Cefas

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Ribble

2011

Cover photo: Intertidal area at Southport.

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STATEMENT OF USE: STATEMENT OF USE: This report provides a sanitary survey relevant to bivalve mollusc beds in the Ribble 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	Consultation Date	Response Date
Environment Agency	13/03/2012	31/07/2012
Mersey Port Health	13/03/2012	31/08/2012
Fylde Council	12/03/2012	-
West Lancashire Council	13/03/2012	07/09/2012
Inshore Fisheries and Conservation Authority	13/03/2012	30/08/2012

DISSEMINATION: Food Standards Agency, Mersey Port Health Authority, West Lancashire Council, Fylde Council, Environment Agency, North Western Inshore Fisheries and Conservation Authority.

The Final Report will also be available via the FSA and Cefas web sites.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2011. Sanitary survey of the Ribble. 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 the BMPA. 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 wild cockles (*Cerastoderma edule*) and mussels (*Mytilus* spp.) harvested in the outer reaches of the Ribble estuary and in the intertidal areas off Lytham St. Annes and Southport, and four genera/species of clams; razor clams (*Ensis* spp.), thick trough shell (*Spisula solida*), soft shell clams (*Mya* spp.) and otter shell clams (*Lutraria lutraria*)) in an area offshore from Southport.

1.2 Site Description

Ribble Coast

The survey area stretches from Southport to Lytham St. Annes and encompasses the outer reaches of the Ribble estuary (Figure 1.1). The intertidal area is vast, with sandflats stretching up to 10km out from the high water mark and supports several areas of cockle beds. It is bisected by the Ribble channel and flanked by extensive sea defences. The shoreline is exposed to the open waters of the Irish Sea to the west and the tidal range here is large and sediments on this shore are mobile. The coastal area is low lying, with saltmarsh bordering the inner and middle reaches of the estuary. Significant urban areas lie adjacent to the estuary at Preston, Southport and Lytham St. Annes.

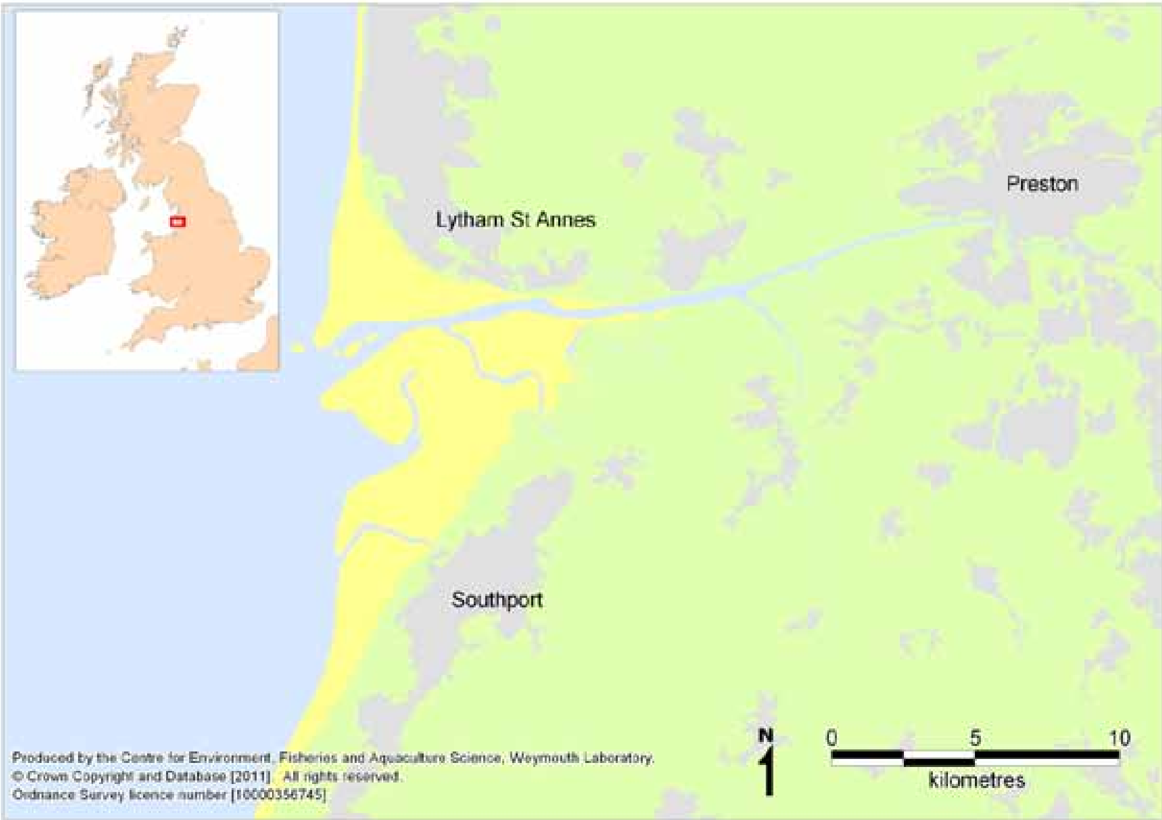


Figure 1.1 Features of the Ribble coast.

Catchment

The Ribble estuary has a catchment area of about 2115km^2. It is low lying near the coast, but rises to about 680m where it extends north-eastwards into the Pennines. Soils are generally poorly draining throughout the area (National Soil Resources Institute, 2011) so a relatively high proportion of rainfall will run off particularly from the steeper areas within the upper catchment. Figure 1.2 shows land cover within this area.

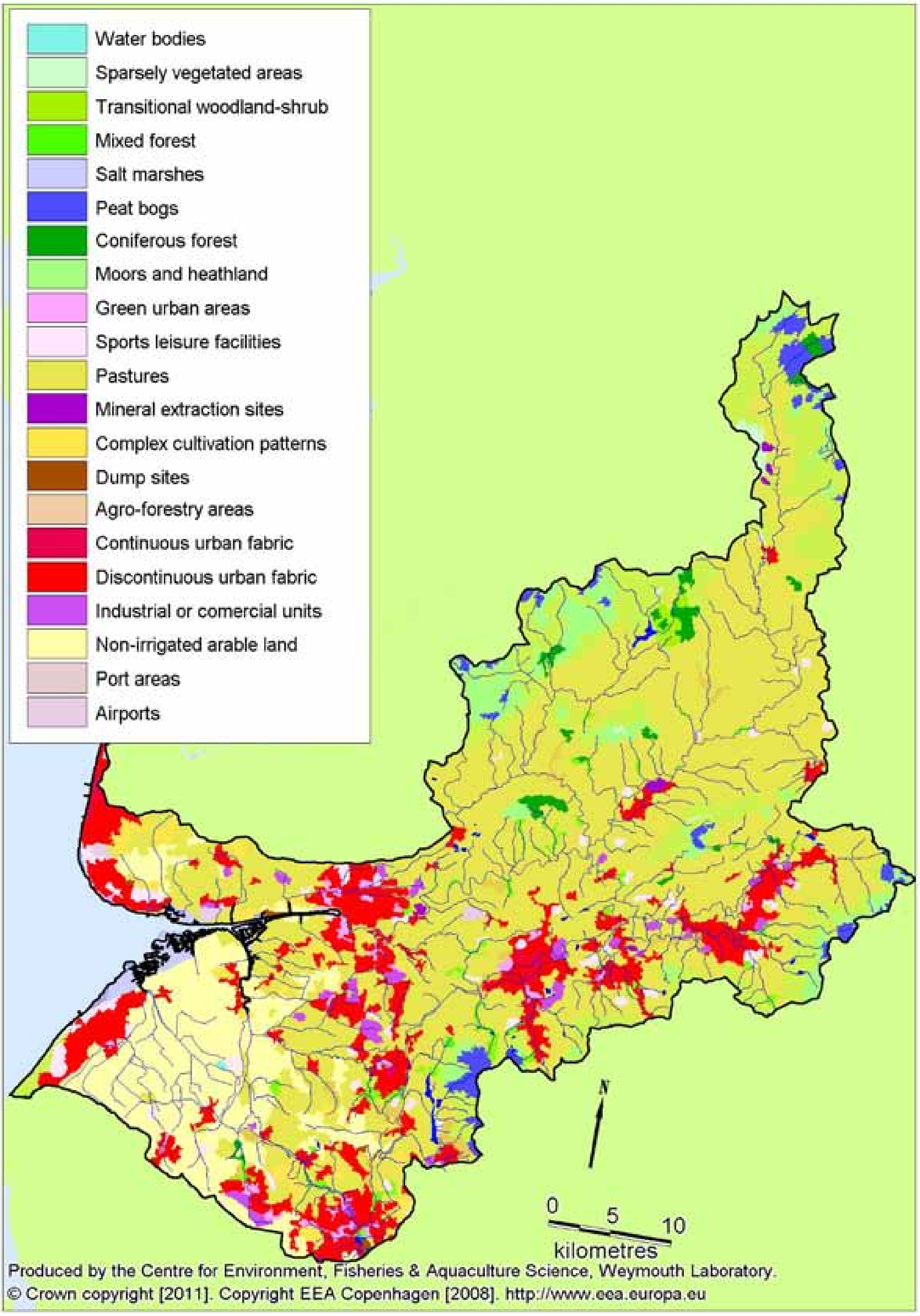


Figure 1.2 Land cover within the Ribble catchment.

About 10% is urbanised and about 75% is devoted to agriculture, the majority of which is pasture although there are significant areas of arable farming in the lower lying areas to the south of the estuary. Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contributions arise from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land cover 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. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for classification of several discrete wild cockle (*Cerastoderma edule*) beds in the intertidal area from Lytham St. Annes through to Southport. A second application was subsequently received for the harvest of four species of burrowing clams (razor clams (*Ensis* spp.), thick trough shell (*Spisula solida*), soft shell clams (*Mya* spp.) and otter shell clams (*Lutraria lutraria*)) in an area offshore from Southport, and this was also included in this report due to its proximity to the cockle beds. The outer Ribble estuary is currently classified for the harvest of mussels (*Mytilus* spp.), and sampling plans are also reviewed for this fishery. Figure 2.1 shows the locations of the cockle and mussel beds, from recent stock surveys undertaken by the NW IFCA, together with the offshore area from which the four species of clams are to be harvested.

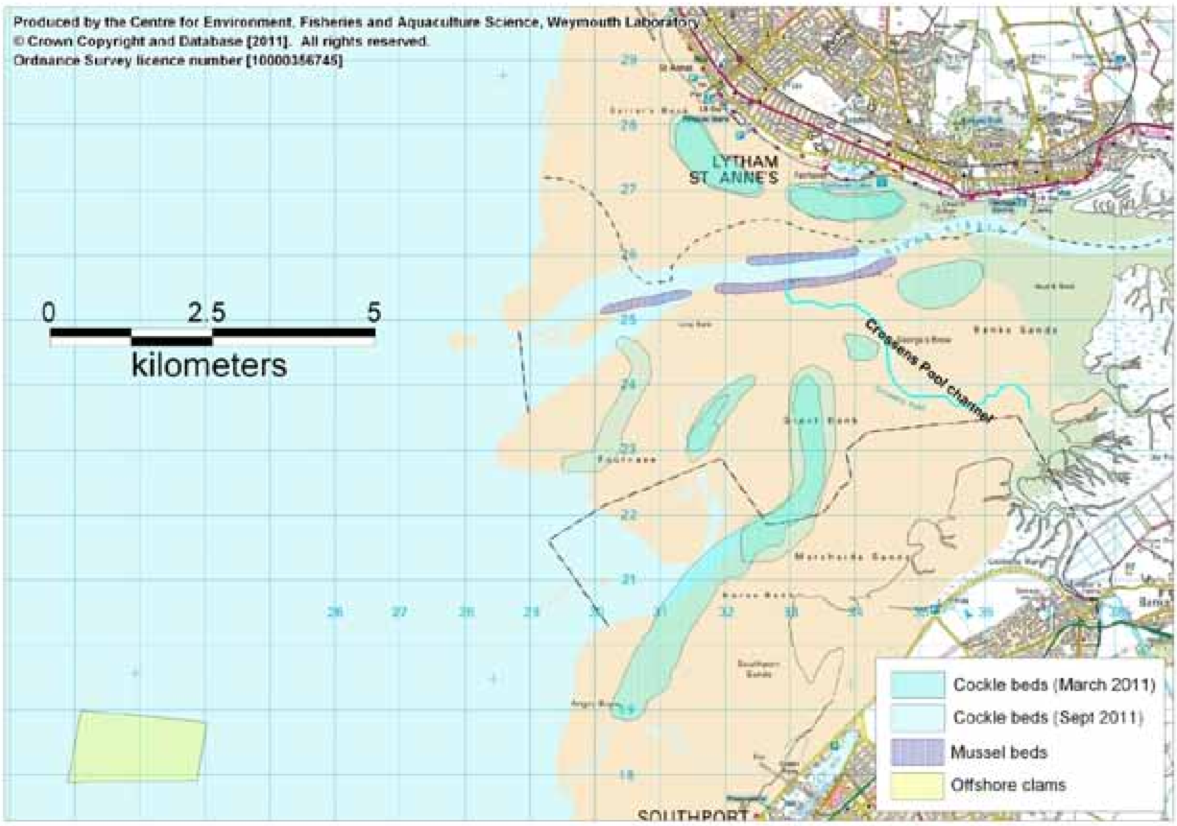


Figure 2.1 Approximate location of bivalve mollusc beds.

Cockle stocks in the area have been at low levels in recent history, but following a good spatfall in 2010, significant stocks of a harvestable size were present for when the season opened on the 1st September 2011. There are also the sparse remnants of older year classes in some areas and it is possible that there are other as yet undiscovered areas supporting high densities of cockles along this stretch of coast although it is believed that Figure 2.1 shows the main areas. These are very substantial, so there are likely to be several thousand tonnes of stock on these beds. No evidence of a significant spatfall in 2011 has been observed (NW IFCA, personal communication).

Mussel beds are located on the rocks constituting the training walls which line the outer Ribble channel. There has been no commercial interest in these stocks in recent years.

Razors and various clam species are present towards the low water mark and extending offshore from Southport through to Lytham St. Annes. Currently, there is no commercial interest in gathering of these stocks from the intertidal zone (NW IFCA, personal communication) although it is possible that interest may arise in the future.

The offshore dredge fishery for razors and various clam species is at an early stage in its development. The area for which classification has been requested covers 2km^2 and lies about 6km offshore from the low water mark. There is no survey information available on the distribution or densities of these stocks. They are likely to be widely distributed off this entire stretch of coastline and the area shown in Figure 2.1 is likely to represent a very small fraction of the potentially exploitable area.

2.2 Growing methods and harvesting techniques

All stocks considered in this report are wild. The intertidal cockles and mussels are exploited by hand gathering. The offshore mixed clam fishery will use a fluidised dredge to extract clams from the substrate.

2.3 Seasonality of harvest, conservation controls and development potential

The cockle fishery in this district operates a closed season running from 1st May to 31st August to protect settling spat. The offshore dredge fishery lies within a potential Special Protected Area, which is due to be formally designated in the near future. This designation is to protect overwintering seabirds and Natural England have indicated that a dredge fishery would be acceptable in the area, but should be restricted to the summer months (April to September) when the birds are largely absent. There is no closed season for mussels.

Statutory minimum landing sizes apply to cockles (20mm), mussels (45mm) and razors (100mm), but not to the other three clam species of interest to the offshore dredge fishery.

Gear limitations (hand gathering only) apply to the intertidal cockle and mussel fisheries, limiting levels of exploitation and preventing the use of techniques more destructive to the stocks and the habitat. Both cockles and mussels are a public fishery and anyone is allowed to take up to 5 kg of each species per calendar day. Greater (commercial) quantities can only be taken by licensed operators. Permits are issued by the NW IFCA, allowing exploitation of cockle and mussel beds within the entire district. Around 400 permits were issued in 2011 and up to 400 individuals have been reported fishing the cockle beds off Southport since the season opened in September 2011. The cockle beds were closed by the NW IFCA in early November 2011 for safety reasons following numerous instances of cocklers requiring rescue by the coastguard. The offshore clam fishery requires authorisation by the NW IFCA under their Byelaw 12 (Restrictions on fishing for bivalve molluscan shellfish) which, once granted, would create a public fishery.

Cockle stocks are likely to fluctuate significantly in their overall biomass and their distribution around the area. Success of spatfalls may vary greatly between years and storms, temperature extremes, diseases, predation and of course exploitation can all affect them and mass mortalities may occur at times. Mussel stocks are likely to vary in quantity from year to year but their distribution is unlikely to change significantly as they require a hard surface (i.e. the training walls) on which to settle.

2.4 SAMPLING CONSIDERATIONS

Cockle and mussel samples from the intertidal areas are routinely collected by the NW IFCA on behalf of the LEAs. Access to some parts of the cockle beds may not be possible at times due to the hazardous nature of the environment, for example the southern part of the main Penfold channel bed becomes inaccessible at certain times of the year due to the softness of the grounds. The NW IFCA indicated that it is not possible for them to access the cockle bed at Georges Brow which lies between the Ribble and Crossens Pool channels. This will also apply to mussels on the training walls on the south side of the channel east of the Crossens Pool. Another consideration regarding cockle sampling is that the geographical distribution of stocks is likely to vary significantly from year to year, so provision to alter the locations of any RMPs on the basis of stock availability should be made in the sampling plan.

The offshore clam dredge fishery presents significant sampling problems, as neither the LEA nor the NW IFCA are suitably equipped with an appropriate dredge or can devote the required resources to regularly sample these species from the required area. It would be prohibitively expensive for the harvester to undertake repeated sampling without reimbursement for his services. Additionally, it is presumed that consent for sampling using a dredge would be required from Natural England. According to classification protocols, a minimum of 10 samples of each of the four species are required before the fishery can be classified. As this is unlikely to be achievable, a more pragmatic approach will be required, particularly as the fishery is a long way offshore and unlikely to be subject to significant contamination. At some fisheries bagged mussels are used as a surrogate for other species, and this approach would remove the requirement for a fluidised dredge. However, little is known about the extent to which *E. coli* is accumulated in otter shells and soft shell clams, so this strategy would require some initial parallel monitoring of at least these two (and preferably all) the clam species alongside mussels. The NW IFCA have day grabs for benthic sampling, but the use of these to collect clam samples is likely to be very laborious unless the clams are present at very high densities. The use of bagged mussels on the offshore grounds would still require a lengthy boat trip out to collect samples, although it may be possible for the NW IFCA to coordinate this alongside any patrol work they carry out in the area. There are doubts as to whether bagged mussels would remain *in situ* given the exposed nature of the area, but such an approach would merit an attempt in the absence of better options. The use of an existing cockle RMP in the intertidal zone is not appropriate as this would lie at least 6km from the fishery and would not be representative of conditions offshore. Once the fishery is classified and in operation, it may be possible for the harvester to collect samples whilst fishing commercially, although the timing and locations of samplings would be dictated by fishing patterns.

2.5 Hygiene Classification

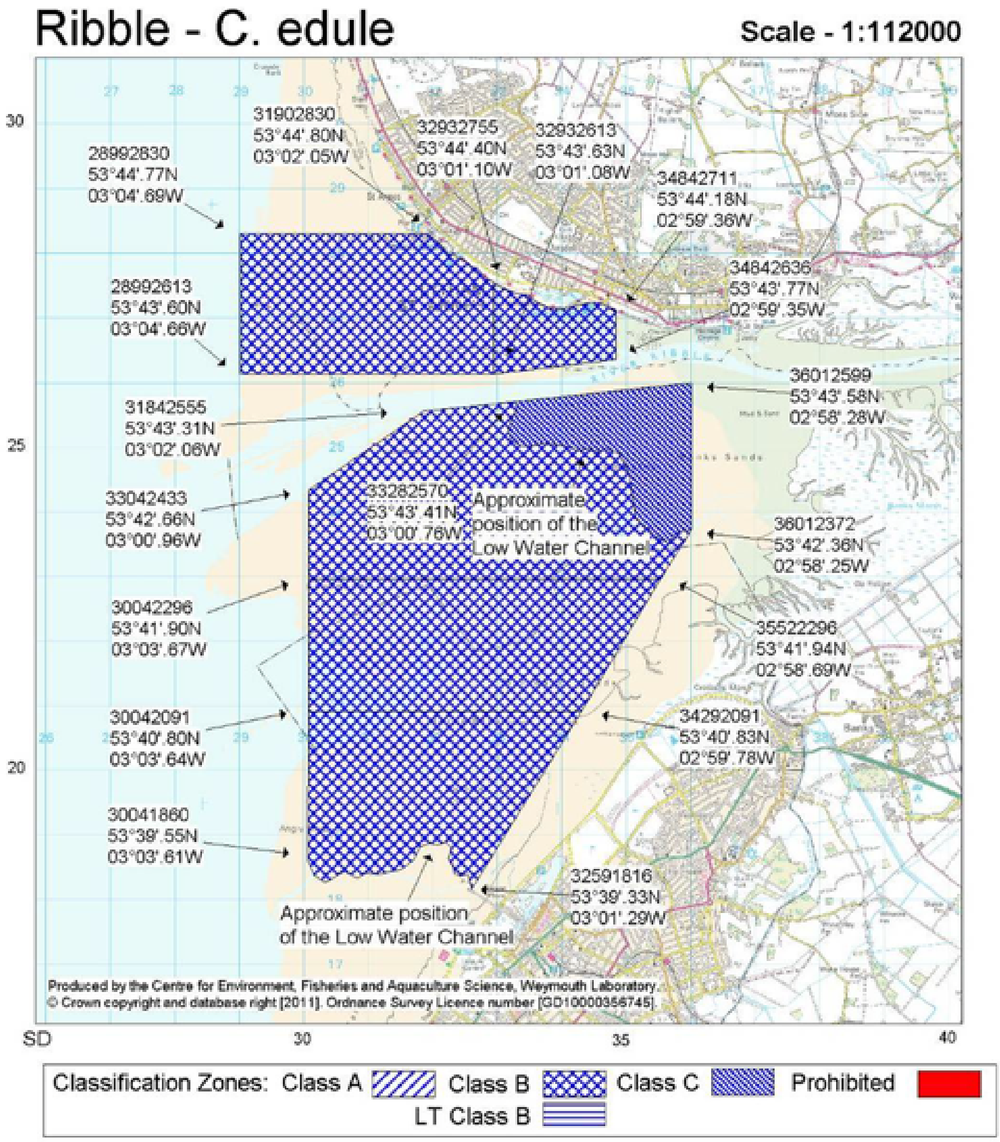
Intertidal cockle and mussel stocks within the Ribble production area have a long classification history dating back to 1993. Currently the only classification within the survey area is for mussels. Cockle classifications lapsed in 2005 and 2006 due to an absence of stock, and up to this point the north side of the estuary had only received C classifications, whereas the south side had varied between B and C. Just before the cockle season opened in September 2011, the area was awarded preliminary classifications on the basis of the results of a bacteriological survey (Appendix XIII) carried out as part of this sanitary survey. It was not possible to sample the cockle bed at Georges Brow, which was awarded a preliminary C classification as a precaution as it was closest to the main contaminating sources up estuary. All other classifications were based on sampling results and were B classifications.

Table 2.1 Classification history for the Ribble, 2001 onwards

Area	Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
All beds	Mussels	C	C	C	C	C	C	B	C	C	C	C
Southern beds	Cockles	B	B	C	B	B	DC					B&C
Northern beds	Cockles	C	C	C	C	DC						B

DC – declassified

Current classification maps are shown for cockles in Figure 2.2 and mussels in Figure 2.3.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2011

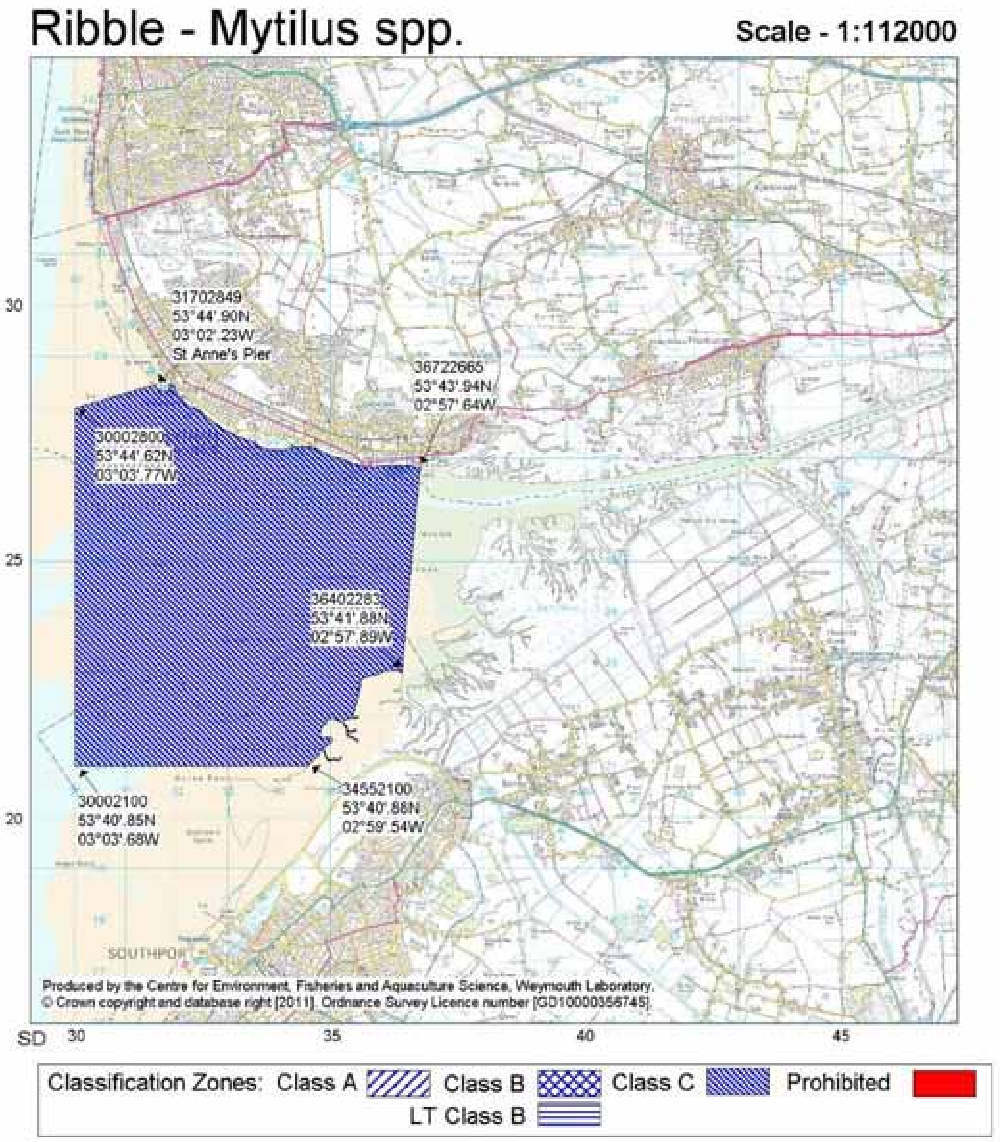
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

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
Seperate map available for Mytilus spp. at Ribble

Food Authorities: West Lancashire District Council
Mersey PHA - (Southside)
Fylde Borough Council

Figure 2.2 Current classifications for cockles.



