lesser extent, mussels.

CATCHMENT

Figure 1.2 shows land cover within the Dee catchment.

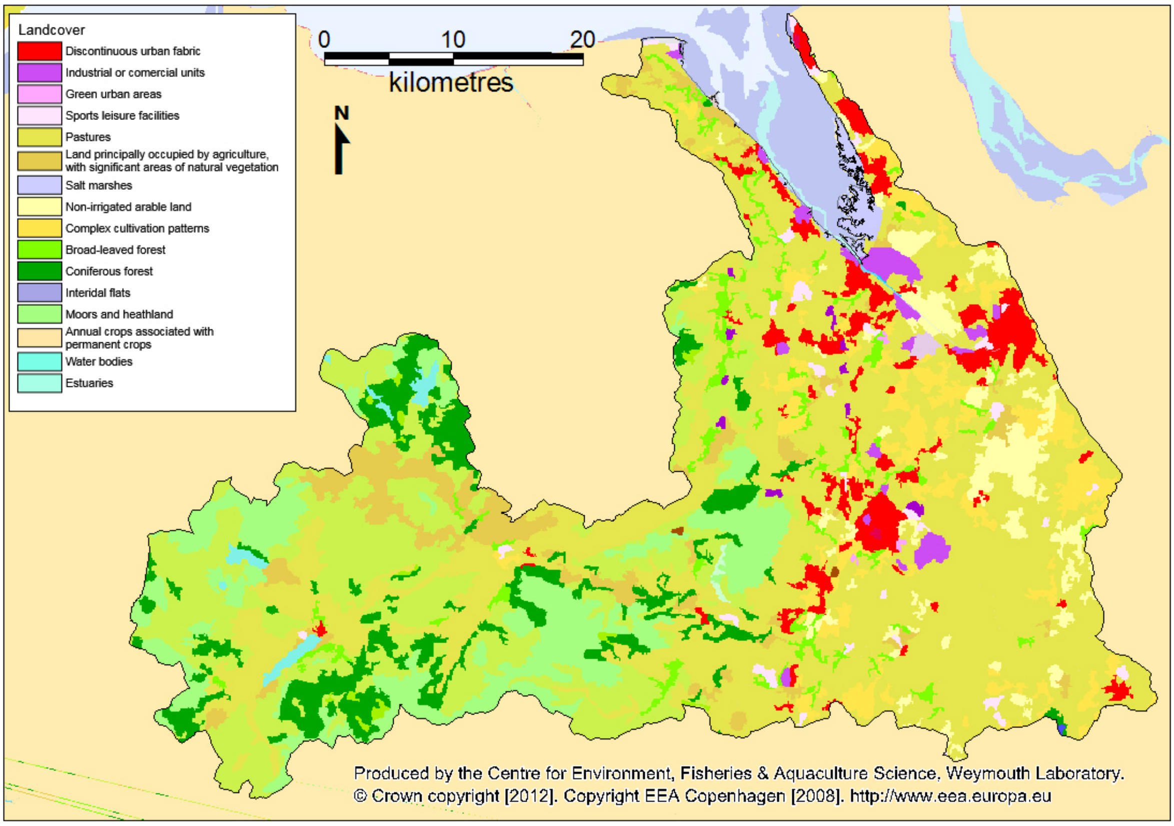

Figure 1.2 Land cover in the Dee Estuary catchment

The River Dee Catchment covers an area of 2,251km^2 (Environment Agency, 2010) and is largely rural, but nevertheless supports a human population of around 0.5 million. Urban and industrial land covers approximately 6% of the catchment and is principally found within the lower catchment. Chester, Wrexham and Deeside are the main conurbations accounting for approximately 60% of the population (Environment Agency, 2010). A significant area of the Dee catchment is pasture but large areas of grassland, moors and forest are found within the upper catchment. This relatively distinct division is also seen in soil types and elevation with impermeable soils and hilly landscape rising to over 800m within the upper catchment and more permeable soils and a low lying and flatter landscape in the lower catchment (NERC, 2010).

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types. (Kay et al. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which may increase up to 100 fold.

2. RECOMMENDATIONS

COCKLES

The following seven zones are proposed for cockles. Each zone has one RMP located to best capture peak levels of contamination within it, taking into account current stock distribution. It is recognised that in future the cockle beds may shift significantly, and RMPs may need to be relocated for stock availability reasons. It is therefore recommended that the locations of the cockle beds are provided by the Environment Agency to the LEAs following the annual stock survey which is reports in May/June, so the LEAs may revise the RMP locations as necessary. Any revision of RMP locations should be based on the principles identified within these recommendations, and should be communicated to the classification team at CEFAS[1].

The Marsh. Sources of contamination influencing this zone include the Greenfield sewage treatment works (STW), Mostyn STW, two small watercourses and up-estuary sources arriving via the main river channel. The assessment suggests that the Greenfield STW generates the largest bacterial loading locally. It is therefore recommended that the RMP be located at the eastern corner of the bed, as close to the main river channel and as far up-estuary as possible. This would also be effective at capturing sources from the wider catchment.

Salisbury. The only major point source direct to this zone is the Mostyn STW. An RMP located at the southern tip of the smaller of the three current beds, as close to the channel as possible would probably be most exposed to contamination from this source.

Mostyn/Talacre. The main contaminating influence direct to this zone is the Llanasa STW and a watercourse at Talacre to which it discharges. This has a well defined drainage channel which runs perpendicular to the shore across the intertidal. Currently the main cockle bed within this zone lies 1km up-estuary from this drainage channel, although in 2010 there was a small patch of cockles immediately in its path. It is therefore recommended that the LEA investigate whether there is stock which can be sampled in the path of this drainage channel. If so the RMP should be located in the path of this channel as close to the high water mark as possible. If not the RMP should be located in the western corner of the existing bed where potential exposure to this source is likely to be greatest.

Heswall channel. This zone encompasses a shallow drainage channel running parallel to the shore, and has historically included the most inshore part of the Thurstaston cockle bed. It is currently prohibited on hygiene grounds due to occasional very high *E. coli* results. It is strongly suspected that the cause of the high results is intermittent sewage discharges from the Heswall sewerage catchment, and an evaluation of *E. coli* results alongside modelled spill event data supports this conclusion. There are currently significant works underway which should greatly reduce the incidence of sewage spills here, which will be completed in the summer. It is anticipated that the improvements will see a significant reduction in

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results exceeding the higher classification thresholds, so the currently prohibited area may now prove to be harvestable from a hygiene perspective. The Heswall channel also receives the effluent from Heswall STW, which is UV treated and only generates a minor bacterial loading. It is recommended that the RMP be located as close to the channel and a far up estuary as possible. The LEA advise there currently there are no stocks within this zone so monitoring is not possible.

Thurstaston. This zone includes the Thurstaston bed, from the crest of the sandbank just off from the Heswall Channel and outwards. The bathymetry and some limited monitoring results suggest that this zone is much less affected by sources from Heswall than the Heswall Channel zone. It is recommended that the RMP be located as close to the inshore boundary of this zone as is possible, and as far up-estuary as possible.

Caldy Blacks. The main contaminating influences within this zone are the sources discharging to the Heswall channel. The RMP should therefore be located as close to this channel as possible, and as far up-channel as possible. The LEA have indicated that safe access of this bed area is not possible and that they will be unable to sample it. This zone will therefore have to be classified based on monitoring results from Thurstaston. This should be broadly representative, but is not ideal as the Caldy Blacks bed lies closer to the Heswall channel.

West Kirby. There is little in the way of direct point sources to this zone. Sources discharging to the Heswall channel may be an influence at times. It is therefore recommended that the RMP be located as close to this channel as stocks extend.

For all cockle RMPs, the sampling frequency should be monthly. The first two months of the closed season (January and February) need not be sampled as long as at least 10 samples are submitted per annum. A tolerance of 100m applies. Samples should be collected by hand raking. If any party other than the LEA is taking the samples, the LEA should consult with the FSA to ensure that sample collection is adequately controlled and supervised.

MUSSELS

For mussels, the following four zones are proposed on the basis of the current stock situation. Each zone has one RMP located to best capture peak levels of contamination within it, taking into account current stock distribution. It is recognised that mussels may settle in new areas, as was the case for the current bed on Salisbury Bank, but where and when this may occur is impossible to predict. Should a new bed arise and require classification then the existing cockle zoning and monitoring recommendations may be used as a basis for designing a sampling plan.

Mostyn Deeps. The existing bed here is small, with no sources of contamination in its immediate vicinity so noticeable spatial variation in levels of contamination across it is not anticipated. Contaminating influences will be a mixture of up-estuary sources, with those discharging to the outer reaches on the Welsh side likely to be most important. The existing zoning and monitoring arrangements should be suitably representative.

Salisbury Bank. The only major point source direct to this zone is the Mostyn STW. An RMP located at the southern tip of the current bed, as close to the channel as possible would probably be most exposed to contamination from this source. This zone is currently unclassified for mussels. The classification team may be able to issue a preliminary classification on the basis of cockle sampling results here on request from the LEA.

Heswall channel. This zone encompasses a shallow drainage channel running parallel to the shore, and includes the most inshore part of the current cockle bed at Thurstaston. It is currently prohibited on hygiene grounds due to occasional very high *E. coli* results. It is strongly suspected that the cause of the high results is intermittent sewage discharges from the Heswall sewerage catchment, and an evaluation of *E. coli* results alongside modelled spill event data supports this conclusion. There are currently significant works underway which should greatly reduce the incidence of sewage spills here, which will be completed in the summer. It is anticipated that the improvements will see a significant reduction in results exceeding the higher classification thresholds, so monitoring should resume here in anticipation that the formerly prohibited area may prove to be harvestable from a hygiene perspective. The Heswall channel also receives the effluent from Heswall STW, which is UV treated and only generates a minor bacterial loading. Within this zone there are some mussels at the end of the slipway, as well as the southern tip of the main mussel bed at West Kirby. It is recommended that the RMP be located within the patch at Caldy Slipway, as close to the channel and as far south east as possible.

West Kirby and Caldy Blacks. This encompasses an area which has been split into two zones for cockles. There seemed little point in having two separate zones as the main mussel bed is relatively compact and straddles the two. The main contaminating influences within this zone are the sources discharging to the Heswall channel. It is therefore recommended that the RMP be located as close to this channel as possible, and as far up-channel as possible.

For all mussel RMPs on the English side, the sampling frequency should be monthly. On the Welsh side the frequency should also be monthly, although the first two months of the closed season (May and June) need not be sampled as long as at least 10 samples are submitted per annum. A tolerance of 100m applies. Samples should be collected by hand. If any party other than the LEA is taking the samples, the LEA should consult with the FSA to ensure that sample collection is adequately controlled and supervised.

3. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Dee estuary
Cefas Main Site Reference	M045
Ordnance survey 1:25,000 map	Explorer 266
Admiralty Chart	Nos. 1978 and 1953

Shellfishery

Species/culture	Mussels Cockles	Wild
Seasonality of harvest	July to December inclusive (cockles) September to April (mussels, Welsh side) Year round (mussels, English side)	

Local Enforcement Authority

Name	Wirral BC Wallasey Town Hall, Brighton Street, Wallasey Wirral CH44 8ED
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Telephone number ☎	0151 6918168
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Environmental Health Officer	Paul Lindsay
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Fax number	01352 703441
E-mail	Paul_Lindsay@flintshire.gov.uk

REQUIREMENT FOR REVIEW

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2019. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones in the Dee estuary

Classification zone (Species)	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species Sampled	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
The Marsh (cockles)	B45AA	Marsh	SJ 1973 7891	53°18.06'N 3°12.36'W	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	
Salisbury (cockles)	B45AB	Salisbury cockles	SJ 1760 8040	53°18.85'N 3°14.30'W	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	
Mostyn/Talacre (cockles)	B45AC	Talacre	SJ 1382 8306	53°20.24'N 3°17.74'W	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	LEA to investigate if sufficient stock in Talacre drainage channel for sampling there instead (preferred option).
Heswall Channel (cockles)	TBA	Heswall channel	TBA	TBA	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	Currently prohibited. No stock in zone at present. RMP to be located as close as possible to the channel and as far upstream as possible.
Thurstaston (cockles)	B45AD	Thurstaston	SJ 2245 8301	53º20.30'N 3º9.97'W	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	
Caldy Blacks (cockles)	TBA	Caldy Blacks cockles	SJ 2186 8427	53°20.97'N 3°10.52'W	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	LEA unable to sample for access reasons. To be classified on basis of Thurstaston results.

Classification zone (Species)	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species Sampled	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
West Kirby (cockles)	B45AE	West Kirby cockles	SJ 2106 8470	53º21.20'N 3º11.25'W	Cockles	Wild	Hand	Hand	100m	Monthly (excluding Jan and Feb)	
Mostyn Deep (mussels)	B045X	Mostyn Deep	SJ 1277 8573	53°21.67'N 3°18.73'W	Mussels	Wild	Hand	Hand	100m	Monthly (excluding May and Jun)	Existing RMP
Salisbury (mussels)	B45AF	Salisbury mussels	SJ 1805 8053	53°18.92'N 3°13.89'W	Mussels	Wild	Hand	Hand	100m	Monthly (excluding May and Jun)	LEA to contact CEFAS classification team regarding preliminary classification if required.
Heswall channel (mussels)	B045O	Caldy Blacks mussels	SJ 2255 8378	53°20.71'N 3°9.89'W	Mussels	Wild	Hand	Hand	100m	Monthly	Currently prohibited. Sampling to start once sewage improvements at Heswall are completed (summer 2013). Existing RMP.
West Kirby (mussels)	B45AG	West Kirby mussels	SJ 2146 8468	53°21.19'N 3°10.88'W	Mussels	Wild	Hand	Hand	100m	Monthly	

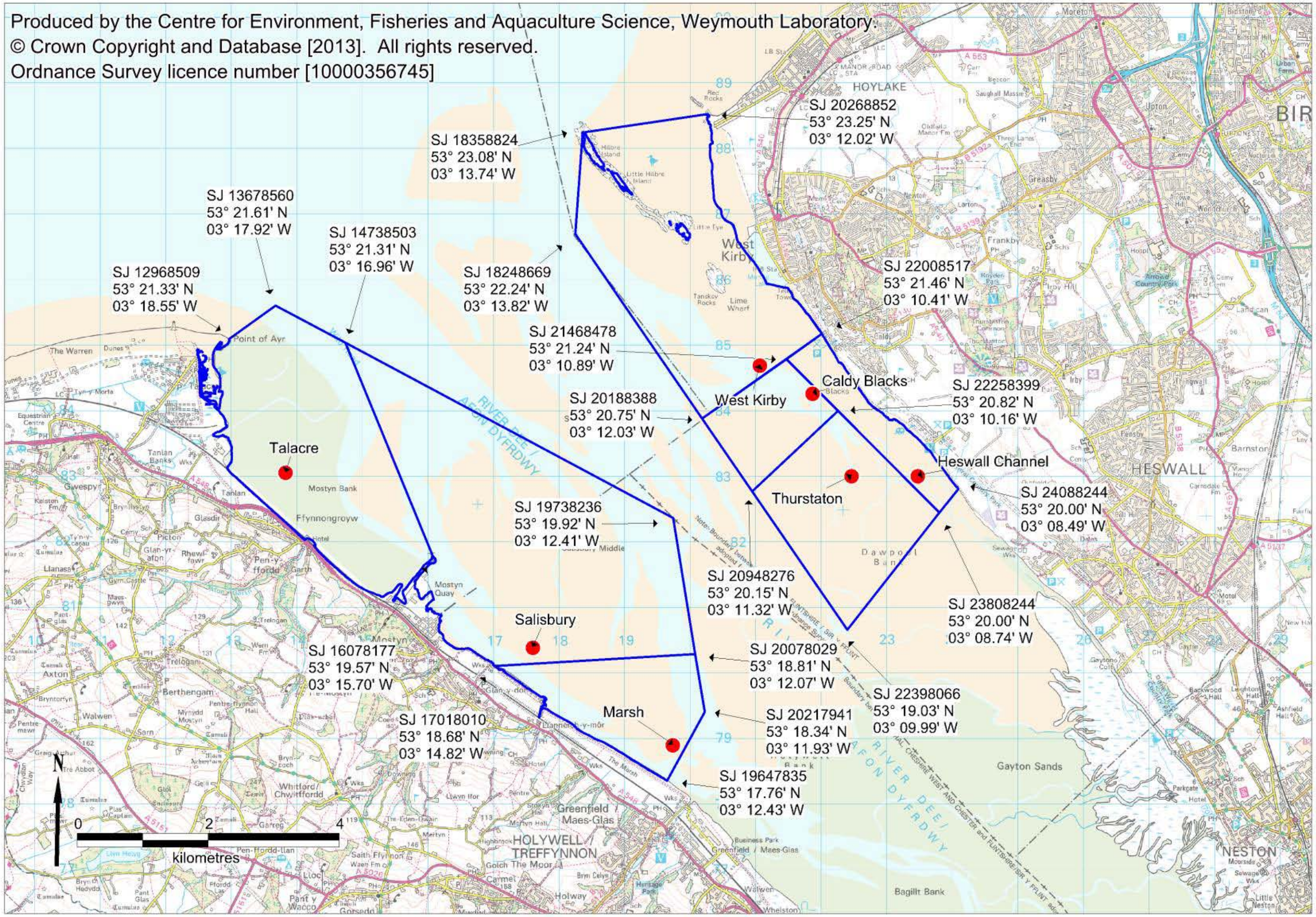


Figure 3.1 Recommended classification zone boundaries and RMP locations for cockles

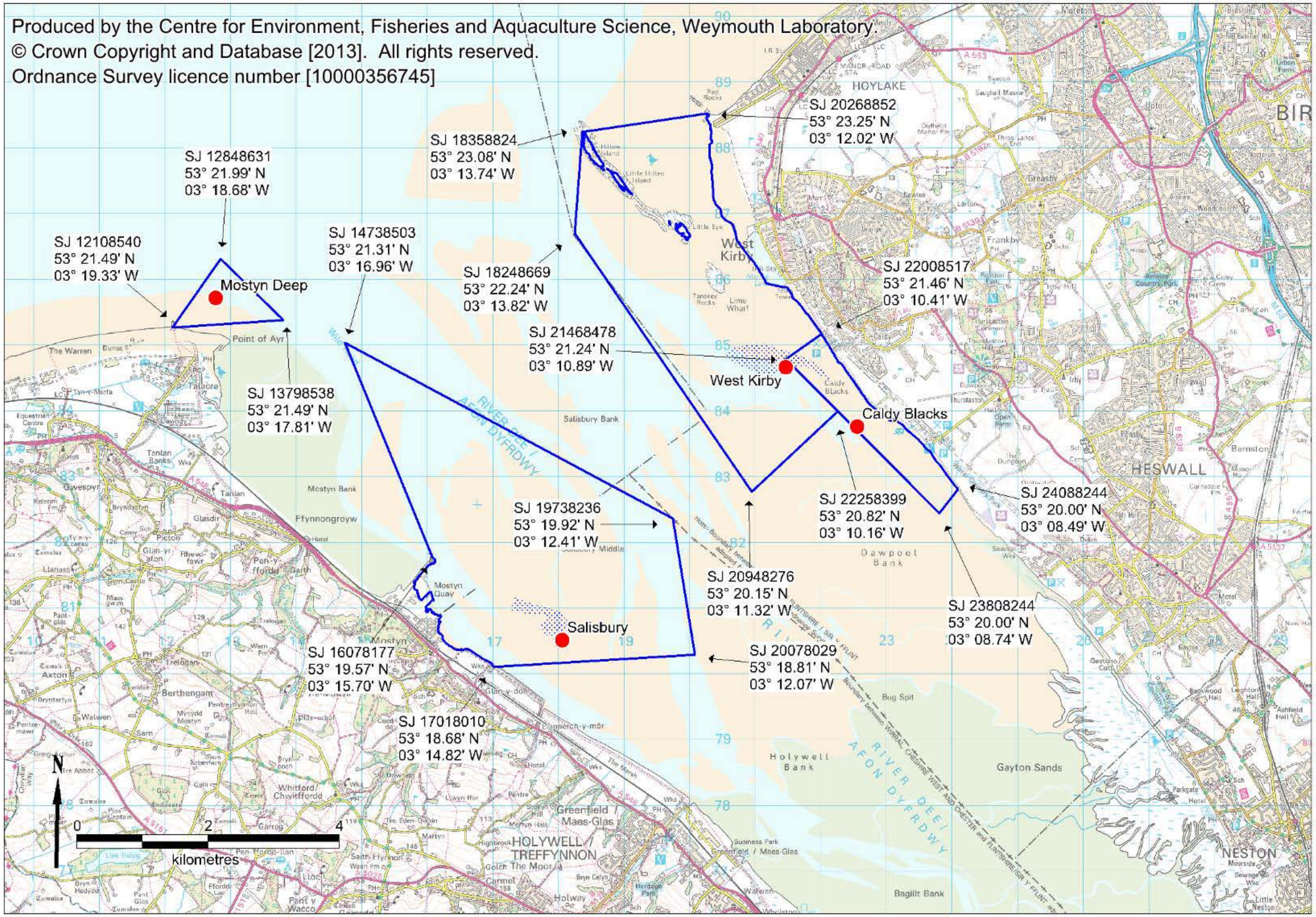


Figure 3.2 Recommended classification zone boundaries and RMP locations for mussels

4. SHELLFISHERIES

4.1 SPECIES, LOCATION AND EXTENT

The Dee estuary supports a relatively stable and profitable cockle fishery. This is managed by the Environment Agency, under the Dee Estuary Cockle Fishery Order, which was established in 2008. There are also naturally occurring stocks of mussels within and just outside the estuary which are harvested commercially, either for seed or market stock. Figure 4.1 shows the locations of the main shellfish beds at the time of writing, and also shows the evolution of cockle distributions in recent years.

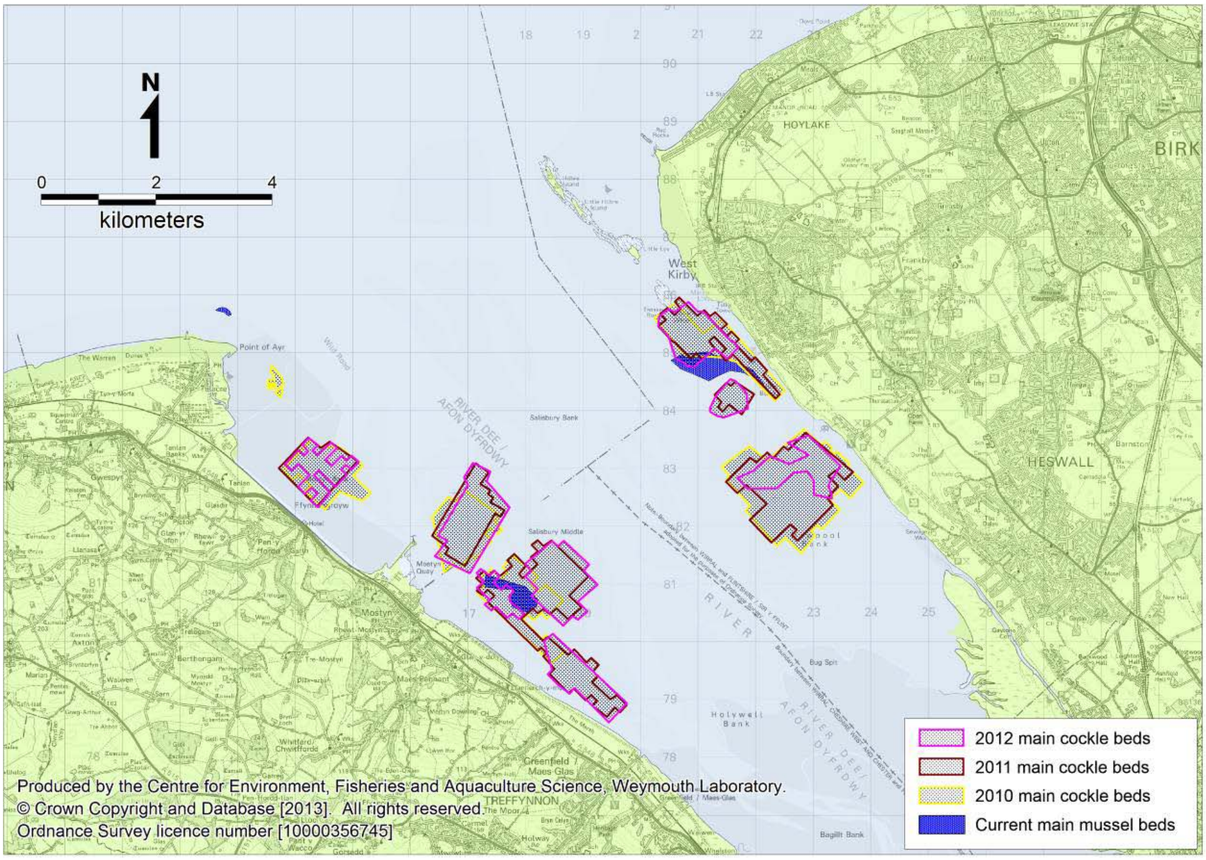


Figure 4.1. Overview of shellfisheries within the Dee
Data from the Environment Agency

There are cockle beds on both the east and west side of the outer estuary, the locations of which have been fairly stable from 2010 to 2012, although there is some variation in their extent between years. Success of spatfalls may vary between years, and storms, temperature extremes, diseases, predation and of course exploitation can all affect them. In some locations mussels have settled on cockle beds to the detriment of cockle stocks. There are 50 licensed gatherers who participate in this fishery.

There is a smaller but nevertheless significant mussel fishery within the estuary. Stocks are quite ephemeral, and at present the two main concentrations are at South Salisbury and Caldy. They generally occur in places where cockle die-off has occurred and dead shells are available to settle on, and do not settle on other areas where the surface is more mobile. As well as the two main concentrations there are likely to be smaller sparser patches in other locations. It is known that there are some mussels by the end of the slipway at Thurstaston, and satellite images suggest there may be a roughly circular patch of mussels about 300m in diameter lying 600m off the marine lake at West Kirby. Mussels are exploited by around a dozen hand gatherers on a seasonal and part time basis. Just outside the estuary there is a small mussel bed on the Welsh side at Wild Road which is harvested by one individual on a seasonal basis.

4.2 GROWING METHODS AND HARVESTING TECHNIQUES

All stocks are wild. Cockle harvesting is via hand raking. Mussels may be harvested by hand, or very occasionally via dredge when they are being cleared to prevent them smothering cockle beds.

4.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

The cockle fishery only opens from July to December inclusive, and at times later in the season individual beds may open and close on a rotational basis to provide some undisturbed areas for birds. It is subject to a raft of management measures, including limiting participation to 50 licence holders, daily and annual total allowable catches (TACs) and a minimum size of 20mm. Stock surveys are undertaken every spring and reported in May/June, from which TACs are derived for the start of the season in July.

Table 4.1 Cockle landings by year under the Dee Estuary Cockle Fishery Order

Year	Landings (tonnes)
2008	1073
2009	1279
2010	657
2011	1250
2012	820

Data from the Environment Agency

Since the inception of the fishery order in 2008 the annual profile of landings has changed from a 'boom and bust' style fishery to a much more stable one, although they do still fluctuate with natural variations in stock biomass. As long as the current management measures remain in place, this situation is likely to continue. Relatively high prices are commanded for the good quality cockles that the fishery now produces. As they are hand gathered from class B areas they may be marketed as live animals. The Dee cockle fishery was certified as sustainable by the Marine Stewardship Council in July 2012 (MSC, 2012).

The mussel fishery is a public fishery regulated via North West IFCA byelaws on the English side, and Welsh Government byelaws on the Welsh side. For the former a permit is required, there is no closed season and a minimum landing size of 45mm applies. For the latter there is a closed season from May to August inclusive and a minimum landing size of 2 ¼ inches. There are around a dozen part time participants in this fishery. Peak activity tends to occur in the three months immediately after the cockle season closes (January to March).

