EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Southend

2012

Cover photo: Intertidal area at Southend.

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STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc classification zones at Southend. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, determined in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. 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	30/08/2012	15/10/2012
London Port Health Authority	31/07/2012	16/10/2012
Inshore Fisheries and Conservation Authority	02/08/2012	13/08/2012
Anglian Water	31/07/2012	29/08/2012

DISSEMINATION: Food Standards Agency, London Port Health Authority, Environment Agency, Kent and Essex Inshore Fisheries and Conservation Authority.

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

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2012. Sanitary survey of Southend. 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*), mussels (*Mytilus* spp.) and Pacific oysters (*Crassostrea gigas*) harvested in the vicinity of Southend, from Canvey Island to the Shoebury Boom.

1.2 SITE DESCRIPTION

SOUTHEND COAST

The survey area lies on the northern shore of the outer Thames estuary and extends from Canvey Island through to the Shoebury Boom (Figure 1.1). The intertidal area is large, stretching up to 3km out from the high water mark and consists of a mixture of mud, sand, shell and gravel. The coastal strip is mostly urbanised, with the exception of the areas adjacent to Benfleet Creek, which separates Canvey Island from the mainland.

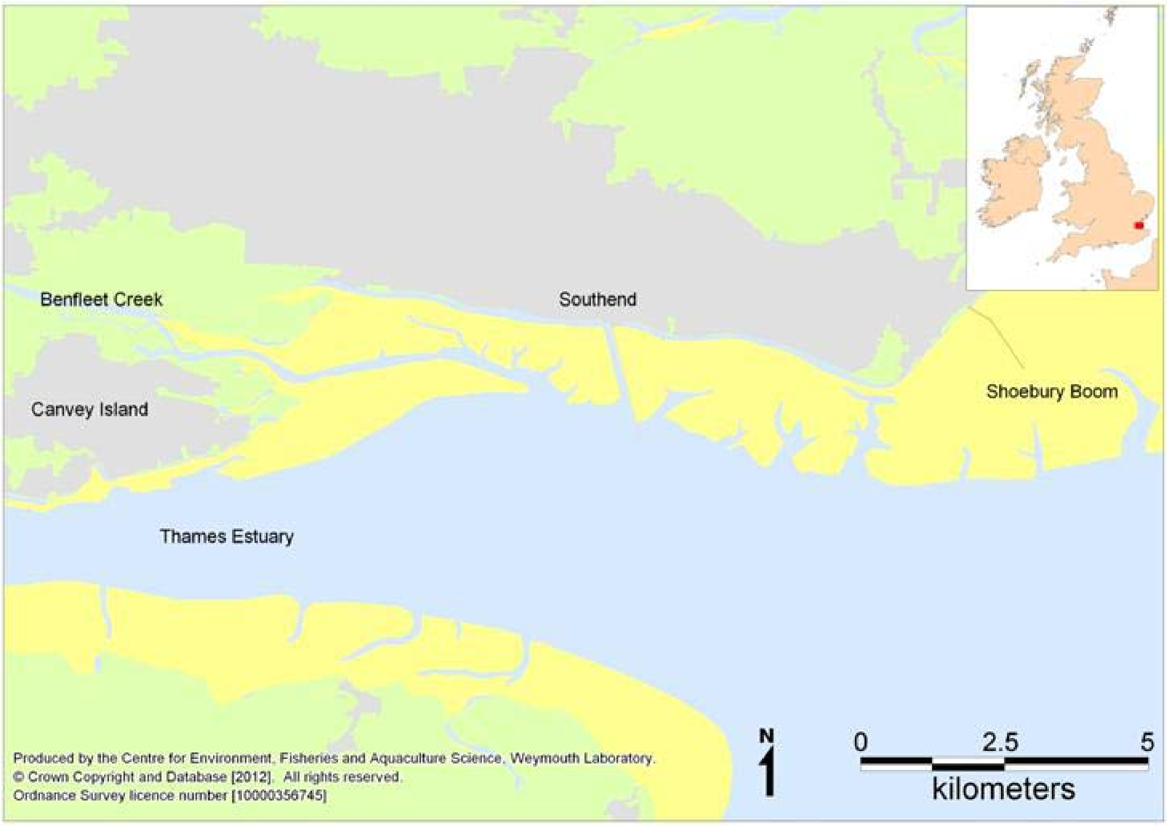

Figure 1.1 Features of the Southend coast.

CATCHMENT

The catchment area draining directly to the survey area is small, and consists of a relatively narrow coastal strip and Canvey Island. The total catchment is difficult to define exactly, and was estimated from the topography. This should represent the land draining directly to the Southend and Canvey Island foreshore and that draining a few kilometres either side. The estimated catchment area shown in Figure 1.2 is only 89km^2. Soils are mainly made of relatively impermeable London Clay (Scott-Wilson, 2010).

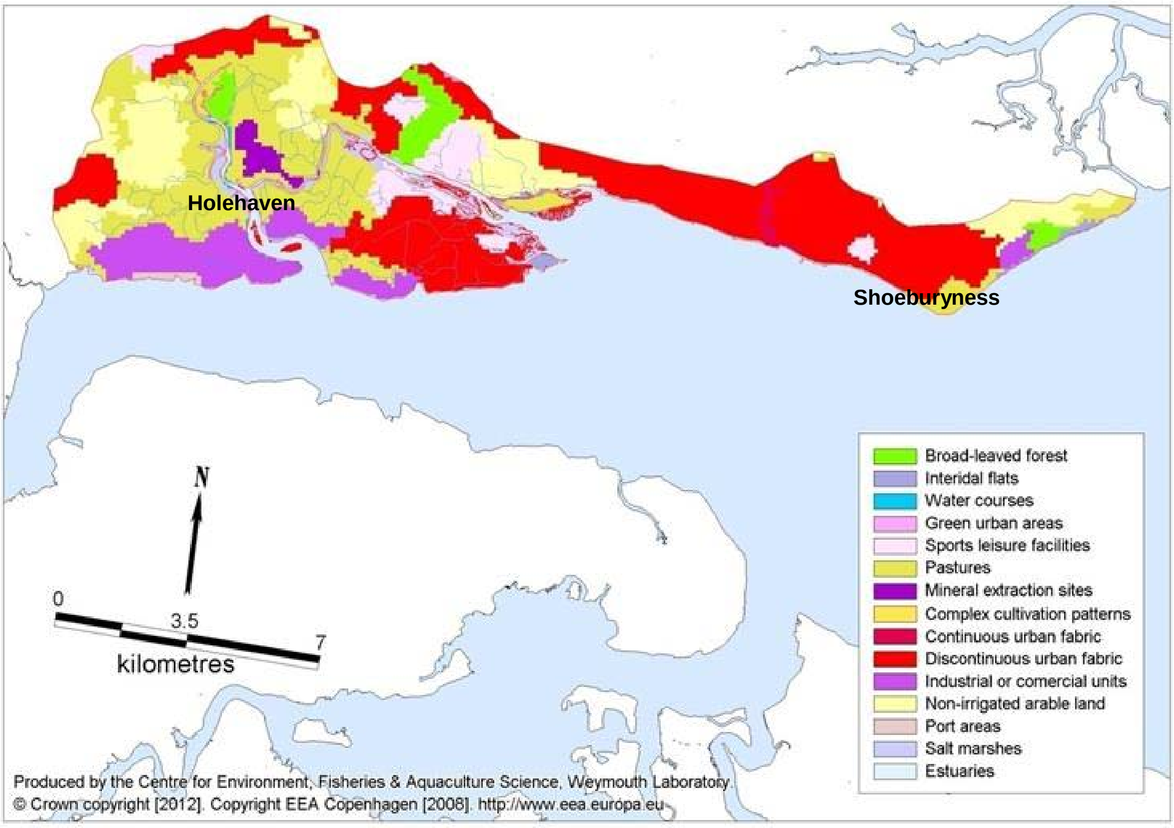

Figure 1.2 Land cover within the Southend catchment.

The vast majority of the coastal strip at Southend and much of Canvey Island is urbanised. Pastures border Vange Creek and the inner reaches of Holehaven Creek. Figure 1.2 shows an area of pasture at Shoeburyness, and although this was confirmed as grassland during the shoreline survey, no livestock or signs of recent use for grazing were seen here at the time. There are significant industrial areas around the mouth of Holehaven Creek.

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. RECOMMENDATIONS

The recommendations detailed below were not applied by the local enforcement authority due to practical concerns (difficulty of access, stock availability, resource constraints etc). A revised sampling plan providing sufficient public health protection as well as addressing the practical issues identified is being negotiated, and will hopefully be issued shortly.

2.1 Pacific oysters

2.1.1 Zoning arrangements and RMP locations

The following three zones are proposed to reflect differences in water quality and relative impacts of various sources of contamination within the survey area and to exclude areas likely to be subject to gross contamination. RMPs proposed are located where peak levels of contamination are anticipated to occur.

- Leigh Foreshore. The main contaminating influence here is the Benfleet STW and other sources within Benfleet Creek such as small watercourses, overwintering birds and yachts and houseboats. There is limited dilution potential within this Creek so relatively high concentrations of faecal indicators will be delivered to this zone during the ebb tide. An RMP should therefore be located as close to the Hadleigh Ray channel as is possible. The most practical location would be just off Canvey Point (TQ 8350 8386) as this should be accessible on foot, but could equally be sampled by dredge.
- Southend Flats. The main source of contamination within this zone is the Southend STW, which discharges through the long sea outfall. The zone boundaries should not extend to within 300m of this outfall. An RMP located by the end of Southend pier (TQ 8942 8308) would probably represent the location most likely to be exposed to the plume (mainly under southerly winds) where samples could be dredged from. This RMP would also be highly effective at capturing contamination from any spills from the Southend STW short sea outfall.
- Phoenix. The main source of contamination within this zone is the Southend STW although this will tend to remain offshore unless the plume is pushed inshore by southerly winds. An RMP located on the south west extremity of the East Knock bank (TQ 9332 8225) would probably represent the location most likely to be exposed to the plume where samples could be dredged from.

2.1.2 Species sampled

The species sampled should be Pacific oysters. Samples may be collected by dredge or by hand. Sampled stock should be of a marketable size.

2.1.3 Sampling frequency

The sampling frequency should be monthly.

2.1.4 RMP tolerances

A tolerance of 100m around these RMPs should be applied to allow repeated dredge or hand sampling.

2.2 Cockles

2.2.1 Zoning arrangements and RMP locations

It is proposed that the existing three zones are used as they cover the full area requiring classification and reflect the east-west gradient in water quality and relative impacts of various sources of contamination. Proposed RMPs are moved to where peak levels of contamination may be anticipated.

- Leigh Foreshore. The main contaminating influence here is the Benfleet STW and other sources within Benfleet Creek such as small watercourses, overwintering birds and yachts and houseboats. There is limited dilution potential within this Creek so relatively high concentrations of faecal indicators will be delivered to this zone during the ebb tide. An RMP should therefore be located as close to the Hadleigh Ray channel as is possible. The most practical location would be just off Canvey Point (TQ 8350 8386) as this should be accessible on foot, but could equally be sampled by dredge.
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- Phoenix. The main source of contamination within this zone is the Southend STW although this will tend to remain offshore unless the plume is pushed inshore by southerly winds. An RMP located on the south west extremity of the East Knock bank (TQ 9332 8225) would probably represent the location most likely to be exposed to the plume where samples could be dredged from.

2.2.2 Species sampled

The species sampled should be cockles. Samples may be collected by dredge or by hand. Sampled stock should be of a harvestable size.

2.2.3 Sampling frequency

A total of 10 samples per year will be required to maintain these classifications. Samples should be taken each month apart from December and January.

2.2.4 RMP tolerances

A tolerance of 100m around these RMPs should be applied to allow repeated dredge or hand sampling.

2.3 Mussels

2.3.1 Zoning arrangements and RMP locations

Mussels are limited in their distribution, so only one zone is proposed. The RMP is located where contamination is likely to be highest within this zone.

- West of Southend Pier. This zone encompasses the mussel bed which lies to the west of Southend Pier. The principle contaminating influences across the intertidal zone here lie to the west. The RMP should be located off Chalkwell, towards the western end of the zone as close as possible to where the Ray Gut and Leigh Creek channels meet (TQ 8608 8466)

2.3.2 Species sampled

The species sampled should be mussels. Samples may be collected by dredge or by hand. Sampled stock should be of a harvestable size.

2.3.3 Sampling frequency

If a full classification is to be maintained, sampling should be year round. This bed is depleted and not presently of commercial interest so classification may not be necessary, although stocks may recover in the future. There are two declassification options the LEA may wish to consider. If sampling frequency is reduced to quarterly, the zone may be maintained as 'temporarily declassified', and can be reclassified as soon as monthly sampling is reinstated. If sampling is stopped completely the zone will be fully declassified at the subsequent annual classification review.

2.3.4 RMP tolerances

A tolerance of 100m around the RMPs should be applied to allow repeated hand sampling.

3. SAMPLING PLAN

General Information

Location Reference

Production Area	Southend
Cefas Main Site Reference	M016
Cefas Area Reference	Southend
Ordnance survey 1:25,000 map	Explorer 176
Admiralty Chart	1185

Shellfishery

Species/culture	Cockles (*Cerastoderma edule*)	Wild
	Mussels (*Mytilus* spp.)	Wild
	Pacific oysters (Crassostrea gigas)	Wild
Seasonality of harvest	Open season for cockles is variable but falls within the June to November window. Other species may be harvested all year round.	

Local Enforcement Authorities

Name	London Port Health Authority, Thamesport & Lower River Division Quarantine Station, Denton, Nr. Gravesend, Kent DA12 2QE
Environmental Health Officer	Keith Wilson
Telephone number ☎	01474 363033
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E-mail	Keith.Wilson@cityoflondon.gov.uk

Requirement for Review

The sampling plan detailed below were not applied by the local enforcement authority due to practical concerns (difficulty of access, stock availability, resource constraints etc). A revised sampling plan providing sufficient public health protection as well as addressing the practical issues identified is being negotiated, and will hopefully be issued shortly.

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 2018. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within the Ribble estuary.

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Leigh Foreshore	TBA	Hadleigh Ray	TQ 8350 8386	51° 31.430' N 00° 38.624' E	Cockles, Pacific oysters	Wild	Dredge	Dredge or hand picked	100m	Monthly for Pacific oysters, Monthly excluding December and January for cockles	Replaces B16AH for cockles, replaces B16BS in part for Pacific oysters.
Southend Flats	TBA	Southend Pier	TQ 8942 8308	51° 30.893' N 00° 43.713' E	Cockles, Pacific oysters	Wild	Dredge	Dredge or hand picked	100m	Monthly for Pacific oysters, Monthly excluding December and January for cockles	Replaces B016D in part for cockles, replaces B16BS in part for Pacific oysters.
Phoenix	TBA	East Knock	TQ 9332 8225	51° 30.366' N 00° 47.053' E	Cockles, Pacific oysters	Wild	Dredge	Dredge or hand picked	100m	Monthly for Pacific oysters, Monthly excluding December and January for cockles	Replaces B16BR for cockles, new RMP for Pacific oysters
West of Southend Pier	TBA	Off Chalkwell	TQ 8608 8466	51° 31.430' N 00° 38.624' E	Mussels	Wild	Hand	Hand	100m	Monthly	Bed depleted and inactive, but may recover. Could be temporarily declassified by dropping sample frequency to quarterly. Replaces B16AX.

*RMP codes will not be generated on the database until the report has been agreed by all consultees, as the locations may be changed during the review process.

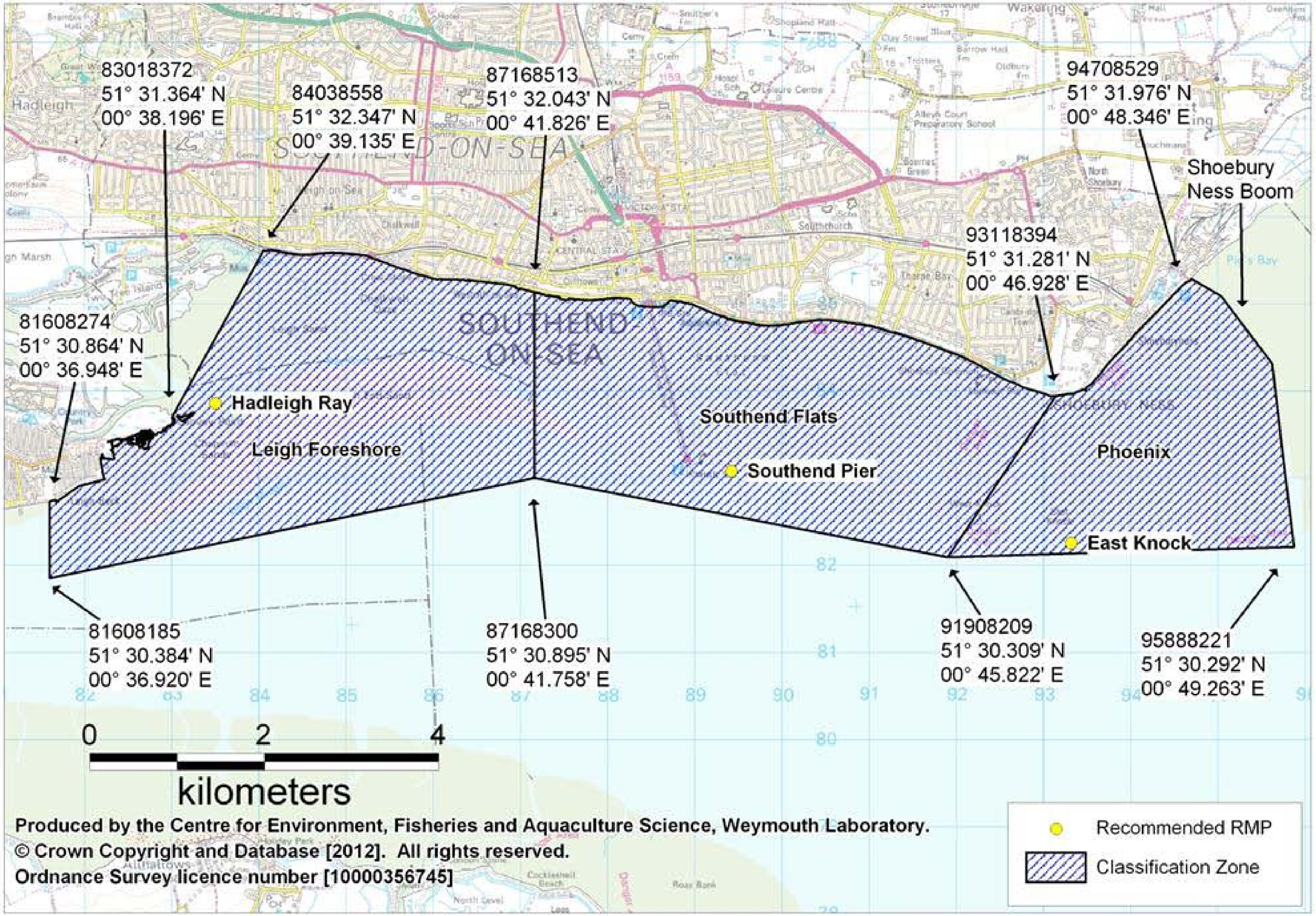


Figure 3.1 Recommended classification zone boundaries and RMP locations for Pacific oysters.

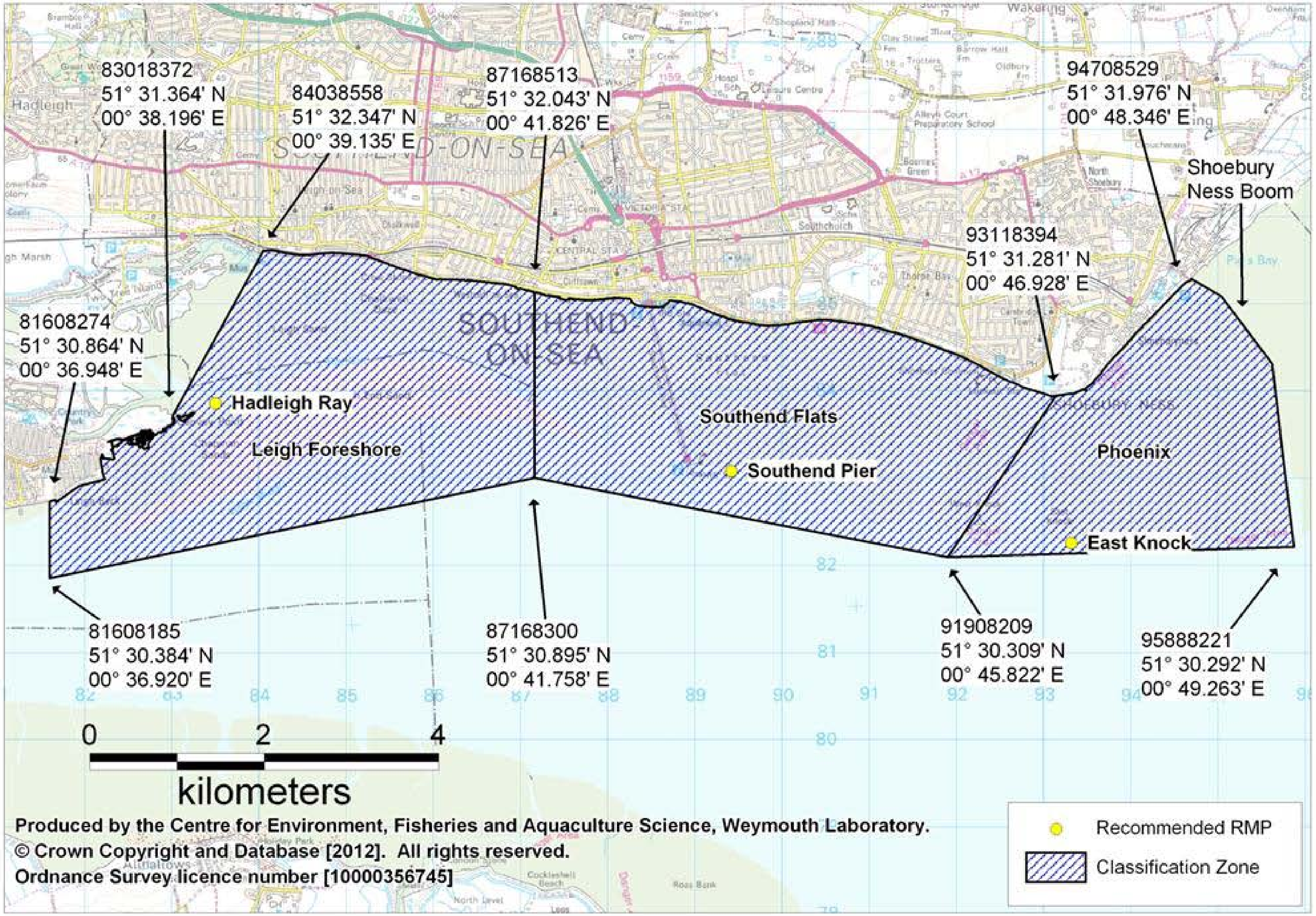


Figure 3.2 Recommended classification zone boundaries and RMP locations for cockles.