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Seperate map available for C. edule at Ribble

Food Authorities: West Lancashire District Council
Mersey PHA - (Southside)
Fylde Borough Council

Figure 2.3 Current classification for mussels

Table 2.2 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 2.2 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* $100g^{-1}$ Fluid 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* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ 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* $100g^{-1}$ FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* $100g^{-1}$ 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*

3. 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 current distribution of the main cockle beds is known from stock surveys undertaken by the IFCA. Further as yet undiscovered patches may exist and in the future, exploitable patches may appear in the intertidal zone where suitable conditions exist and stocks may disappear from areas previously supporting commercial densities. The environment supports rapid growth, with the currently exploitable stock originating almost exclusively from the 2010 spatfall. The location of commercially viable beds is therefore likely to change on an annual basis dependent on previous spatfalls. NW IFCA are likely to be able to advise on the extent of the beds through stock surveys and observations of areas being exploited.

There are several approaches which may be taken to defining the location of the production area boundaries and the RMP for these mobile shellfish beds. These include;

1. classifying a larger zone which covers the wider area into which the bed may expand with a fixed RMP to which stock may be transplanted for sampling, or
2. resetting the RMP(s) and classification zone boundaries during each closed season on the basis of the actual location of the beds, or
3. classifying the wider area and sampling moveable RMP(s) (within one or more identified zones) situated where stock is present at the location within this area likely to be most heavily contaminated.

The first option, whilst being highly protective of public health is likely to suffer from practical issues associated with transplanting and recovering stock from the RMP. The second option allows the RMP to be located in the most contaminated part of the actual beds, but would require annual input from NW IFCA and Cefas and would restrict the harvestable area to known patches, so any newly discovered patches would fall outside classified areas. The third option would allow monitoring in the most appropriate location(s) where stocks are present to be sampled, would not require periodic revision to boundaries, but may require the RMP to be relocated periodically as new patches appear and disappear, which may complicate the interpretation of results for the purposes of classification. The location sampled should be recorded to 10m accuracy by GPS on each sampling occasion to aid interpretation of results. This strategy also relies on up to date information on where stocks are present, which would be based on ongoing intelligence gathering by the three LEAs and NW IFCA on where exploitation is occurring and periodic stock surveys undertaken by NW IFCA.

On balance, the third option is believed to be most appropriate, as it allows the entire area to be classified giving the flexibility to exploit new patches as they are discovered and allows the RMP to be situated at the point considered most vulnerable to contamination where stocks are present. If upon repositioning of the RMP levels of contamination are detected which breach classification thresholds, the competent authority will be automatically alerted as soon as the result is generated and so will be able to pursue an appropriate course of action such as temporary closures, investigations and changes to the classification.

Even though they may vary significantly in numbers and sizes mussel stocks are likely to be relatively consistent from year to year in terms of location, which is dictated by the presence of a suitable hard surface. Therefore a fixed RMP is appropriate for this species. It is not possible to sample the south bank training walls to the east of the Crossens Pool channel for access reasons.

For the offshore dredge fishery this report will recommend a sampling point considered most representative of potential peak levels of contamination within the zone for which classification has been requested, should this classification still be required. If the area requiring classification expands in the future, the RMP should be relocated based on this principle. The LEA and NW IFCA are unable to sample this fishery and the harvester will not be able to collect samples before the fishery is classified and in operation as the costs involved would be prohibitive.

This creates a difficult and at present unique situation which will require some pragmatic decisions to be made at a policy level. The use of a more easily retrieved surrogate species (i.e. bagged mussels) may be appropriate in the first instance and the NW IFCA may be able to service such an arrangement, although it is possible that bagged mussels would not remain *in situ* for various reasons. Also, without parallel sampling of the clam species alongside, it is uncertain how representative bagged mussels would be. The NW IFCA is equipped with day grabs, but the collection of clam samples using these is likely to be laborious at best. There are possibly other methods by which clams may be sampled which may merit further evaluation, such as small toothed dredges. Permission from Natural England may be required for clam sampling depending on the method used.

A classification is unlikely to be awarded unless some samples of clams are submitted, and if bagged mussels are to be used for ongoing classification some parallel sampling of these alongside the clams would be required to determine if they are suitably representative.

POLLUTION SOURCES

FRESHWATER INPUTS

The Ribble estuary receives runoff from a large catchment area of 2115km^2. The catchment is largely rural, supporting pastures and some arable land, but also contains some significant urban areas. The main freshwater input to the estuary is the River Ribble. The River Douglas and several minor rivers also drain to the main Ribble estuary channel below the tidal limit of the Ribble but well upstream of the fishery and before the estuary widens. The Crossens has a highly engineered catchment area of 131km^2 and discharges via a pumping station across the intertidal sandflats just to the west of the cockle bed at Georges Brow before joining the main Ribble channel. Therefore, the vast majority of freshwater inputs enter the area via the main Ribble channel upstream of the fisheries so in general freshwater borne contamination will have the greatest influence towards the head of the estuary and in the vicinity of the main channel, although there will be a more localised influence in the vicinity of the Crossens. These freshwater inputs are the pathways by which the vast majority of contamination (agricultural and urban runoff, sewage discharges) are conveyed into the estuary so RMPs should generally be set at locations most exposed to these inputs.

Runoff volumes are on average highest in the autumn and winter, although high flow events may arise at any time of the year. As well as carrying higher volumes of more contaminated runoff, hydraulic transit times will be faster during high flow events decreasing the potential for bacterial die off, so significantly higher contamination loads will transported during high flow conditions.

Human Population

The total resident population within the Ribble catchment area was just under 1.5 million at the last census in 2001. Most of the population is concentrated in several large conurbations including Preston which lies at the head of the Ribble estuary and the smaller coastal towns of Lytham and Southport which border the outer estuary. The rural parts of the catchment are sparsely populated, particularly the upper reaches. Significant increases in the population within the area will occur during the summer holiday period, mainly within the coastal towns such as Lytham St. Annes and Southport.

Sewage Discharges

A series of water company treatment works are responsible for the majority of the sewage related *E. coli* loading which the estuary receives on a daily basis. Most of these discharge to watercourses which in turn discharge to the estuary well upstream of the fishery, so their combined inputs will be conveyed towards the fishery via the main estuary channel. Four of these (Southport, Preston, Hesketh Bank, Wigan/Skelmersdale) now receive UV treatment, greatly reducing their bacterial loadings and the final effluent of three of these generally carried very low concentrations of faecal coliforms, with higher levels at the Wigan/Skelmersdale works which discharges to the River Douglas. UV plants are scheduled to be installed at several more major STWs within the area over the next few years, promising further reductions in the *E. coli* loading. There are significant volumes of sewage discharges to the Crossens catchment, but the main sewage works here (Southport STW) is UV treated. Therefore, RMPs sited towards the head of the estuary and the main estuary channel would be best placed to capture contamination originating from most sewage works, although some will arrive into the estuary via the Crossens Pool.

A large number of intermittent discharges serve the sewerage networks and some of these have regularly spilled large volumes of storm sewage. This would account for a significant proportion of the sewage related bacterial loading the estuary receives at times. Their locations and hence the geographic profile of their impacts is generally similar to that of the major continuous discharges, i.e. mainly to the upper estuary and tributaries thereof and with some to the Crossens. One exception to this of particular significance to the mussel fishery is the Fairhaven PS as it discharges within the mussel beds and regularly spills large volumes. There are also significant numbers of small private discharges to watercourses draining to the estuary, but their cumulative effects are likely to be very minor in relation to the water company discharges.

AGRICULTURE

About 463,000 sheep and 118,000 cattle were present within the Ribble estuary catchment at the time of the 2009 agricultural census, as well as 2.1 million poultry and 23,000 pigs. The majority of agricultural land is pasture which is primarily used for grazing sheep in the upper catchment and for dairy farming in the lower catchment. There are some significant areas of arable/horticulture farming in the lower lying Crossens and Douglas catchments. On a more local scale livestock are grazed on the salt marshes bordering the estuary from April to September. Grazing animals on pastures will directly deposit faeces *in situ*, which will be carried to coastal waters via land runoff, or in the case of those grazing saltmarsh, via tidal inundation. Manure from grazing livestock housed indoors during the winter, pig and poultry farms and sewage sludge will be applied to agricultural land, including arable land. This may also be carried into watercourses via land runoff, but on a more localised and possibly more acute basis. The magnitude of *E. coli* fluxes through watercourses will be highly rainfall dependent.

Therefore it is concluded that the spatial pattern of impacts will be almost entirely dictated by the locations of the watercourses draining to the estuary, i.e. increasing towards the head of the estuary and towards the main Ribble channel within the estuary. A smaller hotspot may arise where the Crossens flows through the intertidal area and water ebbing from the numerous creeks draining the saltmarshes are also likely to be subject to some livestock contamination whilst grazing animals are present.

It is likely that there is some seasonality in the *E. coli* loadings carried to the estuary from agricultural sources. Numbers of grazing animals on pastures is highest in the summer, so peak levels of contamination from these may 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. During winter grazing animals may be transferred indoors, where their manure will be collected for later application to agricultural land. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Manures from pig and poultry operations and sewage sludge may be spread on land at any time of the year, depending on crop cycles, ground conditions and permitted loadings.

BOATS

Only relatively small vessels (yachts, cruisers, fishing boats etc) can navigate the estuary. Of these, the more sizeable vessels with onboard toilets are presumed most likely to make overboard discharges. There are marinas at Preston, on the Douglas and on the Dow but none have sewage pumpout facilities. Volumes of recreational boat traffic are reported by the Royal Yachting Association as 'moderate' within the estuary and are likely to be highest during the summer. Boats navigating the estuary will generally use the main river channel throughout most of its extent and either the South Gut channel or the trained channel in the outer reaches so shellfish in the vicinity of these paths may be at most risk from contamination originating from boat traffic. Impacts are expected to be minor at most relative to other sources and the timing, location and frequency of overboard discharges are difficult to predict so boats will have no material bearing on the sampling plans.

WILDLIFE

The Ribble estuary attracts major aggregations of overwintering wildfowl and waders. An average total count of around 243,000 waterbirds within the Ribble estuary has been reported in recent years. Smaller but nevertheless significant numbers of gulls (about 20,000 pairs) breed in the estuary over the summer. Therefore birds are likely to be a significant source of diffuse contamination to the estuary, particularly during the winter months. The larger areas of saltmarsh and intertidal habitats are located on the south side of the estuary. Birds foraging on the intertidal areas supporting the shellfisheries will deposit faeces direct to the intertidal zone, perhaps more so towards the high water mark, although the distribution of this may be patchy and somewhat unpredictable. Contamination from those foraging or roosting on the saltmarsh will be conveyed to coastal waters through the numerous creeks via runoff or tidal inundation. Therefore, impacts may be greater within the inshore areas and on the south side of the estuary and near any tidal drainage channels, but on the whole may be considered as diffuse. Impacts from this source will be significantly higher during the winter. No other wildlife populations which may affect the sampling plan have been identified.

DOMESTIC ANIMALS

Dogs are exercised on the beaches along this coast and so also represent a potential minor source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on beaches adjacent to urban areas, i.e. Southport and St. Annes.

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 3.1 and Figure 3.1. The two main contaminating influences have been identified as land runoff from a large predominantly agricultural catchment with significant urban areas and a large number of sewage discharges, both continuous and intermittent which serve the populations within this catchment. The amount of *E. coli* carried into the estuary from these sources increases significantly under wet conditions. Other potential sources which are likely to impact on the shellfish in the Ribble estuary include diffuse inputs the large population of waterbirds that overwinters in the estuary and possibly some minor impacts from dogs exercised on the beaches of Southport and Lytham St. Annes. The vast majority of contamination from sewage discharges and land runoff will enter the main Ribble channel upstream of the fishery, so the patterns by which water from this channel disperses across the shellfish beds is of primary importance to the sampling plan. Other sources which may influence the sampling plans include runoff from the Crossens catchment and effluent from the Southport STW, both of which arrive in the estuary via the Crossens Pool and intermittent discharges to the Southport and Lytham St. Annes shore, particularly the Fairhaven PS which discharges within the mussel beds. Diffuse inputs from birds and dogs, whilst they may be a contaminating influence and may be of increasing significance closer to the high water mark are considered a diffuse input so will be of lesser relevance to the sampling plan. No significant sources of contamination have been identified in the vicinity of the offshore clam fishery, but it is possible that it is impacted to some extent by the plume from the Ribble estuary.

Table 3.1 Qualitative assessment of changes in pollution load within the Ribble estuary.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Continuous sewage discharges	red	red	red	red	red	red	red	red	red	red	red	red
Land runoff	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
Waterbirds	red	red	red	orange	orange	orange	orange	orange	orange	orange	red	red
Domestic animals	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange	orange

Red - high risk; orange - moderate risk.

HYDRODYNAMICS

The estuary is trumpet shaped, with large intertidal areas in its outer reaches bisected by the main river channel, so the potential for dilution increases rapidly as the estuary widens. Therefore there is a presumption for higher levels of contamination towards the head of the estuary, particularly as the main sources (rivers and sewage outfalls) discharge to the narrow upper reaches. The southern part of the outer estuary is more extensive than the northern part, and there are several shallow drainage channels crossing the intertidal area on the south side. The bathymetry of the drainage channels and sandbanks within the outer estuary has evolved gradually over the years and this is likely to continue to do so. Outside of the estuary and intertidal areas the bathymetry gently slopes away to a depth of about 5-8m about 6km off from the mean low water mark where the clam dredge fishery is located.

The tidal range is relatively large. Tidal streams flow into the estuary on the flood and out of the estuary on the ebb, with the directions of the main flows aligning with the main tidal channels, such as the main Ribble channel, the South Gut, the Penfold Channel and the Crossens Pool. Shellfish at lower elevations and in close proximity to these channels may be subject to greater impacts from any shoreline sources as they will be more exposed to water draining away from inshore areas towards the end of the ebb tide. Flows are fastest in the main Ribble channel, where the tidal excursion on spring tides is in the approximate order of 15km. Outside of the estuary, tidal streams slow to about a third of the velocity within the main channel and the ebb plume is carried in the general direction of the clam fishery. It is unlikely that it has much impact there as water from within the estuary would not quite reach the bed on a single spring ebb tide and there is very high dilution potential in the open waters of the Irish Sea.

The majority of freshwater inputs enter within the narrow upper reaches of the estuary upstream of the shellfisheries. The volumes of freshwater entering the estuary are low compared to the tidal exchange and the estuary is well mixed, so density driven circulation is unlikely to be of importance within the outer estuary. Given the shape of the estuary and the location of the freshwater inputs salinity is likely to decrease significantly towards its head. As riverine inputs are likely to be responsible for a significant proportion of the contamination within the estuary, this salinity gradient is likely to translate to a similar underlying gradient in *E. coli* levels.

Strong winds are likely to modify circulation patterns at times, with the prevailing westerly wind tending to push surface currents up estuary. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. The area is exposed to a fetch of about 200km across the Irish Sea so significant wave action will arise here at times and this may re-suspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides.

A hydro-environmental modelling study (based on STW inputs before the improvements started in the late 1990s) predicted increasing levels of faecal coliforms towards the head of the estuary, with highest levels in the upper reaches of the main channel and during spring tides, within the Crossens Pool channel. No contaminating influence from the Ribble was predicted at the offshore clam beds.

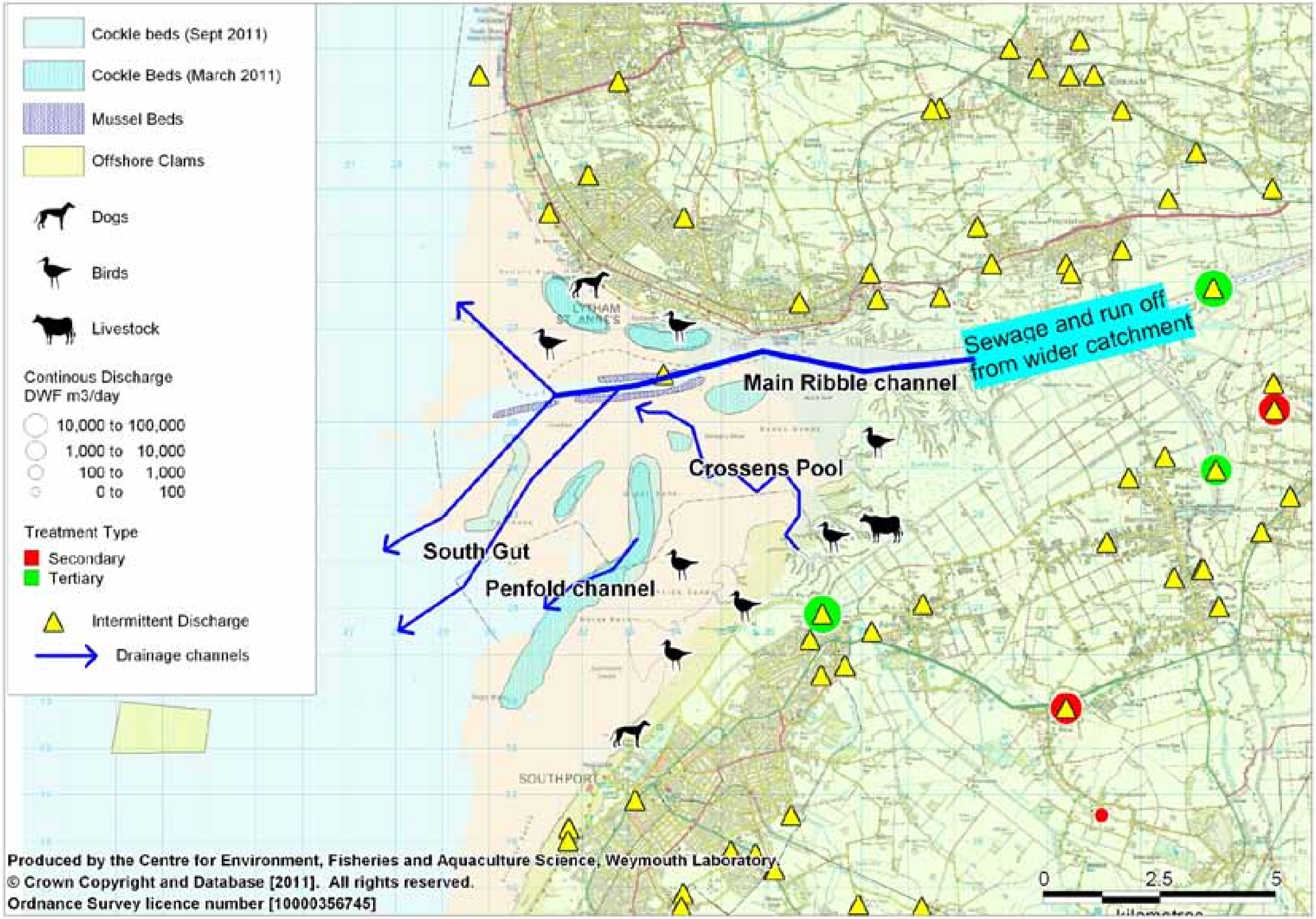


Figure 3.1 Significant sources of microbiological pollution to and main drainage channels of the Ribble estuary.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

Water samples taken under the Bathing Waters monitoring programme from Southport, St Annes and St Annes North gave very similar distributions of faecal coliforms results. Levels of faecal coliforms in paired (same day) samples from St Annes and St Annes North were highly correlated, suggesting that these two monitoring points are subject to similar sources. Similar comparisons could not be made with Southport. At the two St Annes sites (but not Southport) higher levels of faecal coliforms were generally recorded once the tide had started to ebb suggesting up estuary sources are of importance here. A significant tendency for higher results was associated with both rainfall and river discharge and this tendency was strongest at St. Annes and weakest at Southport, suggesting that the influence of freshwater inputs (and possibly CSO discharges) is greatest towards the head of the estuary and/or the main Ribble channel. Levels of faecal coliforms in water samples taken under the Shellfish Waters monitoring programme showed some seasonality with results highest on average during the autumn and also showed positive relationships with rainfall and river discharge.

Classification monitoring samples have only been taken from three locations since 2000 including two cockle RMPs sampled from 2000-2005 and one mussel RMP which is still currently sampled. Results were quite variable at all sites, ranging from class A to class C or prohibited levels. A comparison of results from the two cockle RMPs showed higher average results and a higher proportion of C results at the site north of and closer to the main Ribble channel.

No clear overall temporal pattern was seen in *E. coli* results aside from an increase in the number of lower results in mussels since 2009, although high results have continued to occur. Significant seasonal variation was only detected at the cockle RMP on the south side of the estuary, where results were highest on average in the summer and lowest in the spring. Significant positive correlations with both rainfall and river discharge were found at the mussel RMP, but this could not be investigated at the cockle RMPs as rainfall/river discharge data was not available for the period in which they were sampled. There was some very tentative evidence of elevated results at the mussel RMP following sewage spills from the nearby Lytham PS.

A bacteriological survey was undertaken to investigate geographical variation across the area and to ensure sufficient results were available to allow the area to be classified in the required timescale. A total of 48 cockle samples were taken across five locations, two on the north side of the estuary and three on the south side of the estuary. Levels of contamination were highest on average at the site closest to the head of the estuary and the main Ribble channel (Grannys Bay West, geometric mean of 630 *E. coli* MPN/100g). Results at the other site on the north side of the estuary were lower (North Run, geometric mean of 338 *E. coli* MPN/100g) supporting the general conclusion of higher results towards the head of the estuary and the main Ribble channel. Results from the RMPs on south side of the estuary were generally lower, with the highest individual results from each of the three sites all lower than the highest individual results from the two sites on the north side. The three RMPs were all on the main Penfold Channel bed and from north east to south west (i.e. in order of proximity to the main Ribble channel) the RMPs were named Penfold North, Penfold South and Penfold West. Geometric mean results were similar at Penfold North and Penfold West (geometric means of 105 and 159 *E. coli* MPN/100g respectively) and higher at Penfold South (geometric mean of 436 *E. coli* MPN/100g). Only six samples were taken from Penfold West, but 11 samples were taken from Penfold North and Penfold South. A comparison of paired results from samples taken from Penfold South and Penfold North revealed not only significantly higher results at Penfold South but that results from these two sampling locations were strongly correlated on a sample by sample basis, suggesting that they are under the influence of similar sources, with Penfold South more directly affected. It is presumed that Penfold South is more exposed to contamination ebbing through the Penfold channel. Therefore it is concluded that levels of contamination generally decrease away from the head of the estuary and the main river channel. On the south side some consistent spatial fluctuations in levels of contamination were found, but these do not align with distance from the head of the estuary and may be related to proximity to drainage routes through the intertidal area.

Reduced sampling for seasonal or inactive fisheries

The cockle fishery is closed for the four months from May to August inclusive and the clam fishery is closed for the six months from October to March. Classification of these species for commercial harvest is only required whilst the fisheries are open. It is normally encouraged that monthly monitoring should continue throughout the year (e.g. to check that Prohibited level results do not occur during the closed season). If this is not possible then 12 samples should be taken during the season itself and the preceding 2 months. If the season is short (<6 months) then samples may be taken at fortnightly intervals if necessary. The minimum interval between samples in any event should be 7 days.

The mussel fishery has been inactive for several years and if this situation is likely to continue the sampling frequency may be reduced to quarterly. This would result in the fishery becoming ‘temporarily declassified’ at the next classification annual review, which is undertaken every September. When the classification requires reinstatement, monthly sampling should recommence and a classification can be awarded on receipt of the first monthly sample result.

Overall conclusions regarding the sampling plan

An analysis of pollution sources, water circulation patterns and sampling results suggests that there are increasing levels of contamination towards the head of the estuary and there may be a tendency for higher levels of *E. coli* in shellfish closer to the Crossens Pool and the main tidal drainage channels in the outer estuary. The offshore clam fishery may be impacted in a minor way by the remnants of the Ribble plume, which arrives there from the north east. Zoning and monitoring arrangements should reflect these conclusions.

Cockles

For cockles, it is desirable for the entire intertidal area between Southport and Lytham St Annes to be classified to allow exploitation as new patches appear or are discovered without continual revision of the classification zones and sampling plans. Due to the large area and the variation in levels of contamination across it several zones and RMPs will be needed. RMPs should be positioned within these zones where it is suspected that levels of contamination will be highest and where stock is present. When stock distribution changes significantly the RMPs may therefore require relocation. The cockle bed at Georges Brow is problematic in that it lies where levels of contamination are likely to be highest within the southern half of the estuary, but is inaccessible to sampling officers. Should this bed require classification based on an accessible RMP, samples taken from the upstream end of the Grannys Bay cockle bed may be best representative, although this would be further downstream and on the other side of the main channel.

Razors
Should classification of the intertidal areas be required for razors or other clam species, the sampling plan for cockles may be applied as required using the species of interest instead of cockles, although the NW IFCA indicate that there is no commercial interest in these stocks at present.

Mussels
Mussels are only present in significant numbers on the training walls, so only this area requires classification. An RMP located as close as possible (on the east west plane along which the tides flow) to the Fairhaven PS outlet would capture peak levels of contamination in the event of a spill. It is also towards the upstream end of the bed so would be reasonably well placed to capture contamination arising from upstream sources.

Offshore clams
For the offshore clam fishery, the zone requiring classification has been clearly identified by the applicant. It is unlikely that there is much variation in levels of contamination within this area given that no sources have been identified within a few kilometres of it, but an RMP on the north eastern corner would lie closest to the Ribble estuary and should be adequately representative. Should the area requiring classification expand by up to 4km in any direction in the future then the RMP should be relocated to the new north east corner if this point has moved. Should it expand further than this, a new sanitary assessment may be required. The sanitary survey can only formally recommend sampling all four clam species on at least 10 occasions to derive a classification based on current policies. It is recognised that this may not be achievable, and so may require some discussions between the classification team at Cefas and the FSA to develop an acceptable alternative strategy, should classification of this fishery still be required.