4.5 HYGIENE CLASSIFICATION

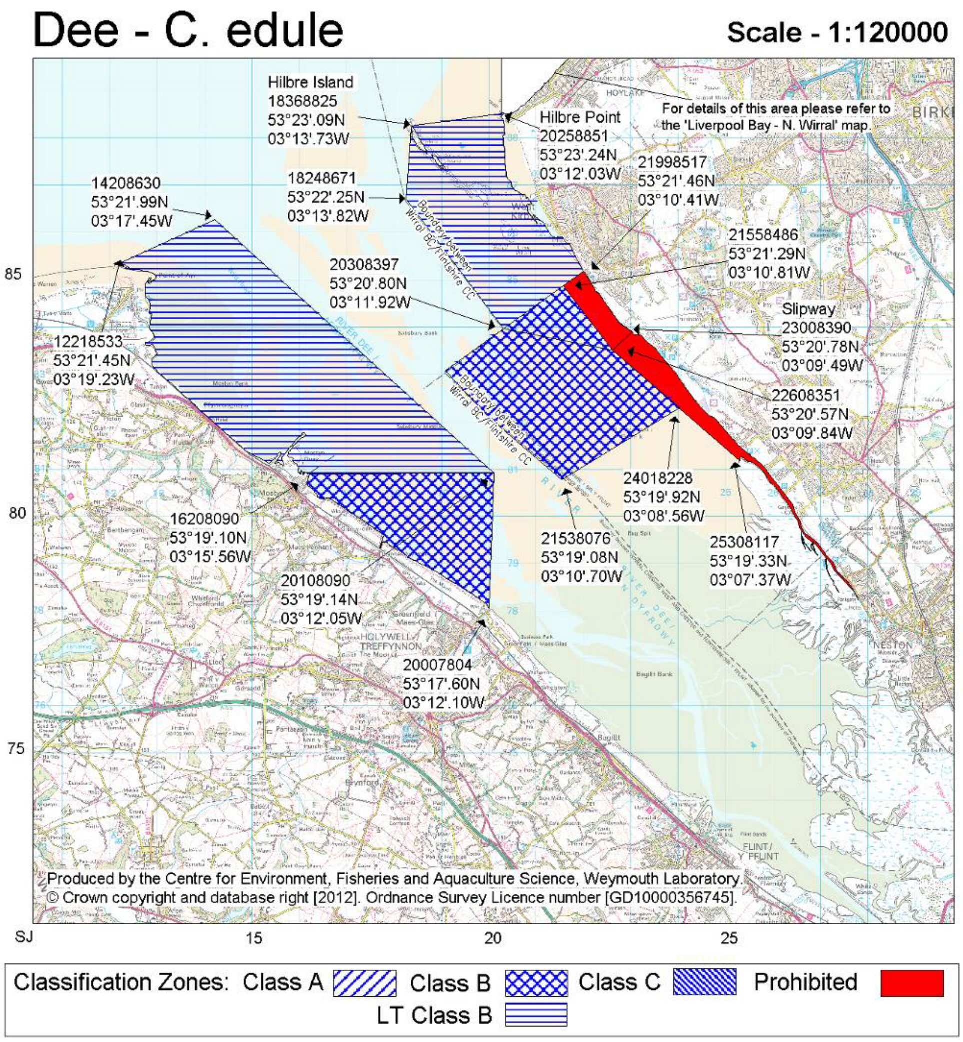
Table 4.1 lists all classifications within the Dee estuary from 2003 onwards.

Table 4.1 Classification history for the Dee, 2003 onwards

Area	Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Caldy Blacks	Cockles									C(P)	
Caldy	Cockles										B
Thurstaston	Cockles	C	B	B							
Thurstaston West	Cockles							C	B	B	B
West Kirby	Cockles	B	B		B	B	B	B	B-LT	B-LT	B-LT
The Marshes	Cockles									C(P)	B
Salisbury middle	Cockles	B	B	B	B	B	B	B	B-LT	B-LT	B-LT
Mostyn Talacre Bank	Cockles	B	B	B	B	B	B	B	B-LT	B-LT	B-LT
All Eastern beds	Mussels	B	B	B	B	B	C	C	C	C	C
Wild Road	Mussels									C(P)	B
Thurstatson East	All species							P	P	P	P

LT denotes long term classification
(P) denotes preliminary classification

Classifications on the west side of the estuary have been stable over the years. There have been fluctuations in the classification on the east side, in the more inshore areas around Thurstaston. There is currently a prohibited area at Thurstaston East.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2012

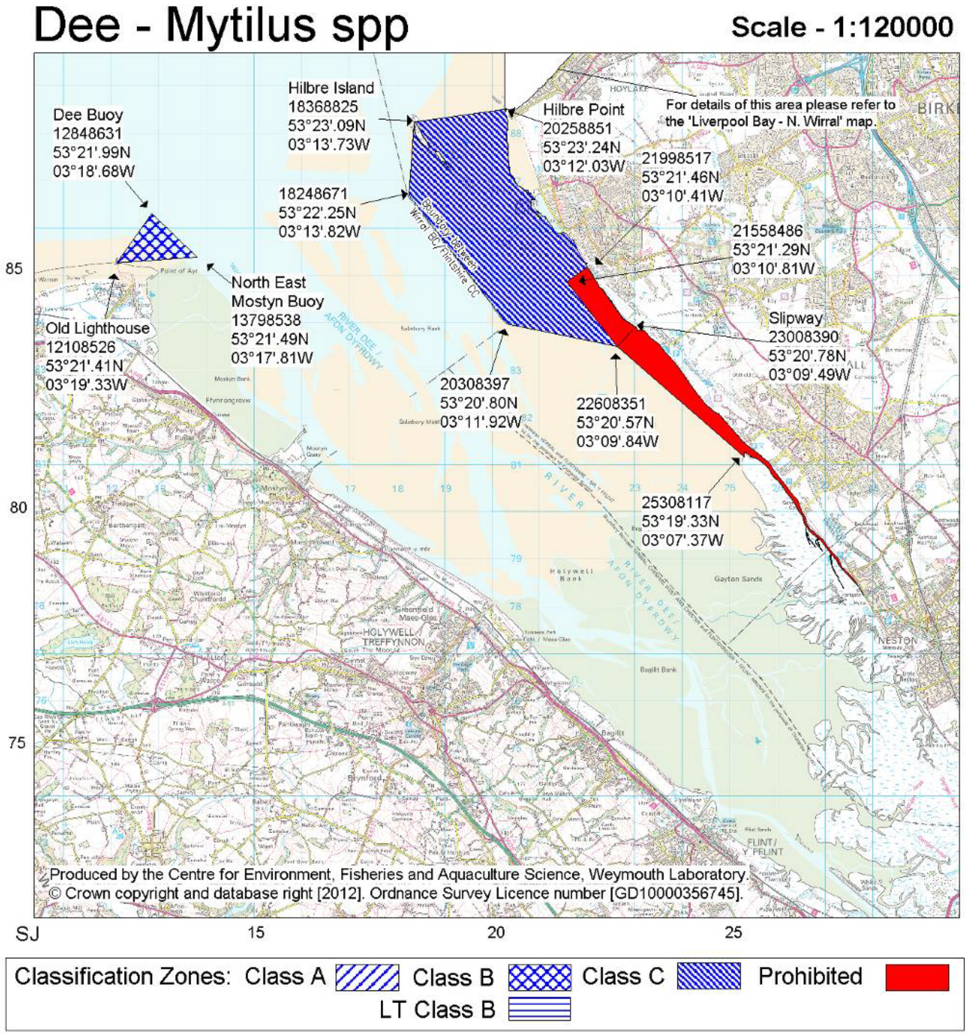
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for Mytilus spp. at the Dee

Food Authority: Metropolitan Borough of Wirral (West Kirby)
Flintshire County Council (Mostyn/Talacre and Salisbury Middle)

Figure 4.3 Current cockle classifications



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N.B. Lat/Longs quoted are WGS84
Separate map available for C. edule at the Dee

Food Authority: Metropolitan Borough of Wirral (Eastern mussel beds)

Figure 4.4 Current mussel classifications

Table 4.2 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli*/100 g Flesh and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli*/100 g FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli*/100 g FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli*/100 g FIL	Relaying for at least two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli*/100 g FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds

5. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of sources of contamination, their likely impacts, and patterns in levels of contamination observed in water and shellfish samples taken in the area under various programmes, summarised from supporting information in the previous sections and the Appendices. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of the bivalve mollusc beds in this geographical area.

SHELLFISHERIES

The Dee estuary supports a major cockle fishery and a smaller but nevertheless significant mussel fishery. The commercial cockle beds are located on both the English and Welsh sides of the outer estuary. Their locations are broadly similar from year to year but do vary, so sampling plans should be suitably flexible to accommodate this. The cockle fishery has been managed by the Environment Agency since 2008, under the Dee Estuary Cockle Fishery Order. The fishery order had the effect of stabilising the fishery from the previous 'boom and bust' cycles so now landings are relatively stable, averaging just under 1000t per annum. The fishery is subject to a variety of management measures, including a closed season running from January to June.

There are also mussel beds amongst the cockle beds on both the English and Welsh sides of the estuary, as well as one on the edge of the Welsh Channel, just outside the mouth of the estuary. These are less extensive than the cockle beds, and also vary significantly in their locations with time. They tend to settle where there is an accumulation of dead cockle shells, sometimes to the detriment of cockle stocks. Mussels on the Welsh side are subject to a closed season from May to August inclusive, but there is no closed season on the English side. Peak activity tends to occur in the three months immediately after the cockle season closes (January to March). The mussel bed at Salisbury Bank is not currently classified but has recently been identified as requiring classification by Flintshire Council. It may potentially require more urgent (provisional or preliminary) classification.

There is no scope for reducing the monitoring burden through the use of surrogate species, as cockles and mussels are not deemed as suitable surrogates for one another (Younger & Reese, 2011). It is usually acceptable for the first two months of any closed season, as long as a minimum of 10 valid samples are submitted through the rest of the year. Monthly monitoring is however preferable for all areas irrespective of whether there is a closed season. Gross contamination events are less likely to be missed, it is often easier to manage, and if a sample is rejected for some reason then there will still be sufficient results on which to base an accurate classification.

POLLUTION SOURCES

FRESHWATER INPUTS

All rivers and streams carry some contamination from land runoff and so will require consideration in this assessment. The survey area is the estuary of a major spate river, and has a catchment area of about 2130km^2. The river Dee is the main freshwater input, draining about 93% of the catchment area of the estuary. Its average discharge is 33m^3/sec, and high flow events exceeding 100m^3/sec occur regularly. Flows are highest on average during late autumn and winter, although high flow events may occur at any time of the year. Discharge is quite variable, so the loadings of faecal indicators it delivers will also vary significantly with rainfall. Most of the land drained by the river Dee is rural, and mainly used for sheep farming in the upper reaches and dairy farming in the lower reaches. It becomes tidal at Chester weir, then passes through a canalised channel before it reaches the main body of the estuary. As most freshwater enters at the head of the estuary there is likely to be a gradient of increasing levels of runoff borne contamination towards the upper reaches of the estuary.

As well as the main freshwater inputs to the head of the estuary, a series of much smaller watercourses drain to the shores of the estuary in the vicinity of the shellfish beds. All significant watercourses were sampled and measured during the shoreline survey, allowing spot estimates of their bacterial loadings to be calculated. The watercourses draining to the Welsh side were generally larger and carried higher bacterial loadings. The most significant of these were a stream at Talacre (>2.28x10^{12} *E. coli*/day), a stream at Pen-y-Fford Garth (3.08x10^{11} *E. coli*/day), a stream at the Marsh (7.08x10^{10} *E. coli*/day) and a stream/creek draining from Heswall and running through saltmarsh to Thurstaston (4.08x10^{10} *E. coli*/day). The first of these receives effluent from Llanasa STW and the last of these receives effluent from Heswall STW. All significant streams may cause localised hotspots of contamination where they enter the estuary and by any drainage channels they follow across the intertidal, so RMPs should be located accordingly.

Human Population

The resident human population in the Dee estuary catchment was about 0.5 million at the time of last census for which data was available. The main population centres are in the lower catchment at Chester, Wrexham and Deeside. The rest of the catchment is mainly rural, particularly within the upper reaches where population densities are very low. There are a number of smaller settlements lining the shores of the estuary. The English side is slightly more urbanised than the Welsh side. The pattern of impacts from human populations will largely depend on the sewerage infrastructure serving the area.

Significant numbers of tourists also visit the Dee estuary catchment area, drawn by historic places such as Chester, seaside towns on the Wirral peninsula and outdoor activities such as golf and walking. There are caravan parks adjacent to the estuary at Talacre and Thurstaston. Increases in human population will result in increased amounts of sewage so overall volumes received and treated by sewage works are likely to be higher during the summer months.

Sewage Discharges

There are nine water company water treatment works that discharge either directly to the Dee estuary, or to short watercourses feeding directly into the estuary, or to the canalised section of the tidal Dee. The majority of sewage (~75% by volume) is discharged to the estuary a significant distance upstream of the shellfisheries so effluent from these may result in an underlying gradient of increasing levels of contamination towards the upper reaches of the estuary. The largest discharge by some margin is Chester waste water treatment works (WWTW) which generates an estimated faecal coliform loading of 1.03×10^{14} cfu/day. There are two other sewage works discharging to the canalised section of the tidal Dee (Queensferry and Connahs Quay) which generate an estimated combined bacterial loading 1.45×10^{13} faecal coliforms/day. Neston and Flint STWs discharge to the upper reaches of the main estuary and both lie over 5km up-estuary from the nearest shellfish beds, and both provide UV treatment. Neston STW discharges to the English side of the estuary and contributes an estimated faecal coliform loading of 1.2×10^{12} faecal coliforms/day, and Flint STW discharges to the Welsh side and contributes an estimated bacterial loading of 7.4×10^{11} faecal coliforms/day.

There are four sewage works which discharge sufficiently close to the shellfish beds to potentially cause noticeable hotspots over and above the background gradient from up-estuary sources. Of these, Greenfield STW, which provides secondary treatment and has a dry weather flow of 3891 m^3/day generates the largest estimated bacterial loading (1.28×10^{13} faecal coliforms/day). Mostyn STW also only provides secondary treatment for a dry weather flow 966 m^3/day and generates an estimated bacterial loading of 3.19×10^{12} faecal coliforms/day. Llanasa STW provides UV treatment for a dry weather flow of 8061m^3/day and generates an estimated bacterial loading of 1.24×10^{11} faecal coliforms/day. These three discharge to the Welsh side of the estuary. Finally, Heswall STW on the English side provides UV treatment for a dry weather flow of 2700m^3/day and generates an estimated bacterial loading of 1.52×10^{11} faecal coliforms/day. Highest impacts are likely to occur in the immediate vicinity of the outfalls and by any drainage channels their effluent follows across the intertidal. It should be noted that UV disinfection is less effective against bacteria than viruses, so their public health impacts may be underestimated through the use of bacterial indicators. Measured flow records were available for three of these discharges (Queensferry, Llanasa and Flint). Flows were higher on average during the winter Queensferry, and higher on average in the spring at Llanasa. The small amount of data for Flint did not reveal any particular pattern.

In addition to the continuous discharges there are a large number of intermittent discharges which may impact on the Dee estuary. The main concentrations of these lie in the more urbanised areas. Modelled spill data was available for all Dwr Cymru/Welsh Water (DCWW) assets discharging in close proximity to the estuary, which account for all but two identified intermittent discharges. Modelling results indicate frequent spills of high volumes for some outfalls in the Chester area. The largest of these in the Chester catchment both had modelled spill volumes of between 750,000 and 1,000,000 m^3 per year. As for Chester STW and catchment sources these may result in an underlying gradient of increasing levels of contamination towards the upper reaches of the estuary following a spill.

Perhaps of most concern to the shellfisheries are the intermittent outfalls from the Heswall sewage catchment, some of which are predicted to spill large volumes on a regular basis. The three main spillers here are Heswall STW settled storm sewage overflow (160,356 m^3 per year, active for 5.4% of the time), Heswall STW storm sewage (115,423 m^3 per year, active for 3.2% of the time) and Riverbank Road combined sewer overflow (CSO) (67,686 m^3 per year, active for 1.4% of the time). All ultimately discharge to the enclosed tidal creek running from Heswall to Thurstaston so storm sewage is periodically delivered relatively undiluted to shellfish beds here. A comparison of modelled spill event data and shellfish monitoring results strongly suggest that the Heswall STW settled storm sewage outfall has been a significant influence on *E. coli* levels in the Thurstaston area. DCWW are currently undertaking works at Heswall to reduce the amount of surface water the catchment collects, to increase the storage capacity of the storm tanks and increase the treatment capacity of the works. This will significantly reduce the frequency and magnitude of spills from the three main spillers. Works will be completed by summer 2013 and should reduce the occurrence of high *E. coli* results in the Thurstaston area, although spill events may still occur from time to time.

None of the intermittent outfalls in other sewage catchments immediately adjacent to the shellfisheries (Greenfield, Mostyn and Llanasa) are likely to be particularly large spillers. The modelled spill frequencies from outfalls in the Llanasa and Mostyn catchments are very low and so are very unlikely to be captured via monthly monitoring used for shellfish hygiene classification. The largest predicted spiller from the Greenfield catchment is the CSO at the sewage works, which had a modelled annual spill volume of 29,239 m^3 and is active for 3.1% of the time.

As well as water company assets there are some privately owned sewage discharges in the vicinity of the Dee estuary. None of these are particularly large, typically serving one or two properties and providing treatment via septic tank or package plant discharging to watercourse or soakaway. As such they have little bearing on the sampling plan, although they may contribute to the bacterial loadings carried by some watercourses.

AGRICULTURE

The majority of land within the Dee catchment is used for agriculture. Most are pastures, although there are many smaller pockets where crops are cultivated. Sheep farming dominates the upper catchment, whereas dairy farming is more prevalent in the lower reaches of the catchment. A total of 136,579 cattle and 686,362 sheep were recorded within the catchment area in the 2010 agricultural census, so significant and widespread impacts from grazing animals are anticipated. Faecal matter from grazing livestock is either deposited directly on pastures, or collected from livestock sheds if animals are housed indoors during the colder months and then applied to agricultural lands as a fertilizer. Significant numbers of poultry and a few pigs are also farmed in the catchment. Manure from pigs and poultry is typically stored and applied tactically to nearby farmland.

Most of the agricultural land drains via the river Dee and other watercourses which enter the upper reaches of the estuary, so higher impacts towards the up-estuary ends of the shellfisheries are generally anticipated on this basis. Almost all significant watercourses will be affected to some extent. Therefore, in general RMPs should be situated at the up-estuary ends of shellfish beds, or at points where other significant watercourses enter the estuary. Livestock grazing areas were recorded between Greenfield and Mostyn during the shoreline survey, so watercourses draining these areas are likely to carry some contamination of livestock origin.

The primary mechanism for mobilisation of faecal matter from agricultural land is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. The seasonal pattern in application of manures and slurries to agricultural land is uncertain, although there are some restrictions in nitrate vulnerable zones which cover large parts of the lower Dee catchment between August and January. Cattle may be housed indoors during the winter, so slurry collected from such operations is likely to be spread in the late winter and spring, depending on the storage capacities of each farm.

Some areas of saltmarsh adjacent to the estuary are grazed, including the Burton Marsh by Neston, and a few smaller patches of saltmarsh on the Welsh side. Contamination deposited in the intertidal areas will carried into the estuary via tidal inundation which is a particularly direct and predictable mechanism, the risk of which is greater during spring tides.

In summary, the upper reaches of the estuary will be most impacted by contamination of livestock origin, but some of the streams draining to the vicinity of the shellfisheries on the Welsh side are also likely to be impacted by livestock. It is likely that the saltmarsh grazing at Burton Marsh, by Neston makes a significant contribution at times. Therefore RMPs situated towards the up-estuary ends of the shellfish beds and by the drainage channels crossing intertidal areas on the Welsh side are likely to capture peak levels of livestock related contamination. Livestock numbers are highest during summer and autumn so some seasonality in impacts may be anticipated. Whilst the flux of contamination from pastures will be highly rainfall dependent, peak fluxes from grazing marsh may be anticipated on spring tides.

BOATS

The Dee estuary is used by a variety of craft, including commercial shipping, fishing vessels, and recreational craft of various sizes. Commercial ship traffic is centred around the port of Mostyn. The majority of pleasure boat activity occurs around Thurstaston and West Kirby, where there are areas of moorings for small yachts and cabin cruisers. Around 40 small fishing vessels operate within and from the estuary.

Commercial shipping is not permitted to discharge to inshore waters so should be of no impact. It is likely that the larger of the private vessels (yachts, cabin cruisers, fishing vessels) which have onboard toilets make overboard discharges from time to time. This may occur whilst boats are on passage, and it is quite likely that any boats in overnight occupation on the moorings will make a discharge at some point during their stay. On this basis, outer reaches of the estuary on the English side and the main channels may be more at risk from overboard discharges. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. However, it is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges, and as such boating will have little material bearing on the sampling plan.

WILDLIFE

The Dee estuary contains a diversity of habitats, including intertidal sand and mudflats and saltmarsh, which support a significant population of overwintering waterbirds (waders and wildfowl). An average total count of 110,730 waterbirds was reported over five winters up to 2010/11 for the Dee Estuary. Outside of this period, the Dee Estuary is also used as a staging area for migratory waterbirds on autumn and spring passages so there will be briefer influxes of migratory waterbirds in the spring and autumn. Some species of waders feed on intertidal invertebrates so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and whilst they may be a significant contaminating influence at times, they will not influence the positioning of any RMPs. Other overwintering waterbirds such as grazing ducks, plovers and lapwings will mainly frequent the saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. RMPs positioned in or by creeks and channels draining from such areas would be best positioned to capture contamination from these.

Although the majority of waterbirds migrate elsewhere to breed, other species such as gulls and terns are present during the summer months. Relatively small numbers of such birds use the Dee estuary, although there is a significant tern and gull breeding colony (490 and 150 pairs) at Shotton Steelworks, adjacent to the canalised section of the tidal Dee. They are likely to forage around the estuary so represent a minor source of diffuse contamination, but this will not influence the sampling plan.

There is a population of grey seals which haul out just to the west of Hilbre Island. During the summer, numbers can exceed 500, but drop to about 50 during the autumn. In spatial terms, contamination is likely to be heaviest on sediments where they haul out. Here, they are likely to be a significant influence at times, although there are no shellfish beds within at least 1km of their haulout site. On a wider scale they are likely to forage throughout the estuary and Liverpool Bay, and so potentially represent a diffuse source of pollution to the shellfish beds. Given the large area they are likely to forage over impacts are likely to be minor, and unpredictable in spatial terms, but will peak during the summer, and be at its lowest during the autumn.

Otters are present within the estuary but exact numbers are not known and are likely to be small. They tend to favour the more secluded areas with access to watercourses. However, given their small numbers otters have no material bearing on the sampling plan. No other wildlife species which have a potentially significant influence on the sampling plan have been identified.

DOMESTIC ANIMALS

Dog walking takes place on beaches and paths adjacent to the shoreline of the estuary and could represent a potential source of diffuse contamination to the near shore zone. The intensity of dog walking is likely to be higher by more urban areas such as West Kirby. As a diffuse source, this will have little influence on the location of RMPs.

SUMMARY OF POLLUTION SOURCES

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in Table 5.1 and Figure 5.1.

Table 5.1 Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff	red	red	red	red	red	red	red	red	red	red	red	red
Continuous sewage discharges	red	red	red	red	red	red	red	red	red	red	red	red
Intermittent sewage discharges	red	red	red	red	red	red	red	red	red	red	red	red
Urban runoff	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange
Waterbirds	red	red	red	yellow	yellow	yellow	yellow	yellow	yellow	yellow	red	red
Boats	yellow	yellow	yellow	yellow	orange	orange	orange	orange	orange	yellow	yellow	yellow

Red - high risk; orange - moderate risk; yellow - lower risk.

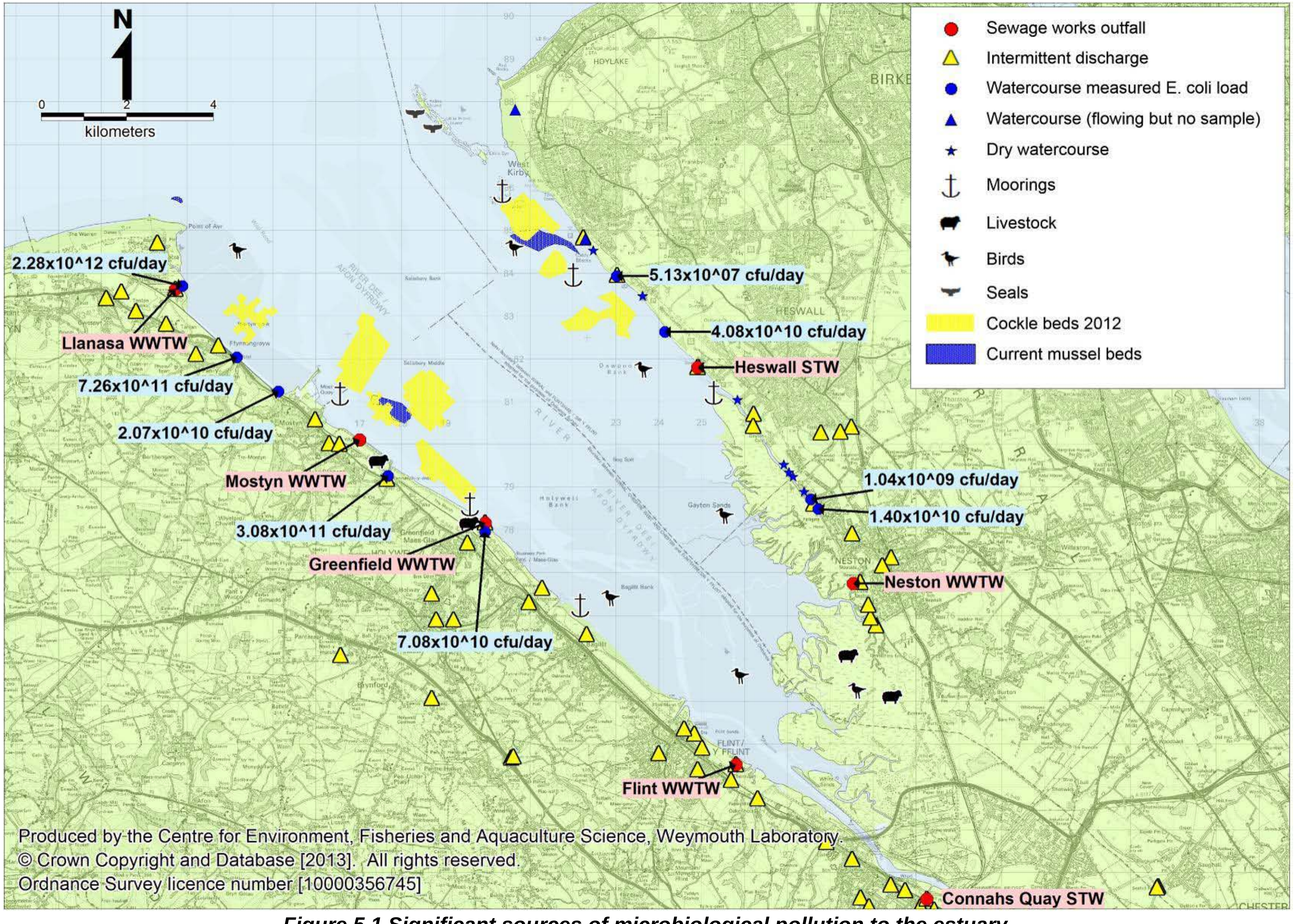

Figure 5.1 Significant sources of microbiological pollution to the estuary.