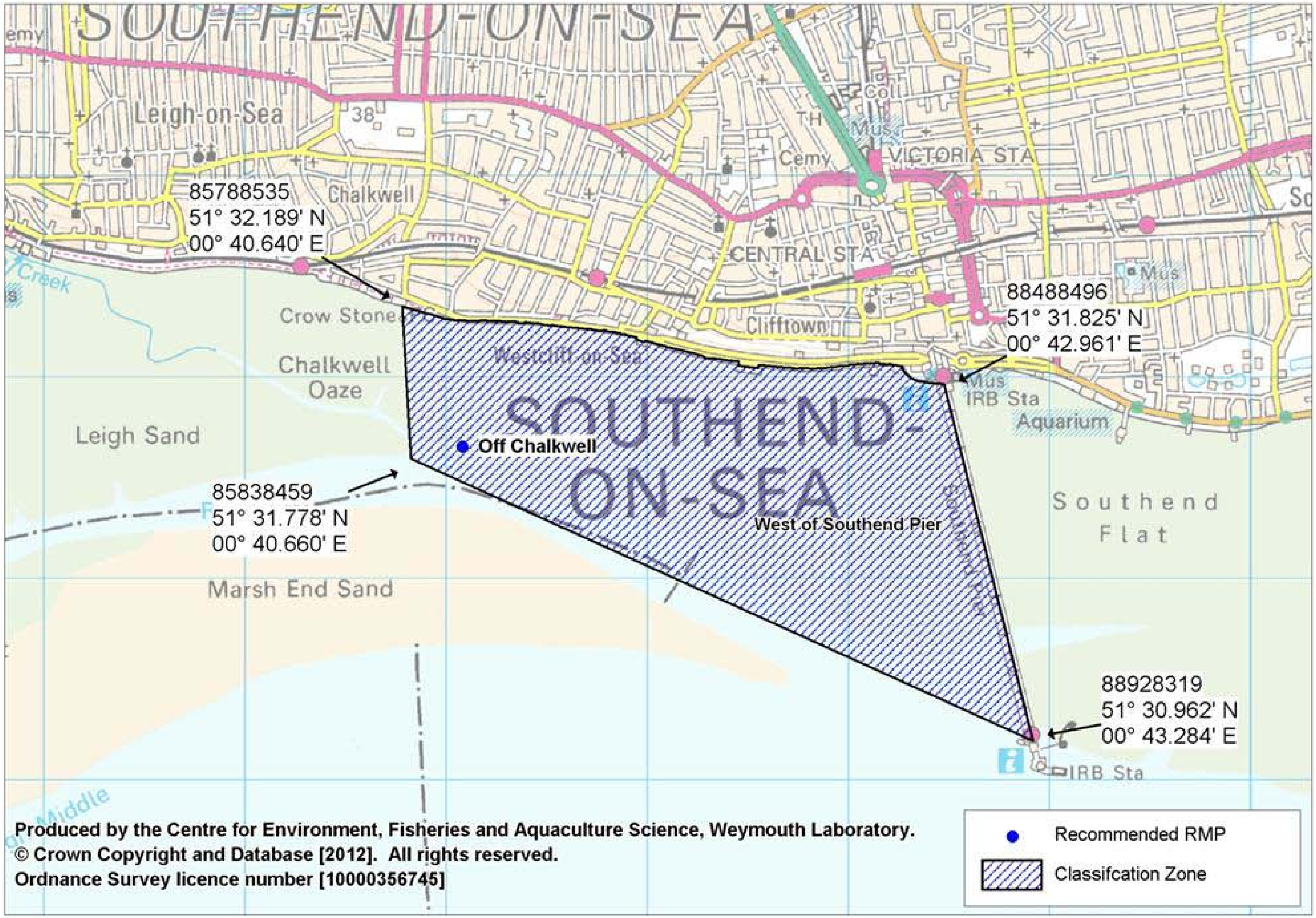


Figure 3.3 Recommended classification zone boundaries and RMP location for mussels.

4. SHELLFISHERIES

4.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for classification of wild Pacific oyster stocks between Southend Pier and Shoebury Boom. Other stocks of current or former commercial interest include wild mussels and cockles.

PACIFIC OYSTERS

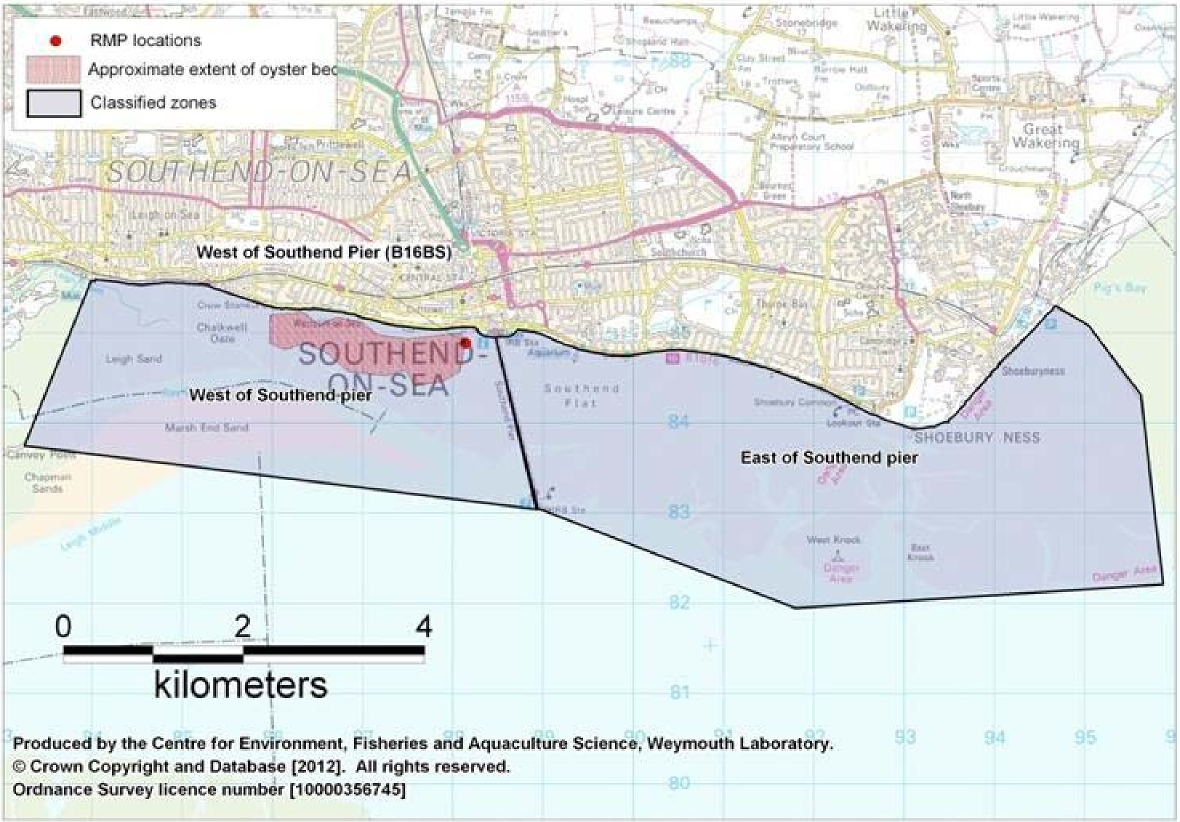


Figure 4.1 Classified zones for Pacific oysters

Naturally occurring Pacific oysters have become more frequent in the outer Thames estuary in recent years, almost due to the extent that reef formation has occurred (e.g. Natural England, 2009). An estimated biomass of nearly 400 tonnes of Pacific oysters on the Southend foreshore was reported in 2004 (Syvret *et al*, 2008). The temperature regime at Leigh-on-sea is thought to be sufficiently warm for successful spatfalls to occur on an annual basis (Syvret *et al*, 2008). More recently, in a mussel survey the Kent & Essex IFCA (K&E IFCA) reported that a former mussel bed off Southend was dominated by Pacific oysters in December 2008 (Wright & Bailey, 2009). Therefore, Pacific oysters appear to be well established, and are present in significant quantities off Southend. The shoreline survey confirmed that Pacific oysters were present throughout the stretch between Leigh-on-Sea and Shoebury Boom so their distribution is much more extensive than shown in Figure 4.1 (from CEFAS historic records). They were most commonly observed attached to hard surfaces in the intertidal zone such as concrete groynes and outfall pipes, although in some places significant numbers were seen lying unattached on sand and gravel. Stock of a range of sizes was seen indicating regular spatfalls. Occasional specimens and dead shells were also seen on the south shore of Canvey Island. A large proportion of the specimens seen were misshapen and so not particularly desirable for the live market. Figure 4.1 (previous page) shows the existing classified zones and RMPs for this species within the survey area. The exact distribution of stocks is uncertain as they have not been subject to a detailed stock survey.

COCKLES

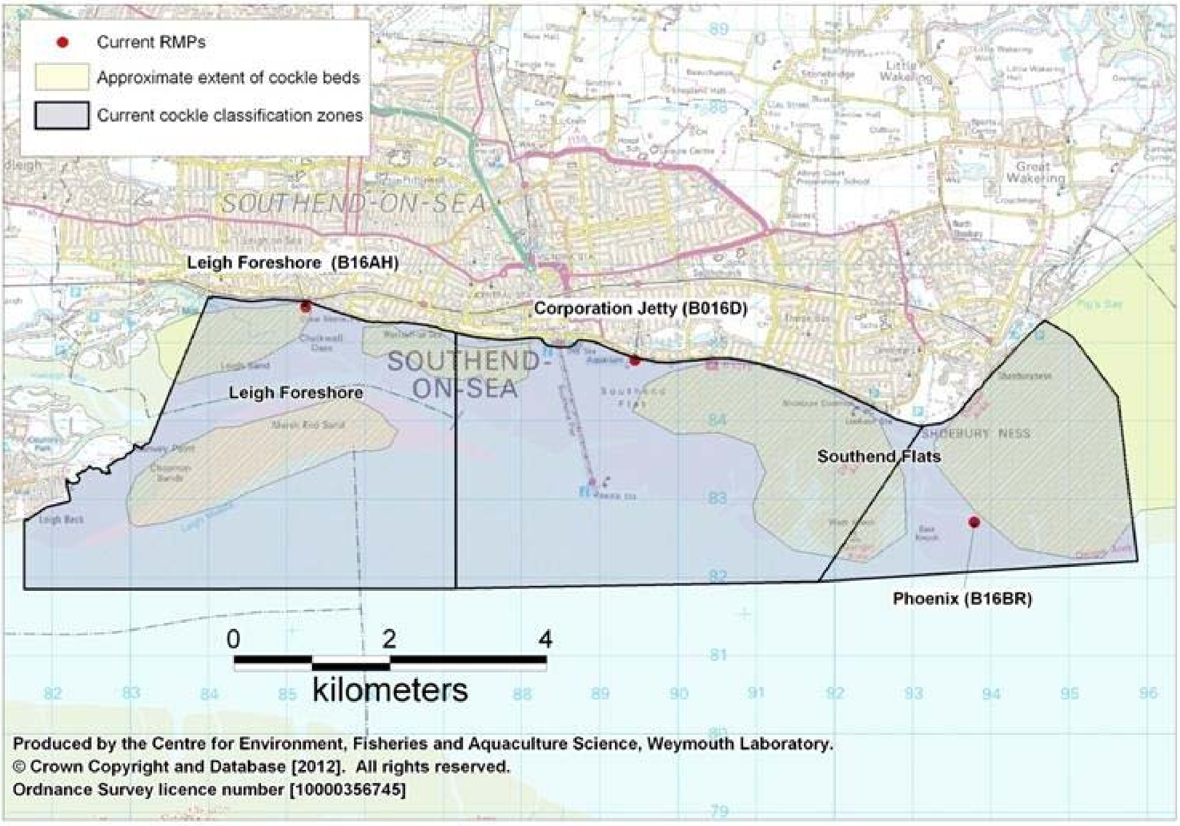


Figure 4.2 Classified zones and approximate bed locations for cockles

There is a significant dredge fishery for cockles throughout the outer Thames estuary, which is monitored and managed by the Kent & Essex IFCA. The main commercial harvesting areas are on Maplin and Foulness sands, just to the east of the survey area, but stocks extend through the intertidal and shallow subtidal areas through as far as Canvey Island. Within the area addressed by this sanitary survey stocks are generally higher towards the eastern end at Shoebury Boom (Bailey *et al*, 2010).

MUSSELS

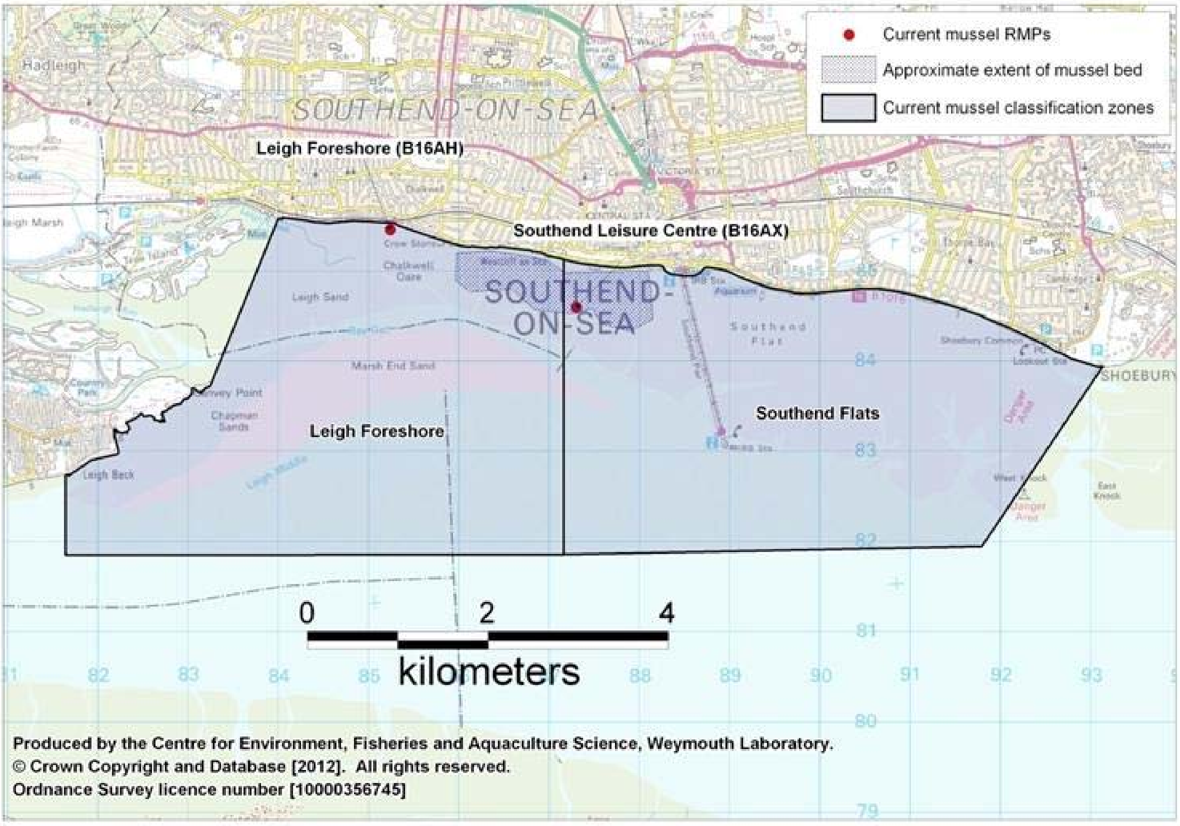


Figure 4.3 Classified zones and approximate bed location for mussels

Mussel beds were historically present within the survey area, but these are now being colonised and displaced by Pacific oysters (Wright & Bailey, 2009) and so are reported to be of little commercial interest at present from a mussel harvesting perspective. Stocks recover in the future, in which case interest in the fishery is likely to be renewed. Most remaining stock comprises undersized ‘seed’ mussels, although some larger animals are present in small numbers. Fishing for seed mussels to be relaid for ongrowing has historically occurred within the outer Thames estuary, but interest in this fishery is not currently strong. No applications to dredge seed mussels from here have been received by the K&E IFCA in the last 2 years. The Thames estuary, including the vast majority of the area covered by this survey, lies within a bonamia (a notifiable oyster disease) control zone. Therefore bivalve molluscs cannot be transported out of this area and relaid in uninfected areas. There are significant seed resources in other parts of the country which are unaffected by such controls and as such are more attractive to shellfish ongrowers.

4.2 GROWING METHODS AND HARVESTING TECHNIQUES

All stocks considered in this report are wild. The Pacific oyster fishery is fished by dredgers most typically by cockle boats during the cockle closed season. Significant commercial hand gathering also occurs (Kent and Essex IFCA, pers comm.) and there is a suspicion that not all Pacific oysters gathered in this manner are marketed legitimately (e.g. Southend Standard, 5th August 2010). Cockles are fished by suction dredge. Mussels may be either dredged or hand gathered.

4.3 Seasonality of harvest, conservation controls and development potential

Pacific oysters

There are no specific conservation controls applying to Pacific oysters such as a closed season or minimum landing size. Harvesting may occur at any time of the year, although increased interest from local shellfish boats is likely to arise during the closed season for cockles (November to May inclusive). Pacific oyster stocks have become more numerous and widespread in recent years throughout the entire outer Thames estuary, and it is likely that their expansion will continue on the whole, although some areas may be cleared through exploitation. There is increased demand for such oysters for relaying and ongrowing in France where juvenile oysters have recently suffered high levels of mortalities due to the oyster herpes virus.

Cockles

The cockle beds east of Leigh-on-Sea are regulated via the Thames Estuary Cockle Fishery Order 1994, whereas those west of here are regulated via K&E IFCA Byelaws. K&E IFCA Byelaws indicate a maximum vessel size (14m) and specify permissible dredge configurations, including a minimum bar spacing of 16mm. The fishery is open to any suitable boats but a permit and prior approval of the vessel and gear via an annual inspection is required. A maximum of 13.6 m^3 of cockles may be retained per vessel per day. Hand gatherers using rakes also require a permit. No more than 10% by weight of a representative sample of the catch can pass through a space 16mm in width. The fishery is only opened at the discretion of the K&E IFCA, based on stock status and other considerations. It was not opened in either 2010 or 2011 to prevent boats from other areas affected by unexplained cockle mortalities from fishing the area and potentially importing diseases. When the fishery does open, it is within the June to November (inclusive) window at which point meat yields are best, most typically during the latter half of this period.

Within the Thames Estuary Cockle Fishery Order only a limited number of licences (14) are issued to dredge for this species. Quotas are assigned on the basis of quarterly stock surveys. The exact timing of the open season varies from year to year but again falls within the June to November window. Effort limitations (days per week) and gear restrictions apply. Specific areas may be closed on the basis of stock survey information. Whilst the fishery is in progress, effort is actively managed by the K&E IFCA with the aim of maximising yield without depleting stocks.

Cockle stocks tend to fluctuate in their size and distribution from year to year. Success of spatfalls may vary greatly between years and stocks may be affected by storms, temperature extremes, diseases, predation and of course exploitation.

Whilst the stock biomass fluctuates significantly from year to year, the locations of cockle beds within the Thames estuary tend to be reasonably stable.

MUSSELS

There is no closed season for mussels. There is a maximum dredge front opening size of 2m for vessels fishing for mussels. A maximum of 13.6 m^3 of mussels may be retained per vessel per day. No more than 10% by weight of a representative sample of the catch can pass through a space 18mm in width. Any fishing for seed mussels requires prior written authorisation from the K&E IFCA. The populations of mussels on harder substrates tend to be reasonably stable, whereas the populations on softer substrates are more variable in their locations and tend to be of smaller seed stocks. On the intertidal areas off Southend mussel beds are being displaced by Pacific oysters, although if stocks recover then renewed commercial interest is likely.

4.4 HYGIENE CLASSIFICATION

Table 4.1 list all classifications within the survey area from 2002 onwards.

Table 4.1 Classification history for Southend areas, 2002 onwards

Area	Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
West of Southend Pier	P. oysters	-	-	B	B	B	B	B	B	B-LT	B-LT
East of Southend Pier	P. oysters	-	-	-	-	-	-	-	-	-	C (P)
Chapman Sands	Cockles	C	C	C	-	-	-	-	-	-	-
Leigh Foreshore	Cockles	C	C	C	C	B	B	B	C	C	C
Southend Flats	Cockles	C	C	C	C	B	B	B	B	C	C
Phoenix	Cockles		B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Chapman Sands	Mussels	C	C	C	-	-	-	-	-	-	-
Leigh Foreshore	Mussels	C	C	C	C	B	B	B	C	C	C
Southend Flats West	Mussels	C	C	C	C	B	B	B	B	-	-
Southend Flats	Mussels	C	C	C	C	B	B	B	B	B-LT	B-LT

LT denotes long term classification
P denotes preliminary classification

Current classification zone boundaries for Pacific oysters, cockles and mussels are shown in Figures 4.1, 4.2 and 4.3 respectively (Pages 17, 18 and 19). A preliminary C classification for Pacific oysters was awarded East of Southend Pier to allow stocks to be fished. The classification history indicates that shellfish beds towards the western end of the survey area are more likely to receive C classifications suggesting the western end is subject to higher levels of contamination.

Table 4.2 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 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

5. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of sources of contamination, their likely impacts and patterns in levels of contamination observed in water and shellfish. samples taken in the area under various programmes. This is 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

Naturally occurring stocks of Pacific oysters, cockles and mussels are present within the survey area and require continued classification. Stocks of Pacific oysters have increased in recent years, and extend through the intertidal area from Canvey Island through to the Shoebury Boom. It is likely that some are present along the south shore of Canvey Island, but the intertidal zone here is much narrower and no request to classify this area has been made. A range of sizes are present off Southend indicating regular settlement and they are now reported to be displacing mussel stocks. Although variable in terms of market appeal, a strong export market for Pacific oysters has developed in the wake of the oyster herpes virus outbreak affecting France. They are fished commercially by dredge and are also hand gathered, possibly on a commercial basis. There is no closed season for this species so a year round classification is required.

Cockles in the outer Thames estuary are the subject of a large commercial dredge fishery. The main commercial harvesting areas are on Maplin and Foulness sands just to the east of the survey area, but stocks extend through the intertidal and shallow subtidal areas through as far as Canvey Island, but are generally more concentrated towards Shoebury. Therefore, the entire intertidal and shallow subtidal area from Shoebury Boom to Canvey Island requires continued classification. Cockle harvesting is closely managed by the Kent and Essex IFCA, and the season opens within the June to November window when meat yields are highest. Classification is therefore only necessary for this period. Sampling this fishery requires significant resources particularly at RMPs sampled via dredge when the fishery is closed and no boats are operating commercially. Stocks east of Leigh-on-Sea (i.e. the majority of stocks) are regulated via the Thames Estuary Cockle Fishery Order 1994, whereas those west of here are regulated via K&E IFCA Byelaws. The latter fishery was not opened in 2010 or 2011.

Mussel beds were historically present within the survey area primarily in the area just west of Southend Pier, but these are mainly undersized and are now being displaced by Pacific oysters. Currently there is little commercial interest in harvesting these stocks so the LEA may wish to consider a temporary declassification of this fishery. Such a strategy allows sampling frequency to drop from monthly to quarterly but allows the fishery to be reclassified immediately on the start of monthly sampling. There is no closed season for mussels in the district so harvesting may potentially occur at any time of the year.

Surrogate species

An investigation into the relative levels of *E. coli* accumulation in different bivalve species was recently carried out by Cefas on behalf of the FSA (Younger & Reese, 2011). Comparisons of paired sample results supported the use of mussels as a surrogate for Pacific oysters. Although cockles accumulated *E. coli* at broadly similar levels to mussels, they appeared to show a tendency for more extreme high results than mussels. Therefore mussels should not generally be used to represent cockles without a period of parallel monitoring to ascertain whether this would be appropriate on a site specific basis.