4. RECOMMENDATIONS

4.1 For cockles, it is desirable for the entire intertidal area between Southport and Lytham St Annes to be classified to allow exploitation as new patches appear or are discovered without continual revision of the classification zones and sampling plans.

4.2 The following zones and RMPs are proposed for cockles.

Table 4.1 Explanation of recommended cockle zones and RMPs

Zone name	Main influences	RMP location
Lytham East	Ebb flow from upper estuary via main river channel	As far south and east within this zone as stocks extend
Lytham West	Ebb flow from upper estuary via main river channel	As far south and east within this zone as stocks extend
Georges Brow	Ebb flow from upper estuary via main river channel	As far north and east within this zone as stocks extend. It is recognised that NW IFCA will not be able to access this bed routinely. If sampling here is not possible and this bed requires classification, the Lytham East would be the most appropriate alternative to use.
Penfold North	Water draining through the Crossens Pool, water draining from the main river channel down the South Gut	As far north within this zone as stocks extend
Penfold South	There may be an area of higher contamination at the head of the Penfold Channel where several smaller drainage channels appear to merge, as suggested by bacteriological survey results	As close as possible to SD 3294 2220 (confluence of drainage channels) as stocks extend
Foulnaze	Ebb flow from main river channel through the South Gut.	As far north and east within this zone as stocks extend

The location of these RMPs may be moved at any time by NW IFCA or the LEAs on the basis of intelligence and stock surveys, but should always be as close as possible to the point or line indicated in Table 4.1. A record of the locations sampled on each occasion should be made via GPS to 10m accuracy and communicated back to Cefas and the FSA. Sampling may either be undertaken on a monthly basis or 12 samples taken may be taken annually at regular intervals least 1 week apart during the open season and the two months preceding it (July to April inclusive).

4.3 For mussels, the zone boundaries can be decreased to encompass only the areas where mussels are present and the RMP should be located as close as possible (on the east west plane along which the tides flow) to the Fairhaven PS outlet (provisionally SD 3376 2603, subject to confirmation of the exact location of the outfall and availability of stock). If the fishery for this species remains inactive sampling frequency may be reduced to quarterly and the zone temporarily declassified. If and when the fishery requires reclassification, monthly sampling should recommence and a classification can be awarded on receipt of the first monthly sample result.

4.4 For the offshore clam fishery, the RMP should be located at the north east corner of the classified zone (SD 2402 1882). Should the area requiring classification expand by up to 4km in any direction in the future then the RMP should be relocated to the new north east corner if this point has moved. Current guidance indicates that all four species should be sampled. It is recognised that this will present practical difficulties and that the Cefas classification team and the FSA may have to develop an acceptable alternative strategy between them. For provisional classification 10 sets of samples should be taken at least 1 week apart. For ongoing classification sampling may either be undertaken on a monthly basis or 12 samples should be taken annually at regular intervals at least 1 week apart during the open season and the two months preceding it (February to September inclusive). Mersey Port Health is advised to check with the applicant that classification is still required before any sampling is undertaken.

4.5 Should classification of the intertidal areas be required for razors or other clam species, the sampling plan for cockles may be applied as required using the species of interest instead of cockles and sampled using the method by which they are commercially gathered.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Ribble
Cefas Main Site Reference	M046
Cefas Area Reference	Ribble
Ordnance survey 1:25,000 map	Southport & Chorley (285) and Blackpool & Preston (286)
Admiralty Chart	Ribble estuary (1981)

Shellfishery

Species/culture	Cockles (*Cerastoderma edule*)	Wild (intertidal)
	Mussels (*Mytilus* spp.)	Wild (intertidal)
	Razor clams (*Ensis* spp.)	Wild (offshore)
	Thick trough shell (*Spisula solida*)	Wild (offshore)
	Soft shell clams (*Mya* spp.)	Wild (offshore)
	Otter shell clams (*Lutraria lutraria*)	Wild (offshore)
Seasonality of harvest	Closed season from 1st May to 31st August (intertidal cockles) Closed season from November to March (offshore mixed clam fishery)	

Local Enforcement Authorities

Name	Mersey Port Health Authority Trident House 105, Derby Road Liverpool L20 8LZ
Environmental Health Officer	Glyn Cavell
Telephone number (	0151 233 2576
Fax number Ê	0151 233 2580
E-mail š	Glyn.Cavell@liverpool.gov.uk
Name	West Lancashire Borough Council Robert Hodge House Stanley Way Skelmersdale West Lancashire WN8 8EE

Environmental Health Officer	Mary Joy
Telephone number (	01695 585265
Fax number Ê	01695 585126
E-mail š	Mary.Joy@westlancs.gov.uk
Name	Fylde Borough Council Environmental Health and Housing Department Public Offices 292 Clifton Drive South Lytham St Annes FY8 1LH
Environmental Health Officer	Sara Carrington
Telephone number (	01253 658627
Fax number Ê	01253 713113
E-mail š	SaraC@fylde.gov.uk

REQUIREMENT FOR REVIEW

The location of the cockle beds may change significantly each season and new patches may be discovered at any time which may necessitate the relocation of the RMPs. This may be undertaken on an *ad hoc* basis by the LEAs and NW IFCA on their behalf. The exact location sampled should be recorded the location of the new RMPs should be communicated to Cefas and FSA.

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 2017. 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 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within the Ribble estuary.

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Lytham East	TBA	Lytham East	SD 3466 2670	53°43.95' N 02°59.52' W	*C. edule*	Wild stocks	Hand (rake)	Hand (rake)	100m	Monthly (or 12 samples taken at least 1 week apart during the open season and the two months preceding it)	Moveable RMP to be located as far south and east within this zone as stocks extend
Lytham West	TBA	Lytham West	SD 3246 2698	53°44.09' N 03°01.52' W	*C. edule*	Wild stocks	Hand (rake)	Hand (rake)	100m	As above	Moveable RMP to be located as far south and east within this zone as stocks extend
Georges Brow	TBA	Georges Brow	SD 3586 2588	53°43.52' N 02°58.41' W	*C. edule*	Wild stocks	Hand (rake)	Hand (rake)	100m	As above	Moveable RMP to be located as far north and east within this zone as stocks extend. It is recognised that NW IFCA will not be able to access this bed routinely. Should this bed require classification the Lytham East RMP would be most appropriate if the suggested Georges Brow RMP cannot be sampled.
Penfold North	TBA	Penfold North	SD 3387 2479	53°42.92' N 03°00.21' W	*C. edule*	Wild stocks	Hand (rake)	Hand (rake)	100m	As above	Moveable RMP to be located as far north within this zone as stocks extend

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Penfold South	TBA	Penfold South	SD 3294 2220	53°41.52' N 03°01.02' W	*C. edule*	Wild stocks	Hand (rake)	Hand (rake)	100m	As above	Moveable RMP to be located as close as possible to SD 3294 2220 as stocks extend
Foulnaze	TBA	Foulnaze	SD 3063 2465	53°42.82' N 03°03.15' W	*C. edule*	Wild stocks	Hand (rake)	Hand (rake)	100m	As above	Moveable RMP to be located as far north and east within this zone as stocks extend
Ribble mussels	TBA	Fairhaven outfall	SD 3376 2603	53°43.59' N 03°00.33' W	*Mytilus* spp.	Wild stocks	Hand	Hand	10m	Monthly if classification is to be retained. Quarterly if the bed can be temporarily declassified, with monthly monitoring to resume one month before reclassification.	To be located as close as possible to the Fairhaven PS outfall. The true location of this outfall and stock availability are to be confirmed.

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Off Southport	TBA	Off Southport	SD 2402 1882	53°39.62' N 03°09.07' W	*Ensis* spp.	Wild stocks	Dredge	Dredge	100m	10 samples at least 1 week apart for provisional classification. Monthly thereafter (or 12 samples taken at least 1 week apart during the open season and the two months preceding it and not less than 1 week apart)	To be located at the north eastern corner of the area. Should the area requiring classification expand by up to 4 km in any direction the new RMP should be relocated to the new north east corner if this has moved.
Off Southport	TBA	Off Southport	SD 2402 1882	53°39.62' N 03°09.07' W	*Spisula solida*	Wild stocks	Dredge	Dredge	100m	As above	As above
Off Southport	TBA	Off Southport	SD 2402 1882	53°39.62' N 03°09.07' W	*Lutraria lutraria*	Wild stocks	Dredge	Dredge	100m	As above	As above
Off Southport	TBA	Off Southport	SD 2402 1882	53°39.62' N 03°09.07' W	*Mya* spp.	Wild stocks	Dredge	Dredge	100m	As above	As above

Figure 5.2 Recommended classification zone boundaries and RMP locations for cockles. Dotted lines show LEA boundaries.

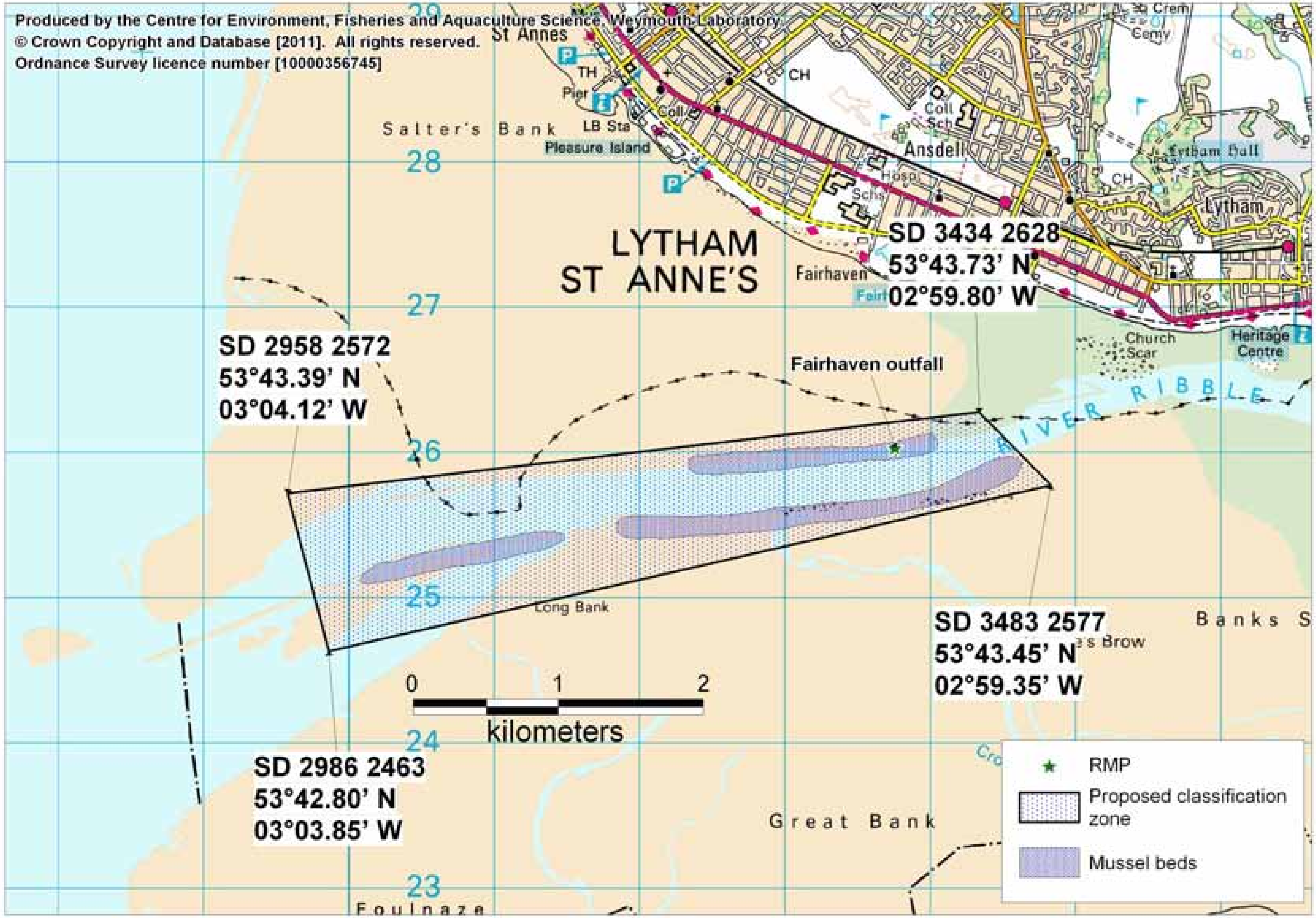


Figure 5.2 Recommended classification zone boundaries and RMP locations for mussels. Dotted lines show LEA boundaries.

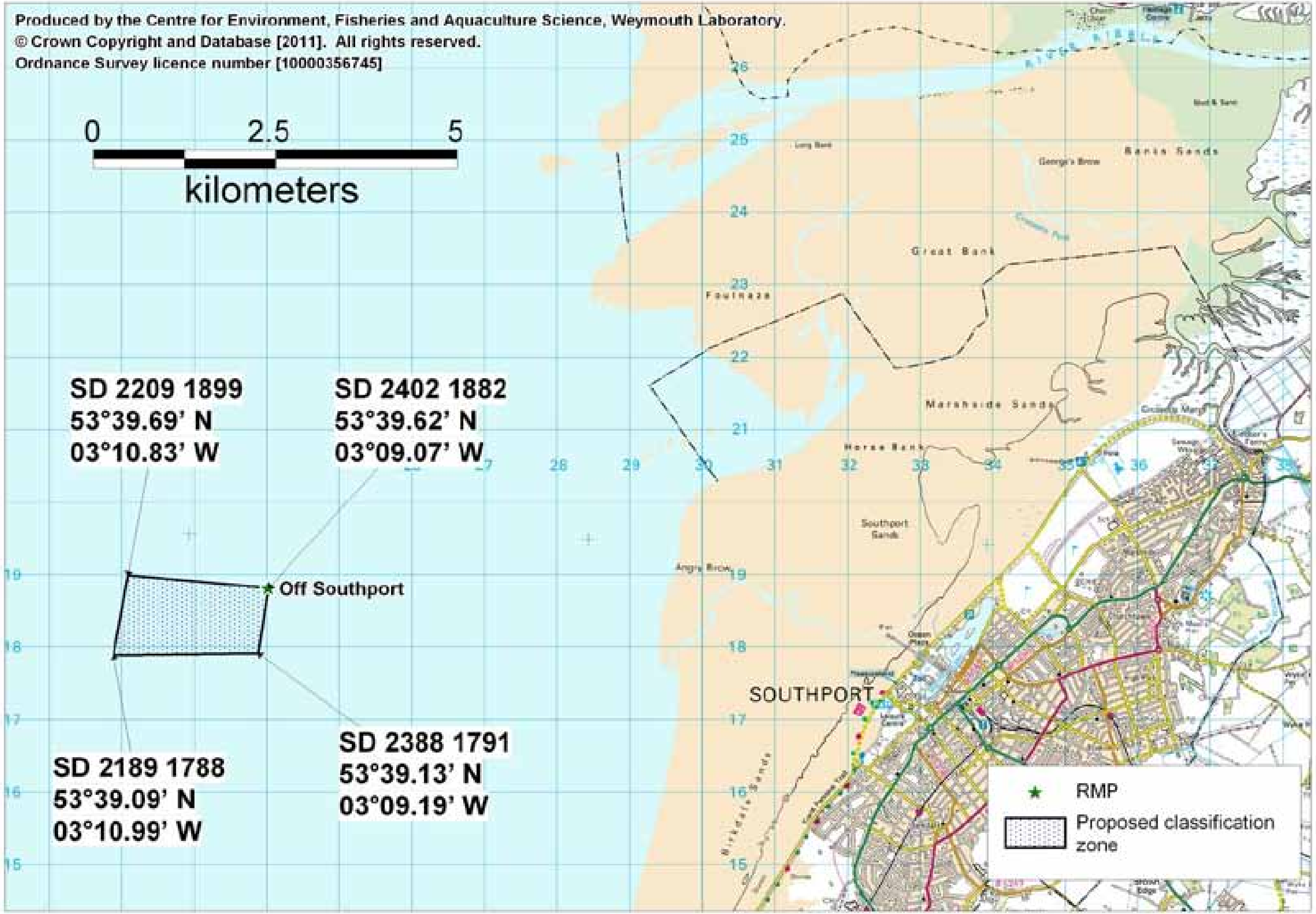


Figure 5.3 Recommended classification zone boundaries and RMP locations for the offshore clam fishery.

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary totally or partially included within the Ribble catchment area is shown in Figure I.1. Total resident human population in the area shown was just under 1.5 million at the last census in 2001.

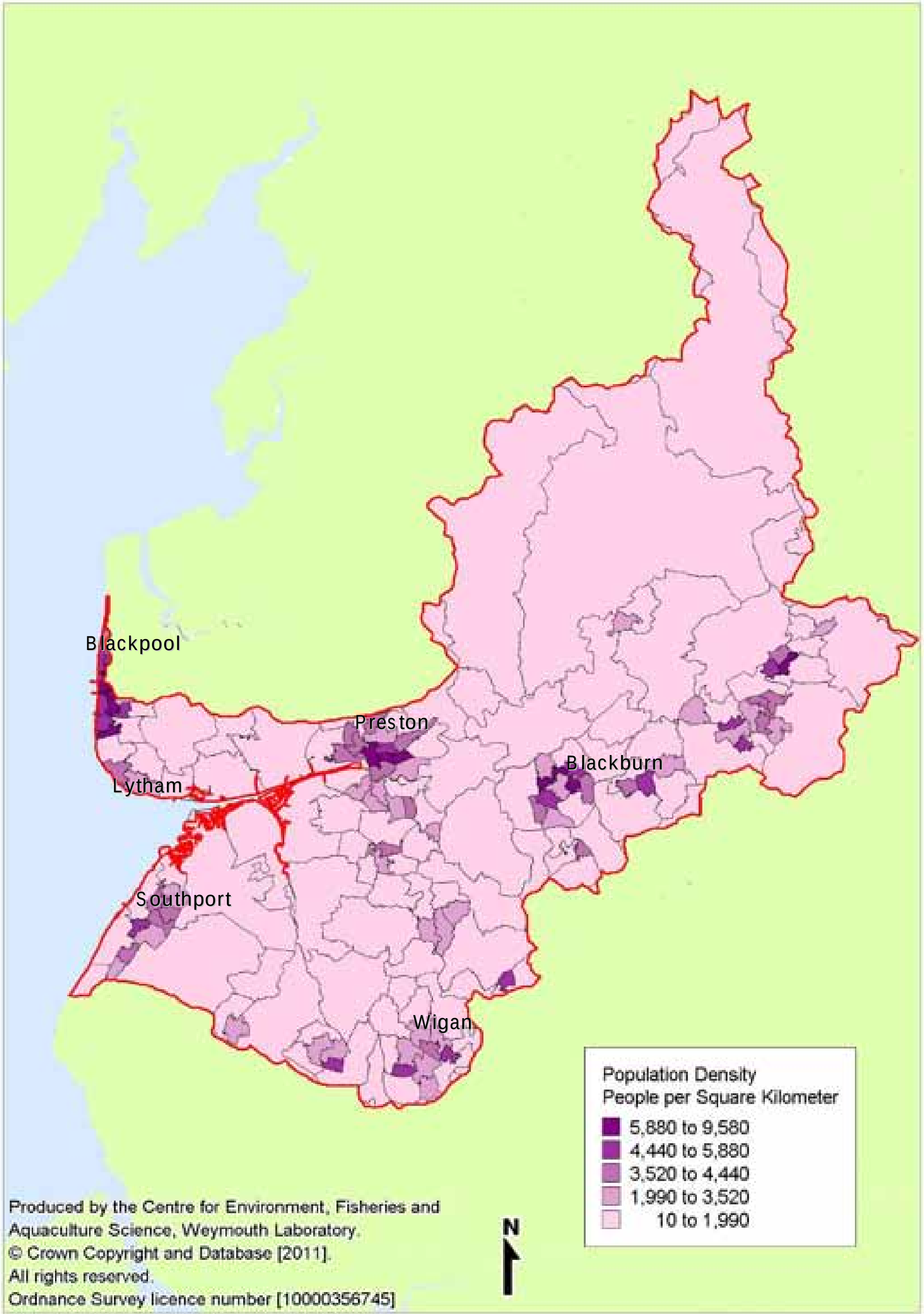


Figure I.1 Human population density in the Dee and Mersey estuary catchments.
Source: ONS, Super Output Area Boundaries (Middle layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

The majority of the catchment area is sparsely populated, particularly within the upper reaches. Most of the population is concentrated in a few large conurbations including Preston which lies at the head of the Ribble estuary. The coastal towns of Lytham and Southport border the shore adjacent to the fisheries and the Ribble estuary catchment also includes part of the town of Blackpool. About 76.6 million tourist days were reported within Lancashire in 2008 (Lancashire County Council, 2011) so tourism is significant within this geographical area. The most popular holiday town is Blackpool, but Southport and Lytham St. Annes are also seaside resorts so influxes of visitors and corresponding increases in sewage volumes will occur here during the summer months

APPENDIX II
HYDROMETRIC DATA: RAINFALL

North West England is one of the wetter regions of England and Wales, but rainfall varies considerably across the region. Areas with higher elevations tend to receive higher rainfalls, so highest rainfalls will arise in the upper Ribble catchment. Figure II.1 presents a boxplot of daily rainfall totals by month for a rain gauge located in Southport.

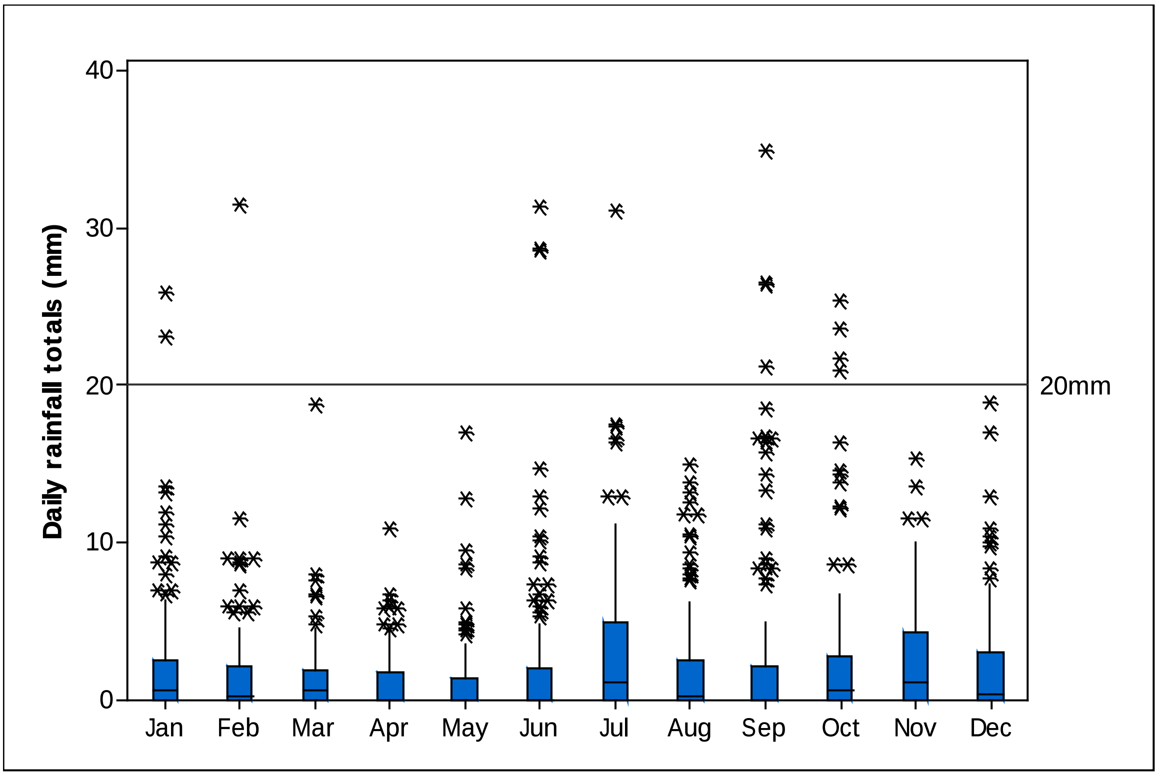


Figure II.1 Boxplot of daily rainfall totals at Southport Greenbank, May 2007 to Feb 2011.

Southport is located in the low lying coastal district and fluctuations in rainfall throughout the year are not particularly marked. No rainfall was recorded on 42% of days. Figure II.1 shows high average daily rainfalls in July. This was due to a series of wet Julys and this pattern is not apparent in long term averages for the region (Met Office 2011). Excluding July, rainfall was highest on average during the autumn and lowest on average during the spring. High rainfall events with over 20mm in a single day were recorded in January, February, June, July, September and October but these were infrequent (1% of days).

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 XI and XII.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

Figure III.1 Freshwater inputs to the Ribble estuary.

The catchment area for the Ribble estuary totals 2115km^2. The main freshwater input to the estuary is the River Ribble. The River Douglas and several other minor rivers also drain to the main Ribble estuary channel below the tidal limit of the Ribble but well upstream of the fishery. The Crossens discharges across the intertidal sandflats just to the west of the cockle bed at Georges Brow before joining the main Ribble channel. Some of these watercourses have flow gauging stations. The locations of the furthest downstream gauging stations for each subcatchment are shown in Figure III.1, summary statistics for each are presented in Table III.1 and boxplots for each by month are presented in Figure III.2.

Table III.1 Summary discharge statistics for selected gauging stations within the Ribble catchment (from NERC 2011).

River	Station	Catchment area (km^2)	Mean Daily Flow ($m^3 s^{-1}$)	Flow exceeded 95% of the time ($m^3 s^{-1}$)	Flow exceeded 10% of the time ($m^3 s^{-1}$)
Ribble	Samelsbury	1145	33.23	4.62	81.3
Darwen	Blue Bridge	128	4.23	1.28	8.77
Douglas	Wanes Blades	198	4.16	1.12	8.53

As may be expected, the vast majority of freshwater discharging into the Ribble estuary originates from the main river Ribble, where some very high flow events of over 300 cumecs were recorded. Similar seasonal patterns of discharge are apparent in Figure III.2, with highest flows on average from November to January. A secondary peak is seen in July, although this is likely to be due to the unusual series of wet Julys during the period presented (Appendix II). Therefore lowest flows are generally anticipated from April to August, but this nevertheless highlights the potential for high flow events during the summer. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation, less transpiration and soils are more likely to be waterlogged so higher proportion of rainfall will run off. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters. They will also decrease residence time in rivers and estuaries and so contamination from more distant sources may have an increased impact during high flow events.

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}. The main river Ribble is about 110km in length, so hydraulic transit times from sources in the upper areas of the Ribble catchment are in the order of days. Therefore bacteriological contamination originating from the upper catchment is likely to suffer significant die off before reaching the estuary.

