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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Swale and Thames (Sheppey)

November 2013

Food Standards Agency

Cover photo: Shellness.

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Statement of use

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

Report prepared by

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal consultation	Fiona Vogt	27/11/2013
2	Draft for client/consultee comment	Simon Kershaw	29/11/2013
3	Final	Simon Kershaw	14/02/2014

Consultation

Consultee	Date of consultation	Date of response
London Port Health Authority	04/12/2013	14/01/2014
Swale Borough Council	04/12/2013	8/1/2014
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Kent & Essex IFCA	04/12/2013	None received
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Shellfish Association of Great Britain	04/12/2013	8/1/2014

Dissemination

Food Standards Agency, London Port Health Authority, Swale Borough Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2013. Sanitary survey of The Swale and Thames (Sheppey). 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 EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

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

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

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

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

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

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

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

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

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

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

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

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

This report documents the information relevant to undertake a sanitary survey for Pacific oysters (*Crassotrea gigas)*, native oysters (*Ostrea edulis*), mussels (*Mytilus* spp.), cockles (*Cerastoderma edule*) and clams (*Tapes* spp.) in the Swale production area, and the part of the Thames Production area adjacent to the Isle of Sheppey. The Swale was prioritised for survey in 2013-14 by a shellfish hygiene risk ranking exercise of existing classified areas, and it was decided to include the Thames Estuary (Sheppey area) in this survey for efficiency reasons.

1.2. Area description

The survey area is situated on the east coast of England in Kent and forms part of the outer Thames estuary. It includes the entire Swale production area, and the part of the Thames production area which lies to the north and east of Sheppey. The two production areas border one another, although the exact boundary is undefined. They also border the North Kent production area to the east, whose boundaries were defined by a previous sanitary survey (Cefas, 2011).

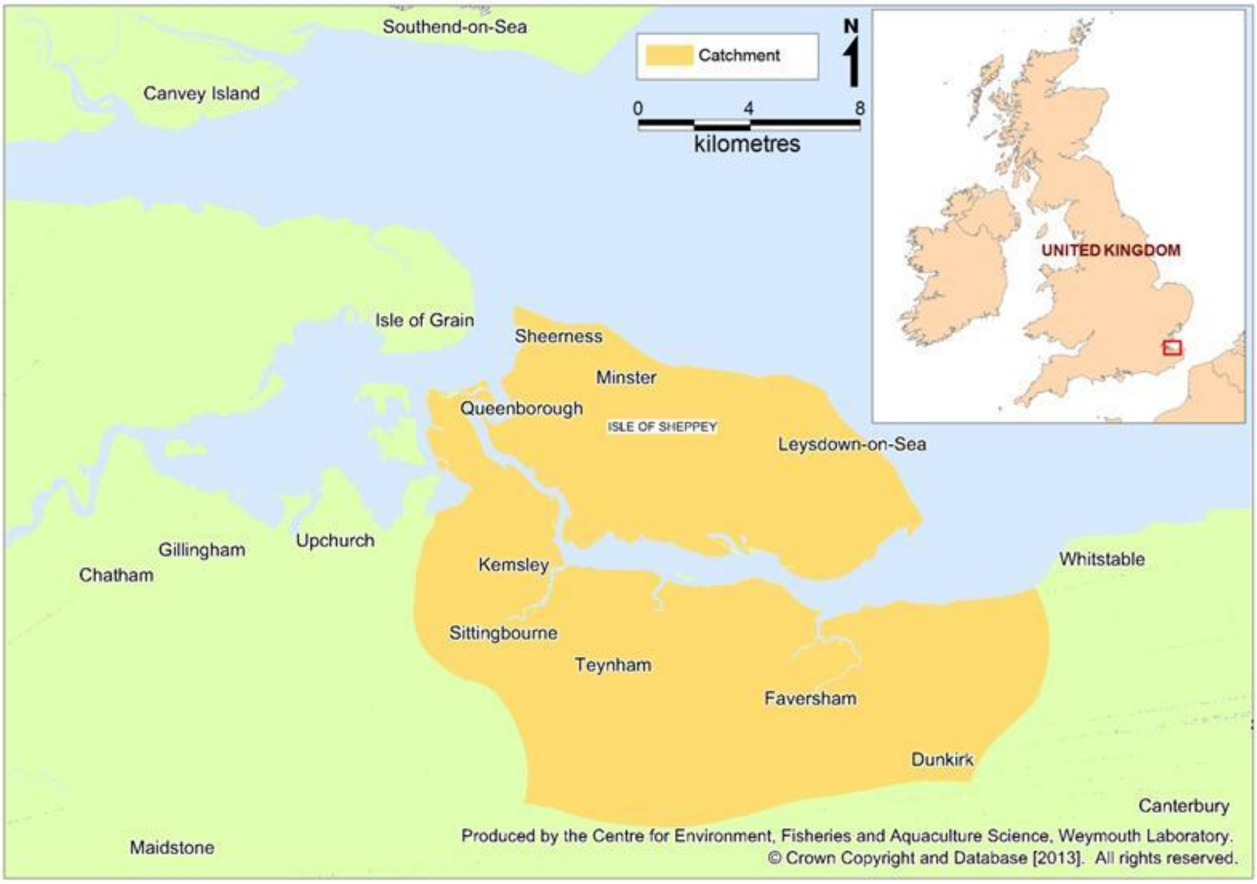


Figure 1.1: Location of the Swale and Sheppey

The Swale estuary covers an area of around 32.8 km², of which 78% is intertidal (Futurecoast, 2002). Its 13 mile channel separates the Isle of Sheppey from the mainland. There are several tidal creeks emanating from it, and it is connected to the Medway estuary at its western end. The area to the east and north of Sheppey is a more open coastline, with intertidal areas extending over 3 km out from the high water mark in places. There are sea walls along most of the coastline as well as groynes and rock armour in places. It supports several different shellfisheries, both for naturally occurring and cultured stocks, with species harvested including Pacific and native oysters, mussels, cockles and clams (*Tapes* spp.).

1.3. Catchment

Figure 1.2 illustrates landcover within the Swale and Sheppey catchment area which covers an area of 260 km². There are no major rivers draining directly to the survey area, with freshwater inputs limited to a series of small watercourses and engineered drainage outfalls. It is predominantly covered by rural land including arable land, areas of horticultural land for the production of orchards and hops and lowland marshes adjacent to the estuary which are used for pasture. There are also significant areas of urbanised land which are situated close to the coast, including the towns of Sittingbourne, Kemsley, Sheerness, Minster, Queenborough and Faversham.

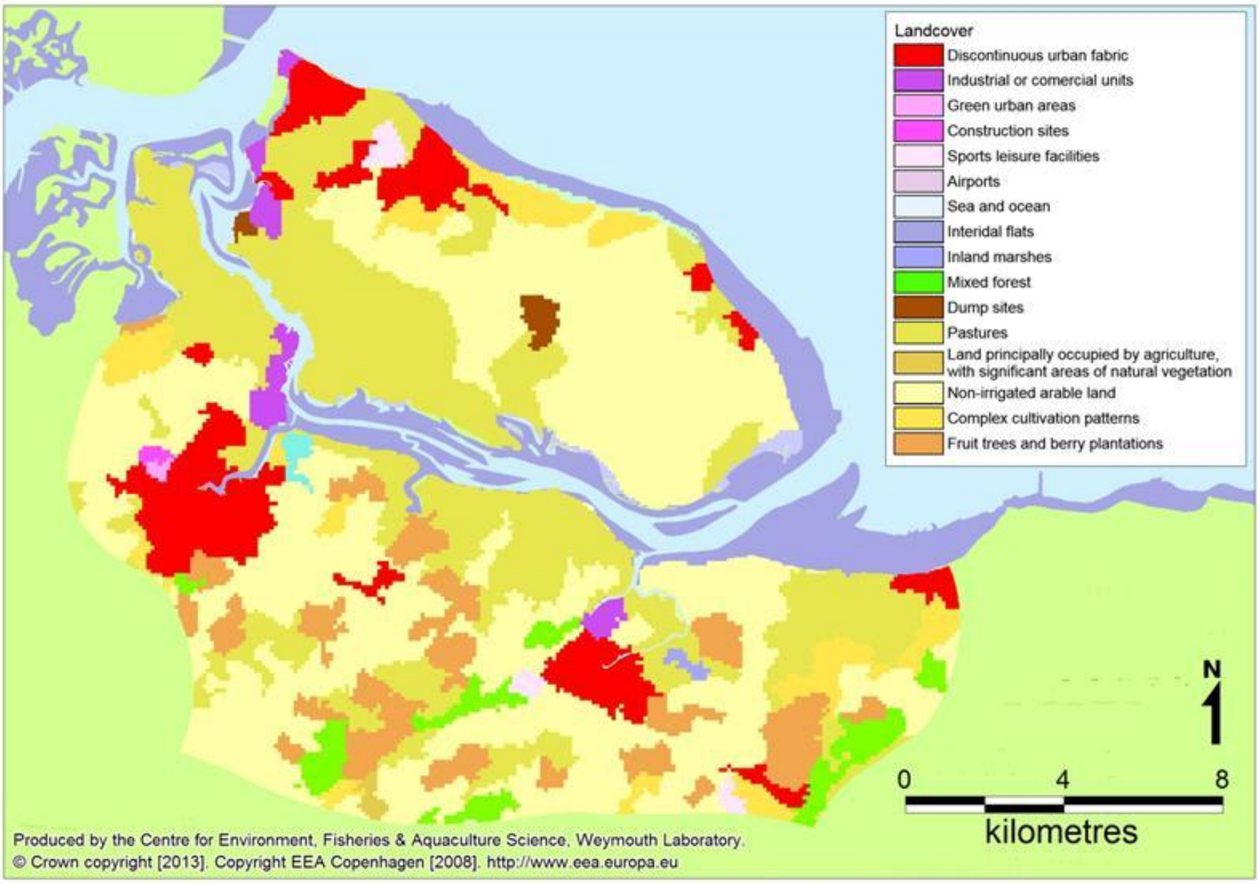


Figure 1.2: Landcover in the Swale and Sheppey catchment area

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

A large proportion of the land that surrounds the Swale is low lying and has been reclaimed. The underlying geology of the catchment comprises highly permeable chalk in the inland reaches, sandstone and limestone in the middle catchment and low permeability marl, sandstone and mudstone adjacent to the coast. The Isle of Sheppey is predominantly comprised of low permeability Marl, sandstone and mudstone (Kent County Council, 2012).

2. Recommendations

It is recognised that the there are some uncertainties about the exact distribution of some stocks, and that the recommended RMPs may require some slight adjustments to their locations following the first sampling run. Any adjustments should follow the principles identified in the recommendations (e.g. samples should be taken as far to the west as stocks extend). Any adjustments should be communicated by the LEA to the classification team at Cefas.

2.1. Pacific oysters

The following four zones are proposed for Pacific oysters:

Swale Inner North.

This zone includes a significant managed plot to the north of Fowley Island where Pacific oysters are cultured on the sea bed. There is likely to be an underlying gradient of increasing contamination towards the inner (western) reaches of this zone. The enclosed Conyer Creek receives some land runoff, sewage effluent from Teynham STW and has significant boat traffic associated with two marinas and an area of moorings. The ebb plume from this is likely to represent a hotspot of contamination in the area, and will travel in an easterly direction, and mainly pass to the south of Fowley Island, although some may pass to the north. The ebb plume from Windmill Creek, which receives freshwater inputs carrying the effluent from Eastchurch STW will also be an influence within this zone. However, the ebb plume does not pass over any identified shellfish resources. It is therefore recommended that the RMP is located on the south western tip of the oyster plot to best capture both the underlying gradient and the peak influence of Conyer Creek.

Swale Inner South

This zone includes a managed plot to the south of Fowley Island where Pacific oysters are cultured on the sea bed. As for Swale Inner North, there is likely to be an underlying gradient of increasing contamination towards the inner (western) reaches of this zone. The ebb plume from Conyer Creek is likely to be the most significant influence, and it will be considerably more marked here than to the north of Fowley Island, perhaps to the extent that a worse classification may be derived. This means that despite their close proximity, the plot to the south of Fowley Island should be monitored separately from the one to the north of Fowley Island, in the first instance at least. It is therefore recommended that the RMP is located on the western end of the oyster plot to best capture both the underlying gradient and the peak influence of Conyer Creek. The requirement for separate monitoring of Swale

Inner North and Swale Inner South should be reviewed by the classification team once a years' worth of results have been accrued.

Swale Causeway

Within this zone there is a small area at the end of the causeway extending from the mainland shore, where market size Pacific oysters are held for ease of access. The main influence here will be from sources to the west. The ebb plume from Faversham Creek will not directly impact on this site as it will be carried in an easterly direction. An RMP located on the end of the Causeway, where the oysters are held, should be suitably representative of this zone.

Swale Outer

Within this zone, there is a managed plot on which oysters are grown on the sea bed on the intertidal off the Graveney Marshes to the east of the mouth of Faversham Creek. The main contaminating influence in this zone will be the ebb plume from Faversham Creek, which receives sewage from Faversham STW, has a marina and significant areas of moorings, as well as receiving some freshwater inputs. Sources further inside the Swale may also be of influence. It is therefore recommended that the RMP be located on the intertidal area off Graveney Marshes, as close to the mouth of Faversham Creek as stocks extend.

Sampling requirements

The species sampled should be Pacific oysters of a market size. Sampling should be on a monthly and year round basis. Sampling should be via hand rather than dredge to avoid disturbance to the managed plots. A tolerance of 50m should apply once RMP locations are confirmed by the LEA to ensure there is sufficient stock for repeated sampling.

2.2. Native oysters

Continued classification for native oysters is only required for the holding area at the end of the causeway extending from the mainland shore just west of Faversham Creek. Native oysters taken from the classified grounds off Whitstable are held here briefly before being sent to market. It is recommended that a classification zone be established here with the same boundaries and RMP as Swale Causeway Pacific oyster zone. The Pacific oysters sampled from the Causeway RMP may be used to classify native oysters here. Although there is a closed season for native oysters (May to August) sampling will nevertheless be year round to maintain the Pacific oyster classification.

2.3. Cockles and mussels

There is limited mussel harvesting within the survey area, but significant volumes of cockles are taken. In order to keep the sampling burden as low as possible, it is recommended that the results of cockle samples be used to classify both species as they accumulate *E. coli* to slightly higher levels, are more widely distributed, and are the main species of commercial interest. Three identical zones are proposed for both cockles and mussels:

North Sheppey

Shellfish resources in this zone comprise of a mussel bed at Barton Point, and a concentration of cockles at Scrapsgate, by Minster. There is little in the way of significant sources of contamination directly to this zone. The ebb plume from the Medway may be an influence along its offshore edge, but this will tend to remain in the deepwater Medway approach channel to the north. The shoreline survey identified a hotspot of contamination associated with a freshwater outfall between Sheerness and Minster. It is therefore recommended that the RMP is located in the intertidal, as close as possible to the path of the drainage channel associated with this outfall.

East Sheppey

Within this zone there is a mussel bed at Shellness, and a significant concentration of cockles off Leysdown. There is little in the way of significant sources of contamination direct to this zone. The main influence is likely to be the ebb plume from the Swale. It is therefore recommended that the RMP is located on the intertidal off Shellness, as far south as cockle stocks extend.

Swale Outer

There are reported to be some cockle and mussel stocks within this zone, but there is no firm information available on their distribution. They are not commercially harvested here at present so this zone will only require classification on request of either Hollowshore Fisheries or the Faversham Oyster Company. The main contaminating influence in this zone will be the ebb plume from Faversham Creek, which receives sewage from Faversham STW, has a marina and significant areas of moorings, as well as receiving some freshwater inputs. Sources further inside the Swale may also be of influence. It is therefore recommended that the RMP be located on the intertidal area off Graveney Marshes, as close to the mouth of Faversham Creek as cockle stocks extend.

Sampling requirements

The species sampled should be cockles of a market size. Sampling should be on a monthly and year round basis as although there is a closed season for cockles in some areas, mussels require a year round classification. The RMPs are intertidal so can be sampled either by hand or dredge. The RMP at Graveney Marshes should be sampled by hand (if needed) to prevent disturbance to any oysters there. Once RMP locations are confirmed by the LEA, a tolerance of 50m should apply to hand gathered samples to ensure there is sufficient stock for repeated sampling, whereas a tolerance of 100m should apply to dredge RMPs.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Swale, Thames Estuary (Sheppey)
Cefas Main Site Reference	M076, M016
Ordnance survey 1:25,000 map	Explorer 149
Chart	Imray 2100.4

Shellfishery

Species/culture	Pacific oysters	Cultured
	Native oysters	Wild/cultured
	Cockles	Wild
	Mussels	Wild/cultured
Seasonality of harvest	Open season within June to November window for cockles, Open season from September to April (native oysters)	

Local Enforcement Authority

Name	London Port Health Authority River Division (Lower) The Quarantine Station Mark Lane Denton Nr. Gravesend Kent. DA12 2QE
Environmental Health Officer	Keith Wilson
Telephone number ☎	01474 363033
Fax number	01474 353354
E-mail	keith.wilson@corpoflondon.gov.uk
Name	Swale Borough Council Swale House East Street Sittingbourne Kent. ME10 3HT
Environmental Health Officer	Peter Lincoln
Telephone number ☎	01795 424341
Fax number	01795 417217
E-mail	csc@swale.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve

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

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

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Local Authority	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Swale Inner North	B076N	North of Fowley Island	TQ 9650 6616	51° 21.631' N 00° 49.264' E	Swale BC	Pacific oyster	Bed culture	Hand	Hand	50m	Monthly	Represents Pacific oysters in this zone.
Swale Inner South	B076O	South of Fowley Island	TQ 9644 6584	51° 21.460' N 00° 49.202' E	Swale BC	Pacific oyster	Bed culture	Hand	Hand	50m	Monthly	Represents Pacific oysters in this zone.
Swale Causeway	B076P	The Causeway	TR 0131 6497	51° 20.889' N 00° 53.363' E	Swale BC	Pacific oyster	Temporary holding area	Hand	Hand	50m	Monthly	Represents Pacific and native oysters in this zone.
Swale Outer	B076Q	Graveney Marshes	TR 0294 6463	51° 20.671' N 00° 54.754' E	Swale BC	Pacific oyster	Bed culture	Hand	Hand	50m	Monthly	Represents Pacific oysters in this zone.
North Sheppey	B076R	Scrapsgate outfall	TQ 9465 7453	51° 26.179' N 00° 47.947' E	London PH	Cockles	Wild	Hand/dredge	Hand/dredge	50/100m	Monthly	Represents cockles and mussels within this zone
East Sheppey	B076S	Shellness	TR 0613 6863	51° 22.757' N 00° 57.638' E	Swale BC	Cockles	Wild	Hand/dredge	Hand/dredge	50/100m	Monthly	Represents cockles and mussels within this zone

Swale Outer	TBA	Graveney Marshes	TR 0294 6463	51° 20.671' N 00° 54.754' E	Swale BC	Cockles	Wild	None at present	Hand	50m	Monthly	Only to be sampled if classification is requested by Hollowshore Fisheries or the Faversham Oyster Company. Represents cockles and mussels within this zone.

**RMP codes will be generated once the report has been agreed and finalised.*

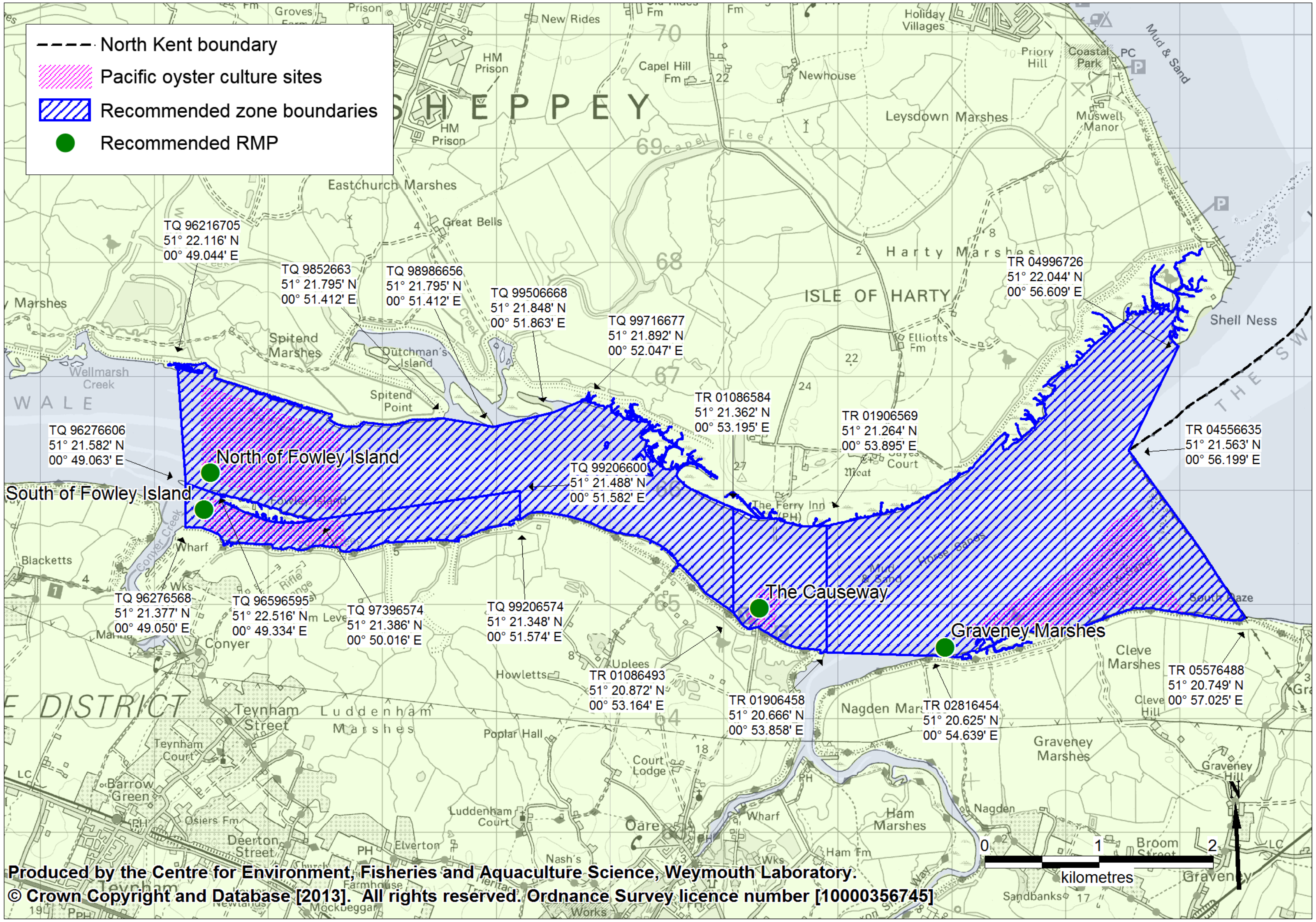


Figure 3.1: Recommended zoning and monitoring arrangements (Pacific oysters)

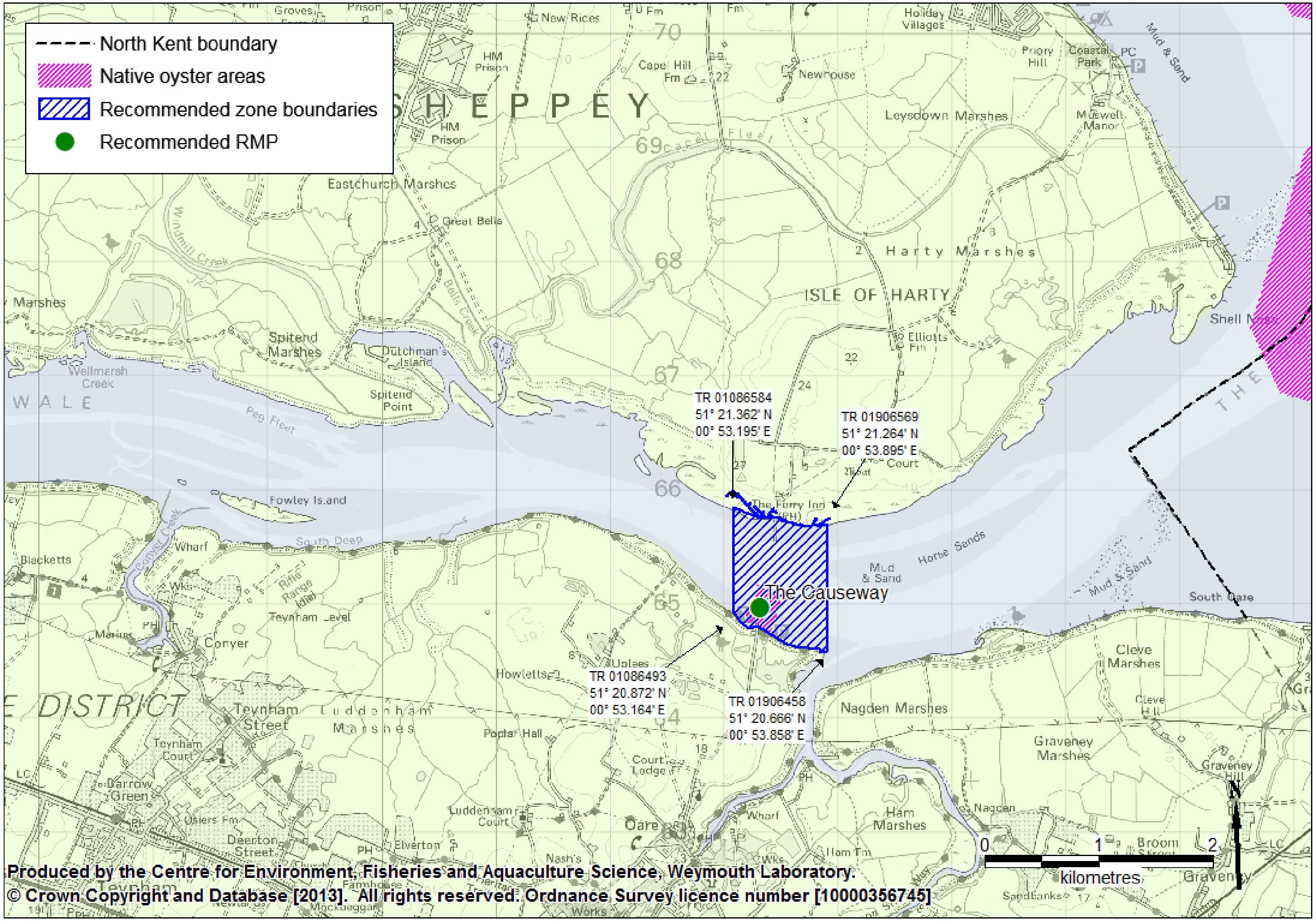


Figure 3.2: Recommended zoning and monitoring arrangements (native oysters)

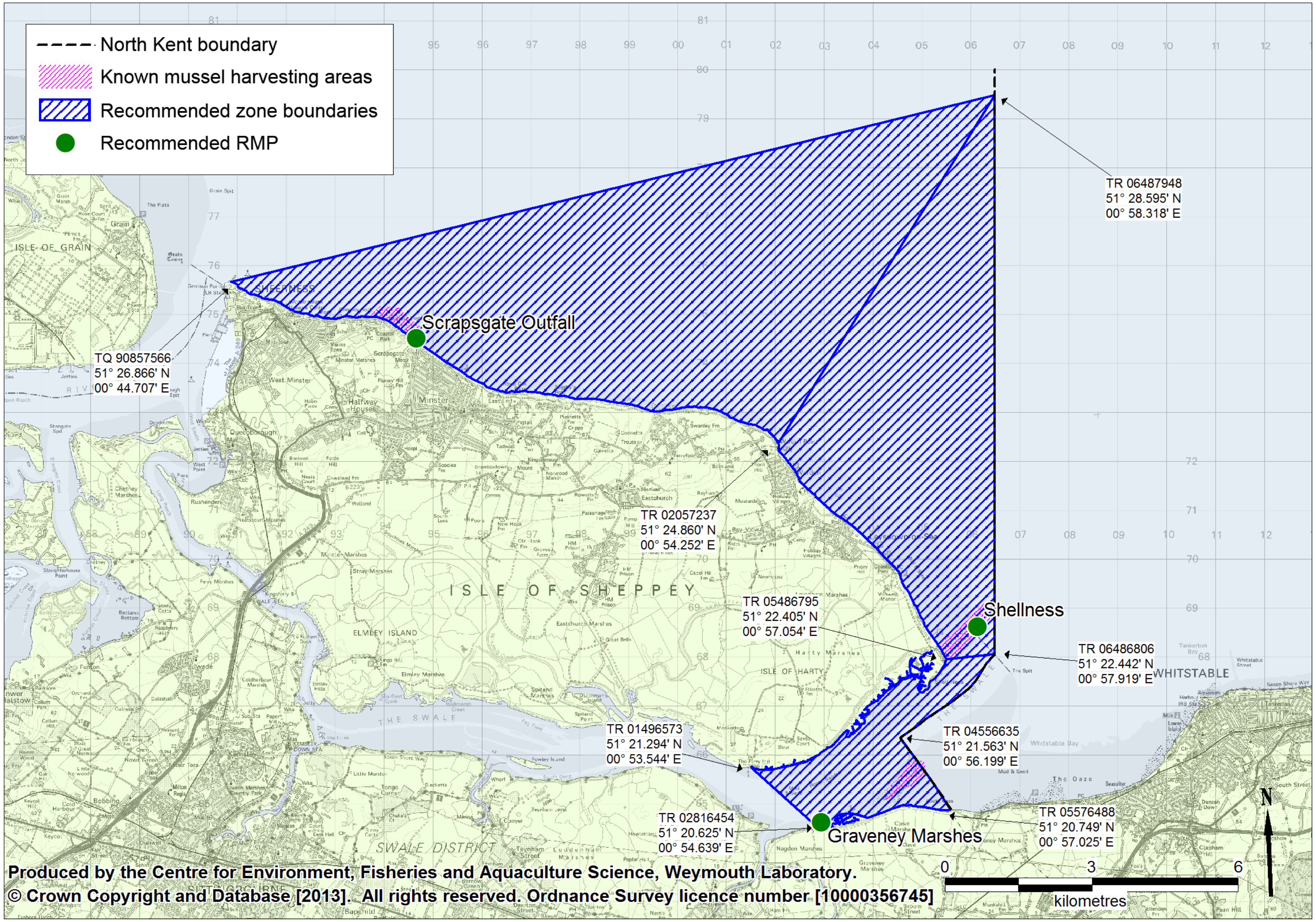


Figure 3.3: Recommended zoning and monitoring arrangements (mussels)