HYDROGRAPHY

The Dee is a funnel shaped, single spit enclosed estuary, about 30km long and 8.5km in width at its mouth, through which the river Dee flows into the Irish Sea. Most of it is intertidal sandflats, which are fringed by saltmarsh in places. Its shallow intertidal nature will promote tidal exchange, but will reduce dilution potential. In the outer estuary there are two main channels lying either side of the West Hoyle Bank. These converge to form one central channel to the south of the Hoyle Bank, which then moves over to the Welsh side of the estuary and runs adjacent to the shore. A secondary dredged channel diverges from the Welsh Channel and leads to Mostyn port. A number of smaller drainage channels cut across intertidal areas some of which carry freshwater inputs from minor watercourses and sewage works. Of particular relevance to the sampling plan are the drainage channels carrying effluent from the Llanasa, Mostyn, Greenfield and Heswall STWs. Satellite images show a well defined drainage channel from Llanasa running perpendicular to the shore. Drainage channels from Mostyn and Greenfield STWs are less defined and only cross a short distance over the intertidal before reaching the Mostyn port channel and the main river channel respectively. The drainage channel from Heswall STW (and intermittent discharges from this catchment) runs parallel to the shore and at lower states of the tide may deliver effluent to the inshore part of cockle beds at Thurstaston with little scope for dilution. The upper reaches of the Dee estuary are canalised from just upstream of Flint through to the tidal limit at Chester weir. The canalised section is about 100m in width, 2m in depth and trapezoidal in cross section, so there is much less scope for dilution within this reach.

Tidal amplitude is large, at 7.7m on spring tides and 4.1m on neap tides at Hilbre Island, but decreases with distance from the mouth of the estuary to 3.4m on spring tides and 1.7m on neap tides at Connah's Quay. Tides also become increasingly flood dominant further up-estuary, ranging from almost symmetrical at the mouth to a 2 hour flood and 10 hour ebb in the canalised section. During the later stages of the ebb tidal waters drain completely from the canalised section leaving only river water.

The tides drive extensive water movements through the estuary. The flood tide conveys relatively clean water into the estuary which follows the main channels up the estuary at lower water levels but is more spread out towards high water. The reverse occurs on the ebb. Therefore, contamination from shoreline sources will tend to drain into the main channels via channels across the intertidal, and travel parallel to the shore when it reaches tidal waters. As a consequence these sources will primarily impact either side of their locations on the same shore to which they discharge, and in the vicinity of any drainage channels they follow across the intertidal. RMPs should therefore be located to reflect this.

Peak measured flood current velocities of around 0.8m/s and 0.5m/s have been reported at the mouth of the estuary within the Hilbre Channel and the Welsh Channel respectively during spring tides. It is likely that current speeds are slower away from the main channels. In the canalised section flood currents reach up to 1.2 m/s but do not exceed 0.5m/s on the much more prolonged ebb. It was not possible to estimate tidal excursion from the available information so the extent of impacts from sources discharging to the canalised section and upper parts of the main body of the estuary are uncertain.

Freshwater inputs may modify the circulation of water around estuaries via density effects. The ratio of freshwater input:tidal exchange is low and the system is predominantly well mixed. This would suggest that density driven circulation is of little or no importance within the outer estuary where shellfish beds are located. Salinity measurements taken from two points within the mouth of the estuary indicate average salinities approaching that of full strength seawater although occasional low salinities were recorded. There is likely to be a horizontal gradient of decreasing salinity in the upper reaches of the estuary, particularly in the canalised section. Decreasing salinity is likely to be accompanied by increasing levels of indicator bacteria from land runoff. As a consequence the general principle of locating RMPs at the up-estuary ends of shellfish beds should be applied where appropriate.

Water circulation may also be modified by the effects of wind, although exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so will be highly dynamic and difficult to predict. Such effects will not therefore influence the sampling plan. Winds drive surface currents, which in turn will create return currents at depth or along sheltered margins. The prevailing wind direction is from the south west, which will tend to push surface water across the estuary from the Welsh side to the English side. Local topography however affords significant shelter from winds from this direction. As well as driving surface currents, onshore winds will create wave action, which may re-suspend any contamination held within sediments. Given the topography and prevailing wind direction the English shore of the outer estuary is likely to be most vulnerable to such effects.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

The Dee estuary has been subject to considerable microbiological monitoring over recent years, deriving from Bathing Waters and Shellfish Waters monitoring programmes as well as shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Only the results of samples since 2006 were considered as major upgrades to the local sewerage systems were ongoing until 2005.

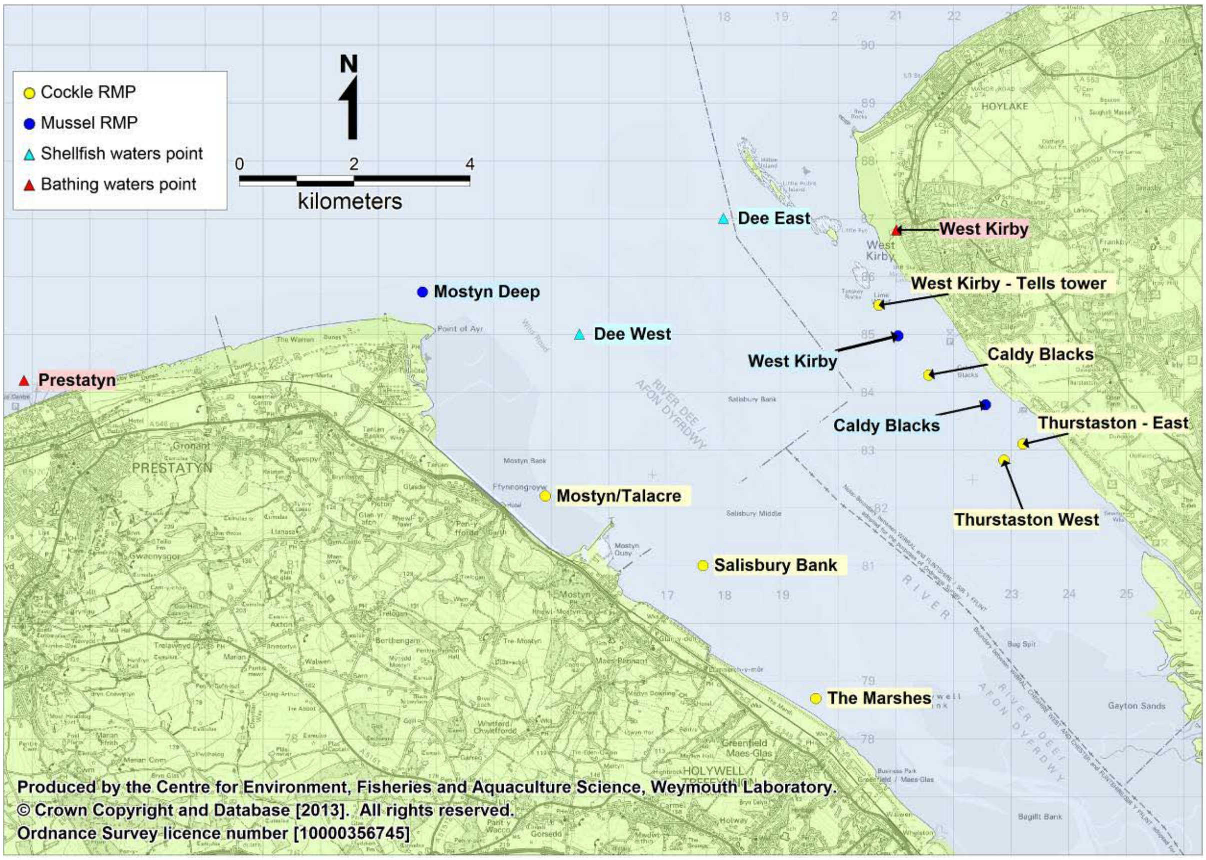

Figure 5.2. Location of shellfish and seawater sampling locations

Two sites were sampled under the Bathing Waters monitoring programme (West Kirby and Prestatyn) where around 20 samples were taken each bathing season (May-September). Levels of faecal coliforms were broadly similar for both sites although Prestatyn had significantly higher average levels of contamination than West Kirby. A significant influence of tide was only found at West Kirby across the spring neap but not the high low cycle. Here, concentrations of faecal coliforms were lower on average during neap tides, suggesting sources some distance away are an influence. A significant influence of recent rainfall was found at both sites, although this was stronger and more consistent at Prestatyn.

Two sites were sampled under the Shellfish Waters monitoring programme, under which water samples were taken and tested for faecal coliforms on a quarterly basis. Some additional samples were taken from Dee East. Results were similar at the two, and no significant difference was found between them. Both displayed statistically significant seasonal variation, with highest results on average during the winter. No influence of the spring/neap tidal cycle was found at either of the shellfish waters sites. Significant variation across the high/low cycle was found at both, with the highest individual results occurred during the flood tide, but fewer low results during the ebb tide. Both sites showed a tendency for higher results at lower salinities, but this effect was only statistically significant at Dee West. Both sites were also significantly influenced by rainfall. The strongest correlations were associated with rainfall 6 days prior to sampling in both cases, which is more consistent with an influence from the main river rather than local streams.

Since 2006 seven RMPs have been sampled for cockles and three RMPs have been sampled for mussels under the shellfish hygiene classification programme. Across the cockle RMPs Thurstaston East had significantly higher results than all other RMPs, with a geometric mean of 851.6, with 14.3% exceeding 4600 and a maximum of 92,000 *E. coli* MPN/100g. All other cockle RMPs had results aligning with a B classification and geometric mean levels of *E. coli* ranging from 79.2 to 220.3 *E. coli* MPN/100g. Sufficient numbers of paired (same day) samples to permit a more robust comparison of results were taken from two site pairings. Mostyn/Talacre and Salisbury Bank shared 83 sampling dates but results were not correlated on a sample by sample basis at either site pairings. This suggests they are under difference contaminating influences despite their close proximity. The same applies to Thurstaston West and West Kirby – Tells Tower, which shared 41 sampling dates. There was no evidence of a strong underlying gradient of higher levels of contamination towards the up-estuary ends of cockle beds on the Welsh side.

Across the three mussel RMPs results were significantly higher at Caldy Blacks than at the other two RMPs. At Caldy Blacks there was a geometric mean of 922.3, with 24.2% exceeding 4600 and a maximum of 160,000 *E. coli* MPN/100g. Together with the high cockle results at Thurstaston East (but not Thurstaston West) this suggests a hotspot of contamination within and around the drainage channel from the Heswall marshes rather than a tendency for higher results towards the up-estuary ends of the beds driven by sources from the wider catchment. Results from the other two mussel RMPs aligned with a B classification. It was not possible to undertake paired comparisons between any mussel RMPs as fewer than 20 same day samples were taken for each of the site pairings.

Since 2006 there have not been any major changes over the years in the average levels of *E. coli* at any RMPs sampled throughout this period. For cockles, there does appear to have been an increased incidence of high results in 2008 on the English side of the estuary, and a slight decrease in average result on both sides of the estuary since 2009.

There was significant seasonal variation at Salisbury Bank but not at any other site, where results were significantly higher in winter than in the spring. Plots of results by season also suggest a broadly similar seasonality at West Kirby and Thurstaston West with higher results in the winter. Mostyn/Talacre appears to have a slightly different seasonal pattern where results tend to be higher on average during the summer and autumn. No significant seasonal variation was seen at the only mussel RMP sampled on sufficient occasions (Caldy Blacks).

A significant influence of tide on the spring/neap cycle was found for cockles at Salisbury Bank and West Kirby - Tells Tower, but sampling was undertaken at lower states of the tide and no pattern was apparent when these data were plotted. A significant influence of tidal state across the spring/neap tidal cycle was found for cockles at Thurstaston West but again no pattern was apparent when these data were plotted.

Correlations between rainfall and the level of *E. coli* in shellfish to some degree at all of the sites analysed with the exception of The Marshes. West Kirby Tells Tower, Thurstaston West and Caldy Blacks saw the most consistent effect of rainfall. All three of these sites are downstream of the Heswall STW overflow, which may be the cause of the increased *E. coli* levels after rainfall events.

Modelled spill data was available for the Heswall settled storm tank intermittent outfall. An analysis of *E. coli* results against this data showed that *E. coli* levels were significantly higher when the sample was taken within 48 hours of a predicted spill event for cockles at Thurstaston East and mussels at Caldy Blacks. None of the other RMPs were significantly affected. Relatively few samples were taken at Thurstaston West and plots of the data from here suggested a tendency for higher results following a spill.

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary totally or partially included within the river catchment areas is shown in Figure I.1. Total resident human population in the Dee estuary catchment was approximately 0.5 million at the time of the 2001 census. Population densities are considerably higher (up to ten times higher) in the towns of Chester and Wrexham. The catchment is largely rural in character; this is reflected in the low population densities of up to 1000 people per km² throughout most of it. Population densities are lowest in the upper reaches, a significant part of which falls within Snowdonia National Park.

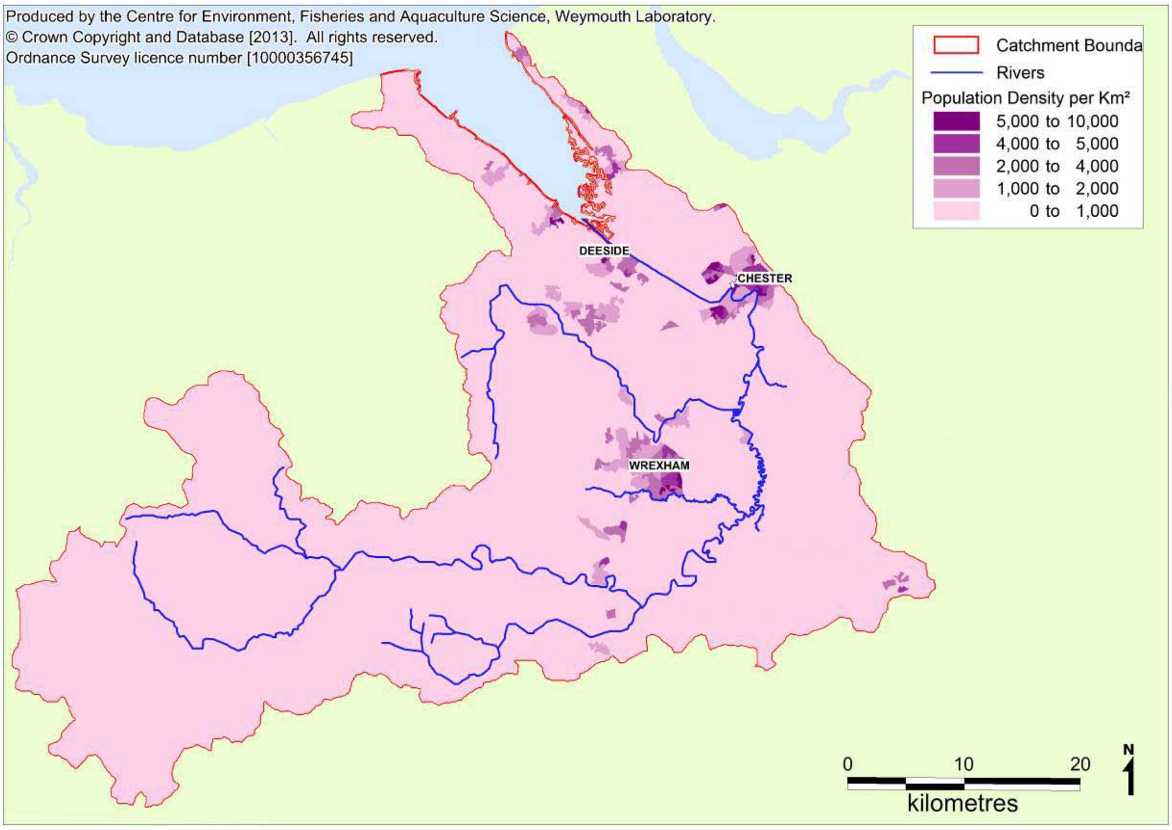

Figure I.1 Human population density in the Dee estuary catchment.

Significant numbers of tourists also visit the Dee estuary catchment area. Attractions include the city of Chester which receives about 8 million visitors a year (Chester Renaissance, 2012), other towns such as Langollen, and to some extent the Dee estuary itself, where there is likely to be a tourist driven increase in population during the summer months. There are static caravan parks adjacent to the estuary at Talacre and Thurstaston. The north Wirral coast is a summer tourist attraction in itself, with the seaside towns of New Brighton and Hoylake at either end, a large holiday park hosting about 300 static caravans, some attractive natural outdoor areas and a golf course. Many activities in the Dee Estuary catchment are undertaken outdoors and consequently attract more visitors in the summer months; 70% of all tourists to North Wales visit in the summer (Tourism Partnership North Wales, 2012). Activities includes walking, mountain biking, white water rafting, kayaking. Visitors to the area will increase the amount of sewage discharged, so overall volumes will be higher during the summer months.

APPENDIX II
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges around the Dee estuary were taken from the Environment Agency's national discharge database. There are nine water company water treatment works that discharge either directly to the Dee estuary, or to short watercourses feeding directly into the estuary, or to the canalised section of the tidal Dee (Table II.1). The largest in terms of volume and estimated bacterial loading by some margin is Chester WWTW. The majority of sewage (~75% by volume) is discharged to the estuary a significant distance upstream of the shellfisheries so the influence of these will be strongest at the up-estuary ends of shellfish beds. Llanasa, Mostyn, Greenfield and Heswall sewage works are sufficiently close to shellfish beds to have more acute impacts in specific areas of then fishery.

Table II.1: Continuous sewage discharges to the Dee Estuary

Name	NGR	Treatment level	Consented dry weather flow (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving water
Chester STW	SJ3939066450	Activated sludge	31,138	1.03×10^{14}	Tidal Dee
Connahs Quay STW	SJ3024069380	Biological filtration	3,272	1.08×10^{13}	Watercourse
Flint WWTW	SJ2578872517	UV disinfection	3,410	7.41×10^{11}	Watercourse
Greenfield WWTW	SJ1994078160	Biological filtration	3,891	1.28×10^{13}	Dee estuary
Heswall STW	SJ2490081790	UV disinfection	2,700	1.52×10^{11}	Dee estuary
Llanasa WWTW	SJ1271583618	UV disinfection	8,061	1.24×10^{11}	Watercourse
Mostyn WWTW	SJ1701780096	Biological filtration	966	3.19×10^{12}	Dee estuary
Neston WWTW	SJ2852476748	UV disinfection	4,074	1.20×10^{12}	Watercourse
Queensferry WWTW	SJ3223068420	UV disinfection	10,000	3.74×10^{12}	Watercourse

*Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs providing secondary treatment (Table II.2).
** Faecal coliforms (cfu/day) based on geometric mean final effluent testing data (Table II.3)

Table II.2 Summary of reference faecal coliform levels (cfu/100ml) for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	7.2×10^{6}
Primary (12)	127	1.0×10^{7}	14	4.6×10^{6}
Secondary (67)	864	3.3×10^{5}	184	5.0×10^{5}
Tertiary (UV) (8)	108	2.8×10^{2}	6	3.6×10^{2}

Data from Kay et al. (2008b).
n - number of samples.
Figures in brackets indicate the number of STWs sampled.

Table II.3: Summary of faecal coliform data for final effluents from continuous discharges

Name	Period	Faecal coliforms (cfu/100 ml)		
		Number of samples	Geometric mean	Maximum
LLanasa WWTW	2007-2011	132	1542	>100,000
Flint WWTW	2007-2011	78	21,743	200,000
Heswall STW	2008-2012	115	5,634	880,000
Neston WWTW	2008-2012	128	29,489	7,200,000
Queensferry WWTW	2011	24	37,359	380,000

Data from the Environment Agency

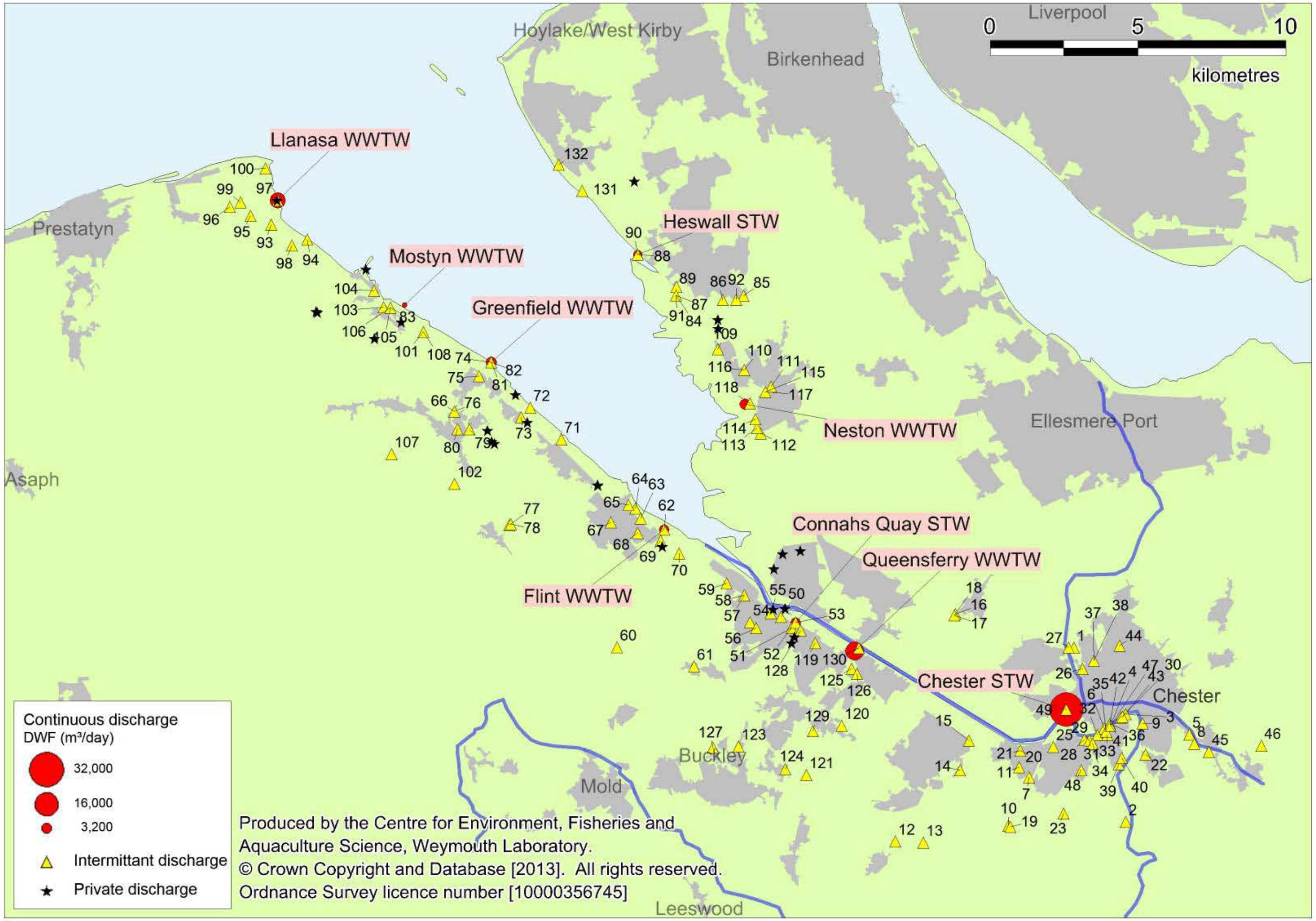

Figure II.1: Sewage discharges to the Dee Estuary. Numbers refer to intermittent discharges listed in Table II.3
Data from the Environment Agency

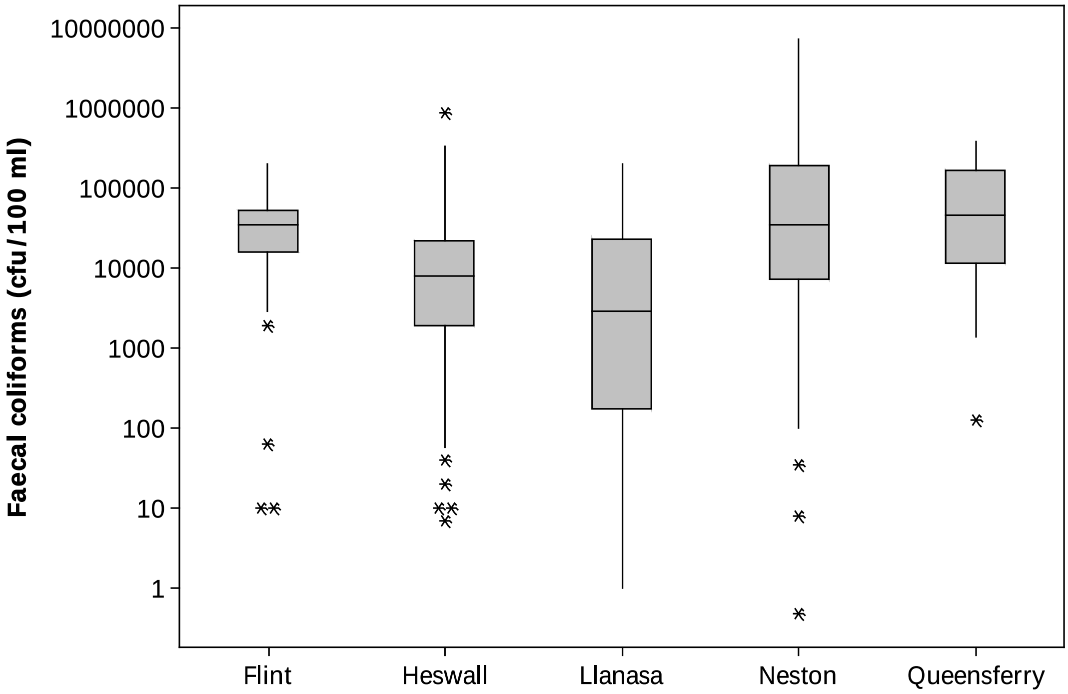

Figure II.2: Boxplots of faecal coliform data for final effluents from continuous discharges
Data from the Environment Agency

Final effluent testing data indicates that all works considered here contain high concentrations of faecal coliforms relative to the average values presented in Table II.3. Average faecal coliform concentrations were lower at Llanasa and Heswall than at the other UV works. Maximum concentrations at individual works were up to 2.4 orders of magnitude higher than mean concentrations. It should be noted that UV is less effective against viruses than bacteria (e.g. Tree et al, 1997) so their importance in public health terms may be underestimated by the bacteriological status of their effluent.

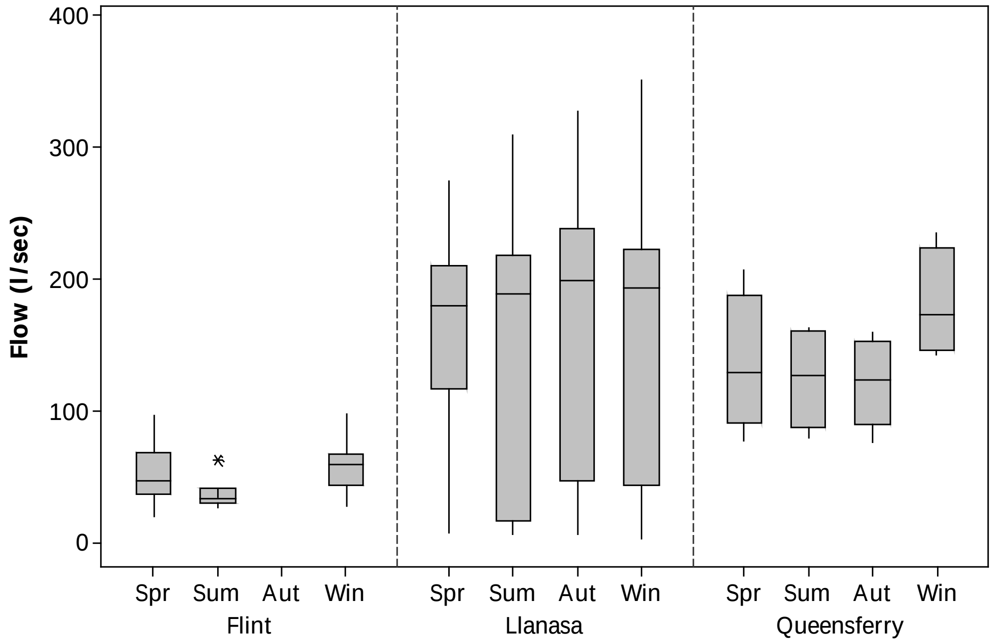

Figure II.3: Boxplots of flow measurements by season for three sewage works
Data from the Environment Agency

Flows were higher on average during the winter Queensferry, and higher on average in the spring at Llanasa. They were quite variable at Llanasa. The small amount of data for Flint did not reveal any particular pattern.