Formal guidelines for the use of surrogate species are yet to be developed and accepted, although such an approach has been endorsed by the competent authority (the FSA) in some areas. As the acceptable surrogate species generally accumulate *E. coli* to similar or slightly higher levels, the use of surrogate species for classification of areas where class B compliance is borderline should not be adopted to avoid potentially disadvantaging the industry.

At Southend, mussels could potentially be used as a surrogate species for Pacific oysters although their somewhat limited distribution would mean that sample bags may have to be maintained in some places. It is unlikely that these would be left undisturbed given the amount of human activity on the foreshore here so this is probably not a viable strategy. Mussels may potentially be used as a surrogate for cockles but only after a period of parallel monitoring to confirm that this is appropriate. Again, given their limited distribution this is unlikely to be practical.

Reduced sampling effort for seasonal classifications/closures

The cockle fishery is open during the June to November window (6 months of the year) and the native oyster fishery is only open from September to April (8 months of the year). Classification of these species for commercial harvesting is only required whilst the fisheries are open. Current classification protocols (Cefas, 2011) indicate that a minimum of 10 samples per year are generally required for classification but do not indicate that further reductions in sampling effort may be made to reflect seasonally inactive fisheries. Sampling of the cockle dredge fishery may also be reduced to 10 occasions per year so sampling for this fishery is only necessary for the 10 months from February to November inclusive. It should be noted that the 10 samples are the minimum requirement for classification so if any of these samples are missed or rejected by the laboratory, resampling would be necessary.

Pollution Sources

Freshwater Inputs

The catchment draining to the survey area is small and largely urban and soils are mainly impermeable. Rainfall in the region is relatively low and much of this is lost to evaporation and transpiration during the warmer months of the year. As a consequence freshwater inputs direct to the survey area are low, especially during the summer, but may carry quite high levels of contamination and are likely to respond rapidly to rainfall.

Along the Southend seafront the principle freshwater inputs are the Prittle Brook flood relief tunnel, the Willingale stream and an unnamed stream at Shoebury, all of which are very minor in terms of volumes discharged. The former was not flowing and the latter two were covered by the tide at the time of the shoreline survey. The Prittle Brook tunnel carries excess flow from the Prittle Brook which runs into the Roach estuary and so only flows after significant rainfall. The Willingale stream passes through balancing ponds at Southchurch Park and enters the sea via a pumping station. Three very minor streams at the western end of the Southend seafront were sampled and measured during the shoreline survey. Although discharge rates were very low (max $103m^3$/day based on spot flow measurements) one small stream at Leigh contained >20,000 *E. coli* cfu/100ml suggesting some sanitary content and carried an estimated bacterial loading of $>1.8x10^{10}$ *E. coli* cfu/day, so may have some localised influence. The contaminating influence of these watercourses is anticipated to be very minor under dry conditions, but may increase to the extent that they may cause small but noticeable hotspots of contamination under wet weather conditions.

In addition to these there are several small watercourses discharging from the mainland to Benfleet Creek, East Haven Creek, Holehaven and Vange Creek, which drain a mix of farm land and developed areas. Again these inputs are likely to be relatively minor and their combined bacterial loadings will be carried out of these creeks towards the shellfisheries on the ebbing tide. Canvey Island lies below the mean high water level and is drained via a network of ponds and ditches which feed a series of pumping stations and gravity sluices which discharge through the sea walls. These are also anticipated to be of minor and localised importance.

HUMAN POPULATION

The area considered in this report is densely populated with a total resident human population of just under 220,000 at the last published census (2001). The majority reside within Southend, with Canvey Island representing a secondary population centre. Both Southend and Canvey Island are popular holiday destinations due to their seaside location, attractions, their close proximity to London and have a large amount of tourist accommodation. Anglian Water estimated seasonal ‘holiday’ population increases of 9 and 16% within the Southend and Canvey Island sewerage catchments respectively. Therefore influxes of visitors and corresponding increases in sewage volumes will occur here during the summer months. Impacts form human settlement on the opposite southern side of the Thames estuary is not considered here as the distances involved and hydrographic regime means that these will not have a practical influence on the outcome of the sampling plan.

SEWAGE DISCHARGES

There are five major sewage works within the survey area, all of which provide secondary treatment. All of these discharges are large in terms of volumes and will generate large bacterial loadings. Tentative estimates were made of the bacterial loadings they generate based on reference values of bacterial concentrations from a range of similar works and consented dry weather flows. The largest is Southend STW (estimated loading $2.3x10^{14}$ faecal coliforms/day) which discharges in 12m of water about 600m off the low water mark between Southend Pier and Shoeburyness. The Canvey Island STW (estimated loading 4.3×10^{13} faecal coliforms/day) discharges direct to the outer Thames estuary about 50m from the south shore of the island just below the low water mark. The Benfleet STW (estimated loading 2.3×10^{13} faecal coliforms/day) discharges to the Benfleet Creek at the northern tip of Canvey Island. The Basildon and Pitsea STWs (estimated combined loading 1.2×10^{14} faecal coliforms/day) both discharge to Vange Creek, which becomes Holehaven Creek in its lower reaches. Elevated levels of contamination are anticipated throughout these enclosed creeks and significant plumes will emanate from the two coastal outfalls and from the mouths of Holehaven and Benfleet Creeks. The shape of these plumes will be largely dictated by tidal streams. RMPs should be set in locations which maximise their exposure to such plumes, and the Southend STW main outfall should be excluded from any classification zone to prevent the harvest of grossly contaminated shellfish.

The sewerage networks associated with these treatment works include a number of intermittent overflow discharges which can deliver large volumes of untreated storm sewage direct to coastal waters. Of most potential significance to the fisheries are the series of intermittent outfalls located along the Southend seafront from Leigh on Sea through to Shoeburyness. Also of potential significance is a small cluster of these discharging to a tributary of Benfleet Creek at South Benfleet. On Canvey Island all intermittent outfalls apart from the overflow from the STW discharge to the network of surface water drainage ditches. All of the other main STW outfalls are also used as overflow discharges with the exception of Pitsea STW, and there is a short sea outfall used for intermittent discharges off Southend about 1km east of the pier head.

Information on spills was provided by the water company for the closest discharges which had telemetry, but this information showed only potential rather than confirmed spills and was in a processed form. It is therefore difficult to make any meaningful assessment of their significance apart from noting their location and potential to deliver large bacterial loadings. Their geographic distribution suggests that the entire Southend seafront, the Benfleet Creek, and the surface water outfalls from Canvey Island may all be affected at times. Of the monitored outfalls, two towards the eastern end of the Southend foreshore recorded the highest number of potential spills. Spills will mainly be associated with wet weather events, particularly within the sewerage networks which collect significant amounts of surface water. The Canvey Island and Southend sewer networks are reported to receive surface water as well as sewage so may be more prone to discharge during wet weather. Occasionally spills may be associated with mechanical failures or blockages which may occur at any time. Without any further information it is impossible to assess which outfalls in each of these networks are the main spill sites. Consequently it is difficult to accommodate the potential impacts of these in the sampling plan, although they may from time to time generate highly significant bacterial loadings.

The vast majority of properties in the Southend catchment are connected to mains sewers but there are a handful of small private discharges to the area, some of which discharge to soakaway and others to watercourses. Of the 30 private discharges which contain sewage the majority discharge to watercourses, so some watercourses will therefore carry some contamination from private discharges. The cumulative bacterial loadings generated by these will be very minor in relation to those from water company discharges.

AGRICULTURE

Livestock census data and land cover maps indicate very limited agriculture within the small catchment area considered in this report. In 2010, there were 19 registered holdings, and a total of 1196 cattle, and an unspecified number of pigs, sheep and poultry, numbers of which are likely to be small as the data was withheld because it related to less than five holdings. The majority of pastures lie adjacent to Vange Creek and the inner reaches of Holehaven. There is a smaller area of pasture at Shoeburyness but no livestock or signs of recent grazing were recorded here during the shoreline survey. There are also some pockets of arable land mainly within the Benfleet Creek, Vange Creek and Holehaven catchment areas to which manures or treated sewage sludge may be periodically applied.

Grazing animals will deposit directly on pastures whilst outdoors. Cattle are likely to be transferred indoors during the winter and their manure will be collected and applied to pastures. Manure from pig and poultry operations is typically stored and spread periodically on nearby farm land. No source of firm information on local practices concerning application of manures and sludge has been identified but such information would aid further assessment. The primary mechanism for mobilisation of faecal matter deposited on agricultural land into watercourses is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Runoff from the majority of the catchment area enters the estuary upstream of the fishery, so in general higher impacts may be anticipated within Vange Creek and the creeks surrounding Canvey Island. RMPs set within the plumes emanating from these creeks would best capture any contamination of agricultural origin, although this is likely to be a minor consideration compared to sewage sources.

There is likely to be seasonality in levels of contamination originating from agriculture. Numbers of cattle will increase significantly in the spring, with the birth of calves and decrease in the autumn when animals are sent to market. Cattle slurry collected during the winter may be stored for long periods, although farms without large storage capacities are likely to spread it during the winter and spring. Therefore peak levels of contamination from 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 manure/slurry/sludge application which may be more likely in winter or spring. Manures and sludges may be applied to arable land at any time of the year.

BOATS

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries at Southend. As well as a major shipping channel through the Thames estuary, there is considerable local boating activity within the area, including pleasure craft (yachts and cabin cruisers), fishing boats and houseboats. There are boatyards/marinas within Leigh Creek, Smallgains Creek (eastern Canvey Island) and Benfleet Creek. Within Benfleet Creek there are a significant number of houseboats in the upper reaches either side of the Benfleet Flood Barrier. There are areas of moorings at Thorpe Bay, Leigh-on-sea, and within the mouths of Benfleet Creek and Holehaven. Tanker terminals are located either side of the mouth of Holehaven.

Merchant shipping will remain in deeper water away from shellfisheries but is anyhow prohibited from making overboard discharges in nearshore waters. The smaller private vessels (yachts, cabin cruisers, fishing vessels etc) may make overboard discharges. There is considerable uncertainty about the extent to which such discharges occur, and whether they impact significantly on shellfish hygiene. Houseboats in occupation are likely to make regular discharges. Crews of vessels within marinas have relatively easy access to onshore facilities so may be less likely to discharge. Boats in occupation on moorings or those in transit may be most likely to discharge overboard. On this basis, Benfleet Creek, Leigh Creek and Thorpe Bay may be most vulnerable to contamination from this source. Peak pleasure craft activity is anticipated during the summer so associated impacts are likely to follow this seasonal pattern.

Wildlife

The intertidal flats, saltmarshes, and muddy creeks in the area provide good habitat which is used extensively by overwintering waterbirds (wildfowl and waders). Peak winter waterbird counts of about 30,000 occur within the Benfleet / Southend Marshes and 8,000 within Holehaven Creek. Densities of foraging waterbirds tend to be lower on the intertidal area off Southend compared to the Leigh-on-sea foreshore, Benfleet Creek, Chapman Sands and Holehaven Creek. 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. There are resident populations of other species such as gulls which are present all year round. Therefore any impacts will be year round but considerably higher during the winter. Pathways will be via direct deposition on the intertidal, via runoff or tidal inundation of areas of saltmarsh and wetland. Such impacts are diffuse, but given their distribution may tend to be more acute within the enclosed tidal creeks. RMPs set to capture contamination ebbing from these creeks may best capture contamination of avian origin.

Marine mammals (seals and small cetaceans) are sporadically recorded within the Thames estuary, but given their ranging habits and sporadic presence they will have no bearing on the sampling plans.

Domestic animals

Dogs exercised on beaches may also be a source of contamination direct to the intertidal zone. Dogs are banned from all Southend beaches from May to September so any impacts would generally arise outside of this period. As a relatively minor and diffuse source of contamination they will have little bearing on the sampling plan.

SUMMARY OF POLLUTION SOURCES

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

Table 5.1 Qualitative assessment of changes in pollution load at Southend.

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
Intermittent sewage discharges	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Land runoff	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Boats	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Orange	Orange	Yellow	Yellow	Yellow
Waterbirds	Orange	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Orange
Domestic animals	Yellow	Yellow	Yellow	Yellow						Yellow	Yellow	Yellow

Red - high risk; orange - moderate risk; yellow – slight risk

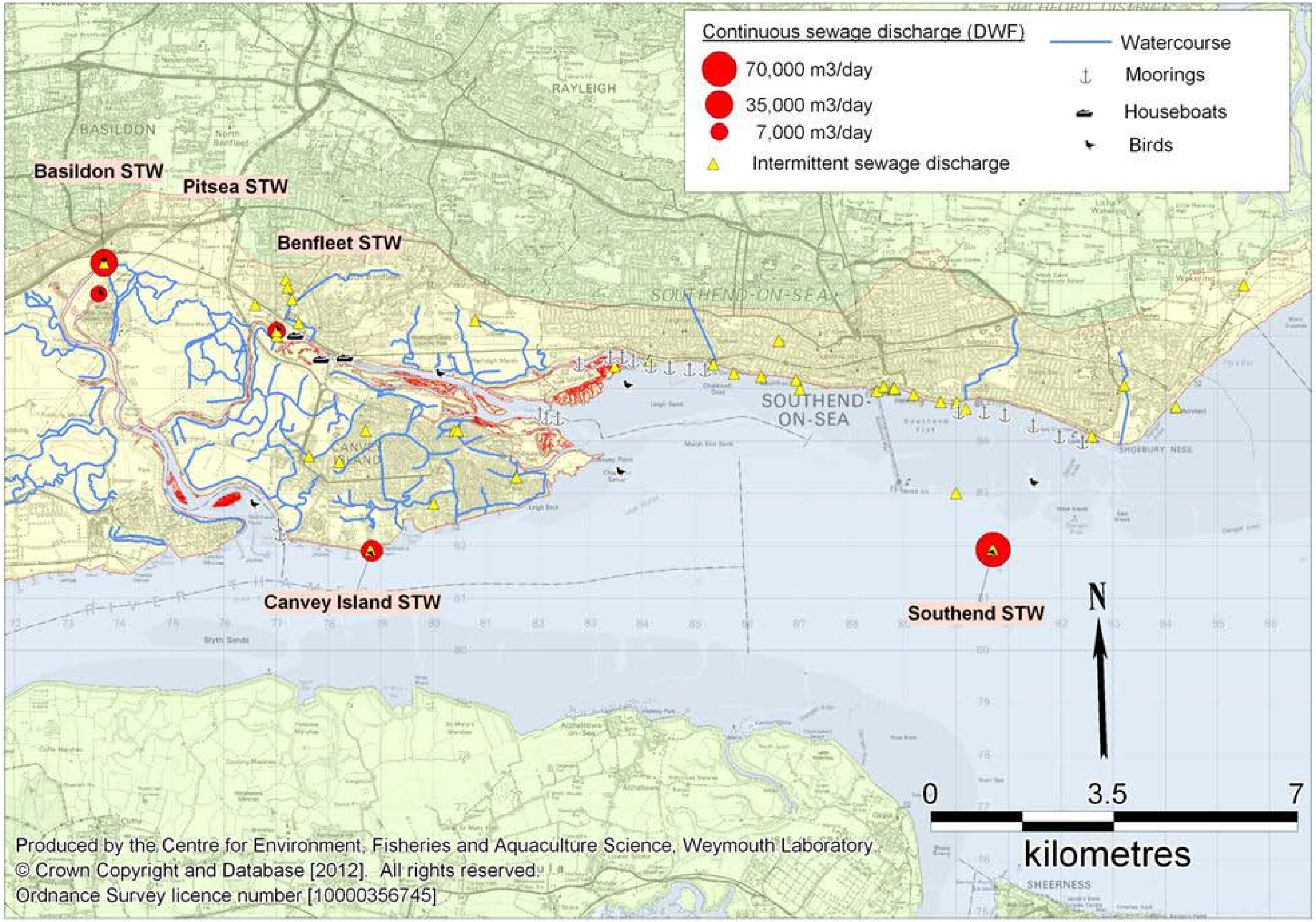


Figure 5.1 Significant sources of microbiological pollution to Southend.

HYDRODYNAMICS

Southend is located on the north shore of the outer reaches of the Thames estuary, which widens significantly from Canvey Island to Shoebury thereby increasing the dilution potential towards the eastern end of the survey area. The intertidal area off Southend in which the shellfisheries are located is gently sloping and extends out to up to about 3km from the high water mark. Below the low water mark depth increases rapidly to about 16m at the eastern end of the Southend foreshore, and more gradually at the western end. The Canvey Island foreshore is much narrower and steeper. The main Thames channel runs parallel to the shore about 4km off Southend and is maintained at a depth of over 10m. A second channel (Leigh Channel) splits from the dredged channel off Shoebury and runs past the end of Southend Pier, becoming progressively shallower towards its western end where it is called Ray Gut. West of Southend pier it crosses the intertidal and splits into two channels one of which (Hadleigh Ray) runs into Benfleet Creek, the other runs into Leigh Creek. Canvey Island is encircled by tidal creeks which are narrowest and shallowest in the stretch located to the north west of the island.

The tidal range is relatively large at 5.3m on spring tides and 2.9m on neap tides, this drives extensive water movements. A tidal diamond located about 3km off Southend indicates that tidal streams are bi-directional, moving west on the flood and east on the ebb. Such a pattern indicates that sources of contamination will generally impact to the east and west of their locations, and impacts will decrease with distance as the plume becomes more dilute. Based on this tidal diamond tidal excursions are in the order of 13-14km on spring tides and 9-10km on neap tides so major sources may potentially impact over such distances. Effluent from the Southend STW will tend to remain in deeper water offshore although on the flood tide it may be carried up the Leigh Channel towards Ray Gut. Effluent from Canvey Island STW will tend to remain on the edge of the deepwater channel as it moves towards the shellfisheries on the ebb tide, but will become more dispersed with distance.

Whilst the tidal diamond off Southend will be representative of flows within the more offshore areas, the bathymetry of the inshore and intertidal areas will modify tidal currents. Flows are likely to be slower in shallower water, and for the most part will run parallel to the shore. To the west of Southend Pier they will tend to align with the channels (Ray Gut, then into Hadleigh Ray and Leigh Creek) particularly during the lower states of the tidal cycle. These channels will convey tidal flows in and out of the tidal creeks which encircle Two Tree Island and Canvey Island.

The tide floods up both Holehaven and Benfleet Creeks simultaneously meeting somewhere in East Haven Creek with the reverse occurring on the ebb. As a consequence, effluent from Benfleet STW and other sources within Benfleet creek will be carried across the shellfish beds by the ebb tide, and the impact will be greatest at the western end of the Southend foreshore. Highest concentrations of associated faecal indicator bacteria will arise in the Benfleet Creek/Hadleigh Ray/Ray Gut channel towards low water. Effluent from the Pitsea and Basildon STWs and other sources in Holehaven and Vange Creek will be carried out through Holehaven on the ebb tide then meet the main Thames estuary where it will be subject to significant dilution but will continue towards the shellfisheries for the duration of the ebb.

The outer reaches of the Thames estuary are well mixed, and there is little in the way of freshwater inputs within the survey area, so density driven circulation will not influence the pattern of water movements here. One density effect of potential importance to the assessment is the tendency for sewage effluent from deepwater outfalls such as Southend STW to float to the surface which may tend to keep it away from any nearby benthic shellfish beds.

Strong winds may drive surface currents to such an extent that they significantly modify water circulation patterns. The surface currents will create return currents along sheltered margins or lower in the water column. 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 east (and from the west to a lesser extent) are likely to have the greatest effects on circulation in the area as a whole because they align with the orientation of the estuary. Easterly winds will tend to push surface water up the estuary and up Benfleet Creek, with westerly winds having the opposite effect. Winds may cause significant variation to the dispersal of the buoyant plume from the Southend STW outfall, and winds with a southerly element will advect this towards the shore and the shellfish beds. Onshore winds will also create wave action which may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column. South easterly winds present the greatest risk to the Southend foreshore in this respect. It is therefore concluded that shellfish beds on the Southend foreshore may be subject to higher levels of contamination during southerly and south easterly winds. Although this will not directly affect the sampling plan it may be a consideration when investigating the causes of high results.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

The survey includes a wealth of bacteriological monitoring data from recent years deriving from the Bathing Waters, Shellfish Waters and hygiene classification monitoring programmes. Results from 2002 onwards were examined in detail. Figure 5.2 shows the locations that these samples were collected from.

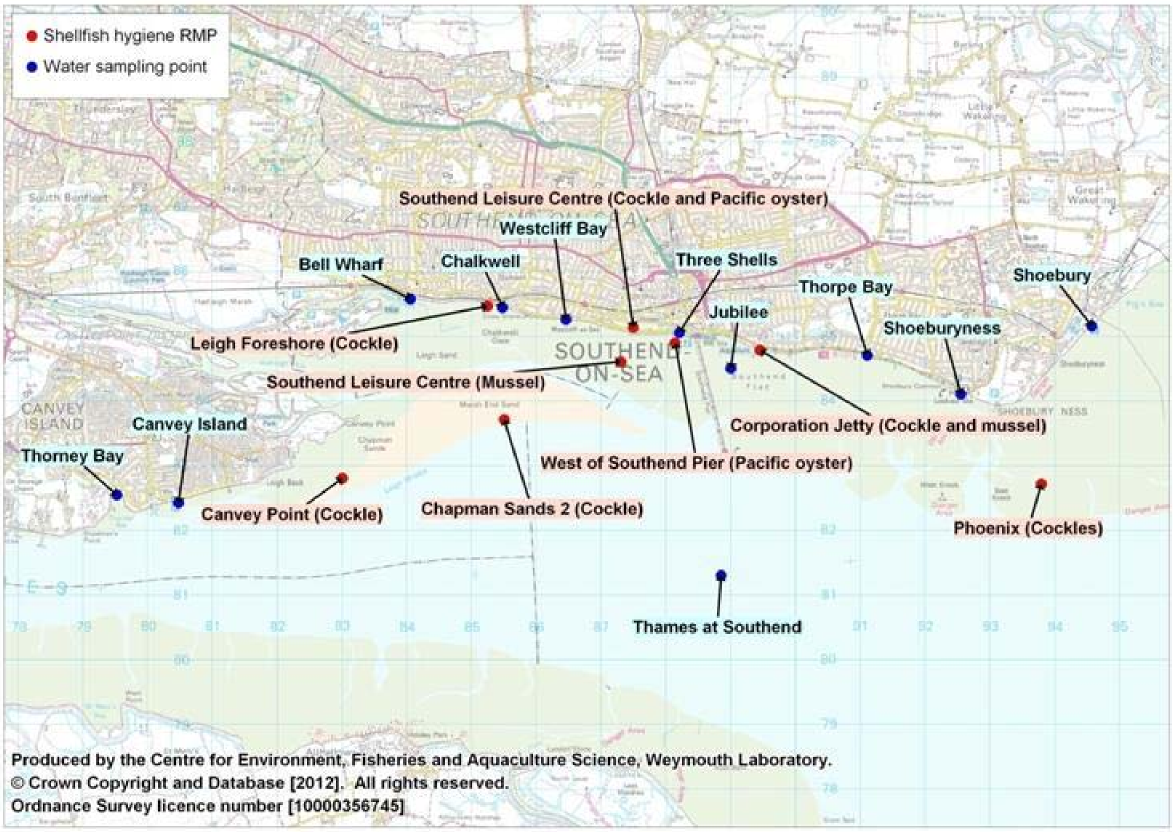


Figure 5.2 Bacteriological sampling points

Faecal coliforms were monitored at 10 bathing beaches from Thorney Bay through to Shoebury during summer bathing seasons. Results from this programme showed a consistent decrease in average levels of contamination across these sites from west to east, although there was a slight peak in average result at Jubilee and Thorpe Bay. When samples taken on the same day were compared with each other, significant correlations were found between all site pairings suggesting the entire stretch is influenced by sources which react in a similar manner to environmental conditions.