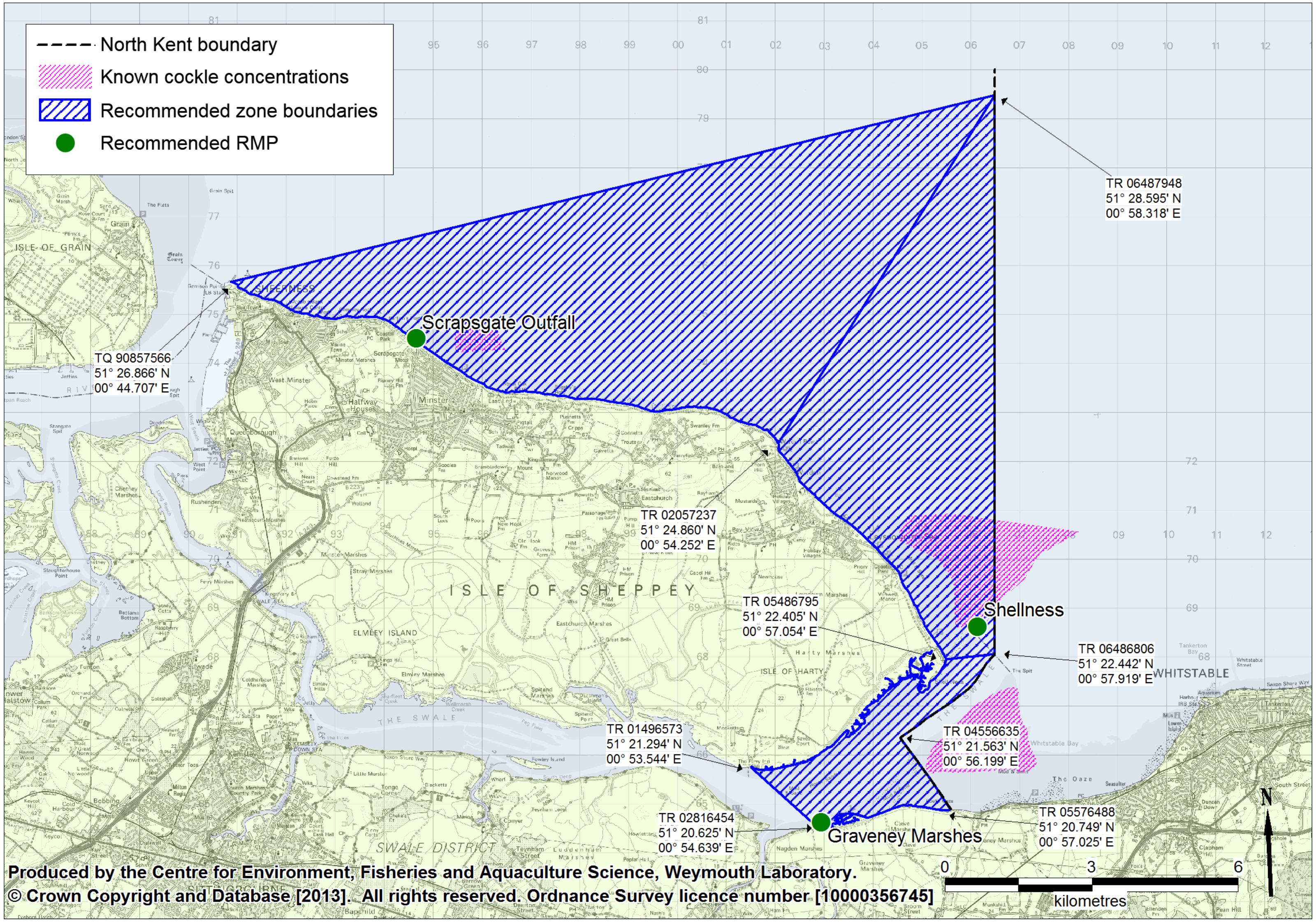


Figure 3.4: Recommended zoning and monitoring arrangements (cockles)

4. Shellfisheries

The survey area supports shellfisheries for Pacific oysters, native oysters, mussels, cockles and clams (*Tapes* spp.). It lies immediately adjacent to the North Kent production area, for which a sanitary survey was undertaken in 2011 (Cefas, 2011). Boundaries between North Kent and the current survey area were defined during this previous survey. Some shellfish resources overlap the boundary between the current and previous survey. In some cases the recommended RMPs for North Kent were deemed suitably representative to cover zones extending slightly into the current survey area. This survey will therefore include consideration of the recommended zoning and monitoring arrangements for the North Kent survey. The RMPs recommended in the North Kent report have now been adopted, but the transition to the new zone boundaries is not complete as yet. It is assumed that the North Kent boundaries will be updated at some point before the sampling plan for the current survey is implemented.

There are private grounds around the mouth of the Swale and extending into the Swale, parts of which are leased to various fishermen at various times, for example when and where there are sufficient cockle stocks to merit dredging. The Ham grounds lie off Leysdown, and the Pollard grounds lie off the mainland shore west of Seasalter and are owned by Seasalter Shellfish. The Faversham Oyster Company grounds bisect the Seasalter Shellfish grounds, and include some subtidal areas within the Swale. Inside the Swale, most of the seabed is privately owned by the Lees Court Estate up to about as far as the mouth of Conyer Creek. They also own Faversham and Oare Creek and lease the grounds to Hollowshore Fisheries. The exact boundaries of these private grounds could not be confirmed at the time of writing.

4.1. Species, location and extent

Pacific oysters

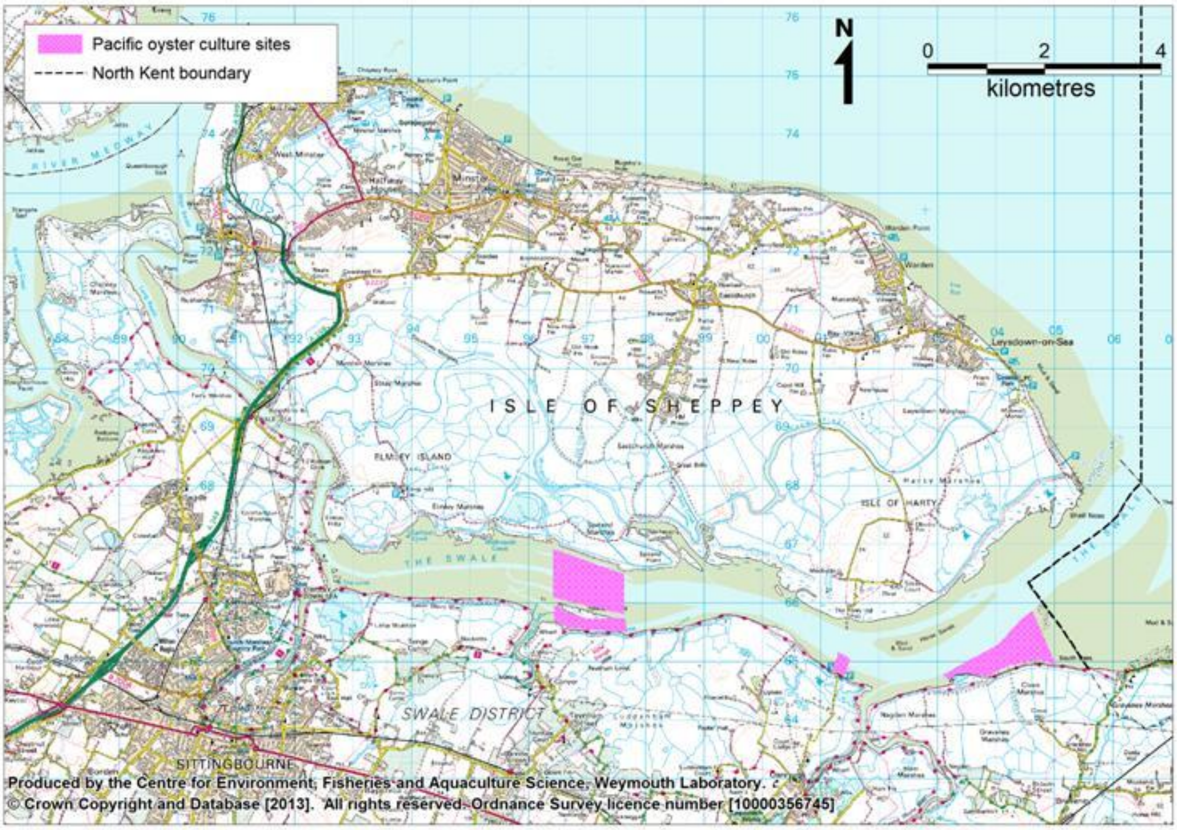


Figure 4.1: Pacific oyster distribution

Pacific oysters are cultured within the Swale by Hollowshore Fisheries. Most stocks are grown on managed beds around Fowley Island. There is a causeway just to the west of the mouth of Faversham Creek which allows easy access to the lower intertidal, where oysters of a market size are held prior to harvest. There is also another area where the substrate is less muddy off the Graveney Marshes, where Hollowshore Fisheries also grow stocks of Pacific oysters. There are some Pacific oysters in Faversham Creek, but Hollowshore Fisheries do not require these to be classified due to the poorer water quality up this creek.

Pacific oysters occur naturally throughout the outer Thames estuary. They are prolific on the North Kent coast from Whitstable to Margate (Natural England, 2009) and form the basis of the oyster culture fishery in the Swale. Their main concentrations are found across the lower intertidal zone. No firm information on their status and distribution along the north coast of Sheppey could be found, and no requests to classify this shoreline for them have been received.

Native oysters

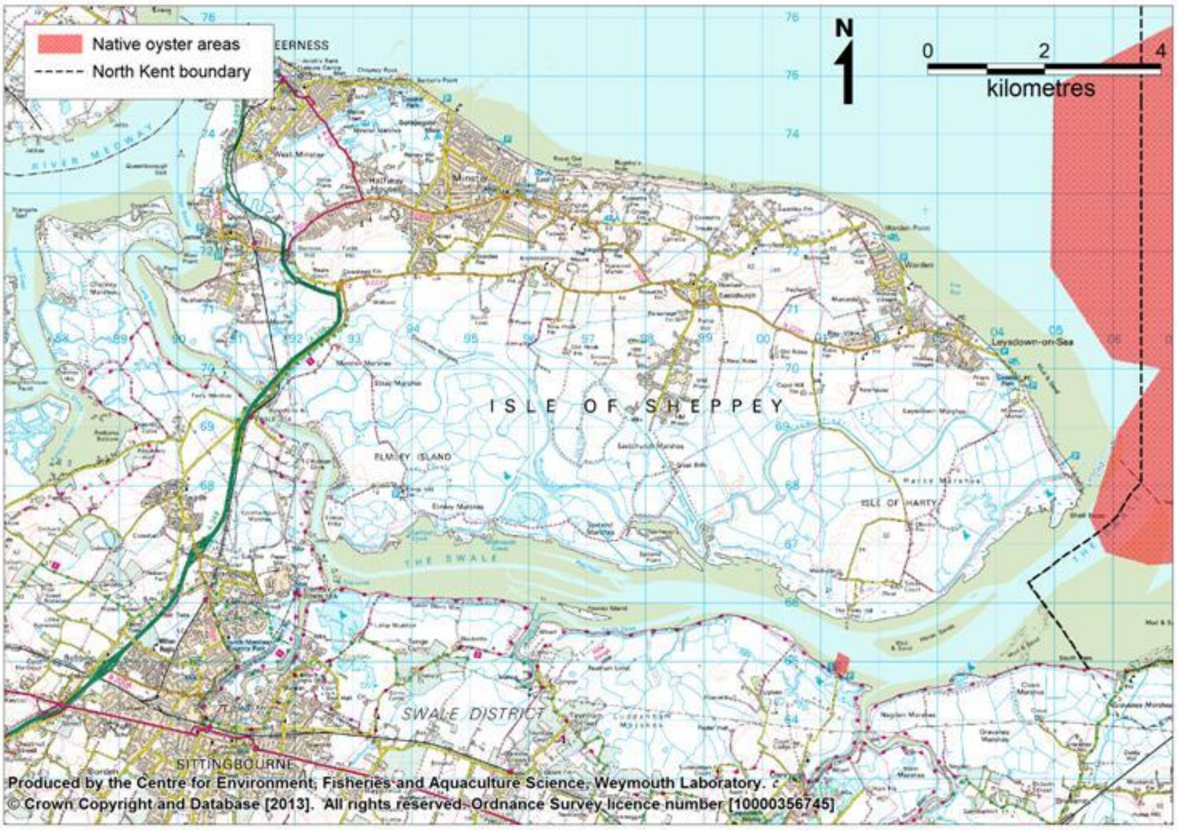


Figure 4.2: Native oyster distribution

The native oyster grounds cover a large area in the subtidal off Whitstable and Herne Bay, and extend just into the eastern boundary of the survey area. This fishery is suitably covered by the existing sampling plan for North Kent. Native oysters are also held for short periods on the Causeway just to the west of Faversham Creek. These are stocks dredged from the main oyster grounds off Whitstable and Herne Bay, parts of which are class A, and parts of which are class B. They are held in the Swale for a few days whilst a sufficiently large batch for sending to market is assembled. They are likely to have a wider distribution across the shallow subtidal, but only the occasional specimen rather than quantities that could be targeted commercially.

Mussels

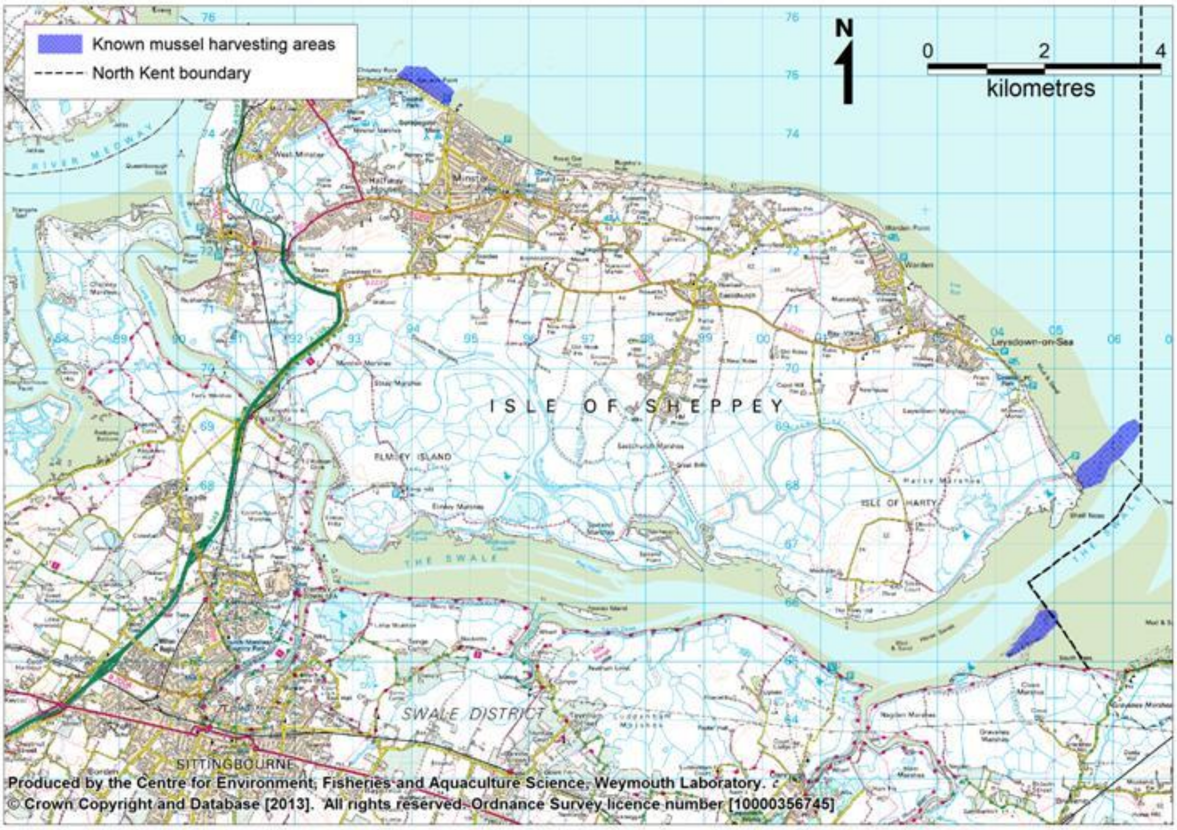


Figure 4.3: Mussel distribution

Mussels are present in various places within the survey area in the lower intertidal and shallow subtidal. Stocks on harder substrates tend to include a wider range of sizes (including those of a harvestable size) and tend to be relatively stable in terms of their location. These stocks are however not generally accessible to dredge fisheries. Mussel beds on softer substrates which are accessible to dredgers are more ephemeral and tend to be almost exclusively seed mussels (Wright & Bailey, 2009) which do not require a hygiene classification. There are regular settlements at Barton Point, Shellness and South Oaze which are subject to relatively small scale commercial harvesting on occasion. It is possible that there are other patches of harvestable mussels in the area and that further beds may develop in the future.

Mussels do not occur in commercial quantities on the Hollowshore Fisheries grounds and their continued classification here is not required (Mr Walpole, pers comm.). It is thought that there are some mussels in the subtidal channels around Horse Sands, within Faverhsam Oyster Company grounds, but it is not known whether they are commercially active and whether they are seed stocks or contain commercial quantities of market size stocks.

Cockles

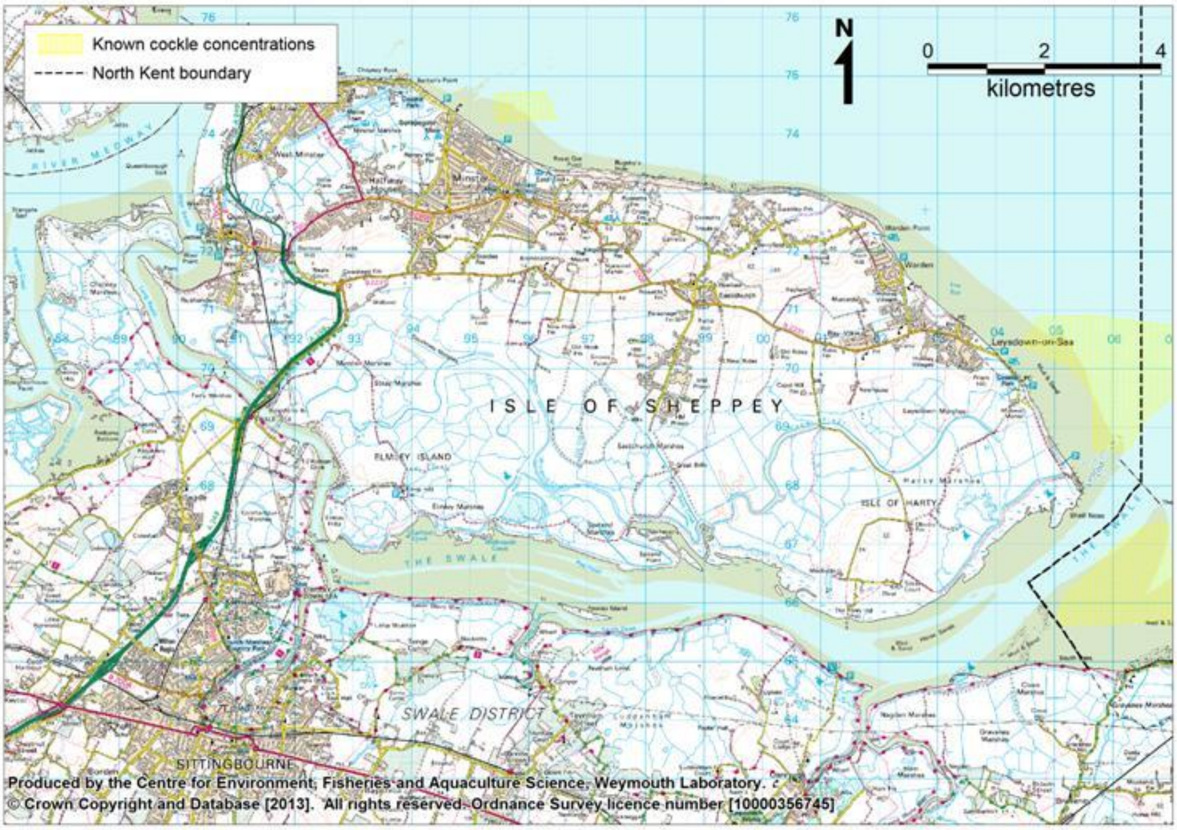


Figure 4.4: Cockle distribution

There is a significant dredge fishery for cockles throughout the outer Thames estuary. The main cockle beds within the survey area lie off Minster, on the Ham Grounds off Leysdown, and on the Pollard Grounds off Whitstable. These areas consistently attract cockle settlements in commercial densities, although they may be present anywhere with a suitable sandy substrate. Cockles also extend into the Swale about as far as the mouth of Faversham/Oare Creek but the locations of the main concentrations within this area are uncertain. From time to time settlements of cockles of an exploitable density are discovered in other locations, including in the deeper water further offshore (Kent & Essex IFCA, pers comm.).

Clams (*Tapes* spp.)

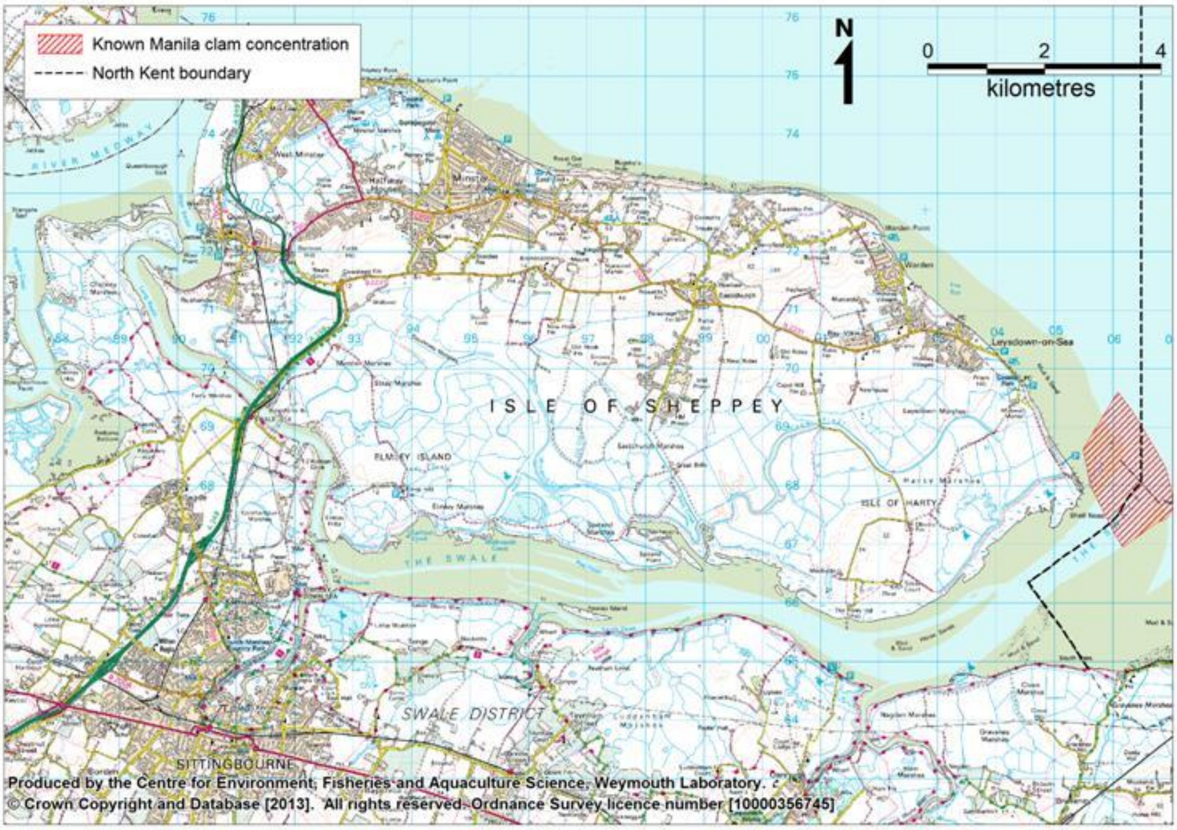


Figure 4.5: Clams (*Tapes* spp.) distribution

The sanitary survey of North Kent identified the presence of naturally occurring Manila clams (*Tapes* spp.) in a discrete patch straddling the border of the two survey areas. A sampling plan was provided for this in the previous survey, so this will require no further coverage in the present survey.

4.2. Growing Methods and Harvesting Techniques

Cockles, mussels and clams (*Tapes* spp.) are wild stocks. Pacific oysters are naturally occurring, and within the Swale they are grown from locally collected naturally occurring stock. Culture is on organised plots on the seabed rather than on trestles. Native oysters on the main offshore grounds are wild stocks. The native oyster site on the Causeway by Faversham Creek is only used as a short term holding area.

4.3. Seasonality of Harvest, Conservation Controls and Development Potential

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. 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 or eradication programmes. The emergence of oyster herpes virus has caused significant losses at some Pacific oyster culture sites in the region in recent years.

There is a closed season for native oysters which runs from May to August inclusive. A minimum landing size of 70mm applies to this species. A maximum width of dredge (or dredges) of 4m applies. Major changes in the distribution and status of these stocks are not anticipated in the immediate future.

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. 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.

The area around the mouth of the Swale (Leysdown and Ham) is regulated via Kent and Essex IFCA Byelaws, whereas the cockle beds along the north coast of Sheppey (West Cant and Scrapsgate) and further offshore from Leysdown and Ham (East Cant, Middle and Red Sand) fall within the Thames Estuary Cockle Fishery Order 1994. Any cockles located around and into the mouth of the Swale fall within private grounds and so are not subject to any management measures.

Kent and Essex 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 13.6m^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 Kent and Essex IFCA, based on stock status and other considerations. 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. It was opened in 2013 for the first time in several years.

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 Kent and Essex IFCA with the aims 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 storms, temperature extremes, diseases, predation and of course exploitation can all affect them. Whilst the stock biomass fluctuates significantly from year to year, the locations of the main cockle beds within the Thames estuary tend to be reasonably stable.

Manila clams (*Tapes* spp.) may be harvested at any time of the year, and the fishery is not subject to any specific conservation controls aside from a minimum landing size of 35 mm.

Any wild shellfish beds outside of the private grounds may be closed at any time by the Kent and Essex IFCA for reasons of fishery management and control of exploitation.