In addition to the continuous discharges there are 132 intermittent discharges to the estuary (Table II.3). The main concentrations of these lie in the more urbanised areas. Modelled spill predictions for the intermittent discharges were taken from the Metoc Water Quality Model Validation report, produced on behalf of Dŵr Cymru Welsh Water (Metoc 2007). Modelled spill data was not presented for the two United Utilities (UU) discharges, but the report indicated that UU modelling had shown they were insignificant spillers compared to the Heswall catchment.

Table II.3. Intermittent discharges to the Dee estuary

No.	Name	Sewerage Catchment	NGR of outfall	Modelled Annual Spill Volume (m³)	Estimated no. spills / year	Modelled Annual Spill Duration (hours)	Modelled Annual Spill Duration (%)
1	Chester Curzon Park North No22	Chester	SJ 3966 6853	23	1	1	0.00%
2	Chester Eccleston SPS	Chester	SJ 4140 6267	317	6	8	0.10%
3	Chester Dee Lane Adj. Deva Terrace	Chester	SJ 4140 6630	29,595	40	60	0.70%
4	Chester STW - River Weir	Chester	SJ 4088 6590	776,470	147	396	4.50%
5	Christleton Trooper Inn Bus Lay by	Chester	SJ 4356 6561	17,212	61	118	1.30%
6	Chester Old Dee Bridge SPS	Chester	SJ 4068 6582	1,187	9	11	0.10%
7	Saltney Chester Road SPS	Chester	SJ 3813 6417	933,710	856	1,748	20.00%
8	Christleton Old Womans Lane	Chester	SJ 4372 6530	0	-	-	-
9	Chester Sandy Lane Car Park SPS EO	Chester	SJ 4197 6599	700	2	2	0.00%
10	Chester Marlston Cum Lache SPS	Chester	SJ 3744 6253	337	8	23	0.30%
11	Saltney Sandy Lane SPS	Chester	SJ 3780 6450	11,212	25	101	1.10%
12	Higher Kinnerton SPS	Chester	SJ 3361 6200	31,388	145	329	3.80%
13	Lower Kinnerton SPS	Chester	SJ 3455 6197	184	4	11	0.10%
14	Bretton Broughton Mills Road / Chester Rd	Chester	SJ 3580 6440	7,836	10	32	0.40%
15	Bretton SPS	Chester	SJ 3610 6540	310,750	537	2,290	26.10%
16	Chester Saughall Seahill Road Bryn Hyfryd	Chester	SJ 3564 6967	3	1	0	0.00%
17	Chester Saughall SPS Track Off Seahill Road	Chester	SJ 3561 6963	235	4	9	0.10%
18	Chester Saughall Village The Poplars NRA	Chester	SJ 3561 6963	5,242	19	28	0.30%
19	Chester Balderton SPS / Common Lane	Chester	SJ 3750 6250	2,879	112	96	1.10%
20	Saltney Bridge Street	Chester	SJ 3784 6506	61,837	146	385	4.40%
21	Saltney Green Lane SPS	Chester	SJ 3784 6506	3,034	15	126	1.40%
22	Saltney Chester Road	Chester	SJ 4208 6494	36	0	0	0.00%
23	Chester Wrexham Road SPS Kings Meadow	Chester	SJ 3930 6295	3	0	0	0.00%
24	Saltney Lache Park Avenue	Chester	SJ 3420 5140	1	0	0	0.00%
25	Saltney Mount Pleasant	Chester	SJ 3896 6519	34,429	508	3,267	37.30%
26	Chester Parkgate Court SPS	Chester	SJ 3994 6783	0	-	-	-
27	Chester Parkgate Road SPS	Chester	SJ 3947 6854	177	16	11	0.10%
28	Chester Dingle Bank Rear No3	Chester	SJ 4000 6544	3,221	54	61	0.70%
29	Chester The Dingle Manhole 1202	Chester	SJ 4017 6541	0	-	-	-
30	Chester Grosvenor Road Bridge	Chester	SJ 4124 6617	501	8	13	0.10%
31	Chester The Dingle Manhole 1405	Chester	SJ 4017 6541	3	0	0	0.00%
32	Chester Little Roodee	Chester	SJ 4044 6560	13,476	86	75	0.90%
33	Chester Handbridge Greenway Street	Chester	SJ 4078 6559	0	-	-	-
34	Chester Castle Drive	Chester	SJ 4066 3780	57,674	93	175	2.00%

No.	Name	Sewerage Catchment	NGR of outfall	Modelled Annual Spill Volume (m³)	Estimated no. spills / year	Modelled Annual Spill Duration (hours)	Modelled Annual Spill Duration (%)
35	Chester Edgars Park	Chester	SJ 4074 6571	6,391	9	13	0.1%
36	Chester The Groves	Chester	SJ 4087 6597	13,207	39	58	0.7%
37	Chester Countess Way Bache Tank	Chester	SJ 4032 6810	24,911	17	27	0.3%
38	Chester Countess Way Bache Tank	Chester	SJ 4032 6810	23,040	17	26	0.3%
39	Chester Handbridge Greenbank Eaton Road	Chester	SJ 4117 6461	16	1	1	0.0%
40	Chester Belgrave Park	Chester	SJ 4127 6482	0	-	-	-
41	Chester The Groves Rd Nr Boathouse PH	Chester	SJ 4087 6597	0	0	0	0.0%
42	Chester Boathouse PH Car Park	Chester	SJ 4087 6597	5,103	90	152	1.7%
43	Chester Grosvenor Park Terrace	Chester	SJ 4130 6620	14,732	37	36	0.4%
44	Chester Wealstone Lane Near Youth Club	Chester	SJ 4119 6861	2,308	21	26	0.3%
45	Christleton Whitchurch Road SPS	Chester	SJ 4421 6503	528	10	15	0.2%
46	Christleton Plough Lane East SPS	Chester	SJ 4599 6523	0	-	-	-
47	Chester Sandy Lane Car Park SPS	Chester	SJ 4088 6591	20,406	25	33	0.4%
48	Chester Crane Street Waste Ground Nr Manweb	Chester	SJ 3990 6440	2,684	10	15	0.2%
49	Chester STW - Storm Tanks	Chester	SJ 3939 6645	0	-	-	-
50	Cestrian Street CSO	Connahs Quay	SJ 2974 6957	476	1	2	0.0%
51	Connahs Quay Low Level CSO	Connahs Quay	SJ 3010 6920	87,059	157	388	4.4%
52	Connahs Quay Low Level PS	Connahs Quay	SJ 3010 6920	24,903	39	58	0.7%
53	Connahs Quay WwTW Storm Tank Overflow	Connahs Quay	SJ 3024 6938	14,716	27	133	1.5%
54	Deva Avenue CSO	Connahs Quay	SJ 2870 6940	0	-	-	-
55	Dock Road PS Overflow	Connahs Quay	SJ 2940 6970	154	2	2	0.0%
56	Englefield Avenue CSO	Connahs Quay	SJ 2890 6920	0	-	-	-
57	Golftyn PS Overflow	Connahs Quay	SJ 2850 7030	109	17	0	0.0%
58	Golftyn PS High Level Overflow	Connahs Quay	SJ 2850 7030	10,863	0	43	0.5%
59	Kelsterton PS Overflow	Connahs Quay	SJ 2790 7070	35	2	2	0.0%
60	Northop Hall PS Overflow	Connahs Quay	SJ 2420 6855	2,097	11	24	0.3%
61	St Mary's Drive CSO	Connahs Quay	SJ 2680 6790	158	5	7	0.1%
62	Flint WwTW storm tank overflow	Flint	SJ 2579 7252	14,639	263	685	7.8%
63	Dee Cottages PS Overflow	Flint	SJ 2500 7290	18	1	1	0.0%
64	Bryn Bardyn PS Overflow	Flint	SJ 2482 7323	41,474	50	135	1.5%
65	Castle No.1 PS Overflow	Flint	SJ 2458 7335	28	1	1	0.0%
66	Aber Road PS Overflow	Flint	SJ 1870 7650	261	9	19	0.2%
67	The Meadows PS Overflow	Flint	SJ 2399 7277	0	-	-	-
68	Maes Gwyn CSO	Flint	SJ 2490 7240	11,687	69	96	1.1%
69	Oakenholt PS Overflow	Flint	SJ 2568 7215	45	1	1	0.0%

No.	Name	Sewerage Catchment	NGR of outfall	Modelled Annual Spill Volume (m³)	Estimated no. spills / year	Modelled Annual Spill Duration (hours)	Modelled Annual Spill Duration (%)
70	Papermill PS Overflow	Flint	SJ 2630 7172	0	0	0	0.0%
71	Bagilt East PS Overflow	Greenfield	SJ 2231 7555	1,896	8	11	0.1%
72	Bagilt West PS Overflow	Greenfield	SJ 2127 7663	2,065	25	41	0.5%
73	Boot & Ship PS Overflow	Greenfield	SJ 2096 7630	0	-	-	-
74	Greenfield No.1 PS Overflow	Greenfield	SJ 1994 7816	857	6	6	0.1%
75	Greenfield Road CSO	Greenfield	SJ 1953 7769	8,853	466	121	1.4%
76	Halls (Holywell) CSO	Greenfield	SJ 1870 7650	1,479	17	32	0.4%
77	Llygain-Y-Wern (Pentre Halkyn) PS Overflow	Greenfield	SJ 2055 7267	871	54	61	0.7%
78	Pentre Halkyn PS Overflow	Greenfield	SJ 2060 7270	3,085	14	35	0.4%
79	Pen-y-Maes PS Overflow	Greenfield	SJ 1920 7590	1,820	22	56	0.6%
80	Strand Walks CSO	Greenfield	SJ 1880 7590	405	3	7	0.1%
81	Greenfield WwTW CSO	Greenfield	SJ 1994 7816	29,239	36	269	3.1%
82	Holywell WwTW Storm Tank Overflow	Greenfield	SJ 1994 7816	19,567	76	135	1.5%
83	Coast Road / Greenfield Road CSO	Greenfield	SJ 1654 8000	22,671	52	217	2.5%
84	Heswall WwTW settled storm sewage	Heswall	SJ 2619 8042	160,356	73	473	5.4%
85	Boathouse Lane Pumping Station	Heswall	SJ 2848 8040	--------Does not spill to the environment--------			
86	Seabank Road CSO	Heswall	SJ 2777 8026	0	-	-	-
87	Riverbank Road CSO	Heswall	SJ 2619 8042	67,686	34	121	1.4%
88	Cottage Lane PS Overflow	Heswall	SJ 2490 8179	121	2	6	0.1%
89	Gayton Cedarway PS EO	Heswall	SJ 2620 8070	0	-	-	-
90	Gayton Parkway Overflow (surface water)	Heswall	SJ 2490 8179	18,388	1	869	9.9%
91	Heswall WwTW storm sewage	Heswall	SJ 2619 8042	115,423	64	278	3.2%
92	Gayton Parkway CSO	Heswall	SJ 2823 8028	659	2	8	0.1%
93	Tan Lan PS EO	Llanasa	SJ 1250 8280	48	7	4	0.0%
94	Ffynnongrotw West PS	Llanasa	SJ 1372 8230	0	0	0	0.0%
95	Gwespyr Tan Lan Bach PS EO	Llanasa	SJ 1180 8310	48	7	4	0.0%
96	Gwespyr Old STW CSO	Llanasa	SJ 1110 8340	0	-	-	-
97	Llanasa WwTW overflow	Llanasa	SJ 1272 8362	2,571	5	28	0.3%
98	Pen-y-ffordd Farm CSO	Llanasa	SJ 1320 8210	154	3	4	0.0%
99	Talacre Argoed PS EO	Llanasa	SJ 1146 8356	0	0	0	0.0%
100	Talacre Morfa Camp PS EO	Llanasa	SJ 1230 8470	71	1	3	0.0%
101	Carmel Gorsedd CSO	Mostyn	SJ 1765 7918	2,821	22	39	0.4%
102	Crooked Horn PS Overflow	Mostyn	SJ 1870 7406	3	1	1	0.0%
103	Ffordd Ddfdwy CSO	Mostyn	SJ 1630 8001	1,825	8	66	0.8%
104	Greenfield (Knitmesh) PS Overflow	Mostyn	SJ 1598 8057	137	5	7	0.1%

No.	Name	Sewerage Catchment	NGR of outfall	Modelled Annual Spill Volume (m³)	Estimated no. spills / year	Modelled Annual Spill Duration (hours)	Modelled Annual Spill Duration (%)
105	Marsh Farm PS Overflow	Mostyn	SJ 1654 8000	1,432	8	32	0.4%
106	Marsh Farm PS No.2 Overflow	Mostyn	SJ 1654 8000	53	2	3	0.0%
107	Naid Y March PS Overflow	Mostyn	SJ 1657 7506	334	10	13	0.2%
108	Pantasaph PS Overflow - Unknown	Mostyn	SJ 1765 7918	1	0	0	0.0%
109	Dee Cottages CSO	Neston	SJ 2760 7860	1,105	6	6	0.1%
110	Earle Drive CSO	Neston	SJ 2850 7790	1,813	17	18	0.2%
111	Gladstone Road CSO	Neston	SJ 2941 7734	4,442	12	16	0.2%
112	Greenfield Road CSO	Neston	SJ 2906 7576	19,922	122	180	2.1%
113	Harp Inn CSO	Neston	SJ 2893 7594	1,268	15	22	0.3%
114	Marshland PS Overflow	Neston	SJ 2888 7624	4,923	31	50	0.6%
115	Mill Lane PS Overflow	Neston	SJ 2921 7716	0	-	-	-
116	Parkgate PS Overflow	Neston	SJ 2850 7790	14,349	60	90	1.0%
117	Tankfields CSO	Neston	SJ 2921 7716	13,507	31	48	0.5%
118	Neston WwTW storm tank overflow	Neston	SJ 2869 7677	61,545	51	113	1.3%
119	Ash Grove PS Overflow	Queensferry	SJ 3090 6870	5,535	41	65	0.7%
120	Cross Tree Lane CSO Hawarden	Queensferry	SJ 3180 6590	123	4	3	0.0%
121	Dobshill PS Overflow	Queensferry	SJ 3060 6425	2,771	9	12	0.1%
122	Factory Road CSO	Queensferry	SJ 3186 3765	12,802	50	119	1.4%
123	Liverpool Road CSO	Queensferry	SJ 2830 6520	11	1	0	0.0%
124	Drury Lower Farm CSO	Queensferry	SJ 2989 6444	227	8	24	0.3%
125	Mancot Storage Tank Overflow	Queensferry	SJ 3213 6783	1,350	4	13	0.1%
126	Pentre (Queensferry) PS Overflow	Queensferry	SJ 3232 6766	65	1	1	0.0%
127	The Willows PS Overflow	Queensferry	SJ 2744 6517	-	-	-	-
128	Wepre PS Overflow	Queensferry	SJ 3041 6912	2,949	22	31	0.3%
129	Wood Lane CSO	Queensferry	SJ 3082 6572	45,257	82	227	2.6%
130	Queensferry WwTW Storm Tank Overflow	Queensferry	SJ 3238 6852	12,844	5	36	0.4%
131	Long Hey Rd/Croft Drive East, Caldy CSO*	United Utilities	SJ 2302 8394	--------------------------------No data------------------------			
132	Croft Drive/Shore Road, Caldy CSO*	United Utilities	SJ 2223 8482	--------------------------------No data------------------------			

The top five spillers (Nos. 91, 84, 15, 4 & 7 in Table II.3) all have annual spill volume exceeding 100,000 m³ per year. The two largest intermittent outfalls (Chester STW and Chester Road SPS) both discharge between 750,000 and 1,000,000 m³ per year to the River Dee at Chester and so may significantly contribute to the sewage contamination in the upper reaches of the estuary. The Heswall STW storm overflows were also major spillers and discharge to a tidal creek near shellfish beds at Thurstaston. A comparison of modelled spill event data (only available for Heswall settled storm sewage) and shellfish hygiene monitoring results suggest that this outfall has been a significant influence on shellfish hygiene in the Thurstaston area (Appendix XI). DCWW are currently undertaking works at Heswall to reduce the amount of surface water the catchment collects, and to increase the treatment and storage capacity of the works. This has been predicted to reduce the frequency of reported spills from the three main spillers (Heswall WWTW settled storm sewage, Heswall WWTW storm sewage and Riverbank Road) to 10 per year, from the present estimated frequency of 73, 64 and 34 per year respectively. The works should be finished by summer 2013 (DCWW, pers comm.).

As well as water company assets there are some privately owned sewage discharges in the vicinity of the Dee estuary. None of these are particularly large, typically serving one or two properties and providing treatment via septic tank or package plant discharging to watercourse or soakaway. As such they have little bearing on the sampling plan, although they may contribute to the bacterial loadings carried by some watercourses.

APPENDIX III
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

The majority of land within the Dee catchment is used for agriculture. Most are pastures, although there are many smaller pockets where crops are cultivated (Figure 1.2). Table VIII.1 and Figure VIII.1 present livestock numbers and densities for the catchments draining to the estuary. This data was provided by Defra and Welsh Government and is based on the 2010 census. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, the data should give a good indication of the numbers of livestock within the catchment.

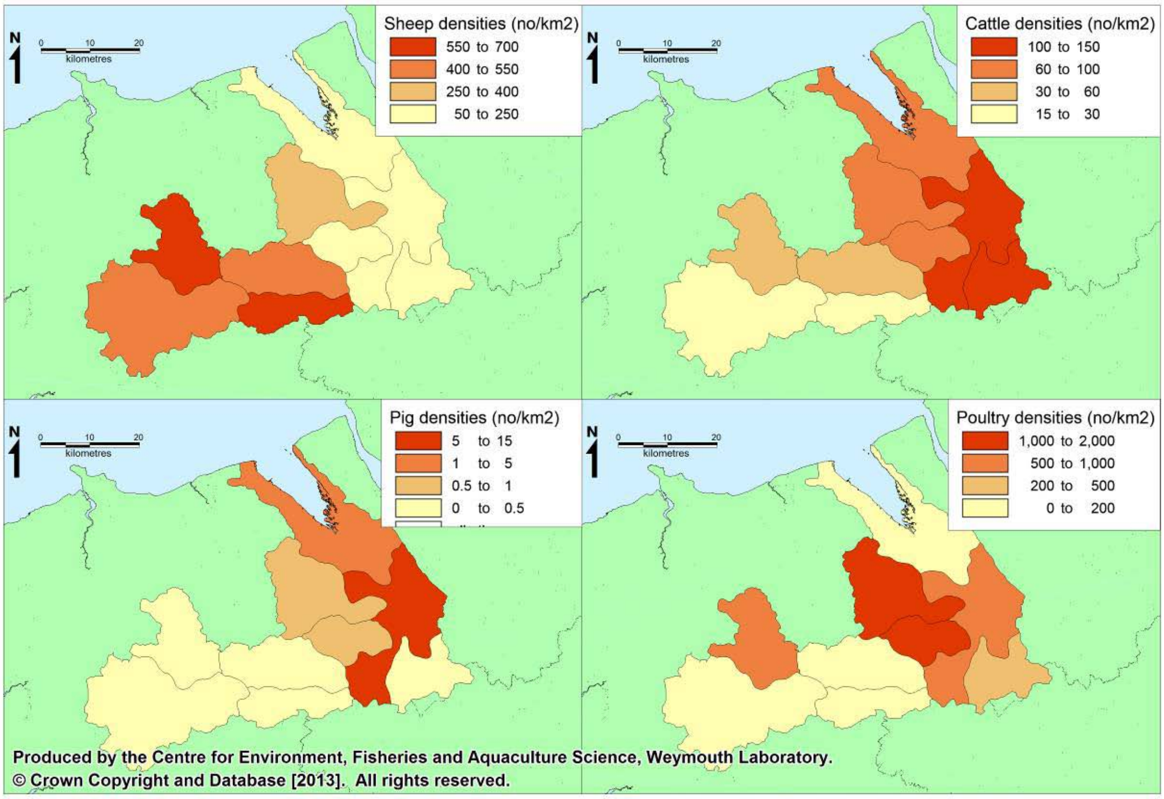

Figure VIII.1. Livestock densities within the Dee catchment
Data from Defra and Welsh Government

Table VIII.1 Summary statistics from 2010 livestock census for the Dee catchment

	Numbers				Density (animals/km^2)			
Catchment name	Sheep	Cattle	Pigs	Poultry	Sheep	Cattle	Pigs	Poultry
Alwen	129,663	7,231	31	102,947	641	36	0.2	509
Alyn	79,021	16,185	154	435,712	320	66	0.6	1,764
Ceiriog	75,252	3,388	4	677	577	26	0.0	5
Clywedog	18,376	7,551	90	185,777	159	66	0.8	1,612
Dee (Lower)	18,613	44,778	3,614	287,606	60	145	11.7	934
Dee (Middle)	102,879	8,356	38	18,048	483	39	0.2	85
Dee (Upper)	210,543	8,843	104	2,877	472	20	0.2	6
Dee Estuary	38,859	22,032	1,305	21,435	122	69	4.1	67
Worthenbury	13,155	18,215	52	36,786	89	123	0.4	248
TOTAL	686,362	136,579	5392	1,091,864	322	64	2.5	513

Data from Defra and Welsh Government

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.1.

Table VIII.1 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Farm Animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^8
Pig	3,300,000	2,700	8.9×10^8
Human	13,000,000	150	1.9×10^9
Cow	230,000	23,600	5.4×10^9
Sheep	16,000,000	1,130	1.8×10^{10}

Data from Geldreich (1978) and Ashbolt et al. (2001).

There are large numbers of grazing animals within the catchment with almost 100,000 cattle and over 700,000 sheep. Sheep are present in highest densities in the upper reaches of the catchment, so their main concentrations are some distance from the estuary although there are significant numbers in the lower parts of the catchment. Cattle are mainly found within the lower reaches of the catchment so may be more of an influence. Significant diffuse inputs associated with grazing livestock are therefore anticipated via direct deposition on pastures. Slurry is also collected from livestock sheds when cattle are housed indoors and subsequently applied to fields as fertilizer. Large numbers of poultry and relatively small numbers of pigs are also raised within the catchment. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Given the ubiquity of pastures throughout the catchment most, if not all watercourse will be impacted to some extent by agriculture. Runoff from the majority of the catchment area enters the estuary upstream of the fisheries. Higher impacts may therefore be anticipated towards the up-estuary ends of the shellfish beds on this basis, although there are some smaller watercourses feeding into the lower estuary which will also carry some agricultural contamination. Some livestock were observed on fields adjacent to the shore between Greenfield and Mostyn during the shoreline survey.

There are extensive areas of saltmarsh in the Dee estuary, most of which lies in the upper reaches of the estuary on the English side, with some small areas on the Welsh shore. Sheep are grazed on some areas of marsh on the Welsh shore in the mid to upper estuary and on the Burton Marsh on the English shore to maintain the habitat for wildlife (Natural England & CCW, 2010). Contamination from animals grazing on saltmarsh may be carried into the estuary via tidal inundation as well as runoff. The latter is a particularly direct and predictable mechanism which may result in large amounts of faecal matter being washed into estuary during spring tides. An Environment Agency study conducted in the Ribble estuary found a significant increase in levels of faecal coliforms within saltmarsh creeks in grazed areas as the tide started to ebb following tidal inundation (Dunhill, 2003) so this is a recognised phenomenon.

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Highest sheep counts on the grazing marshes on the south shore of the estuary are reported to occur from April to October. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry/pig manure and sewage sludge may be spread at any time of the year. There are some seasonal restrictions on manure spreading in nitrate vulnerable zones which form a large part of the lower Dee catchment. On shallow or sandy soils no spreading is permitted on grasslands from September to December, or on tillage land from August to December. On other soil types no spreading is allowed from 15 October to 15 January on grasslands and from 1 October to 15 January on tillage land (Environment Agency, pers comm.). Peak levels of contamination from agriculture may therefore arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application, which is perhaps more likely in late winter or spring.

APPENDIX IV
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Dee estuary. There is significant boat traffic within the Dee estuary, it hosts one commercial port and is also used commercial fishing vessels and small pleasure craft. Figure IX.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

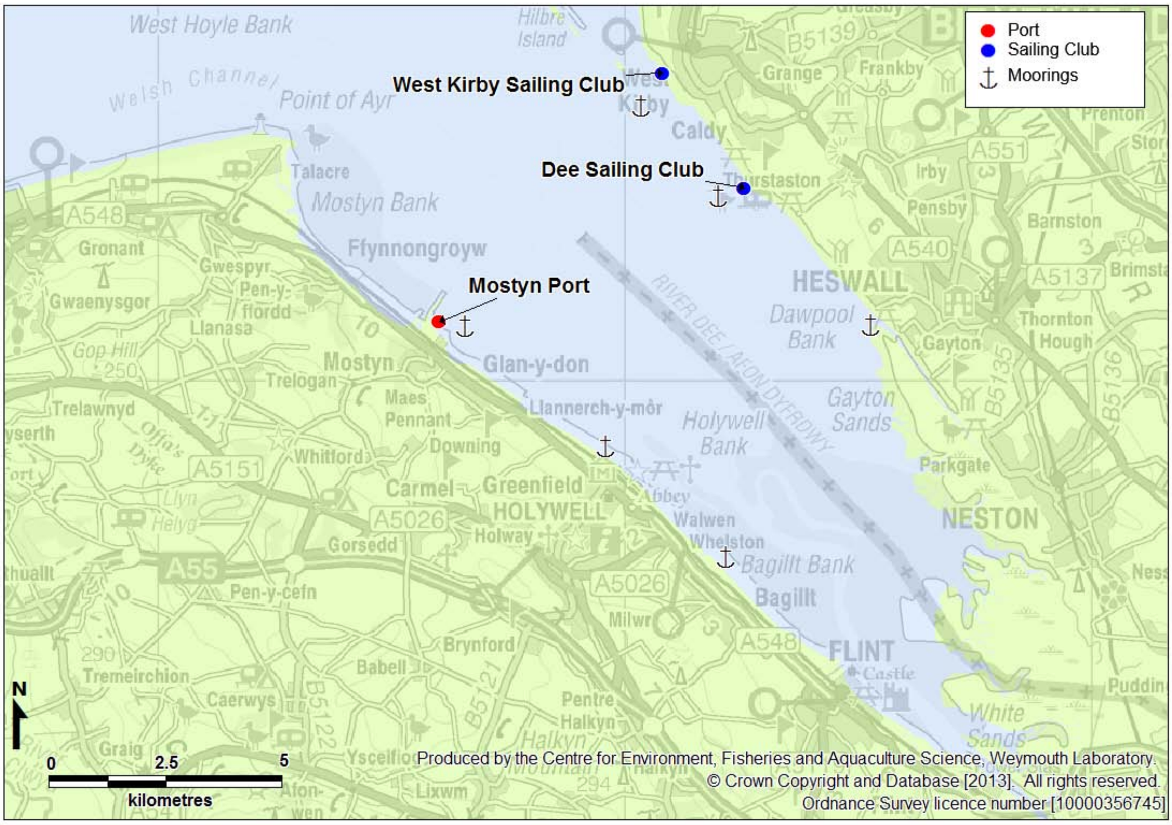

Figure IX.1 Overview of boat

The Port of Mostyn, a commercial port, is situated just inside the mouth of the Dee estuary on the Welsh side. Mostyn is an export port dealing with the exportation of steel to Europe and cargoes including, animal feed, fertiliser and aggregates. Over the last decade with the port has received substantial development, as a result of this there has been an increase in the number of larger ships docking here. Navigation to the port uses the Welsh Channel, Mostyn Deep and the Inner Channel to reach the port. Merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land[2] so vessels associated with the commercial port should produce little or no impact.

Approximately 40 commercial fishing boats and a small fleet of recreational angling vessels operate from the Dee estuary targeting a variety of fish and shellfish species.

[2] The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008

The cockle fishermen use small open vessels to land on the sandbanks at low tide, but these appear too small to have onboard toilets.

Two sailing clubs (West Kirby Sailing Club and the Dee Sailing Club at Thurstaston) are located within the outer reaches of the estuary on the English side. Yachts and cabin cruisers are kept on a relatively small number of moorings maintained by the West Kirby Sailing Club and Dee Sailing Club. These boats may contain toilet facilities and therefore occasional overboard discharges maybe made. In addition to these moorings there are also small numbers of drying moorings found all along the edge of the Dee estuary, close to slipways. Boats on these dry moorings appear to be too small to contain toilet facilities and therefore pose little microbiological pollution potential.