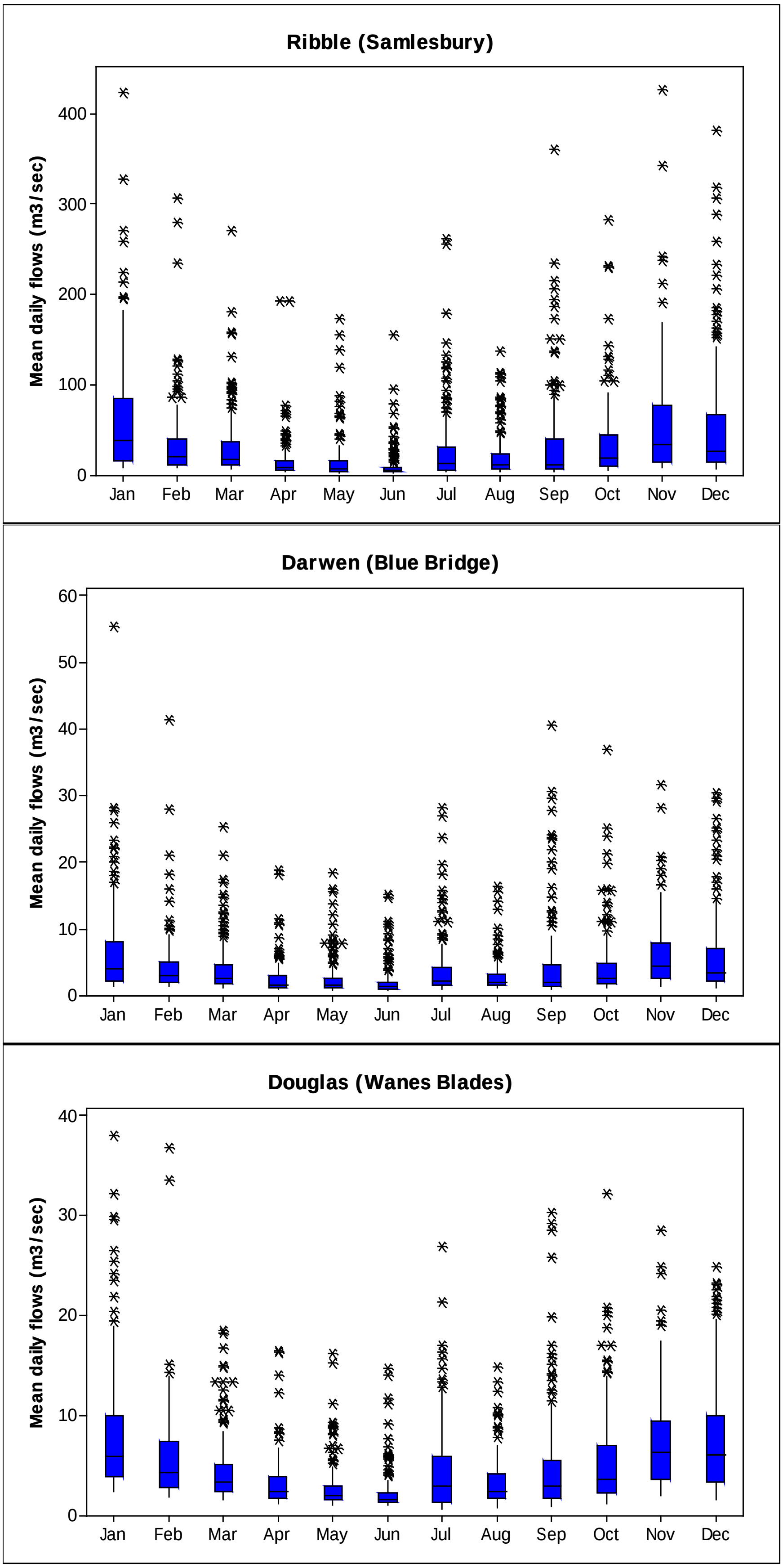


Figure III.2 Boxplots of mean daily flow records from selected gauging stations, March 2006 to February 2011 (Data from the Environment Agency)

No flow gauging records were available for the Crossens catchment, which has an area of 131km^2. This is a highly engineered catchment drained by a pumping station (with a tidal gate) fed by complex network of field drains, with a series of satellite pumping stations raising water from lowlying areas to the main drains. It is managed with the aims of abstraction for crop irrigation and flood defence. From April to August water is held back for irrigation and little is pumped out (Environment Agency, 2007) and water that is pumped out may have been in residence for a considerable period which would promote bacterial die off. Pumping rates are higher throughout the rest of the year and may be increased at any time following heavy rainfall to reduce the risk of flooding. As well as the main pumped outlet at Crossens, there is a smaller pumping station at Banks Marsh and water from this flows through saltmarsh before joining the Crossens channel in the intertidal area.

In conclusion, the vast majority of freshwater inputs enter the area via the main Ribble channel upstream of the fisheries so in general freshwater borne contamination will have the greatest influence towards the head of the estuary and in the vicinity of the main channel. The Crossens channel which lies between the main Southport cockle beds and the bed at Georges Brow is likely to have some localised influence in its vicinity. Runoff volumes are generally highest in the autumn and winter, although high flow events may arise at any time of the year. Contamination from sources in the upper Ribble catchment may be of limited significance as hydraulic transit times are such that significant bacterial die off should occur, particularly under low flows.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

The Ribble estuary is trumpet shaped, about 11km wide between Southport and St. Annes piers and about 22km long from Preston Dock to the end of the main river channel. An area of up to 100km^2 is exposed at low tide, consisting of gently undulating sand banks in the outer estuary where the cockle beds are located and more silty sediments in the inner estuary. It is bisected by the main river channel which is straightened and stabilised by training walls flanking most of its length. The intertidal area is larger on the south side of this channel. Some parts of the saltmarshes flanking the estuary are inundated with seawater on the larger tides. Given the shape and bathymetry of the estuary, the potential for dilution is much lower within its inner reaches so there will be a general presumption for higher levels of contamination towards its head,

There are several tidal drainage channels crossing the intertidal area off Southport. The River Crossens Channel meanders in a northwesterly direction from Crossens Marsh and joins the main Ribble channel and carries runoff from the Crossens catchment. The South Gut channel emanates in a south westerly direction from a gap in the south training wall of the main Ribble channel. The Penfold Channel to the south of this follows a similar path but loses its identity some distance south of the Ribble channel. Further south still, the Bog Hole channel meanders in a seaward direction from the end of Southport Pier. Topography of sandbanks and paths of channels have been subject to change over the decades (Holden, 2008) and this evolution is likely to gradually continue. No significant tidal drainage channels are apparent on the north side of the main Ribble channel off Lytham St. Annes.

Outside of the estuary and intertidal areas the bathymetry is uncomplicated, gently sloping away to a depth of about 5-8m 6km off from the low water mark where the clam dredge fishery is located.

Environment Agency holds LIDAR (Light Detection And Ranging) remote sensing data obtained in 1999 for this section of the Fylde coast which would provide updated and more accurate bathymetry for this area, notably the pattern of drainage channels through the cockle beds. This could be made available to Cefas on behalf of FSA at a cost of approximately £2,000. At this point in time, it is not considered a priority to purchase this within the resource available for this work.

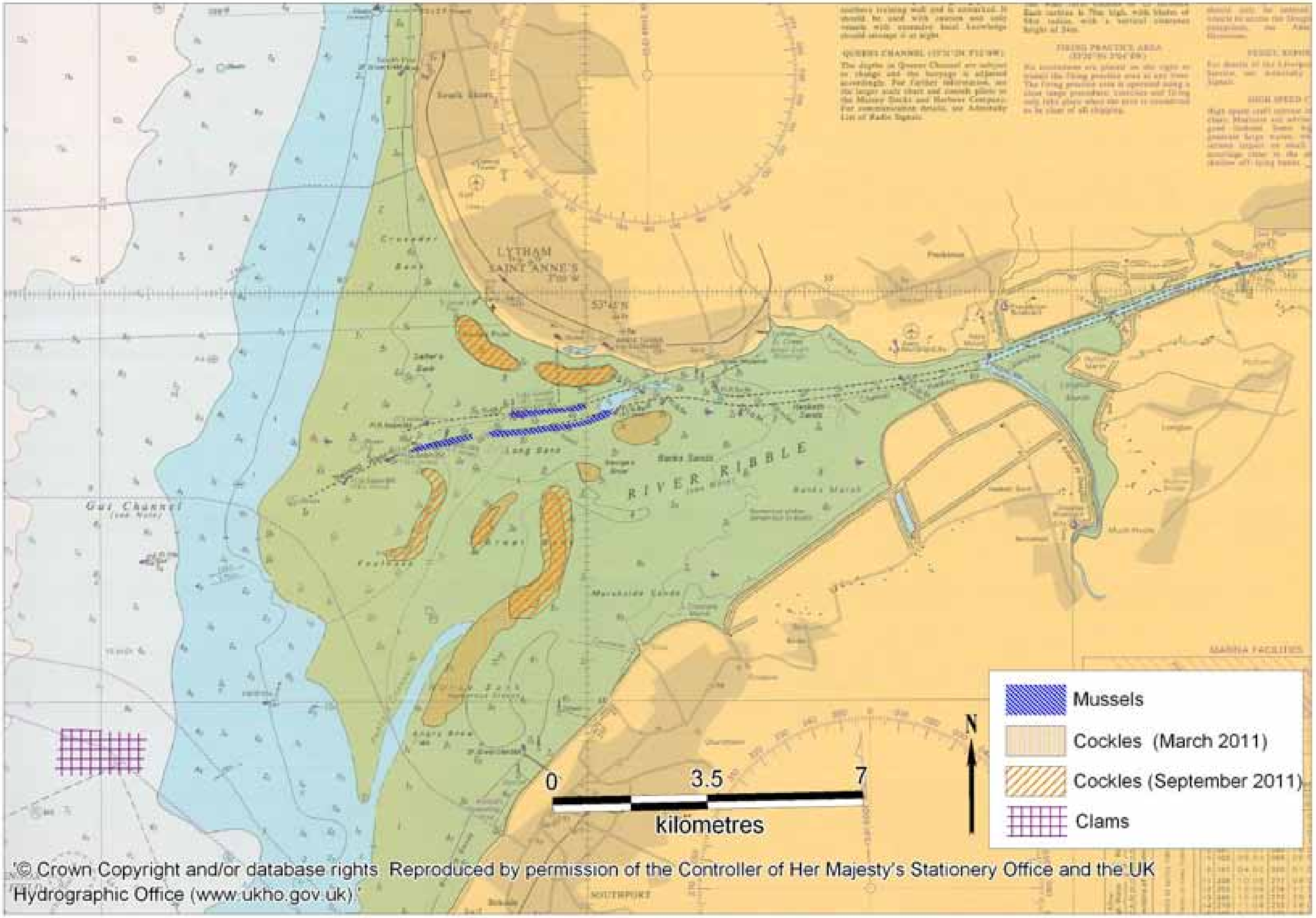


Figure IV.1 Bathymetry chart of the Ribble estuary

APPENDIX V
HYDRODYNAMIC DATA: 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 the south, with tides arriving almost simultaneously from these two directions, meeting around the Isle of Man, then flowing east towards the Ribble estuary. After high water, the tide reverses to flow west. Tidal amplitude is large and tides are semi-diurnal (i.e. two tidal cycles per day).

Table V.1 Tide levels and ranges at Blackpool, Preston and Formby.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Blackpool	8.90	7.00	2.80	1.00	7.90	4.20
Preston	5.30	3.30	0.10	0.10	5.20	3.20
Formby	9.00	7.30	2.90	1.00	8.00	4.40

Data from the Proudman Oceanographic Office

The hydrodynamic regime in the area is dominated by tidally driven processes interacting with the sandbanks and shallow channels, as well as the presence of a major freshwater input. The nearest tidal diamond is some 22.5km offshore from the Ribble Estuary at Jordan’s Spit buoy (53°36’10 N, 3°19’00 W). Peak flow on the flood tide (rates at spring tide) is in the order of 0.72m/s in a west to east direction. On the ebb, the flow is in the order of 0.57m/s in the opposite direction. This provides a reasonable approximation of the pattern of tidal currents over the offshore clam fishery. Figures V.1 and V.2 present depth averaged tidally driven mid-flood and mid-ebb flows on spring tides within the outer estuary (Halcrow, 2010).

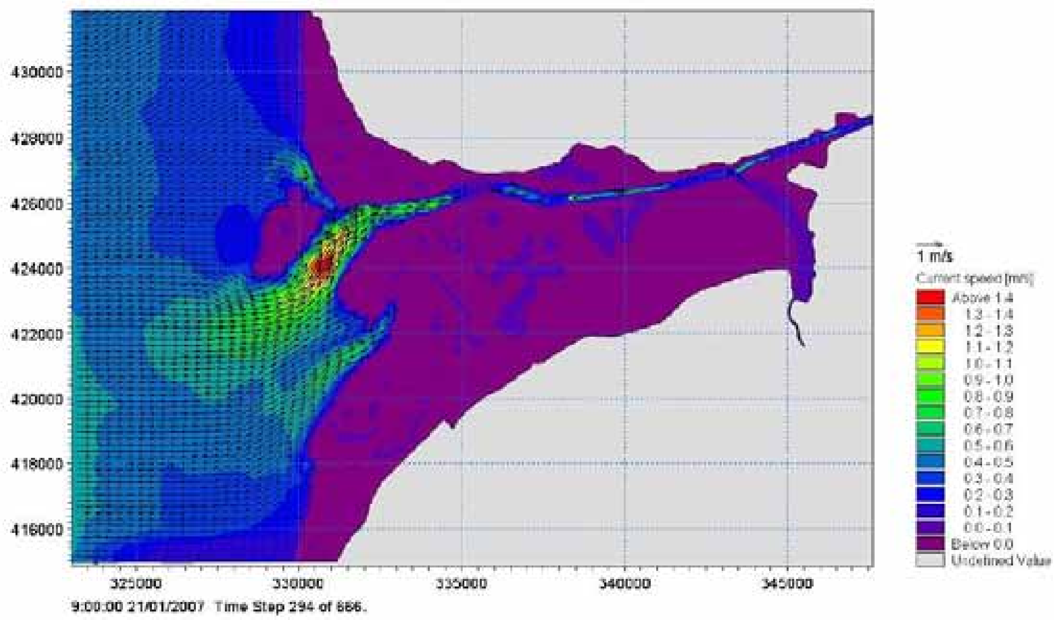


Figure V.1 Modelled spring tide mid-flood flows within the Ribble estuary.
Reproduced with permission from Halcrow, 2010.

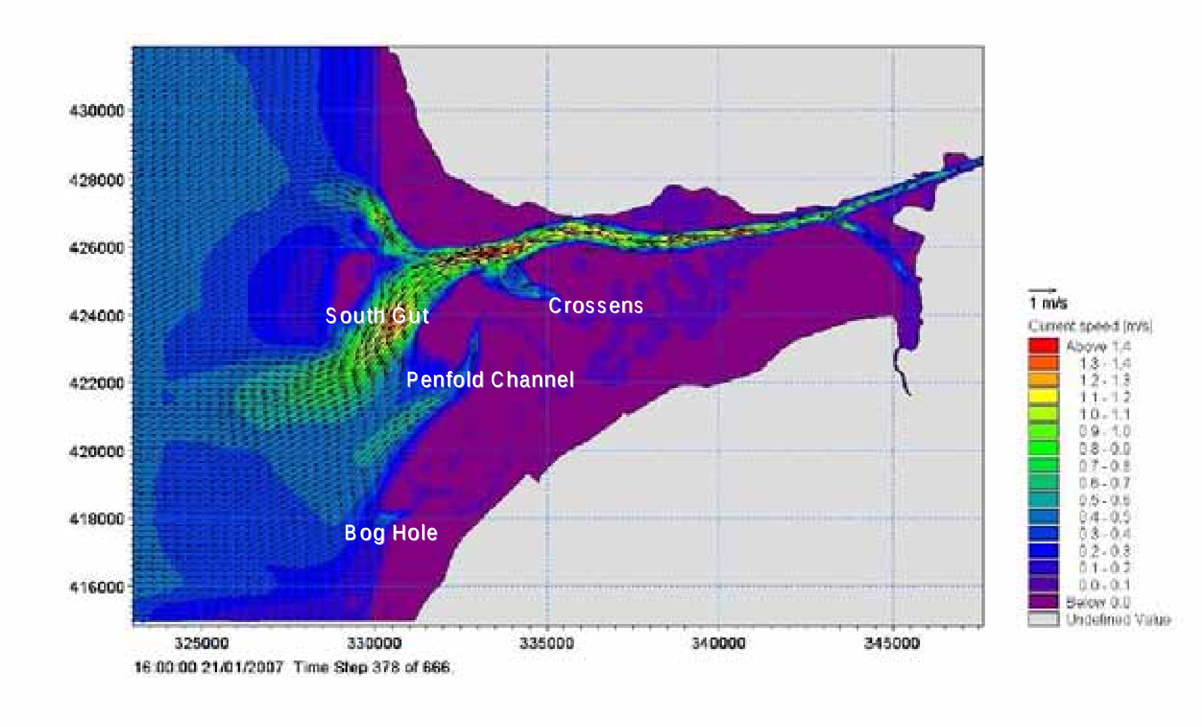


Figure V.2 Modelled spring tide mid-ebb flows within the Ribble estuary.
Reproduced with permission from Halcrow, 2010.

Tidal currents are bi-directional, flooding into the estuary and ebbing out from it. The flood tide will convey relatively clean water originating from the open Irish Sea into the estuary, whereas the ebb tide will carry contamination from shoreline sources out through the estuary and into contact with the shellfish beds. Strongest currents of up to about 1.5m/s are found within the main channel, through which water and hence contamination originating in the upper estuary drains. In the outer estuary the main flows split into two streams around a sandbank at the mouth where a higher proportion of the water passes through the South Gut, which lies adjacent to the South Gut cockle bed. After passing through the South Gut, this stream slows to about 0.5m/s and continues in the direction of the offshore clam bed. The Penfold channel and the Crossens Pool are significant channels for water draining from the intertidal area off Southport. Shellfish at lower elevations and in close proximity to these channels may be subject to greater impacts from any shoreline sources as they will be more exposed to water draining away from inshore areas towards the end of the ebb tide. The mussel beds on the training walls are likely to be most vulnerable to contamination ebbing out through the main channel.

A very approximate estimate of tidal excursion within the main channel on spring tides is in the order of 15km. A release of Rhodamine dye tracer was made from Clifton Marsh STW at spring high water. The dye was subsequently detected on the following flood tide on the beach at Lytham as far as the Fairhaven lake, about 13km from the release site (Environment Agency, 1998). Therefore, contamination from sources in the vicinity of Preston would not quite reach the closest shellfishery over the course of a single spring ebb tide. The tidal prism (the volume of water exchanged on each tide) decreases exponentially towards the head of the estuary (Halcrow, 2010) indicating a decreasing potential for dilution in the upper reaches.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. The majority of freshwater enters the estuary at Preston and all riverine inputs except for the Crossens enter upstream of the shellfisheries into the narrow inner estuary. The flow ratio (freshwater input: tidal exchange) is low and the system is well mixed (Futurecoast, 2002), so density driven circulation is unlikely to be of importance within the outer reaches of the estuary at least. Given the shape of the estuary and the location of the freshwater inputs, salinity will decrease towards its head, although the profile of this gradient will vary with tidal cycles and river discharge. As riverine inputs are likely to be responsible for a significant proportion of the contamination within the estuary, this salinity gradient is likely to translate to a similar underlying gradient in *E. coli* levels.

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^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. The area is most exposed to the west, which is the prevailing wind direction. A modelling study concluded that the plume shape and movements along the Ribble estuary and Fylde coast were noticeably affected by the wind magnitudes and directions (Kashefipour *et al*, 2002). Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. Winds from the prevailing westerly direction will tend to push surface water up estuary. Winds with a northerly element will push any contamination from the main channel in a southerly direction towards Southport and those with a southerly element will push it towards Lytham St. Annes. As well as driving surface currents, onshore winds will create wave action. There is a long fetch across the open Irish Sea to the west, so energetic wave action will occur in the area during strong westerly winds. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides.

APPENDIX VI
METEOROLOGICAL DATA: WIND

The strongest winds are associated with the passage of deep depressions and the frequency and strength of these depressions is greatest in the winter (Met Office, 2011). As Atlantic depressions pass England and Wales, the wind typically starts to blow from the south or southwest, but later comes from the west or northwest as the depression moves away.

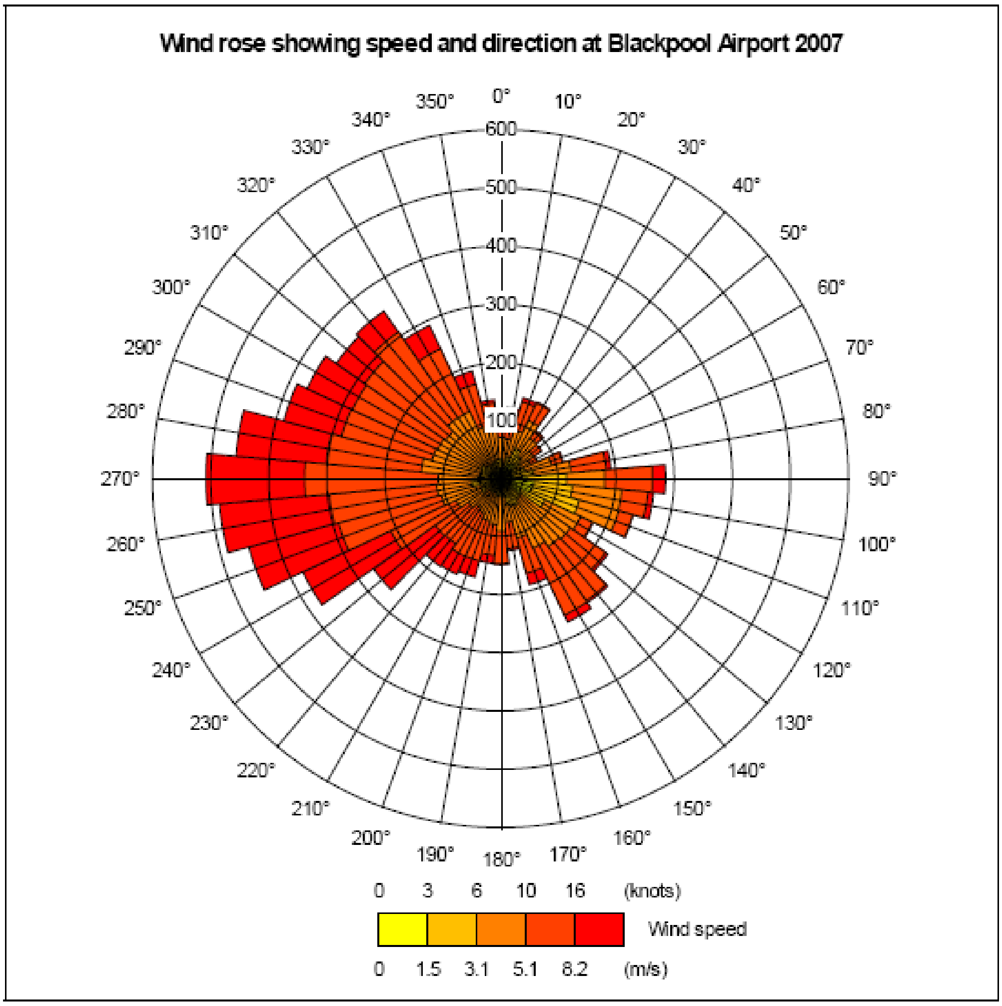


Figure VI.1 Wind speed and direction at Blackpool Airport, 2007.
Reproduced with the permission of Lancaster City Council.

Blackpool airport is located in a low lying coastal location 2.5km north of St Annes Pier, so should be representative of conditions within the survey area although only one years data is presented. The prevailing wind direction is from the west and the strongest winds almost always blow from that direction. The Ribble estuary is exposed to the open Irish Sea to the west and winds from this direction travels across up to 200 km of open water before reaching the shore.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Figure VII.1 presents a map showing the locations and sizes of continuous water company sewage discharges to the Ribble catchment. Table VII.1 shows further details of these discharges.

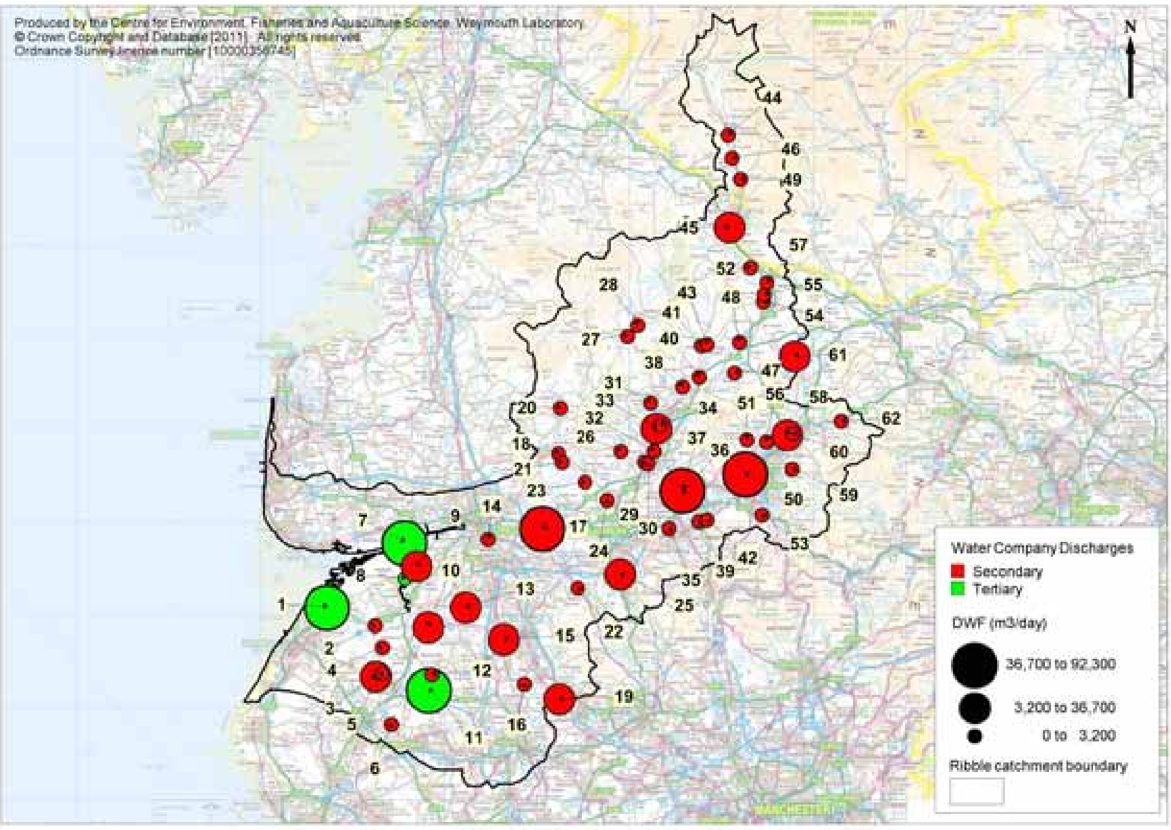


Figure VII.1. Locations and size of major continuous water company sewage discharges

Aside from the first five discharges in Table VII.1 which discharge within the Crossens catchment, all of these sewage works discharge to subcatchments which drain to the estuary well upstream of the fishery. Therefore, the majority of sewage related contamination would reach the shellfisheries via the main Ribble estuary channel, with some additional inputs via the Crossens Pool.