Hygiene Classification

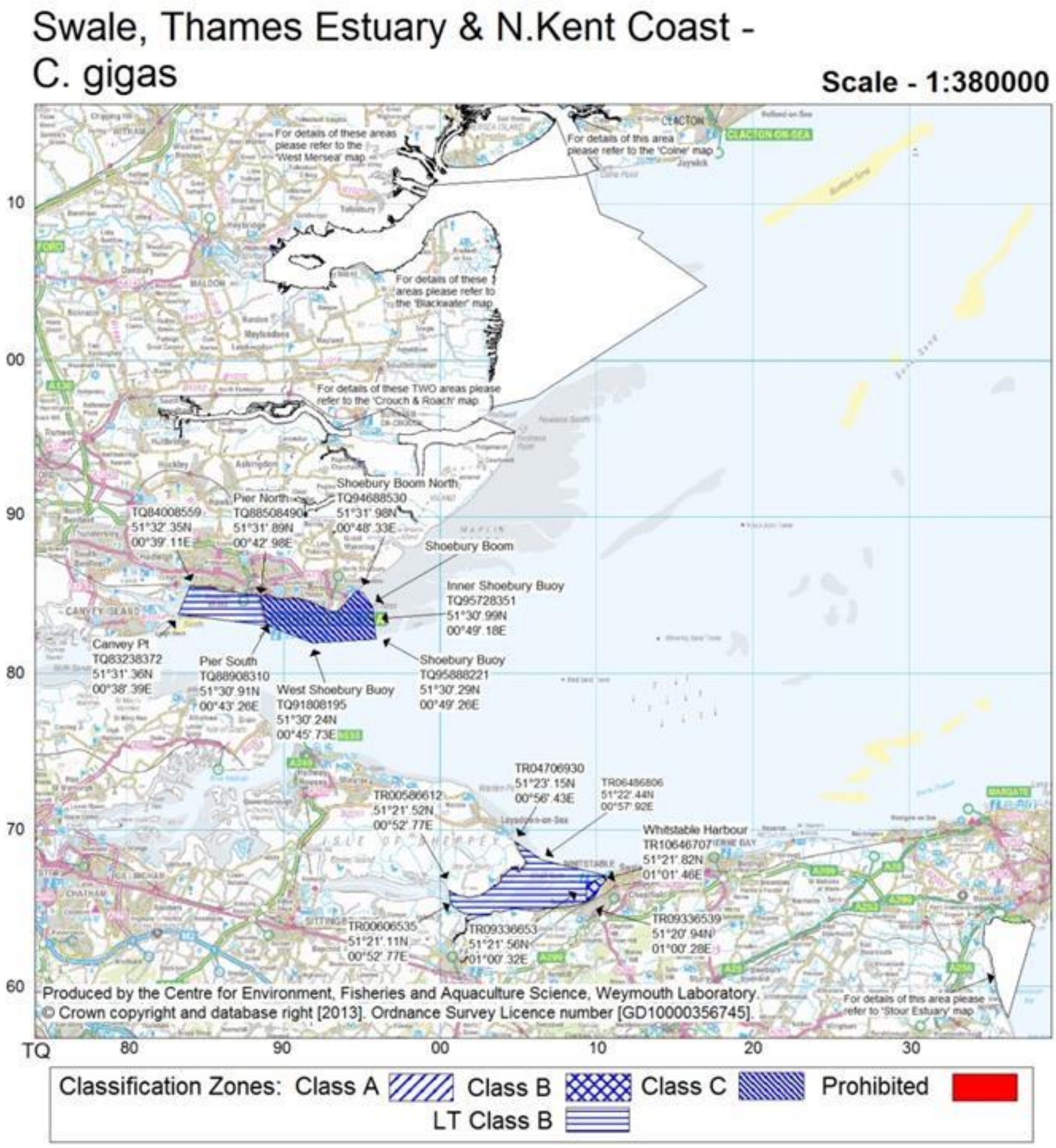
Table 4.1 lists all classifications within the survey area since 2004.

Table 4.1: Classification history for Swale and Thames (Sheppey), 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Scrapsgate	Cockle	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Sheppey	Mussel	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 1	Mussel	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 2	Mussel	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 4	Native oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 4	Pacific oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 6	Mussel	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 6	Cockle	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 7	Mussel	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 7	Cockle	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 8	Mussel	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Swale River Bed 8	Cockle	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT

LT denotes long term classification

All classifications have been B for the last decade. This includes mussels at Swale Bed 1 and 2, where 18.7% of samples have returned results exceeding 4600 *E. coli* MPN/100g over the last decade. This bed has recently been the subject of an application to classify Pacific oysters here, and mussels are not harvested here. Beds 1, 2, 6 and 7 are due to be downgraded to a C, following the implementation of the FSA classification proposals, in April 2014.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2013

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

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

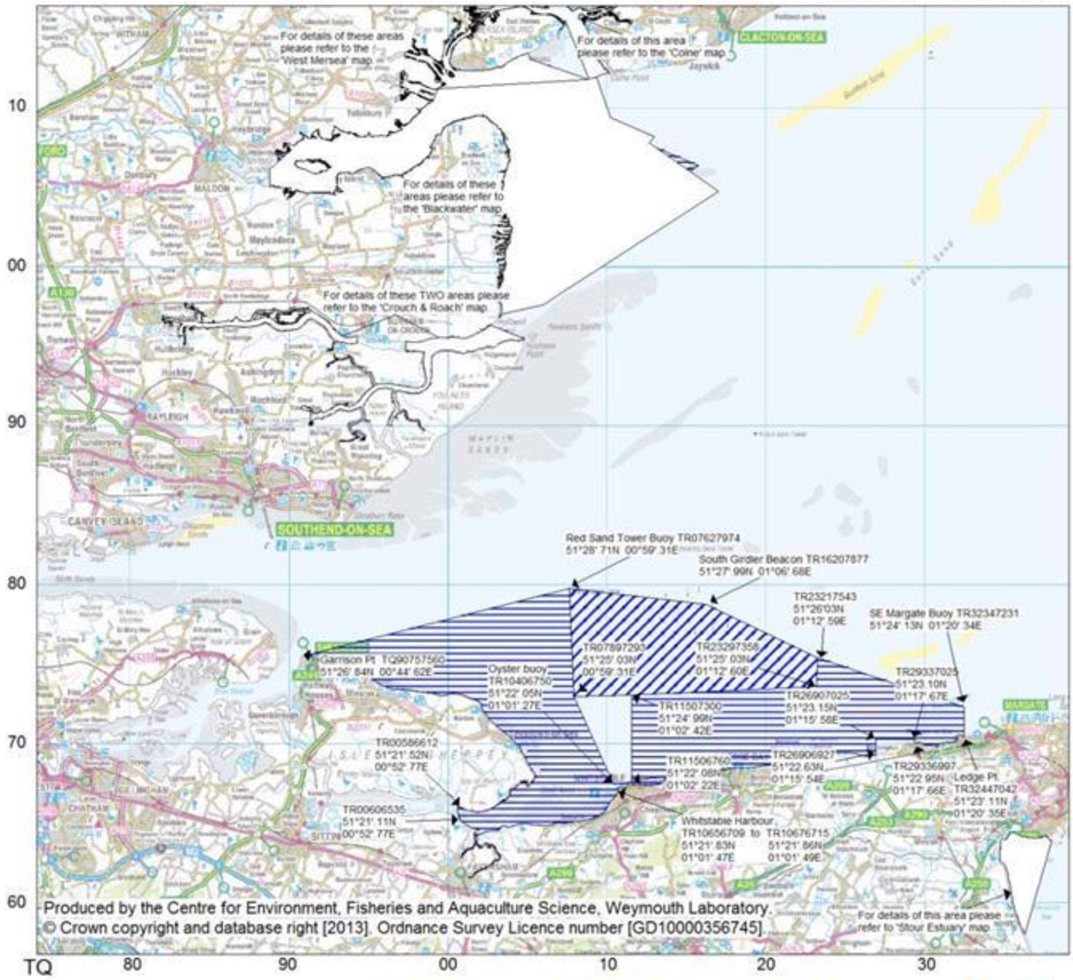
N.B. Lat/Longs quoted are WGS84
Separate maps available for O. edulis, C. edule, Clams (T. philippinarum) and Mytilus spp. for this area

Food Authorities: Swale Borough Council (Swale River and Estuary)
Canterbury City Council (North Kent Coast)
London Port Health Authority (Thames Estuary)

Figure 4.6: Current Pacific oyster classifications

Swale, Thames Estuary & N.Kent Coast - O.edulis

Scale - 1:380000



Classification Zones: Class A ▨ Class B ▩ Class C ▧ Prohibited ■
LT Class B ☰

<u>Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2013</u>

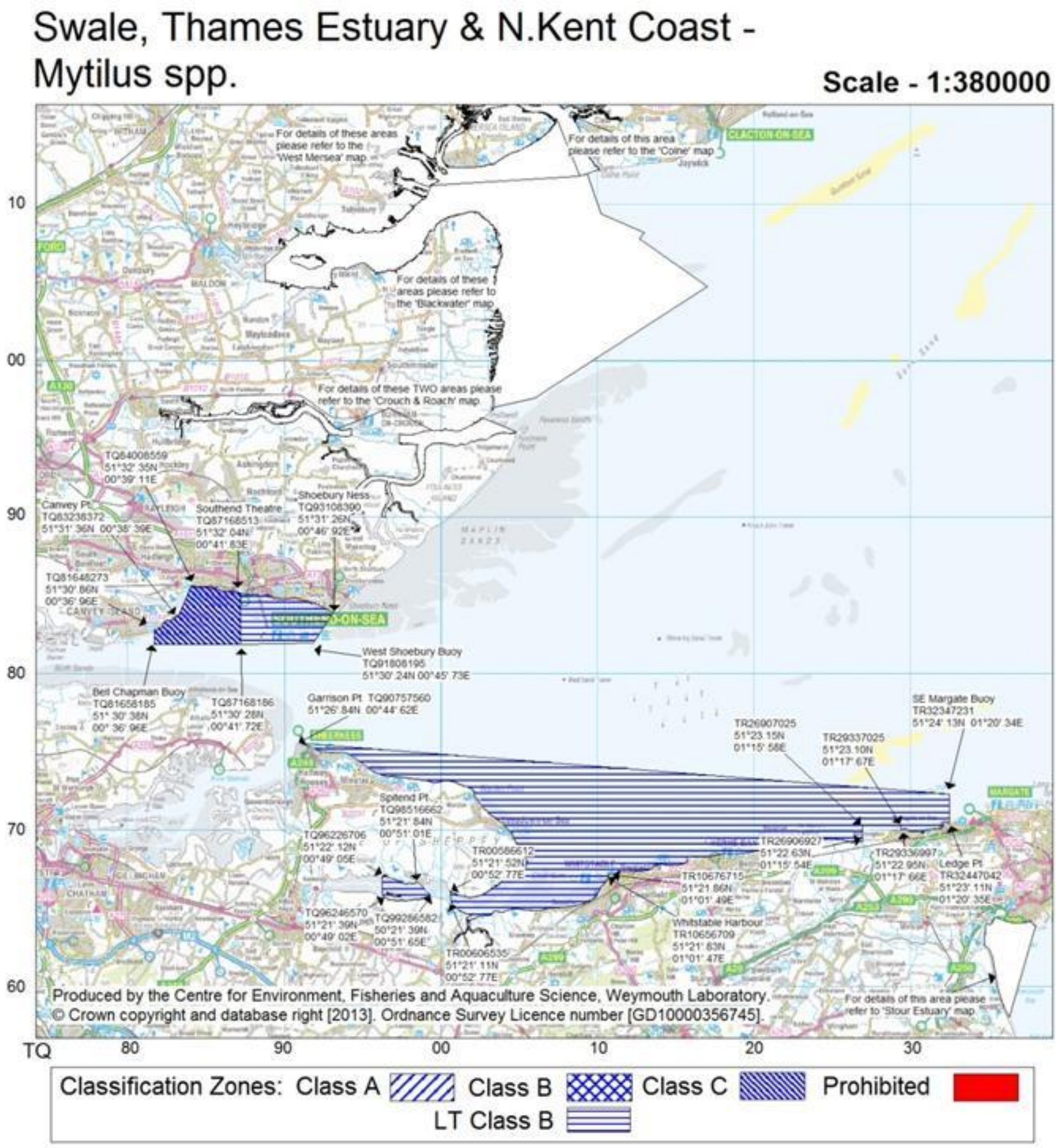
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004

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

N.B. Lat/Longs quoted are WGS84
Separate maps available for C. gigas, C. edule, Clams (T. philippinarum) and Mytilus spp. for this area

Food Authorities: Thanet District Council (Minnis Bay, North of Hook, South of Hook and Margate Sands)
Swale Borough Council (Swale River and Estuary)
Canterbury City Council (North Kent Coast)

Figure 4.7: Current native oyster classifications



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2013

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

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

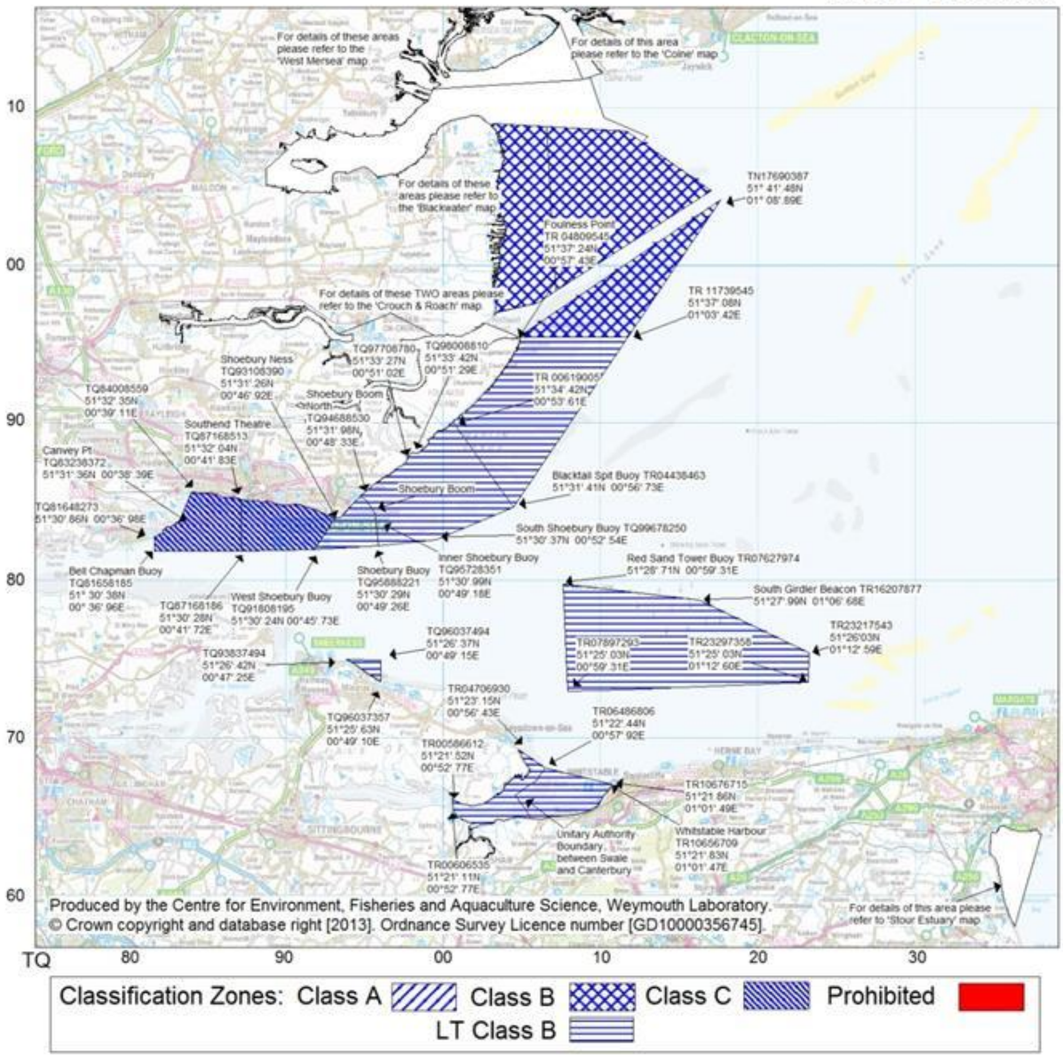
N.B. Lat/Longs quoted are WGS84
Separate maps available for C. gigas, C. edule, Clams (T. philippinarum) and O. edulis for this area

Food Authorities: Thanet District Council (Minnis Bay, North of Hook, South of Hook and Margate Sands)
Swale Borough Council (Swale River and Estuary)
Canterbury City Council (North Kent Coast)
London Port Health Authority (Thames Estuary)

Figure 4.8: Current mussel classifications

Swale, Thames Estuary & N.Kent Coast - C. edule

Scale - 1:380000



<u>Classification of Bivalve Mollusc Production Areas: Effective from 6 November 2013</u>

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

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

N.B. Lat/Longs quoted are WGS84
Separate maps available for C. gigas, Mytilus spp., Clams (T. philippinarum), and O. edulis for this area

Food Authorities: Thanet District Council (Minnis Bay, North of Hook, South of Hook and Margate Sands)
Swale Borough Council (Swale River and Estuary)
Canterbury City Council (North Kent Coast)
London Port Health Authority (Thames Estuary)

Figure 4.9: Current cockle classifications

Swale, Thames Estuary & N.Kent Coast - Tapes spp.

Scale - 1:380000

Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2013

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

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

N.B. Lat/Longs quoted are WGS84
Separate maps available for C. gigas, O. edulis, C. edule and Mytilus spp. for this area

Food Authorities: Canterbury City Council (North Kent Coast)

Figure 4.10: Current clam classifications

Table 4.2: Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* $100g^{-1}$ 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

5.1. Aim

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

5.2. Shellfisheries

The survey area includes private grounds under various ownership within the Swale and around its mouth, and public grounds off the north/east coast of Sheppey. Within these areas there are fisheries for Pacific and native oysters, mussels, cockles and Manila clams (*Tapes* spp.). The adjacent North Kent production area was subject to a sanitary survey in 2011, which provided a sampling plan for some of the shellfish resources that straddled the boundary between the two.

The Pacific oyster fishery is limited to the private grounds within the eastern part of the Swale channel. Here Pacific oysters are cultured on the sea bed from naturally occurring seed stock of local origin. The area requiring classification for this species extends from the mouth of Conyer Creek through to the boundary with the North Kent production area. Harvesting may occur at any time of the year so a year round classification is required.

The main native oyster fishery is in the shallow subtidal extending several km offshore from Whitstable and Herne Bay. It mainly lies within the North Kent production area, and although it does extend slightly into area considered in this survey, a sampling plan was provided to cover the entire fishery in the North Kent sanitary survey. There is a site within the Swale, on the end of a causeway just to the west of Faversham Creek, where native oysters harvested from the main oyster grounds are held for a few days before being sent to market. Although not strictly a harvesting or a relay area according to legal definitions, this site will require classification to maintain control and traceability. It is not considered a high risk situation as the oysters originate from a less contaminated area, which currently holds a mixture of A and B classifications. The native oyster season runs from September to April, so classification is not required outside of these times.

There are a few discrete areas where intertidal mussels are harvested commercially, albeit at relatively low levels. These are located at Barton Point, Shellness, and on the South Oaze. Mussels do not occur in commercial quantities on the Hollowshore Fisheries grounds and their continued classification here is not required. There may be some mussels in the subtidal channels around Horse Sands, within Faverhsam Oyster Company grounds. It is not known whether they are commercially active and whether they are seed stocks or contain commercial quantities of harvestable stocks. It is therefore concluded that the three intertidal mussel beds will require continued classification, and the mussels in the Swale Channel by Horse Sands should be provided with a sampling plan which can be applied at the request of the Faversham Oyster Company. The latter provides some difficulties as there is a great deal of uncertainty regarding the actual extent of the bed. All mussel classification should be year round as there is no closed season for this species.

The main cockle concentrations tend to arise at Scrapsgate, Leysdown, and on the Pollard Ground. Exploitable concentrations may arise in other areas including the deeper water further offshore. There are also some cockles extending into the mouth of the Swale about as far as the mouth of Faversham Creek, although it is uncertain where the main concentrations here are located. The area requiring classification will therefore need to cover all these areas, and extend offshore from the north/east coast of Sheppey towards the edge of the deepwater channel. Whilst the cockle season within the Thames Estuary Cockle Fishery areas and the public grounds controlled by the IFCA is within the June to November window, harvesting from the private grounds around the mouth of the Swale may occur at any time of the year.

A patch of clams (*Tapes* spp.) straddling the border between the current survey area and the North Kent production area was identified in the North Kent sanitary survey. A sampling plan covering the entire bed was provided in the North Kent survey, so it will not be considered here further.

Pacific and native oysters accumulate *E. coli* to similar levels (Younger & Reese, 2011) and so the use of Pacific oyster sample results to classify native oysters, and vice versa, is considered an acceptable option in some situations. This would not only reduce laboratory costs but would allow the more abundant and widespread lower value species (Pacific oysters) to be sampled.

Cockles and mussels accumulate *E. coli* to similar levels, but a tendency for cockles to return more extreme high results has been noted (Younger & Reese, 2011). As such, cockles would be the preferred species to monitor on public health protection grounds. Mussels are used as a surrogate for Pacific oysters in some places, although they do tend to accumulate *E. coli* to slightly higher levels. Where class B compliance is borderline, the species sampled should be the species to be classified to be sure a fair classification results. Pacific oysters should therefore be classified on the basis of Pacific oyster rather than mussel sample results in the Swale channel, particularly on the beds by Fowley Island. Class B compliance is good outside of the Swale channel so cockles may be used to classify mussels, assuming this is appropriate in terms of their locations relative to sources of contamination.

Faversham and Oare Creek are currently classified for the harvest of Pacific and native oysters, mussels and cockles. No shellfish sampling has been undertaken within these creeks, which are likely to be considerably more contaminated than the main Swale channel. These creeks fall within a private fishery, and whilst there are reported to be some Pacific oysters within them, the harvester has indicated that he has no interest in exploiting these stocks due to the poor water quality. These creeks should therefore be declassified for all species with immediate effect.

5.3. Pollution Sources

Freshwater Inputs

All watercourses will carry some contamination from various sources, and so will require consideration in this assessment. The survey area has a relatively small hydrological catchment area of 262km² which is drained by a series of minor watercourses. They predominantly drain low lying rural land, most of which is either arable farmland or pasture, although there are some significant pockets of urbanised land at Sheerness, Sittingbourne and Faversham.

The mainland catchment is underlain with chalk in its upper reaches, so groundwater flows predominate here. The geology changes towards the coast, where these groundwater flows re-emerge via springs and are then carried by surface watercourses. The lengthy transit times through chalk aquifers mean that faecal indicator bacteria from the chalk areas are unlikely to reach coastal waters in a viable state. Sheppey has a similar hydrogeology to the lower mainland catchment and so is drained via surface watercourses.

Most of the land adjacent to the Swale is low lying, and is drained by a series of ditches which discharge via regulated outfalls. Water levels within these are monitored, and during the winter they are kept low to prevent flooding, whilst during the summer months they are kept full to act as a wet barrier/fencing system to livestock and provide water for abstraction. Most of these outfalls were not measured during shoreline survey, but some were sampled and none contained particularly high levels of *E. coli* (maximum 520 cfu/100ml). A few small surface water outfalls discharge to the north/east shore of Sheppey. All of these are minor in terms of volumes discharges, but one culverted stream at Minster was carrying high levels of *E. coli* (23,000 cfu/100ml) at the time of shoreline survey. It must be noted that the central north/east coast of Sheppey and the south coast of Sheppey to the west of the Harty Marshes were not surveyed, although it is apparent from maps of the area that there are several other minor surface water inputs to these areas.

In geographic terms these freshwater inputs may create minor hotspots of contamination where they meet coastal waters. These will be most pronounced in the immediate vicinity of any drainage channels they follow across the intertidal, which may contain relatively high concentrations of faecal indicator bacteria at lower states of the tide. As such, RMPs should be located by these channels to best capture contamination from these watercourses. The extent of these impacts are likely to vary greatly from day to day depending on rainfall. There will also be some seasonality in average flow rates. During the colder months of the year rainfall is slightly higher and there is less evaporation and transpiration so a higher proportion of precipitation will run off. Also, the water levels in the field drains is held back in the summer but not in the winter. Whether this results in seasonal fluctuations in the average bacterial load delivered to coastal water is however uncertain.

Human Population

The total resident population within the Swale and the Isle of Sheppey catchment area was approximately 129,000 at the time of the last census. The main population centres are Sittingbourne (around Milton Creek), Faversham (around the head of Faversham Creek) and Sheerness and Minster, towards the western end of the north coast of Sheppey. These areas are likely to be most at risk from contaminated urban runoff. The geographical profile of sewage impacts will depend on the nature of the sewerage infrastructure serving the area.

The district attracts significant numbers of tourists, principally during the summer holiday period. There is a large concentration of caravan sites on the north shore of the Isle of Sheppey where many visitors use the beaches of Sheerness, Minster Leas and Leysdown. Sewage works serving these areas will therefore receive effluent from an increased population at this time so the bacterial loading they generate may increase.

Sewage Discharges

There are six continuous water company discharges to the area:

- Faversham (Abbey Fields) STW discharges to the head of Faversham Creek and provides secondary treatment for a consented dry weather flow of 7,000 m^3/day.
- Teynham STW discharges to the head of Conyer Creek, and provides secondary treatment for a consented dry weather flow of 848 m^3/day.
- Sittingbourne STW discharges to the head of Milton Creek and provides secondary treatment for a consented dry weather flow of 11,800 m^3/day.
- Eastchurch STW discharges to a watercourse draining to the head of Windmill Creek, and provides secondary treatment for a consented dry weather flow of 4,500 m^3/day.

- Queenborough STW discharges to the western end of the Swale channel, and provides secondary treatment for a dry weather flow of 11,225 m^3/day.
- Grain STW discharges to the western side of the Medway approach channel, and provides secondary treatment for a consented dry weather flow of 402m^3/day.

Faversham, Milton, Windmill and Conyer Creek will all therefore be impacted by sewage discharges which feed into their upper reaches. As such, higher levels of faecal indicator bacteria are likely to arise within these creeks, extending into the Swale channel via their ebb plumes. Effluent from Queenborough and Grain STWs will be carried out past the north coast of Sheppey via the Medway approach channel by the ebb tide and will not impact on the shellfisheries in the eastern reaches of The Swale.

Associated with the water company sewerage network are 44 permitted intermittent overflow discharges which may be of impact on the shellfisheries. The main clusters are located around the towns of Sittingbourne and Faversham, and there are also a number along the north shore of Sheppey. Around half of these do not have spill monitoring equipment so it is difficult to assess their impacts aside from noting their locations and potential to spill untreated sewage either at times of heavy rainfall or in the event of a problem such as a power cut or a blockage.

Spill event durations from the monitored outfalls were analysed for the period April 2011 to March 2013. The most active was Grain WWTW storm overflow discharge, which spilled for just over 5% of the period. This discharges to the eastern tip of the Isle of Grain so may be of occasional significance to the north coast of Sheppey. The overflows from Queenborough and Sittingbourne STWs spilled for about 4% of the period considered, to the same outfall location to which their treated effluents are discharged. The Wards Hill PS on the north coast of Sheppey at Minster was active for almost 3% of the time. All other monitored outfall spilled for less than 2% of the time, and so whilst they may be of occasional influence their impacts are very unlikely to be captured during monthly shellfish monitoring.

Intermittent discharges create issues in management of shellfish hygiene however infrequently they spill. Their impacts' are not usually captured during a year's worth of monthly monitoring from which the classification is derived as they only operate occasionally. Thus when they do have a significant spill, heavily contaminated shellfish may be harvested under a better classification than the levels of *E. coli* within them may merit.

Although the vast majority of properties within the survey area are served by water company sewerage infrastructure, there are a few private discharges which may have some impact on the shellfisheries. These are generally small treatment works such as package plants, serving one or two properties. Most discharge to watercourses both on the mainland and on Sheppey, so will make a minor contribution to the concentrations of faecal indicator bacteria carried by these. The largest private discharges are from two caravan parks, consented for a maximum flow of 120 and 19m^3/day, which discharge to short watercourses draining to the central part of the north coast of Sheppey. These may have some impacts on shellfisheries in this area.

Agriculture

Most of the land within the hydrological catchment is used for agriculture. On the mainland, most coastal areas are pasture, and further inland there is a mix of arable farming and fruit plantations. The central areas of Sheppey are arable farmland, with a band of pasture around most of the coast. The catchment supports potentially significant numbers of sheep (21,311 at the time of the 2010 census) as well as some cattle, pigs and poultry (3481, 556 and 7,179 respectively). During the shoreline survey approximately 1000 sheep were observed on the Luddenham Marshes, just east of Conyer Creek. Around 110 cattle were observed on the Harty Marshes, and although they were fenced into fields behind the sea bank, there was evidence on the ground to suggest they are allowed to graze on the saltmarsh on the seaward side of the sea bank. Another 50 cattle were recorded just east of Faversham Creek. There are significant areas of pastures on the south shore of Sheppey to the west of the Harty marshes, but this area was not visited during the shoreline survey.

Faecal matter from grazing livestock is either deposited directly on pastures, or collected from livestock sheds if animals are housed indoors during the colder months and then applied to agricultural lands as a fertilizer. Manure from pigs and poultry is typically stored and applied tactically to nearby farmland. Treated sewage sludge may also be applied to some crops. These will then be washed into watercourses with field runoff, so fluxes of agricultural contamination into coastal waters are highly rainfall dependent and vary significantly from day to day. Where flows are via aquifers, as is the case in the inner reaches of the mainland catchment, transit times are lengthy so faecal indicator bacteria from fields here are unlikely to survive passage. Contamination deposited on saltmarsh areas by grazing livestock will be washed directly into coastal waters via tidal inundation, and such fluxes will be greatest on the larger spring tides.