Private vessels such as yachts, cabin cruisers and fishing vessels of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the relative calm of the estuary. The areas that are at highest risk from microbiological pollution therefore include the mooring areas for larger private vessels (primarily West Kirby) and the main navigation routes through the estuary. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Appendix V
Sources and Variation of Microbiological Pollution: Wildlife

The Dee estuary features large areas of intertidal sand, mud flats and saltmarsh habitat which support internationally important populations of migrant and overwintering wildfowl and waders. As a consequence has been designated as a Site of Special Scientific Interest, Ramsar Site, a Special Protection Area and a Special Area of Conservation. An average total count of 110,730 waterbirds (wildfowl and waders) was reported over five winters up to 2010/11 for the Dee Estuary, (Holt *et al*, 2012). Outside of this period, the Dee Estuary is also used as a staging area for migratory waterbirds on autumn and spring passages (English Nature & CCW, 2010) so there will be briefer influxes of migratory waterbirds in the spring and autumn. Waders such as oystercatchers feed on intertidal invertebrates so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this will probably vary from year to year. Other species such as grazing ducks and geese, plovers and lapwings will use the saltmarsh areas, most of which are in the upper reaches of the estuary on the English side. Their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000).

The majority of migratory waterbirds breed elsewhere, but other seabird species such as gulls and terns are present during the summer months. The main concentration of breeding seabirds is at the Shotton Steel works, which lies on the English side of the lower reaches of the canalised section. Here 150 pairs of gulls and 490 pairs of terns were recorded during a survey of breeding seabirds in 2000 (Mitchell *et al*, 2004). Seabirds are likely to forage widely throughout the area, therefore faecal inputs could be considered as diffuse, and there are no major colonies in the immediate vicinity of the fisheries. Therefore during the summer months there are likely to be considerably lower impacts from birds.

There is a population of grey seals which haul out on the east side of the West Hoyle sand bank, just to the west to the Hilbre islands, about 2 km off the east shore of the outer estuary (Cheshire Region Biodiversity Partnership, 2010). They use this site to haul out, feed and moult, but not to breed, so breeding adults will leave the area during the autumn. During the summer, numbers can exceed 500, but drop to about 50 during the autumn. In spatial terms, contamination is likely to be heaviest in the immediate vicinity of their haulout site, which is at least 1km from the nearest cockle bed. On a wider scale they are likely to forage throughout the estuary and Liverpool Bay, and so potentially represent a diffuse source of pollution to the shellfish beds. Given the large area they are likely to forage over impacts are likely to be minor, and unpredictable in spatial terms, but will peak during the summer, and be at its lowest during the autumn.

Otters are present in the Dee estuary (Natural England, 2002) and although no information on exact numbers is available the population is likely to be very small. Given their likely wide distribution and small numbers they have no material bearing on the sampling plan. No other wildlife species which have a potentially significant influence on levels of contamination within shellfish on the Dee estuary have been identified. Dog walking takes place along coastal paths that run adjacent to the shoreline of the estuary this could represent a potential source of diffuse contamination to the near shore zone.

APPENDIX VI
METEOROLOGICAL DATA: RAINFALL

The Chester weather station, which is located near to the tidal limit of the estuary, received an average of 690mm per year between 2000 and 2012. Further inland and at higher elevations annual rainfall is much higher, for example Snowdonia receives annual totals exceeding 3000mm (Met Office, 2012). Figure II.1 presents a boxplot of daily rainfall records by month at Chester.

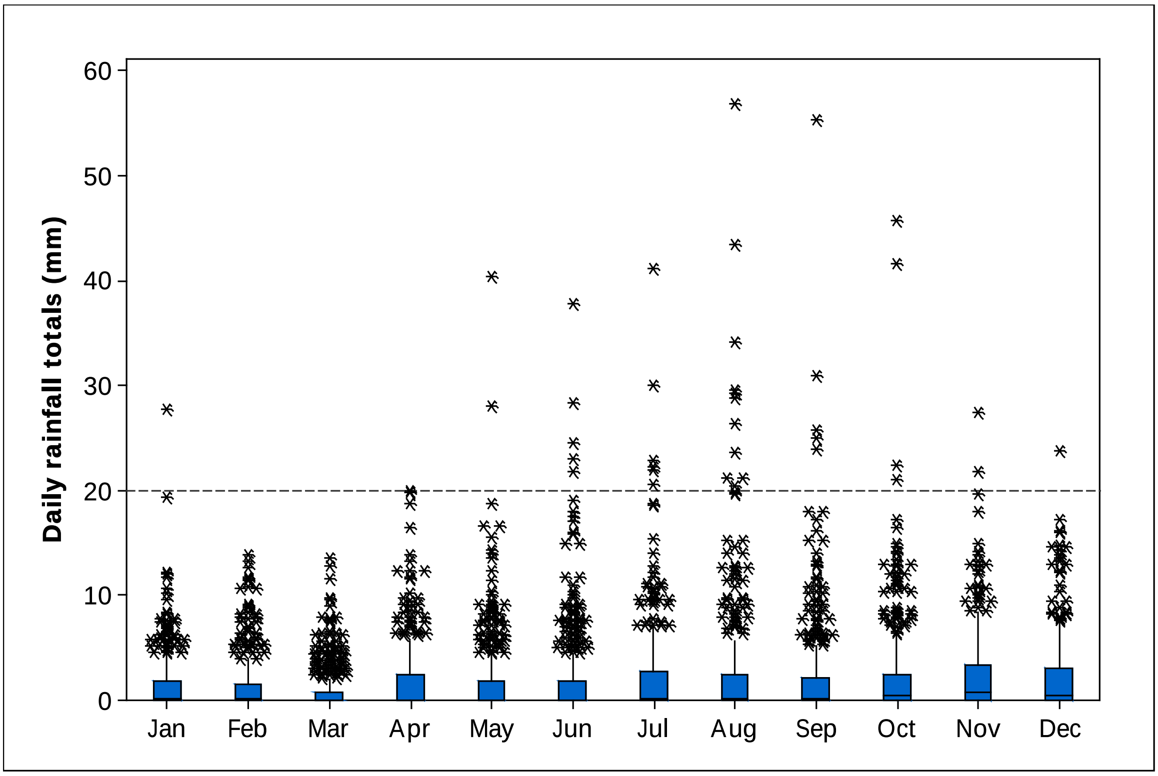

Figure II.1 Boxplot of daily rainfall totals at Chester, January 2000 to October 2012.
Data from the Environment Agency

Rainfall records from Chester, which is representative of conditions in the vicinity of the shellfish beds indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average from January to March and highest on average in from August to November. Daily totals of over 20mm were recorded on 0.8% of days and 45% of days were dry. High rainfall events, whilst relatively rare, tended to occur most during the summer and autumn.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). Representative monitoring points located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices X and XI.

APPENDIX VII
METEOROLOGICAL DATA: WIND

The Northwest of England is one of the most exposed parts of the UK. The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from December to February, and this is when mean speeds and gusts are strongest (Met Office, 2012).

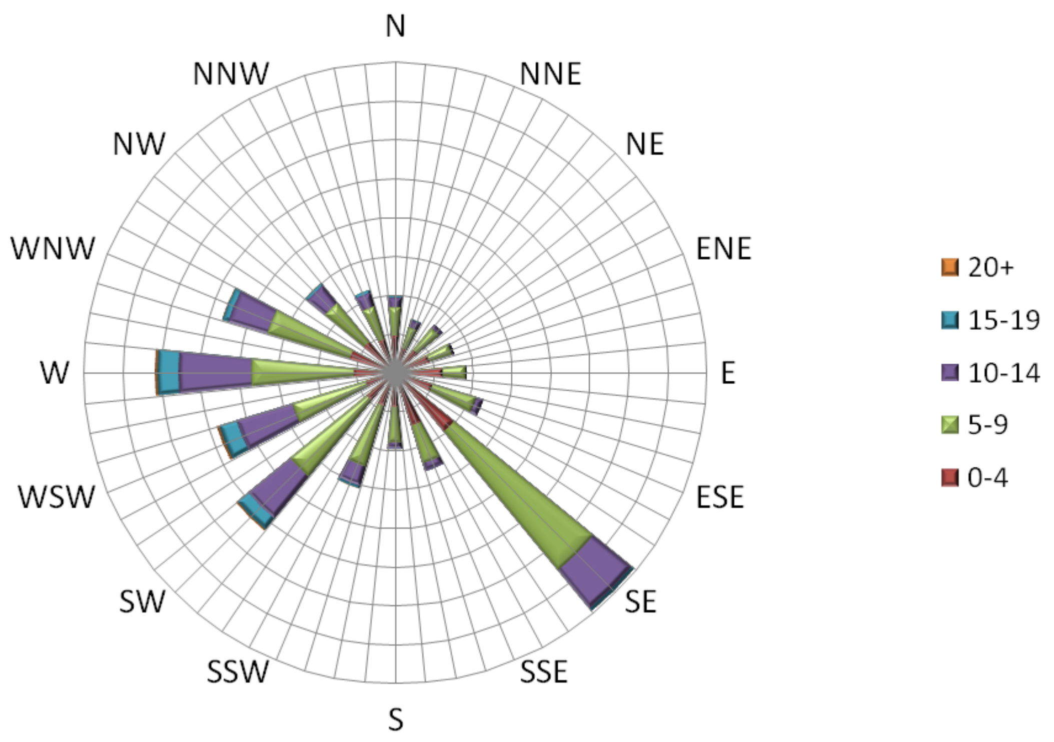

Figure VI.1 Wind speed and direction at Hilbre Island for the period 2005-2009.
Data provided by the Proudman Oceanographic Laboratory Coastal Observatory Project.

There is a prevailing south to south-westerly wind direction through the year, but a high frequency of north to north-east winds in spring (Met Office, 2012). Figure VI.1 reveals that the prevailing wind direction is from the west, at Hilbre Island, situated in the mouth of the Dee estuary, there is also a high occurrence of light winds from the south east. It is uncertain how this effect arises but it may be a consequence of the instruments location in relation to topographic features. The Dee estuary has a faces the open Irish Sea to the north west, so it is most exposed to winds from this direction.

APPENDIX VIII
HYDROMETRIC DATA: FRESHWATER INPUTS

The main input to the Dee estuary is the river Dee, a major spate river whose catchment accounts for around 93% of the total 2130 km² catchment area. The river Dee's source is at Dduallt in Snowdonia and it runs approximately 110 km before discharging into Liverpool Bay. The Dee is canalised from its tidal limit at Chester Weir to the main body of the estuary. Much of the catchment is rural, with sheep grazing predominating in its upper reaches and intensive dairy farming in its lower reaches. Six percent of the catchment is urban including Wrexham, Chester and Deeside.

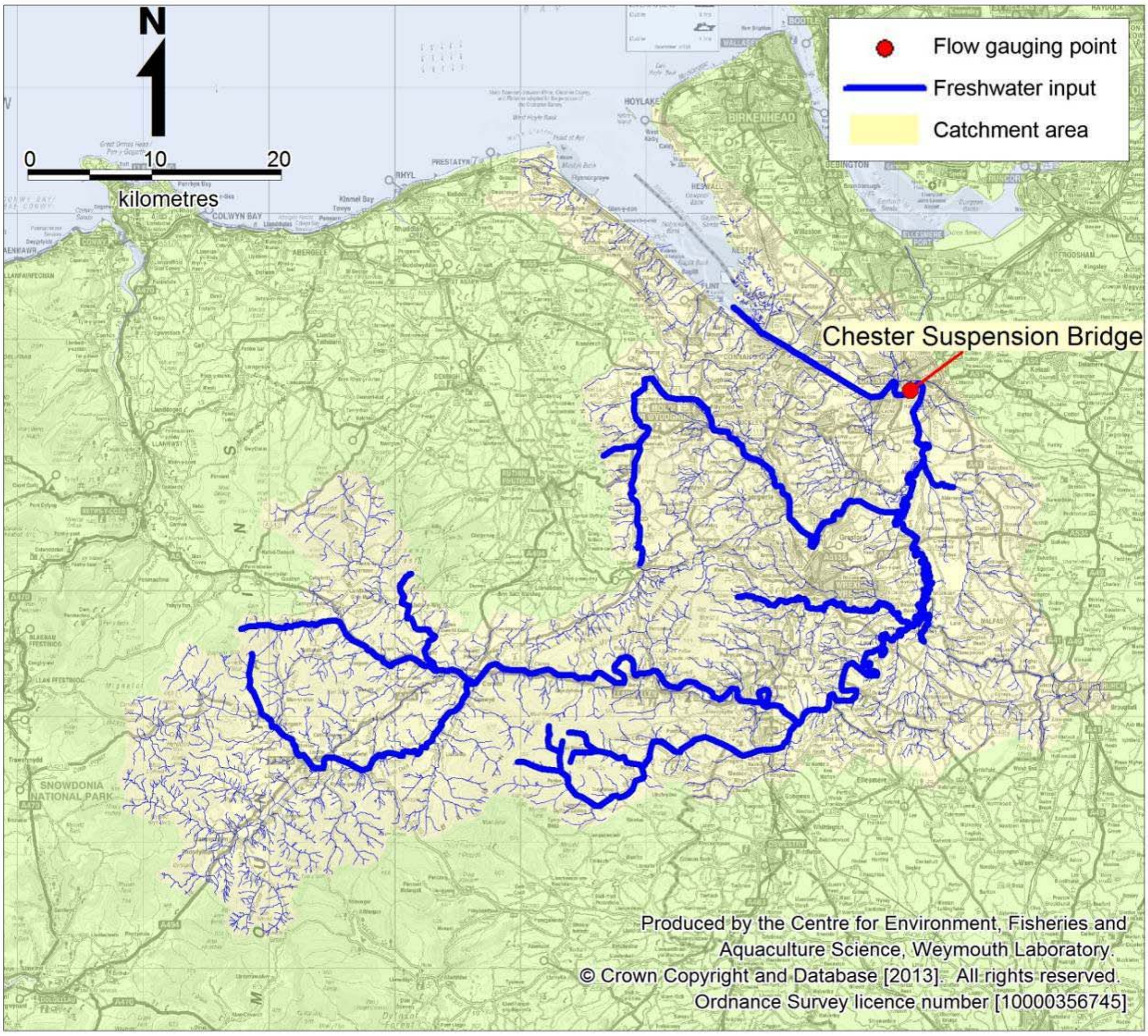

Figure VIII.1: Watercourses within the survey catchment area

Given that the vast majority of freshwater enters the upper reaches of the estuary, upstream of the shellfisheries, a gradient of decreasing levels of contamination towards the seaward ends of the shellfish beds is anticipated. The Dee will receive microbiological pollution from several point and diffuse sources such as STW discharges and urban and agricultural runoff. It is therefore potentially a significant source of microbiological contamination for the shellfisheries in the estuary. An

Environment Agency initiative collated and analysed the results of dye tracer studies in England (Guymer, 2002), and found that solute travel velocities in a selection of watercourses averaged about 24km d^{-1} and ranged from 1.7 to 91 km d^{-1}. Therefore hydraulic transit times from sources in the upper areas of larger catchments are likely to be several days, so bacteriological contamination originating from here is likely to suffer significant die off before reaching the estuary.

Summary statistics for the Chester Suspension Bride flow gauge are presented in Table VIII.1. Boxplots of mean daily flow records by month at the Chester Suspension bridge gauging station are presented in Figure VIII.2.

Table VIII.1: Summary flow statistics for Chester suspension bridge

Watercourse	Station name	Catchment area (km^2)	Mean annual rainfall 1961-90 (mm)	Mean flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Dee	Chester Suspension Bridge	1816.8	1111	33.3	5.1	87.9

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow). Data from NERC (2012).

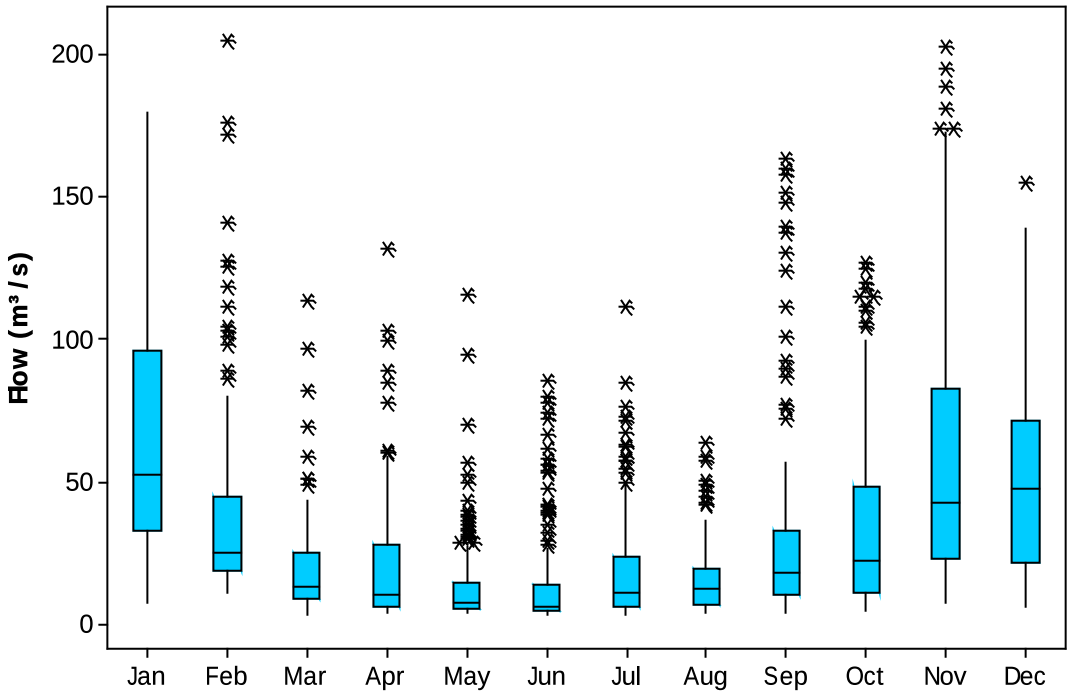

Figure 2: Boxplots of mean daily flow records from the Chester Suspension Bridge gauging station on the River Dee from 2008-2012 *Data from the Environment Agency*

The Dee is a large river with a mean flow of over $30m^3$/sec, and frequent high flow events exceeding $100m^3$/sec. Flows were highest in the colder months at Chester Suspension Bridge. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

As well as the main freshwater inputs to the head of the estuary, a series of much smaller watercourses drain to the shores of the estuary in the vicinity of the shellfish beds. These may cause localised hotspots of contamination where they enter the estuary and by any drainage channels they follow across the intertidal. All those that were flowing were sampled and measured during the shoreline surveys. Figure VIII.3 shows the results of these, as well as points of streams and pipes that were not sampled. Table VIII.2 shows the summary of the flow and loading data for these points.

Table VIII.2 Stream and pipe flows and E. coli loadings measured during the 2011 and 2012 shoreline surveys.

No.	Date & time	NGR	Daily discharge (m^3)	E. coli / 100 ml	Loading (E. coli / day)
1	24/08/2011 12:18	SJ 12879 83691	11,405	>20,000	$>2.28\times10^{12}$
2	24/08/2011 11:40	SJ 14151 82034	5,184	14,000	7.26×10^{11}
3	24/08/2011 11:17	SJ 15121 81234	238	8,700	2.07×10^{10}
4	24/08/2011 09:13	SJ 17679 79260	5,806	5,300	3.08×10^{11}
5	24/08/2011 10:02	SJ 19942 77954	1,728	4,100	7.08×10^{10}
6	23/08/2011 10:43	SJ 27716 78490	70	>20,000	$>1.40\times10^{10}$
7	23/08/2011 11:00	SJ 27544 78713	9	12,000	1.08×10^{9}
8	23/08/2011 11:06	SJ 27378 78903	Drain, not flowing		
9	23/08/2011 11:16	SJ 27120 79250	Dry stream		
10	23/08/2011 11:19	SJ 27026 79352	Dry stream		
11	23/08/2011 11:22	SJ 26904 79533	Drain, not flowing		
12	23/08/2011 12:00	SJ 25824 81043	Surface water outfall, not flowing		
13	23/08/2011 12:27	SJ 24942 81878	Surface water outfall, not flowing		
14	23/08/2011 12:48	SJ 24133 82621	7,776	525	4.08×10^{10}
15	23/08/2011 13:09	SJ 23615 83473	Dry stream		
16	23/08/2011 13:32	SJ 23013 83924	5	990	4.95×10^{7}
17	13/11/2012 09:16	SJ 22466 84537	Groundwater from golf course		
18	13/11/2012 09:32	SJ 22269 84796	127	Samples lost by lab	
19	13/11/2012 10:49	SJ 20642 87810	852	Samples lost by lab	

Most freshwater inputs to the lower estuary were relatively minor. The watercourses draining to the Welsh side were generally larger. Watercourse 1 was carrying the highest loading, and was sampled and measured downstream of where it receives the Llanasa STW effluent. Watercourses 2 and 4 are also likely to be of some significance. Watercourse 6 was a small ditch draining from Heswall which had some sewage odour at the time, perhaps suggesting some sewage inputs. Watercourse 14 was the tidal creek draining from Heswall, downstream of the Heswall STW outfall. Flows at the time were exclusively fresh water, mainly originating from the Heswall STW outfall. The creek was carrying relatively low concentrations of *E. coli* at the time.

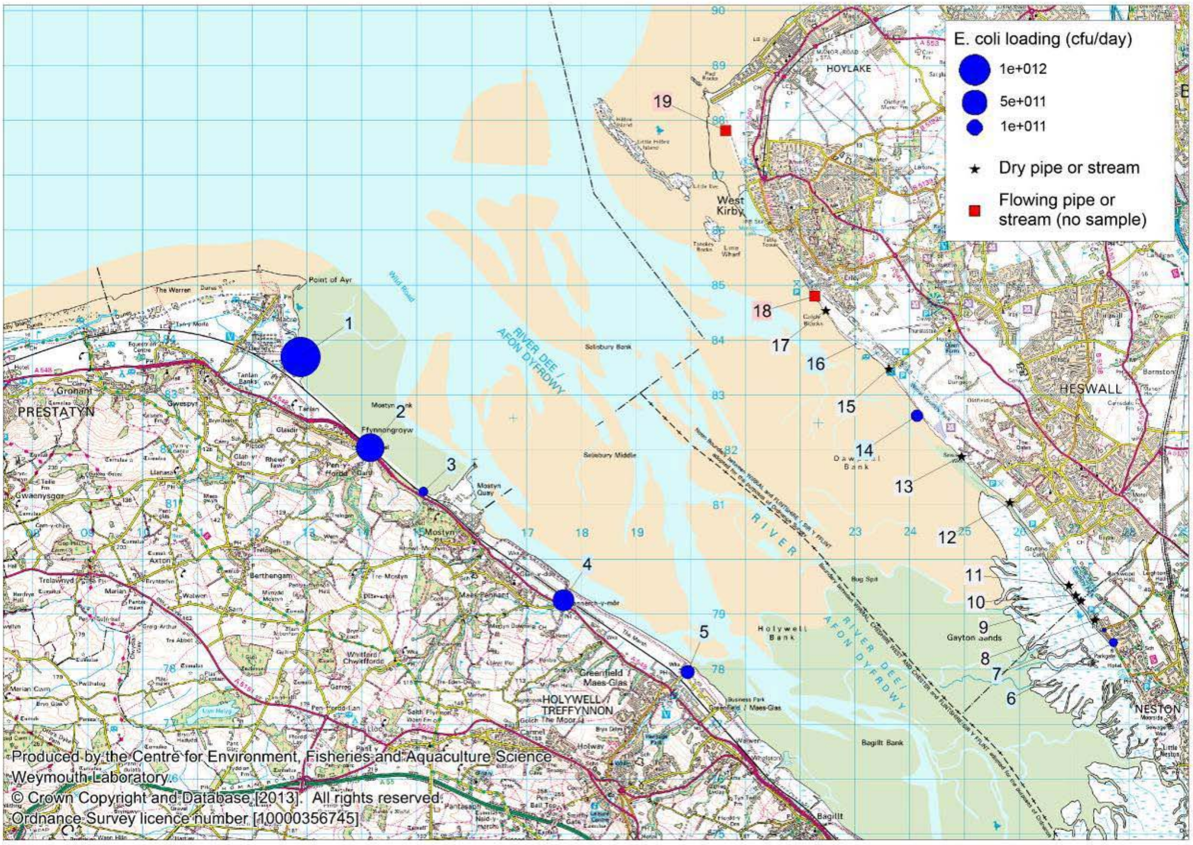

Figure VIII.3 Measured stream and pipe flows and* E. coli *loadings from shoreline surveys

APPENDIX IX
HYDROGRAPHY

BATHYMETRY

Source data for part of the admiralty chart presented in Figure IV.1 was mainly gathered in the 1980's and 1990's therefore the bathymetry may be slightly different now, however important features discussed below are unlikely to have significantly changed. Detailed bathymetric information is only provided for the outer reaches of the estuary however.

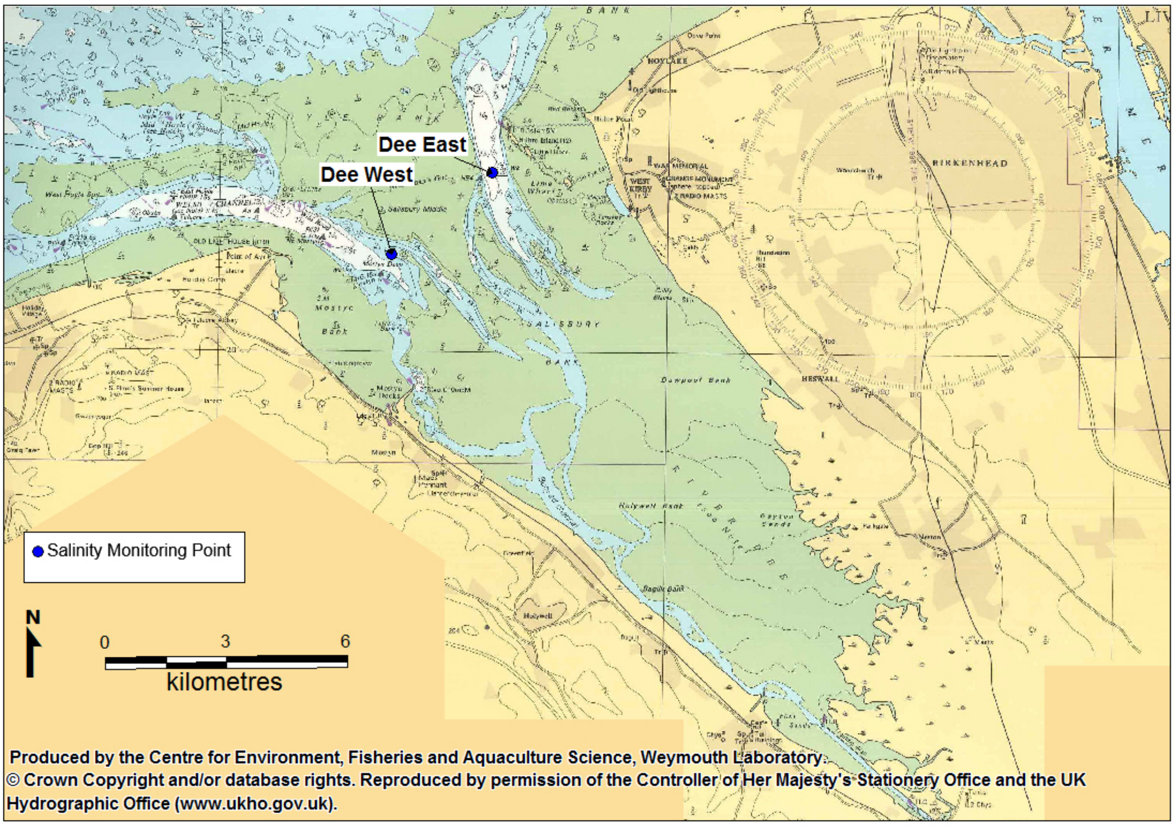

Figure IV.1 Bathymetry chart of the Dee

The Dee estuary is a single spit enclosed estuary (Futurecoast, 2002) approximately 30km in length (Moore et. al, 2009) and forms a well-developed ebb delta. It is relatively wide throughout increasing from approximately 4 km at Neston, to 8.5 km at its widest point, between Hilbre Point and Point of Ayr at its mouth. There is a hard sandstone outcrop (Hilbre Island) at the eastern edge of the mouth and on the western edge there is a small rounded spit at Point of Ayr.