Significant correlations between levels of faecal coliforms in the water and tidal state on the high/low tidal cycle were only found for Bell Wharf and Thorpe Bay despite sampling being strongly targeted around high water. At Bell Wharf results appear to deteriorate once the tide starts ebbing implying that sources to the west (i.e. in Leigh Creek) are of importance. A much weaker correlation was found for Thorpe Bay where results were slightly higher on average on the ebb, again implying sources to the west (perhaps the Willingale Stream) are of some consequence. Correlations with the spring/neap tidal cycle were found at Canvey Island, Chalkwell, Westcliffe Bay and Shoebury, but the only pattern apparent when these datasets were plotted was a very slight tendency for higher results on spring tides at Canvey Island and Westcliffe Bay.

Some influence of recent rainfall was detected at all of the bathing waters monitoring points. This was weakest at Bell Wharf, Canvey Island and Shoeburyness. Rainfall two days prior to sampling was the most consistent influence, and together with the geographic variations in influence this suggests nearby small watercourses may be of importance.

Faecal coliforms were also monitored at one offshore shellfish waters monitoring point (Thames at Southend) on a quarterly basis. Results were on average similar to those recorded on the beaches under the bathing waters programme. Strong seasonality was found here, with highest results in the winter and autumn. A very strong correlation was found between faecal coliforms results and the high/low tidal cycle but not the spring/neap tidal cycle. Across the high/low tidal cycle there was a clear pattern of higher results around low water. This implies that upstream sources are of most significance and that contamination from the Southend STW outfall is not the major influence at this monitoring point, perhaps because the plume is generally advected past this point to its north under the tidal regime. A similar pattern in influence of rainfall to that observed at the bathing waters sites was found, with the rainfall 2 days prior to sampling being of most influence despite the more offshore location of this sampling point.

Since 2002, shellfish samples have been taken from 10 RMPs under the hygiene classification monitoring programme and tested for *E. coli*. Of these, four RMPs were only sampled on three or fewer occasions (Pacific oysters and cockles at Southend Leisure Centre, Cockles at Canvey Point and mussels at Corporation Jetty). The remaining six RMPs were sampled on 30 or more occasions. Results at these were quite variable, ranging from class A levels through to class C levels at each.

Only one Pacific oyster RMP and one mussel RMP were sampled on more than three occasions so it was not possible to assess geographic variation for these species. Across the four cockle RMPs sampled on multiple occasions a significant difference in mean results was found with significantly lower levels of *E. coli* at Phoenix compared to the other three RMPs. The proportion of results exceeding both 230 and 4600 *E. coli* MPN/100g was also significantly lower at Phoenix than at the other three RMPs. This suggests that contamination levels are broadly similar from Chapman Sands through to the Corporation Jetty, but decrease to the east of here. The Corporation Jetty and Leigh Foreshore cockle RMPs were sampled on the same day on 105 occasions allowing a more robust comparison of results from these two sites. There was no significant difference in mean results for this set of paired samples but the *E. coli* results were strongly correlated on a sample by sample basis indicating that levels of contamination are similar at the two, and that they are under the influence of the same sources or of sources that respond in a similar way to environmental variables. Chapman Sands 2 and Phoenix were sampled on the same day on 21 occasions, and for these paired samples results were significantly higher at Chapman Sands 2. The results were however strongly correlated on a sample by sample basis suggesting the entire area is under the influence of the same or similar sources of contamination, but these influences are weaker at Phoenix.

The only obvious strong overall temporal pattern in results observed was a decrease in the amount of lower results at Phoenix since 2008. The reasons for this are uncertain, and no other RMPs appear to have been affected. Similar seasonal variation was observed for all RMPs, with results highest on average during the winter. Variation was statistically significant for cockles at Leigh Foreshore, Corporation Jetty and Phoenix and for mussels at Southend Leisure Centre.

The only significant correlation found between results and tidal cycles was a relatively weak correlation between levels of *E. coli* in cockles at Corporation Jetty and the high/low tidal cycle. Sampling was strongly targeted towards low water and no pattern was apparent when the data was plotted. The influence of recent rainfall on levels of *E. coli* in shellfish at Southend was weak. No influence at all was detected for cockles at Chapman Sands but sample numbers were low relative to the other RMPs considered. The strongest influence was found for cockles at Leigh Foreshore. Where some influence was found rainfall 2 days prior to sampling was most commonly correlated with higher levels of *E. coli*.

Mussels have been identified as a possible surrogate species which could be used to classify both species. There was no single location where both species were sampled from, but a comparison of results for Pacific oysters at West of Southend Pier and mussels from Southend Leisure Centre, 900m away may provide some local indication of how they compare. These two RMPs were sampled on the same day on 107 occasions. Results were similar at the two, although slightly higher in terms of geometric mean result and proportion of results exceeding 4600 *E. coli* MPN/100g for mussels. The difference in mean result was not statistically significant and results were strongly correlated on a sample by sample basis indicating they respond in a similar manner to variations in levels of indicator bacteria in the water column. On this basis, mussels appear to be a suitable surrogate for Pacific oysters at Southend, although the comparison should be treated with caution as the RMPs are located some distance from each other.

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary totally or partially included within the Southend catchment area is shown in Figure I.1. Total resident human population in the area shown was just under 220,000 at the last census in 2001, most of whom reside within Southend. Results of the 2011 censes were yet to be released at the time of writing.

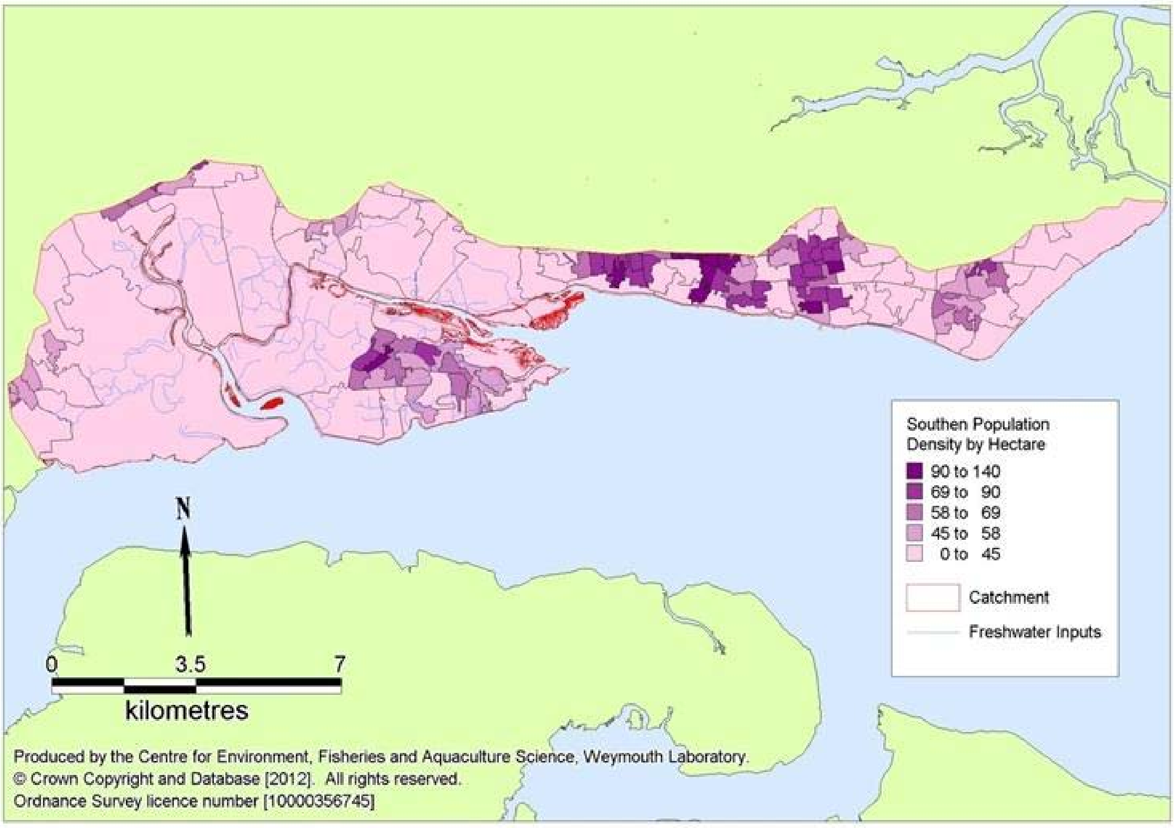


Figure I.1 Human population density in the Southend catchments.
Source: ONS, Super Output Area Boundaries (Lower layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Southend is located near to London, and with the world's longest pleasure pier and various other attractions is a popular seaside resort. In 2004 there were about 6.4 million visitors to Southend, although the majority of these were day visitors and did not stay overnight (Southend-on-Sea Borough Council, 2006). Canvey Island also has significant tourist accommodation. Information provided by Anglian Water during the permitting process indicates 'holiday' population estimates of 13,898 for Southend STW (resident population 158,705) and 5,816 for Canvey STW (resident population 37,470) representing increases of 9 and 16% respectively. Therefore influxes of visitors and corresponding increases in sewage volumes will occur here during the summer months.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

Due to its sheltered location relative to rain-bearing weather systems feeding in off the Atlantic, Southend is within one of the drier areas of the UK, typically receiving less than 650mm of rain a year. The Atlantic Lows are more vigorous in autumn and winter and bring most of the rain that falls in these seasons. In summer, convection caused by solar surface heating sometimes forms shower clouds and a large proportion of rain falls from showers and thunderstorms at these times (Met Office, 2012). Figure II.1 presents a boxplot of daily rainfall records by month at Southchurch Park, central Southend.

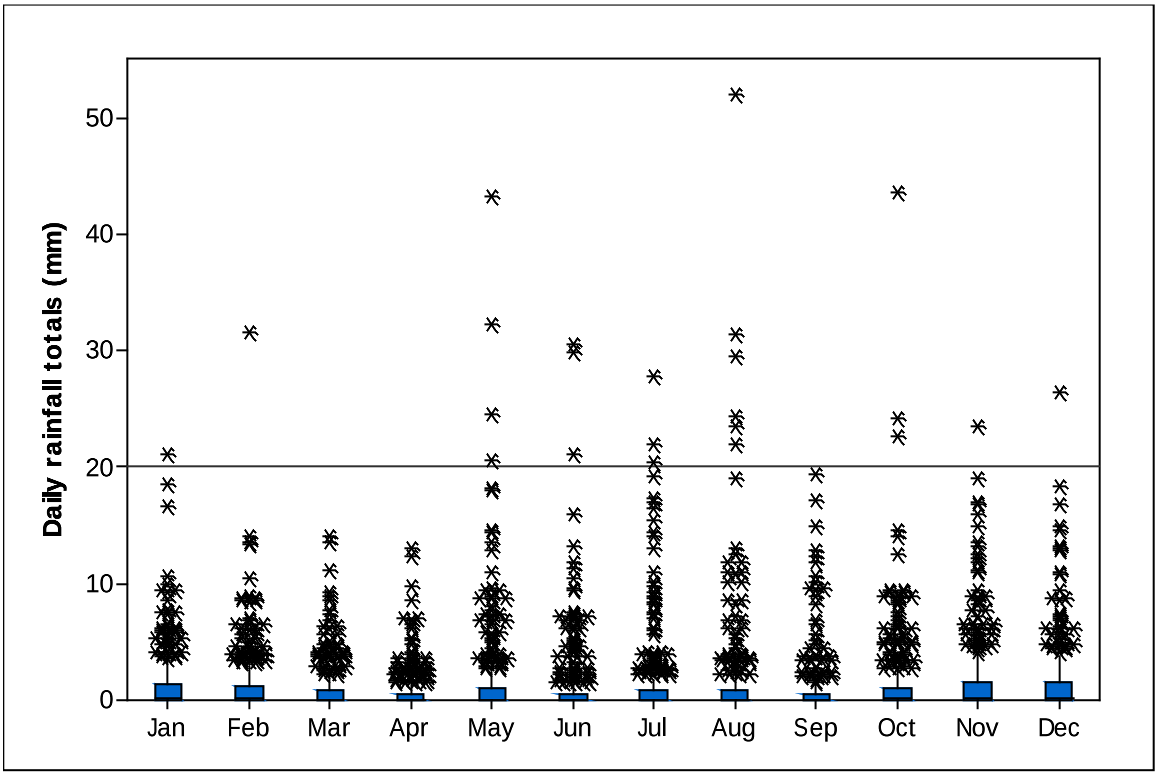


Figure II.1 Boxplot of daily rainfall totals at Southchurch Park, January 2002 to February 2012.
Data from the Environment Agency

Rainfall records from Southchurch Park, which is representative of conditions in the vicinity of the shellfish beds indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average in March and April and highest on average in November and May. Daily totals of over 20mm were recorded on 0.6% of days and 52.6% of days were dry. High rainfall events, whilst relatively rare, tended to occur most during the summer but events of over 20mm were recorded in all months apart from March, April and September.

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

The catchment area draining directly to the survey area as estimated by local topography is only about 89km^2. Rainfall is relatively low (Appendix II) and of this a high proportion is lost to evaporation and transpiration mainly during the summer months (Scott-Wilson, 2010). As a consequence freshwater inputs direct to the survey area are low especially during the summer. Figure III.1 shows the location of the main watercourses draining the area and pertinent shoreline observations.

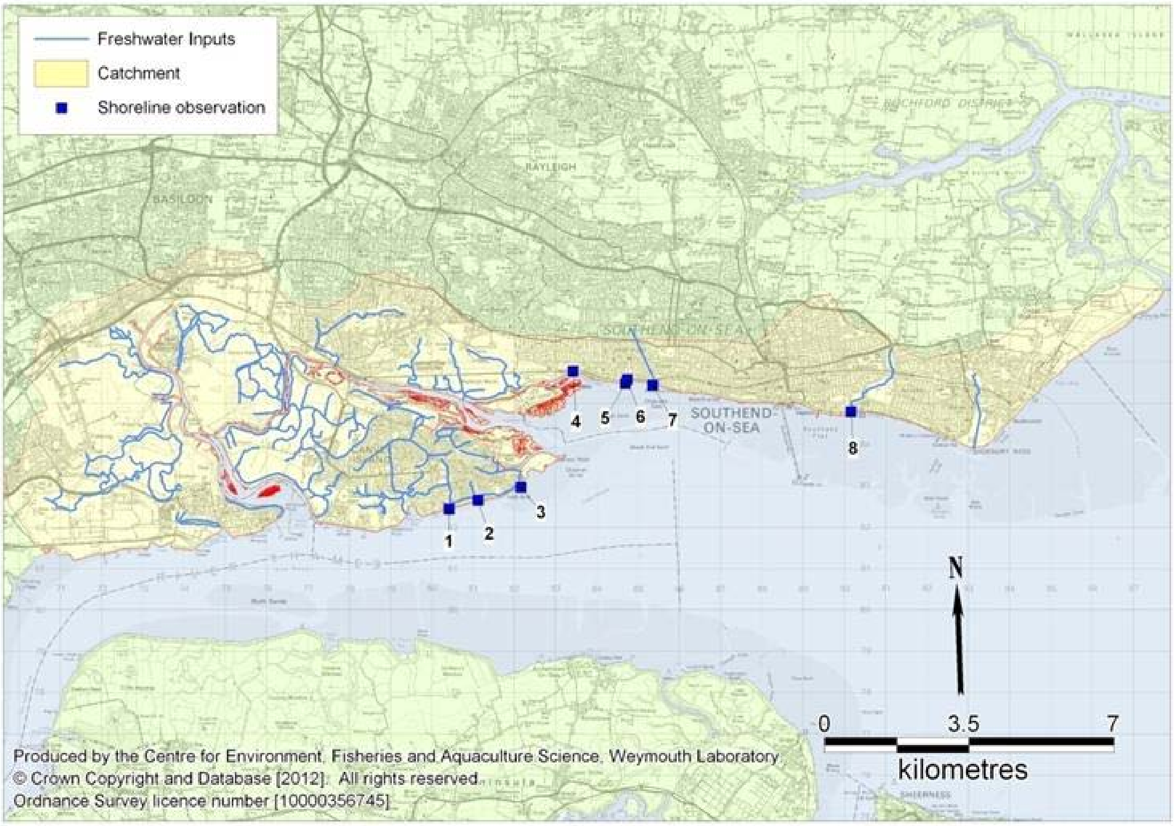


Figure III.1 Watercourses within the survey catchment area.

Table III.1. Details of shoreline observations from Figure III.1

Ref.	Observation
1	Surface water sluice outfall not flowing
2	Surface water sluice outfall not flowing
3	Surface water sluice outfall not flowing
4	Small stream, flowing (89.6m^3/day), >20000 *E. coli* cfu/100ml, loading of >1.8x10^{10} cfu/day
5	Outfall pipe, flowing (26.4m^3/day), 738 *E. coli* cfu/100ml, loading of 2.0x10^8 cfu/day
6	Small stream, flowing (103m^3/day), 2200 *E. coli* cfu/100ml, loading of 2.3x10^9 cfu/day
7	Prittle Brook flood relief tunnel outfall (dripping)
8	Willingale stream pumping station (outfall end covered by tide)

There are three main watercourses discharging to the Southend foreshore, all of which are small, drain largely urban areas and are modified to some extent. As a consequence flows are generally low but increase rapidly in response to rainfall. The unnamed stream at Shoebury and the Willingale were not sampled or measured during the shoreline survey as their outfalls were covered by the tide at the time.

The latter has a pumping station on the seafront which was seen during the shoreline survey. There was no measurable flow from the Prittle Brook flood relief tunnel at the time of survey (Table III.1, line 7). This watercourse carries excess flows from the Prittle Brook (which discharges to the Roach estuary) to its outfall to prevent localised flooding following high rainfall events and also receives some surface water and road runoff (Scott-Wilson, 2010). Three small flows of surface water were sampled and measured, all of which carried very low flows but one of which (Table III.1, line 4) was found to contain a very high concentration of *E. coli* perhaps indicating that it had some sanitary content.

In addition to these there are several small watercourses draining from the mainland to Benfleet Creek, East Haven Creek, Holehaven and Vange Creek, which drain a mix of farm land and developed areas. Again these inputs are likely to be relatively minor and their combined bacterial loadings will be carried out of these creeks towards the shellfisheries on the ebbing tide. Canvey Island lies below the mean high water level and is surrounded by sea walls. Surface drainage is via a network of ponds and ditches which feed pumping stations and gravity sluices. Three such outfalls were seen during the shoreline survey of south east Canvey Island (Table III.1, lines 1-3). Volumes of water discharged and levels of contamination are uncertain but it is likely discharges from these will peak during the winter months.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

Southend is located on the north shore of the outer reaches of the Thames estuary. The estuary widens significantly from Canvey Island to Shoebury thereby increasing the dilution potential towards the eastern end of the survey area. The intertidal area off Southend in which the shellfisheries are located is gently sloping, and extends out to up to about 3km from the high water mark at Shoebury Boom, and is defended by seawalls and timber groynes. The substrate is a mainly of sand, with some gravel and mud. Past the intertidal area, depth increases rapidly to about 16m at the eastern end of the Southend foreshore. At the western the depth increases much more gradually. Off Canvey Island, the foreshore is much narrower and steeper. The main Thames shipping channel (the Yantlet Channel) runs parallel to the shore about 4km off Southend and is maintained at a depth of over 10m by dredging. A second channel (Leigh Channel) splits from the dredged channel off Shoebury and runs past the end of Southend Pier, becoming progressively shallower towards its western end. West of Southend pier it crosses the intertidal and splits into two channels, one of which runs into Benfleet Creek, the other of which runs into Leigh Creek. These channels will convey tidal flows in and out of the tidal creeks which encircle Two Tree Island and Canvey Island.

The tidal creeks encircling Canvey Island are narrowest and shallowest in the stretch located to the north west of the island (East Haven Creek) and this may influence the pattern of flows around it. They are flanked by flood defences, and there are two flood barriers across them at Benfleet and East Haven which are only closed occasionally in response to a threat of tidal flooding. The Benfleet STW oufall discharges to Benfleet Creek between these two barriers about 1km inshore of the Benfleet Barrier.

Neither the Southend Pier nor the Shoebury Boom are solid structures so tidal streams will pass through them relatively unimpeded, although they may create some turbulence which could induce vertical mixing of the water column. The Southend STW outfall is located in 12m of water about 600m off from the edge of the intertidal zone, about 2km south east of the end of Southend Pier. The Canvey Island STW outfall discharges just below the low water mark off the south shore of Canvey Island.

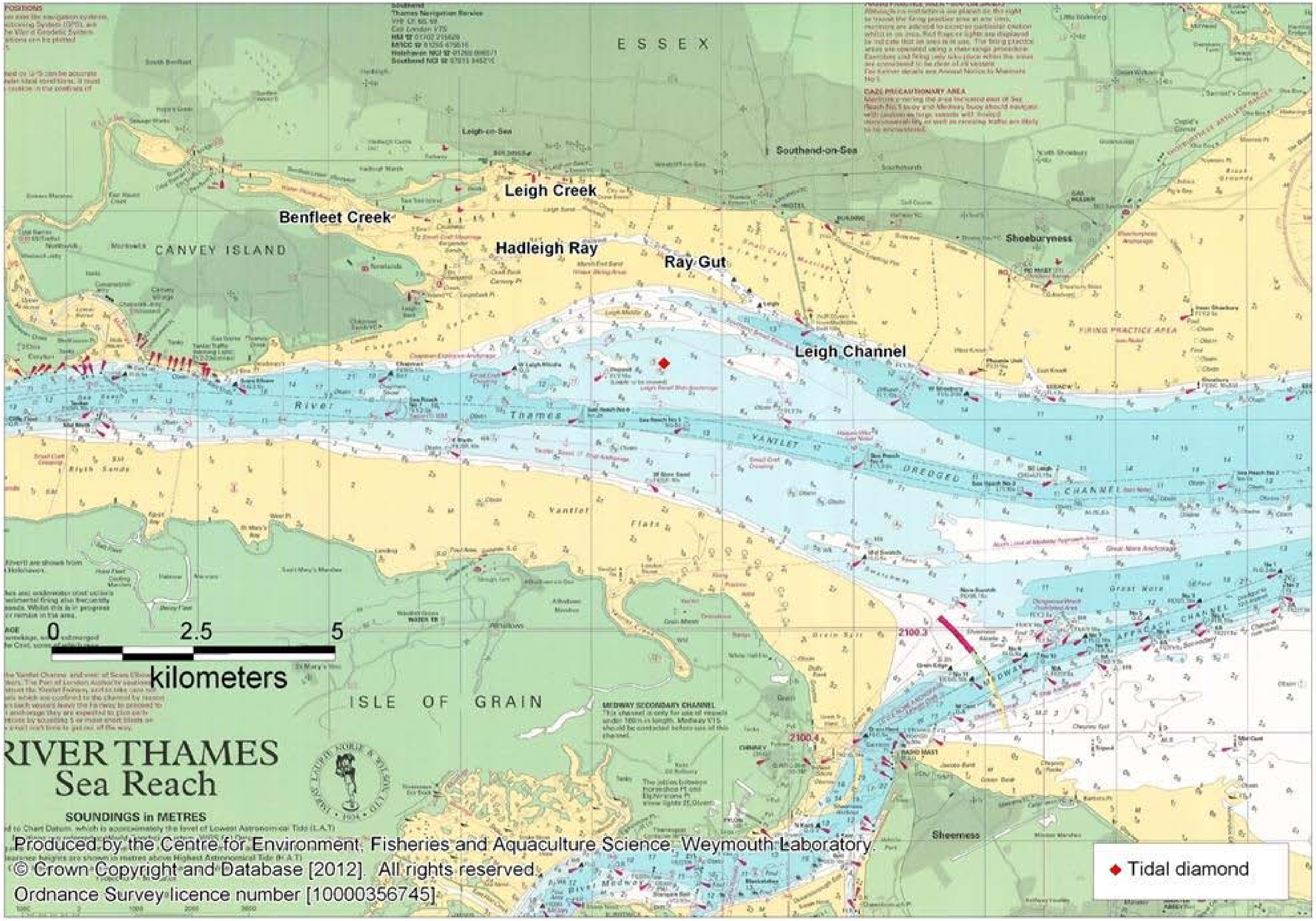


Figure IV.1 Bathymetry chart of the Southend area

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal range is relatively large (Table V.1) and drives extensive water movements through the outer Thames estuary.