Most, if not all watercourses will carry contamination of agricultural origin at times. Those draining the grazing marshes are likely to be impacted to the greatest extent. The saltmarsh at the south eastern tip of Sheppey and possibly other areas may be grazed at times so creeks draining these places may convey significant bacterial loadings into coastal waters on the larger tides. There is likely to be some seasonality in the amount of agricultural contamination washed into the survey area. Water tends to be held back in the field drains during the summer, but not in the winter. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Slurry generated from the indoor housing of cattle in the winter is likely to be spread in the late winter and spring, depending on the storage capacities of each farm. The seasonal pattern of application of pig and poultry manures and sewage sludge to agricultural land is uncertain. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush').

Boats

There is significant boat traffic within the area including merchant shipping, pleasure craft and fishing vessels. Boats may make sewage discharges and are therefore a potential source of contamination to the shellfisheries. There are large volumes of shipping traffic to and from the various ports in The Medway, and to a lesser extent to the Ridham Sea Terminal in the western Swale. Merchant shipping is not permitted to make overboard discharges within 3 nautical miles of land and so should be of no impacts apart from possibly in the offshore areas to the north east of Sheppey.

There is significant pleasure craft activity within the survey area. Both the Swale Channel and the north coast of Sheppey are used heavily by craft such as yachts and cabin cruisers. There are three yacht marinas within the Swale based in the Faversham and Conyer Creeks, which collectively hold around 390 berths. Queenborough Harbour in the western Swale has around 60 berths. In addition to these facilities there are numerous moorings in Faversham Creek and Conyer Creek, and within the western end of the main Swale channel. Sewage pump out facilities are only available at the marina in Faversham Creek. The Kent fishing fleet numbers about 55 full time vessels, most of which are under 10m in length. Some of these operate out of Queenborough on the Medway, and others are based in Whitstable. About 20 houseboats were recorded in the upper reaches of the eastern arm of Faversham Creek during the shoreline survey.

It is likely that the larger of the private vessels (yachts, cabin cruisers, fishing vessels) which have onboard toilets make overboard discharges from time to time. Boats in marinas may be less inclined to make overboard discharges as it is antisocial and onshore facilities are easily accessed. Those in occupation on moorings, or those in transit through the estuary may be most likely to discharge. Moorings are present in Faversham and Conyer Creeks, and in various locations in the western Swale, so these areas together with the aforementioned navigation routes may be most at risk. Pleasure craft activity is much higher during the summer, so associated impacts are likely to follow this seasonal pattern.

It is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges. Overboard discharges made by vessels on passage may occur almost anywhere and at any time so will not influence the sampling plan. Those made by moored boats may be best captured by locating RMPs within the various mooring areas if appropriate.

Dredging is undertaken from time to time to maintain the shipping channels, and this may re-suspend contamination from within sediments. The temporal and geographic patterns of this activity are uncertain, so it will have no bearing on the sampling plan. It may however have detrimental effects on shellfish hygiene, and should be considered when investigating the causes of elevated *E. coli* monitoring results.

Wildlife

The Swale and Sheppey encompasses a variety of habitats including intertidal mud and sand flats, small areas of saltmarsh, seagrass beds, grazing marsh and saline lagoons which support various wildlife populations. The most significant wildlife aggregation in terms of shellfish hygiene is likely to be overwintering waterbirds (waders and wildfowl). An average total count of 77,162 waterbirds was reported over five winters up to 2010/11 for the Swale. Some species of waders feed on intertidal invertebrates so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and whilst they may be a significant contaminating influence at times, they will not influence the positioning of any RMPs. Other overwintering waterbirds such as ducks and geese will mainly frequent the saltmarsh and coastal grasslands, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. RMPs positioned in or by creeks and channels draining from such areas would be best positioned to capture contamination from these.

Although the majority of waterbirds migrate elsewhere to breed, other species such as gulls and terns are present during the summer months. Significant numbers of these use the south coast of Sheppey to breed, with almost 4,000 pairs recorded during a survey in 2000. Most of these were nesting on a small island just east of Spitend Point (Flanders Mare). Although not in the survey area, large numbers (7,644 pairs) of seabirds were also recorded on the marshy islands within The Medway. These seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal or through tidal inundation. RMPs are best located within or near to the drainage channels that originate from nesting sites to capture contamination. As such, the Spitend Point area is most at risk from contamination from seabirds.

The Thames estuary supports a significant seal colony, which has been recently estimated at just over 700 individuals. Significant haulout sites within the survey area include Horse Sand, a sandbank in the eastern Swale channel by Faversham Creek. This lies in close proximity to, but does not coincide exactly with, the location of some shellfish resources. Contamination will be deposited on the sand here by resting seals. They tend to spend more time hauled out during the summer pupping and moulting season, but are resident all year round. Given the large area they are likely to forage over impacts are likely to be minor, and unpredictable in spatial terms outside of haul out sites. No other wildlife species which may be of significance to shellfish hygiene in the survey area have been identified.

Domestic animals

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

Summary of Pollution Sources

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in

Table 5.1 and Figure 5.1.

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

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

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

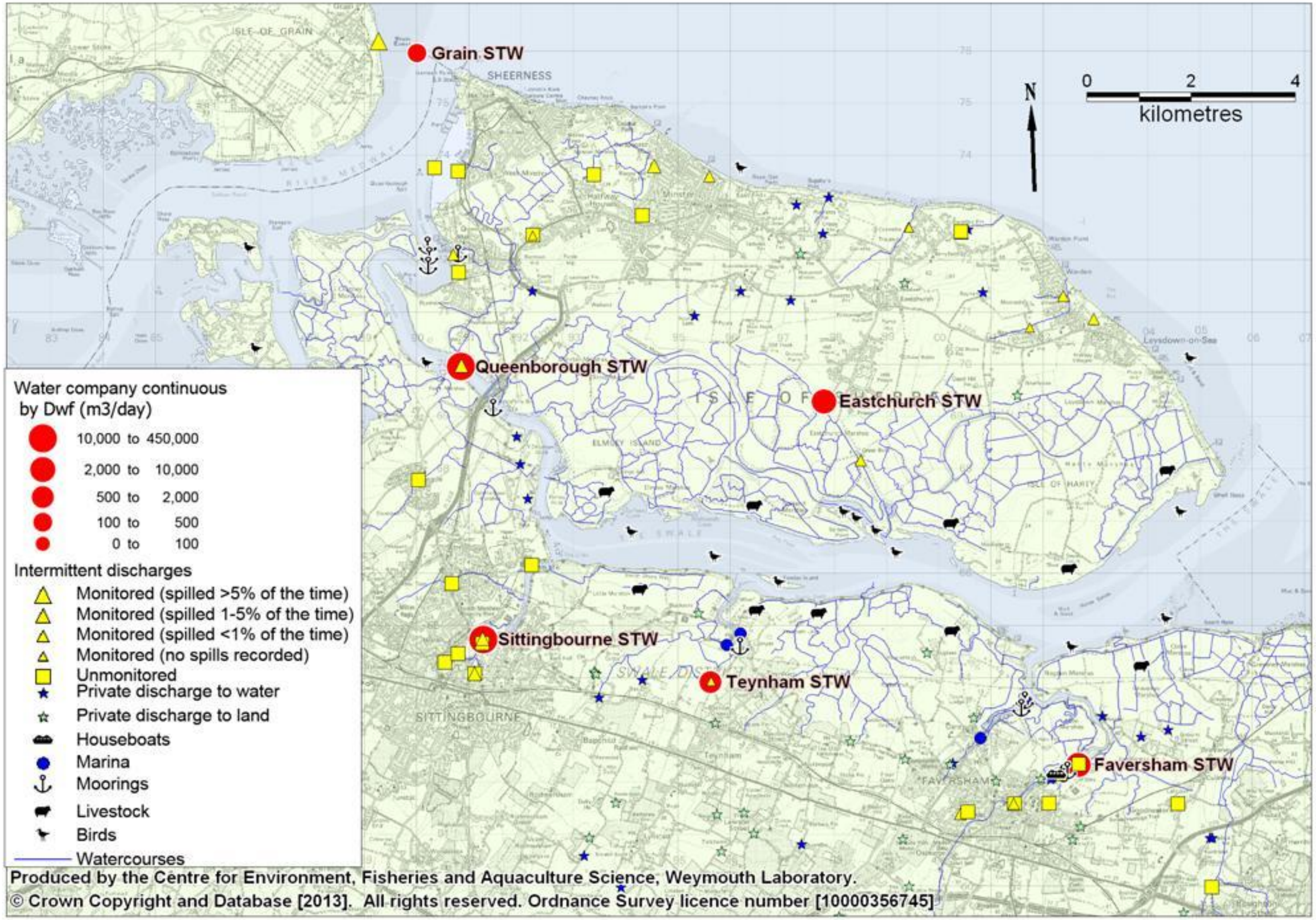


Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The areas considered in this survey are the Swale, a tidal channel separating the Isle of Sheppey from the mainland, and the intertidal and shallow subtidal areas extending off the north/east coast of Sheppey, where the Thames estuary opens out into the North Sea.

The Swale channel varies from 200m to about 1km in width and is wider and less meandering with a larger intertidal area in its eastern reaches. It has a central subtidal channel which varies from less than 1m to about 10m in depth relative to chart datum. Three additional parallel subtidal channels have formed in its eastern reaches starting at Conyer Creek, which merge with the central subtidal channel by Spitend Point. There are also several intertidal drainage channels cutting across the intertidal at various locations, some of which carry land runoff from freshwater outfalls. These may contain relatively high concentrations of faecal indicator bacteria at lower states of the tide. Four creeks emanate from the eastern reaches of the Swale channel; Milton, Conyer and Faversham Creeks, on the mainland side, and Windmill Creek on the Sheppey side. Given the enclosed and shallow nature of the system the dilution potential will be relatively low, although a large proportion of the water will be exchanged each tide. All four creeks receive input from sewage works and minor watercourses so levels of contamination within them are anticipated to be higher than within the main Swale channel.

The north/east shore of Sheppey is an open coast environment lying between the eastern mouth of the Swale, and the mouth of the Medway. It has an extensive, gently sloping intertidal area extending 3.9km from the high water mark at the mouth of the Swale and 0.3km at the mouth of the Medway. The subtidal areas continue to slope gently until they meet the Medway approach channel, which is a dredged channel maintained at a minimum depth of 12.5m extending in an ENE direction from the mouth of the Medway. The shallow subtidal flats between Sheppey and the Medway approach channel become more extensive further to the east.

The tidal range in the area is relatively large (5.3m on spring tides at Grovehurst Jetty by the mouth of Milton Creek) and this drives extensive water movements through the area. Tidal streams move up the outer Thames estuary on the flood, and move back down on the ebb. They therefore run parallel to the coast along most of the north shore of Sheppey, although they are weaker and more perpendicular to the shore in the vicinity of Leysdown. The main tidal stream in and out of the Medway is via the deeper approach channel, so the main ebb plume from the Medway passes out through this channel, but will impact to some extent towards the offshore edge of the adjacent shallow subtidal flats where some shellfish resources lie. The flood tides enter the Swale Channel from both ends, and meet in the vicinity of Milton Creek. They then reverse, and ebb out in the opposite direction. Contamination discharged to the western Swale, such as that from Queenborough STW, will not impact on the shellfish resources in the eastern Swale, but will be carried out into the outer reaches of The Medway, then out via the Medway approach channel. There is some uncertainty about the path followed by the ebb plume from Milton Creek as it lies roughly where the tides meet. The exact location where the tides meet is likely to vary with tide size and meteorological conditions. It is therefore assumed that it will have some influence on shellfisheries in the eastern Swale, but perhaps not every tide. The ebb plumes from the creeks to the east of Milton Creek will only impact to the east of the creek mouths, and will tend to remain on the side of the Swale channel to which they discharge. The ebb plume from Conyer Creek will pass to the south of Fowley Island along the South Deep, thus avoiding the shellfish beds which lie to the north of this island.

Tidal diamonds and modelling studies indicate that the strongest tidal streams align with the main channels, where they can exceed 1 m/s on spring tides. They become weaker across shallower and intertidal areas (<0.5m/s). Approximate estimates of tidal excursion (the distance a particle will travel during the course of a flood or ebb tide), which give some idea of the distance over which sources of contamination may potentially impact are:

- 15km on spring tides and 10km on neap tides within the Medway approach channel.
- 10km on spring tides and 6km on neap tides in the eastern Swale channel, although this may be a slight overestimate.
- 8km on spring tides and 5km on neap tides along the shallow subtidal flats off the north coast of Sheppey.

Whilst tides are the main driver for water circulation, tidal streams in coastal waters can be modified by the effects of freshwater inputs and wind. There is little in the way of freshwater inputs to the survey area, particularly along the open north/east coast of Sheppey, so no significant density driven circulation is anticipated here. Within the Swale channel, the ratio of freshwater input:tidal exchange is very low, indicating little scope for density driven circulation. Measurements indicate that salinity is approaching that of full strength seawater throughout the survey area confirming that density driven circulation is unlikely to be of significance. Salinities were marginally lower on average at the two measurement locations within the enclosed Swale channel, compared to those at more open sites suggesting that land runoff may be of slightly greater influence here. This geographical pattern in average salinity is likely to reflect that of runoff borne contamination.

Strong winds will modify circulation by driving surface currents, which in turn create return currents either at depth or along sheltered margins. The north east coast of Sheppey is most exposed, although is sheltered to some extent from the prevailing south westerly winds, whilst the Swale channel is afforded some shelter from most directions by the surrounding land. Northerly winds would tend to push the ebb plume from the Medway towards the north coast of Sheppey, whilst easterly winds would tend to hold back the ebb tide at the surface within the eastern Swale Channel. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be re-suspended. Given the enclosed nature of the Swale strong wave action is not anticipated, however the north/east coast of the Isle of Sheppey will be quite exposed to wave action from the North Sea when winds blow from the north east quadrant.

5.5. Summary of Existing Microbiological Data

The survey has been subject to considerable microbiological monitoring over recent years, deriving from Bathing Waters and Shellfish Waters monitoring programmes as well as shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Results from 2003 onwards are considered in this assessment.

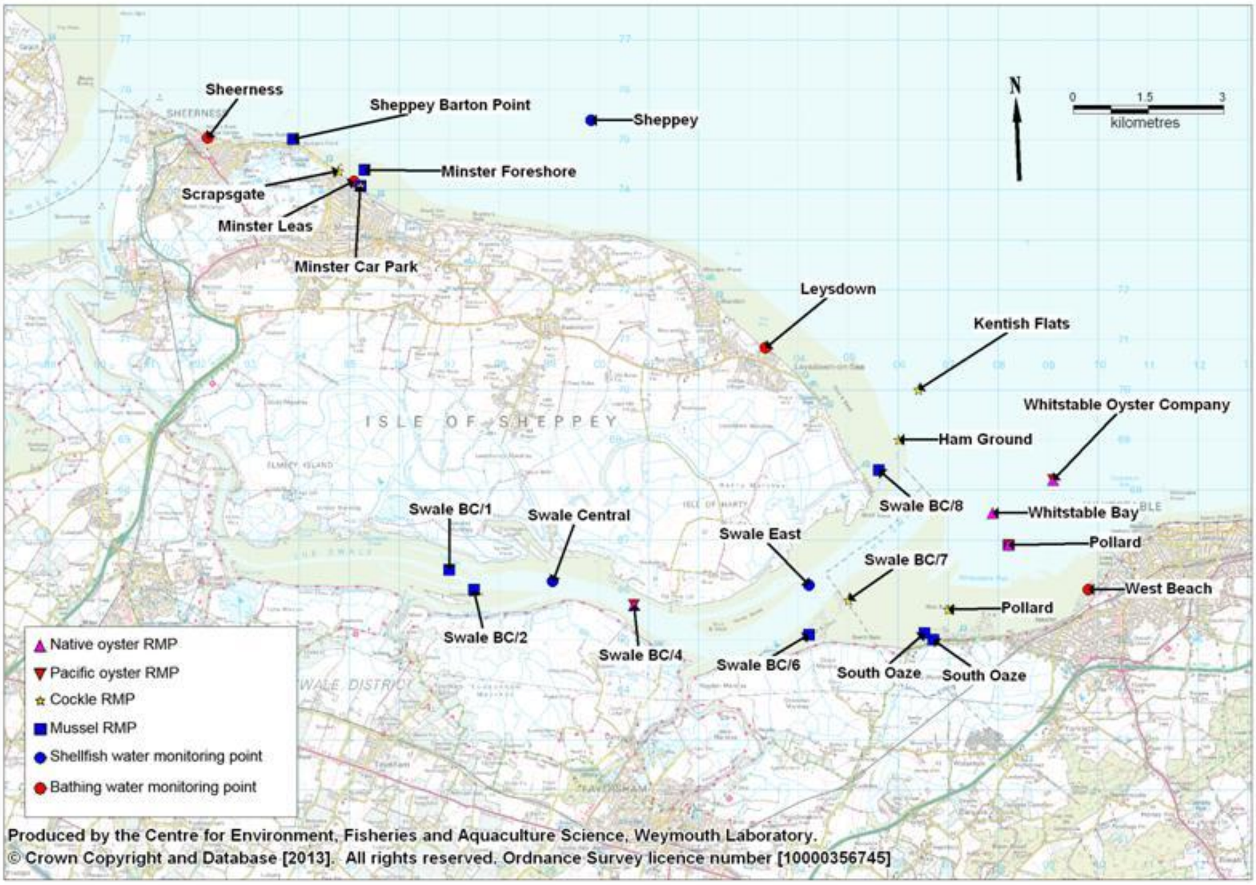


Figure 5.2: Microbiological sampling sites

Bathing waters

There are four bathing waters relevant to the survey area, located at Sheerness, Minster Lees, Leysdown and West Beach (Whitstable), where around 20 water samples were taken each bathing season (May-September) and enumerated for faecal coliforms. While there appears to be a slight trend of increasing faecal coliform levels from west to east, no statistically significant difference was detected in average results between them. Comparisons of paired (same day) samples revealed correlations between each site pairing, suggesting that they are under subject to contamination from similar sources.

Faecal coliform levels have remained relatively stable at all bathing waters sites since 2003. Significant correlations between tidal state on the high/low tidal cycle were detected at all four points. Plots of the data suggested that the higher results tended to occur around high water, although the reasons for this are unclear. Significant variation in results across the spring/neap tidal cycle was also found for all for locations, with a slight tendency for lower results during neap tides. Faecal coliform levels at all four bathing water sites are influenced by rainfall to some extent. The influence was weaker at Minster Lease, but whether this was a consequence of its location or the lower number of samples taken is uncertain.

Shellfish waters

Under the shellfish waters monitoring programme three sites (Sheppey, Swale Central and Swale East) were sampled for faecal coliforms in water on a quarterly basis. Significant differences in average results were found between them. Swale Central and Swale East had higher faecal coliform levels than Sheppey, and Swale Central had higher faecal coliform levels than Swale East. This indicates lower levels of contamination at the open coast site, and increasing levels of contamination towards the central part of the Swale channel. The latter suggests a gradient of increasing contamination to the west of the shellfisheries in the Swale, and RMPs should be located accordingly. Comparisons of paired (same day) samples revealed correlations between the two locations in the Swale, but not between the sites in the Swale and the Sheppey site. This suggests that the Swale Channel and the north coast of Sheppey may be subject to different sources of contamination and so these areas would require monitoring separately.

Levels of faecal coliforms have increased on average at all three sites since 2005. All monitoring points showed a tendency for highest results during the winter months. Seasonal variation in average faecal coliform results was statistically significant in all cases. At Sheppey, faecal coliform levels were significantly higher in winter than in autumn. At Swale Central, faecal coliform levels were significantly higher in autumn and winter than spring and higher in winter than in summer. At Swale East, faecal coliform levels were significantly higher in winter and autumn than in summer and higher in winter than in spring. A significant influence of tidal state across the high/low tidal cycle was found at all three monitoring points. At Swale Central and Swale East, the lowest results tended to occur at higher states of the tide when dilution potential was greatest. At Sheppey, most results were very low during the ebb tide, with some slightly higher results arising during the flood tide. This suggests that sources to the east are of some significance, and also suggests that the ebb plume from the Medway has little impact at this location. Significant correlations between faecal coliform concentrations and the state of the tide across the spring/neap cycle were found for the two sites in the Swale, but not at Sheppey. At Swale East results tentatively appear slightly higher on average around neap tides. At Swale Central, the correlation was weak and no pattern was apparent when the data was plotted. Little, if any influence of rainfall was detected for Sheppey. Both sites in the Swale showed a significant influence of rainfall, and this was slightly stronger at Swale Central. Significant correlations were found between faecal coliform levels and salinity at all three locations.

Shellfish hygiene

For the purposes of this assessment, all RMPs within the survey area, and other selected RMPs from the western end of the adjacent North Kent production area were considered. This included a total of 7 cockle RMPs, 10 mussel RMPs, four native oyster RMPs and three Pacific oyster RMPs.

Of the seven cockle RMPs, four were sampled on less than 10 occasions (Minster Car Park, Kentish Flats, Ham Ground and Pollard 2) so could not be subject to statistical analyses. Across the other three cockle RMPs statistically significant differences in average results were found, with significantly lower levels of *E. coli* at Scrapsgate compared to Swale BC/7 and Pollard. No results exceeded 4600 *E. coli* MPN/100g at Scrapsgate, whereas at the two main RMPs around the mouth of The Swale (Swale BC/7 and Pollard) the proportions of results exceeding this classification threshold were 7.5% and 7.6% respectively. This indicates there are higher levels of contamination in and around the mouth of The Swale compared to the open coast off Sheppey. There were not enough matching sampling days between any of the cockle RMP pairings for any correlation of results on a sample by sample basis to be investigated.

Of the 10 mussel RMPs, four were sampled on less than 10 occasions (Minster Foreshore, Minster Car Park, Pollard and South Oaze 2) so could not be subject to statistical analyses. Across the remaining six mussels RMPs, statistically significant differences in average results were found. Sheppey Barton Point had significantly lower levels of *E. coli* than all other sites. Swale BC/1 had significantly higher levels of *E. coli* than all sites except Swale BC/2. Two of the main mussel RMPs did not return any results exceeding 4600 *E. coli* MPN/100g (Swale BC/2 and South Oaze). The proportions of results exceeding this classification threshold at the other four main RMPs (Swale BC/1, Swale BC/8, Swale BC/6 and Sheppey Barton Point) were 18.7%, 4.8%, 4.7% and 0.8% respectively. Comparisons of paired (same day) sample results could only be run between Swale BC/1, Swale BC/2, Swale BC/6 and Swale BC/8. Swale BC/1 correlated significantly with Swale BC/2 and Swale BC/6. However Swale BC/6 did not correlate significantly with Swale BC/2. Additionally there were significant correlations between Swale BC/8 and Swale BC/6 which are both at the eastern end of the Swale. Overall these results suggest that levels of contamination are lowest on average along the open coast of Sheppey, increase around the mouth of the Swale, and continue to increase further within the channel.

Of the four native oyster RMPs, two had been sampled on less than 10 occasions (Pollard and Whitstable Bay) so were not included in detailed analyses. Across the remaining tow native oyster RMPs, results were significantly higher on average at Swale BC/4 compared to Whitstable Oyster Company. The proportion of results exceeding 2600 *E. coli* MPN/100g at these two RMPs was 4.5% and 0% respectively. Again this indicates increasing levels of contamination towards and into the Swale Channel. There were not enough matching sampling days for these two RMPs for any correlation of results on a sample by sample basis to be investigated.

Of the three native oyster RMPs, one was only sampled on one occasion (Swale BC/4) so was not considered further. Of the remaining two native oyster RMPs, results were significantly higher at Pollard than at Whitstable Oyster Company, once more reinforcing the geographic pattern observed in other species. There was however little difference in the percentage of results exceeding 4600 *E. coli* MPN/100g (2.0% and 1.4% respectively).

Results fluctuated to varying extents at all RMPs from sample to sample, and some overall fluctuations in average results were observed at the various RMPs during the period 2003 to present, but no consistent overall temporal pattern was observed across them. Significant seasonal variation was observed at all three of the main cockle RMPs. The general tendency was for highest results on average during the winter. Statistical tests identified that at Scrapsgate and Pollard, there were significantly higher levels of *E. coli* found in winter than during any other season, and at Swale BC/7 *E.coli* levels were significantly lower in summer than any other season. Broadly similar patterns were observed across the main mussel RMPs, with highest average results arising in winter in all cases. At Sheppey Barton Point, *E. coli* levels were significantly higher in winter than during summer and autumn. At Swale BC/1 *E. coli* levels were significantly higher in spring and winter than during summer and autumn. At Swales BC/6, *E. coli* levels were higher in the winter, than in spring and summer; and spring and autumn levels were higher than the summer. At Swale BC/8 *E. coli* levels were higher in winter than summer. The seasonal pattern in the two main native oyster RMPs was one of highest average results in the autumn, but the variation was not statistically significant in either case. The two main Pacific oyster RMPs showed highest average *E. coli* levels during the winter. This was not statistically significant at Pollard, but at Whitstable Oyster Company *E. coli* levels were significantly higher in winter and spring than in summer.

Statistically significant correlations between *E. coli* levels and tidal state on both the high/low and spring/neap tidal cycles were detected at some RMPs. For many of these instances sampling was targeted towards a certain tidal state (e.g. low water) and no obvious pattern in results could be seen when they were plotted against the tidal cycle. At the Pollard cockle RMP, there was a significant correlation with the high/low cycle and a plot of the data indicated that higher *E. coli* results tended to occur around low tide. This suggests that sources within the Swale may be an influence. At the Whitstable Oyster Company Pacific oyster RMP, there was a significant correlation with the high/low cycle and a plot suggested that lower *E. coli* results tended to occur during the ebb tide. This suggests sources to the east (rather than within the Swale) are an influence here, contrary to the pattern observed at Pollard. A significant correlation with the spring/neap tidal cycle was found for Pollard cockles, where a tendency for higher results during neap tides and tides of increasing size was apparent. A significant correlation was found for the spring/neap tidal cycle at Swale BC/6, and the plot tentatively suggested a tendency for lower results during neap tides implying more distant sources may be an influence here.

The influence of rainfall on *E. coli* levels on shellfish was very limited. Most of the positive correlations were detected within the Swale Channel and around its mouth, with some influence also detected in mussels at Barton Point. At Whitstable Oyster Company, increased rainfall was weakly associated with decreased levels of *E. coli* in both oyster species. The reasons for this are unclear given that there are limited freshwater inputs and so large and abrupt changes in salinity which may cause the oysters to cease feeding are not anticipated here.

Bacteriological survey

Due to the comprehensive monitoring history and the short contractual deadlines it considered neither necessary nor possible to undertake a bacteriological survey to the specification indicated in the contract. As well as the standard practice of sampling and measuring freshwater inputs, a total of 18 additional seawater samples were taken to assist in understanding the spatial profile of contamination across the survey area. These indicated generally low levels of *E. coli* along the north/east shore of Sheppey, with a localised hotspot towards the western end of Minster. They also indicate that levels of contamination increase to high levels within the confines of Faversham and Oare Creek.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within or partially within the Swale and Sheppey catchment area, derived from data collected from the 2011 census.

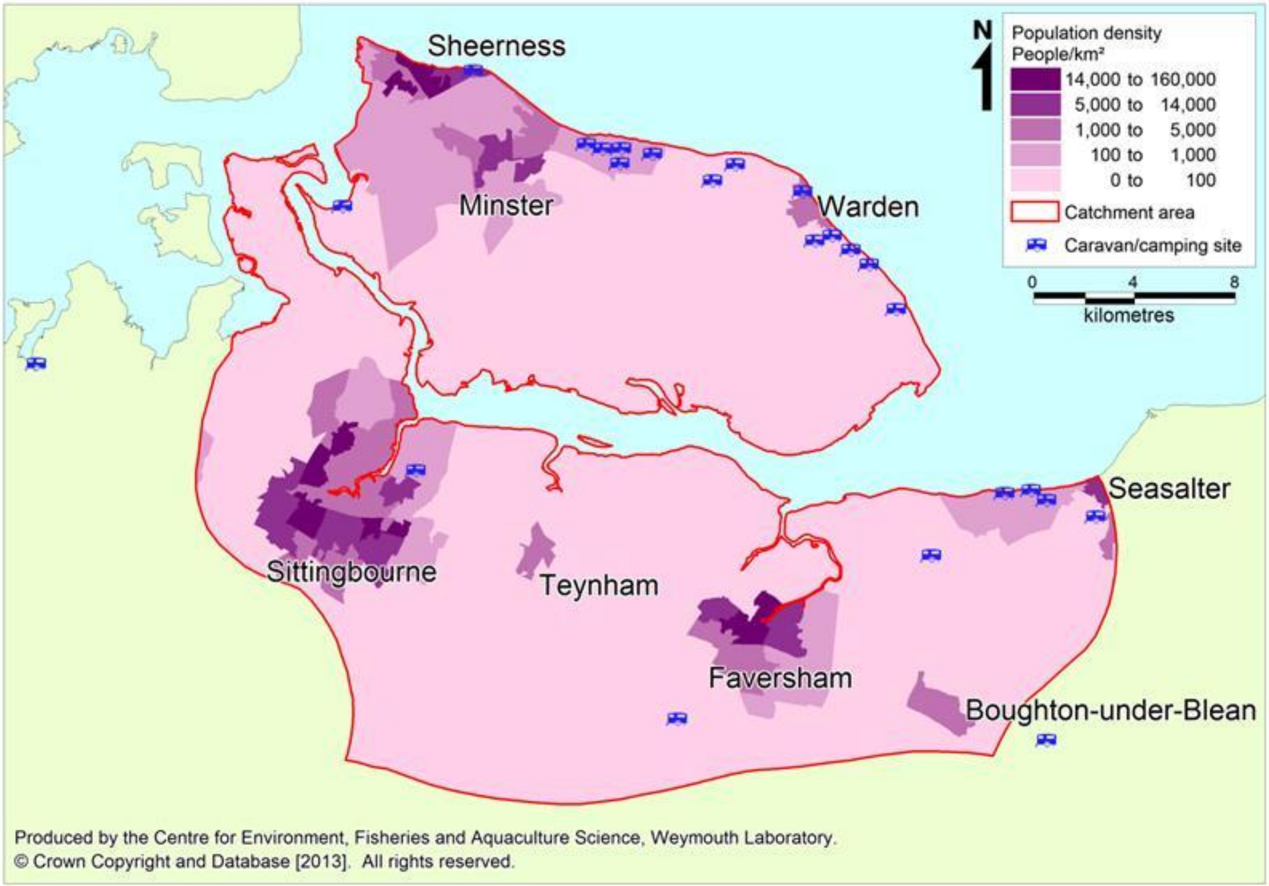


Figure I.1: Human population density in census areas in the Swale and the Isle of Sheppey catchment.