There has been an ongoing programme of targeted improvements to discharges impacting the Ribble estuary over the last decade driven by failures to meet Bathing Waters bacteriological standards. As a result discharges from Hesketh Bank. Southport, Wigan and Preston STWs now undergo UV treatment and those at Walton-le-Dale, Blackburn and Croston STWs are due to have UV plants installed over the next few years. Results of bacteriological testing of final effluents from three of the UV treated discharges are shown in Table VII.2. For calculating the geometric mean, sample results of 0 cfu/100ml were adjusted to 0.5 cfu/100ml as these results would likely have been originally reported as <1 cfu/100ml.

Table VII.1 Details of major continuous water company sewage discharges to the area

ID	Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)*	Receiving Water
1	Southport WWTW	SD3717020890	37,900	Tertiary	$6.5x10^{10}$	Crossens Pool
2	Mere Brow STW	SD4240018870	1,300	Secondary	$4.3x10^{12}$	Tarleton Runner
3	Burscough STW	SD4245013430	8,070	Secondary	$2.7x10^{13}$	Boathouse Sluice
4	Holmeswood STW	SD4316016580	-	Secondary	No DWF	Catchwater Drain
5	Tarsclough Lane WWTW	SD4318013850	-	Secondary	No DWF	Marsh Moss
6	Westhead STW	SD4414008280	521	Secondary	$1.7x10^{12}$	Castle Brook
7	Preston WWTW	SD4556027880	79,600	Tertiary	$6.9x10^{11}$	River Ribble Estuary
8	Hesketh Bank STW	SD4562023980	1,382	Tertiary	$1.1x10^{10}$	Douglas Estuary
9	Longton STW	SD4687025280	3,242	Secondary	$1.1x10^{13}$	Tarra Carr Gutter
10	Croston STW	SD4810018690	4,950	Secondary	$1.6x10^{13}$	River Yarrow
11	Wigan/Skelmersdale WWTW	SD4817012020	92,220	Tertiary	$9.6x10^{12}$	River Douglas
12	Bispham Green WWTW	SD4853013640	33	Secondary	$1.1x10^{11}$	Trib Bentley Brook
13	Leyland STW	SD5215020810	10,940	Secondary	$3.6x10^{13}$	River Lostock
14	Walton-Le-Dale STW	SD5460028200	1,300	Secondary	$4.3x10^{12}$	River Ribble Estuary
15	Chorley STW	SD5628017400	17,150	Secondary	$5.7x10^{13}$	River Yarrow
16	Coppull STW	SD5853012600	-	Secondary	No DWF	Trib Buckhow Brook
17	Blackburn STW	SD6047029410	72,000	Secondary	$2.4x10^{14}$	Hole Brook
18	Spade Mill Reservoir STW	SD6220037500	-	Secondary	No DWF	Trib for Drainage area
19	Horwich STW	SD6229010960	11,500	Secondary	$3.8x10^{13}$	Pearl Brook
20	Chipping STW	SD6244042400	150	Secondary	$5.0x10^{11}$	Chipping Brook
21	Ribchester Hospital STW	SD6263036530	-	Secondary	No DWF	Trib River Ribble
22	Abbey Village STW	SD6435022930	-	Secondary	No DWF	River Roddlesworth
23	Ribchester STW	SD6516034400	-	Secondary	No DWF	River Ribble
24	Wilpshire STW	SD6755032440	500	Secondary	$1.7x10^{12}$	Showley Brook
25	Darwen STW	SD6898024400	22,200	Secondary	$7.3x10^{13}$	River Darwen
26	Hurst Green STW	SD6910037750	-	Secondary	No DWF	Dean Brook
27	Newton-in-Bowland STW	SD6980050200	-	Secondary	No DWF	River Hodder
28	Slaidburn STW	SD7090051400	-	Secondary	No DWF	River Hodder
29	Billington STW	SD7160036600	-	Secondary	No DWF	River Calder
30	Whalley WWTW	SD7200036390	1,500	Secondary	$5.0x10^{12}$	River Calder
31	Waddington STW	SD7226042950	240	Secondary	$7.9x10^{11}$	Bashall Brook
32	Kingsmill STW	SD7265037760	-	Secondary	No DWF	Trib River Calder

ID	Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)*	Receiving Water
33	Clitheroe STW	SD7292040170	7,340	Secondary	$2.4x10^{13}$	Barrow Clough
34	Nr Clitheroe STW	SD7330040560	-	Secondary	No DWF	Pendleton Brook
35	Nr Coppy Clough STW	SD7426729372	-	Secondary	No DWF	River Hyndburn
36	Hyndburn Valley STW	SD7571033090	-	Secondary	No DWF	Hyndburn Brook
37	Hyndburn STW	SD7573033530	74,900	Secondary	$2.5x10^{14}$	River Calder
38	Grindleton STW	SD7575044720	134	Secondary	$4.4x10^{11}$	River Ribble
39	Wood Cottages STW	SD7751030140	-	Secondary	No DWF	Trib Clough Brook
40	Sawley STW	SD7754045740	-	Secondary	No DWF	River Ribble
41	Holden STW	SD7775049150	-	Secondary	No DWF	Holden Beck
42	181-183 Burnley Lane STW	SD7840030300	-	Secondary	No DWF	Castle Clough Brook
43	Bolton-By-Bowland STW	SD7840049300	-	Secondary	No DWF	Skirden Beck
44	Horton-in-Ribblesdale STW	SD8066071870	155	Secondary	$5.1x10^{11}$	River Ribble
45	Settle STW	SD8080061960	3,400	Secondary	$1.1x10^{13}$	River Ribble
46	Helwith Bridge STW	SD8111069390	-	Secondary	No DWF	Trib River Ribble
47	Rimington STW	SD8138046250	-	Secondary	No DWF	Rimington Beck
48	Gisburn STW	SD8190049520	461	Secondary	$1.5x10^{12}$	River Ribble
49	Stainforth STW	SD8199067100	-	Secondary	No DWF	Stainforth Beck
50	Burnley STW	SD8251035310	36,700	Secondary	$1.2x10^{14}$	River Calder
51	Newchurch-in-Pendle STW	SD8270039000	55	Secondary	$1.8x10^{11}$	Dimperley Clough
52	Long Preston WWTW	SD8306057620	201	Secondary	$6.6x10^{11}$	Long Preston Beck
53	Burnley Higher Timberhill	SD8433030840	4	Secondary	$1.3x10^{10}$	Soakaway
54	Halton Place East WWTW	SD8448053920	13.3	Secondary	$4.4x10^{10}$	Ged Beck
55	Halton West Ribble WWTW	SD8455054700	4.8	Secondary	$1.6x10^{10}$	Candle Rush Beck
56	Laund Farm STW	SD8483038770	-	Secondary	No DWF	Trib River Calder
57	Hellifield STW	SD8486055990	333	Secondary	$1.1x10^{12}$	Hellifield (Pan) Beck
58	Colne STW	SD8705039490	5,350	Secondary	$1.8x10^{13}$	Colne Water
59	Lane Bottom STW	SD8760035800	-	Secondary	No DWF	Pig Hole Clough
60	Greenfield HSE Farm STW	SD8764039680	-	Secondary	No DWF	Trib Colne Water
61	Barnoldswick STW	SD8785048000	6,880	Secondary	$2.3x10^{13}$	Stock Beck
62	Colne-Barnside STW	SD9290041000	-	Secondary	No DWF	Monkroyd Beck

**Based on geometric mean result from samples of final effluent for the UV treated discharges (Table VII.2) or base flow averages from a range of UK STWs (Table VII.3). These estimates are intended for comparative purposes only and bacterial loadings generated by each STW are likely to fluctuate significantly.*

Table VII.2 Summary statistics of faecal coliform results for final effluents for UV treated discharges, January 2007 to June 2011 inclusive.

	Faecal coliforms (cfu/100ml)				
Name	Number of samples	Geometric mean	Minimum	Maximum	95%ile
Hesketh Bank	112	787	<1	1,300,000	76,450
Preston	107	872	<1	160,000	82,500
Southport	109	172	<1	90,000	4,420
Wigan/Skelmersdale	106	10,364	<1	410,000	165,000

Levels of faecal coliforms found in effluents indicate that the UV plant at Southport is usually highly effective. Levels of faecal coliforms in effluents from other plants were more variable and those at the Wigan/Skelmersdale works were considerably higher on average than for the others. The bacterial loadings generated by these UV treated discharges are much lower than those generated by works of a similar size which only provide secondary treatment. It must be noted however that UV disinfection is less effective at removing viruses than bacteria. STWs with disinfection systems are required to show a 25,000fold reduction in bacterial loading across the entire works to be consented as such, whereas they are only required to demonstrate a 10fold reduction in viral loading (Environment Agency, 2001).

Table VII.3 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 sewage overflows (53)			200	$2.5x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

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

In addition to the continuous sewage discharges, there are a large number of intermittent discharges within the area. The city of Preston alone has over 100 of these. Figure VII.2 shows the location of those within about 10km of the estuary. Again, the majority discharge to watercourses draining to the upper estuary or to the estuary upstream of the fisheries. A small number discharge to the outer estuary and may therefore result in hotspots of contamination within the shellfish beds whilst they are active and so may influence the locations of any RMPs. Of these, spill records were available for the three outfalls which are labelled on Figure VII.2, for which summary statistics are presented in Table VII.4.

Table VII.4 Summary statistics of recent spill records from Fairhaven PS, Southport STW and Lytham PS

		2006	2007	2008	2009	2010
Fairhaven PS	No. spills	12	15	52	13	19
	Mean volume (m^3)*	13,036	14,114	10,085	7,047	11,285
Southport STW	No. spills	33	25	11	5	6
	Mean volume (m^3)*	18,338	22,919	43,651	20,696	48,241
Lytham PS	No. spills	3	4	11	16	14
	Mean volume (m^3)*	3,900	1,275	3,927	2,243	2,779

Averages only include spills for which volume was recorded. No data for quarter 4 in 2008 for all outlets and no data for Q2 2008 and Q4 2009 at Southport.

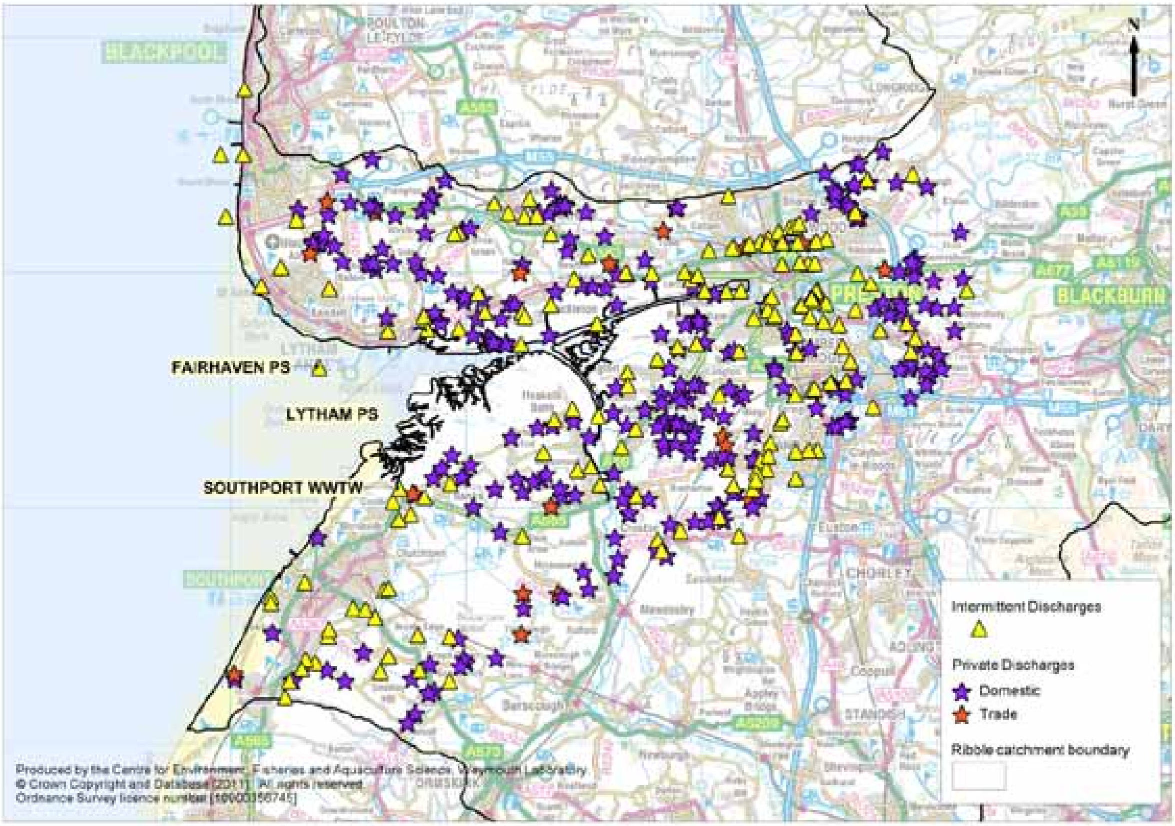


Figure VII.2 Intermittent water company discharges and private discharges in the vicinity of the Ribble estuary.

Table VII.4 indicates that high volume spills occur on a regular basis from the intermittent discharges examined. Based on values in Table VII.3, a spill of 10,000 m^3 would contain $2.5x10^{14}$ faecal coliforms, roughly equivalent to the daily loading generated by a large secondary STW serving about 375,000 people. Therefore, major additional impacts may be anticipated when such large spills occur. The Fairhaven PS outfall is likely to be of particular significance to the mussel stocks as it discharges within the mussel bed located on the north training wall. The Southport STW overflow will impact on the Crossens Pool, so sporadic but major increases in the bacterial loading carried by this watercourse may be anticipated. The Lytham PS discharges to a tidal creek on the north shore several km upstream of the fisheries, so would combine with the other inputs from up estuary. Although spill records were available for some of the other discharges further up-estuary and inland it was considered unnecessary to present detailed data on these. Spills from several of the other monitored intermittent discharges further up the estuary have occurred frequently, have often been of large volumes similar to those in Table VII.4. Contamination from such events will be carried towards the shellfishery via the main Ribble estuary channel. Storm overflow discharges will generally be associated with wet weather. A major programme of improvements to reduce the impact of these discharges is ongoing. In total schemes to reduce spills at 21 of these intermittent discharges are due to be completed between 2011 and 2014. The Environment Agency has estimated that these schemes, together with the installation of UV treatment at Blackburn, Walton-le-Dale and Croston WwTWs and reduction in the diffuse agricultural load as a result of the Catchment Sensitive Farming Delivery

Initiative in the Ribble Catchment will reduce the bacteriological load to the Ribble Estuary by 40% (Environment Agency, pers comm.).

Although the majority of properties in the Ribble catchment are connected to mains sewers, there are a significant number of small private discharges to the area, some of which discharge to soakaway and others to watercourses. Of the 286 private discharges shown on the map which contain sewage (i.e. excluding discharges such as cooling water or surface water), the average maximum permitted flow (where stated) was 3.2 m^3/day so they are generally small, with most serving one or a few properties. The majority (94%) discharge to watercourses, with the remainder discharging to soakaway or direct to the upper estuary. Therefore, most watercourses will carry some contamination from private discharges, but the cumulative bacterial loadings generated by these will be very minor in relation to those from water company discharges.

In summary, the large secondary treated water company discharges are responsible for the majority of the sewage related *E. coli* loading which the estuary receives. Most of these are discharge to watercourse well upstream of the fishery, so their combined inputs will reach the fishery via the main estuary channel. There are also significant sewage inputs to the Crossens catchment, but the main sewage works here is UV treated. A large number of intermittent discharges serve these sewage networks and some of these have regularly spilled large volumes of storm sewage. Their locations and hence the geographic profile of their impacts is generally similar to that of the major continuous discharges. Of particular significance to the mussel fishery is the Fairhaven PS as it discharges within the mussel beds. There are significant numbers of small private discharges within the catchment, but their cumulative effects are likely to be very minor in relation to the water company discharges.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Figure VIII.1 presents thematic maps of livestock densities for river subcatchment areas draining the Ribble estuary. This data was provided by Defra and is based on 2009 census data. 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 two or more of the subcatchment areas. Nevertheless, Figure VII.1 should give a broad overview of the distributions of livestock within the Ribble estuary catchment and Table VII.1 presents summary statistics by subcatchment.

Table VIII.1 Summary statistics from 2009 livestock census by subcatchment

	Numbers				Density (animals/km^2)			
Catchment name	Cattle	Pigs	Sheep	Poultry	Cattle	Pigs	Sheep	Poultry
Calder (Lancs)	13,417	1,271	84,971	300,828	42	4	267	947
Crossens	1,590	345	1,297	189,401	11	2	9	1,263
Darwen	9,386	1,318	17,001	339,386	66	9	120	2,390
Douglas	7,758	1,074	7,750	204,635	38	5	38	993
Douglas (Tidal)	4,190	2,642	7,046	329,700	43	27	73	3,399
Hodder	5,119	17	65,820	324	3	0	37	0
Lostock	4,351	284	5,822	110,644	65	4	87	1,651
Loud	12,262	**	36,123	936	135	**	397	10
Ribble	11,495	1,288	22,187	86,287	107	12	207	806
Ribble (Middle)	28,197	742	128,282	121,423	89	2	403	382
Ribble (Upper)	2,758	7	54,297	177	21	<1	411	1
T Ribble/Savick Bk/SF Drains	12,108	10,895	17,635	312,958	60	54	88	1,557
Yarrow	5,709	3,280	15,517	131,803	57	32	154	1,305
Total	118,338	23,163	463,749	2,128,500	56	11	220	1,010

*** Data suppressed for confidentiality as it relates to less than five holdings*

The agricultural land is predominantly used for grazing, with some significant areas of intensive arable/horticulture farming in the lower lying Crossens and Douglas catchments. The main Ribble catchment supports large numbers of grazing animals. The higher land in the upper catchment is mainly used for grazing sheep, whereas dairy farming predominates on the lower river. There are poultry and pig farms dotted throughout the area, mainly within the lower reaches. Of possible local significance, saltmarshes within the national nature reserve bordering the Ribble estuary are grazed by up to 700 cattle from April to September (Natural England, 2011) and it is likely that other areas of saltmarsh adjacent to the estuary are also grazed . 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).

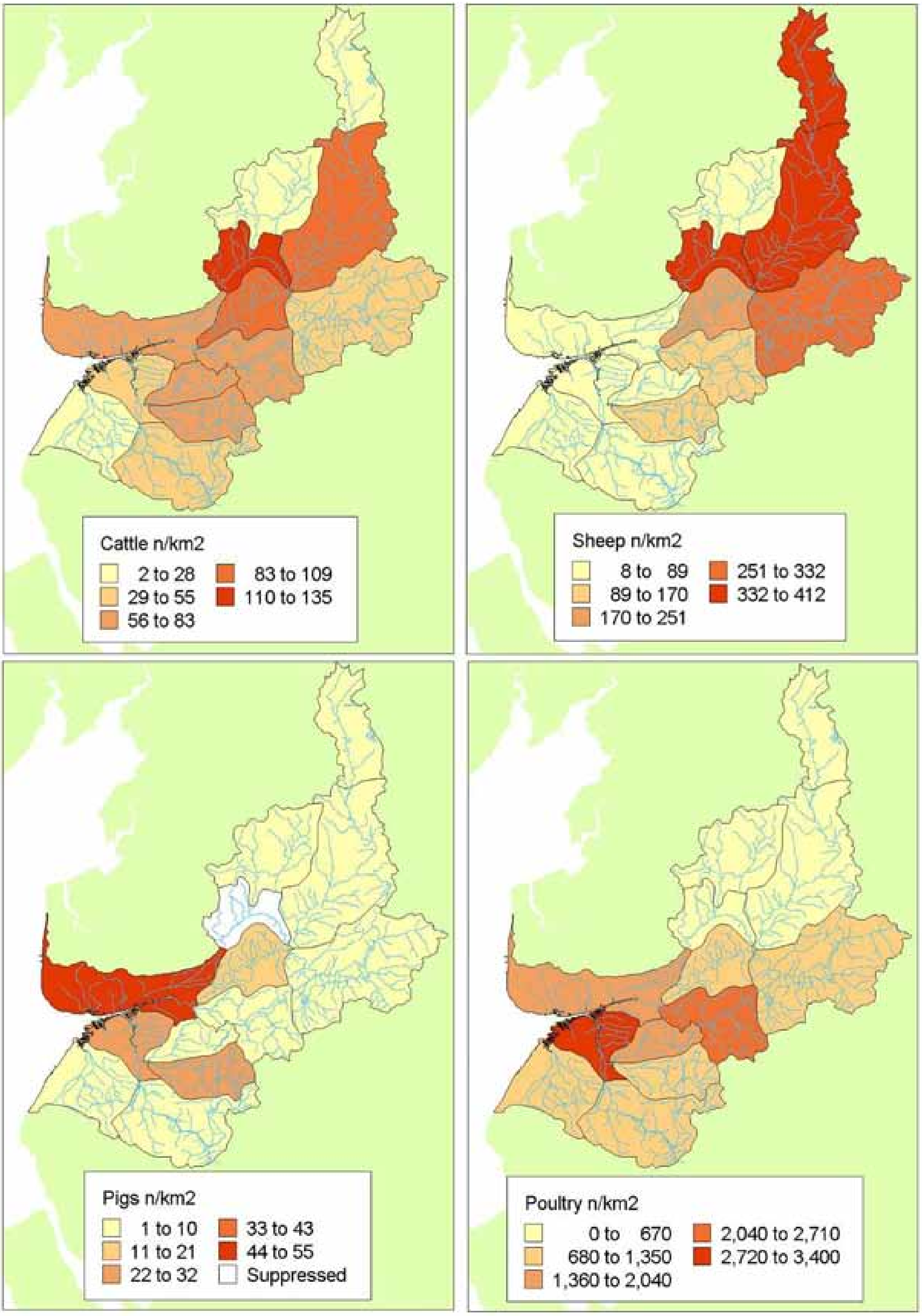


Figure VIII.1 Estimated densities of livestock by subcatchment (Data provided by Defra)

Runoff from all these catchments aside from the Crossens joins the Ribble estuary upstream of the fishery, so the vast majority of contamination of livestock origin will be carried to the fisheries via the main Ribble channel and then out through the estuary on the main ebb streams. Contamination associated with the spreading of organic manures within the Crossens catchment would be conveyed to the estuary via the Crossens Pool. Creeks draining saltmarsh areas will carry associated faecal contamination into coastal waters either via runoff or through tidal inundation. An Environment Agency study found a significant increase in levels of faecal coliforms within such creeks in the Ribble estuary as the tide started to ebb following saltmarsh inundation (Dunhill, 2003). Overall, it is concluded that RMPs located towards the head of the estuary and within or in very close proximity to the main channel would be best positioned to capture contamination of agricultural origin, although some agricultural inputs may affect the Crossens Pool and inputs of a more diffuse nature may be anticipated from cattle grazing the marshes.

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. 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. Cattle are only grazed on the marshes within the nature reserve from April to September. Manure/slurry from pig and poultry operations are typically spread on nearby farm land (Defra, 2009) and this may occur at any time of the year. Therefore peak levels of contamination from sheep and cattle may 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 more likely in winter or spring.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

Preston Port was closed to commercial traffic in 1981 and since then the navigation channel has not been maintained so no large vessels navigate the area any more. It is still possible for smaller vessels (yachts, cruisers, fishing boats etc) to navigate the estuary, which is reported to receive 'moderate' levels of recreational use (RYA, 2004). There are berths and other facilities for yachts at Preston Marina on the Ribble, Douglas Boatyard on the Douglas and Freckleton Marina on the Dow (Figure IX.1) but none of these have sewage pumpout facilities (Reeds, 2011). There is also a sailing club (Ribble Cruising Club) at Lytham St Annes, but this mainly serves smaller racing dinghies. A handful of moorings were recorded just west of this club during the shoreline survey, where seven small fishing vessels and one small yacht were seen. There is another similar club which uses the marine lake in Southport rather than coastal waters (not shown on map).

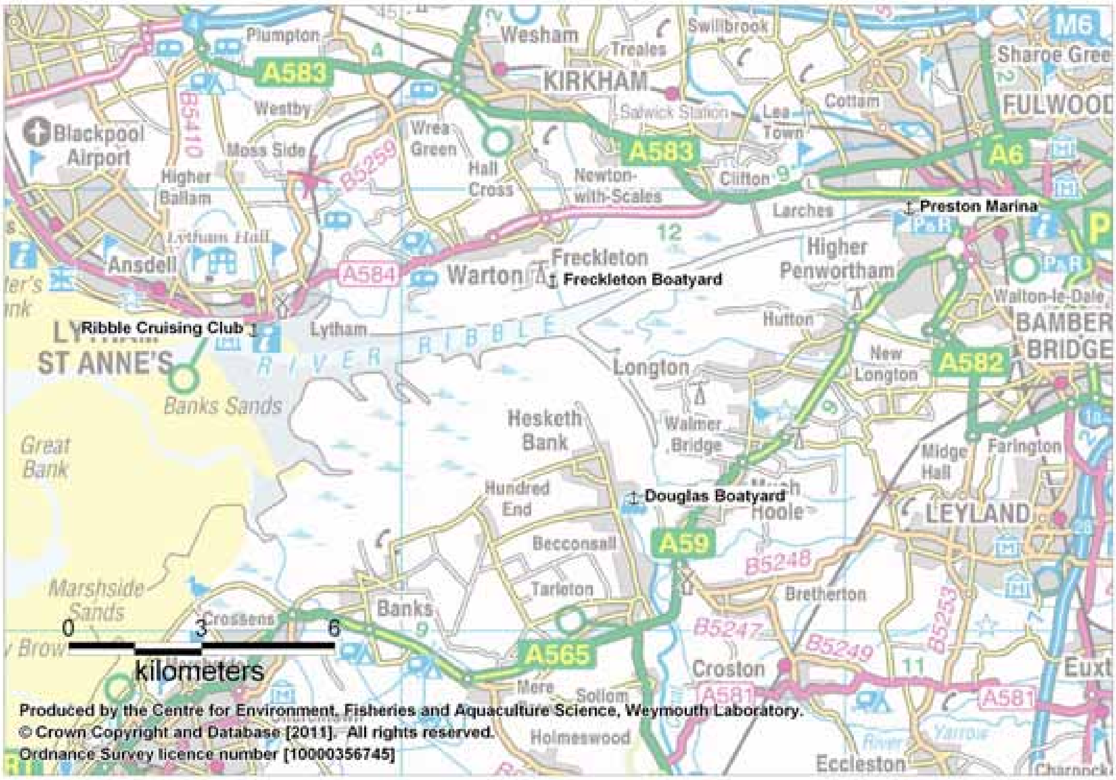


Figure IX.1 Summary of shipping and boating activity in the area.