Table V.1 Tide levels and ranges at Southend.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Southend	5.68	4.50	1.60	0.42	5.26	2.90

Data from the Proudman Oceanographic Office

There is one tidal diamond on the Admiralty Chart located about 3km off Westcliffe in 5m of water (Figure IV.1). Table V.2 presents tidal stream information from this tidal diamond, which should be representative of the general pattern of tidal flows off Southend.

Table V.2 Direction and current velocity for the tidal diamond off Westcliffe

	Direction (°)	Spring rate (m/s)	Neap rate (m/s)
HW -6	-	0.00	0.00
HW -5	256	0.10	0.10
HW -4	277	0.82	0.57
HW -3	277	0.93	0.62
HW -2	277	0.82	0.57
HW -1	277	0.62	0.41
HW	300	0.41	0.31
HW +1	092	0.15	0.21
HW +2	092	0.98	0.67
HW +3	098	1.29	0.87
HW +4	098	0.93	0.62
HW +5	098	0.41	0.31
HW +6	092	0.10	0.10

Flows are bi-directional and run parallel to the coast, moving up the estuary on the flood and back down the estuary on the ebb. Currents peak at 1.29 m/s mid ebb. Based on this tidal diamond, tidal excursion is about 13-14km on spring tides and 9-10km on neap tides. This means that shoreline sources will impact at either side of their locations, decreasing with distance as the plume becomes more dilute. Whilst this diamond will be representative of flows within the more offshore areas, the bathymetry of the inshore and intertidal areas will modify tidal currents. Flows are likely to be slower in shallower water, and for the most part will run parallel to the shore. To the west of Southend Pier they will tend to align with the channels (Ray Gut and Leigh Creek) particularly during the lower states of the tidal cycle.

This pattern of flows will mean that effluent from the Southend STW will tend to remain in deeper water offshore although on the flood tide it may be carried up the Leigh Channel towards Ray Gut. The pattern of tidal flows through the creeks around Canvey Island will determine the extent of impacts from sources discharging to these creeks (e.g. Benfleet STW) on shellfish beds on the Southend foreshore. Around Canvey Island, tides are thought to flow up and down the Benfleet and

Holehaven Creeks on the flood and ebb, meeting somewhere in East Haven Creek (Port of London Authority Hydrographic Service, pers. comm.). As a consequence, effluent from Benfleet STW will be carried across the shellfish beds by the ebb tide, and the impact will be greatest at the western end of the Southend foreshore, and highest concentrations of associated faecal indicator bacteria will arise in the Benfleet Creek/Ray Gut channel towards low water. Effluent from the Pitsea and Basildon STWs will be carried out through Holehaven Creek on the ebb tide then meet the main Thames estuary where it will be subject to significant dilution.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. The Thames estuary is described as well mixed (Futurecoast, 2002), so density driven circulation is unlikely to be of importance within the outer reaches of the estuary at least. River, catchment and sewage sources to the upper reaches of the estuary, combined with the increasing width across the survey area may result in a gradient of decreasing ‘background’ levels of contamination across the survey area from west to east.

As the effluent from sewage discharges will be less dense than saline coastal waters it will tend to rise to the top of the water column. The main Southend STW outfall is fitted with diffusers which will enhance mixing with the receiving water at the point of discharge, thereby reducing the buoyancy of the plume. A plume from the Canvey Island STW outfall could be clearly seen on satellite imagery (Google Earth, accessed 17/5/2012) demonstrating its buoyant nature.

Strong winds will modify surface currents. The outer Thames estuary and the Southend foreshore are most exposed to winds from the east and south. 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}. These surface currents create return currents which may flow at depth or along sheltered margins. 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 east (and from the west to a lesser extent) are likely to have the greatest effects on circulation as they align with the orientation of the estuary. Easterly winds will tend to push surface water up the estuary and up Benfleet Creek, with westerly winds having the opposite effect. Winds with a southerly element will push surface water from offshore towards the Southend foreshore, which will convey the plume from the Southend STW outfall towards the shellfish beds. Onshore winds will also create wave action. 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. It is therefore concluded that shellfish beds on the Southend foreshore may be subject to higher levels of contamination during southerly and south easterly winds, although it targeting such conditions in the sampling plan is unlikely to be practical.

APPENDIX VI
METEOROLOGICAL DATA: WIND

The strongest winds are associated with the passage of deep depressions and the frequency and strength of these is greatest in the winter (Met Office, 2012). As Atlantic depressions pass England and Wales, the wind typically comes from the west or northwest as the depression moves away. For this reason south east England is one of the less windy parts of England and Wales. A wind rose for Coltishall (Norfolk) shows that the prevailing wind direction is from the south-west and that the strongest winds nearly always blow from the range of directions west-southwest (Figure VI.1). The frequency of gales is relatively low.

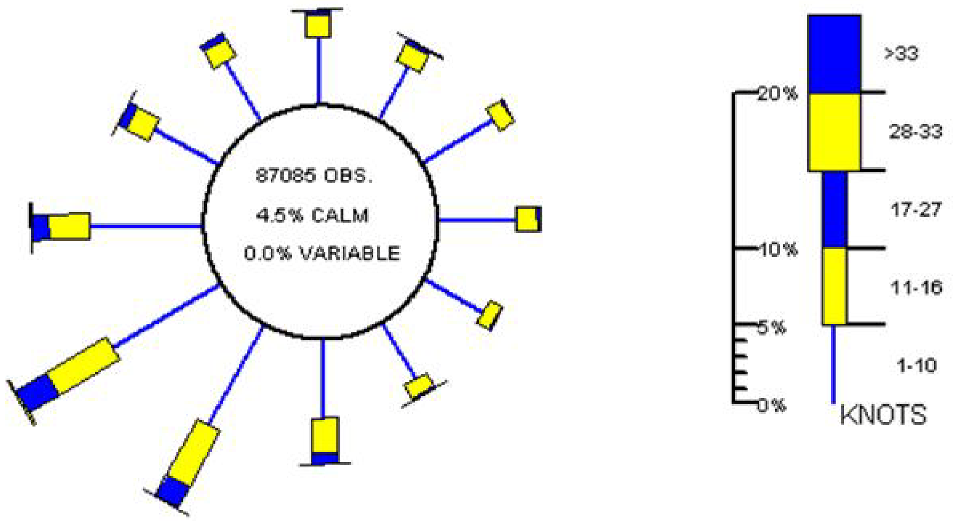


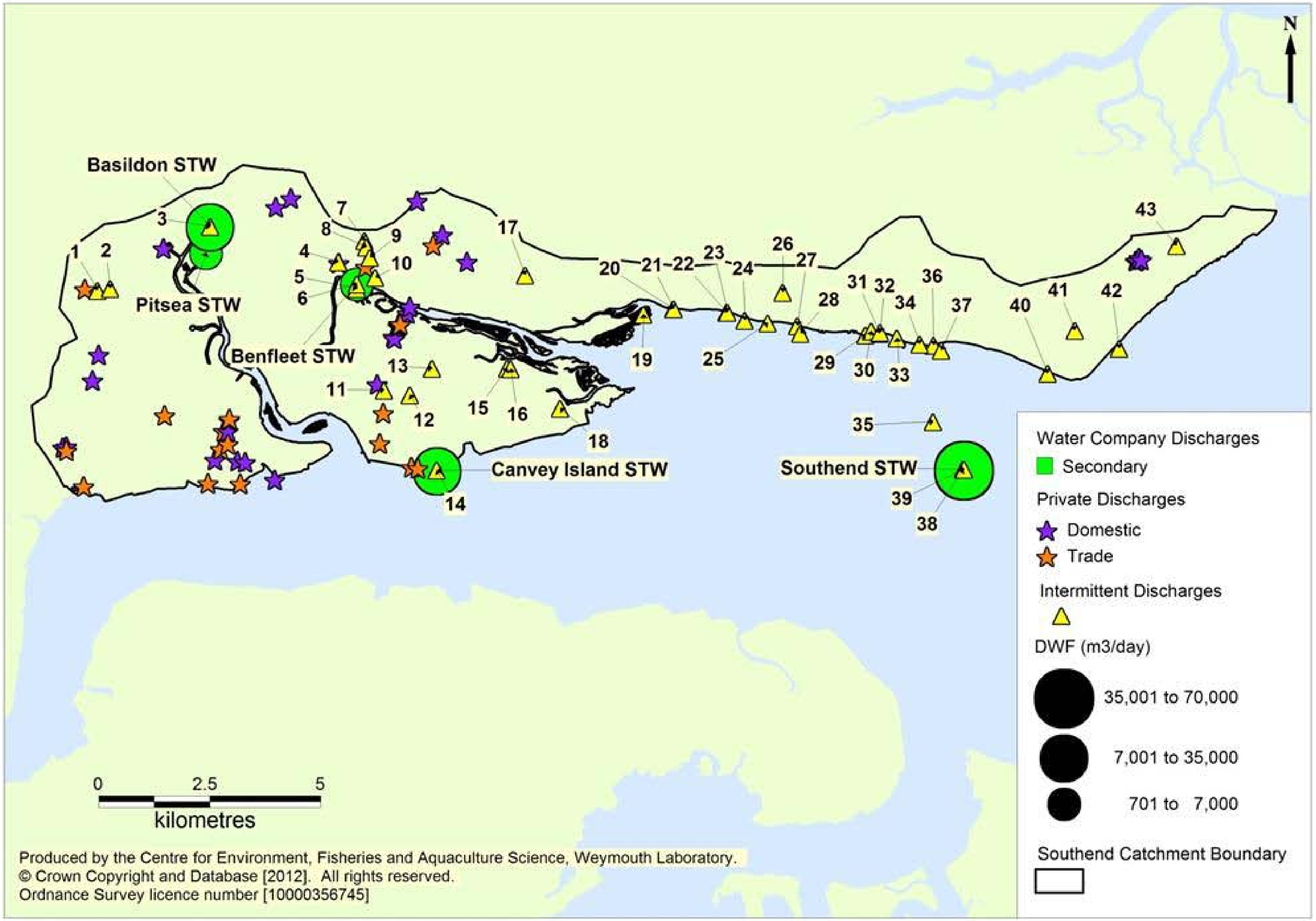
Figure VI.1 Wind rose for Coltishall, Norfolk.
Period of data: January 1995–December 2004.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0.

The east-west aspect of the outer Thames estuary means it is most exposed to winds from the east, although westerly winds will also align with the estuary. Therefore winds from these directions will probably have the greatest overall effect on water circulation patterns by creating surface water currents with or against the tide. The Southend foreshore is exposed to winds from a southerly direction, which may create significant wave action on the shore. Winds with a southerly element will also blow the plume from the Southend STW towards the shore. The potential impacts of wind on the circulation of water at Southend are discussed in more detail in Appendix V.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Figure VII.1 presents a map showing the locations and sizes of the major continuous discharges to the survey area, and Table VII.1 shows further details of these. All five of these provide secondary treatment, so concentrations of faecal indicator bacteria in their effluents should be broadly similar. The estimates of bacterial loading generated by these works presented in Table VII.1 should however be treated with some caution as they are based on published reference values of bacterial concentrations in effluents rather than effluent testing data from the actual works. The largest is Southend STW, which discharges in 12m of water about 600m off the low water mark between Southend Pier and Shoeburyness. The Canvey Island STW also discharges direct to the outer Thames estuary about 50m from the south shore of the island. The remaining three sewage works discharge to enclosed tidal creeks. The Benfleet STW discharges to the Benfleet Creek at the northern tip of Canvey Island. As Canvey Island is encircled by tidal creeks, effluent from this discharge may be carried directly towards Southend via the Benfleet Creek, or past the western shore of Canvey Island through East Haven Creek and Hole Haven Creek depending on patterns of tidal circulation. The Basildon and Pitsea STWs both discharge to Vange Creek, which becomes Holehaven Creek in its lower reaches after it merges with East Haven Creek. All of these discharges are large in terms of volumes and will generate large bacterial loadings. Elevated levels of contamination are anticipated throughout the enclosed creeks to which three of them discharge, and significant plumes will emanate from the two coastal outfalls and from the mouths of Holehaven and Benfleet Creeks. The shape of these plumes will be largely dictated by tidal streams.

The sewerage networks associated with these treatment works include a number of intermittent overflow discharges the locations of which are also shown on Figure VII.1. Of most potential significance to the fisheries are the series of intermittent outfalls located along the Southend seafront from Leigh on Sea through to Shoeburyness. Also of potential significance is a small cluster of these discharging to a tributary of Benfleet Creek at South Benfleet. All of the main STW outfalls are also used as overflow discharges with the exception of Pitsea STW. There is a second sea outfall off Southend, about 1km east of the pier head which is used as an overflow discharge. On Canvey Island all intermittent outfalls apart from the overflow from the STW discharge to the network of surface water drainage ditches.


Basildon STW
Pitsea STW
Benfleet STW
Canvey Island STW
Southend STW
N
Water Company Discharges
Secondary
Private Discharges
Domestic
Trade
Intermittent Discharges
DWF (m3/day)
35,001 to 70,000
7,001 to 35,000
701 to 7,000
Southend Catchment Boundary
0 2.5 5
kilometres
Produced by the Centre for Environment, Fisheries and Aquaculture Science, Weymouth Laboratory.
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Ordnance Survey licence number [10000356745]

Figure VII.1. Locations and size of major continuous, intermittent and private discharges within the area

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

Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)*	Receiving Water
Pitsea STW	TQ 7360 8680	6,060	Secondary	$2.0x10^{13}$	Timbermans Creek
Basildon STW	TQ 7370 8740	31,095	Secondary	$1.0x10^{14}$	Pitsea Creek
Benfleet STW	TQ 7700 8610	6,970	Secondary	$2.3x10^{13}$	Benfleet Creek
Canvey Island STW	TQ 7882 8190	13,000	Secondary	$4.3x10^{13}$	Thames Estuary
Southend STW	TQ 9070 8192	68,274	Secondary	$2.3x10^{14}$	Thames Estuary

*Based on 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.3 Summary of reference faecal coliform levels (cfu/100ml) for different sewage treatment levels under different flow conditions.

Treatment Level (number of samples)	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).

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Table VII.3 Details of intermittent discharges situated within the catchment.

ID	Name	Location	Type	No. spills 2010	No. spills 2011
1	North Fobbing SPS	TQ7115785959	Emergency		
2	Woodlands Drive PS	TQ7144086000	Emergency		
3	Basildon STW	TQ7370087400	Storm & Emergency		
4	South Benfleet	TQ7659086600	Storm & Emergency	1	1
5	Benfleet Creek	TQ7700086000	Storm		
6	Benfleet STW	TQ7700086100	Storm & Emergency	0	0
7	Jotmans Lane/High Road CSO	TQ7718087080	Storm		
8	Richmond Avenue CSO	TQ7722086930	Storm		
9	Res. Development at Danesfield	TQ7730086700	Storm		
10	SPS at Benfleet Marshes	TQ7742086250	Storm & Emergency	7	18
11	Dyke Crescent CSO	TQ7762083710	Storm		
12	New Road	TQ7820083600	Storm & Emergency		
13	Champlain Avenue	TQ7870084200	Storm & Emergency		
14	Canvey Island STW	TQ7880081910	Storm & Emergency		
15	Nevada Road/High St SPS	TQ8040084200	Storm & Emergency		
16	Nevada Road CSO	TQ8047084190	Storm		
17	Castle Lane	TQ8080086300	Storm		
18	Point Road PS	TQ8159083300	Storm & Emergency		
19	Southend Storm Overflows	TQ8347085420	Storm		
20	Southend Storm Overflows	TQ8414085540	Storm	0	0
21	Southend Storm Overflows	TQ8415085540	Storm	1	1
22	Adjacent Prittle Brook Outfall	TQ8535085460	Storm	0	0
23	Southend Storm Overflows	TQ8536085460	Storm	0	4
24	Chalkwell Esplanade Outfall	TQ8575085280	Storm	10	11
25	Southend Storm Overflows	TQ8627085220	Storm	3	5
26	Southend Storm Overflows	TQ8661085910	Storm		
27	Southend Storm Overflows	TQ8694085160	Storm		
28	Southend Storm Overflows	TQ8701084990	Storm	0	0
29	Southend Storm Overflows	TQ8848084950	Storm	11	4
30	Southend Storm Overflows	TQ8861085040	Storm		
31	Southend Storm Overflows	TQ8880084990	Storm	13	5
32	Southend Storm Overflows	TQ8881085010	Storm		
33	Southend Storm Overflows	TQ8919084880	Storm	21	28
34	Southend Storm Overflows	TQ8970084740	Storm		
35	Overflow from Harvest Road	TQ9000083000	Storm		
36	Elizabeth Road Outfall	TQ9001084720	Storm		
37	Southend Storm Overflows	TQ9018084610	Storm	0	0
38	Southend Storm Overflows	TQ9068081920	Storm	0	0
39	Southend Sewage Works	TQ9070081920	Storm & Emergency		
40	Southend Storm Overflows	TQ9259084090	Storm	47	31
41	Towerfields Estate SPS	TQ9320785059	Emergency		
42	Southend Storm Overflows	TQ9420084650	Storm	0	0
43	Seaview Estate PS	TQ9550086970	Storm & Emergency		

Data from the Environment Agency and Anglian Water

Their geographic distribution suggests that the entire Southend seafront, the Benfleet Creek, and the surface water outfalls from Canvey Island may all be affected at times. Spills will mainly be associated with wet weather events, particularly within the sewerage networks which collect large amounts of surface water. The Southend and Canvey Island sewer networks are both older combined systems (Scott Wilson, 2009) and the former is currently working at full capacity. It is therefore likely that regular overflow spills are a feature of these two networks. Occasionally spills may be associated with mechanical failures or blockages which may occur at any time.

Information on the spill frequencies from selected outfalls with telemetry was provided by Anglian Water for 2010 and 2011. For spill counting purposes, a spill of 24 hours or less is counted as 1 spill, and if a spill continues for longer than 24 hours, each subsequent 24 hours counts as a further spill. If several spills occur within a 24 hour period, they are counted as 1 spill. The events reported as a spill are actually water levels alarms, which indicate high water levels in the wet well but do not necessarily mean that a spill has occurred. Therefore, each recorded spill indicates that a spill (or spills) of 24 hours or less may potentially have occurred, but does not give any indication of spill volume nor actual date of occurrence. The two outfalls which recorded the most potential spill events during this period were both located on towards the eastern end of the Southend seafront. Potential spills from other monitored outfalls did occur from time to time but occurred less frequently. With no confirmation whether these events were actually spills or indication of volumes discharged, it is difficult to draw meaningful conclusions from this data. For other unmonitored outfalls, it is difficult to make an assessment of their significance aside from noting their locations and their potential to deliver large bacterial loadings. Spills will mainly be associated with wet weather events, particularly within the sewerage networks that collect larger amounts of surface water. Occasionally spills may be associated with mechanical failures or blockages which may occur at any time.

Although the majority of properties in the Southend catchment are connected to mains sewers, there are a small number of small private discharges to the area, some of which discharge to soakaway and others to watercourses. Of the 30 private discharges which contain sewage (i.e. excluding discharges such as cooling water or surface water), the majority (23) discharge to watercourses, with 4 discharging to the estuary and 3 to land/soakaway. Although some watercourses will therefore carry some contamination from private discharges, the cumulative bacterial loadings generated by these will be very minor in relation to those from water company discharges.

In summary, Southend STW generates the largest bacterial loading which is just offshore from the shellfisheries but within relatively deep open water. Benfleet STW has an estimated bacterial loading of approximately one order of magnitude lower than Southend STW but discharges to the relatively confined waters of the Benfleet Creek where there is much less potential for dilution. Canvey Island STW discharges to the south shore of Canvey Island and may also be of some influence to the shellfish beds off Southend. The two sewage works discharging to Vange Creek (Pitsea and Basildon) may also contribute to levels of contamination carried towards the shellfish beds on the ebb tide. A series of intermittent outfalls are located all along the Southend seafront, and there are further clusters of these outfalls which discharge to Benfleet Creek and to the surface water drains at Canvey Island. There are also overflow discharges from the Southend STW long and short sea outfalls and the Canvey Island STW outfall. No information on spills from these was available, but the Canvey Island and Southend sewer networks do receive surface water so may be more prone to discharge during wet weather. There are also a few small private discharges within the catchment but the cumulative effects of these are likely to be very minor in relation to the water company discharges.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Agricultural census data from the 2010 census was provided by Defra, and indicates that there were 19 registered holdings, and a total of 1196 cattle within the catchment boundary defined for the purposes of this survey. Additionally, an unspecified number of pigs, sheep and poultry were present but these data were suppressed for confidentiality as they relate to less than five holdings. It is therefore concluded that impacts from livestock are likely to be very minor in relation to those of human origin given the human population of around 220,000 in the same area. 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 1.2 (page 8) indicates that the majority of pastures within the catchment area lie adjacent to Vange Creek and the inner reaches of Holehaven. There is a smaller area of pasture at Shoeburyness but no livestock or signs of recent grazing were recorded here during the shoreline survey (March). Manure from any pig and poultry operations are typically stored then applied strategically to arable land (Defra, 2009) as may be sewage sludge. There are also some pockets of arable land mainly within the Benfleet Creek, Vange Creek and Holehaven catchment areas, although no information on local manure/sludge application practices could be found. Contamination of agricultural origin will be carried into these creeks via streams draining the farmland, and the magnitude of such fluxes will be highly rainfall dependent.

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of cattle will increase significantly in the spring, with the birth 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. Therefore peak levels of contamination from 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 may be more likely in winter or spring.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries at Southend. As well as a major shipping channel through the Thames estuary, there is considerable local boating activity within the area, including pleasure craft (yachts and cabin cruisers), fishing boats and also houseboats. The route along the Southend seafront and into the Benfleet Creek receives heavy recreational use (RYA, 2004).