Total resident population within the Swale and the Isle of Sheppey catchment area was approximately 129,000 at the time of the last census. Figure I.1 indicates that along the mainland shore of the Swale, population densities are highest around the creeks. In both Sittingbourne and Faversham population densities reach approximately 37,000 people/km². Towards the eastern end of the Swale, Seasalter has a population density of approximately 6,000 people/km². On the Isle of Sheppey, Sheerness is the largest population centre and has population densities reaching approximately 22,000 people/km².

An estimated 395,618 overnight trips were made to the Swale district in 2006. Around 37% (146,300) of these stays were in caravan or camping accommodation (Visit Kent, 2009). Figure 1.1 shows the locations of the caravan parks and campsites in the Swale district. There is a large concentration of caravan sites on the north shore of the Isle of Sheppey where many visitors use the beaches of Sheerness, Minster Leas and Leysdown.

Given the large numbers of tourist that visit the area it can be assumed that there will be seasonal variation of population levels in the catchment and bacterial loadings from sewage treatment works serving the area would be expected to fluctuate accordingly.

Appendix II. Sources and Variation of Microbiological Pollution: Sewage Discharges

Details of all consented sewage discharges in the Swale and Thames Sheppey hydrological catchment were taken from the most recent update of the Environment Agency national permit database (March 2013). These are mapped in Figure II.1.

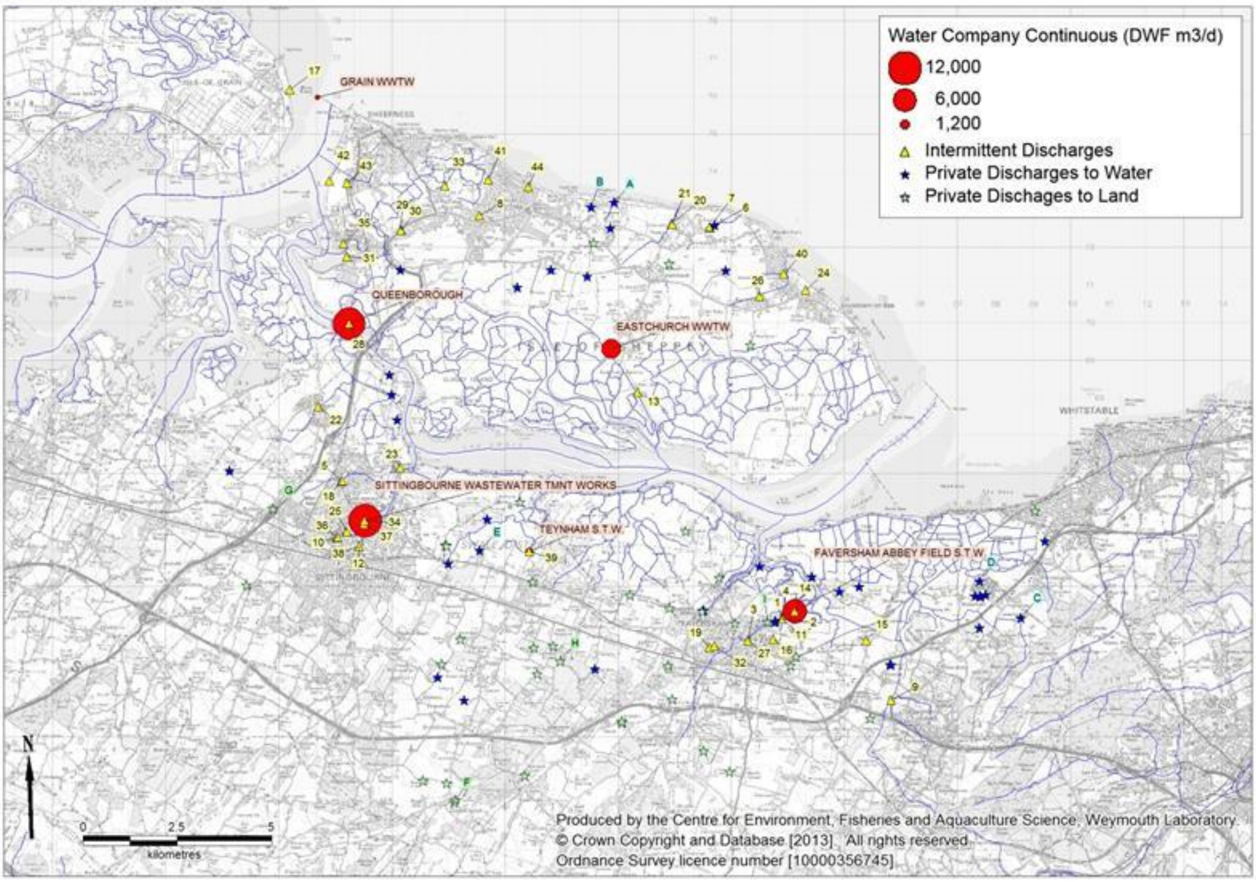


Figure II.1: Sewage discharges to the Swale and Thames Sheppey catchment

There are six continuous water company discharges to the area, details of which are presented in Table II.1.

Table II.1: Details of continuous water company sewage works

Name	NGR	Treatment	Dry weather flow (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
Teynham STW	TQ9563063920	Secondary	848	$2.80x10^{12}$	Frognal Drain
Queenborough STW	TQ9085069970	Secondary	11225	$3.71x10^{13}$	Swale Estuary
Eastchurch WWTW	TQ9780069300	Secondary	4500	$1.49x10^{13}$	Bells Creek
Faversham Abbey Field STW	TR0268062330	Secondary	7000	$2.31x10^{13}$	Faversham Creek
Sittingbourne WWTW	TQ9128064740	Secondary	11800	$3.89x10^{13}$	Milton Creek
Grain WWTW	TQ9001075980	Secondary	402	$1.33x10^{12}$	Medway Estuary

Faecal coliforms (cfu/day) based on base flow averages from a range of UK STWs providing secondary treatment (Table II.2).

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

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	$7.2x10^6$
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).
n - number of samples.
Figures in brackets indicate the number of STWs sampled.

The largest two discharges in the area are Sittingbourne STW and Queenborough STW, which are situated approximately 6km and 7.75km west of the nearest classified area in the Swale estuary. These discharge 11800 and 11225 m^3/day dry weather flow (DWF) of secondary treated effluent respectively to Milton Creek and the Swale. These discharges generate a significant bacterial loading but the extent of their impacts on the shellfisheries will depend on water circulation patterns in the area.

Whilst Faversham STW is smaller, discharging 7000 m^3/day DWF of secondary treated effluent, it will have a significant impact on the shellfisheries as it discharges directly into Faversham Creek. Its impacts will be greatest in the upper reaches of this creek.

Eastchurch WWTW is located on the Isle of Sheppey, and is consented to discharge 4500 m^3/day DWF of secondary treated effluent to a watercourse draining to the north shore of the Swale estuary. This discharge will primarily be of influence where this water course meets tidal waters, and to the east and west of this point.

Teynham STW is consented to discharge 848 m^3/day DWF of secondary treated sewage. Although this discharge is smaller than other water company continuous discharges, it will nevertheless be of some significance within Conyer Creek, to which it discharges via a short watercourse, and possibly beyond.

Grain WWTW is located at the mouth of the River Medway, discharging 402 m^3/day DWF of secondary treated effluent to the western edge of the Medway approach channel. The extent of its impacts on any of the shellfisheries will largely depend on water circulation patterns.

In addition to those continuous water company discharges listed above, there are two major sewage discharges off the North Kent Coast (Margate and Swalecliffe STWs). Both provide UV disinfection and as such the bacterial loading they generate is very minor (Cefas, 2011) in relation to that generated by the works which only provide secondary treatment. This, together with their distance from the survey area indicates that they should be of no significance.

There are various continuous and intermittent discharges to the River Medway. Contamination from these will be carried out of the Medway approach channel on the ebbing tide, so will not impact on shellfisheries in the Swale, but may be an influence on any shellfish beds to the north of Sheppey.

In addition to the continuous sewage discharges, intermittent water company discharges associated with the sewerage networks are also shown in Figure II.1. Details of these are provided in Table II.3. Those highlighted in green have spill event monitoring but no recorded spills from April 2011 to March 2013, and those highlighted in yellow did have recorded spills within this period.

Table II.3: Intermittent discharges within the Swale and Thames Sheppey catchment

No.	Name	Grid reference	Receiving water	Type
1	Abbey Fields Faversham SPS	TR0233062130	Faversham Creek	Storm Overflow
2	Abbey Road CSO	TR0233032130	Faversham Creek	Storm Overflow
3	Abbey Street	TR0144061570	Faversham Creek	Storm Overflow
4	Abbeyfields Combined Sewer Overflow	TR0232062160	Freshwater River	Storm Overflow
5	Attlee Way Grovehurst WWPS	TQ9065065790	Milton Creek via drain	Pumping station
6	Barrows Brook Eastchurch CEO	TR0043072530	Barrows Brook	Storm Overflow
7	Barrows Brook Waste Water Pumping	TR0042072540	Freshwater River	Pumping Station
8	Between Noreen & Sunnyside Avenue	TQ9431072850	Freshwater River	Storm Overflow
9	Boughton Pumping Station	TR0522059980	Freshwater River	Storm Overflow
10	Chalkwell Road Sittingbourne CSO	TQ9053064290	Trib of Milton Creek	Storm Overflow
11	Cyprus Rd / Whitstable Rd CSO	TR0234062130	Faversham Creek	Storm Overflow
12	East St / Shakespeare CSO Sittingbourne	TQ9111064060	Freshwater River	Storm Overflow
13	Eastchurch WWTW	TQ9850068150	Bells Creek	Storm Overflow
14	Faversham Abbey Field STW	TR0268062330	Faversham Creek	Storm Overflow
15	Goodstone Pumping Station	TR0457061570	Freshwater River	Pumping Station
16	Gordon Square SPS	TR0210061590	Freshwater River	Storm Overflow/ Pumping Station
17	Grain WWTW	TQ8927076180	Medway Estuary	Storm Overflow
18	Grovehurst M23 Pumping Station	TQ9066065800	Freshwater River	Storm Overflow
19	Hazebrouck Road Faversham	TR0041061380	Faversham Creek (via	Storm Overflow

	WWPS		drain)	
20	Hens Brook WWPS	TQ9941072630	Hens Brook	Storm Overflow
21	Hens Brook WWPS	TQ9943072620	Freshwater River	Pumping Station
22	Iwade Ejector Station	TQ9003067780	Freshwater River	Storm Overflow
23	Kemsley Sewage Pumping Station	TQ9220066150	Saline Estuary	Storm Overflow
24	Little Groves Leysdown on Sea WWPS	TR0296070860	North Sea (via drain)	Storm Overflow / Pumping Station
25	Millway, Sittingbourne CSO	TQ9079064450	Milton Creek	Storm Overflow
26	Mustards Road Pumping Station	TR0174070700	Warden Bay Drain	Pumping Station
27	North Lane Faversham CSO	TR0143061570	Faversham Creek	Storm Overflow
28	Queenborough STW	TQ9085069970	Swale Estuary	Storm Overflow/ Storm Tank
29	Queenborough Road Halfway	TQ9222072470	Freshwater River	Storm Overflow
30	Queenborough Road Queenborough WWPS	TQ9222072460	Trib of the West Swale	Pumping Station
31	Rushenden Road	TQ9080071760	Controlled Sea	Storm Overflow
32	Sewage Pumping Station, Faversham	TR0055061420	Freshwater River	Storm Overflow
33	Sheerness East WWPS	TQ9339073630	Freshwater River	Pumping Station
34	Sittingbourne WWTW	TQ9126064740	Milton Creek	Storm Overflow / Storm Tank
35	South Street PS QO9	TQ9070072100	River Swale Estuary	Storm Overflow
36	St Pauls Street Sittingbourne CSO	TQ9054064300	Milton Creek	Storm Overflow
37	Surf. Water Sewer Sittingbourne	TQ9125064650	Nontidal Trib of Milton Creek	Storm Overflow
38	Surf. Water Sewer Sittingbourne	TQ9111064060	Nontidal Trib of Milton Creek	Storm Overflow
39	Teynham STW	TQ9563063920	Frognal Drain	Storm Overflow / Storm Tank
40	Warden Bay Pumping Station	TR0238071300	Trib of the North Sea	Pumping Station
41	Wards Hill Wastewater PS	TQ9454073790	Freshwater River	Pumping Station
42	West Minster / Brielle Way WWPS	TQ9033073760	River Medway Estuary	Pumping Station
43	West Minster / Brielle Way WWPS	TQ9079073700	The Swale	Pumping Station
44	Westcliffe Drive PS Q18	TQ9560073600	NorthSea	Storm Overflow

Data from the Environment Agency

The main clusters of intermittent discharges are located around the towns of Sittingbourne and Faversham. There are also a number along the north shore of Sheppey. For those without event monitoring it is difficult to assess their potential impacts aside from noting their location and potential to spill untreated sewage. For those with event monitoring some spill summary statistics covering the period April 2011 to March 2013 are shown in Table II.4. The event durations were calculated by subtracting the stop time from the start time. This may provide an overestimate of spill duration in some cases, as the outfall may not have spilled continuously throughout the event.

Table II.4: Summary of spill records, April 2011 to March 2013.

Name	Spring			Summer			Autumn			Winter			Total		
	No. events	Total duration (Hrs)*	% of time active	No. events	Total duration (Hrs)*	% of time active	No. events	Total duration (Hrs)*	% of time active	No. events	Total duration (Hrs)*	% of time active	No. events	Total duration (Hrs)*	% of time active
Abbey Road CSO	5	18.0	0.41%	7	7.6	0.17%	12	50.8	1.16%	8	13.1	0.30%	32	89.6	0.51%
Abbeyfields Faversham SPS	1	0.4	0.01%	11	48.5	1.10%	5	27.0	0.62%	1	0.1	0.00%	18	76.0	0.43%
Attlee Way Grovehurst WWPS	0	0.0	0.00%	1	42.2	0.96%	9	42.3	0.97%	4	5.6	0.13%	14	90.1	0.51%
Barrows Brook Eastchurch CEO	4	35.0	0.79%	8	67.7	1.53%	6	78.8	1.80%	6	25.6	0.59%	24	207.1	1.18%
Cyprus Road CSO	0	0.0	0.00%	4	0.7	0.02%	3	24.2	0.55%	2	0.2	0.01%	9	25.2	0.14%
East Street Sittingbourne	3	20.6	0.47%	9	217.5	4.93%	8	65.0	1.49%	5	9.8	0.23%	25	312.9	1.78%
Eastchurch WWTW	2	33.8	0.77%	0	0.0	0.00%	1	49.6	1.14%	1	105.4	2.43%	4	188.8	1.08%
Grain WWTW	20	177.8	4.03%	24	318.6	7.21%	21	165.9	3.80%	25	287.8	6.63%	90	950.1	5.42%
Hazebrouck Road Faversham WWPS	1	2.8	0.06%	0	0.0	0.00%	0	0.0	0.00%	1	23.7	0.55%	2	26.5	0.15%
Little Groves Leysdown WWPS	2	14.8	0.34%	0	0.0	0.00%	6	39.3	0.90%	5	45.1	1.04%	13	99.2	0.57%
North Lane Faversham CSO	0	0.0	0.00%	2	2.6	0.06%	4	106.7	2.44%	1	0.2	0.00%	7	109.4	0.62%
Queenborough STW	0	0.0	0.00%	0	0.0	0.00%	5	443.9	10.16%	4	215.0	4.95%	9	658.9	3.76%
Sittingbourne WWTW	6	134.3	3.04%	9	72.8	1.65%	9	195.3	4.47%	11	311.0	7.16%	35	713.4	4.07%
South Street Chailey PS	2	6.9	0.16%	0	0.0	0.00%	1	23.0	0.53%	1	17.6	0.40%	4	47.4	0.27%
St Pauls Street Sittingbourne CSO	3	17.2	0.39%	12	77.6	1.76%	8	35.6	0.82%	1	0.7	0.02%	24	131.0	0.75%
Warden Bay PS	2	20.3	0.46%	5	49.8	1.13%	3	14.9	0.34%	5	61.7	1.42%	15	146.7	0.84%
Wards Hill WPS	6	66.2	1.50%	19	193.8	4.39%	13	120.6	2.76%	13	90.8	2.09%	51	471.4	2.69%
Westcliffe Drive PS	0	0.0	0.00%	1	1.2	0.03%	0	0.0	0.00%	1	1.1	0.03%	2	2.3	0.01%

*Event durations calculated from start and stop time. Actual spills may not have been continuous throughout these events.

Data from the Environment Agency

If classification is based on 10 samples per year, the impacts of an intermittent discharge would be captured once a year or more on average for those intermittent outfalls spilling for 10% or more of the time. Of the monitored discharges, the most active in recent years was Grain WWTW storm overflow discharge, which spilled for just over 5% of the period considered. This discharges to the eastern tip of the Isle of Grain so may be of some limited significance to the north coast of Sheppey. The overflows from Queenborough and Sittingbourne STWs spilled for about 4% of the period considered, to the same outfall location to which their treated effluents are discharged. The Wards Hill PS was active for almost 3% of the time, and discharges to the north coast of Sheppey immediately adjacent to a mussel bed where it may therefore be a significant but occasional contaminating influence. All other monitored outfalls spilled for less than 2% of the time, and so whilst they may be of occasional influence their impacts are very unlikely to be captured during monthly shellfish monitoring.

Although the vast majority of the survey area is served by water company sewerage infrastructure, there are also a number of private discharges in the area. Where specified, these are generally treated by small treatment works such as package plants. The majority of these are small, serving one or two properties. Details of the larger private discharges (>5m^3/day maximum permitted flow) are presented in Table II.5.

Table II.5: Details of private sewage discharges of 5m^3/day or over

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Ashcroft Caravan Park	TQ9788073200	Package treatment plant	120	Coastal
B	The Horse Shoe Caravan Park	TQ9726073060	Package treatment plant	19	Trib of the North Sea
C	Lamberhurst Farm	TR0866062160	Unspecified	10.5	Freshwater River
D	Hernhill Nursery	TR0757263136	Unspecified	9	Trib of Hawkins Hill Drain
E	Bax Farm	TQ9431063950	Unspecified	5	Freshwater River
F	Treatment Plant Compound	TQ9363057260	Unspecified	15.4	Into land
G	Bobbing Village School	TQ8882065060	Unspecified	11.5	Into land
H	Premises at The Trefoil	TQ0195062060	Package treatment plant	7.2	Underground strata
I	Brent Industrial Estate	TR0195062060	Unspecified	5	Freshwater Stream

Data from the Environment Agency.

There are a number of private discharges that may impact on the shellfisheries. There are two caravan park discharges on the north coast of the Isle of Sheppey, one of which is relatively large, discharging 120m^3/day DWF. Both of these discharges are treated with package treatment plants, which are likely to be using secondary biological treatment. These two discharges will have a local impact on microbial water quality in the immediate vicinity, and are likely to have a seasonal influence with higher loads in the summer months. Other small private discharges will make a contribution to the levels of *E. coli* in some watercourses draining to the Swale and north of the Isle of Sheppey, but overall impacts from these will be minor.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Most of the land within the hydrological catchment is used for agriculture, with a mix of pastures, orchards and arable crops (Figure 1.2). The central areas of Sheppey are arable farmland, with a band of pasture around most of the coast. There are also pastures along most of the mainland coast, with the inland areas predominantly a mixture of arable land and orchards. Numbers and overall densities of livestock as recorded in the 2010 agricultural census are presented in Table III.1. Data from 2010 is used as more recent censuses were less detailed.

Table III.1: Summary statistics from 2010 livestock census within the survey catchment

	Number	Density (animals/km^2)
Cattle	3,481	13.3
Sheep	21,311	81.4
Poultry	7,179	27.4
Pigs	556	2.1

Data provided by Defra

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table III.2.

Table III.2: 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).

Numbers and densities of livestock within the area are not particularly high, but there are a potentially significant number of grazing animals within the survey area. According to the distribution of pastures within the catchment, these will mainly be grazed in land adjacent to the coast. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing. There may therefore be some impacts arising from the periodic application of organic fertilizers to arable lands.

The main livestock aggregation observed during the survey was approximately 1000 sheep, which were on the Luddenham Marshes, just east of Conyer Creek. Around 110 cattle were observed on the Harty Marshes, and although they were fenced into fields behind the sea bank, there was evidence on the ground to suggest they are allowed to graze on the saltmarsh on the seaward side of the sea bank. Another 50 cattle were recorded just east of Faversham Creek. It must be noted that a large proportion of the south shore of Sheppey, where there are significant areas of pastures were not surveyed, and that the observations apply to the day of survey only.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the survey will be highly variable and depend on rainfall. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Most, if not all significant watercourses will be impacted to some extent by agriculture. The largest and most consistent fluxes of indicator bacteria into coastal waters are anticipated to arise from grazed areas adjacent to the shore. Also of possible significance is the possible presence of cattle on the sea banks and on the saltmarsh and the seaward side of the sea banks on the south eastern tip of Sheppey. These animals will defecate on the saltmarsh, and this will be washed directly into the coastal waters via tidal inundation on the larger spring tides. An Environment Agency study conducted in the Ribble estuary found a significant increase in levels of faecal coliforms within saltmarsh creeks in grazed areas as the tide started to ebb following tidal inundation (Dunhill, 2003) so this is a recognised phenomenon.

As well as significant day to day variation driven by rainfall (and tide size in the case of saltmarsh grazing) there is likely to be some seasonal differences in the fluxes of faecal indicator bacteria of agricultural origin into the survey area. Number of sheep and cattle will increase in the spring with the birth of lambs and calves, and then decrease in the autumn as they 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. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring. The seasonal pattern of impacts from adjacent pastures will also depend on any seasonal variations in water level management strategies.

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Swale and Sheppey. There is significant boat traffic within the area including merchant shipping, pleasure craft and fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

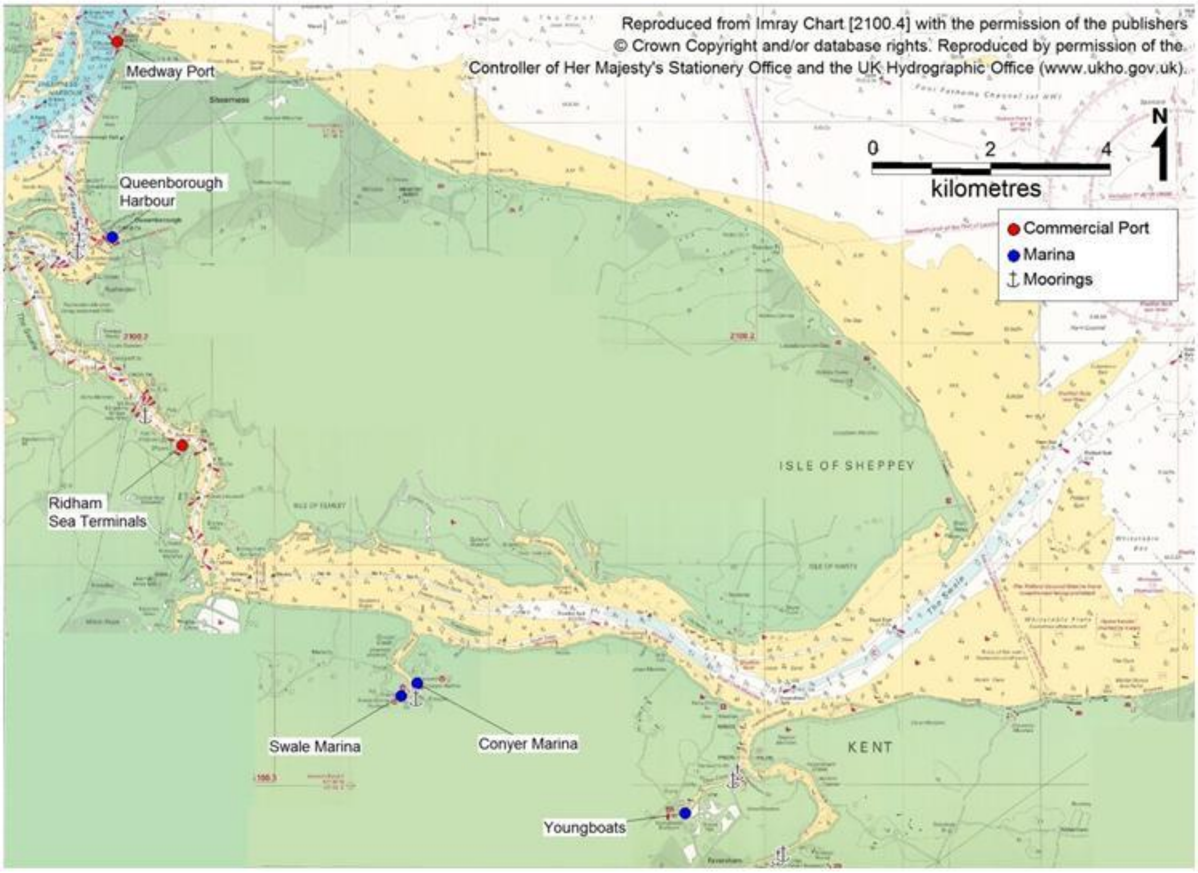


Figure IV.1: Boating activity in the Swale and Sheppey

There are three large commercial ports in the Medway, which together handled over 16 million tonnes of freight in 2011, about 3% of the UK total (Department for Transport, 2012). There is also a large amount of shipping passing through the Thames estuary en route to ports further west such as Tilbury Docks. Towards the western end of the Swale there is also a cargo terminal at Ridham. Merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land[1]. There will not therefore be any discharges made in the Swale, Medway, and in close proximity to Sheppey, although there may be regular large overboard discharges in the central outer areas of the Thames estuary. For vessels approaching and leaving ports this area represents the last and first opportunities to make overboard discharges.

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

There are two yacht clubs, Queenborough and Conyer Yacht Clubs, and two sailing clubs within the survey area, which offer a variety of racing and courses for yachts and dinghies. However, the smaller recreational boats are not large enough to contain onboard toilet facilities and therefore are therefore unlikely to make overboard discharges.

The area supports a commercial fleet, consisting mainly of vessels of under 10m in length. In 2008 a total of 55 commercial full time fishing vessels were registered in Kent (MacAlister Elliot & Partners Ltd. 2010). Some of these vessels operate out of Queenborough on the Medway, and others are based in Whitstable although exact numbers at each are uncertain. There are also several charter boats which can be hired for fishing and cruising trips operating in the area.

The Swale channel, the navigation route to the north of Sheppey, and the approaches to the Medway have been described as being in 'heavy recreational use' (RYA, 2004). There are three yacht marinas within the Swale based in the Faversham and Conyer Creeks, which collectively hold around 390 berths. Queenborough Harbour in the north of the Swale, holds around 60 berths. In addition to these there are numerous moorings in Faversham Creek and Conyer Creek, and within the western end of the main Swale channel. Sewage pump out facilities are only available at the marina in Faversham Creek (Youngboats website, 2013).

About 20 houseboats were recorded in the upper reaches of the eastern arm of Faversham Creek during the shoreline survey.

Dredging is undertaken from time to time within the Swale to maintain the shipping channels (Ian Udal, Environment Agency, pers comm.). This may re-suspend contamination from within sediments. The temporal and geographic patterns of this activity are uncertain, so whilst it may possibly have detrimental effects on shellfish hygiene, it will have no bearing on the sampling plan.