In the outer estuary there are two main channels lying either side of the West Hoyle Bank (The Welsh Channel and the Hilbre Channel). These converge to form one channel in the middle of the estuary to the south of the Hoyle Bank, which then moves over to the Welsh side of the estuary and runs adjacent to the shore. A smaller secondary dredged channel diverges from the Welsh Channel and leads to Mostyn port. A number of smaller drainage channels cut across intertidal areas some of which carry freshwater inputs from minor watercourses. The deepest points are present within the mouth in the Hilbre channel (16.5m at CD) and Mostyn channel (21.4m at CD), likely to be a result of the scouring effect caused by high water flows in these channels.

The Dee estuary contains extensive areas of intertidal mud/sand flats and some saltmarsh, which cover a large proportion of its area. On an average tide, the volume of water increases by over 80% between mean low water and mean high water (Moore et. al, 2009). Consequently water exchange is high but dilution potential will be quite low away from the main channels. Much of the estuary's perimeter is protected by sea defences including revetments, sea walls, embankments and gabions. The extensive area of saltmarsh in the upper reaches of the English side of the estuary acts as a natural sea defence on (Halcrow Group, 2009). The very upper reaches were canalised in the 18th century from, Connahs Quay up to its tidal limit at Chester, to reclaim adjacent land and improve navigation to Chester. The canalised section is about 12km long, 100m in width, 2m or less in depth at low tide and approximately trapezoidal in cross-section (Simpson *et* al, 2004).

TIDES AND CURRENTS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The Irish Sea is open to both the north and south, with tides arriving almost simultaneously from these two directions, meeting around the Isle of Man and then flowing east into Liverpool Bay. Tidal streams then divert south at the mouth of the Dee and flow into the estuary. After high water the tide reverses to flow back out of the estuary and then west out of Liverpool Bay. Tidal amplitude is large, and tidal streams are likely to dominate patterns of water circulation in the area under most conditions.

Table IX.1 Tide levels and ranges within the Dee

	Height (m) above Chart Datum				**Range (m)**	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Hilbre Island	9.0	7.2	3.1	1.3	7.7	4.1
Mostyn Docks	8.5	-	6.7	-	-	-
Connah's Quay	4.7	-	3.0	-	-	-

Data from the Admiralty Total Tides

The tidal range at Hilbre Island is 7.7m on spring tides and 4.1m on neap tides (Table IX.1). At Connah's Quay the tidal range is significantly smaller, at 3.4m on spring tides and 1.7m on neap tides (Halcrow Group, 2009). The general pattern of tidal circulation within the estuary as a whole is bi-directional, with water moving up the estuary on the flood and back out on the ebb, with the main flows aligning with the main channels. On a flood tide the principal tidal streams flow in a south easterly direction into the Dee and follow the two main scoured channels up estuary where they converge south of the Salisbury Bank. They then flow upstream in a south easterly direction along the river channel adjacent to the Welsh shore. As the main channels fill the tidal streams move up intertidal channels and spread over the extensive intertidal sandflats. The reverse occurs on an ebb tide. In the canalised section tidal waters drain out completely, leaving the natural level of the river flowing into the estuary towards the end of the ebb tide.

Tides are asymmetrical within the estuary, with increasing flood dominance further upstream. At the mouth they are almost symmetrical, whereas in the canalised section the flood tide only lasts for about 2 hours with a prolonged ebb tide of about 10 hours (Simpson *et al*, 2004). There are no tidal diamonds within the Dee from which tidal stream information can be taken and used to make estimates of tidal excursion. Peak measured flood current velocities of around 0.8m/s and 0.5m/s have been reported in the Hilbre Channel and the Welsh Channel during spring tides (Bolanos and Souza, 2010). It is likely that current speeds are slower away from the main channels. In the canalised section flood currents reach up to 1.2 m/s but do not exceed 0.5m/s on the much more prolonged ebb (Simpson *et al*, 2004).

In addition to tidally driven currents are the effects of freshwater inputs and wind. The flow ratio (freshwater input:tidal exchange) is low and the system is predominantly well mixed. This would suggest that density driven circulation is of little importance within the outer estuary. Salinity measurements taken between 2008 and 2012 at two points within the mouth of the estuary (locations are shown in Figure IX.1) indicate average salinities approaching that of full strength seawater although occasionally lower salinities were recorded (Figure IX.2). There is likely to be a horizontal gradient of decreasing salinity in the upper reaches of the estuary, particularly in the canalised section. Decreasing salinity is likely to be associated with increasing levels of runoff related contamination.

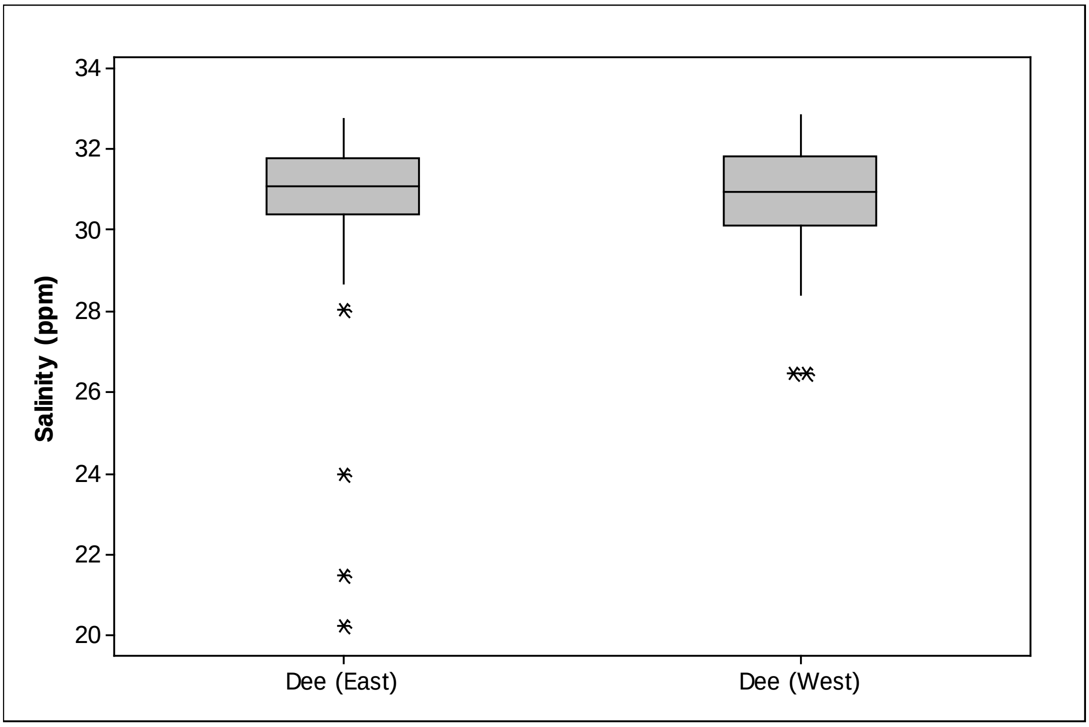

Figure IX.2. Box-and-whisker plots of levels of salinity readings taken between May and September (for the period 2008 – 2012) *Data from the Environment Agency.*

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These currents in turn drive return currents which may travel lower in the water column or along sheltered margins. The prevailing south-westerly winds will tend to push surface water in a north-easterly direction, although the surrounding land will afford some shelter from these winds. Exact effects are dependent on the wind speed and direction well as state of the tide and other environmental variables so a great range of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be re-suspended. Given the topography and prevailing wind direction the English shore of the outer estuary is likely to be most vulnerable to such effects.

APPENDIX X
MICROBIOLOGICAL DATA: SEAWATER

BATHING WATERS

Due to changes in the analyses of bathing water quality by the Environment Agency from 2012, only data produced up to the end of 2011 was used in these analyses. Additionally, as a result of the major upgrades to the Dee sewerage scheme between 2003 and 2006, only results from 2006 onwards were considered. There are 2 bathing waters within the survey area (Council of the European Communities, 1975).

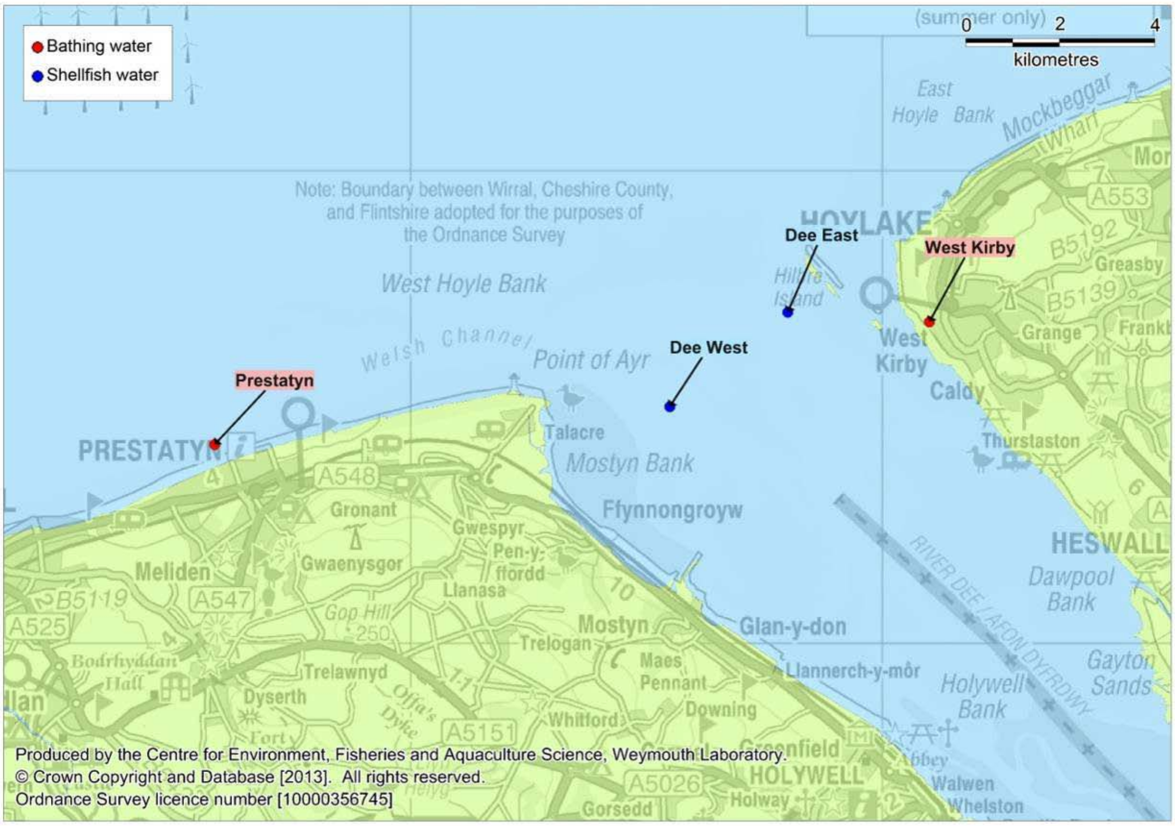

Figure X.1 Location of designated bathing waters monitoring points at the Dee estuary.

Twenty water samples were taken from each of the bathing waters sites during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples. Summary statistics of all results from 2006 to 2011 by bathing water are presented in Table X.1 and Figure X.2 presents box plots of these data.

Table X.1 Summary statistics for bathing waters faecal coliforms results, 2002-2011 (cfu/100ml).

Site	N	Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Prestatyn	120	26.3	<2	1680	13.3	1.7
West Kirby	120	15.7	<2	4231	18.3	1.7

Data from the Environment Agency

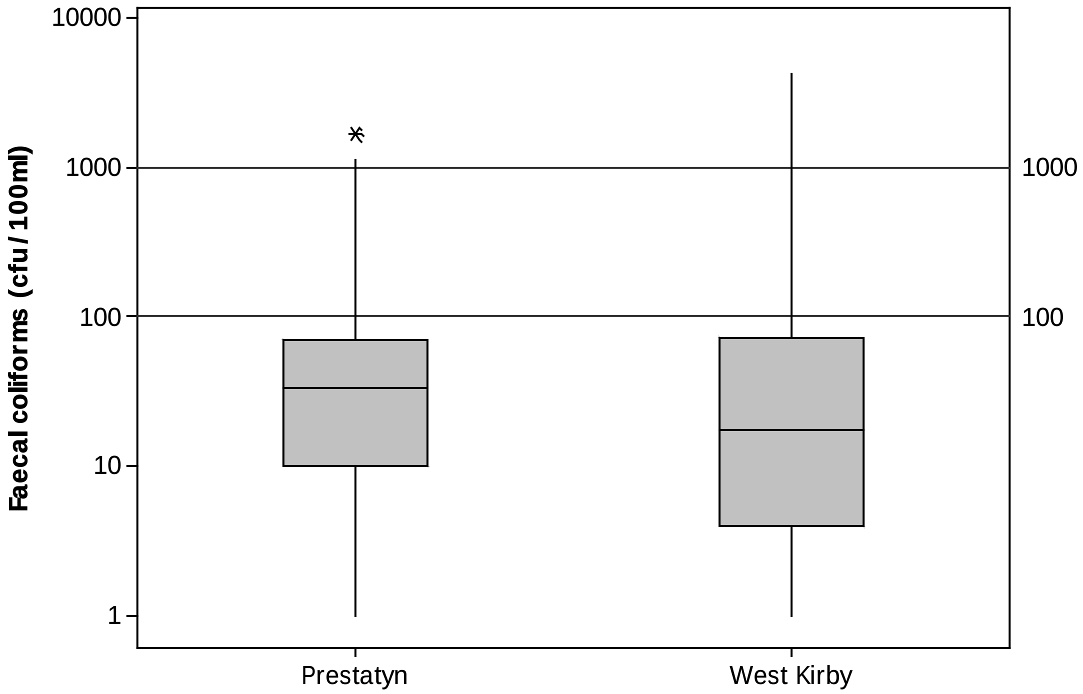

Figure X.2 Boxplots of all faecal coliforms results by site (2006-2011)
Data from the Environment Agency

Levels of contamination were similar for both sites at the Dee estuary. However, comparisons showed that Prestatyn had significantly higher levels of contamination than West Kirby (2 sample T-test, p=0.025). This indicates contamination is slightly greater either outside the estuary or nearer the western shore. Figure X.3 presents box plots of all results from both sites by year from 2006 to 2011.

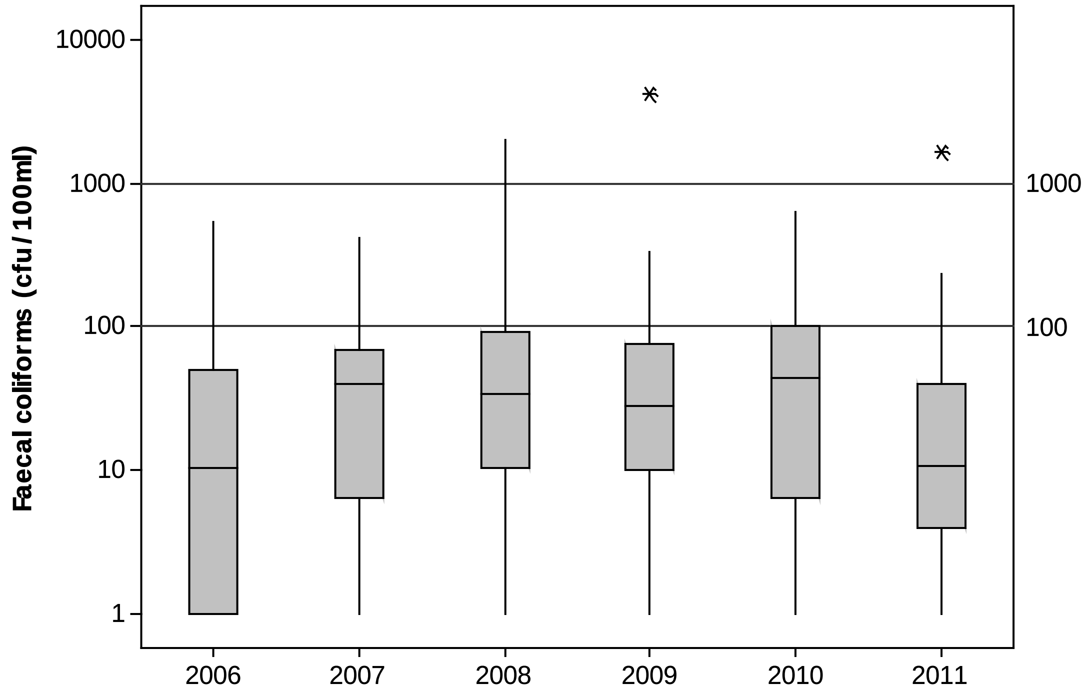

Figure X.3 Box-and-whisker plots of all faecal coliforms results (2006-2011)
Data from the Environment Agency

Comparisons of these results indicated that there was a significant difference in faecal coliforms between years (1-way ANOVA, p=0.006). Posthoc Tukey tests showed that only 2006 and 2008 had significant differences in the level of faecal coliform contamination, while all other years had no significant differences.

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of the bathing waters sampling points. Correlation coefficients are presented in Table X.2, with statistically significant correlations highlighted in yellow.

Table X.2 Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

		high/low		spring/neap	
Site	n	r	p	r	p
Prestayn	120	0.059	0.661	0.087	0.415
West Kirby	120	0.112	0.230	0.310	<0.001

Data from the Environment Agency

Figure X.4 presents a polar plot of $\log_{10}$ faecal coliform results against the lunar spring/neap cycle for West Kirby. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

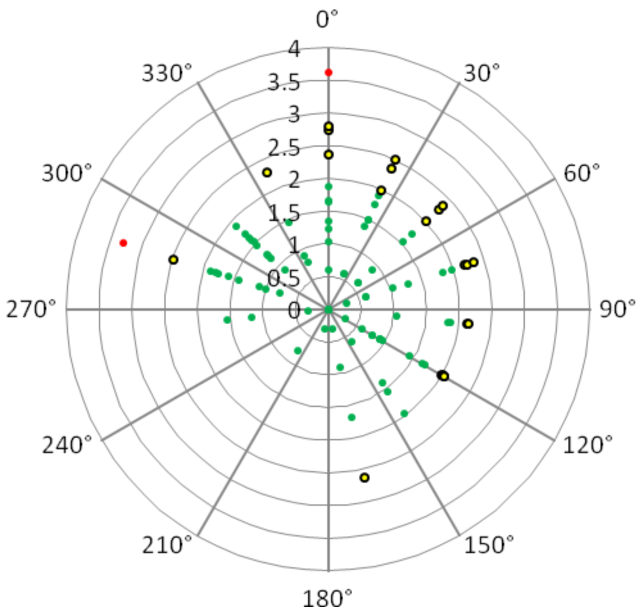

Figure X.4. Polar plot of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for West Kirby bathing waters monitoring point
Data from the Environment Agency

The numbers of faecal coliforms at the West Kirby bathing waters monitoring point are lower on average during neap tides.

To investigate the effects of rainfall on levels of contamination at the bathing waters sites Spearman's rank correlations were carried out between rainfall recorded at the Chester weather station (Appendix II for details) over various periods from 2003 until 2012 running up to sample collection and faecal coliforms results. These are presented in Table X.4 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.4 Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

		Prestatyn	West Kirby
	No.	120	120
24 hour periods prior to sampling	1 day	0.273	0.228
	2 days	0.286	0.229
	3 days	0.440	0.110
	4 days	0.303	0.118
	5 days	0.265	0.072
	6 days	0.120	0.223
	7 days	0.179	0.157
Total prior to sampling over	2 days	0.291	0.267
	3 days	0.446	0.180
	4 days	0.407	0.168
	5 days	0.420	0.151
	6 days	0.411	0.166
	7 days	0.405	0.179

Data from the Environment Agency

Table X.4 suggests a higher influence of rainfall at Prestatyn compared to West Kirby, although the reasons for this are unclear.

SHELLFISH WATERS

Figure X.1 shows the location of the Dee Estuary shellfish water monitoring points, designated under Directive 2006/113/EC (European Communities, 2006). Table X.5 presents summary statistics for bacteriological monitoring results from these points. Only water sampling results are presented as flesh results from the shellfish hygiene monitoring programme are used to assess compliance with bacteriological standards in shellfish flesh.

Table X.5 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2006-2012.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Dee west	27	7.2	<2	231	7.4%	0%
Dee east	36	4.1	0	672	8.3%	0%

Data from the Environment Agency

No significant difference was found between the two shellfish water sites (2 sample t-test, p=0.260). Figure X.5 indicates that there is some seasonality in levels of contamination in the Dee Estuary, with highest results in the winter. Statistically significant differences were found between seasons at both sites (One-way ANOVA, p=0.002 & 0.004 at Dee West and Dee East respectively). Post ANOVA tests (Tukey) showed that winter faecal coliform levels were significantly greater than in all other seasons at Dee West, and winter faecal coliform levels were significantly greater than in the spring and summer at Dee East.

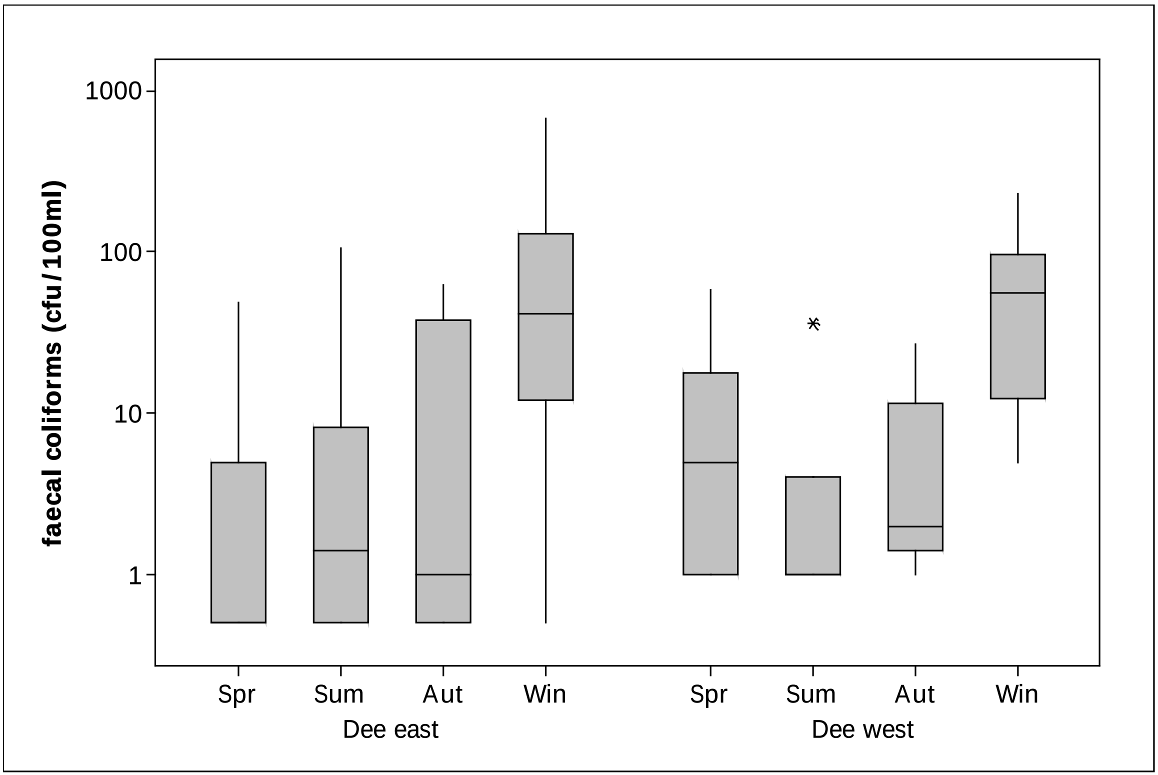

Figure X.5 Boxplot of shellfish growing waters faecal coliforms results by season
Data from the Environment Agency

No significant correlations were found between the levels of faecal coliforms and the tidal state on the spring neap cycle (p=0.632 and 0.526 at Dee West and Dee East respectively). Significant correlations were found between levels of faecal coliforms concentrations and tidal state on the high/low cycle at both (p<0.001 in both cases).

Figure X.6 presents polar plots of $\log_{10}$ faecal coliforms against tidal state, where high water is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, and those from 101 to 1000 are plotted in yellow.

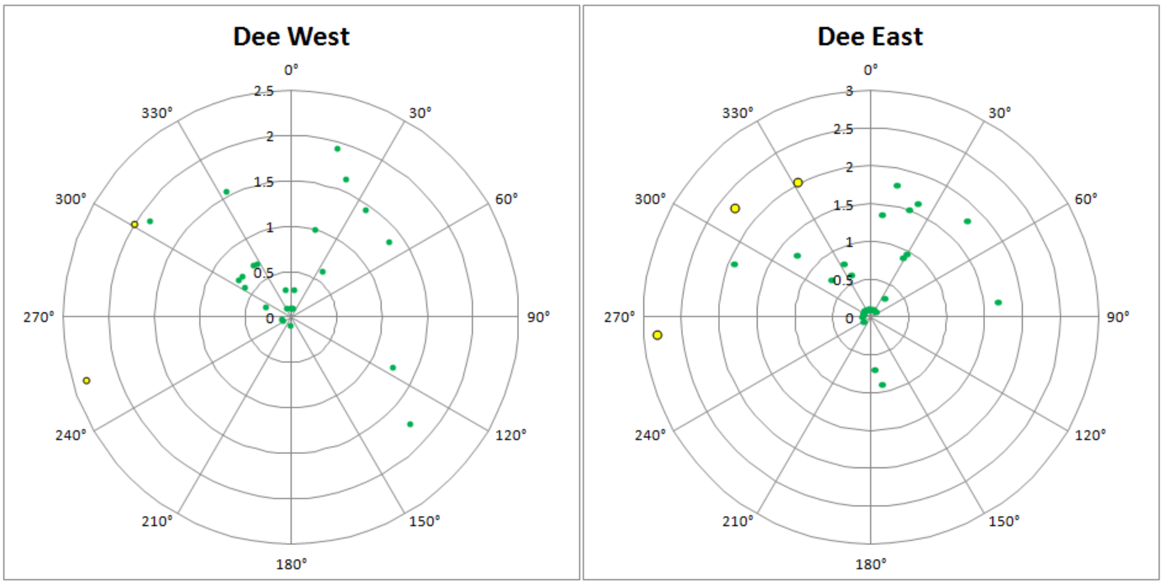

Figure X.6 Polar plots of $\log_{10}$* E. coli *result against tidal state (high/low cycle)
Data from the Environment Agency

In both cases the highest individual results occurred during the flood tide, but there were fewer low results whilst the tide was ebbing. Figure X.7 presents scatterplots of faecal coliform concentrations against salinity.