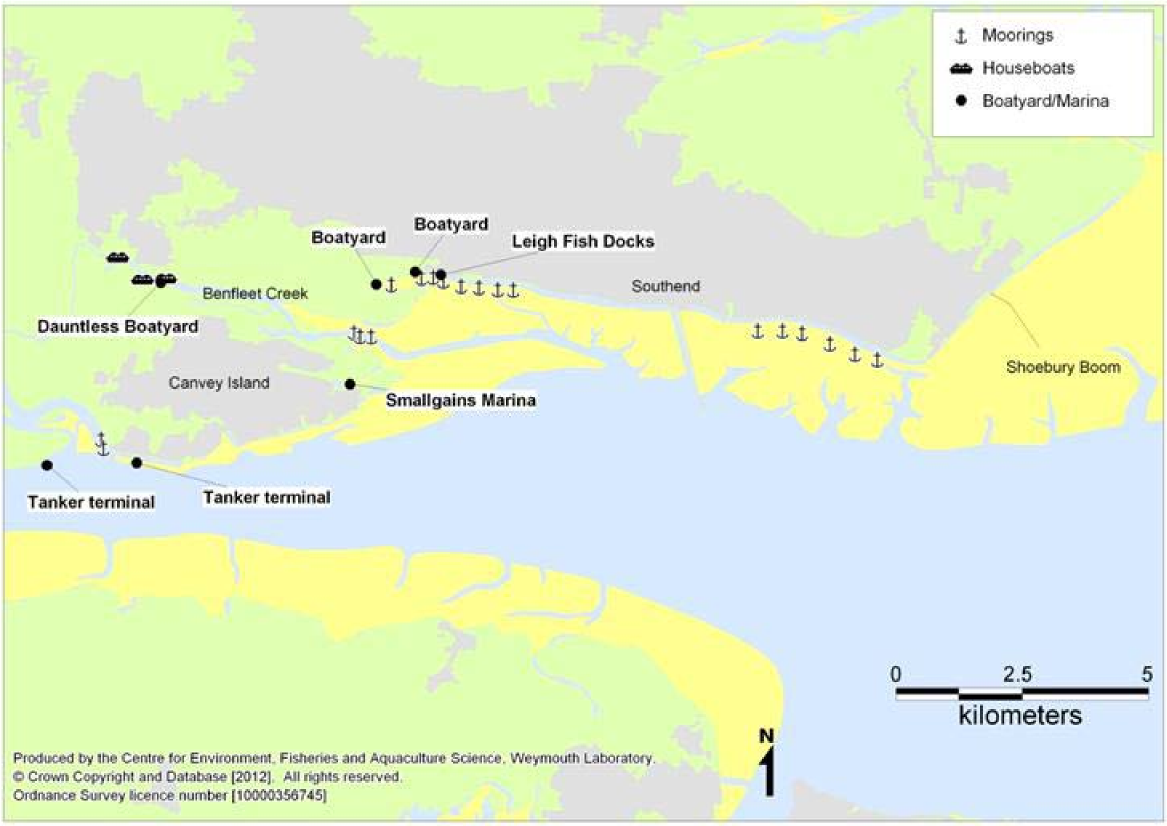

Figure IX.1 Locations of moorings, marinas and houseboats.

Off Thorpe Bay, at the eastern end of Southend there is an area of moorings where just over 60 small pleasure craft were moored at the time of shoreline survey (March). There is a second large area of moorings at Leigh-on-sea as well as the fish docks from which a small fishing fleet operates. Around 40 small vessels including yachts and fishing boats were noted here during the shoreline survey. There are also two boatyards at the top of Leigh Creek where yachts were in storage. Benfleet Creek hosts an area of moorings near its mouth and a large marina/boatyard near the flood barrier. Opposite the boatyard there are about 80 boats some of which appeared to be houseboats. Past the flood barrier a further 20 or so houseboats were seen. Only a small proportion of these appeared to be occupied at the time of shoreline survey, but this was difficult to confirm and occupation rates may increase during the summer. Another large marina/boatyard is located within Smallgains Creek which is located on the easterly point of Canvey

Island. There are tanker terminals used by the hydrocarbons industry either side of Holehaven Creek and a few yacht moorings in the outer reaches of this creek.

Merchant shipping associated with the tanker terminals and passing up and down the Thames estuary *en route* to the various London docks are not permitted to make overboard discharges within 3 nautical miles of land[1] so should be of no impact. Smaller private vessels such as yachts, cabin cruisers and fishing vessels are likely to make overboard discharges from time to time. No sewage pump-out facilities are available at any of the boatyards/marinas in the area (Reeds, 2012) but the crews of boats in marinas will have easy access to onshore facilities. Those in overnight occupation on moorings or at anchor may be more likely to make overboard discharges. As the main concentrations of moorings and marinas are at Thorpe Bay, Leigh-on-sea, Benfleet Creek and Smallgains Creek these areas may be considered most at risk from such discharges. However, boats may also make discharges whilst on passage so impacts may arise anywhere. Houseboats in occupation are particularly likely to make regular discharges so overall Benfleet Creek may receive the largest volumes of sewage from boats and houseboats. Peak pleasure craft activity is anticipated during the summer so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

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

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

Within the survey area there are saltmarshes, muddy creeks and intertidal flats which provide bird foraging habitat. Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). The Thames estuary as a whole supports large numbers of overwintering waterbirds (wildfowl and waders) with an average total count of 180,681 over the five winters up to 2009/10 (Holt et al, 2011). More locally, peak winter numbers of about 30,000 and 8,000 waterbirds occur at the Benfleet / Southend Marshes and Holehaven Creek respectively (Port of London Authority, 2007). Density maps indicate lower densities of waterbirds on the Southend foreshore compared to the Leigh-on-sea foreshore, Benfleet Creek, Chapman Sands and Holehaven Creek (Port of London Authority, 2012). The spatial profile of impacts from waterbirds is likely to reflect their preferred foraging areas. Numbers will 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. 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). No seabird breeding colonies were recorded within the survey area, although breeding colonies of 116 pairs of gulls and 149 pairs of terns were recorded on Maplin Bank, just to the east of Shoebury Boom. There will be therefore be some seabirds in the area during the summer months which will forage widely and be a possible source of diffuse contamination but will not affect the location of RMPs.

Marine mammals are sporadically sighted within the Thames estuary. These sightings are recorded by the Zoological Society for London (Kowalik *et al*., 2008). From July 2004 to June 2007 340 sightings of 691 animals between Teddington Lock and Shoeburyness. Of the live sightings about 64% were seals and 36% were of small cetaceans, mainly dolphins and porpoises. Sightings were recorded throughout the year, and within the survey area most sightings were of seals off Southend. Due to their wide ranging habits and sporadic presence marine mammals will have no bearing on the sampling plans.

No other wildlife species of potential influence to the sampling plans have been identified. Although not wildlife, dogs exorcised on beaches may also be a source of contamination direct to the shore. Dogs are banned from all Southend beaches from 1st May to 31st September so any impacts would generally arise outside of this period. As a diffuse source this will have little bearing on RMP locations however.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are 10 bathing waters within the survey area, 8 of which are designated under the Directive 76/160/EEC (Council of the European Communities, 1975). The two sites at Canvey Island are not designated under this directive but have been monitored nonetheless, although monitoring here was discontinued at the end of the 2009 season.

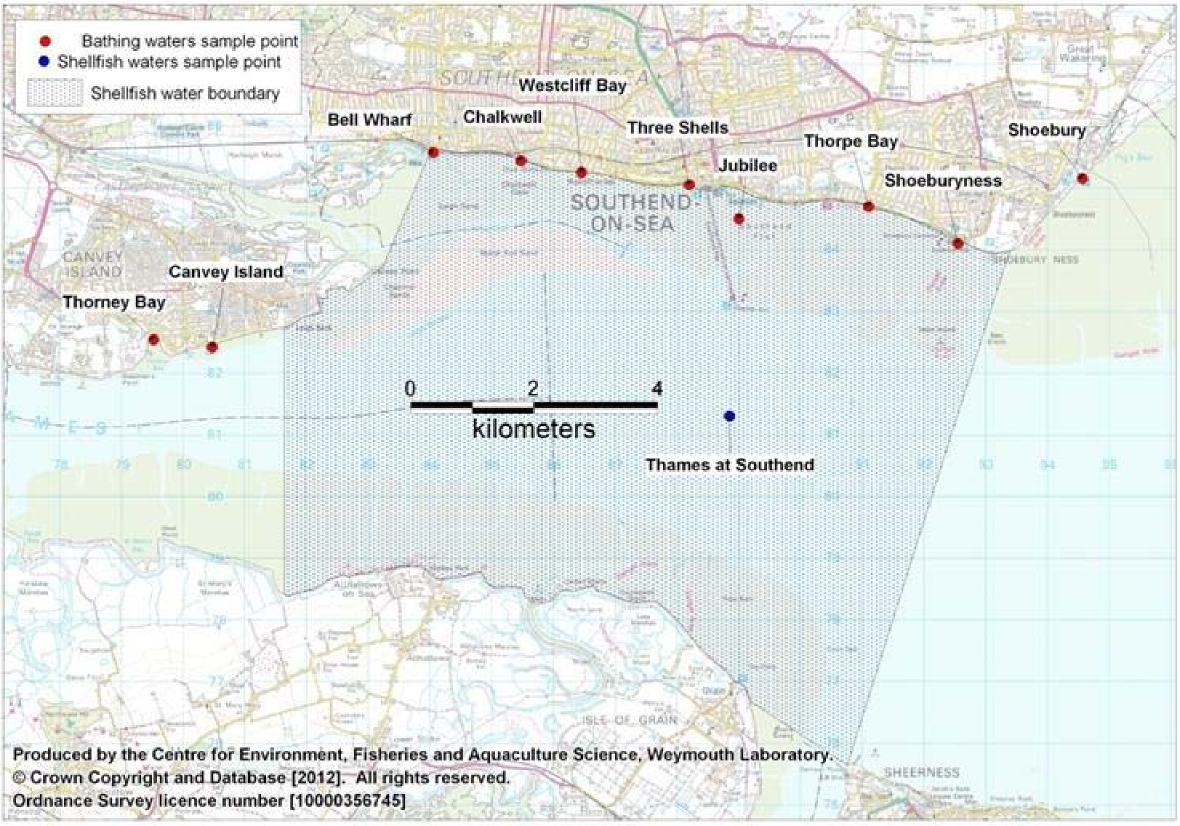

Figure XI.1 Location of designated bathing waters monitoring points at Southend.

Around 20 water samples were taken from each of the bathing waters sites during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples. Summary statistics of all results from 2002 to 2011 by bathing water are presented in Table X1.1 and Figure XI.2 presents box plots of this data.

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

Site	Years	No.	Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Thorney Bay	2002-09	159	49.9	<2	1520	29.6%	1.9%
Canvey Island	2002-09	161	41.6	2	1848	21.7%	1.2%
Bell Wharf	2002-11	203	30.8	<2	1872	21.2%	1.0%
Chalkwell	2002-11	192	28.2	<2	18900	19.3%	1.0%
Westcliffe Bay	2002-11	203	22.3	<2	828	13.8%	0.0%
Three Shells	2002-11	202	22.6	<2	3000	15.3%	1.0%
Jubilee	2002-11	193	23.9	<2	10200	19.2%	3.6%
Thorpe Bay	2002-11	204	24.7	<2	6800	18.6%	2.0%
Shoeburyness	2002-11	203	11.2	<2	4000	9.4%	1.0%
Shoebury	2002-11	203	10.5	<2	1340	4.9%	0.5%

Data from the Environment Agency

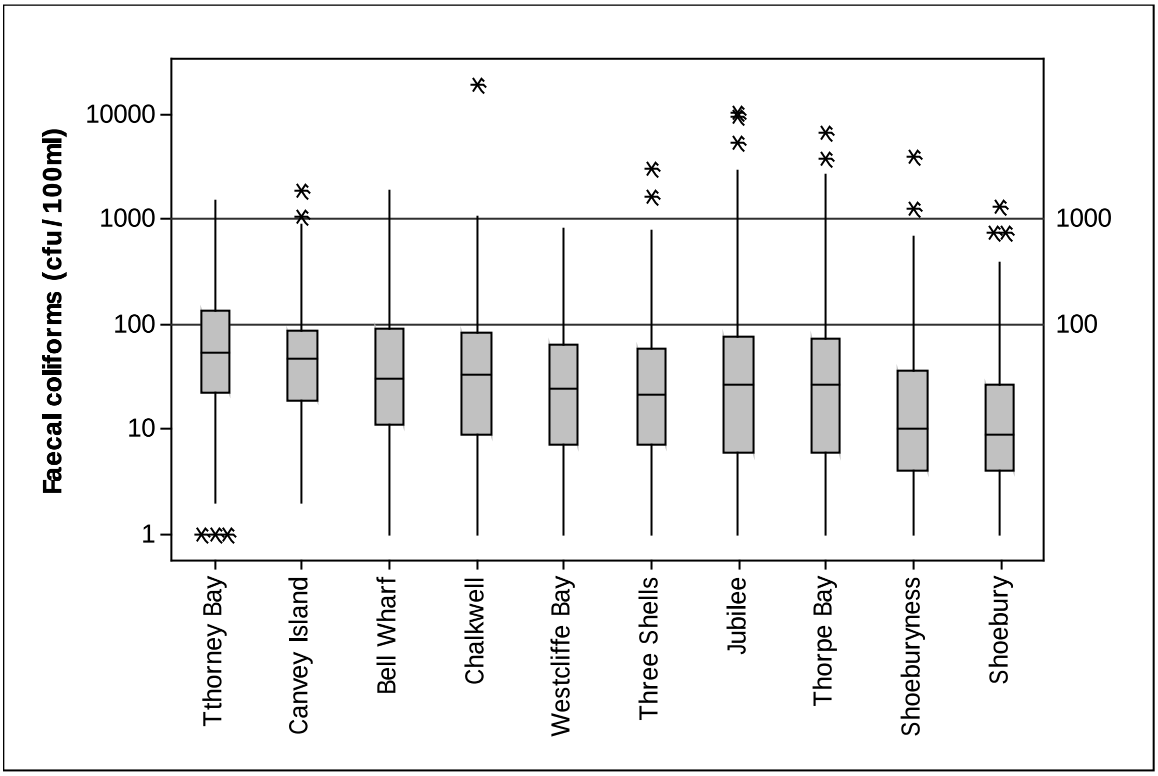

Figure XI.2 Box-and-whisker plots of all faecal coliforms results by site (2002-2011)
Data from the Environment Agency

Levels of contamination were highest on average at the two sites on Canvey Island. Along the Southend foreshore, results were highest at Bell Wharf, at the western end of the stretch. Results were fairly similar from Bell Wharf through to Thorpe Bay, and then dropped away to lower average levels at the two Shoebury sites. The highest proportions of results over 1000 cfu/100ml arose at Jubilee and Thorpe Bay.

Paired comparisons of the results from the 133 occasions when all 10 monitoring points were sampled on the same day found a significant differences by both site and sampling date (2-way ANOVA, p=0.000 for both). This indicates that not only do the sites differ significantly in the average level of contamination but also that levels of contamination tend to vary in a similar way temporally across the general area.

Post ANOVA testing (Tukey's comparison) indicated that results for Thorney Bay were significantly higher than all sites from Chalkwell eastwards, results for Canvey Islad were significantly higher than all sites from Westcliffe Bay eastwards, and results for sites from Bell Wharf through to Thorpe Bay were significantly higher than at Shoeburyness and Shoebury. Significant correlations were found between each site pairing (Pearson's correlation, r=0.185 or greater, p=0.033 or less) indicating all sites are influenced by a similar range of sources which react in a similar manner to environmental conditions.

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

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

		high/low		spring/neap	
Site	n	r	p	r	p
Thorney Bay	159	0.077	0.393	0.115	0.129
Canvey Island	161	0.086	0.310	0.159	0.018
Bell Wharf	203	0.242	0.000	0.111	0.086
Chalkwell	192	0.093	0.195	0.150	0.015
Westcliffe Bay	203	0.098	0.144	0.201	0.000
Three Shells	202	0.071	0.366	0.089	0.204
Jubilee	193	0.109	0.104	0.022	0.914
Thorpe Bay	204	0.133	0.028	0.067	0.405
Shoeburyness	203	0.044	0.675	0.047	0.646
Shoebury	203	0.081	0.269	0.191	0.001

Data from the Environment Agency

Figure XI.3 present polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Southend 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.

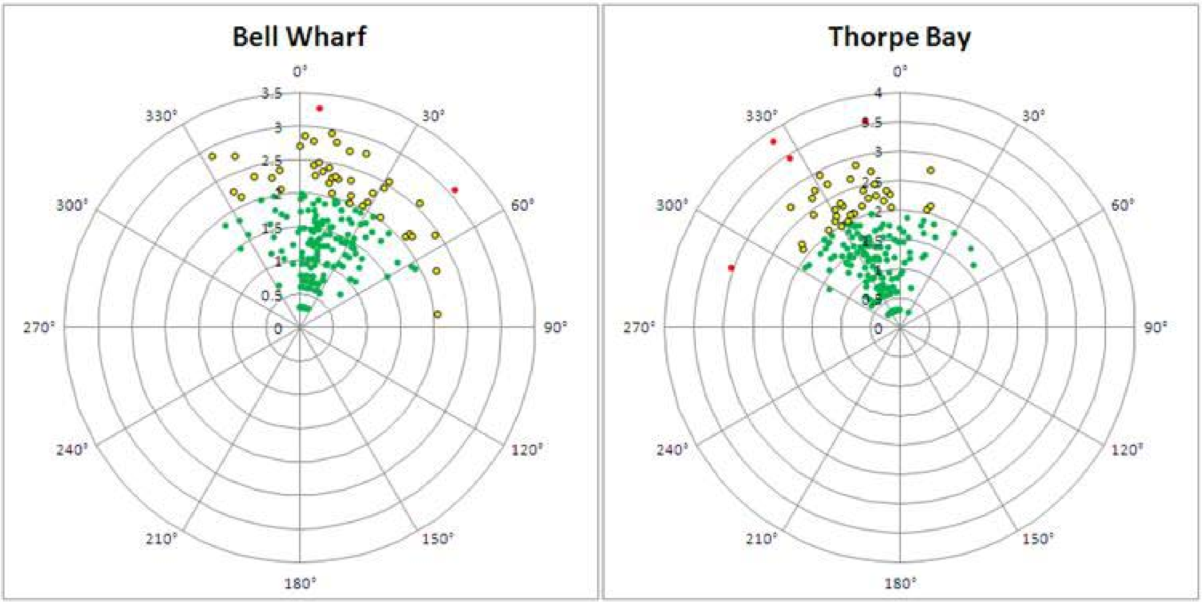

Figure XI.3. Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At both sites sampling was targeted towards high water. At Bell Wharf the correlation was very strong, and results appear to deteriorate once the tide starts ebbing implying that sources to the west are of importance. A much weaker correlation was found for Thorpe Bay, and results were slightly higher on average after high water.

Figure XI.4 presents polar plots of faecal coliform results against the lunar spring/neap cycle, where a statistically significant correlation was found. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

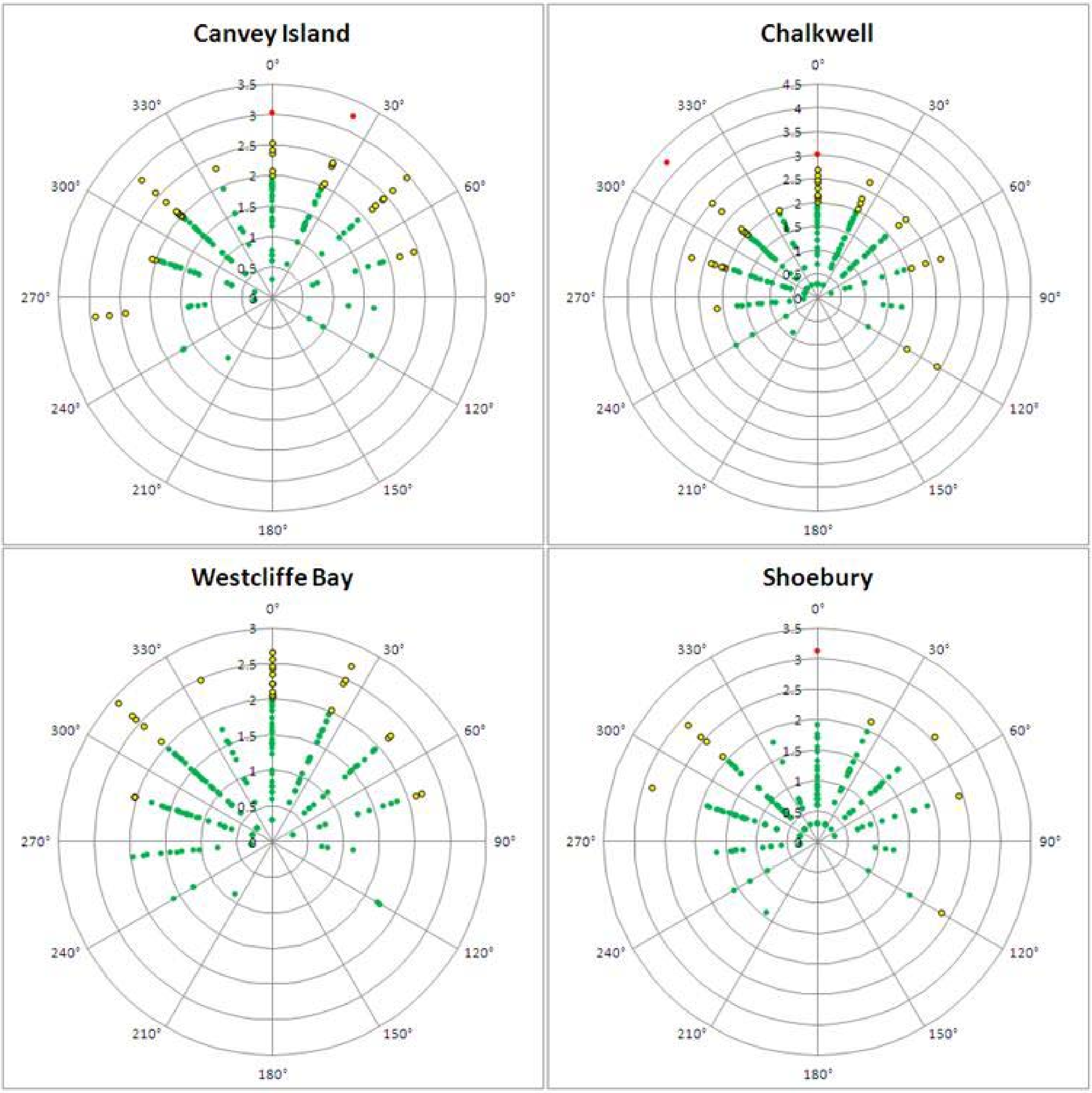

Figure XI.4. Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

Although correlations were found no particularly clear patterns are apparent in Figure XI.4, apart from perhaps a tendency for higher results at Westcliffe Bay and Chalkwell around spring tides.