Private vessels such as yachts, motor cruisers and fishing vessels of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the relative calm of the estuary. Occupied yachts on pontoon berths may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and facilities on land are easier to access. The areas that are at highest risk from microbiological pollution therefore include the mooring areas for larger private vessels and the main navigation routes through the area. As such, Faversham and Conyer Creek, and to a lesser extent the main Swale Channel are probably at greatest risk. When occupied, the houseboats in the upper reaches of Faversham Creek are also likely to make regular discharges. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The Swale and Sheppey encompasses a variety of habitats including intertidal mud and sand flats, small areas of saltmarsh, seagrass beds, grazing marsh and saline lagoons. The whole of the Swale has been classified as a Special Protection Area (SPA) under the EC Birds Directive 1979 due to the presence of bird assemblages of European importance. Various parts of the survey area are also protected by other international and national environmental legislations including: Special Site of Scientific Interest (SSSI), a Ramsar Site, and a National Nature Reserve (NNR).

Overwintering waterbirds (wildfowl and waders) represent the most significant wildlife influence on shellfish hygiene in the area. 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). Over the five winters up until 2010 an average total count of 77,162 overwintering birds and wildfowl were recorded (Holt *et al*, 2012) within the Swale. Large numbers of these are often observed on the Oare and Elmey nature reserves on the south shore of the Swale estuary. On the shoreline survey large flocks of birds were observed throughout and in particular large numbers, around 3,000, were recorded on the marshes on the south east corner of the Isle of Sheppey.

Geese and ducks will mainly frequent the grassland and saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas will be best located to capture contamination from this source. Waders, such as dunlin and oystercatchers forage upon shellfish and so will forage (and defecate) directly on any shellfish beds on the intertidal. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but this will probably vary from year to year. Contamination via direct deposition may be patchy, with some shellfish containing high levels of *E. coli* while others a short distance away are unaffected. At high tide waders are likely to frequent the saltmarsh and the perimeter of the estuary. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence during the winter months.

Most of these waterbirds migrate elsewhere to breed outside of the overwintering period. Seabirds (gulls, terns, cormorants etc) are present within the survey area all year round, although numbers are considerably lower. A survey of breeding seabirds undertaken in 2000 counted 3,848 pairs of breeding seabirds on the south coast of Sheppey, between Shell Ness and Spitend Point (Mitchell *et al*, 2004). The majority of these were recorded on a small island just east of Spitend Point (Flanders Mare). A few pairs (60) were also recorded on the Murston Gravel pits by Milton Creek. Although not in the survey area, large numbers (7,644 pairs) of seabirds were also recorded on the marshy islands within the Medway. These seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal or through tidal inundation. RMPs are best located within or near to the drainage channels that originate from nesting sites to capture contamination. As such, the Spitend Point area is most at risk from contamination from seabirds.

Across Kent, Essex and Suffolk, 379 harbour seals were recorded in the last August moult survey in 2010 (SCOS, 2012). A more recent count (August 2013) identified a total of 706 seals in the Thames estuary, of which about 500 were harbour seals and 200 were grey seals. Results of this latter survey are yet to be confirmed and formally reported. Significant haulout sites within the survey area include Horse Sand, in the Swale off Faversham Creek, where 20 to 40 harbour seals where sighted here on two separate occasions in August 2013. Any impacts are likely to be greatest in the immediate vicinity of their haulout sites. They tend to spend more time hauled out during the summer pupping and moulting season, but are resident all year round. Given the large area they are likely to forage over, impacts are likely to be minor, and unpredictable in spatial terms outside of haul out sites.

No other wildlife species which may be of significance to shellfish hygiene in the survey area have been identified.

Appendix VI. Meteorological Data: Rainfall

Due to its sheltered location relative to rain-bearing weather systems feeding in off the Atlantic, the Kent coast is 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 then (Met Office, 2012). The Sheerness Golf Course weather station, received an average of 485 mm per year between 2003 and 2012. Figure VI.1 presents a boxplot of daily rainfall records by month at this rain gauge.

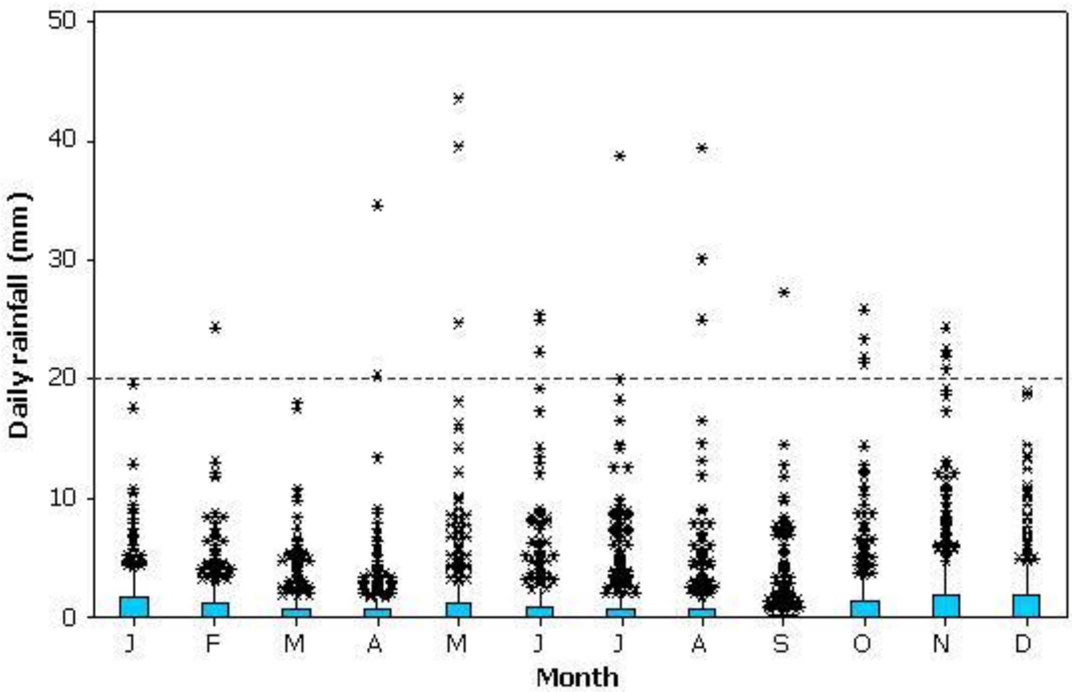


Figure VI.1: Boxplot of daily rainfall totals at Sheerness Golf Course, January 2003 to December 2012.
Data from the Environment Agency

Rainfall records from Sheerness Golf Course, which is representative of conditions in the vicinity of the shellfish beds indicate that the seasonal variation in rainfall is not particularly large. Average rainfall is lower during early spring, and higher in late autumn/early winter. There is a secondary peak in rainfall in late spring/early summer. Daily totals of over 20mm were recorded in most months, and 60% of days were dry.

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 VII. Meteorological Data: Wind

Southern England is one of the more sheltered parts of the UK, since the windiest areas are to the north and west, closer to the track of Atlantic storms. The strongest winds are associated with the passage of deep depressions across or close to the UK. The frequency of depressions is greatest during the winter months so this is when the strongest winds normally occur (Met Office, 2012). The frequency of gales in south east England is relatively low.

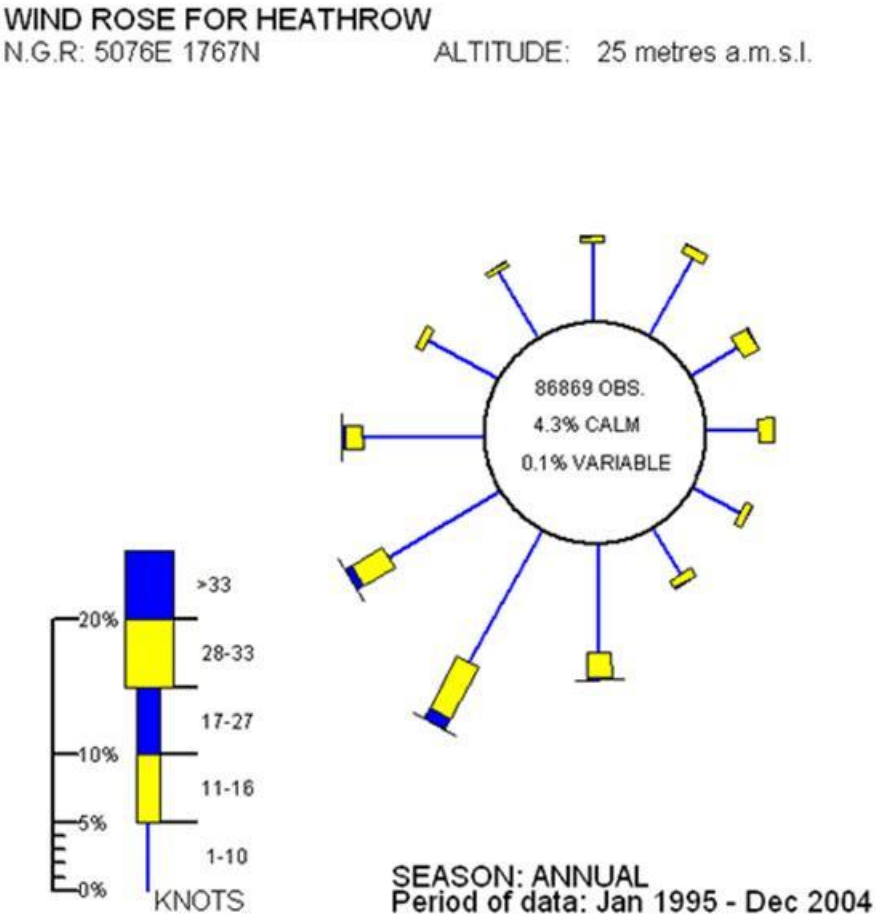


Figure VII.1: Wind Rose for Heathrow

Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Heathrow is typical of open, level locations across the region. The prevailing wind direction is from the south west and the strongest winds usually blow from this direction. A higher frequency of north easterly winds occurs during spring. The Swale is a channel between the Isle of Sheppey and the mainland, opening to the north west into the Medway estuary and with a wider opening to the south east out towards Whitstable. It is therefore relatively sheltered by the land from the prevailing winds, but its entrance is quite exposed to easterly winds which may tend to be funnelled up it. The north eastern edge of the Isle of Sheppey is an open coast, and is exposed to winds from the north and east.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The Swale and Sheppey have a hydrological catchment area of 262 km². There are no major rivers that discharge into the Swale and Sheppey although the tidal Swale estuary is designated as a 'River' by Defra (Swale BC, 2009). There are several smaller watercourses which are a mixture of spring fed and surface water streams. The low lying land along the south coast of Sheppey and the eastern part of the mainland coast is drained by a series of engineered field drains and outfalls. Figure VIII.1 shows the location of the main watercourses.

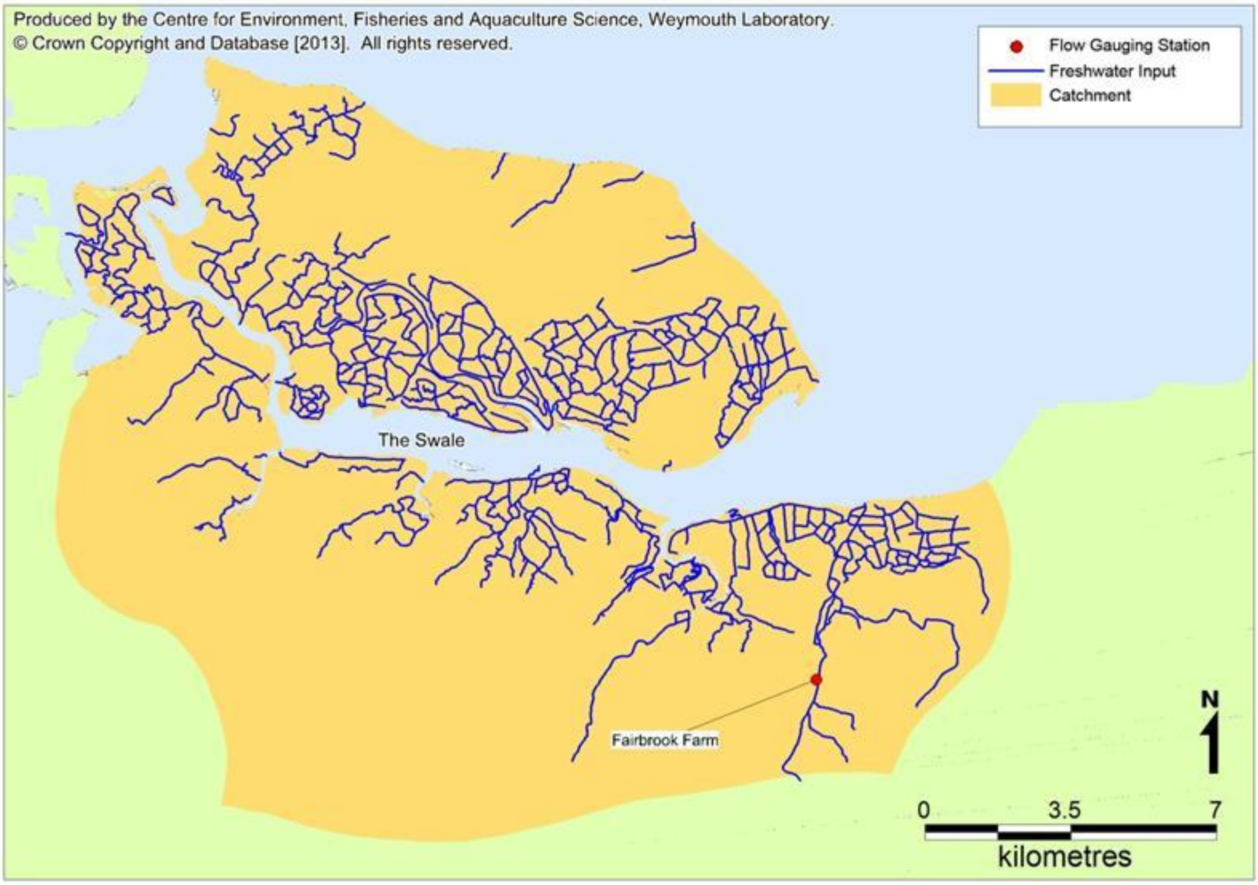


Figure VIII.1: Freshwater Inputs into the Swale Sheppey

Watercourses flow predominantly through low lying rural land, most of which is either arable farmland or pasture. There are pockets of urbanised land close to the coast representing the towns of Sheerness, Sittingbourne and Faversham. Watercourses will receive microbiological pollution from point and diffuse sources such as sewage works and urban and agricultural runoff. They are therefore a significant pathway of microbiological contamination to the shellfisheries in the Swale and Sheppey.

The mainland catchment is characterised by highly permeable chalk in its upper reaches, with less permeable geology in its lower reaches (Kent County Council, 2012).

Groundwater flows therefore predominate in the upper catchment, re-emerging via springs and then flowing via surface watercourses where the geology changes. Groundwater flow through aquifers is typically very slow between 1m/year to 1m/day (Environment Agency, 2011) and the retention time of 50 days is deemed sufficient in the removal of microbial contamination from groundwaters. It is therefore unlikely that microbiological contamination of water originating from aquifers poses a significant threat to coastal waters. There is significant abstraction within the catchment, mainly from the aquifers in the inland reaches (Environment Agency, 2013). Sheppey has a similar hydrogeology to the lower mainland catchment so surface flows predominate here. Water levels in the lowland marshes are monitored, and during the winter they are kept low to prevent flooding, whilst during the summer months the field drains are kept full to act as a wet barrier/fencing system to livestock and provide water for abstraction (Swale BC, 2009).

There is only one river flow gauging station within the survey area, which is located in the upper reaches of the River White Drain. Summary statistics for this gauging station are presented in Table VIII.1 covering the period 2003 to 2013.

Table VIII.1 Summary Flow statistics for Fairbrook Farm gauging station on the River White Drain

Watercourse	Station Name	Catchment Area (Km^2)	Mean Annual Rainfall 1961-1990 (mm)	Mean Flow (m^3/s)	[1]Q95 (m^3/s)	[2]Q10 (m^3/s)
River White Drain	Fairbrook Farm	31.8	726	0.14	0.02	0.30

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

The mean flow rate at this gauging station is only 0.14 m^3/s, although it is some distance from the sea so this only represents a proportion of its discharge, and abstraction occurs upstream of it. Boxplots showing mean daily flow records by month are presented in Figure VIII.2.

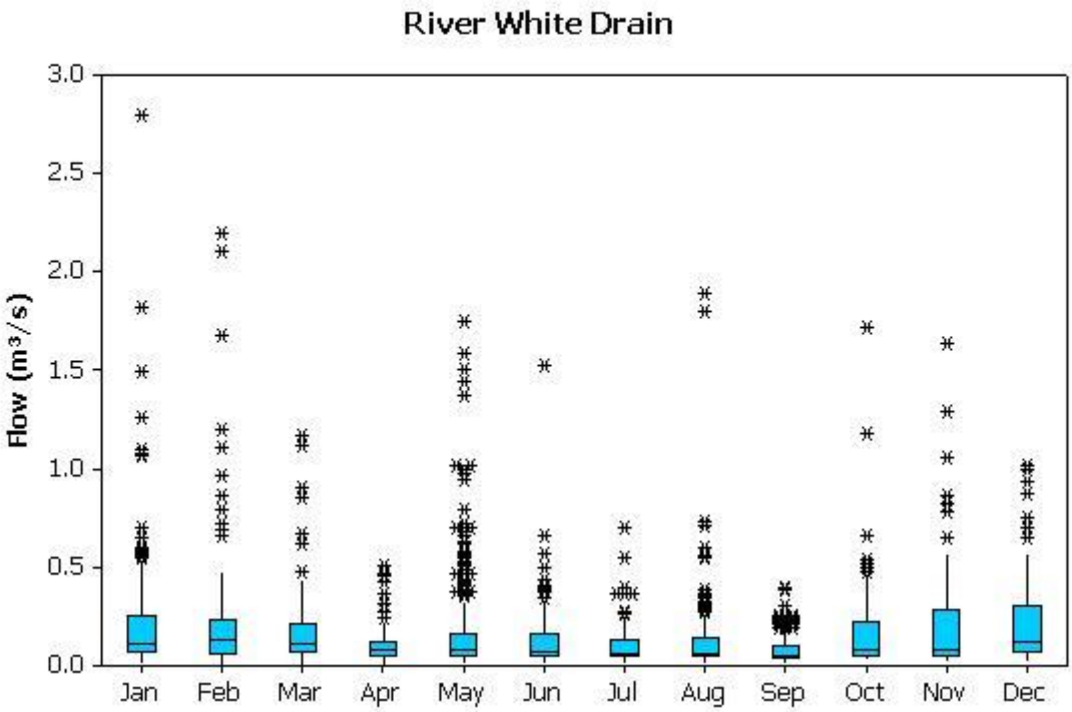


Figure VIII.2: Boxplots of mean daily flow records from the Fairbrook Farm gauging station on the River White Drain watercourse (2003 – 2013)
Data from the Environment Agency

Average flows were highest in the colder months; the maximum flow recorded was 2.8 m^3s^{-1} in January 2008. High flow events of more than 1 m^3/sec were recorded in most months of the year. There may be seasonal variations in the amount abstracted from this watercourse. Whether a similar seasonality is observed in discharge rates from other water courses in the area is uncertain. There is likely to be less day to day variation in discharge rates in the spring fed watercourses, with higher base flows in the winter when the water table is higher. There is abstraction from the field drains in winter, and water is held back in them in the summer. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration. This in turn leads to a greater level of runoff or percolation into aquifers immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in watercourse, allowing contamination from more distant sources to have an increased impact during high flow events.

During the shoreline survey, which was conducted under dry conditions, watercourses which could be safely accessed were sampled for *E. coli* and spot flow measurements were made. A large number of these could not be accessed for flow measurement, but could be sampled using a sampling pole. Also, the entire shoreline adjacent to the fisheries was not surveyed for various reasons noted in the shoreline survey report (Appendix XII). The areas not surveyed were the central north coast of Sheppey, and the south coast of Sheppey west of the Harty Marshes. The results and locations are presented in Table VIII.2 and Figure VIII.3.

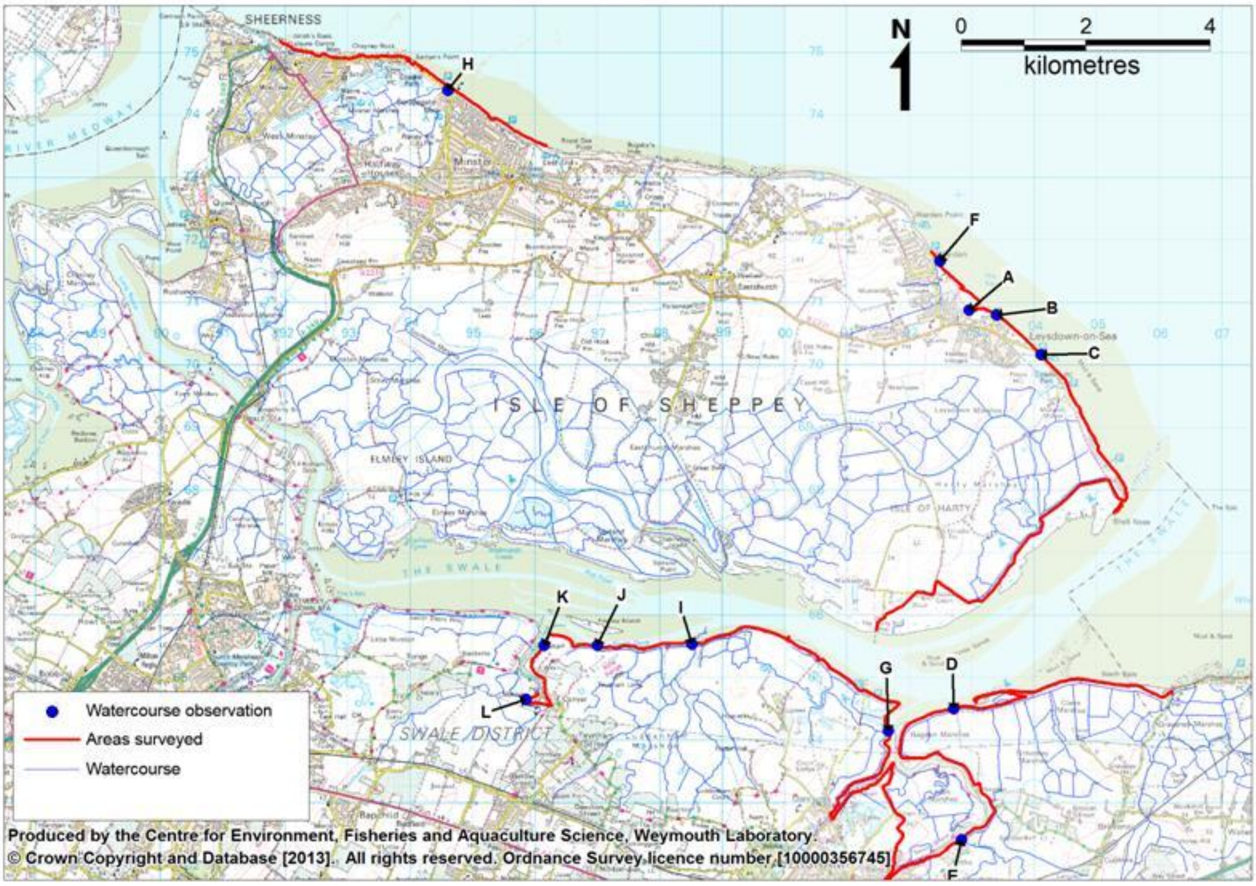


Figure VIII.3: Locations of shoreline survey freshwater input observations

Table VIII.2: Summary of shoreline survey freshwater input observations

Ref	Description	Discharge (m^3/day)	*E. coli* concentration (CFU/100 ml)	*E. coli* loading (CFU/day)
A	Ditch	Not flowing	20	
B	Surface water pipe	1.9	7200	$1.38x10^8$
C	Surface water pipe	8.6	7400	$6.39x10^8$
D	Marsh drainage sluice	Not flowing	10	
E	Culverted stream	Not flowing	520	
F	Surface water pipe	11.5	610	$7.02x10^7$
G	Marsh drainage sluice	Inaccessible	50	
H	Culverted stream	Inaccessible	23000	
I	Ditch	No outfall from ditch	160	
J	Marsh drainage sluice	Inaccessible	<10	
K	Culverted stream	13705.5	470	$6.44x10^{10}$
L	Culverted stream	Inaccessible	70	

All outfalls encountered were engineered in some way. None of those for which spot flow measurements could be made carried particularly large bacterial loadings. The two culverted streams (K & L) discharging to the head of Conyer Creek are likely to be an influence within this water body. The culverted stream at Minster (H) carried a high concentration of *E. coli*, but could not be accessed to measure. The photograph (Figure XII.10) suggests the discharge volumes from here were relatively minor but it may nevertheless be of local influence.

Appendix IX. Hydrography

IX.1. Bathymetry

The Swale is classified as a spit enclosed estuary (Futurecoast, 2002), although it is open at either end and does not receive land runoff from any major watercourses. It is connected to the Medway estuary at its western end and the North Sea at its eastern end. The survey area also includes the intertidal and shallow subtidal areas of the north/east coast of Sheppey where the Thames estuary opens out into the North Sea.

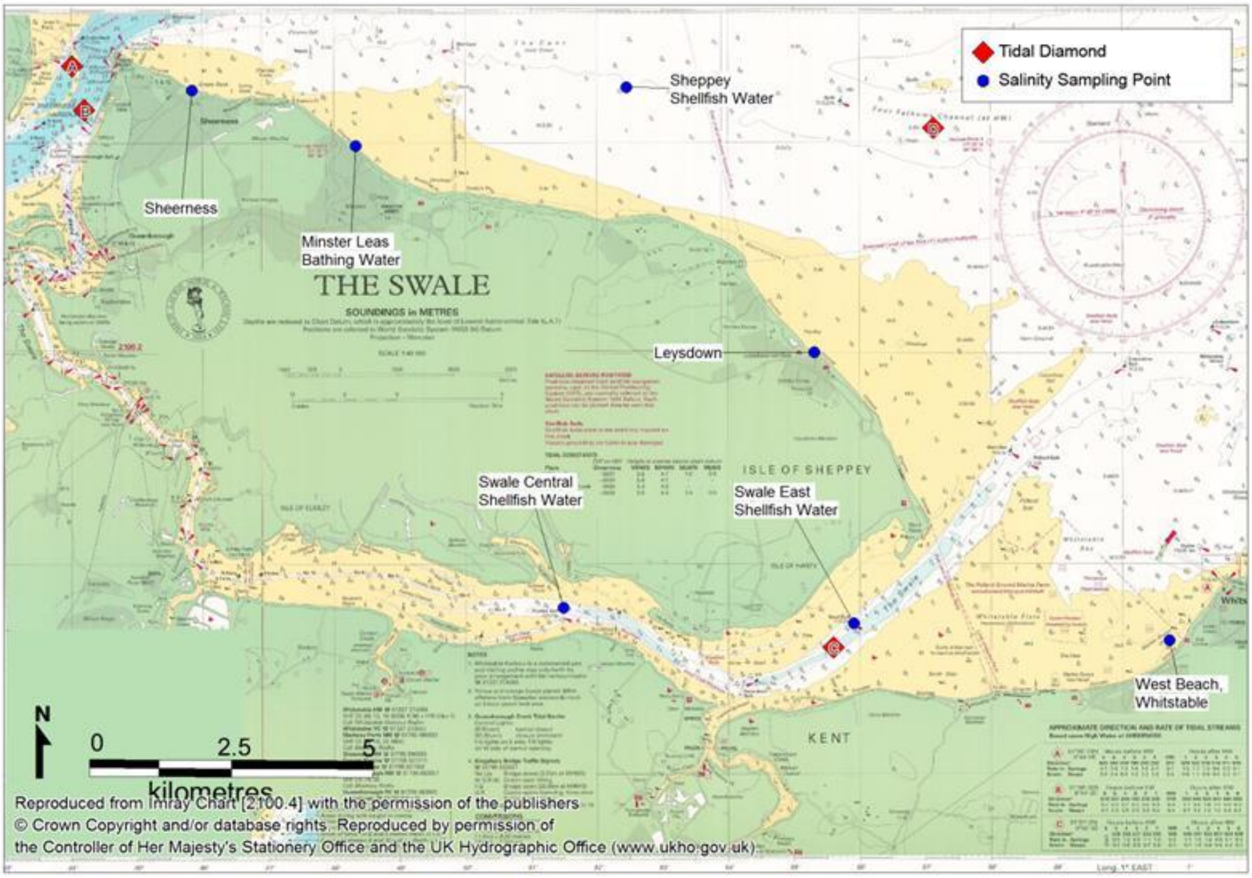


Figure IX.1: Bathymetry of the Swale and Sheppey

The Swale covers an area of around 32.8km², of which 78% is intertidal (Futurecoast, 2002). It is a tidal channel of about 23km in length, which separates the Isle of Sheppey from the North Kent coast. Its western reaches are meandering and relatively narrow (200-400m), where maximum depths range from about 1 to 7m. It opens out to about 1km in width at Milton Creek and the size of the intertidal area increases, and the central channel shallows to less than 1m in depth. At Conyer Creek, an additional three subtidal channels appear, and run parallel to the central channel. Fowley Island lies between the southernmost two of these channels. The separate channels then merge to form a single, wider and deeper central channel by Spitend Point, which deepens to almost 10m in places. This relatively deep, wide channel continues through to the eastern mouth of the

Swale, which is flanked by two spits (Columbine Spit and Pollard Spit). There are four tidal creeks emanating from the Swale channel. On the mainland side there are Milton, Conyer and Faversham Creeks, and on the Sheppey side there is Windmill Creek. Within the Swale to the east of Milton Creek, there are also a number of smaller intertidal channels feeding into the main channel, which drain areas of saltmarsh and some of which carry freshwater inputs.