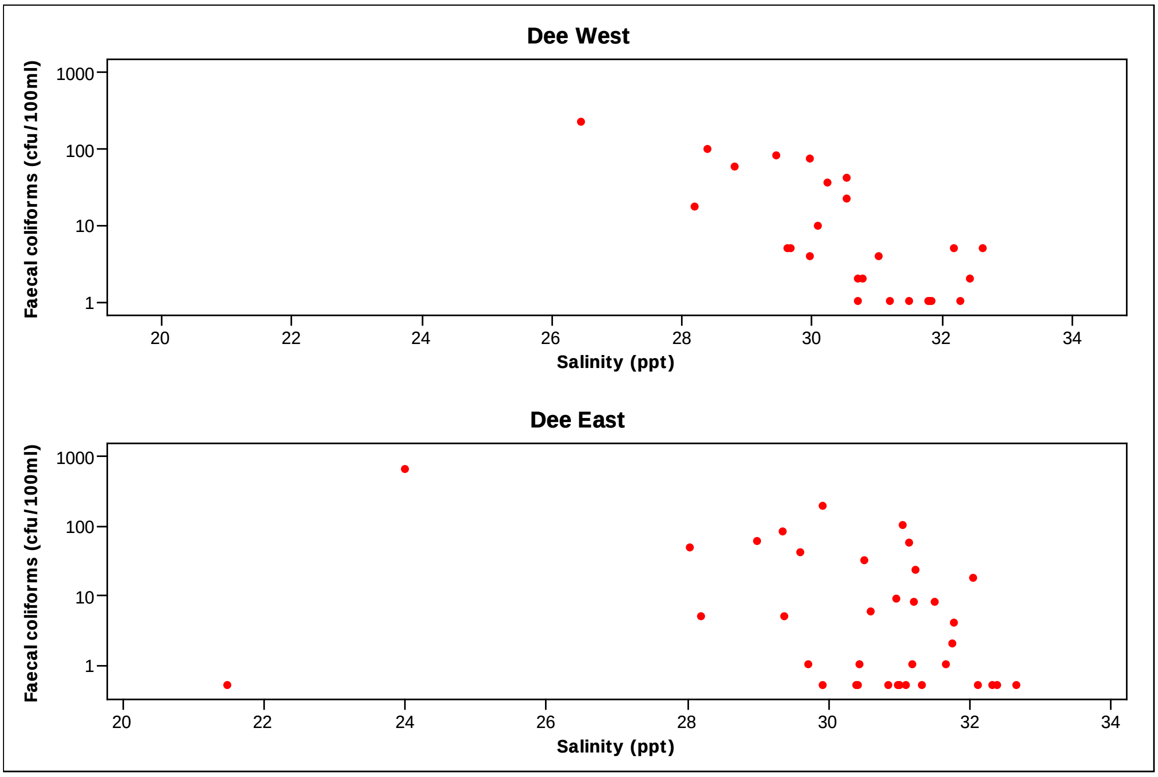

Figure X.7 Scatterplots of faecal coliforms concentrations against salinity.
Data from the Environment Agency

Both scatterplots suggest that higher results are associated with lower salinities. For Dee West a significant correlation was found (Pearsons correlation, r=-0.757, p=0.000) but there was no significant correlation for Dee East (r=-0.281, p=0.097).

To investigate the effects of rainfall on levels of contamination at the bathing waters sites Spearman's rank correlations were carried out between rainfall recorded at the weather station over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.6 where statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.6 Spearmans Rank correlation coefficients for faecal coliform results against recent rainfall

	Site	Dee West	Dee East
	n	27	35
24 hour periods prior to sampling	1 day	0.241	0.240
	2 days	0.307	0.228
	3 days	0.180	0.322
	4 days	0.420	0.113
	5 days	0.478	0.218
	6 days	0.529	0.439
	7 days	0.324	0.254
Total prior to sampling over	2 days	0.253	0.237
	3 days	0.238	0.296
	4 days	0.339	0.206
	5 days	0.429	0.309
	6 days	0.493	0.401
	7 days	0.578	0.457

Data from the Environment Agency

Both sites were influenced by rainfall to a similar degree. The strongest correlations were associated with rainfall 6 days prior to sampling in both cases, which is more consistent with an influence from the main river rather than local streams.

APPENDIX XI
MICROBIOLOGICAL DATA: SHELLFISH FLESH

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites sampled on 10 or more occasions Figure XI.2.

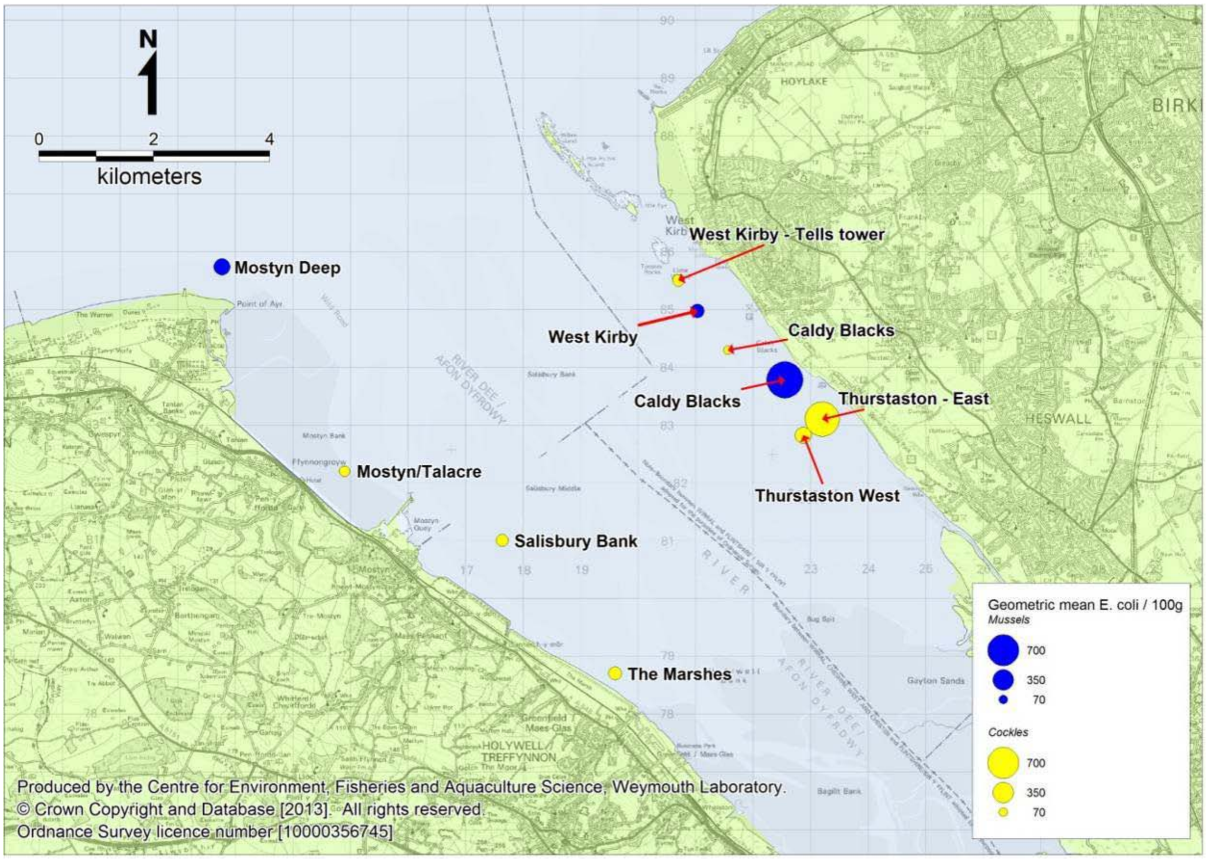

Figure XI.1 RMPs active since 2003

Table XI.1 Summary statistics of* E. coli *results (MPN/100g) from cockle, mussel, native oyster and pacific oyster RMPs sampled from 2003 onwards

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
The Marshes	Cockles	17	31/05/2011	17/09/2012	147.2	<20	940	35.3	0.0
Salisbury Bank	Cockles	83	18/01/2006	18/09/2012	133.8	<20	9,100	36.1	1.2
Mostyn/Talacre	Cockles	83	18/01/2006	18/09/2012	108.2	<20	5,400	28.9	2.4
Thurstaston West	Cockles	48	09/06/2008	19/09/2012	220.3	<20	35,000	37.5	4.2
Thurstaston - East	Cockles	21	21/02/2006	30/09/2008	851.6	50	92,000	76.2	14.3
Caldy Blacks	Cockles	8	30/06/2011	12/04/2012	79.2	20	230	0.0	0.0
West Kirby - Tells tower	Cockles	73	21/02/2006	19/09/2012	140.6	<20	13,000	37.0	1.4
Caldy Blacks	Mussels	66	21/03/2006	19/09/2012	922.3	<20	160,000	75.8	24.2
West Kirby	Mussels	10	18/10/2011	19/09/2012	178.3	<20	2,200	40.0	0.0
Mostyn Deep	Mussels	15	06/07/2011	17/09/2012	238.7	50	1,300	46.7	0.0

Of these RMPs, one was sampled on less than 10 occasions so will not be considered in detail in the following analyses (Caldy Blacks, cockles).

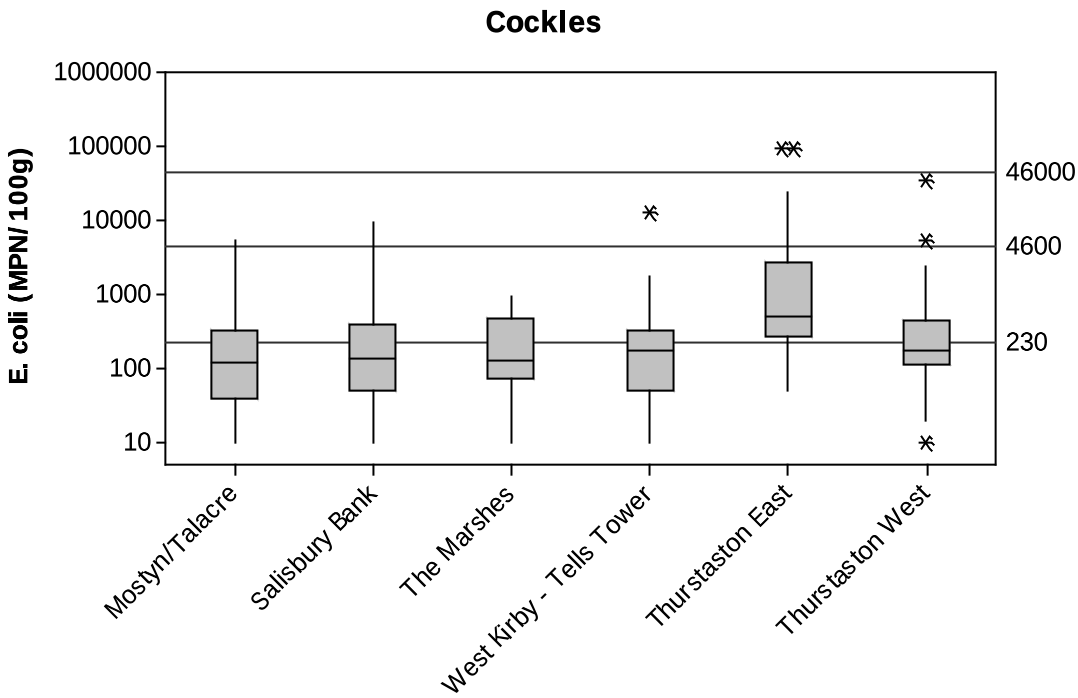

Figure XI.2 Boxplots of **E. coli** ***results from cockle RMPs sampled on 10 or more occasions from 2006 onwards.***

Across the six cockle RMPs, the levels of *E. coli* were fairly consistent, with all but one site (The Marshes) exceeding 4600 *E. coli* MPN/100g on at least one occasion. Comparisons of the results show that there was a significant difference between RMPs (One-way ANOVA, p<0.001). Posthoc tests (Tukeys comparison) show that Thurstaston East has significantly higher levels of *E. coli* in cockles than at all other sites.

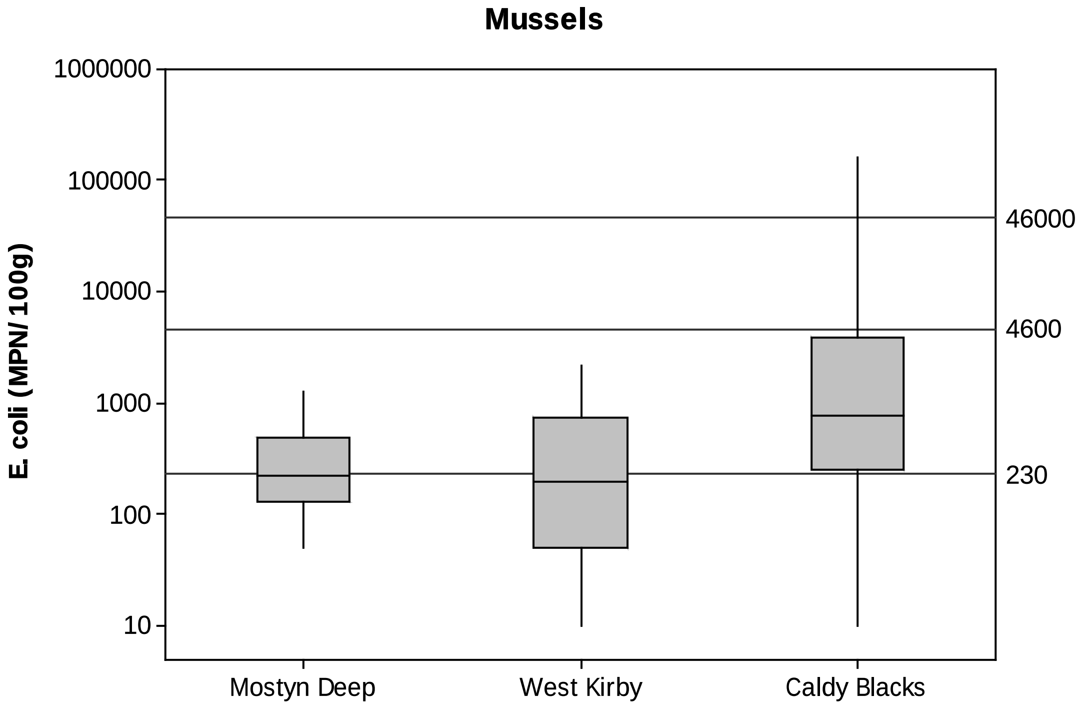

Figure XI.3 Boxplots of* E. coli *results from mussel RMPs sampled on 10 or more occasions from 2006 onwards.

Of the three mussel RMPs, the level of *E. coli* only exceeded 4,600 MPN/100g at Caldy Blacks. Comparisons of the three sites showed significant variation between sites (1-way ANOVA, p=0.005. Post ANOVA tests (Tukey) showed that Caldy Blacks had significantly higher levels of contamination than Mostyn Deep and West Kirby.

More robust comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates and therefore environmental conditions. Mostyn/Talacre and Salisbury Bank shared 83 sampling dates and did not have a significant correlation (p=0.564) despite their relatively close proximity. Thurstaston West and West Kirby – Tells Tower shared 41 sampling dates and also did not correlate significantly (p=0.560). A lack of significant correlations between sites suggest that the site compared are under different contaminating influences. It was not possible to undertake meaningful paired comparisons between any mussel RMPs as fewer than 20 same day samples were taken for each of these pairings.

OVERALL TEMPORAL PATTERN IN RESULTS

The overall variation in levels of *E. coli* found in bivalves is shown in Figures XI.4 and XI.5. Only RMPs with data for more than two years were included.

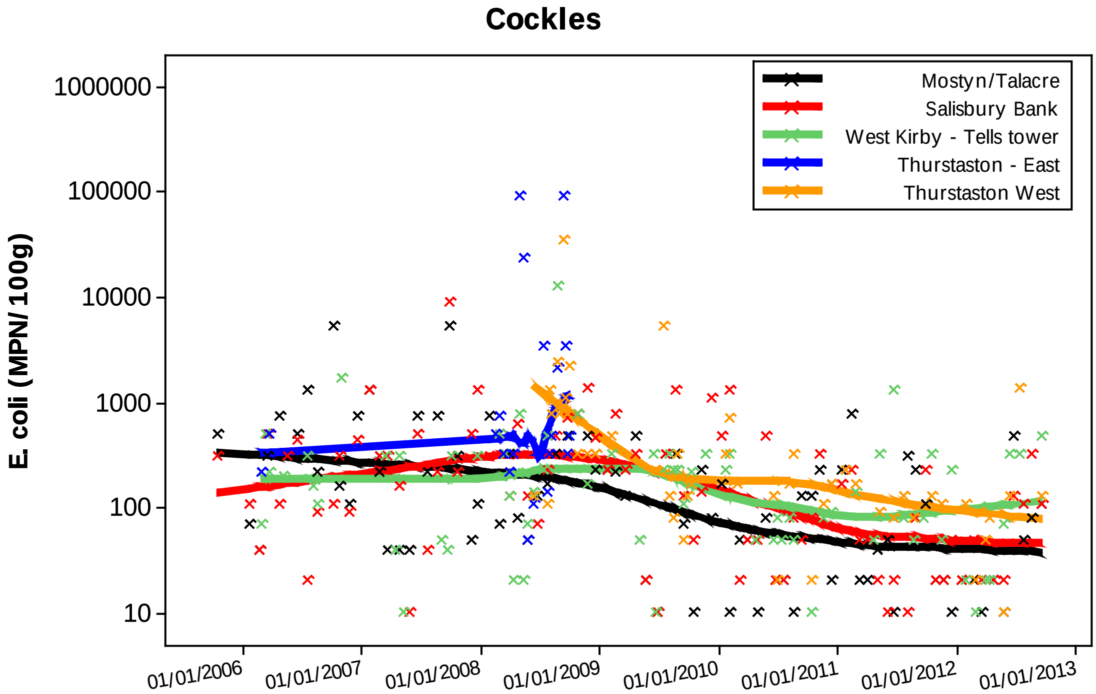

Figure XI.4 Scatterplot of **E. coli** ***results for cockles by RMP and date, overlaid with loess lines for each RMP***

Figure XI.4 shows that the level of *E. coli* found in cockles has varied only slightly in most RMPs over the sampling period. Thurstaston West appeared to have the reduction in *E. coli* numbers between the start of sampling in 2008 and 2009, after which only a gradual decrease in *E. coli* numbers was seen.

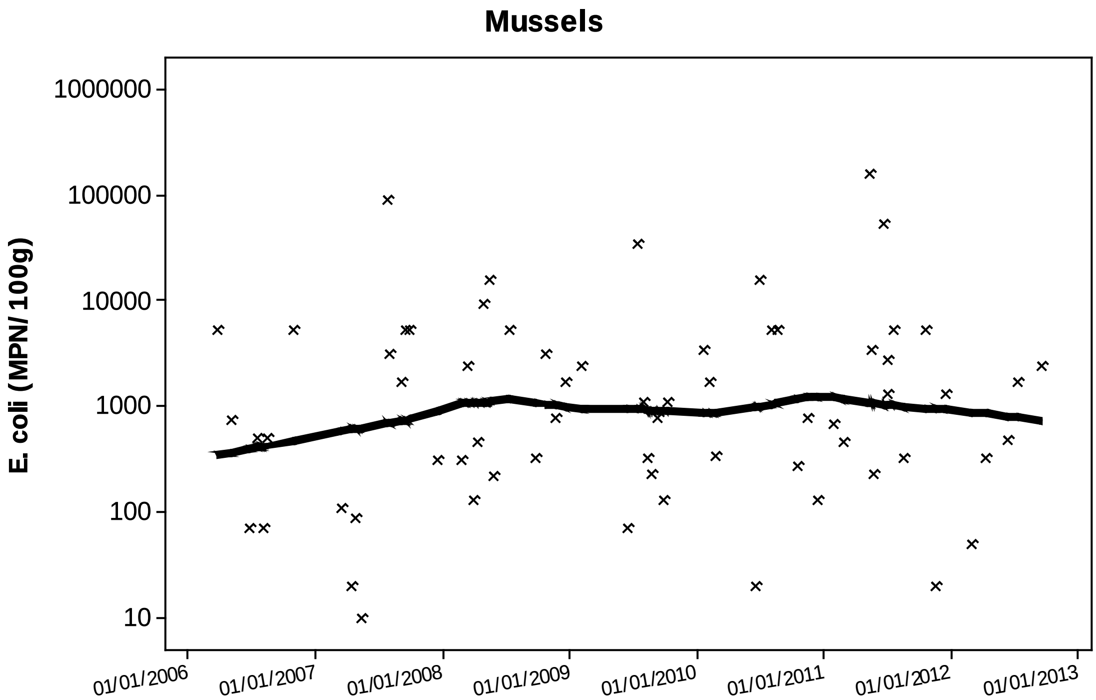

Figure XI.5 Scatterplot of **E. coli** ***results for mussels at Caldy Blacks, overlaid with loess lines.***

Figure XI.5 shows that over the years that mussels have been sampled at Caldy Blacks, the level of *E. coli* found have remained fairly consistent.

SEASONAL PATTERNS OF RESULTS

The seasonal patterns of results from 2006 onwards were investigated for all RMPs where at least 30 samples had been taken.

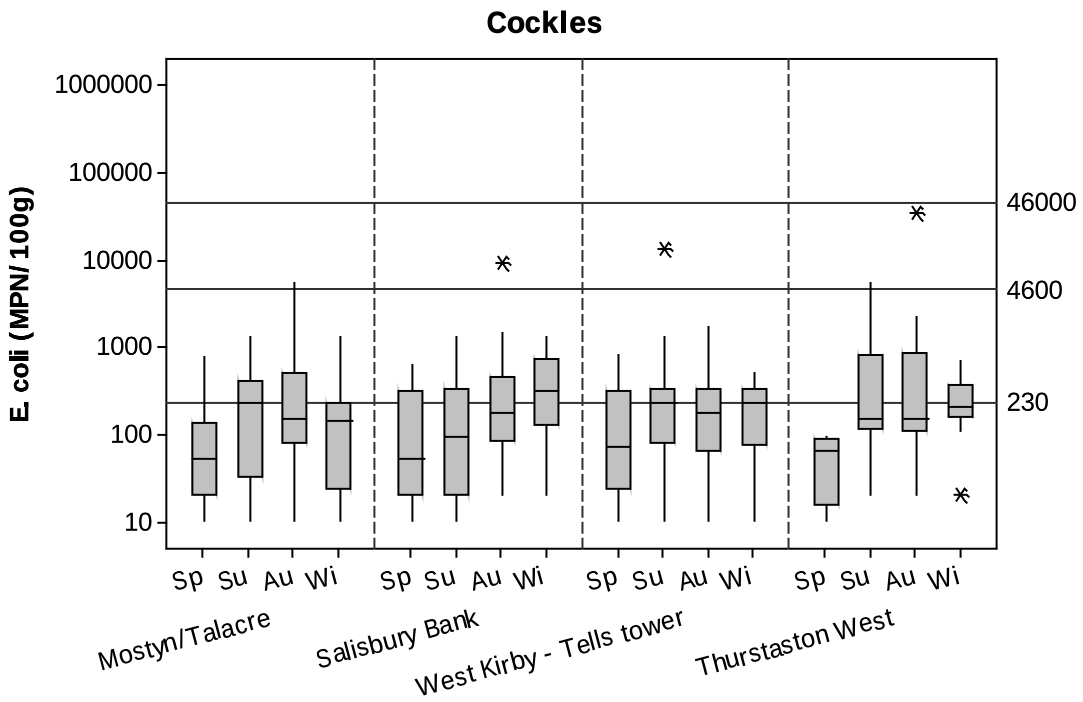

Figure XI.6 Boxplot of cockle* E. coli *results by RMP and season

There was significant seasonal variation at Salisbury Bank (1-way ANOVA, p=0.010) but not at any other site. Post ANOVA tests (Tukeys) showed that at Salisbury Bank *E. coli* numbers were higher in winter than in the spring. The plots also suggest a broadly similar seasonality at Salisbury Bank, West Kirby and Thurstaston West with higher results in the winter. Mostyn Talacre appears to have a slightly different seasonal pattern where results tend to be higher on average during the summer and autumn.

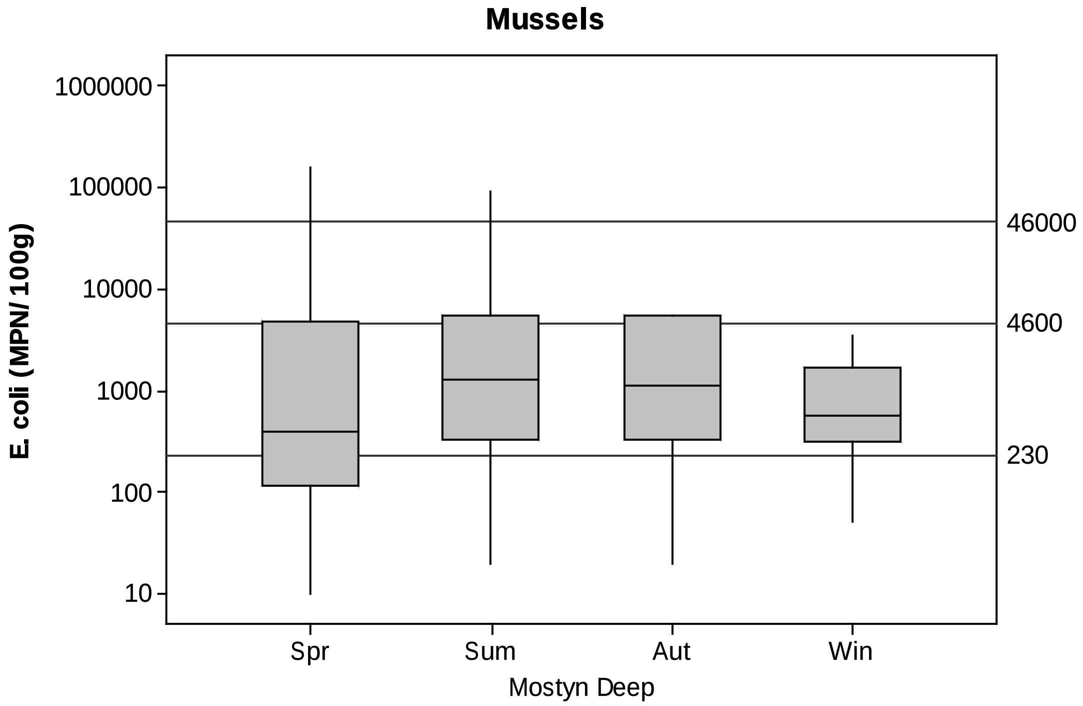

Figure XI.7 Boxplot of mussel* E. coli *results by RMP and season

Only Caldy Blacks had more than 30 samples for mussels, and so was the only RMP analysed for seasonal variation. No significant variation was found at in *E. coli* levels between seasons (1-way ANOVA p=0.321).

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the spring/neap tidal cycle for each RMP where at least 30 samples had been taken since 2006. Results of these correlations are summarised in table XI.2, and significant results are highlighted in yellow.