It is likely that overboard discharges are made from time to time by the larger boats with on board toilets such as live aboard yachts as they pass through the estuary. Peak pleasure craft activity is anticipated during the summer. Boats navigating the estuary will use the main river channel throughout most of its extent and either the South Gut channel or the trained channel in the outer reaches so shellfish in the vicinity of these paths may be at most risk from contamination originating from boat traffic. Impacts are expected to be very minor and the timing, location and frequency of such occurrences are difficult to predict so boats will have no material bearing on the sampling plans.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

The Ribble estuary contains large areas of saltmarsh and wet grassland as well as the intertidal sand and mudflats where the cockle fishery is located and these features attract major aggregations of overwintering waterbirds (wildfowl and waders). 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). An average total count of 243,000 waterbirds was reported over the five winters up to 2008/9 within the Ribble estuary (Calbrade et al, 2010). It is likely that a large proportion of these mainly use the salt marshes and wetland to forage and roost, although some waders are likely to forage directly on the intertidal areas supporting the shellfisheries. Those foraging on the intertidal areas may tend to favour areas closer to the shore, as has been reported at cockle beds on the north Wirral (Cefas, 2010). Therefore, impacts from these waterbirds are likely to peak in the winter and impact on the shellfisheries via direct deposition on the intertidal or via runoff or tidal inundation of areas of saltmarsh and wetland. Whilst direct deposition from birds may be considered as a diffuse input, it is possible that impacts may be greater on the more inshore areas although there are no direct observations to support this within the survey area. Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected.

Of these birds, some species may remain in the area to breed in the summer, but the majority are likely to migrate elsewhere to breed. The seabird 2000 survey carried out counts of breeding seabirds (gulls, cormorants etc) during the early summer of 2000 (Mitchell *at al*, 2004). Large numbers of breeding seabirds were recorded on the marshes on the south side of the estuary (17,321 pairs of gulls and 98 pairs of terns) with smaller but nevertheless significant numbers on the north side of the estuary (2,452 pairs of gulls). These constitute a small fraction of the bird population reported to be present during the winter months. Again, any impacts will be either via direct deposition on the intertidal area, or via runoff or tidal inundation of the marshes and wetlands.

There are no significant seal populations in the vicinity of the Ribble estuary (SMRU, 2010) although it is likely that they visit the area in small numbers from time to time.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified. Dogs are exercised on the beaches along this coast and so also represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on beaches adjacent to urban areas, i.e. Southport and St. Annes.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are three bathing waters within the survey area, designated under the Directive 76/160/EEC (Council of the European Communities, 1975): St. Annes North, St. Annes and Southport (Figure XI.1).

Figure XI.1 Location of designated bathing waters, shellfish growing waters and associated monitoring points on the north Wirral coast.

Around 20 samples were taken from each of these sites during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples. Figure XI.2 presents box plots of all results from 2006 to 2010 by bathing water.

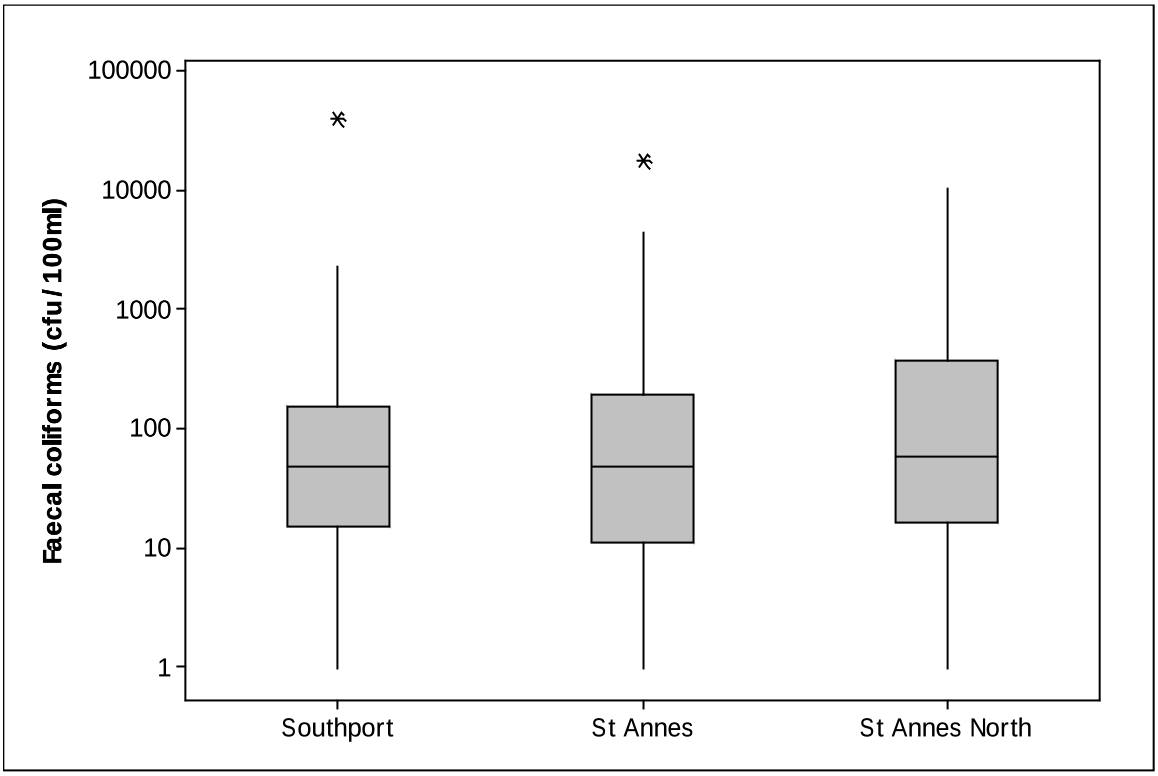


Figure XI.2 Box-and-whisker plots of all faecal coliforms results by site (2006-2010)

Table XI.1 Summary statistics for bathing waters faecal coliforms results (cfu/100ml) by site, 2006-2010.

Site	No.	Mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Southport	100	44.6	<2	39600	33%	3%
St Annes	99	54.1	<2	17600	39%	11%
St Annes North	100	63.7	<2	10500	40%	10%

In terms of geometric mean results and the distribution of results shown in Figure XI.2 all three sites were very similar, with no significant difference between them (One way ANOVA, p=0.489). A wide range of results were recorded, including some very high results of over 1000 cfu/100ml at all three sites. Southport had the lowest geometric mean result and proportion of high results. The two sites at St. Annes were generally sampled on the same day, whereas the Southport site was almost always sampled independently. Therefore it was possible to compare results of samples taken on the same day and hence under the same environmental conditions for the two St. Annes sites, but not between Southport and either of the two St. Annes sites. Figure XI.3 presents a scatter plot comparing the results of these paired samples from St. Annes and St. Annes North.

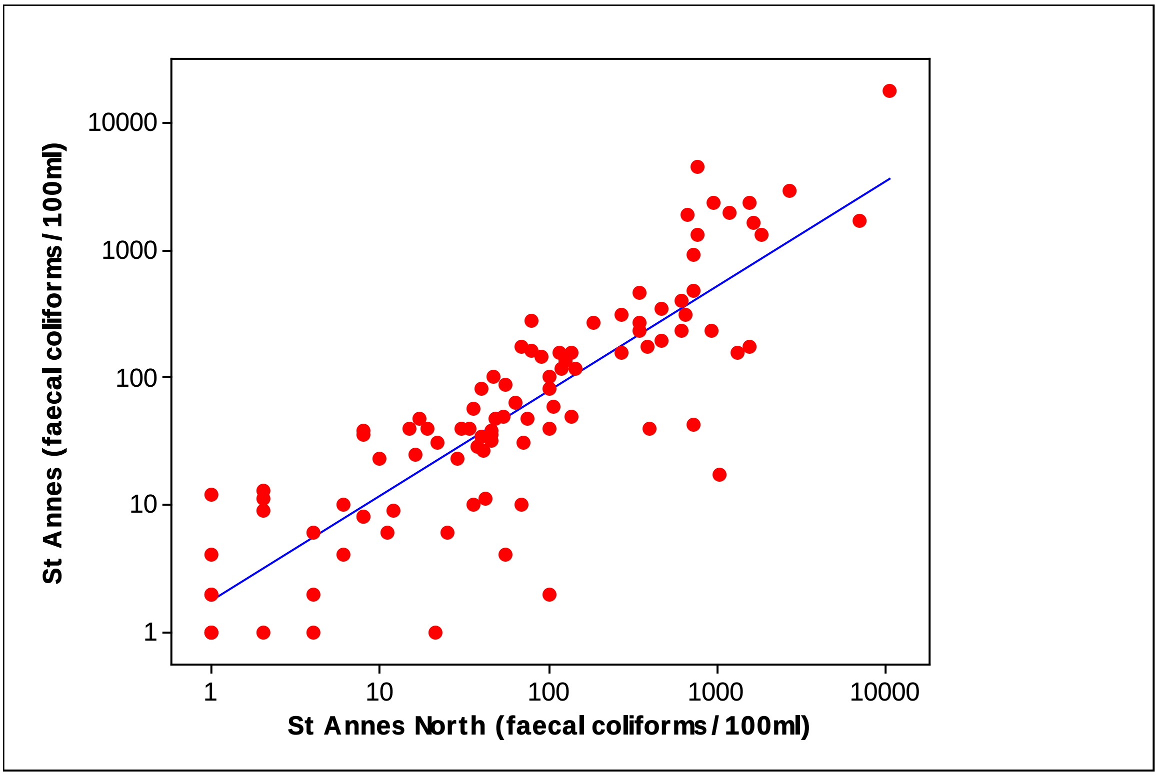
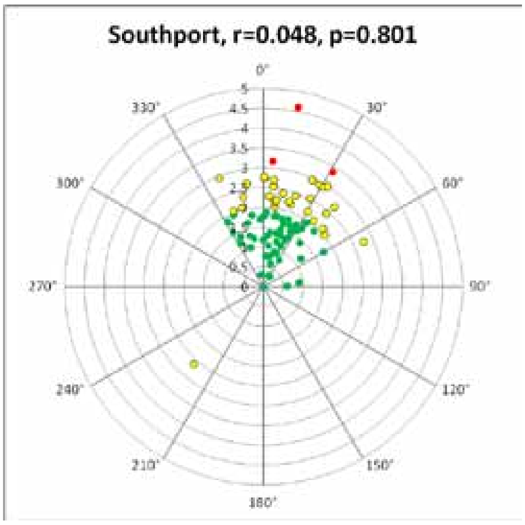


Figure XI.3 Scatterplot of paired sample results from the two bathing waters at St. Annes

Figure XI.3 indicates that the levels of contamination at these two sites are likely to be very similar on any given day (Pearsons correlation, r=0.857, p=0.000) despite the distance between them (2.6km) and the large range of results recorded. This suggests that they are influenced by the same sources, or a similar range of sources which react in the same way to environmental conditions.

Figure XI.4 presents polar plots of $\log_{10}$ faecal coliforms (cfu/100ml) against tidal state on the high low cycle for each monitoring point. High water at Southport is at 0° and low water is at 180°. 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. Circular linear correlations were carried out on these results and correlation coefficients (r) and p values are presented for each chart.



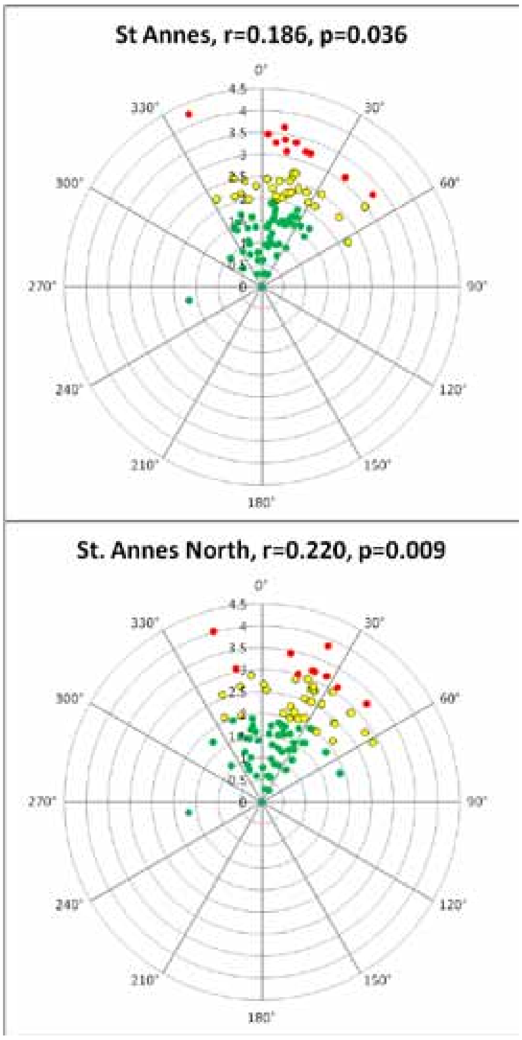


Figure XI.4. Polar plots of log_{10} faecal coliform results (cfu/100ml) against tidal state on the high low cycle for the three bathing waters monitoring points (2006-2010)

Sampling was strongly targeted towards high water. Significant but fairly weak correlations between tidal state and levels of contamination were found at St Annes and St Annes North. For both these monitoring points an increase in contamination can be seen after the tide had started to ebb.

Figure XI.5 presents polar plots of log_{10} faecal coliforms (cfu/100ml) against tidal state on the spring neap cycle for each monitoring point. 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.

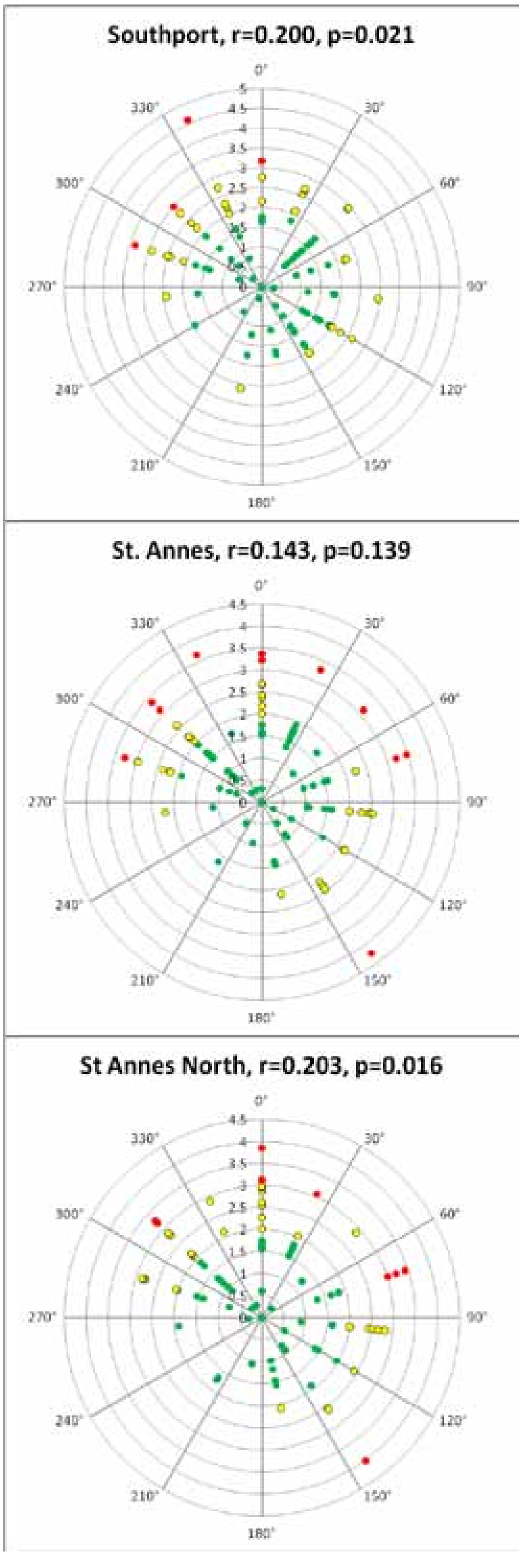


Figure XI.5. Polar plots of log_{10} faecal coliform results (cfu/100ml) against the spring neap tidal cycle for the three bathing waters monitoring points (2006-2010)

Weak correlations were found for Southport and St. Annes North. No strong patterns are apparent for either of these sites in Figure XI.5, aside from perhaps a slight tendency for higher results at Southport as tide size increased towards springs.

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 Southport weather station (Appendix II for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table XI.2 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.2 Spearman's Rank correlations between rainfall recorded at Southport and Bathing Waters sample results from sites in the Ribble estuary (2007-2010)

		Southport	St. Annes	St. Annes North
	No.	76	75	75
24 hour periods prior to sampling	1 day	0.254	0.188	0.138
	2 days	0.230	0.479	0.456
	3 days	0.187	0.420	0.349
	4 days	0.196	0.217	0.159
	5 days	0.151	0.284	0.262
	6 days	-0.014	0.328	0.445
	7 days	0.211	0.247	0.304
Total prior to sampling over	2 days	0.221	0.419	0.385
	3 days	0.227	0.469	0.437
	4 days	0.233	0.495	0.445
	5 days	0.282	0.481	0.399
	6 days	0.273	0.490	0.473
	7 days	0.297	0.499	0.484

A significant influence of rainfall was found at all three bathing waters monitoring points. The influence was strongest at St Annes and weakest at Southport.

To investigate the effects of river flow on levels of contamination at the bathing waters sites Spearman's rank correlations were carried out between mean daily flow recorded on the Ribble at Samelsbury over various periods running up to sample collection and faecal coliforms results. 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 mean daily flow recorded on the Ribble at Samelsbury and Bathing Waters sample results from sites in the Ribble estuary (2006-2010)

		Southport	St. Annes	St. Annes North
	No.	98	97	98
24 hour periods prior to sampling	1 day	0.443	0.702	0.583
	2 days	0.432	0.701	0.579
	3 days	0.442	0.605	0.513
	4 days	0.475	0.552	0.499
	5 days	0.425	0.544	0.507
	6 days	0.391	0.529	0.490
	7 days	0.409	0.478	0.364
Total prior to sampling over	2 days	0.451	0.715	0.586
	3 days	0.447	0.697	0.578
	4 days	0.461	0.675	0.572
	5 days	0.469	0.659	0.575
	6 days	0.479	0.658	0.579
	7 days	0.489	0.649	0.564

Highly significant correlations with discharge from the Ribble and faecal coliform levels in bathing waters samples were found throughout. This suggests that runoff is a highly major source of contamination and accounts for much of the variation in results. Again, correlations were strongest at St. Annes and weakest (but still highly significant) at Southport and this pattern corresponds to their proximities to the head of the estuary and the main river channel.

SHELLFISH WATERS

The Ribble estuary has been designated under Directive 2006/113/EC as a Shellfish Water since 1999 (European Communities, 2006) (Figure XI.6). Table XI.4 presents summary statistics for recent bacteriological monitoring results from the Ribble shellfish growing water monitoring point, which is located in the main channel. Only water sampling results are presented as flesh results from the shellfish hygiene monitoring point for mussels (B046C, Appendix XII) are used to assess compliance with bacteriological standards in shellfish flesh.

Table XI.4 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2006-2011.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Ribble (SD 3500 2629)	35	97.3	<2	3346	54%	11%

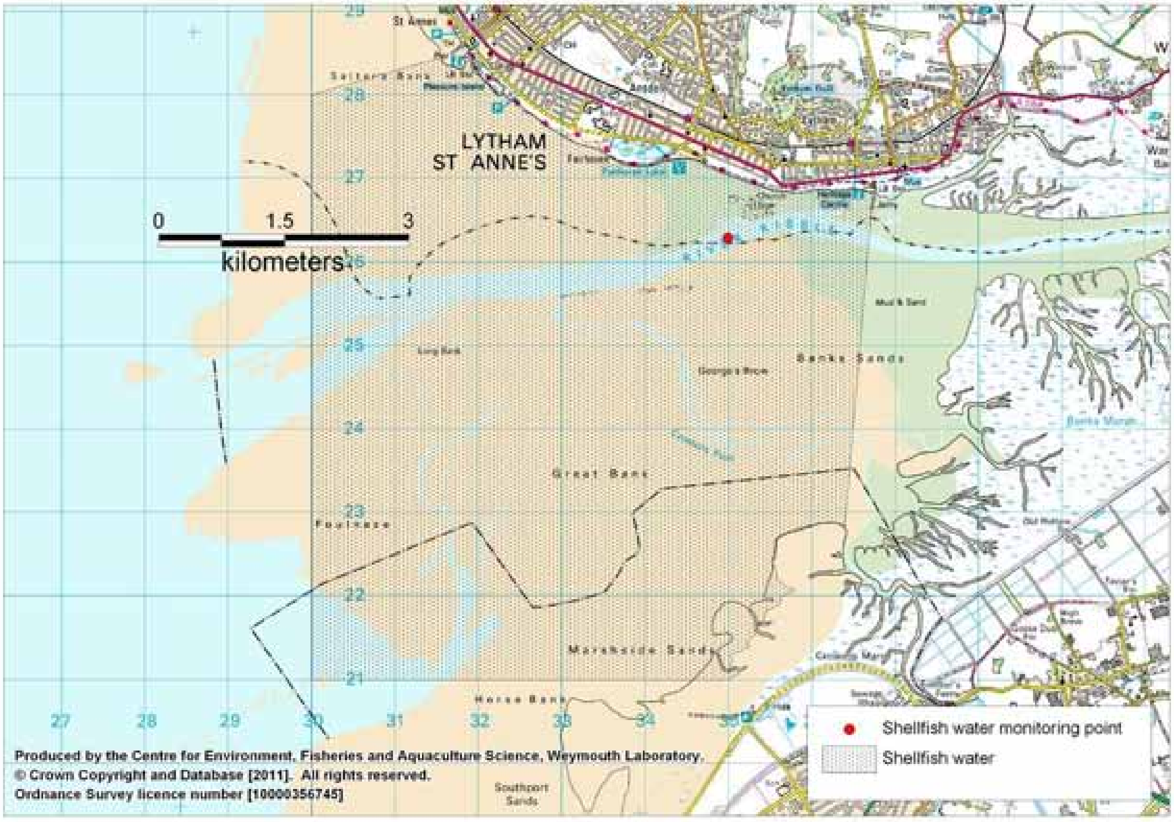


Figure XI.6 Ribble shellfish growing water

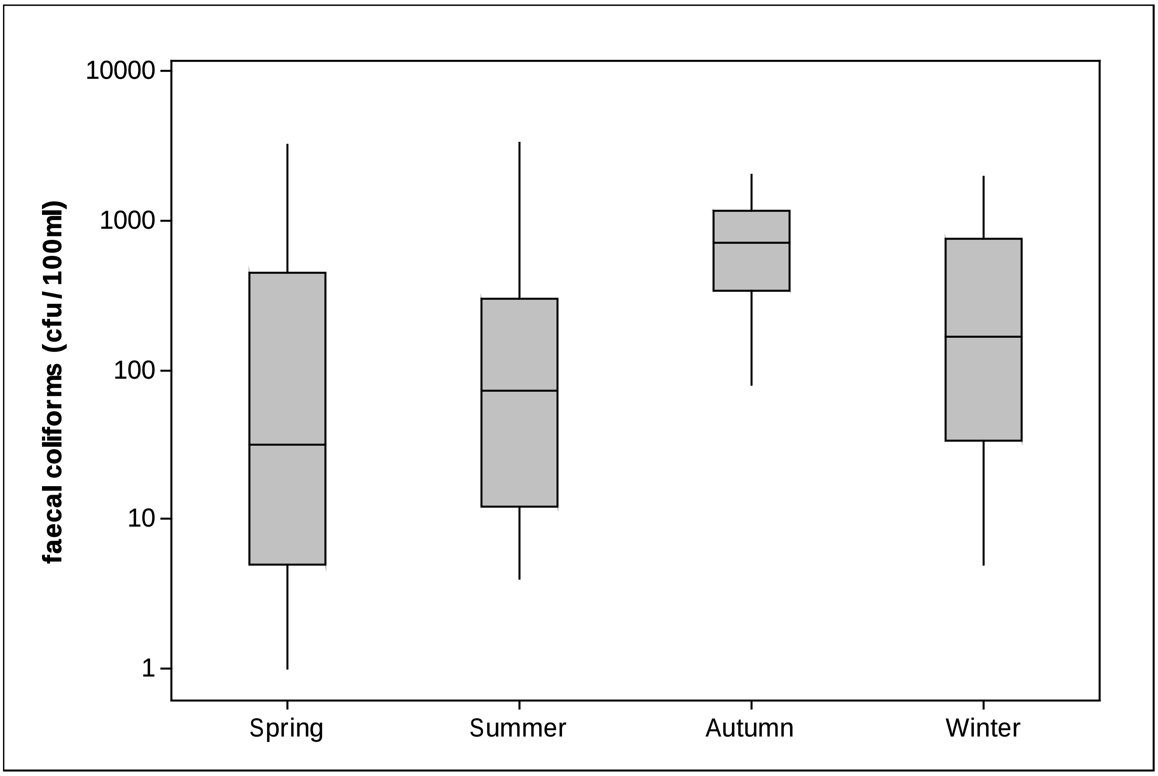


Figure XI.7 Boxplot of shellfish growing waters faecal coliforms results by season

Figure XI.7 indicates that there is some seasonality in levels of contamination at this monitoring point, with higher results in the autumn, although this effect was not statistically significant (One-way ANOVA, p=0.108).