The north/east coast of Sheppey is open to the outer Thames estuary and North Sea, and has a gently sloping intertidal area extending 3.9 km at the mouth of the Swale and to 0.3km at the mouth of the Medway. The subtidal areas continue to slope gently until they meet the Medway approach channel, which is a dredged channel maintained at a minimum depth of 12.5m that emanates in an ENE direction from the mouth of the Medway. The shallow subtidal flats between Sheppey and the Medway approach channel become more extensive further to the east.

Intertidal areas within the Swale are largely comprised of mud. Where it opens out in the east, and along the north/east coast of Sheppey, the substrates are a mixture of sand, gravel and shell. Saltmarshes fringe the intertidal flats in places within the Swale, and most of the shoreline is protected by sea walls. The north/east coast of Sheppey has a mixture of groynes and sea walls protecting the shore against coastal erosion and flooding.

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The Swale is macro-tidal with a tidal range of 5.3m on spring tides at Grovehurst Jetty by the mouth of Milton Creek.

Table IX.1 Tide Levels and ranges within the Swale Estuary

Port	Height above chart datum (m)				Range (m)	
	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Grovehurst Jetty	5.8	4.7	1.5	0.5	5.3	3.2
Faversham	5.6	4.5	-	-	-	-
Whitstable Approaches	5.4	4.5	1.5	0.5	4.9	4.0

Data from Admiralty Total Tide

Table IX.2 presents the direction and rate of tidal streams at the four tidal diamonds on spring and neap tides and at hourly intervals before and after high water, the locations of which are illustrated on Figure IX.1. Figure IX.2 presents modelled tidal vectors during mid flood and mid ebb on spring tides. These were taken from model outputs provided by the Environment Agency, and originally produced by Scott Wilson Ltd (2010) on behalf of Southern Water.

Table IX.2 The direction and rate of tidal streams on spring and neap tides and at hourly intervals before and after high water

Time before /after High Water	Station A			Station B			Station C			Station D		
	Direction	Rate (m/s)		Direction	Rate (m/s)		Direction	Rate (m/s)		Direction	Rate (m/s)	
		Spring	Neap		Spring	Neap		Spring	Neap		Spring	Neap
HW-6	26	0.05	0.00	73	0.10	0.05	Slack	Slack	Slack	274	0.15	0.10
HW-5	204	0.31	0.21	207	0.21	0.15	229	0.41	0.26	254	0.41	0.26
HW-4	200	0.67	0.41	209	0.36	0.26	238	0.62	0.41	242	0.46	0.31
HW-3	199	0.82	0.51	193	0.26	0.15	237	0.46	0.31	244	0.36	0.21
HW-2	202	0.98	0.62	216	0.26	0.15	230	0.57	0.36	246	0.31	0.21
HW-1	202	1.08	0.67	235	0.15	0.10	236	0.51	0.31	249	0.21	0.15
HW	201	0.36	0.21	19	0.21	0.15	50	0.10	0.05	113	0.15	0.10
HW+1	29	0.77	0.46	36	0.57	0.36	46	0.57	0.36	88	0.67	0.41
HW+2	22	0.87	0.57	44	0.93	0.62	41	0.77	0.51	75	0.72	0.46
HW+3	18	0.67	0.46	39	0.93	0.62	33	0.67	0.41	69	0.46	0.31
HW+4	10	0.31	0.21	41	0.77	0.51	27	0.41	0.26	37	0.26	0.15
HW+5	11	0.67	0.10	45	0.46	0.31	24	0.21	0.15	326	0.15	0.10
HW+6	10	0.05	0.05	55	0.21	0.15	20	0.05	0.05	287	0.15	0.10
Excursion (flood)		15.17	9.44		4.44	2.96		9.25	5.92		7.96	5.19
Excursion (ebb)		12.21	6.66		14.99	9.99		9.99	6.48		8.15	5.19

Data from Imray Chart 2100.4(The Swale) and Admiralty Chart 1607 (Thames Estuary Southern Part)

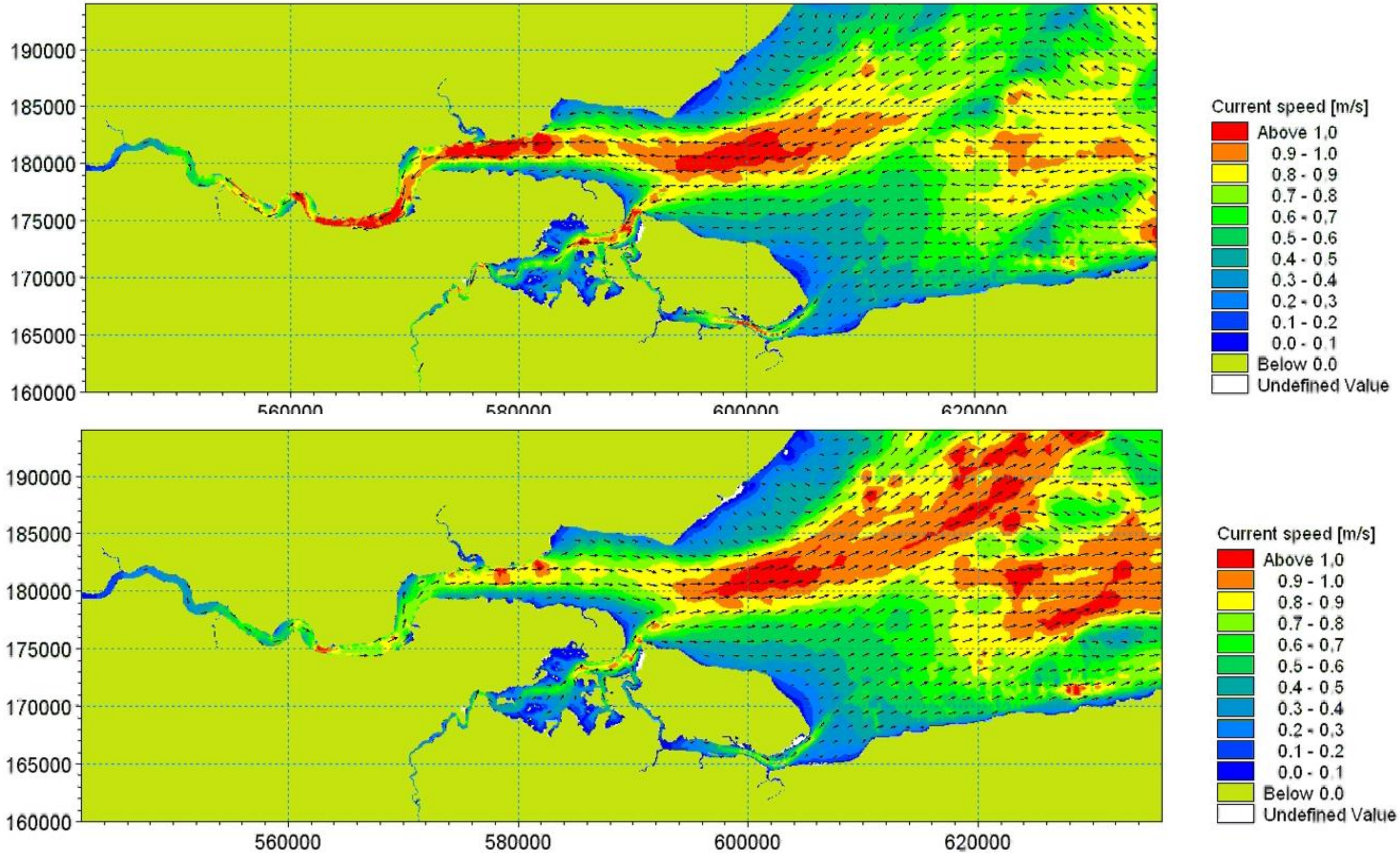


Figure IX.2: Modelled mid flood (top) and mid ebb (bottom) tidal vectors (spring tides)
Images provided by the Environment Agency

Tidal diamonds A and B are located in the mouth of the Medway. These indicate a bidirectional tidal stream flooding into and ebbing out of the Medway. They also suggest that the main tidal streams tend to flood up the western side of this channel, and ebb along the eastern side. Estimates of tidal excursion based on these diamonds are up to 15km on spring tides and up to about 10km on neap tides. It is likely that the bulk of the ebb plume from the Medway continues along the Medway approach channel out into deeper water at a similar rate, as can be seen in the model outputs. It will therefore mainly pass by the shallow subtidal area off the north coast of Sheppey where some shellfish resources are located. Any shellfish on the outermost fringes of these subtidal flats will be most exposed to contamination originating from the Medway.

Tidal diamond C lies in the eastern end of the Swale, and also shows a bidirectional pattern, with tides flooding up the channel and ebbing back out along it. Estimates of tidal excursion based on this tidal diamond are about 10km on spring tides and about 6km on neap tides. It is likely that the strength of tidal streams decrease away from the central channel, and further inside the Swale. There are no tidal diamonds towards the other end of the Swale Channel. Tides within the Swale Channel are reported to flood in at both ends, and meet in the middle in the vicinity of Milton Creek, with the reverse occurring on the ebb. This cannot be seen on the model outputs due to the low resolution, but is apparent in the port and starboard navigation buoys, which change sides here to align with the direction of the incoming tide (visitmyharbour website, 2013). This means that contamination from sources discharging between Milton Creek and the Medway will not pass Milton Creek during the flood tide, and will be carried out via the north western mouth into the Medway on the ebb tide. The tidal creeks in the eastern Swale (Faversham Creek, Conyer Creek, and Windmill Creek) will fill with water originating from the east during the flood tide, and drain into the Swale Channel and be carried back in an easterly direction on the ebb tide. Any associated ebb plumes will tend to remain on the side of the channel to which they discharge, becoming progressively more dispersed. Contamination from Conyer Creek will be carried along the channel to the south of Fowley Island. There is some uncertainty about from which side Milton Creek is filled from and drains to as it lies roughly where the tides meet. It is quite likely that the exact spot where tides meet varies with tidal amplitude and meteorological conditions.

Tidal diamond D lies in about 3m of water approximately 4km off the north coast of Sheppey, and should be reasonably representative of tidal streams along this shoreline. Current velocities are slower than the other three diamonds which are located in well defined channels. Diamond D indicates bidirectional tidal streams here, which run parallel to the coast. Estimates of tidal excursion based on this diamond are about 8km on spring tides and 5km on neap tides. It is likely that current speeds become slower in shallower water and across the intertidal due to friction, and this is apparent in the model outputs. The model outputs also indicate that tidal streams do not run parallel to the coast of Sheppey around Leysdown, but flood and drain perpendicular to the shore at a slower rate. As already discussed, the ebb plume from the Medway will be of some impact at the eastern end of the north Sheppey coast, whereas any ebb plume from the Swale will tend to follow the channel in a north easterly direction, so its impacts will be largely confined to the outer edges of the Pollard and Columbine Spits.

In addition to tidally driven currents, are the effects of freshwater inputs and wind. There are several small freshwater inputs that discharge into the Swale and Sheppey. The flow ratio (freshwater input:tidal exchange) is likely to be low and so the system is likely to be well mixed (Futurecoast, 2002). The open coast to the north of Sheppey receives little in the way of freshwater inputs, is unenclosed and offers a high dilution potential. Density driven circulation is therefore unlikely to modify tidal circulation within the survey area. Repeated near surface salinity measurements were taken at seven points within the survey area between 2003 and 2013. Their locations are shown in Figure IX.1 and boxplots of these measurements are shown in Figure IX.3.

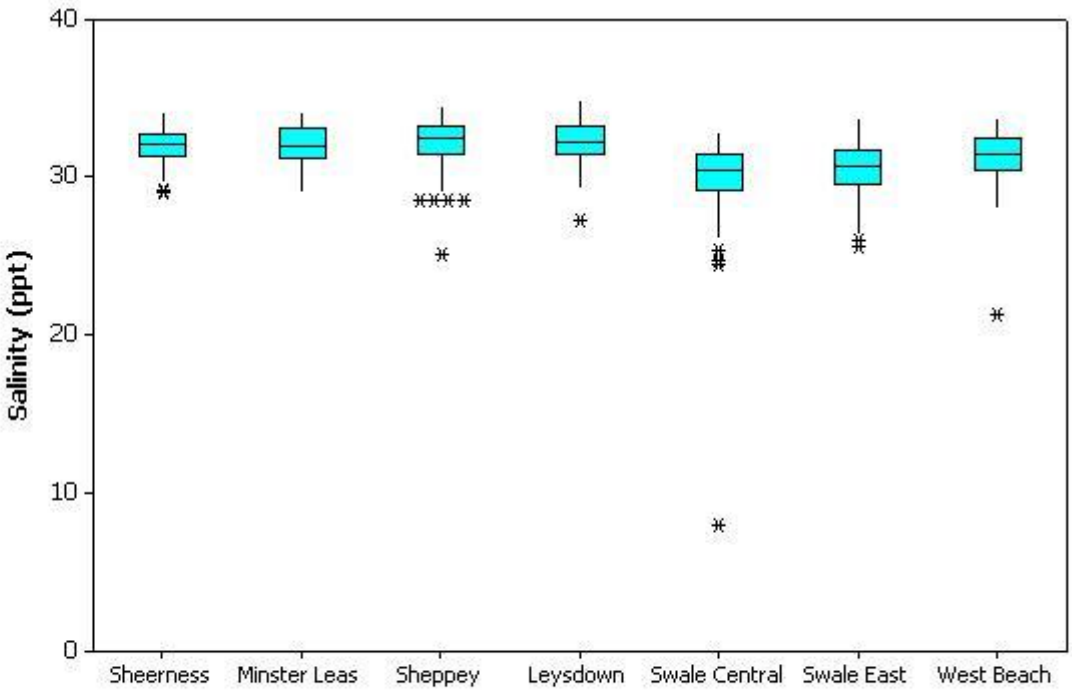


Figure IX.3:
Boxplot of salinity readings covering the periods 2003-13 (Sheppey, Swale Central and Swale East), 2007-2012 (Sheerness, Leysdown and West Beach) and 2010-2012 (Minster Leas)
Data from the Environment Agency

The geographical pattern of salinity is likely to reflect that of runoff borne contamination. Salinities were approaching that of full strength seawater at all seven locations confirming that density driven circulation is unlikely to be of significance. Unsurprisingly, salinities were slightly lower on average at the two locations within the enclosed Swale channel, suggesting that land runoff may be of greater influence here.

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so gale force wind (34 knots or 17.2 m/s) would drive a surface water current of around 0.5 m/s. These in turn create return currents which may travel lower in the water column or along sheltered margins. The prevailing south westerly winds will tend to push surface water in a north easterly direction. An easterly wind would tend to push surface water up the eastern part of the Swale channel. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be resuspended, although given the enclosed nature of the Swale strong wave action is not anticipated, however the east coast of the Isle of Sheppey will be quite exposed to wave action from the North Sea when winds blow from the north east quadrant.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

There are four bathing waters relevant to the survey area, designated under the Directive 76/160/EEC (Council of the European Communities, 1975). Due to changes in the analyses of bathing water quality by the Environment Agency from 2012, only data produced up to the end of 2011 was used in these analyses.

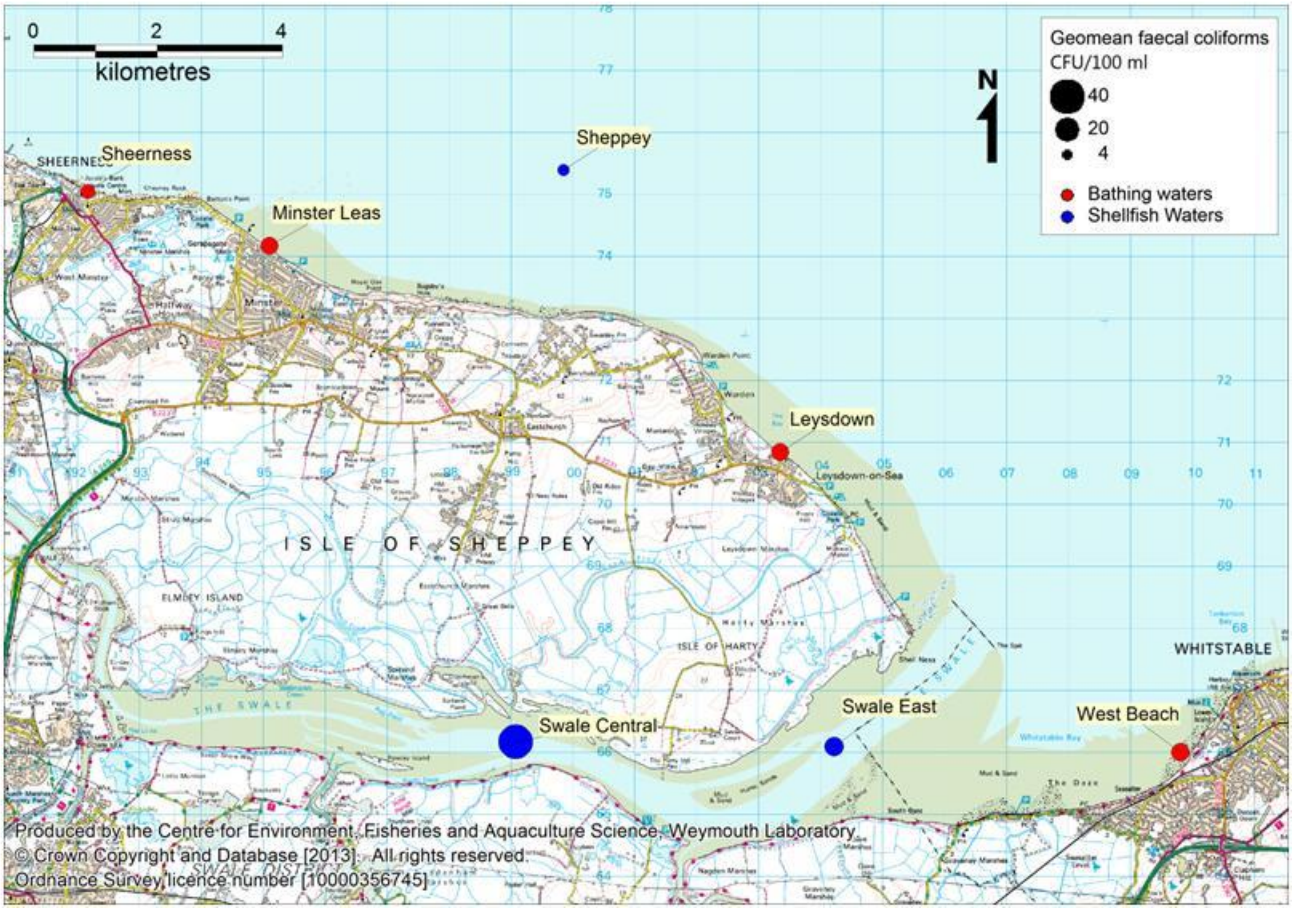


Figure X.1: Location of designated bathing waters and shellfish waters monitoring points.

Around twenty water samples were taken from each of the bathing waters sites during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms were enumerated in all these samples. Summary statistics of all results by bathing water are presented in

Table X.1, and Figure X.2 presents box plots of these data.

Table X.1: Summary statistics for bathing waters faecal coliforms results, 2003-2011 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
Sheerness	187	07/05/2003	19/09/2011	9.1	2	1,296	7.0	0.5	0.0
Minster Leas	40	04/05/2010	19/09/2011	11.8	2	936	7.5	0.0	0.0
Leysdown	182	07/05/2003	19/09/2011	12.4	1	27,000	10.4	2.2	0.5
West Beach	182	07/05/2003	19/09/2011	12.6	2	2,800	12.1	1.1	0.0

Data from the Environment Agency

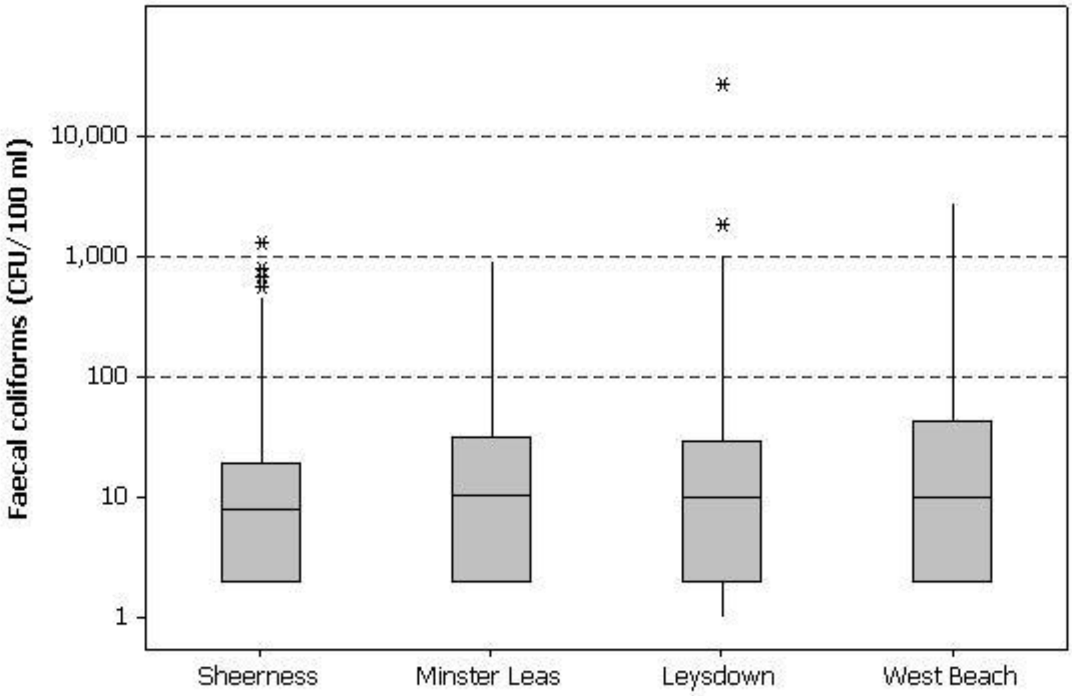


Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
Data from the Environment Agency

All sites had results exceeding 100 faecal coliforms/100 ml. While West Beach had the highest geometric mean of faecal coliforms cfu/100 ml, Leysdown had the highest individual result of 27,000 cfu/100 ml and had the greatest proportion of results over 1,000 cfu/100 ml. While there appears to be a slight trend of increasing faecal coliform levels from west to east, one-way ANOVAs show that there are no significant differences between faecal coliform levels between sites ($p = 0.173$).

Comparisons of sites were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. There were significant correlations ($p < 0.05$) between all site pairings, suggesting that they are all influenced by similar sources.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at bathing water sites sampled for two years or longer is shown in Figure X.3.

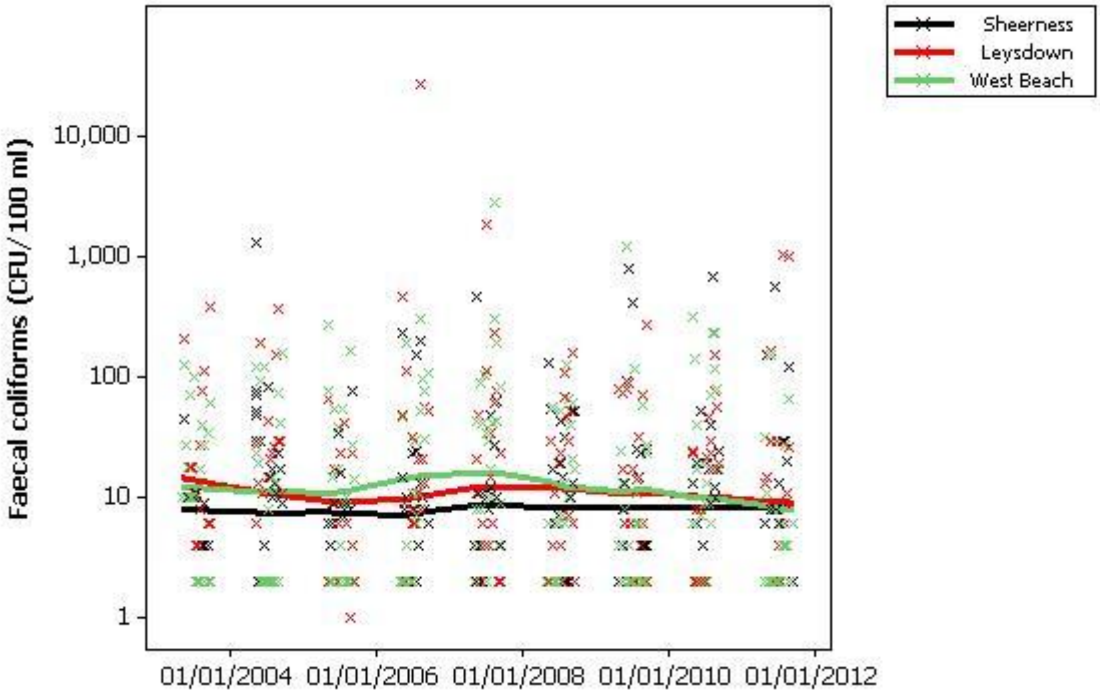


Figure X.3: Scatterplot of faecal coliform results for bathing waters overlaid with loess lines.
Data from the Environment Agency

Faecal coliform levels have remained stable at all bathing waters sites since 2003.

Influence of tides

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 X.2, with statistically significant correlations highlighted in yellow.

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Sheerness	0.319	<0.001	0.242	<0.001
Minster Leas	0.380	0.005	0.298	0.037
Leysdown	0.390	<0.001	0.403	<0.001
West Beach	0.360	<0.001	0.306	<0.001

Data from the Environment Agency

Correlations were found for both tidal cycles at all four sites. Figure X.4 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle.

High water 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.

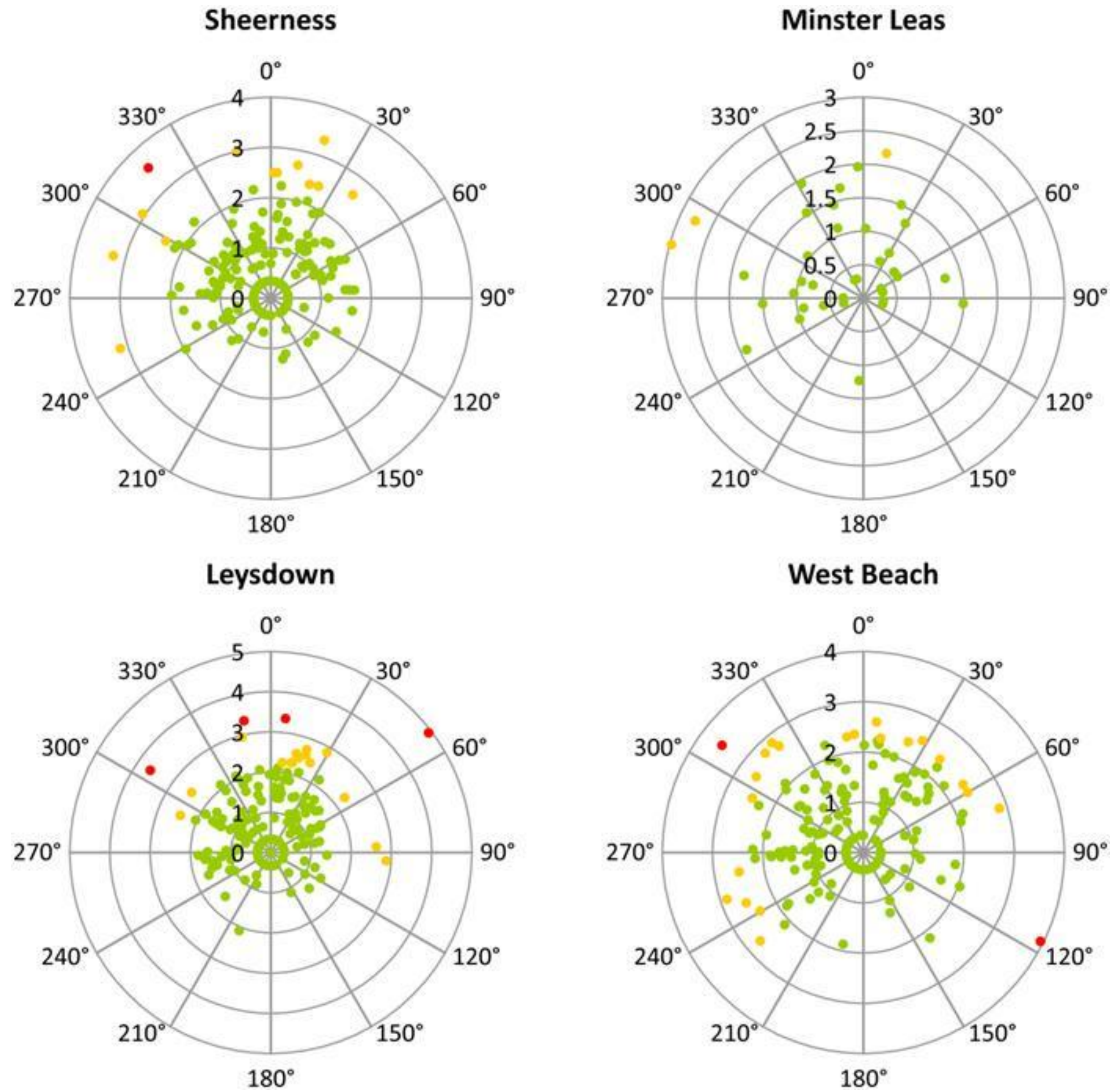


Figure X.4: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At all four sites, the higher results tended to arise during the higher states of the tide.