Table XI.2 Circular linear correlation coefficients (r) and associated p values for* E. coli *results against the high/low and spring/neap tidal cycles

			High low		Spring neap	
Site	**Species**	**n**	**r**	**p**	**r**	**p**
Salisbury Bank	Cockles	83	0.200	0.040	0.063	0.729
Mostyn/Talacre	Cockles	83	0.056	0.776	0.126	0.282
Thurstaston West	Cockles	48	0.140	0.413	0.354	0.004
West Kirby - Tells tower	Cockles	73	0.339	<0.001	0.189	0.083
Caldy Blacks	Mussels	66	0.048	0.864	0.140	0.292

Figure XI.8 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Hilbre Island is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

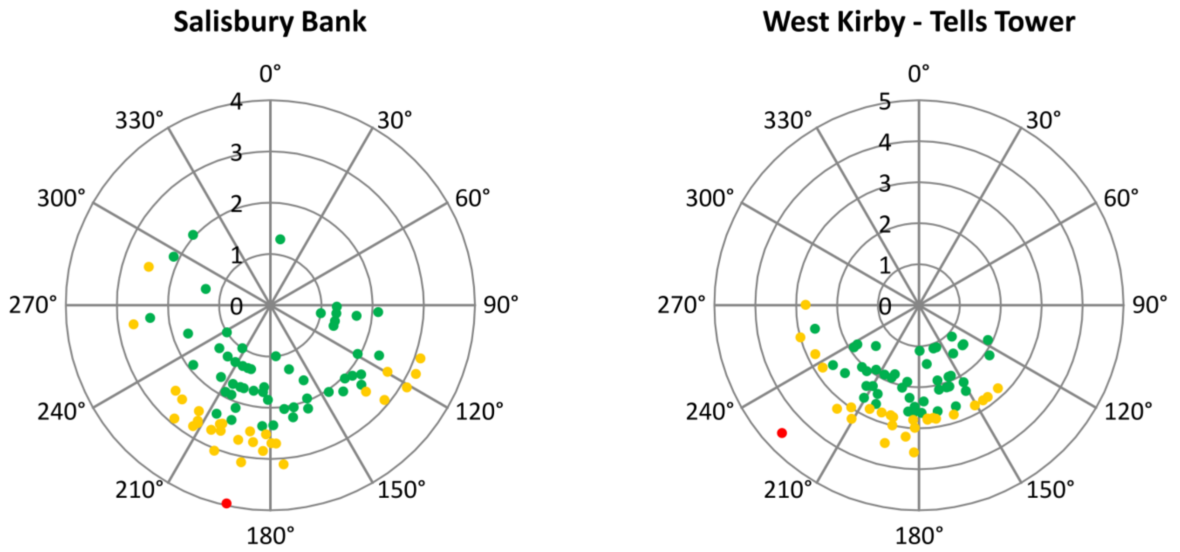

Figure XI.8 Polar plots of log10 **E. coli** *results (MPN/100g) against high/low tidal state*

No obvious patterns are apparent in Figure XI.8. Figure XI.9 presents polar plots of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for each RMP. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

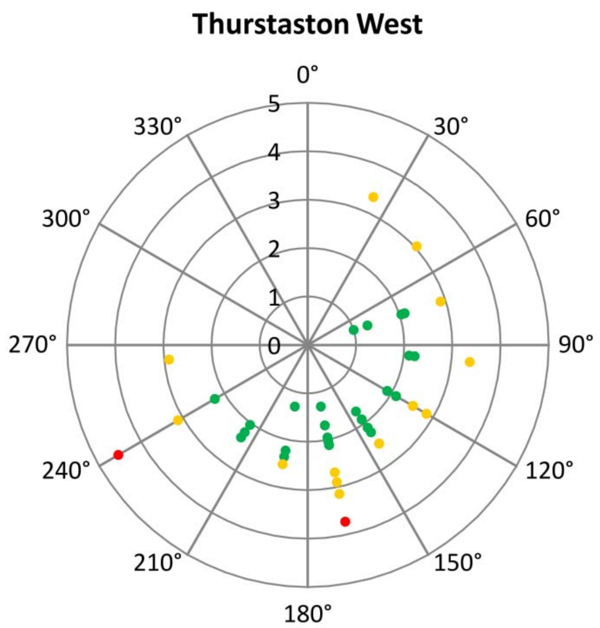

Figure XII.9 Polar plots of log10 **E. coli** *results (MPN/100g) against spring/neap tidal state*

No obvious patterns are apparent in Figure XI.9.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Chester weather station (Appendix II for details) over various periods between 2003 and 2012 running up to sample collection. These are presented in Table XI.3, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.3 Spearman's Rank correlations between rainfall recorded at Chester and shellfish hygiene results

	Site	Mostyn/ Talacre	Salisbury Bank	The Marshes	West Kirby Tells tower	Thurstaston East	Thurstaston West	Mostyn Deep	West Kirby	Caldy Blacks
	Species	Cockles						Mussels		
	n	83	83	17	73	21	48	15	10	66
24 hour periods prior to sampling	1 day	0.089	0.097	-0.194	**0.344**	0.050	**0.341**	0.386	**0.627**	**0.268**
	2 days	0.134	0.111	0.178	**0.202**	**0.408**	0.218	0.430	0.347	**0.245**
	3 days	**0.191**	0.141	0.364	0.136	0.193	0.148	-0.058	0.318	0.078
	4 days	0.146	**0.201**	0.268	**0.285**	0.103	-0.021	-0.023	0.151	**0.238**
	5 days	**0.190**	0.106	-0.449	**0.307**	-0.033	0.185	-0.203	0.456	0.097
	6 days	0.080	0.020	0.314	0.153	0.006	0.101	0.235	0.452	**0.217**
	7 days	**0.239**	**0.279**	-0.434	0.122	0.046	0.236	-0.271	0.063	-0.008
Total prior to sampling over	2 days	0.125	0.154	0.181	**0.298**	0.262	**0.351**	**0.475**	0.491	**0.269**
	3 days	**0.186**	**0.209**	0.196	**0.308**	0.275	**0.327**	**0.500**	0.468	**0.328**
	4 days	**0.218**	**0.248**	0.284	**0.338**	0.256	**0.257**	**0.517**	**0.695**	**0.360**
	5 days	**0.238**	**0.233**	-0.049	**0.375**	0.309	**0.380**	0.171	**0.695**	**0.359**
	6 days	**0.220**	0.181	0.049	**0.426**	0.270	**0.391**	0.201	**0.695**	**0.408**
	1 day	**0.302**	**0.267**	-0.087	**0.454**	0.297	**0.462**	0.262	**0.583**	**0.341**

Correlations between rainfall and the level of *E. coli* in shellfish to some degree at all of the sites analysed with the exception of The Marshes. West Kirby Tells Tower, Thurstaston West and Caldy Blacks saw the most consistent effect of rainfall. All three of these sites are downstream of the Heswall STW overflow, which may be the cause of the increased *E. coli* levels after rainfall events. It should be noted that on average an apparently significant correlation will arise by chance on 5% of occasions.

INFLUENCE OF SEWAGE SPILLS

To investigate the impact of sewage spills on the level of *E. coli* found in shellfish flesh, modelled spill data for the Heswall WWTW were compared with shellfish hygiene data. Figure XI.10 shows boxplots to compare hygiene data from those samples taken when a spill had or had not occurred within 48 hours prior to sampling. Table XI.4 shows the results of 2 sample t-tests comparing the level of *E. coli* in shellfish when a spill had or had not occurred within time periods from 1 hour to 48 hours.

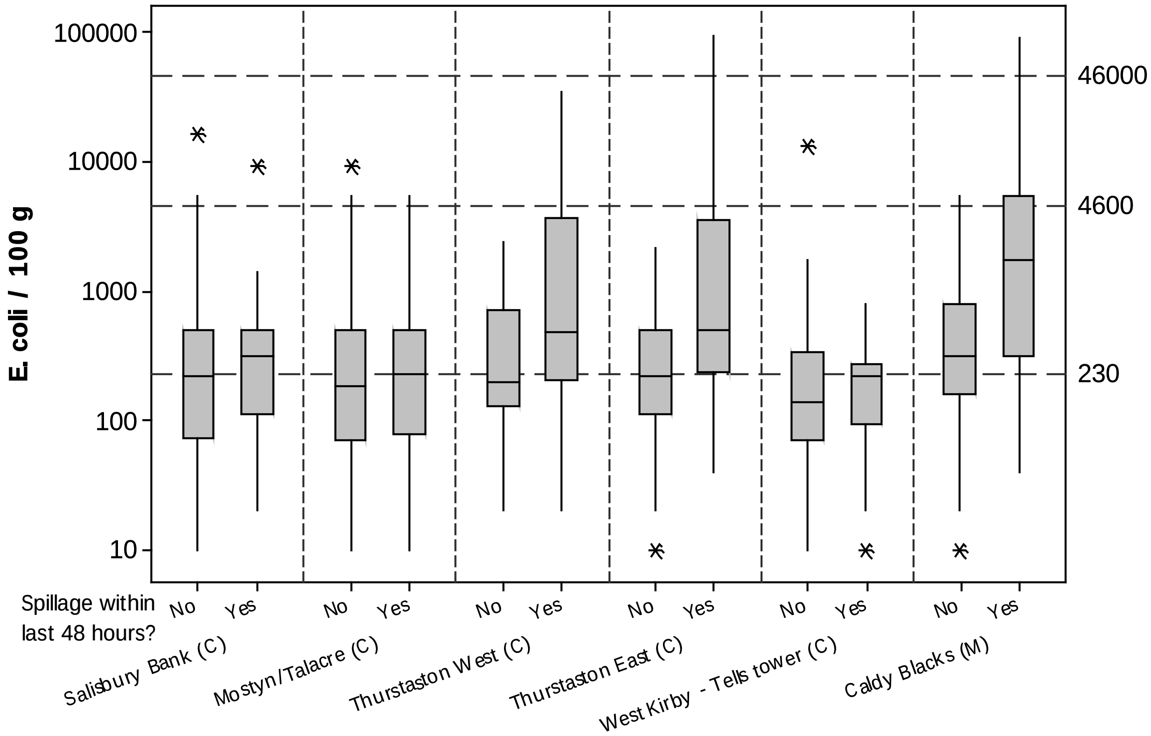

Figure XI.10: Boxplots to show the effect spillages from Heswall WWTW on E. coli levels in shellfish samples within 48 of a spillage event.

Table XI.4: Results of t-tests between E. coli results of samples that had or had not been taken within a specified period after a spillage event. Significant ($p < 0.05$) results are highlighted in yellow. Numbers in brackets are degrees of freedom.

	Species	**Cockles**					**Mussels**
	Site	**Salisbury Bank**	**Mostyn/ Talacre**	**Thurstaston West**	**Thurstaston East**	**West Kirby - Tells tower**	**Caldy Blacks**
Number of hours prior to sampling where spillage occurred	1	0.963 (7)	0.856 (7)	0.612 (3)	0.450 (8)	0.588 (15)	0.983 (12)
	2	0.434 (7)	0.290 (10)	0.612 (3)	0.414 (10)	0.588 (15)	0.983 (12)
	4	0.494 (10)	0.334 (11)	0.612 (3)	0.414 (10)	0.588 (15)	0.746 (14)
	8	0.500 (14)	0.482 (14)	0.338 (4)	0.186 (12)	0.231 (21)	0.091 (16)
	16	0.904 (25)	0.852 (26)	0.351 (6)	0.141 (19)	0.317 (33)	0.008 (28)
	24	0.378 (49)	0.742 (48)	0.351 (6)	0.019 (19)	0.974 (45)	0.003 (35)
	48	0.253 (82)	0.502 (82)	0.264 (8)	0.006 (27)	0.937 (58)	0.004 (50)

Spillages had a significant effect on *E. coli* levels at Thurstaston East and Caldy Blacks, but not at any other RMP. This is perhaps not surprising as both of these sites are within close proximity to the outfall. However no significant effect was seen at Thurstaston West, which is also close to the outfall. This is likely due to the low number of samples at Thurstaston West which coincided with recent spillages. The pattern seen in Figure XI.10 would seem to suggest that given more data, a significant effect would become apparent at Thurstston West. It must be noted that the spill data used was modelled data rather than actual spill records.

APPENDIX XII
SHORELINE SURVEY

Date (time): 23 August 2011 (10:00-14:00 BST) and
24 August 2011 (09:00-13:30 BST) and
13 November 2012 (08:30-11:00 GMT)

Cefas Officer: Alastair Cook (August 2011)
David Walker (November 2012)

Local Enforcement Authority Officers: Daniel Dawson & Nicola Pulford (Wirral Council, 23 August), Paul Lindsay (Flintshire Council, 24 August), Mark Davies (Wirral Borough Council, 13 November)

Area surveyed: Selected parts of the Dee estuary shoreline (Figure 1).

Weather: 23 August– winds E force 2, 17°C, cloudy/sunny
24 August – winds S force 3, 16°C, cloudy/light rain
13 November - winds W force 1, 14°C, Overcast

Tidal predictions (Hilbre Island):

Admiralty TotalTide - Hilbre Island 53°23'N 3°13'W England. Times GMT+0100.

23/08/2011
High 05:47 7.0 m
Low 12:32 3.6 m
High 18:20 6.9 m

24/08/2011
Low 01:25 3.7m
High 07:10 6.9 m
Low 13:57 3.6 m
High 19:47 7.1 m

13/11/2012
Low 04:18 1.4 m
High 09:48 9.3 m
Low 16:37 1.3 m
High 22:06 9.5 m

Predicted heights are in metres above Chart Datum.

Objectives: (a) confirm the location of previously identified sources of contamination; (b) obtain spot flow estimates and samples of freshwater inputs for bacteriological testing; and (c) identify any additional sources of contamination in the area. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are mapped in Figure XII.1. Photographs referenced in Table XII.1 are presented in Figures XII.3-20.

Background

The estuary supports wild populations of cockles and mussels, which in turn support economically significant fisheries, particularly for cockles. The distributions and densities of stocks vary considerably from year to year so any sampling plan should be sufficiently flexible to be adaptable to changing stock distribution, and not overly restrictive in terms of the area classified. Classification sampling results in the area off Caldy have been very variable in recent years, and occasional prohibited level results have arisen here, which has created problems for classification and zonation of this area. Wirral BC indicated that a reappraisal of RMP locations off Caldy is desirable as accessing RMPs to the seawards side of drainage channels is difficult, time consuming and hazardous.

Sources of contamination

On the eastern side of the estuary within the area surveyed, potentially significant shoreline sources included the Heswall STW, several intermittent sewage discharges, and a number of very minor watercourses. At the time of survey conditions were dry and many of these watercourses were not flowing. One that was flowing may have been carrying some foul water (Table XII.1, observation 3, Table XII.2, row 6). Also, some sanitary related debris was seen in the path of one dry stream (Table XII.1, observation 22, Table XII.2, row 15, Figure XII.8). Contamination from most of these sources, including the Heswall STW and various intermittent sewage outfalls is carried towards the shellfisheries by the drainage channel which runs along the shore from Heswall northwards. At the time of survey the majority of the flow from this channel appeared to originate from the Heswall STW outfall. The flow from this channel was measured and two replicate water samples were taken (Table 1, observation 20, Table 2, row 14) and at the time of survey the bacterial loading it carried was not particularly large. This indicates that at the time, the UV treatment applied at Heswall STW was functioning properly. However, during times of increased inputs, particularly when spills are occurring from the intermittent discharges, this drainage channel could deliver highly contaminated water to the shellfish beds particularly towards the end of the ebb tide when the dilution potential will be lowest. It was also apparent that the saltmarsh here is accreting, as it extended further than indicated on the ordnance survey map. Additionally, about 30 small yachts were seen moored in this channel just off Caldy.

On the western side the locations of three sewage works were confirmed (Greenfield, Mostyn and Llanasa). The watercourses on this side of the estuary were more substantial in terms of discharge volumes, and all carried fairly high concentrations of *E. coli,* particularly the watercourse receiving effluent from the Llanasa STW (Table 2, row 1). Some livestock were observed on fields adjacent to the shore between Greenfield and Mostyn (60 cattle, 8 horses, 15 sheep). A large aggregation of seagulls was recorded on the intertidal area off here, and 8 fishing boats were noted on moorings just to the south of the Mostyn Port.

Figure XII.1. Locations of shoreline observations

Table XII.1. Details of shoreline observations

No.	Date & Time	Position	Photograph	Details
1	23/08/2011 10:34	SJ 28018 77862		Inspection cover in marsh
2	23/08/2011 10:35	SJ 28059 77853	Figure XII.3	Parkgate SPS enclosure
3	23/08/2011 10:43	SJ 27716 78490		Stream 18cmx3cmx0.15m/s, some odour, water sample C1
4	23/08/2011 10:49	SJ 27674 78558		Similar sized stream to 4 but not flowing
5	23/08/2011 10:53	SJ 27604 78642		Similar sized stream to 4 but not flowing
6	23/08/2011 10:54	SJ 27607 78635		Ceramic pipe to ditch, surface drain?
7	23/08/2011 11:00	SJ 27544 78713		Surface water outfall 5cmx1cmx0.2m/s, water sample C2
8	23/08/2011 11:06	SJ 27378 78903		Pool of stagnant water with drain not flowing
9	23/08/2011 11:16	SJ 27120 79250		Dry stream
10	23/08/2011 11:19	SJ 27026 79352		Dry stream
11	23/08/2011 11:22	SJ 26904 79533		Drain not flowing
12	23/08/2011 11:27	SJ 26708 79778		Inspection cover on footpath
13	23/08/2011 11:37	SJ 26434 80127	Figure XII.4	Photo of creek
14	23/08/2011 11:44	SJ 26176 80443	Figure XII.5	2x~45cm diameter outfalls to creek, not flowing (Heswall Storm tank CSO)
15	23/08/2011 12:00	SJ 25824 81043		Surface water outfall not flowing
16	23/08/2011 12:10	SJ 25272 81508		Boatyard
17	23/08/2011 12:19	SJ 24898 81798	Figure XII.6	Heswall STW outfall
18	23/08/2011 12:27	SJ 24942 81878		Surface water outfall not flowing
19	23/08/2011 12:37	SJ 24522 82257		Fresh sanitary debris (rag)
20	23/08/2011 12:48	SJ 24133 82621	Figure XII.7	Creek, 9mx8cmx0.125m/s. Water samples C3 and C4
21	23/08/2011 13:01	SJ 23928 83006		Broken pipe (has been broken >8yrs). Several hundred gulls out on sand
22	23/08/2011 13:09	SJ 23615 83473	Figure XII.8	Dry stream, sanitary debris (rag) in its path, unusual for it not to be flowing.
23	23/08/2011 13:11	SJ 23623 83483		Inspection cover
24	23/08/2011 13:32	SJ 23013 83924		Stream (or seep) 2cmx1cmx0.3m/s, water sample C5, manhole cover at top of cliff. About 30 small yachts on moorings in channel just off the end of the track across the beach.
25	24/08/2011 09:09	SJ 17671 79175	Figure XII.9	Sewage pumping station with outfall to stream
26	24/08/2011 09:13	SJ 17679 79260		Stream 480cmx7cmx0.2m/s, water sample M1
27	24/08/2011 09:34	SJ 18783 78863		Several hundred gulls on sandbanks
28	24/08/2011 09:38	SJ 19013 78719		8 horses
29	24/08/2011 09:40	SJ 19151 78631		15 sheep
30	24/08/2011 09:54	SJ 19931 78138	Figure XII.10	Boil from Greenfield STW outfall about 2m from edge of water, 25 cattle
31	24/08/2011 10:02	SJ 19942 77954		Stream 200cmx8cmx0.125m/s, water sample M2
32	24/08/2011 10:07	SJ 19950 77960	Figure XII.11	STW outfall to stream, doesn’t appear to be flowing
33	24/08/2011 10:17	SJ 16865 80063	Figure XII.12	35 cattle in field adjacent to trickling filter STW (Mostyn)
34	24/08/2011 10:26	SJ 17023 80091	Figure XII.13	Mostyn STW outfall
35	24/08/2011 10:38	SJ 16517 80352	Figure XII.14	8 fishing boats to the north on moorings
36	24/08/2011 11:03	SJ 14416 81763		Sanitary debris (Rag)
37	24/08/2011 11:17	SJ 15121 81234		Stream 55cmx5cmx0.1m/s, water sample M3
38	24/08/2011 11:40	SJ 14151 82034		Stream 160cmx8cmx0.5m/s, water M4

No.	Date & Time	Position	Photograph	Details
39	24/08/2011 12:13	SJ 12722 83618	Figure XII.15	Outfall to creek, possibly Llanasa STW
40	24/08/2011 12:18	SJ 12879 83691		Stream 440cmx10cmx0.3m/s, water sample M5
41	13/11/2012 08:56	SJ 23013 83929	Figure XII.16	Probable sewerage over flow outlet from Long Hey road. Covered with boulders (193.2 m³/day)
42	13/11/2012 09:05	SJ 22770 84102		Cotton buds
43	13/11/2012 09:16	SJ 22466 84537	Figure XII.17	Groundwater from golf course
44	13/11/2012 09:32	SJ 22269 84796	Figure XII.18	Groundwater from golf course (127.0 m³/day)
45	13/11/2012 09:47	SJ 21961 85286		Dog walkers
46	13/11/2012 10:42	SJ 20685 87665	Figure XII.19	Birds ~30, 50m 270°
47	13/11/2012 10:49	SJ 20642 87810	Figure XII.20	Surface water in marsh (852.2 m³/day)

Sample results

Spot flow measurements were taken from all watercourses and samples were taken and tested for *E. coli*. This allowed spot estimates of the bacterial loadings of each watercourse to be made. Results of the samples and measurements are presented in Table XII.2 and the Figure XII.2. Samples taken on the 13th November 2012 arrived at the laboratory within 24 hours of collection, but were misplaced for 24 hours and so were no longer fit for analysis.

Table XII.2. Watercourse details, sample results and spot flow estimates

No.	Date & time	NGR	Daily discharge (m³)	E. coli / 100 ml	Loading (E. coli / day)
1	24/08/2011 12:18	SJ 12879 83691	11,405	>20,000	$>2.28\times10^{12}$
2	24/08/2011 11:40	SJ 14151 82034	5,184	14,000	7.26×10^{11}
3	24/08/2011 11:17	SJ 15121 81234	238	8,700	2.07×10^{10}
4	24/08/2011 09:13	SJ 17679 79260	5,806	5,300	3.08×10^{11}
5	24/08/2011 10:02	SJ 19942 77954	1,728	4,100	7.08×10^{10}
6	23/08/2011 10:43	SJ 27716 78490	70	>20,000	$>1.40\times10^{10}$
7	23/08/2011 11:00	SJ 27544 78713	9	12,000	1.08×10^{9}
8	23/08/2011 11:06	SJ 27378 78903	Drain, not flowing		
9	23/08/2011 11:16	SJ 27120 79250	Dry stream		
10	23/08/2011 11:19	SJ 27026 79352	Dry stream		
11	23/08/2011 11:22	SJ 26904 79533	Drain, not flowing		
12	23/08/2011 12:00	SJ 25824 81043	Surface water outfall, not flowing		
13	23/08/2011 12:27	SJ 24942 81878	Surface water outfall, not flowing		
14	23/08/2011 12:48	SJ 24133 82621	7,776	525*	4.08×10^{10}
15	23/08/2011 13:09	SJ 23615 83473	Dry stream		
16	23/08/2011 13:32	SJ 23013 83924	5	990	4.95×10^{7}
17	13/11/2012 09:16	SJ 22466 84537	Groundwater from golf course		
18	13/11/2012 09:32	SJ 22269 84796	127	Samples lost by lab	
19	13/11/2012 10:49	SJ 20642 87810	852	Samples lost by lab	

*2 samples taken, results of 520 and 530 *E. coli* cfu/100ml returned

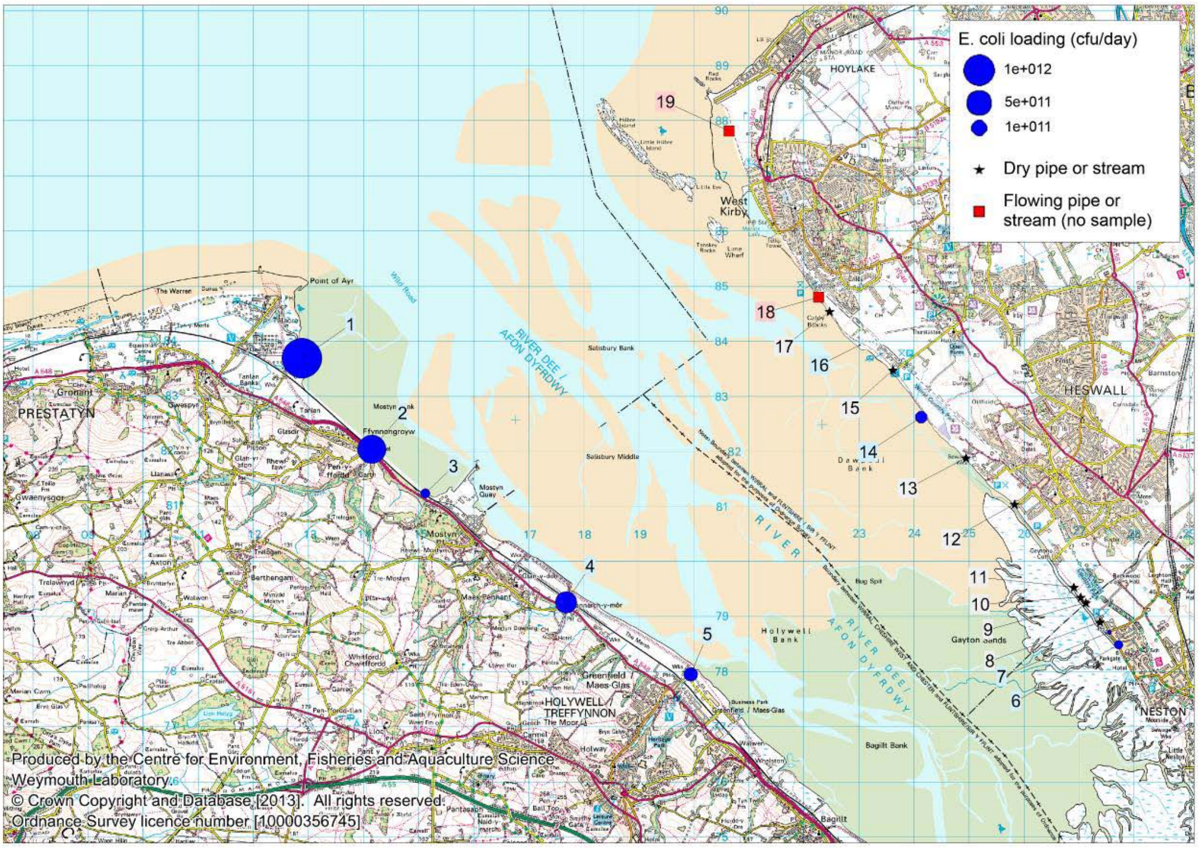

Figure XII.3. Estimated bacterial loadings from watercourses

Conclusions

The following conclusions should be taken into consideration when the sanitary survey is carried out:

- Due to the variable nature of stocks, any sampling plans should aim to classify the entire area within which stocks may potentially extend, and should be sufficiently flexible to accommodate changing stock distribution.
- Any RMPs should not only be positioned to be suitably protective of public health, but also should be safely accessible to sampling officers, consequently, this may have implications for the location of classification zone boundaries.
- On the eastern side of the estuary, intermittent discharges to the tidal creek running close inshore from Heswall combines with a bathymetry that allows quite concentrated effluent to reach the area off Caldy at certain states of the tide. As these discharges are intermittent, and the extent of dilution and their advection to the shellfisheries will vary with the tide, very variable levels and gradients of contamination are likely to arise off Caldy. The sanitary survey will need to consider microbiological testing results alongside spill information and tidal state to investigate the influence of these intermittent discharges. Detailed and up to date bathymetry (or elevation) maps would greatly assist in determining the extent of the area at highest risk, and hence appropriate zonation of the shellfishery.

- On the western side of the estuary, there are three significant sewage works and a number of watercourses which were carrying significant bacterial loadings. These are likely to be the primary cause of any spatial variation across the more inshore parts of the shellfisheries and RMPs and classification zones should be defined accordingly.

Figure XII.3 –Parkgate SPS enclosure

Figure XII.4 – Creek just off Heswall

Figure XII.5 – Heswall storm tank CSO outfalls

Figure XII.6 – Heswall STW main outfall to creek

Figure XII.7 - Approximate location where Heswall creek was sampled and measured.

Figure XII.8 – Dry stream, sanitary debris in channel

Figure XII.9 – Sewage pumping station adjacent to stream

Figure XII.10 – Boil from Greenfield STW outfall (pipe covered by tide)

Figure XII.11 - Intermittent outfall to watercourse by Greenfield STW

Figure XII.12 – Mostyn STW, cattle in background

Figure XII.13 – Outfall from Mostyn STW

Figure XII.14 – Fishing boats at anchor, Mostyn Port in background

Figure XII.15 –outfall to watercourse

Figure XII.16 - Long Hey Road outlet

Figure XII.17 Groundwater from golf course

Figure XII.18 Groundwater from golf course

Figure XII.19 Birds

Figure XII.20 Stream

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List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DCWW	Dwr Cymru/Welsh Water
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
IFCA	Inshore Fisheries and Conservation Authority
ISO	International Organization for Standardization
Km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
M	Metres
Ml	Millilitres
Mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
NM	Nautical Miles
NRA	National Rivers Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
TAC	Total Allowable Catch
UV	Ultraviolet
WGS84	World Geodetic System 1984
WWTW	Waste Water Treatment Works

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (E. coli)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. *coli* O157 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer, goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygiene Regulations, Shellfish and Bathing Water Directives, *E. coli* is the most `common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44°C as well as 37°C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and preceding the ebb tide.

Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	LOcally WEighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the *n* data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

Summary of consultations on draft report

Consultee	Comment	CEFAS response
Environment Agency		
DCWW		
Wirral Borough Council		
Flintshire Borough Council		
Welsh Government (Fisheries)		
North West IFCA		

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