Table XI.5 Spearman's Rank correlations between rainfall at Southport (2007-2010) and mean daily flow recorded on the Ribble at Samelsbury (2006-2010) and shellfish growing waters water sample results

		Southport rainfall	Ribble discharge
	No.	21	26
24 hour periods prior to sampling	1 day	0.003	0.620
	2 days	0.309	0.670
	3 days	0.529	0.747
	4 days	0.390	0.742
	5 days	0.300	0.408
	6 days	0.034	0.486
	7 days	0.373	0.455
Total prior to sampling over	2 days	0.324	0.679
	3 days	0.446	0.694
	4 days	0.553	0.759
	5 days	0.535	0.718
	6 days	0.492	0.694
	7 days	0.520	0.700

As with the bathing waters results, correlations were found with both rainfall at Southport and discharge from the Ribble, with a stronger and more consistent influence from discharge of the Ribble.

Sampling was strongly targeted towards high water, but was conducted throughout the spring neap cycle. No correlation was found between levels of faecal coliforms at this monitoring point and either the high low or spring neap tidal cycles (circular linear correlation, p=0.252 and 0.051 respectively), although there did appear to be a slight tendency for lower results during spring tides (Figure XI.8).

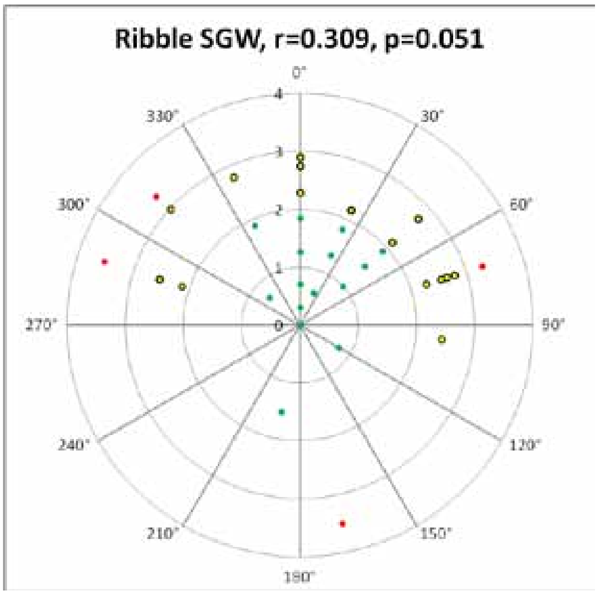


Figure XI.5. Polar plot of $\log_{10}$ faecal coliform results (cfu/100ml) against the spring neap tidal cycle for the Ribble shellfish growing waters monitoring point

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

Mussels taken from the training walls lining the outer Ribble channel have been regularly sampled for *E. coli* for classification purposes from the 1990s to the present. Only one location has been sampled for mussels since 2000, so no spatial analysis of levels of contamination within this species is possible. Aside from the bacteriological survey initiated as part of this sanitary survey (Appendix XIII) no cockles have been sampled for *E. coli* since 2005. Nevertheless, samples taken from 2000 to 2005 were considered in this analysis to permit an evaluation of the difference in levels of contamination between the two points sampled during this time, which lie on either side of the Ribble channel. Locations sampled are presented in Figure XII.1 and summary statistics are presented in Table XII.1 for these three points. No bacteriological sampling results pertinent to the offshore clam fishery were available at the time of writing.

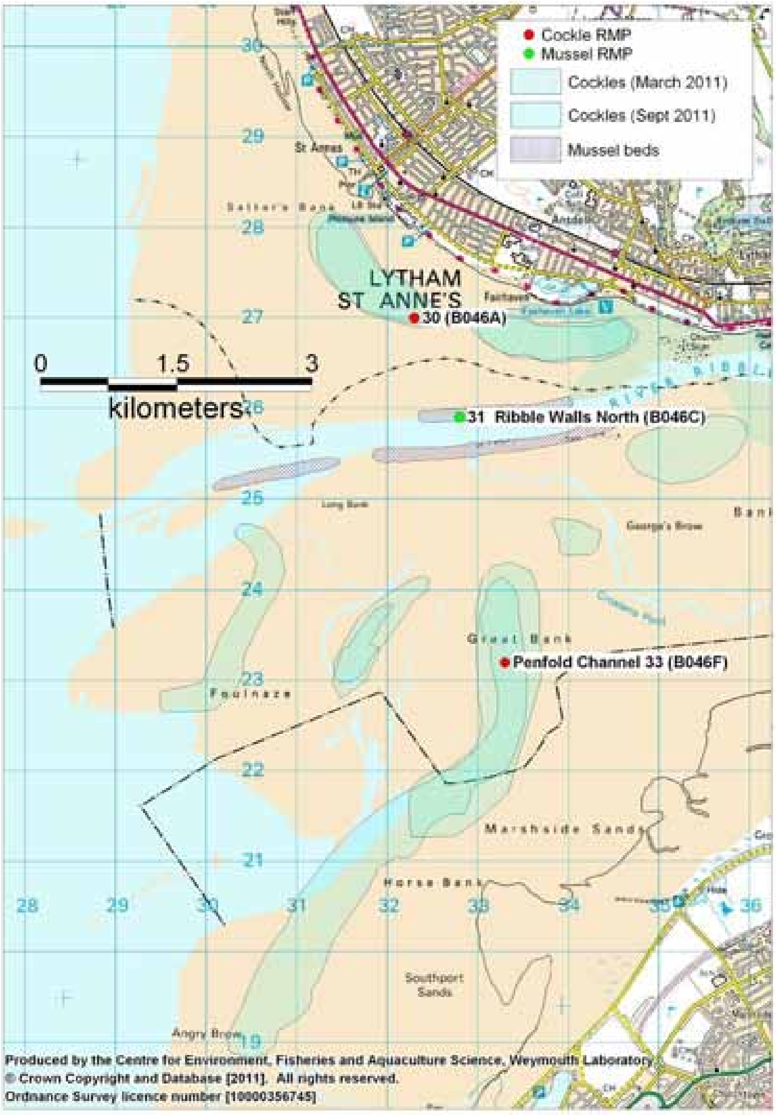


Figure XII.1 Hygiene monitoring RMPs active since 2000

Table XII.1 Summary statistics of* E. coli *results (MPN/100g) from RMPs sampled from 2000 onwards

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
B046C	Mussels	119	19/01/2000	06/07/2011	1697	90	35000	92%	20%
B046A	Cockles	40	31/01/2000	16/08/2005	1639	<20	91000	80%	28%
B046F	Cockles	57	23/02/2000	07/09/2005	795	90	160000	88%	12%

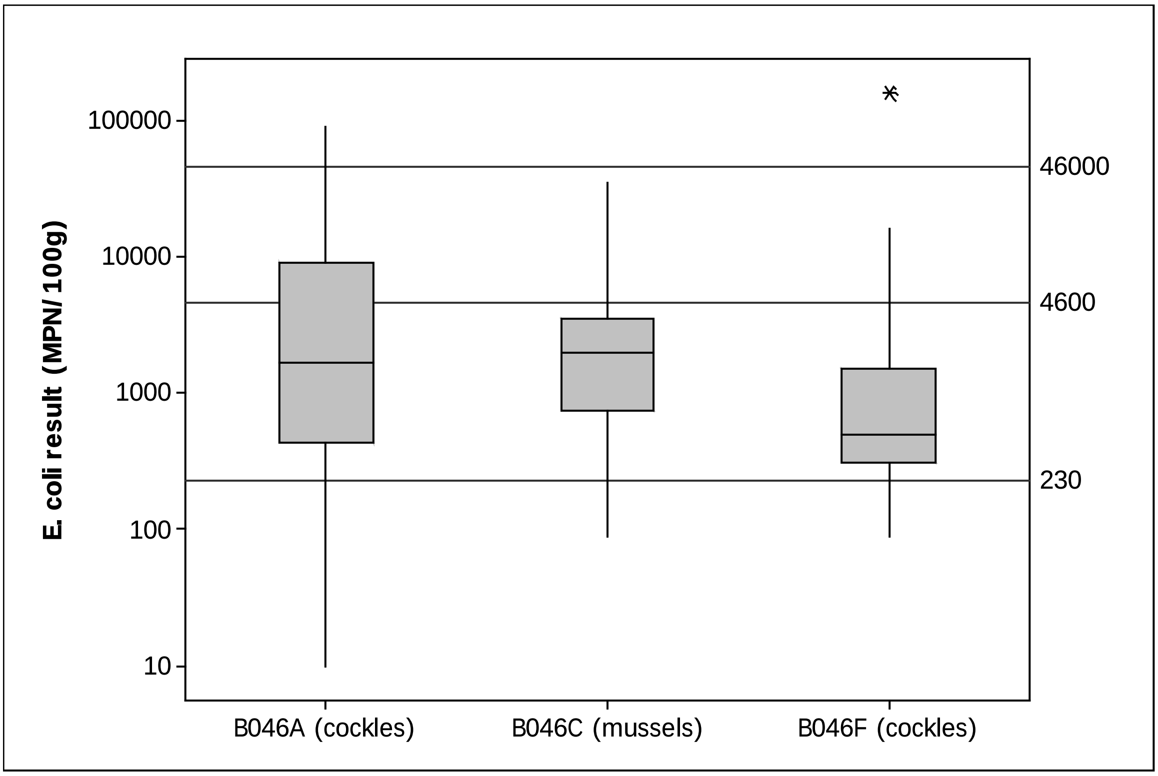


Figure XII.2 Boxplots of* E. coli *results from 2000 onwards by RMP

A large range of results were recorded at all three sites, ranging from class A to class C or prohibited levels indicating highly variable water quality throughout the area. A comparison of mean results for the two cockle RMPs showed that differences between the mean *E. coli* results (T-test, p=0.054) and in the proportion of results exceeding 4600 *E. coli* MPN/100g (Chi-square, p=0.059) were not quite significant at 0.05 level. Nevertheless, the RMP north of and closer to the main Ribble channel (B046A) was consistently more contaminated with a higher frequency of C results throughout this period of monitoring. The two cockle RMPs were always sampled on different occasions so it was not possible to undertake more robust comparisons of paired (same day) sample results.

OVERALL TEMPORAL PATTERN IN RESULTS

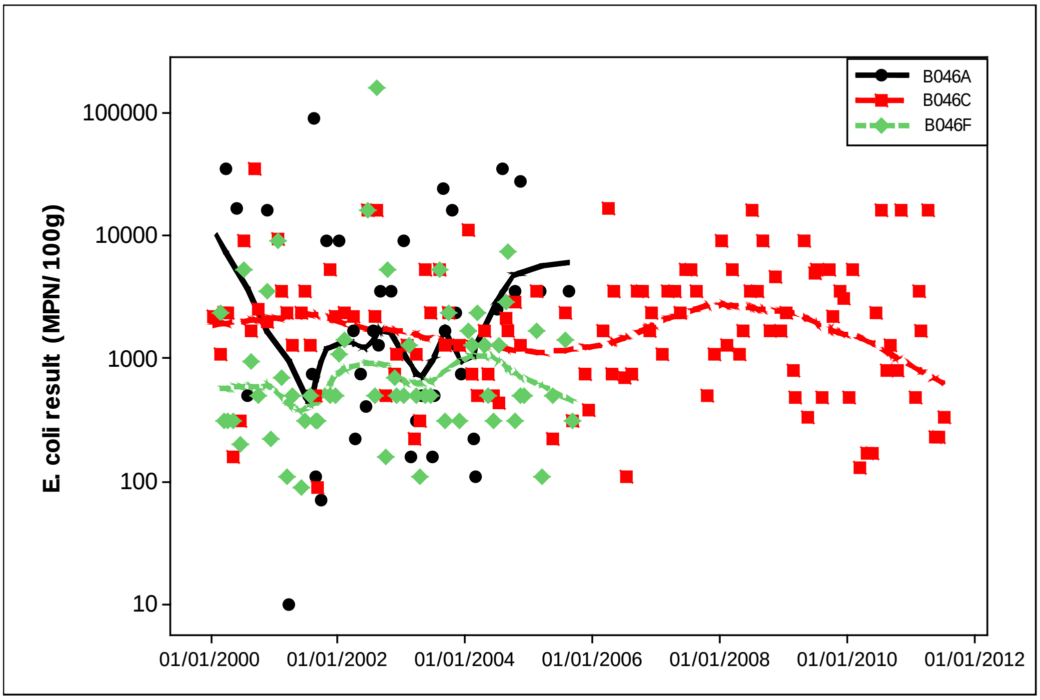


Figure XII.3 Scatterplot of* E. coli *results by RMP and date, overlaid with loess lines for each RMP

Figure XII.3 indicates that results at the cockle RMPs, particularly B046A fluctuated throughout the period with no obvious pattern. Mussel results did not fluctuate quite so much and appear to have improved since 2009 with a higher frequency of lower results, although high results continue to occur.

SEASONAL PATTERNS OF RESULTS

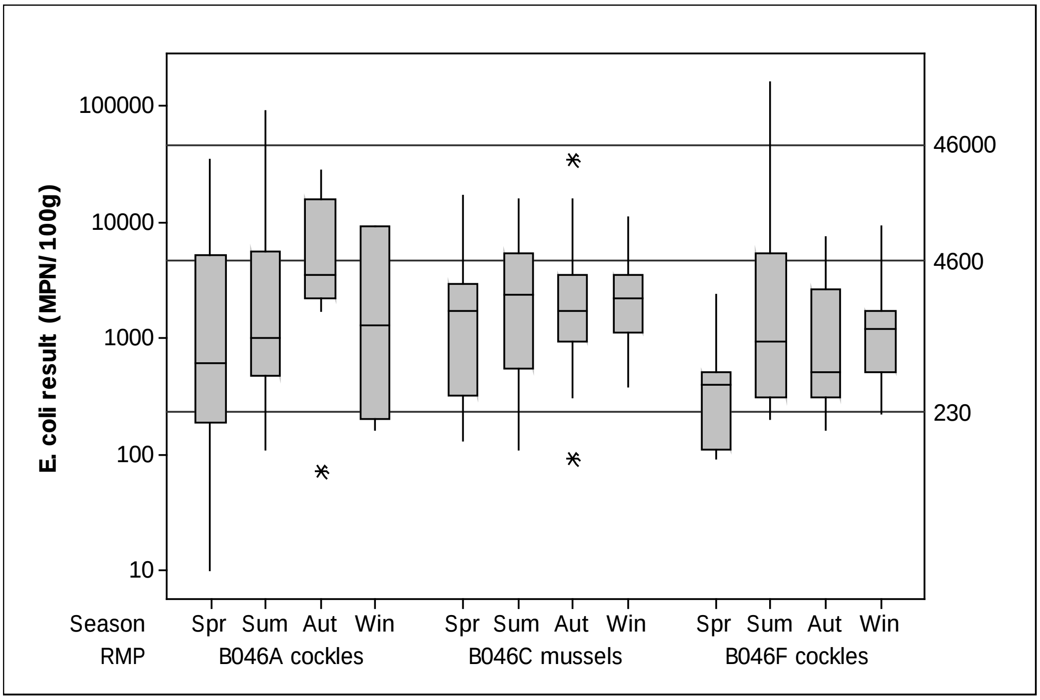


Figure XII.4 Boxplot of E. coli results by RMP and season

Figure XII.3 indicates that seasonal variation is greater for the cockle RMPs than for the mussel RMP. At B046A results were highest on average in the autumn and lowest on average in the spring, but this effect was not statistically significant (One way ANOVA, p=0.375). At B046C there was no noticeable seasonal variation aside from slightly lower average results in the spring (One way ANOVA, p=0.311). At B046F results for the summer were significantly higher than those for the spring (One way ANOVA, p=0.030, Tukeys comparison). All results of over 46,000 *E. coli* MPN/100g arose during the summer.

INFLUENCE OF TIDE

All shellfish samples had to be collected around low water, during the period in which they are exposed to the air, so it was not appropriate to investigate the distribution of results in relation to the high/low tidal cycle. Sampling was always undertaken at spring tides so it was not possible to investigate results in relation to the spring/neap tidal cycle either.

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 Southport weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XII.2 and statistically significant correlations (p<0.05) are highlighted in yellow. Rainfall data was only available from May 2007 onwards so this investigation was limited to samples from B046C.

Table XII.2 Spearman's Rank correlations between rainfall recorded at Southport and shellfish hygiene results from the B046C (May 2007 onwards)

	No.	43
24 hour periods prior to sampling	1 day	0.105
	2 days	0.349
	3 days	0.494
	4 days	0.458
	5 days	0.351
	6 days	0.447
	7 days	0.110
Total prior to sampling over	2 days	0.186
	3 days	0.378
	4 days	0.481
	5 days	0.539
	6 days	0.568
	7 days	0.524

Correlations between *E. coli* results at B046C and rainfall at Southport were found for most intervals prior to sampling. Levels of *E. coli* in shellfish take 2-3 days to respond as evidenced by the lack of correlation with rainfall on the previous day and the total for the previous 2 days.

INFLUENCE OF RIVER FLOW

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out with mean daily flows at the river gauging stations detailed in Appendix III. Flow gauging records were only available from March 2006 onwards so this investigation was limited to samples from B046C.

Table XII.3 Spearman's Rank correlations between mean daily river flows and* E. coli *results B046C (March 2006 onwards)

		Ribble (Samelsbury)	Douglas (Wanes Blades)	Darwen (Blue Bridge)
	No.	55	51	45
24 hour periods prior to sampling	1 day	0.463	0.402	0.674
	2 days	0.422	0.355	0.637
	3 days	0.406	0.423	0.624
	4 days	0.206	0.231	0.482
	5 days	0.192	0.122	0.335
	6 days	0.054	0.021	0.257
	7 days	0.057	0.016	0.183
Average prior to sampling over	2 days	0.464	0.415	0.694
	3 days	0.463	0.460	0.693
	4 days	0.452	0.409	0.684
	5 days	0.434	0.370	0.654
	6 days	0.396	0.332	0.621
	7 days	0.371	0.288	0.584

Table XII.3 indicates that mean daily flow in the preceding 3-5 days and average mean daily flow over the 7 days prior to sampling is correlated to *E. coli* levels in mussels at B046C. The strongest correlations consistently arose with flows on the River Darwen, although the reasons for this are unclear.

MUSSEL SAMPLING RESULTS IN RELATION TO SPILLS FROM THE FAIRHAVEN PS OUTFALL

The Fairhaven PS outfall lies about 1km east of the mussel RMP, both of which are located on the north bank of the main Ribble channel, so whilst the tide is ebbing any discharge from this outfall would be carried directly towards the RMP. From 2006 to 2010 inclusive the mussels were sampled on five occasions when this outfall was active or had discharged within the previous 25 hours. Table XII.4 presents summary statistics for these samples and for other mussel samples taken within the same period but when the outfall was not active.

Table XII.4 Mussel results in relation to discharges from Fairhaven PS

Outfall active in 24 hours prior to sampling?	*E. coli* results (MPN/100g)				
	No. samples	Geometric mean	min	max	%>4600
Yes	5	4263	1300	16,000	40%
No	47	1814	110	17,000	26%

Results were higher on average and the proportion of results exceeding 4600 was higher during or just after a spill. However, only five samples were collected under spill conditions and it is possible that other factors such as rainfall were also an influence, so it is not possible to conclude whether these apparently elevated results were a direct consequence of spills from Fairhaven PS.

APPENDIX XIII
MICROBIOLOGICAL DATA: BACTERIOLOGICAL SURVEY

On receipt and acceptance of the application for classification of the cockle beds in October 2010 it became clear that classification would be required for the opening of the season on 1st September 2011. As soon as the cockles were of a sufficient size to be sampled, a bacteriological survey was initiated to obtain information on spatial variation in levels of contamination across the survey area and to accrue monitoring results towards a preliminary classification. After undertaking an initial desk-based study and a shoreline survey, the location of five monitoring points were identified. The locations of these sampling points are shown on Figure XIII.1. It was not possible to sample the cockle bed at Georges Brow for access reasons. It was recommended that these points should be sampled at least 10 times for cockles at regular intervals not closer than weekly and not more than monthly and tested for the statutory indicator of contamination (*E. coli*). Results of these samples are presented in Table XIII.1.

Figure XIII.1 Bacteriological survey points

Table XIII.1 Bacteriological survey results to date (*E. coli *MPN/100g)

	Grannys Bay West B046N	North Run B046O	Penfold North B046L	Penfold South B046M	Penfold West B046P
16/03/2011			460	2400	
29/03/2011			20	110	
07/04/2011	1300	2400			
13/04/2011			50	490	
18/04/2011	10	50			
27/04/2011			20	220	
03/05/2011	80	220			
10/05/2011			70	230	
11/05/2011	230	130			
24/05/2011			170	630	330
25/05/2011	3500	80			
08/06/2011			90	330	170
15/06/2011	2400	3500			
22/06/2011			110	330	20
27/06/2011	5400	330			
11/07/2011	330	170	130	330	330
22/07/2011	3500	330			
27/07/2011			260	2200	330
08/08/2011	790	1100			
09/08/2011			490	330	130
No.	10	10	11	11	6
Geomean	630	338	105	436	159
Min.	<20	50	20	110	20
Max.	5400	3500	490	2400	330
%>230	70%	50%	27%	73%	50%
%>4600	10%	0%	0%	0%	0%

Figure XIII.2 presents a boxplot of these results by site

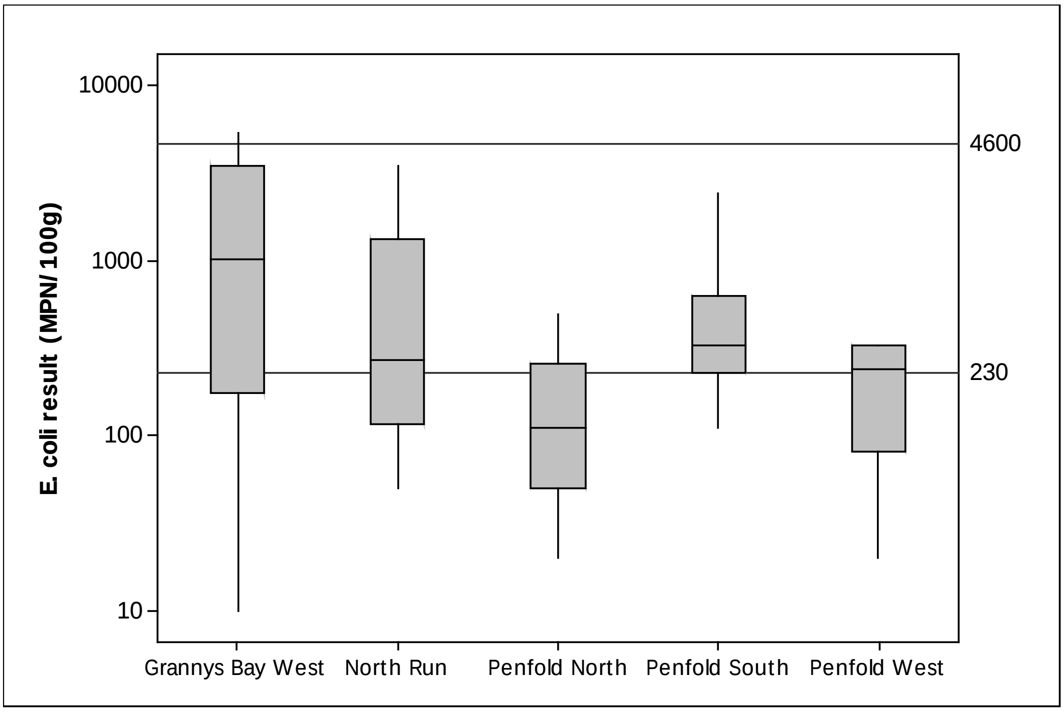


Figure XIII.2 Boxplot of bacteriological survey results by site

Results were highest on average at Grannys Bay West, although they did just fall within the required thresholds for a B classification. Results at all other sites were well within the thresholds for B classification. A comparison of all results by site revealed a statistically significant difference in mean result, with results from Penfold North significantly lower than for those from Grannys Bay West (one way ANOVA, p=0.034, Tukeys comparison). The low sample numbers perhaps prevent the detection of further differences between the sites, which might be revealed with a more lengthy set of monitoring data.

The two sites on the north of the river were always sampled together on the same day and hence under the same conditions. There was no significant difference between these results (paired T-test, p=0.300) nor was there a correlation between results from these paired samples (Pearsons correlation, r=0.491, p=0.149). Again, sample numbers were perhaps too low for a meaningful analysis. It is apparent that levels of *E. coli* are generally higher at Grannys Bay West and the only result exceeding 4600 *E. coli* MPN/100g was recorded at this point. This is unsurprising as it is closer to the head of the Ribble estuary and the main Ribble channel.

On the south side of the estuary, results were generally lower, with the highest individual results all lower than the highest individual results recorded at the two monitoring points on the north side. Geometric mean results however were higher at Penfold South compared to North Run. A comparison of paired results from samples taken from Penfold South and Penfold North revealed not only a significant difference in mean result (paired T-test, p=0.000) but that results from these two sampling locations were strongly correlated on a sample by sample basis (Pearsons correlation r=0.715, p=0.013, Figure XIII.3). Taken together this suggests that they are under the influence of similar sources, with Penfold South more directly affected.

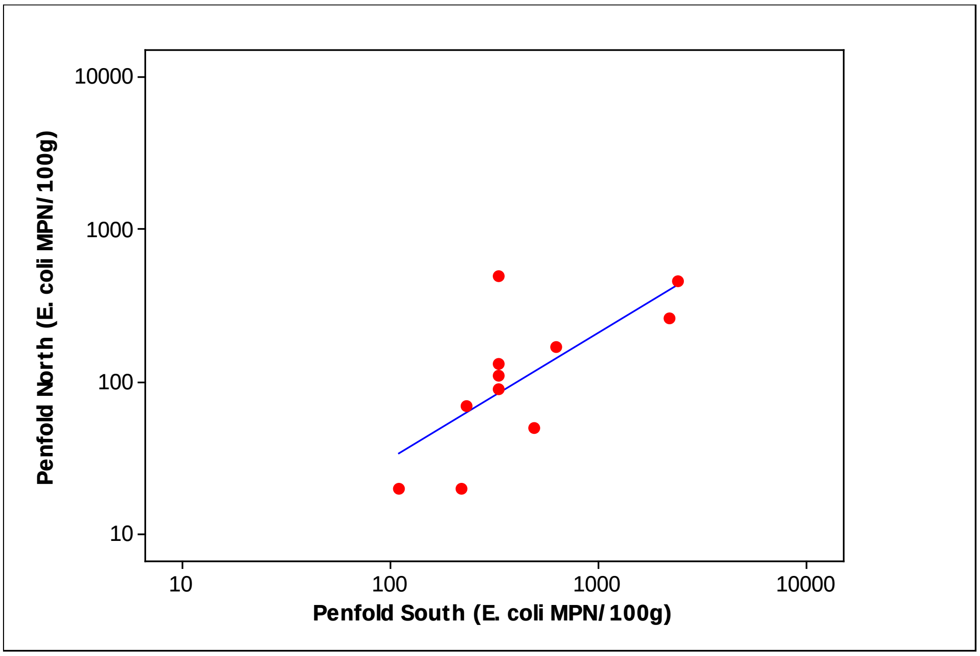


Figure XIII.3 Scatterplot comparison of paired sample results from Penfold South and Penfold North

Due to the small size of cockles there early in the year too few samples have been taken from Penfold West for a meaningful comparison with the other sites, but so far the results appear to be most similar to those at Penfold North and lower on average than those at Penfold South.