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

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

		Thorney Bay	Canvey Island	Bell Wharf	Chalkwell	Westcliffe Bay	Three Shells	Jubilee	Thorpe Bay	Shoebury-ness	Shoebury
	No.	97	98	137	123	134	133	121	131	121	128
24 hour periods prior to sampling	1 day	0.161	0.154	0.117	0.210	0.144	0.131	0.213	0.126	0.104	0.134
	2 days	0.213	0.223	0.071	0.345	0.169	0.151	0.428	0.320	0.265	0.103
	3 days	0.147	0.062	0.009	0.058	-0.002	0.038	0.041	0.114	-0.048	0.012
	4 days	0.047	0.079	0.080	0.087	0.139	0.213	0.084	0.037	-0.009	0.139
	5 days	-0.028	-0.050	-0.062	0.021	0.027	0.041	0.082	-0.021	0.007	0.057
	6 days	-0.016	0.100	0.103	0.104	0.158	0.074	-0.085	0.096	-0.063	0.040
	7 days	0.207	0.049	0.036	0.214	0.146	0.025	0.233	0.010	0.082	0.008
Total prior to sampling over	2 days	0.207	0.231	0.151	0.355	0.235	0.218	0.374	0.285	0.262	0.228
	3 days	0.294	0.192	0.152	0.276	0.195	0.245	0.287	0.291	0.184	0.210
	4 days	0.225	0.165	0.182	0.224	0.200	0.279	0.229	0.228	0.110	0.227
	5 days	0.240	0.160	0.139	0.215	0.188	0.275	0.223	0.174	0.130	0.268
	6 days	0.209	0.109	0.177	0.235	0.212	0.270	0.216	0.180	0.130	0.276
	7 days	0.230	0.096	0.172	0.237	0.203	0.271	0.225	0.159	0.150	0.271

Data from the Environment Agency

Table XI.4 shows that some influence of recent rainfall was detected at all of the bathing waters monitoring points. Influence of rainfall was weakest at Bell Wharf, Canvey Island and Shoeburyness. Rainfall two days prior to sampling was the most consistent influence, and together with the variable geographic influence this suggests nearby small watercourses may be of importance.

SHELLFISH WATERS

Various parts of the Thames estuary have been designated under Directive 2006/113/EC as Shellfish Waters since 1999 (European Communities, 2006). One of these zones (Southend) has a water monitoring point within the survey area (Figure XI.6). Table XI.5 presents summary statistics for bacteriological monitoring results from the Southend shellfish growing water monitoring point. Only water sampling results are presented as flesh results from the shellfish hygiene monitoring programme (Appendix XII) are used to assess compliance with bacteriological standards in shellfish flesh.

Table XI.5 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2002-2011.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Thames at Southend	50	34.2	<2	589	22%	0%

Data from the Environment Agency

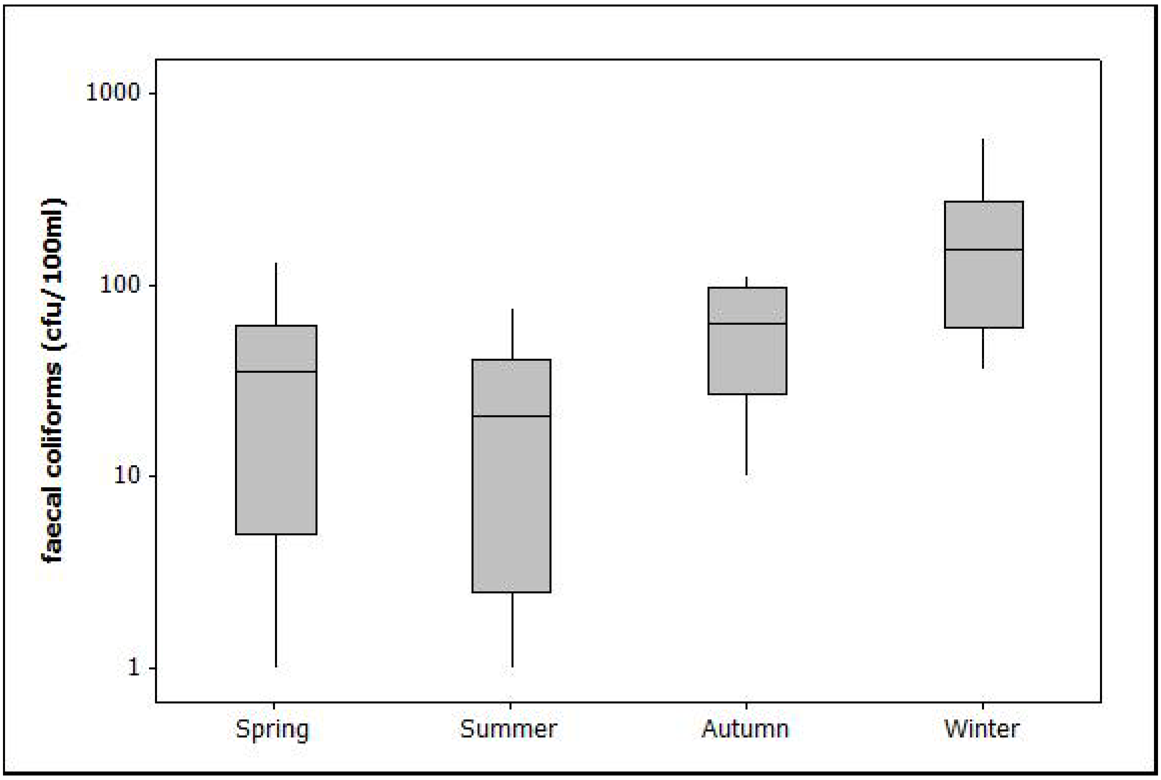

Figure XI.5 Boxplot of shellfish growing waters faecal coliforms results by season
Data from the Environment Agency

Figure XI.5 indicates that there is strong seasonality in levels of contamination at this monitoring point, with highest results in the winter. A statistically significant difference was found between seasons (One way ANOVA, p=0.000), with results for the winter significantly higher than spring and summer, and results for the autumn significantly higher than for the summer (Tukeys comparison).

A very strong correlation was found between faecal coliforms results and the high/low tidal cycle (r=0.509, p=0.000) but not the spring/neap tidal cycle (circular-linear correlation, r=0.248, p=0.056). Figure XI.6 presents a polar plot of $\log_{10}$ faecal coliforms results against tidal state on the high/low cycle. High water at Southend is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, and those from 101 to 1000 are plotted in yellow.

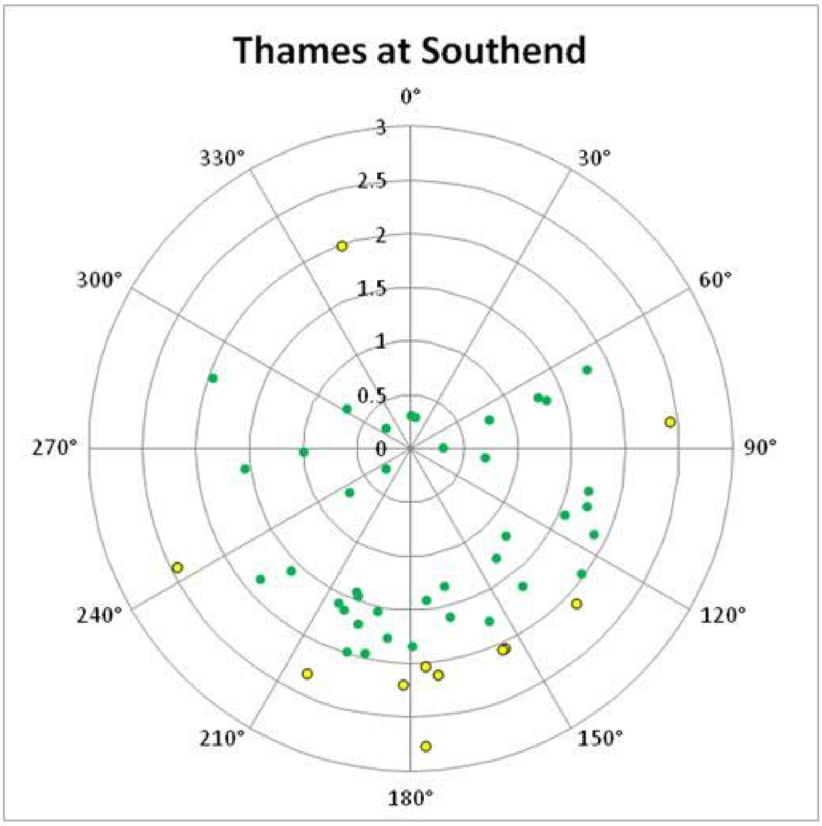

Figure XI.3. Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for Southend shellfish water
Data from the Environment Agency

Figure XI.3 shows a clear pattern of higher results around low water. This implies that upstream sources are of most significance and that contamination from the Southend STW outfall is not of major significance at this monitoring point despite its location about 2km ENE of the sampling point.

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 Southchurch weather station over various periods running up to sample collection and faecal coliforms results. These are presented in Table XI.6 and statistically significant correlations (p<0.05) are highlighted in yellow.

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

		Thames at Southend
	No.	35
24 hour periods prior to sampling	1 day	0.328
	2 days	0.455
	3 days	0.294
	4 days	0.292
	5 days	0.258
	6 days	0.061
	7 days	0.135
Total prior to sampling over	2 days	0.492
	3 days	0.390
	4 days	0.351
	5 days	0.349
	6 days	0.263
	7 days	0.236

Data from the Environment Agency

A similar pattern to that observed at the bathing waters sites, with the rainfall 2 days prior to sampling being of most influence despite the more offshore location of this sampling point.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

Since 2002, samples cockles, mussels and Pacific oysters have been taken from the area and tested for *E. coli* for classification monitoring. The results are summarised by RMP in Table XII.1, plotted in Figure XII.2, and the locations sampled are shown in Figure XII.1.

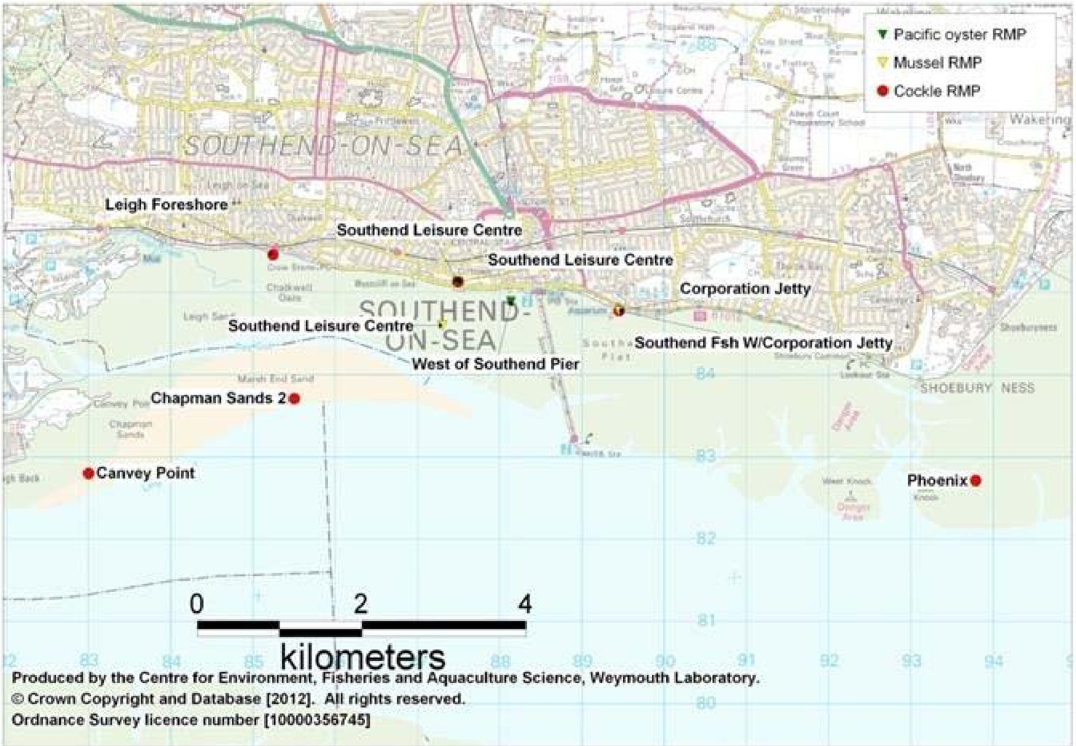

Figure XII.1 Hygiene monitoring RMPs active since 2002

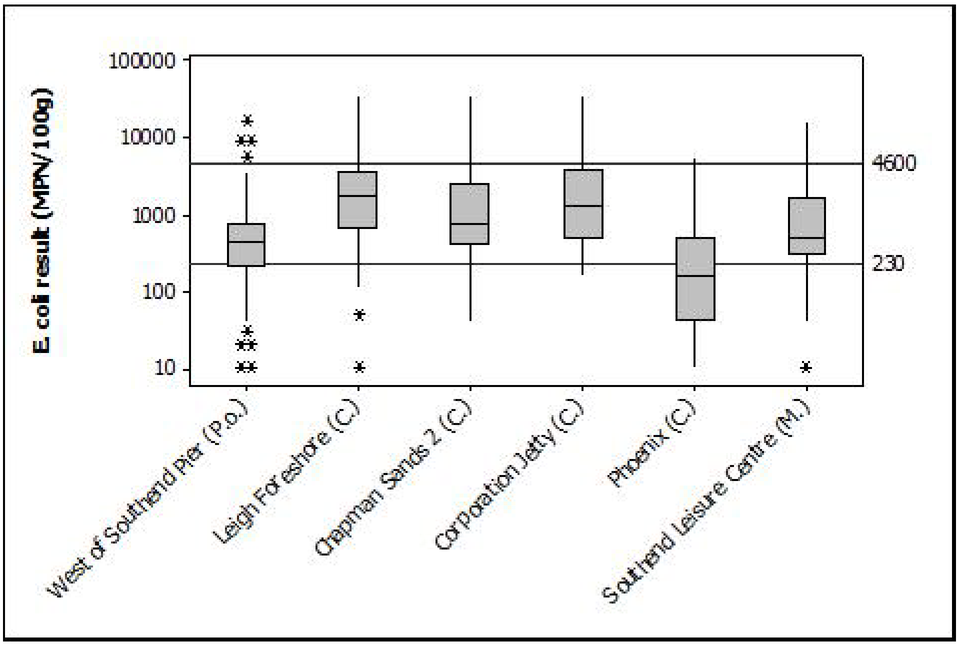

Figure XII.2 Boxplot of E. coli *results by RMP*

Table XII.1 Summary statistics of* E. coli *results (MPN/100g) from RMPs sampled from 2002 onwards

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Southend Leisure Centre	Pacific oysters	1	12/02/2003	12/02/2003	1400	1400	1400	100%	0%
West of Southend Pier	Pacific oysters	119	28/05/2002	28/11/2011	410	<20	16000	65%	3%
Canvey Point	Cockles	1	06/09/2005	06/09/2005	40	40	40	0%	0%
Leigh Foreshore	Cockles	118	17/01/2002	28/11/2011	1643	<20	>18000	90%	23%
Chapman Sands 2	Cockles	30	12/02/2002	15/03/2005	921	40	35000	83%	17%
Southend Leisure Centre	Cockles	1	14/04/2004	14/04/2004	70	70	70	0%	0%
Corporation Jetty	Cockles	110	17/01/2002	19/04/2011	1571	160	>18000	95%	25%
Phoenix	Cockles	112	14/01/2002	09/01/2012	157	<20	5400	38%	2%
Southend Leisure Centre	Mussels	120	17/01/2002	28/11/2011	623	<20	16000	78%	7%
Southend Fsh W/Corporation Jetty	Mussels	3	02/05/2002	16/12/2003	457	220	1400	67%	0%

Results at all RMPs sampled on more than three occasions were quite variable, ranging from class A levels through to class C levels. Of the two Pacific oyster RMPs, one was only sampled on only one occasion so it was not possible to assess geographic variation for this species. Similarly, for mussels one of the two RMPs was only sampled on three occasions so geographic comparisons were not possible for this species either.

For cockles, four RMPs were sampled on multiple occasions. A comparison of all results from these RMPs revealed a significant difference in mean results with significantly lower levels of *E. coli* at Phoenix compared to the other three RMPs (One-way ANOVA, p=0.000). The proportion of results exceeding both 230 and 4600 *E. coli* MPN/100g was also significantly lower at Phoenix than at the other three RMPs (Chi-square, p=0.000 in both cases). This suggests that contamination levels are similar from Leigh on Sea through to the Corporation Jetty, but decrease to the east of here.

The Corporation Jetty and Leigh Foreshore were sampled on the same day on 105 occasions allowing a more robust comparison of results from these two sites. There was no significant difference in mean results for this set of paired samples (paired T-test, p=0.228) but the *E. coli* results were strongly correlated on a sample by sample basis (Pearsons correlation, r=0.540, p=0.000). This suggests that levels of contamination are similar at the two, and that they are under the influence of the same sources or of sources that respond in a similar way to environmental variables.

Chapman Sands 2 and Phoenix were sampled on the same day on 21 occasions, and for these paired samples results were significantly higher at Chapman Sands 2 (paired T-test, p=0.000). The results were however strongly correlated on a sample by sample basis (Pearsons correlation, r=0.694, p=0.000). Taken together this suggests that these two RMPs are under the influence of the same or similar sources of contamination, but these influences are weaker at Phoenix.

Overall temporal pattern in results

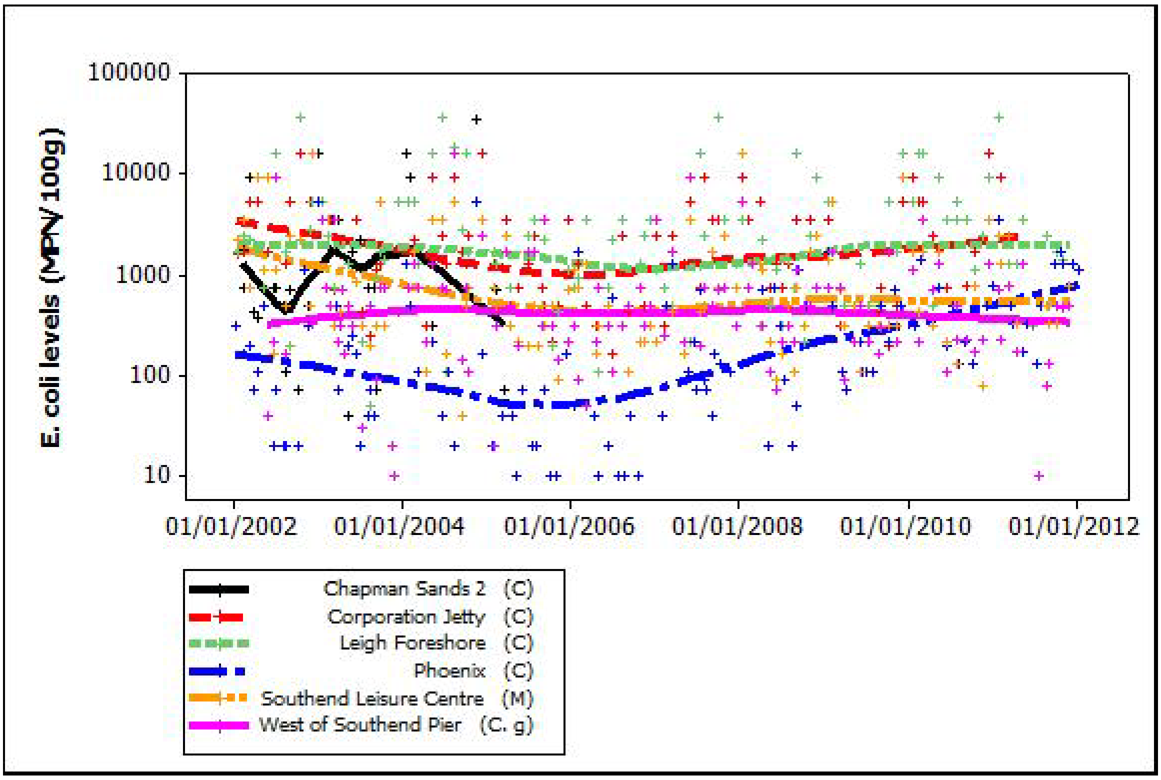

Figure XII.3 Scatterplot of* E. coli *results by RMP and date, overlaid with loess lines for each RMP

The only obvious temporal pattern in results apparent in Figure XII.3 is a decrease in the amount of lower results at Phoenix since 2008. The reasons for this are uncertain, and no other RMPs appear to have been affected.

SEASONAL PATTERNS OF RESULTS

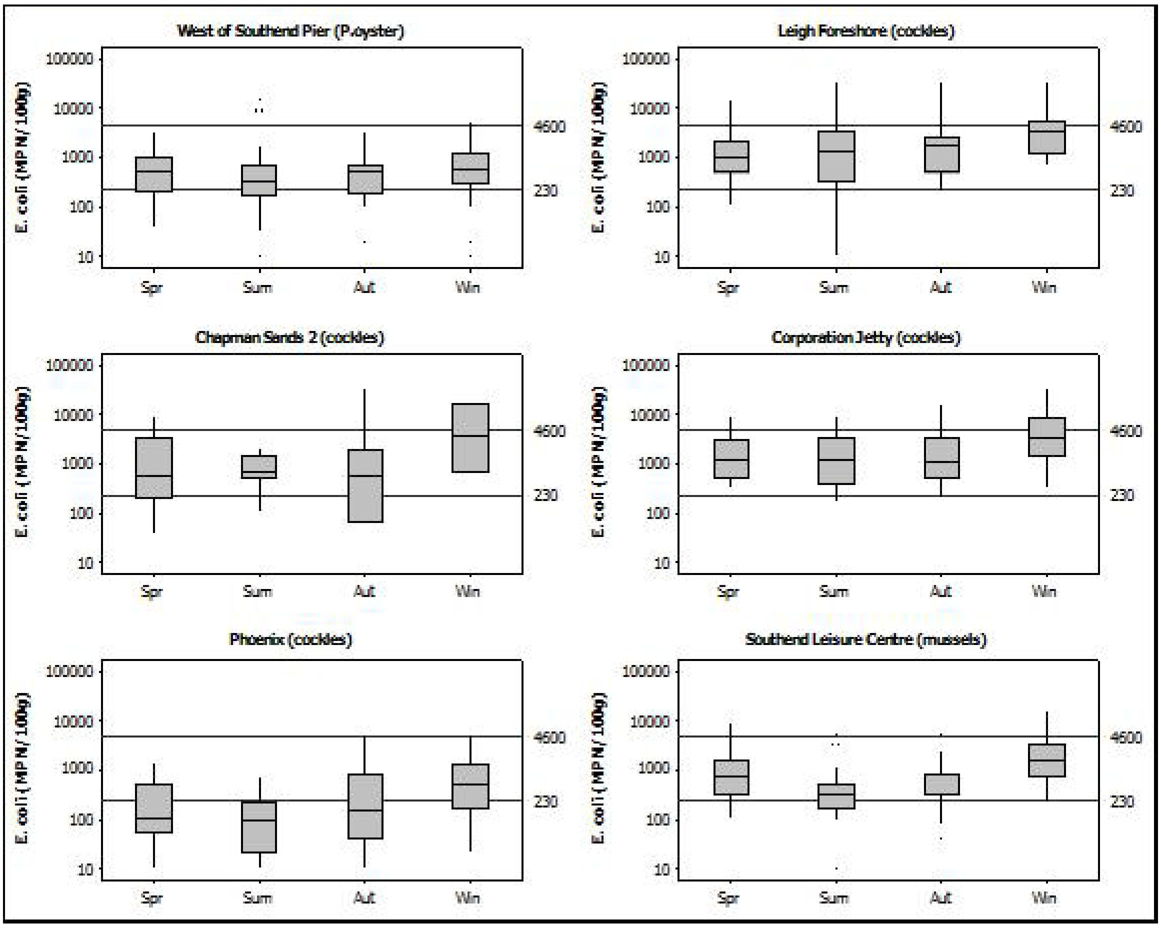

Figure XII.4 Boxplot of* E. coli *results by RMP and season

Similar seasonal variation was observed for all RMPs, with results highest on average during the winter. Statistically significant seasonal variations in mean result were found at Leigh Foreshore, Corporation Jetty, Phoenix and Southend Leisure Centre (One way ANOVA, p=0.017, 0.002, 0.000 and 0.000 respectively). Post ANOVA tests (Tukeys comparisons) indicate results were significantly higher for winter compared to spring and summer at Leigh Foreshore and Phoenix, significantly higher for winter compared to the other three seasons at Corporation Jetty, and significantly higher for winter compared to summer and autumn at Southend Leisure Centre.