Therefore it is tentatively concluded that the north side of the estuary is generally subject to higher levels of contamination and this decreases with distance from the head of the estuary. On the south side there are some spatial fluctuations in levels of contamination, but these do not appear to align with distance from the head of the estuary possibly because they are further away from its influence. No samples were taken from the bed at Georges Brow, but on the basis of results at Grannys Bay and its proximity to the head of the estuary, it is anticipated that higher levels of contamination are likely to arise here than at the other sites sampled on the south side.

APPENDIX XIV
STUDIES INTO BACTERIOLOGICAL CONTAMINATION IN THE AREA

The Ribble estuary has been the subject of many investigations and studies, most of which were originally driven by failures to meet the faecal coliforms standards required under the Bathing Waters Directive at sites along the Sefton and Fylde coast. Several of these are of direct relevance to the sanitary survey and so are discussed within this appendix.

MODELLED FLUXES OF FAECAL COLIFORMS INTO THE RIBBLE ESTUARY

A study recently undertaken by the Centre for Research into the Environment and Health (CREH) estimated the flux of faecal coliforms into the Ribble estuary during summer, from sewage and agricultural sources. Predictions were based on resident populations (both human and livestock), the current sewerage systems serving the area and information on rainfall and river flow (J. Crowther, unpublished data).

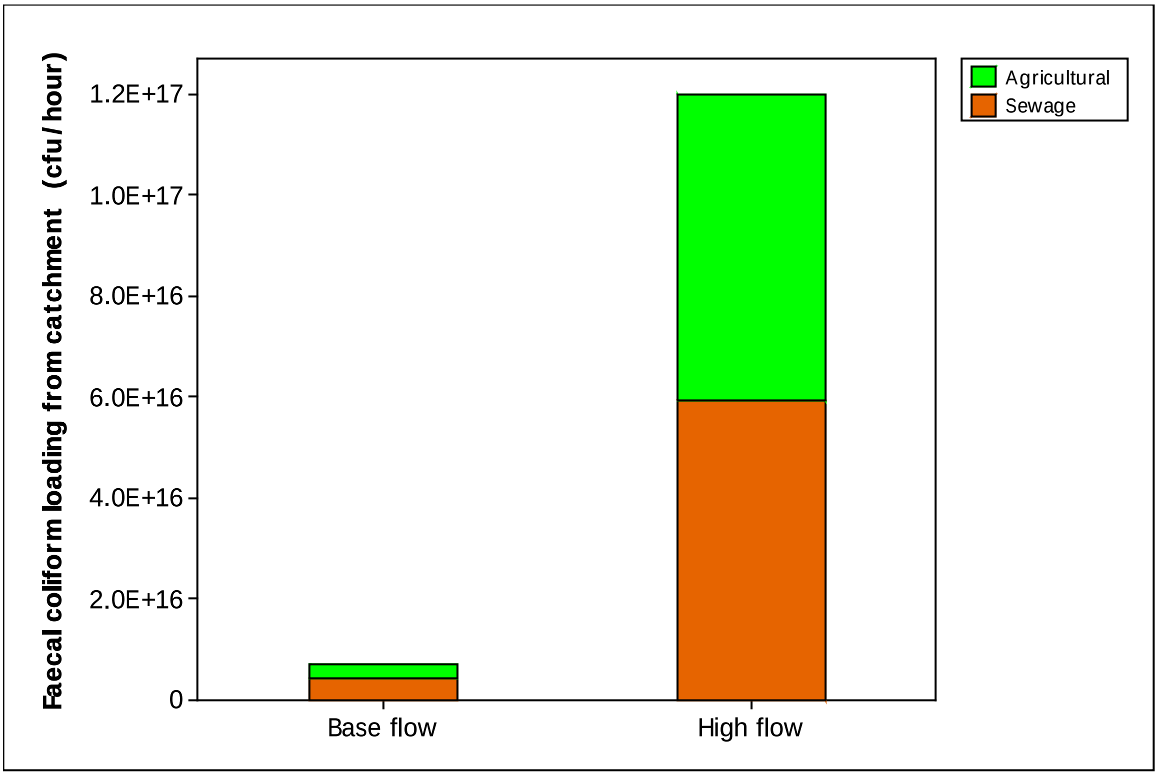


Figure XIV.1 Estimated summer fluxes of faecal coliforms into the Ribble estuary under base flow and high flow conditions

Table XIV.1 Estimated summer fluxes of faecal coliforms to the Ribble estuary under base flow and high flow conditions

	Base flow	High flow
Sewage sources	61.12 %	49.53 %
Agricultural sources	38.88 %	50.48 %
Total flux (faecal coliforms cfu/hour)	7.0×10^{15}	1.2×10^{17}

This study estimated a 17fold increase in fluxes of faecal coliforms into the estuary under high flow conditions so there is likely to be a significant increase in levels of *E.*

coli in shellfish within the estuary whilst river flows are elevated. The proportion derived from sewage sources was about 60% under base flow conditions and 50% under high flow conditions.

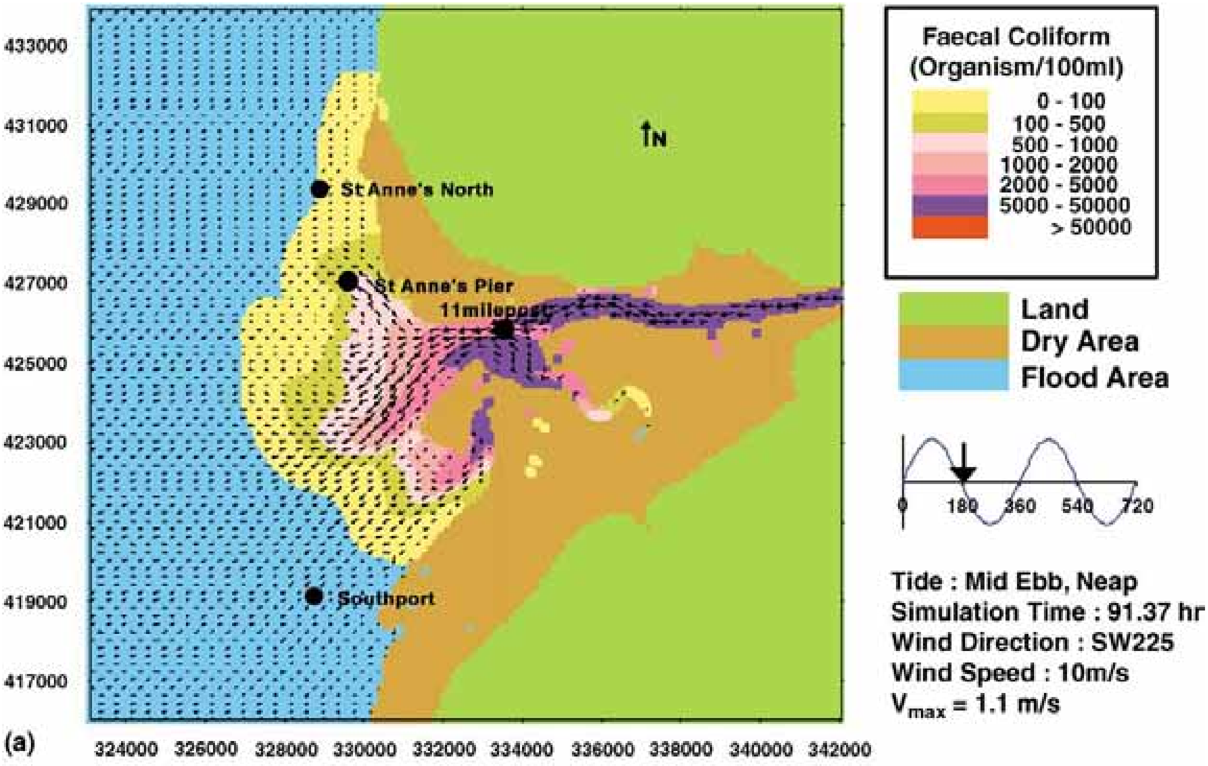
SOURCE APPORTIONMENT STUDY

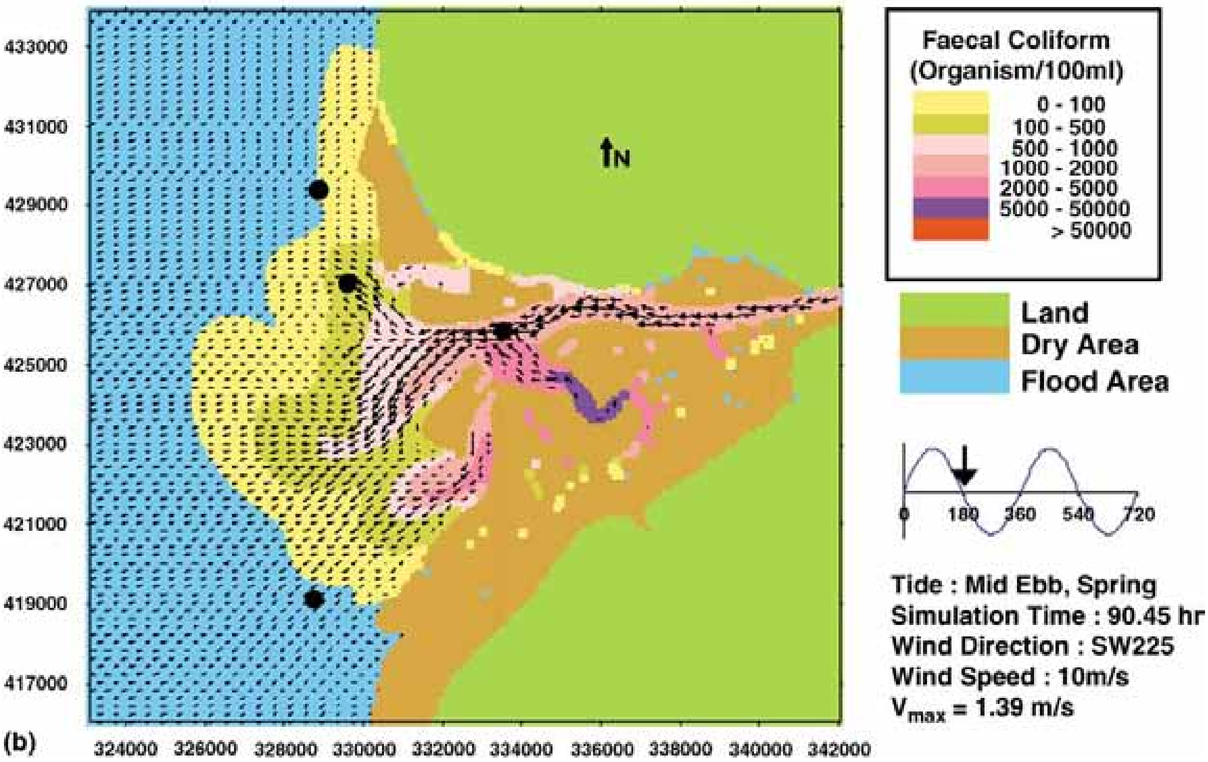
In 2007, the Environment Agency conducted a semi-quantitative source apportionment study within the Ribble estuary (Environment Agency, 2009). The results indicated a high (>39%) contribution from water company discharges and a medium (10 to 39%) contribution from each of agriculture (rough grazing), urban runoff and animal/bird sources. The methods used were not described in the report.

HYDRO-ENVIRONMENTAL MODELLING

Kashefipour *et al* (2002) modelled concentrations of faecal coliforms throughout the Ribble estuary under various environmental conditions. This was undertaken in 1999 before a significant programme of improvements to the main sewage works, but should nevertheless provide useful information on the relative levels of faecal coliforms throughout the study areas. Field measurements and sampling results were in good agreement with the model predictions. Figure XIV.2 (a-d) present some typical outputs from this model.

A large proportion of the shellfish beds are on areas which are dry in Figure XIV.2, but nevertheless some useful conclusions can be drawn. As expected, there is a consistent gradient of increasing levels of contamination towards the head of the estuary and some very high levels of faecal coliforms were predicted within the area, particularly in the upper reaches of the main channel. Predicted levels of faecal coliforms were generally lower throughout the outer estuary during spring tides compared to neap tides, although Figure XIV.2 indicates that during spring tides there is a more noticeable hotspot of contamination within the Crossens Pool. No contaminating influence from the Ribble was predicted at the offshore clam beds.


433000
431000
429000
427000
425000
423000
421000
419000
417000
324000 326000 328000 330000 332000 334000 336000 338000 340000 342000
(a)
N
St Anne's North
St Anne's Pier
11milepost
Southport
Faecal Coliform
(Organism/100ml)
0 - 100
100 - 500
500 - 1000
1000 - 2000
2000 - 5000
5000 - 50000
> 50000
Land
Dry Area
Flood Area
0 180 360 540 720
Tide : Mid Ebb, Neap
Simulation Time : 91.37 hr
Wind Direction : SW225
Wind Speed : 10m/s
Vmax = 1.1 m/s


433000
431000
429000
427000
425000
423000
421000
419000
417000
324000 326000 328000 330000 332000 334000 336000 338000 340000 342000
(b)
N
Faecal Coliform
(Organism/100ml)
0 - 100
100 - 500
500 - 1000
1000 - 2000
2000 - 5000
5000 - 50000
> 50000
Land
Dry Area
Flood Area
0 180 360 540 720
Tide : Mid Ebb, Spring
Simulation Time : 90.45 hr
Wind Direction : SW225
Wind Speed : 10m/s
Vmax = 1.39 m/s

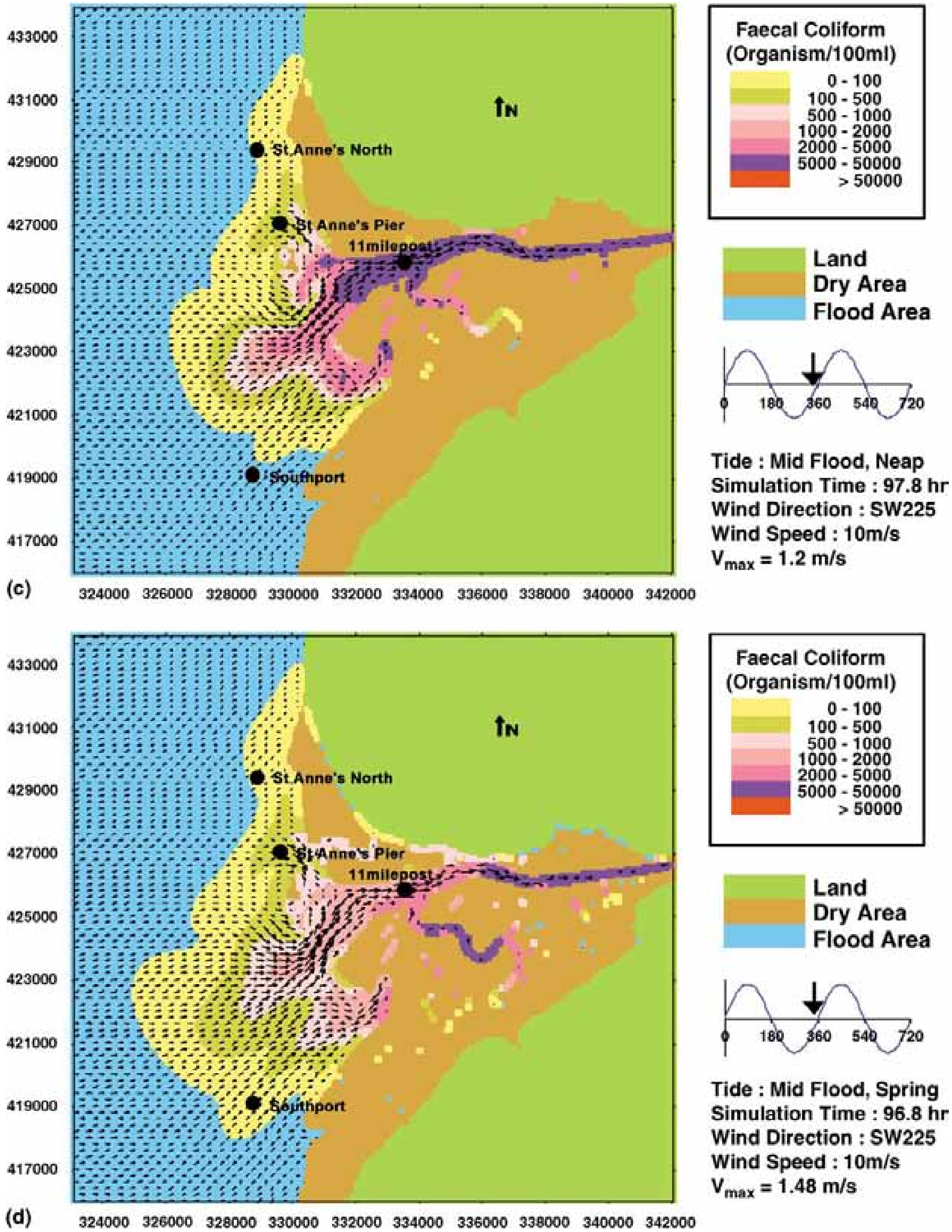


Fig. XIV.2. (a) Predicted velocity and FC concentration distributions for mid-ebb neap tide with south westerly wind. (b) Predicted velocity and FC concentration distributions for mid-ebb spring tide with south westerly wind. (c) Predicted velocity and FC concentration distributions for mid-flood neap tide with south westerly wind. (d) Predicted velocity and FC concentration distributions for mid-flood spring tide with south westerly wind.

From: Kashefipour et al, 2002. Reproduced with the permission of the authors.

Appendix XV
Shoreline Survey

Date (time): 15th February 2011 (10:30-15:00 GMT) and 16th February 2011 (08:00-12:30 GMT)

Applicant: Mary Joy, West Lancashire District Council (not present)

Cefas Officers: Nicola Mitchard, Alastair Cook

Local Enforcement Authority Officers: Glyn Cavell, Mersey Port Health Authority, Mary Joy, West Lancashire District Council, Mike Walker, Fylde Borough Council.

Area surveyed: Southport and Lytham St. Annes.

Weather: 15th February – winds E force 4, 4°C, overcast
16th February – winds E force 2, 6°C, sunny

Tidal predictions (Blackpool):
Admiralty TotalTide – 0445 Blackpool 53°49'N 3°04'W England. Times GMT+0000. Predictions are based on Liverpool (Gladstone Dock)

15/02/2011

Low	02:33	2.5m
High	08:28	7.4m
Low	15:13	2.1m
High	20:59	7.6m

16/02/2011

Low	03:32	2.0m
High	09:21	8.0m
Low	16:09	1.5m
High	21:49	8.2m

Predicted heights are in metres above Chart Datum

Objectives: (a) confirm the location of sources of contamination to the shoreline at Southport and Lytham St. Annes and; (b) identify any additional sources of contamination in the area. A full list of recorded observations is presented in Table XV.1 and the locations of these observations are mapped in Figure XV.1. Photographs referenced in the text are presented in Figures XV.3-6.

Description of Fishery

None of the shellfish beds were visited or sampled during the shoreline survey for reasons of safety. There are extensive cockle beds on both sides of the Ribble estuary. The approximate areas in which they are located are shown in Figure XV.1, based on surveys undertaken by NWSFC in February 2011. The vast majority of stock originated from the 2010 spatfall, so at the time of shoreline survey was too small for harvesting or sampling. It is anticipated that they will be of an exploitable size in time for the opening of the season on 1st September 2011, so a classification is required by this time. Densities are sufficient for these stocks to be of interest to hand gatherers. Small numbers of larger cockles from previous year classes are present in some areas which will facilitate an early start to sampling. Some areas are very difficult to access (Georges Brow and South Gut) so regular sampling here is not possible.

Mussel beds line the edges of the main channel of the outer Ribble estuary. The locations of these are also shown on Figure XV.1 (from information held by CEFAS).

Large amounts of empty razor shells were washed up in the tideline throughout the area (Figure XV.3), suggesting considerable stocks of these species are present around the low water mark and below.

Sources of contamination

The most potentially significant point source of contamination recorded was the Southport STW, which discharges to a watercourse known as the Crossens Pool (Figure XV.4). However, water samples 1 and 2, taken upstream and downstream of this discharge suggested that the final effluent was actually less contaminated than the receiving water. An intermittent discharge was also observed at Lytham St. Annes, just north of the boating lake (Figure XV.5). Sanitary related plastics were recorded at Southport, but these did not appear to be of very recent origin. Sanitary related debris of more recent origin (rag) was recorded towards the south eastern end of the Lytham St. Annes shoreline, suggesting spills of untreated sewage had occurred somewhere nearby relatively recently.

No significant watercourses were observed on the shoreline of Southport or St. Annes. The marine lakes at both these towns had overflows/outfalls, but neither was in operation at the time of survey. The closest significant watercourse to the Southport cockle beds is the Crossens Pool and there are several other significant rivers, including the Ribble itself, which discharge to the inner Ribble estuary. These rivers are likely to be the most significant pathways by which contamination is carried into the area along with tidal dispersion of any discharges to southern part of the Fylde coast and off Southport.

Both the Lytham St. Annes and Southport beaches are used by dog walkers and dog faeces were recorded on both these beaches. Seagulls and other waterbirds were sporadically encountered. Large aggregations of birds were recorded within the marshes at the north end of Southport (Figure XV.6) and to a lesser extent in the intertidal zone at Lytham St. Annes by the boating lake.

Some small areas of pasture were seen on the marshes just west of Crossens, but no livestock were present on these at the time of survey.

Sample results

Three seawater samples were taken at Lytham St. Annes and all showed fairly high levels of contamination, with results ranging from 400 to 1,400 *E. coli* cfu/100ml. Two samples were taken from the Crossens Pool watercourse, which contained

1,600 and 3,200 *E. coli* cfu/100ml downstream and upstream of the Southport STW outfall respectively.

Figure XV.1. Locations of shoreline observations and approximate locations of cockle areas

Table XV.1. Details of shoreline observations

No.	Date & Time	Position	Details
1	15/02/2011 10:42	SD 29743 13037	Dog walkers, dog droppings on beach, ~50 seagulls
2	15/02/2011 11:02	SD 31660 16203	Old sanitary debris (cotton buds)
3	15/02/2011 11:23	SD 32197 16785	Dog droppings, sanitary plastics widespread around here
4	15/02/2011 11:28	SD 32354 17119	~40 seagulls
5	15/02/2011 12:22	SD 34804 19865	Several hundred wildfowl on marshes inshore of road, about 200 geese on seawards side.
6	15/02/2011 13:16	SD 37159 20930	Southport STW outfall. Freshwater sample 1 (downstream Southport STW outfall)
7	15/02/2011 13:21	SD 37265 20836	Freshwater sample 2 (upstream Southport STW outfall)
8	16/02/2011 09:14	SD 32045 16397	Dog walkers
9	16/02/2011 09:18	SD 37029 26894	Fresh sanitary related debris
10	16/02/2011 09:25	SD 36751 26756	Seawater sample 3
11	16/02/2011 09:39	SD 35910 26889	Moorings, 7 small fishing vessels, one small yacht
12	16/02/2011 10:03	SD 34049 27168	Seawater sample 4
13	16/02/2011 10:08	SD 33793 27200	About 200 gulls on sand. Fresh sanitary related debris in tideline
14	16/02/2011 10:13	SD 33517 27231	Sewage outfall (not discharging)
15	16/02/2011 10:20	SD 33113 27472	Several hundred waders and gulls
16	16/02/2011 11:06	SD 30739 29576	Seawater sample 5

Table XV.2. Details of samples taken

Sample	Date & Time	Position	*Type*	*E. coli* (cfu/100ml)
1	15/02/2011 13:16	SD 37159 20930	Freshwater	1,600
2	15/02/2011 13:21	SD 37265 20836	Freshwater	3,200
3	16/02/2011 09:25	SD 36751 26756	Seawater	900
4	16/02/2011 10:03	SD 34049 27168	Seawater	1,400
5	16/02/2011 11:06	SD 30739 29576	Seawater	400

Conclusions

It is likely that the land runoff and sewage discharges to the Ribble estuary are the most significant sources of contamination to the area. Therefore, it is anticipated that levels of contamination are higher in areas more under the influence of the Ribble estuary, such as the cockle beds at Georges Brow and Grannys Bay. Crossens Pool, which carries the effluent from Southport STW is likely to be of most significance to beds at Georges Brow and Penfold Channel. Evidence of recent sewage spills on the Lytham St. Annes shore suggests that overflow discharges may be of significance here. Dogs and birds represent a diffuse source of contamination to the entire stretch of coastline and they are likely to have the greatest impacts in the inshore region. There is some pasture at the marshes by Crossens which is likely to be grazed by sheep or cattle during the warmer months of the year. As the cockle beds are generally quite far away from contamination sources, steep gradients in levels of contamination across them are not generally anticipated.

Figure XV.3 – Empty razor shells in tideline

Figure XV.4 – Southport STW outfall to Crossens Pool

Figure XV.5 – Intermittent discharge at Lytham St. Annes

Figure XV.6 – Wildfowl on marshes at northern end of Southport

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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
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
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
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
SSSI	Site of Special Scientific Interest
UV	Ultraviolet
WGS84	World Geodetic System 1984

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 a skewed data such as one 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 data set, 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”.

Acknowledgements

Cefas would like to thank Nigel Pontee (Halcrow), Helen Hoult (DEFRA), Phil Wittred (EA), Stephen Atkins, Steve Brown, Bob Houghton & Andrew Brownrigg (NWSFC), John Crowther (CREH), Prof. R. Falconer (Cardiff University).