INFLUENCE OF TIDE

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

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

			High/low cycle		Spring/neap cycle	
RMP	Species	n	r	p	r	p
West of Southend Pier	Pacific oyster	119	0.103	0.293	0.111	0.241
Chapman Sands 2	Cockles	30	0.083	0.832	0.213	0.293
Leigh Foreshore	Cockles	118	0.053	0.724	0.042	0.819
Corporation Jetty	Cockles	110	0.188	0.022	0.027	0.926
Phoenix	Cockles	112	0.068	0.600	0.132	0.151
Southend Leisure Centre	Mussels	120	0.103	0.289	0.065	0.609

The only significant correlation found was a relatively weak correlation between levels of *E. coli* in cockles at Corporation Jetty and the high/low tidal cycle. Figure XII.5 presents a polar plot of log_{10} *E. coli* against the high/low tidal cycle. High water at Southend is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, and those 231 to 4600 are plotted in yellow and those exceeding 4600 are plotted in red.

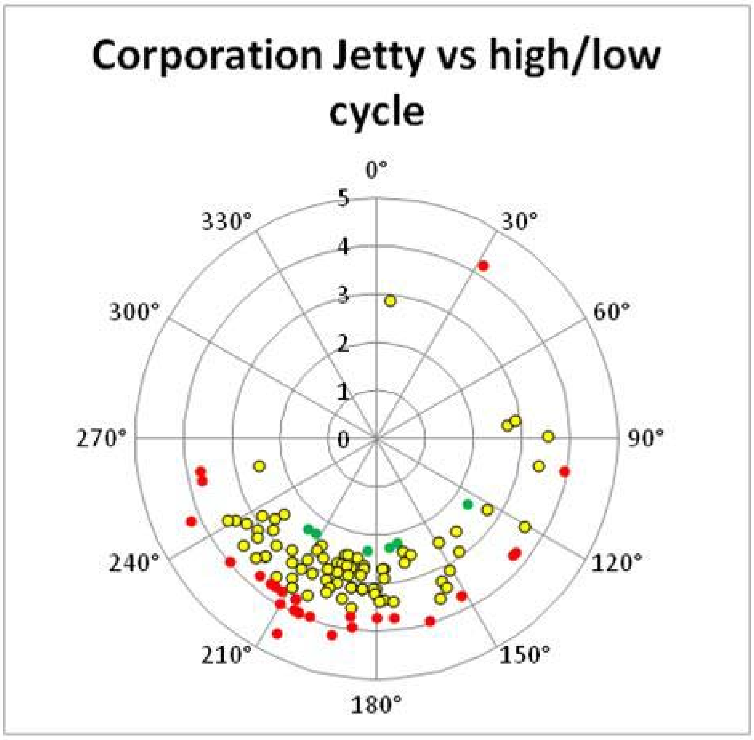

Figure XII.5 Polar plot of log_{10} E. coli against tidal state on the high/low tidal cycle for Corporation Jetty

Sampling was strongly targeted towards low water and no pattern in results in relation to tidal cycle is apparent in Figure XII.5. It is therefore concluded that tidal cycles have little effect on levels of *E. coli* within shellfish within the survey area.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination within shellfish Spearman's rank correlations were carried out between rainfall recorded at the Southchurch Park weather station over various periods running up to sample collection and *E. coli* results. These are presented in Table XI.4 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XII.3 Spearmans Rank correlation coefficients for* E. coli *results against recent rainfall

	RMP	West of Southend Pier	Chapman Sands 2	Leigh Foreshore	Corporation Jetty	Phoenix	Southend Leisure Centre
	Species	P. oysters	Cockles	Cockles	Cockles	Cockles	Mussels
	No.	83	22	83	74	76	82
24 hour periods prior to sampling	1 day	-0.098	0.024	0.121	0.193	0.236	-0.033
	2 days	0.214	0.407	0.362	0.225	0.354	0.265
	3 days	0.115	0.022	0.170	0.084	0.037	0.144
	4 days	0.234	0.258	0.179	0.053	-0.018	0.128
	5 days	-0.041	0.010	0.085	0.119	0.084	-0.033
	6 days	-0.118	0.076	0.189	0.068	0.011	0.077
	7 days	0.026	0.019	0.111	-0.140	-0.087	-0.081
Total prior to sampling over	2 days	0.059	0.224	0.305	0.258	0.293	0.164
	3 days	0.081	0.119	0.327	0.257	0.253	0.183
	4 days	0.162	0.301	0.307	0.202	0.205	0.186
	5 days	0.117	0.180	0.330	0.192	0.138	0.155
	6 days	0.076	0.144	0.342	0.172	0.096	0.144
	7 days	0.059	0.155	0.299	0.101	0.102	0.078

Table X indicates that the influence of recent rainfall on levels of *E. coli* in shellfish at Southend is weak. No influence at all was detected at Chapman Sands but sample numbers were quite low. The strongest influence was found at Leigh Foreshore. Where some influence was found rainfall 2 days prior to sampling was most commonly correlated with higher levels of *E. coli*. Together with the variable influence across the area this suggests that relatively small rainfall dependent sources are of minor and localised influence at these monitoring points.

USE OF MUSSELS AS A SURROGATE FOR PACIFIC OYSTERS

Of relevance to the sampling plan, mussels have been identified as a possible surrogate species which could be used to classify both species (Younger & Reese, 2011). There was no single location where both species were sampled from, but a comparison of results for Pacific oysters at West of Southend Pier and mussels from Southend Leisure Centre, 900m away may provide some local indication of how they compare. These two RMPs were sampled on the same day on 107 occasions. Some summary statistics for these paired samples are presented in Table XII.4.

Table XII.4 Summary statistics for paired samples taken from West of Southend Pier (Pacific oysters) and Southend Leisure Centre (mussels)

RMP	Southend Leisure Centre	West of Southend Pier
Species	mussel	Pacific oyster
No.	107	107
Geomean	495	386
Max	16,000	9,100
%>4600	4%	2%

Results were similar at the two, although slightly higher in terms of geometric mean result and proportion of results exceeding 4600 *E. coli* MPN/100g for mussels. The difference in mean result was not statistically significant (paired T-test, p=0.051) and results were strongly correlated on a sample by sample basis (Pearsons correlation, r=0.458, p=0.000). On this basis, mussels appear to be a suitable surrogate for Pacific oysters at Southend. This comparison should be treated with caution as the RMPs are located some distance from each other and may therefore be subject to differing levels of contamination.

APPENDIX XIII
SHORELINE SURVEY

Date (time): 8th March 2011 (09:00-16:00 GMT)
9th March 2011 (09:00-14:00 GMT)

Applicant: London Port Health Authority

Cefas Officer: Alastair Cook

Local Enforcement Authority Officer: Keith Wilson, London Port Health Authority.

Observer: Karen Pratt, Food Standards Agency (8th March)

Area surveyed: Shoebury Boom to Leigh on Sea, Benfleet Creek, Canvey Island.

Weather: 8th March 2011 - Wind WSW 5km/h, 8 °C, Sunny
9th March 2011 - Wind WSW 20km/h, 7°C, Overcast

Tidal predictions (Southend):

Admiralty TotalTide - Southend 51°31'N 0°43'E England. Times GMT+0000. Predicted heights are in metres above chart datum. MHWS 5.7m, MLWS 0.4m.

8th March 2011		9th March 2011	
High 02:16	5.7m	High 02:46	5.6m
Low 08:26	0.5m	Low 08:51	0.6m
High 14:32	5.5m	High 15:01	5.4m
Low 20:39	0.8m	Low 21:07	0.8m

Objectives:

This sanitary survey was initiated by London Port Health Authority in order to obtain classification for wild Pacific oyster stocks between Southend Pier and Shoebury Boom. A second objective is to rationalise the existing classification monitoring arrangements for this and adjacent areas.

The shoreline survey aims to; (a) establish the geographical extent of the fisheries and its *modus operandus*; (b) obtain samples of seawater and freshwater inputs to the area for bacteriological testing; (c) identify any additional sources of contamination in the area.

A full list of recorded observations is presented in Table XIII.1 and the locations of these observations are mapped in Figure XIII.1. Photographs referenced in Table XIII.1 and the text are presented in Figures XIII.4-10 (pages 82-85).

Description of Fishery

A full shellfish stock survey was beyond the scope of the shoreline survey, and this report only presents observations made during the survey. Wild stocks of Pacific oysters are present throughout the stretch between Leigh-on-Sea and Shoebury Boom. Occasional specimens and dead shells were also seen on the south shore of Canvey Island. As this latter stretch was not surveyed at low water, it is possible that significant stocks are present here but not seen.

Pacific oysters were most commonly observed attached to hard surfaces in the intertidal zone such as concrete groynes and outfall pipes, although in some places significant numbers were seen lying unattached on sand and gravel (Figure XIII.10, taken about 3.5km west of Southend Pier). Stock of a range of sizes was seen indicating regular recruitment to the population. They were absent or present in very low densities across most of the intertidal sediment. As a consequence RMPs must be given sufficient tolerance and sited in areas where sufficient stock is present for repeated sampling. Given the amount of human activity along this shore, bagged shellfish are unlikely to be left unmolested in the intertidal zone, so their use at monitoring points is probably not practical. They are subject to a dredge fishery, and are generally sent to France for restocking fisheries impacted by Oyster Herpes virus. Casual gatherers also collect oysters by hand along this shore, and it is possible that some of these are sold on. The zone from Leigh-on-Sea to Southend Pier currently holds a long term B classification for this species, whilst the area from Southend Pier to Shoebury Boom holds a preliminary C classification.

Large stocks of cockles are present throughout the area which are the subject of a dredge fishery. The classified zones for this species cover a larger area, stretching from Canvey Island to Foulness. West of Shoeburyness they hold C classifications, and east of Shoeburyness they hold B classifications. The Thames estuary cockle fishery is only open to licenced boats, and is highly regulated via closed seasons, quotas and limited days at sea.

Other species such as mussels, razors and some clam species are present in places, but are not currently believed to be of commercial interest.

Sources of contamination

Sewage discharges

There are three major sewage treatment works serving the area surveyed. The Southend STW has a long sea outfall discharging about 2.7km off Southend. Due to its offshore location it was not possible to visit the discharge point, although the marker buoy indicating its location was seen from a distance. Associated with this Southend sewerage network were a series of intermittent (emergency and/or storm overflow) discharges at regular intervals along the Southend seafront. It is likely that some of the pipes observed carry surface runoff rather than sewage spills. Most outfall pipes were confirmed as such, but others were covered by the tide at the time, and whilst marker posts and concrete casings consistent with the presence of outfalls were seen, the presence of an outfall pipe could not be confirmed.

The Benfleet STW discharges to the Benfleet Creek, and its location was confirmed (observation 46). Canvey Island is served by its own STW, which is located on the south shore. The location of the plant was confirmed (observation 48) but it was not possible to visit the outfall location due to access constraints. A pumping station outfall was seen on the south east corner of Canvey Island (observation 53). Sanitary related debris was noted on the Southend shore (observations 7 and 14) as well as at Canvey Island (observation 49).

Freshwater inputs

There were very few freshwater inputs recorded during the course of the shoreline survey and those seen were very minor in terms of volumes discharged. The shoreline survey was undertaken during a dry period.

Three small freshwater inputs were sampled and measured along the Southend shoreline (observations 4, 5 and 42). Measured loadings for these are presented in Table 2. Of these, the culverted stream at Leigh on Sea (observation 42) carried the highest *E. coli* loading, and the high *E. coli* concentration within this watercourse suggested some possible sanitary content. It is probable that some of the outfall pipes along the Southend seafront carry surface runoff following rainfall.

In addition to these watercourses, three surface water outfalls via sluice were recorded on south shore of Canvey Island. None was flowing at the time of survey. There are likely to be some minor freshwater inputs to Benfleet Creek.

Boats and Shipping

Large numbers of small vessels including fishing boats, yachts and houseboats were recorded in the area. Leigh-on-Sea is a small fishing port, from which several cockle dredgers operate. Here, a total of around 40 small vessels were observed including some small yachts (observation 1). Boatyards were noted at Leigh-on-Sea and adjacent to Benfleet Creek (observations 43 and 44) where large numbers of yachts were in storage. Around 100 boats some of which were houseboats were seen in Benfleet Creek, although few appeared to be in occupation at the time (observations 44 and 45). A total of 62 small boats were also recorded on various areas of moorings between Southend Pier and Shoebury Ness (observations 23, 31, 34 and 38). It is likely that considerably more pleasure craft are afloat in the general area during the summer months.

Livestock

No livestock were seen during the course of the survey. Dog walkers were recorded at Leigh-on-Sea (observation 2). Signs indicated that dogs are banned from all Southend beaches from May to September.

Wildlife

Small aggregations of seagulls and waders were seen within Benfleet Creek and at Shoeburyness (observations 37 and 44).

Sample results

Some seawater samples were taken, and where possible any freshwater inputs were sampled and spot discharge measurements taken, to give spot estimates of their *E. coli* loadings (Table XIII.2 and Figure XIII.2).

Seawater samples showed higher levels of *E. coli* on the south shore of Canvey Island (range of 75 to 1,000 cfu/100ml) compared to those taken off Southend (range of 16 to 66). The sample taken within Leigh on Sea harbour gave the lowest *E coli* result (16 cfu/100ml).

It is likely that levels of *E. coli* were relatively high within Benfleet Creek given its sewage inputs, boating activities and confined nature, but it was not possible to safely sample seawater from here due to the steep banks and soft mud.

Figure XIII.1. Locations of shoreline observations

Table XIII.1. Details of shoreline observations

No.	Date and time	NGR	Photograph	Observation
1	08/03/2011 10:01	TQ 83501 85746	Figure XIII.4	Drying moorings, about 40 small vessels
2	08/03/2011 10:19	TQ 84047 85630		Dog walkers
3	08/03/2011 10:30	TQ 84669 85585		Intermittent discharge outfall
4	08/03/2011 10:33	TQ 84682 85480	Figure XIII.5	Flow from pipe end 15cmx1cmx0.204m/s. Water sample 1
5	08/03/2011 10:40	TQ 84738 85585	Figure XIII.6	Stream 12cmx2cmx0.497m/s. Water sample 2.
6	08/03/2011 10:53	TQ 85348 85438	Figure XIII.7	Intermittent outfall, 4 pipes alongside each other. One dripping.
7	08/03/2011 11:02	TQ 85543 85443		Cotton buds
8	08/03/2011 11:07	TQ 85751 85299		Intermittent outfall pipe
9	08/03/2011 11:13	TQ 86000 85242		Intermittent outfall pipe
10	08/03/2011 11:19	TQ 86266 85239		Intermittent outfall pipe
11	08/03/2011 11:26	TQ 86612 85263		Intermittent outfall pipe
12	08/03/2011 11:30	TQ 86818 85188		Intermittent outfall pipe
13	08/03/2011 11:34	TQ 87056 85159		Intermittent outfall pipe (longer than the others)
14	08/03/2011 11:52	TQ 88155 85049		Intermittent outfall pipe. Old cotton buds.
15	08/03/2011 11:59	TQ 88510 84972	Figure XIII.8	Round tank under pier. Advised by London Port Health contacts that this is not in use and associated with a bowling alley that has now burned down.
16	08/03/2011 12:02	TQ 88575 84973		Intermittent outfall pipe
17	08/03/2011 12:05	TQ 88793 85050		Intermittent outfall pipe
18	08/03/2011 12:09	TQ 89025 84985		Intermittent outfall pipe
19	08/03/2011 12:12	TQ 89194 84914		Intermittent outfall pipe
20	08/03/2011 13:09	TQ 90003 84777		Outfall marker post? End covered by tide.
21	08/03/2011 13:10	TQ 90082 84788		Outfall marker post? End covered by tide.
22	08/03/2011 13:14	TQ 90158 84798	Figure XIII.9	Anglian Water buliding. 2 possible outfall markers just off here covered by tide.
23	08/03/2011 13:16	TQ 90213 84806		4 possible outfall marker posts. 14 small boats on moorings.
24	08/03/2011 13:23	TQ 90642 84819		Possible outfall marker post
25	08/03/2011 13:23	TQ 90664 84815		Possible outfall marker post
26	08/03/2011 13:24	TQ 90728 84805		Possible outfall marker post
27	08/03/2011 13:25	TQ 90790 84797		Possible outfall marker post
28	08/03/2011 13:26	TQ 90858 84787		Possible outfall marker post
29	08/03/2011 13:28	TQ 91026 84759		Possible outfall marker post
30	08/03/2011 13:29	TQ 91060 84752		Possible outfall marker post
31	08/03/2011 13:29	TQ 91100 84744		Possible outfall marker post. 14 small boats on moorings.
32	08/03/2011 13:32	TQ 91273 84695		Outfall pipe
33	08/03/2011 13:35	TQ 91269 84681		Water sample 3.
34	08/03/2011 13:37	TQ 91339 84676		16 small boats on moorings
35	08/03/2011 13:44	TQ 91863 84488		Short outfall pipe, another marker post about 200m offshore

No.	Date and time	NGR	Observation
36	08/03/2011 13:50	TQ 92272 84314	18 boats on moorings
37	08/03/2011 13:54	TQ 92555 84170	About 100 dunlins. Marker post about 200m offshore
38	08/03/2011 13:57	TQ 92715 84182	Anglian Water pumping station
39	08/03/2011 14:33	TQ 94106 84744	Outfall pipe
40	08/03/2011 14:48	TQ 94675 85280	Water sample 4
41	08/03/2011 15:27	TQ 83462 85770	Water sample 5
42	09/03/2011 09:39	TQ 83421 85782	Culverted stream, 85cmx1cmx0.122m/s. Water sample 6
43	09/03/2011 09:59	TQ 82441 85472	Leigh motor boat club. 1 large houseboat
44	09/03/2011 10:54	TQ 78343 85621	About 80 boats on pontoons including some houseboats. Boatyard with many large yachts on opposite bank. About 100 waders and gulls on mud in benfleet creek
45	09/03/2011 11:16	TQ 77467 86006	About 20 houseboats, all but one appear unoccupied.
46	09/03/2011 11:34	TQ 76967 86110	Benfleet STW main outfall
47	09/03/2011 11:45	TQ 77667 85900	Attempted to take seawater sample but access problematic and unsafe
48	09/03/2011 12:24	TQ 78768 82332	Canvey STW main gate
49	09/03/2011 12:30	TQ 79630 82524	Water sample 7. Sanitary debris (rag) in tideline
50	09/03/2011 12:46	TQ 80411 82451	Surface water outfall via sluice, not flowing
51	09/03/2011 12:51	TQ 80661 82502	Water sample 8
52	09/03/2011 12:58	TQ 81113 82659	Surface water outfall via sluice, not flowing
53	09/03/2011 13:12	TQ 82160 82981	Pumping station outfall. Surface water outfall via sluice (not flowing)
54	09/03/2011 13:14	TQ 82230 82991	Water sample 9
55	09/03/2011 13:21	TQ 82198 83470	Island yacht club boatyard. Water sample 10
56	09/03/2011 13:26	TQ 82004 83414	Smallgains Marina.

Table XIII.2. Water sample* E. coli *results

No.	Date and time	NGR	Type	*E. coli* result (cfu/100ml)	Measured discharge (m^3/day)	Estimated loading (*E. coli*/day)*
1	08/03/2011 10:33	TQ 84682 85480	Freshwater (pipe)	738	26.4	1.95×10^8
2	08/03/2011 10:40	TQ 84738 85585	Freshwater (stream)	2200	103	2.27×10^9
3	08/03/2011 13:35	TQ 91269 84681	Seawater	66		
4	08/03/2011 14:48	TQ 94675 85280	Seawater	24		
5	08/03/2011 15:27	TQ 83462 85770	Seawater	16		
6	09/03/2011 09:39	TQ 83421 85782	Freshwater (stream)	>20,000	89.6	$>1.79 \times 10^{10}$
7	09/03/2011 12:24	TQ 79630 82524	Seawater	1000		
8	09/03/2011 12:51	TQ 80661 82502	Seawater	384		
9	09/03/2011 13:14	TQ 82230 82991	Seawater	75		
10	09/03/2011 13:21	TQ 82198 83470	Seawater	111		

*Number of *E. coli* cfus carried into coastal water per day by each freshwater input, as calculated from a spot gauging of discharge and the *E. coli* result from a sample of the water taken at the same time.

Figure XIII.2. Water sample results

Conclusions

Classification monitoring arrangements for the Southend area require rationalisation, and this will be addressed in the full sanitary survey report. In the meantime, a bacteriological survey should be initiated for wild Pacific oysters from Southend Pier to Shoebury Boom to assess spatial variation in levels of *E. coli* within oysters and to accrue monitoring results towards a preliminary classification.

A likely problem is the uncertain, patchy and generally sparse distribution of Pacific oysters within this stretch. It is likely that most hard structures lower down the shore host oysters, but probably not enough for repeated sampling. There may also be some areas of sediment where oysters have accumulated to sufficient densities for repeated sampling, although it is uncertain where these are, and they may not coincide with the most appropriate RMP locations in the context of public health protection. The use of bagged shellfish is thought to be impractical due to the numbers of people using the shore here, but may have to be trialled in the absence of other options. Clear warning signs attached to the bags may help deter interference with them.

Within this stretch there are several outfall pipes, some of which will carry overflow discharges from the Southend sewerage network, and some of which will carry urban runoff. Without more details on these such as their spill frequencies, which will be sought as part of the main sanitary survey report, it is difficult to assess their significance, aside from noting their location and potential to cause significant localised decreases in water quality. The main concentration of sewage overflows between Southend Pier and Shoebury Boom, according to records held on databases at CEFAS is within the 1.5km stretch immediately east of the pier. There are also additional sewage overflows on the western boundary of the danger area at Shoeburyness and about 800m to the west of the Shoebury Boom. Shoreline observations suggest there are additional outfall pipes between these locations. The Southend STW long sea outfall discharges treated effluent about 2.7km offshore 2km southeast of end of Southend Pier. Contamination from this discharge is not expected to significantly impact on shellfish within the intertidal area as it will generally be carried parallel to the coast in an easterly or westerly direction by tidal streams.

Aside from these, some diffuse inputs from seabirds and possibly dog walkers (from October to April) may contribute to levels of contamination seen in shellfish here. Any impacts from these will be diffuse, with no predictable spatial pattern. It is also possible that the small craft on moorings, which are present throughout this stretch will make overboard discharges. This will be more likely to occur during the summer, but will be geographically widespread and unpredictable.

Figure XIII.4

Figure XIII.5

Figure XIII.6

Figure XIII.7

Figure XIII.8

Figure XIII.9

Figure XIII.10

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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
K&E IFCA	Kent and Essex Inshore Fisheries and Conservation Authority
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
STW	Sewage Treatment Works
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”.

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