Figure X.5 presents polar plots of faecal coliform results against the lunar spring/neap cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

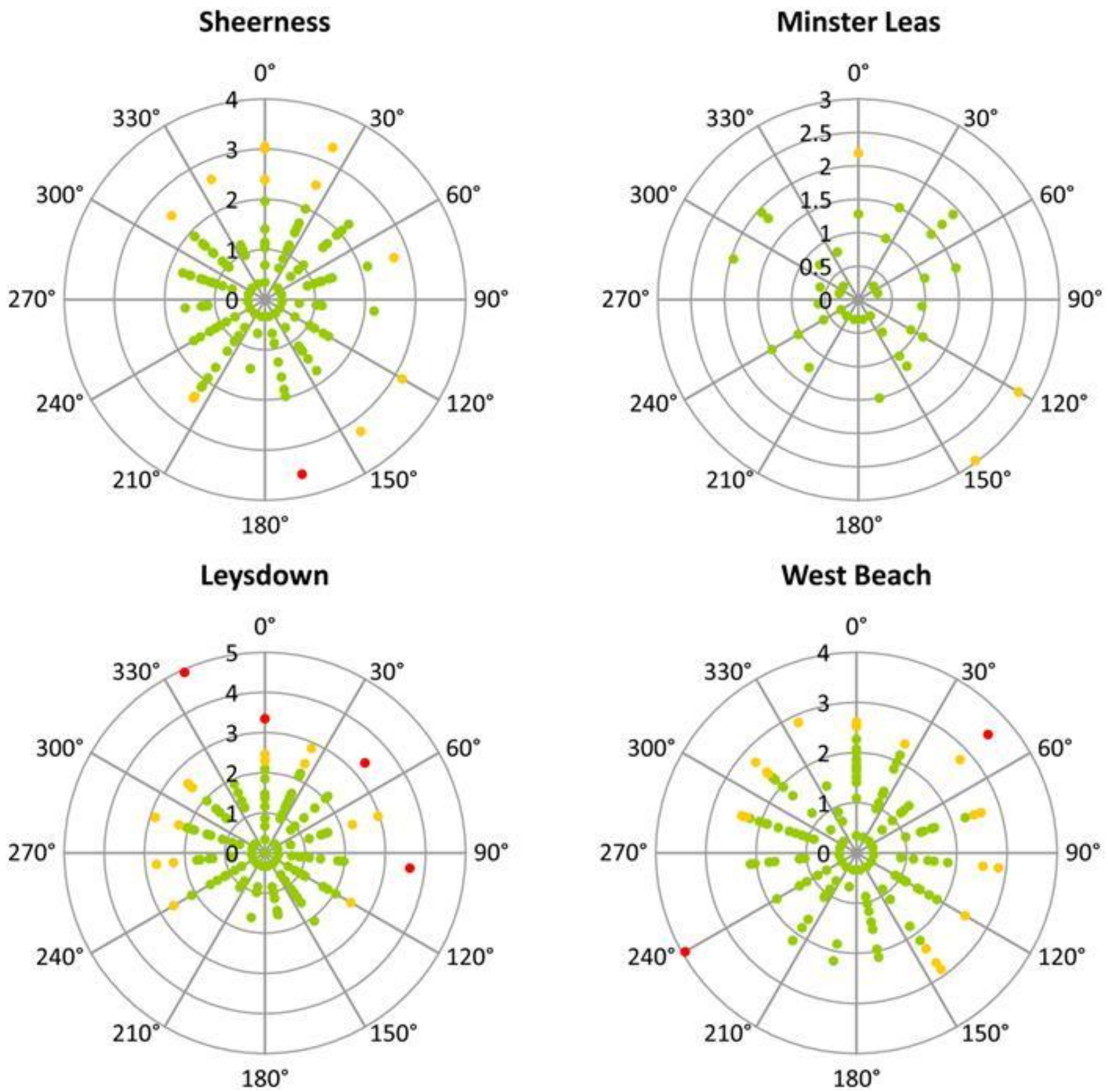


Figure X.5: Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At Leysdown, lower results tended to occur just before the neap tide. At Sheerness, Minster Leas and West Beach, lower results tended to occur around the neap tide.

Influence of Rainfall

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 Sheerness Golf Course weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.3: Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

Site		Sheerness	Minster Leas	Leysdown	West Beach
n		183	40	182	182
24 hour periods prior to sampling	1 day	0.189	0.101	0.230	0.124
	2 days	0.132	0.223	0.187	0.211
	3 days	0.119	0.196	0.139	0.096
	4 days	0.056	0.002	-0.021	0.151
	5 days	0.086	0.027	0.068	0.153
	6 days	0.125	-0.017	-0.004	0.061
	7 days	0.067	-0.061	0.096	0.060
Total prior to sampling over	2 days	0.168	0.208	0.219	0.214
	3 days	0.184	0.340	0.255	0.213
	4 days	0.164	0.291	0.215	0.203
	5 days	0.214	0.329	0.227	0.227
	6 days	0.229	0.325	0.244	0.229
	7 days	0.221	0.312	0.235	0.226

Data from the Environment Agency

Faecal coliform levels at all four bathing water sites are influenced by rainfall to some extent. The influence was weaker at Minster Leas, but whether this was a consequence of its location or the lower number of samples taken is uncertain.

X.2. Shellfish Waters

Summary statistics and geographical variation

There are three shellfish waters monitoring sites designated under Directive 2006/113/EC (European Communities, 2006) around the Isle of Sheppey and the Swale. Figure X.1 shows the location of these sites. Table X.4 presents summary statistics for bacteriological monitoring results and Figure X.6 presents a boxplot of faecal coliform levels from the monitoring point.

Table X.4: Summary statistics for shellfish waters faecal coliform results, 2003 to 2013 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Sheppey	50	05/02/2003	07/04/2013	5.5	2	381	2.0	0.0
Swale Central	47	05/02/2003	11/04/2013	39.1	2	1760	31.9	2.1
Swale East	47	05/02/2003	11/04/2013	14.6	2	277	12.8	0.0

Data from the Environment Agency

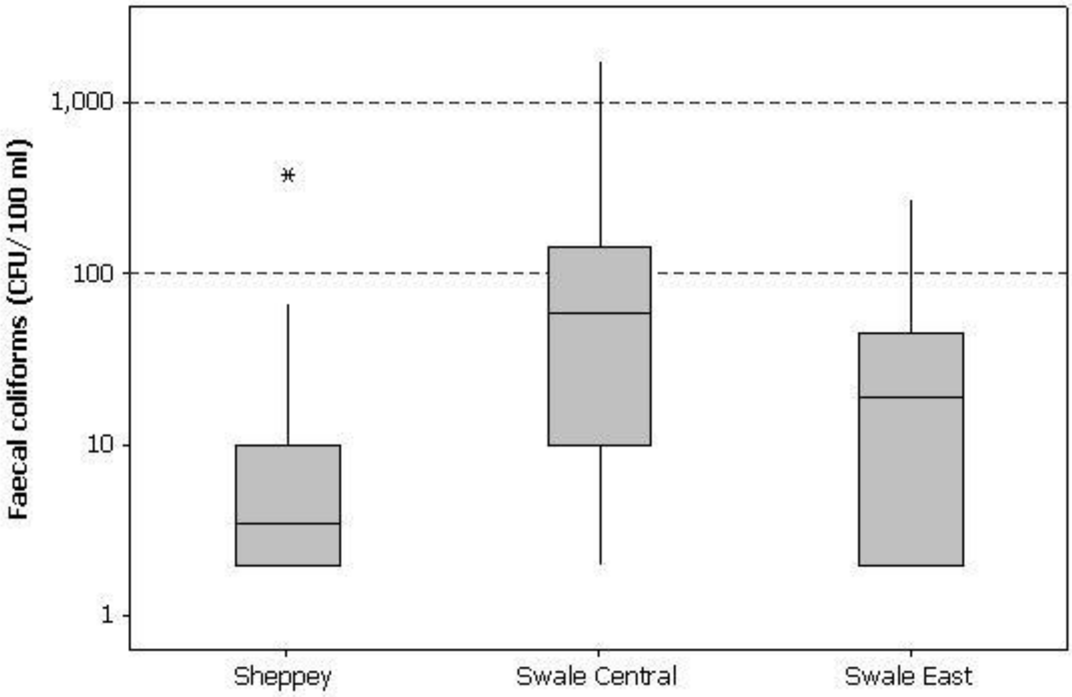


Figure X.6: Box-and-whisker plots of all faecal coliforms results
Data from the Environment Agency

All sites had samples with more than 100 faecal coliform cfu/100 ml, however Swale Central was the only site to have samples that exceeded 1,000 cfu/100 ml. One-way ANOVA tests showed that there were significant differences in faecal coliform levels between sites ($p < 0.001$). Post ANOVA Tukey tests showed that the Swale Central and Swale East had higher faecal coliform levels than Sheppey, and Swale Central had higher faecal coliform levels than Swale East.

Comparisons of sites were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. Results from Swale Central and Swale East significantly correlated suggesting that these sites are similar contamination sources. Sheppey did not correlate with either of the other sites, suggesting that contamination sources here are separate from the two other sites.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at shellfish water sites over time is shown in Figure X.7.

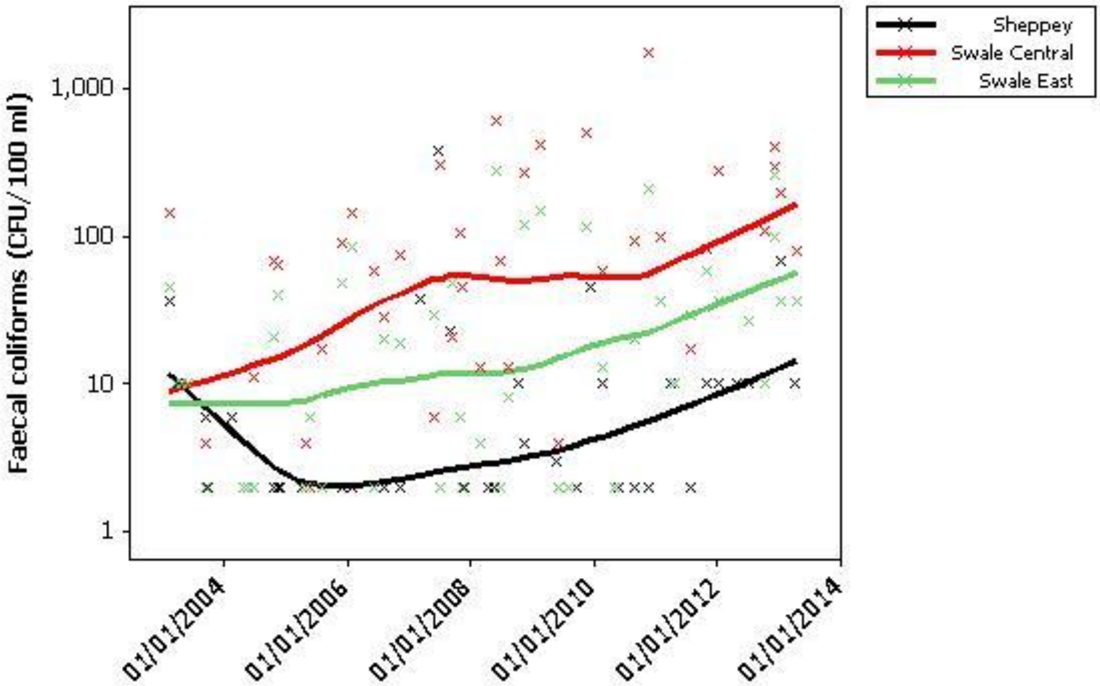


Figure X.7: Scatterplot of faecal coliform results by date, overlaid with loess lines
Data from the Environment Agency

In 2003 all three sites had similar levels of faecal coliforms. From 2003 to 2005, faecal coliform levels at Sheppey declined. Since 2005, faecal coliform levels have been increasing at all sites.

Seasonal patterns of results

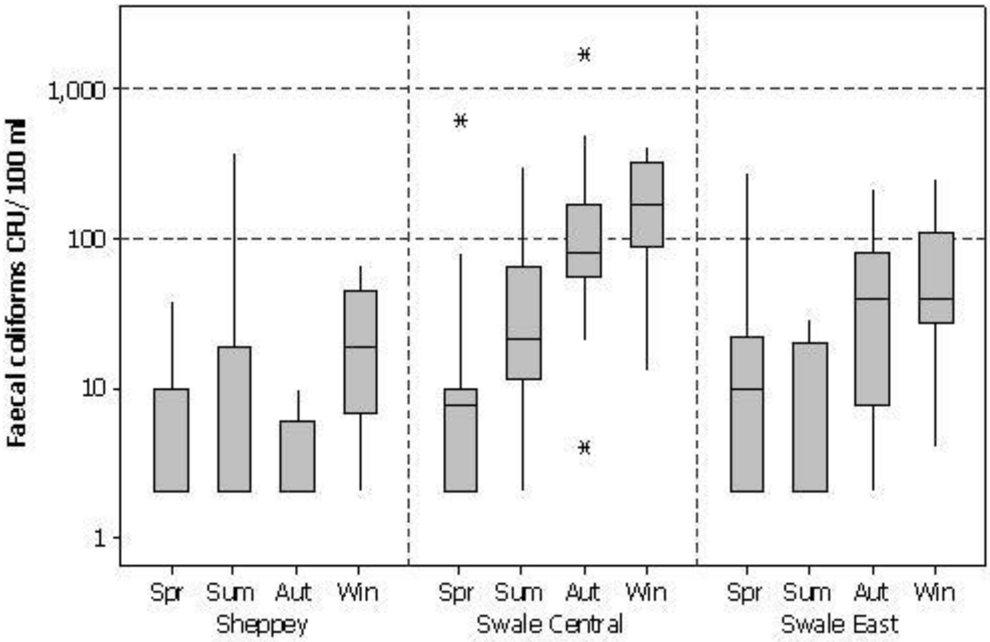


Figure X.8: Boxplot of faecal coliform results by site and season
Data from the Environment Agency

All monitoring points showed a tendency for highest results during the winter months. Comparisons (One-way ANOVA) of faecal coliform levels revealed that there were significant differences between seasons at all three sites (p = 0.013, <0.001 and 0.002 at Sheppey, Swale Central and Swale East respectively). Post ANOVA Tukey tests showed that at Sheppey, faecal coliform levels were higher in winter than in autumn. At Swale Central, faecal coliform levels were higher in autumn and winter than spring and higher in winter than in summer. At Swale East, faecal coliform levels were higher in winter and autumn than in summer and higher in winter than in spring.

Influence of tide

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 shellfish waters sampling points. Correlation coefficients are presented in Table X.5, with statistically significant correlations highlighted in yellow.

Table X.5: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Sheppey	0.315	0.009	0.179	0.221
Swale Central	0.351	0.004	0.277	0.034
Swale East	0.472	0.000	0.360	0.003

Data from the Environment Agency

Figure X.9 presents polar plots of log_{10} faecal coliform results against tidal states on the high/low cycle. High water 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.

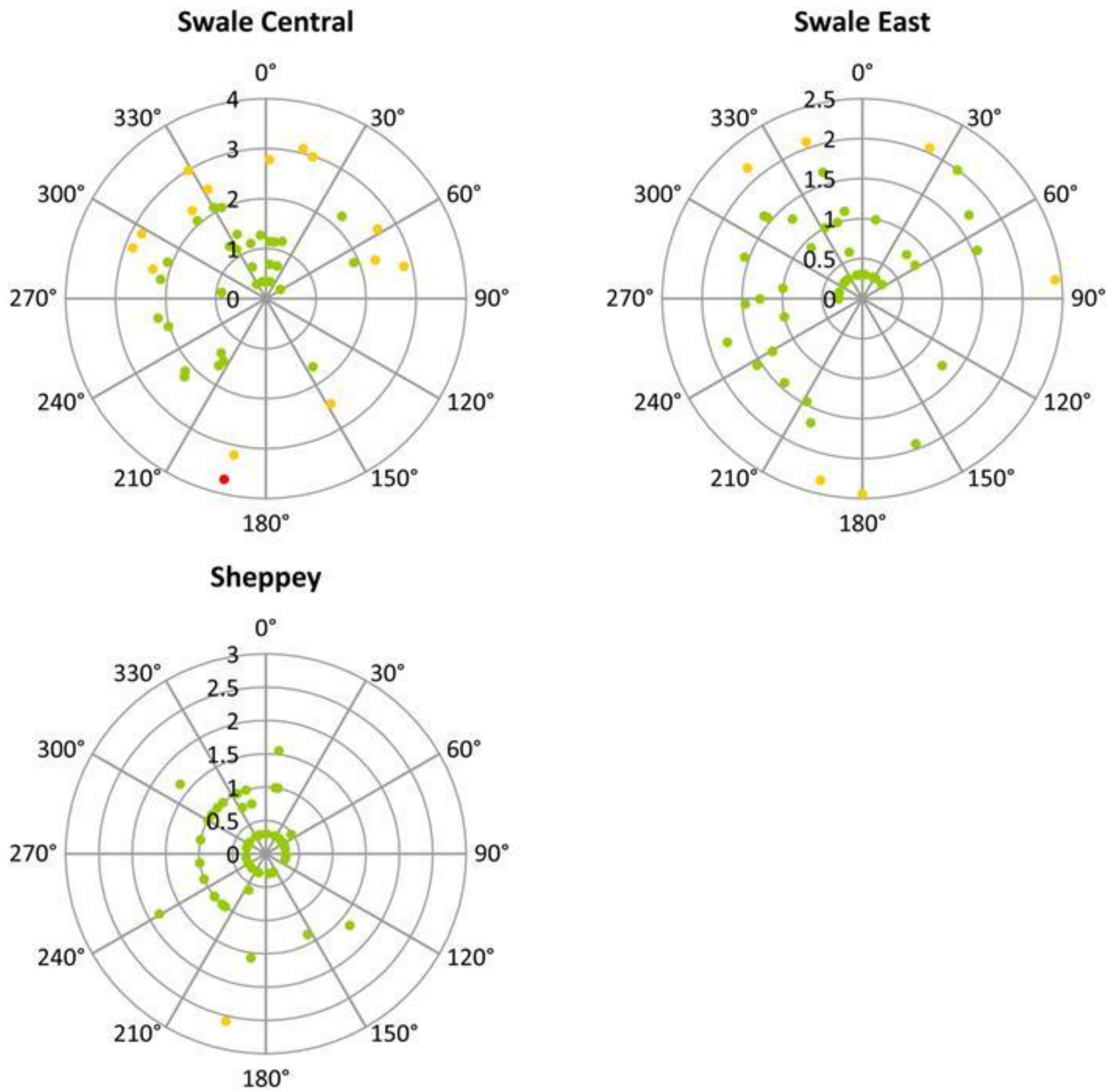


Figure X.9: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for shellfish waters monitoring points with significant correlations
Data from the Environment Agency

At Swale Central and Swale East, the lowest results tended to occur at higher states of the tide. At Sheppey, most results were very low during the ebb tide, with some slightly higher results arising during the flood tide.

Figure X.10 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.

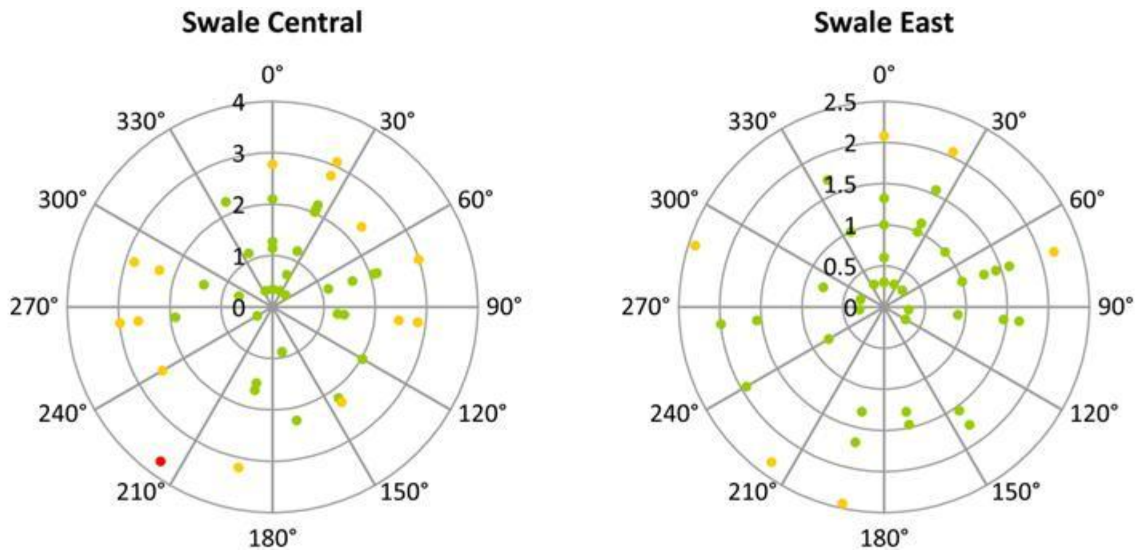


Figure X.10: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At Swale Central, the correlation was weak and no pattern is apparent in the polar plot. At Swale East results tentatively appear slightly higher on average around neap tides.

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Sheerness Golf Course weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.6 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

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

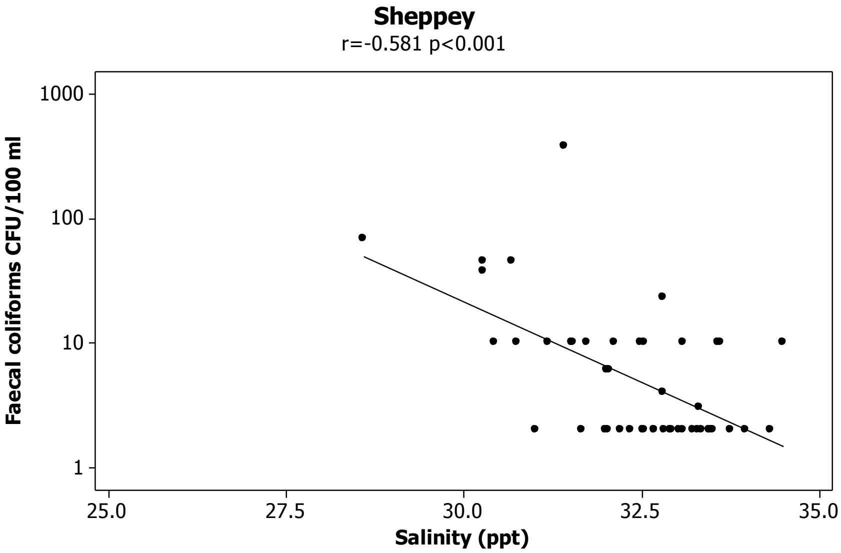
	Site	Sheppey	Swale Central	Swale East
	n	47	46	46
24 hour periods prior to sampling	1 day	-0.058	-0.017	-0.180
	2 days	-0.108	0.209	0.011
	3 days	-0.068	0.263	0.291
	4 days	0.019	0.410	0.467
	5 days	0.032	0.507	0.535
	6 days	0.425	0.442	0.193
	7 days	0.073	0.387	0.213
Total prior to sampling over	2 days	-0.144	0.276	0.048
	3 days	-0.150	0.242	0.173
	4 days	-0.137	0.299	0.228
	5 days	-0.055	0.338	0.289
	6 days	0.113	0.378	0.305
	7 days	0.152	0.422	0.340

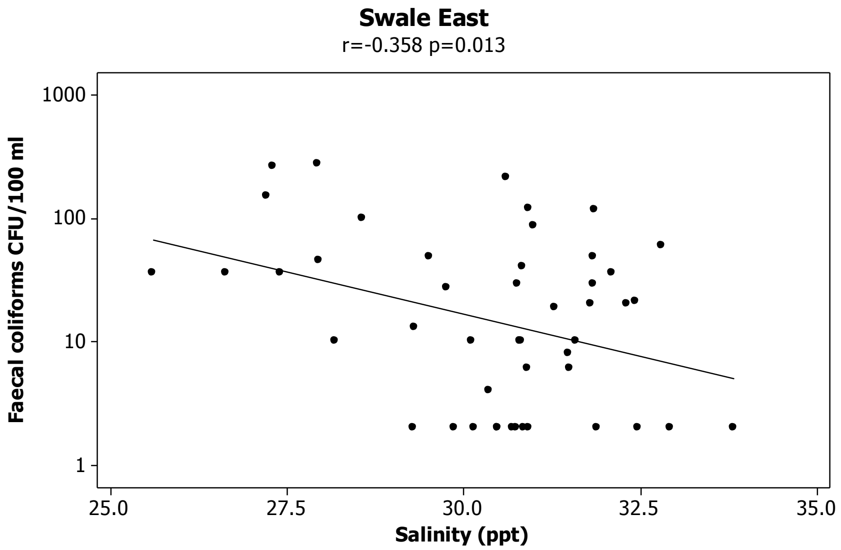
Data from the Environment Agency

The influence of rainfall was weakest at Sheppey, where little if any effect was apparent. Both sites in the Swale showed some influence of rainfall, and this was slightly stronger at Swale Central.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.11 shows scatter-plots of those sites with significant correlations between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at shellfish waters sites.





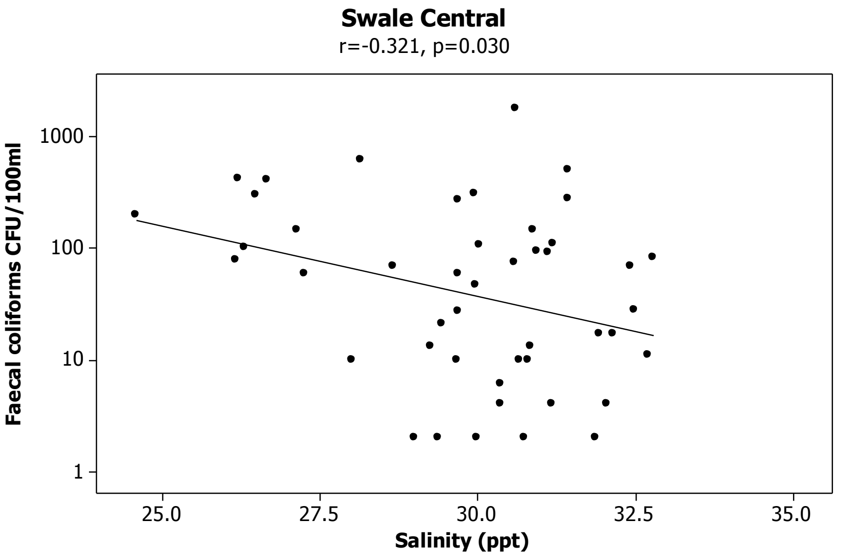


Figure X.11: Scatter-plots of salinity against faecal coliforms.
Data from the Environment Agency

There were significant correlations between faecal coliform levels and salinity at all three monitoring points. Surprisingly, this was weakest at Swale Central and strongest at Sheppey.

Appendix XI. Microbiological Data: Shellfish Flesh Hygiene

XI.1. Summary statistics and geographical variation

There are a total of seven RMPs in the Swale that have been sampled between 2003 and 2013; one cockle, four mussel, one native oyster and one Pacific oyster. In the part of the Thames estuary production area which is relevant to this report, there are a total of five RMPs that have been sampled between 2003 and 2013; two cockle and three mussel RMPs. All RMPs west of Whitstable in the North Kent Coast production area will be included to allow geographical patterns to be assessed. There are a total of 12 RMPs in the North Kent Coast production area relevant to this report that have been sampled between 2003 and 2013; four cockle, three mussel, three native oyster and two Pacific oyster.

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.1 to Figure XI.4. Summary statistics are presented in Table XI.1 and boxplots for those sites with 10 or more samples are shown in Figure XI.5 to Figure XI.8.

Figure XI.1: Cockle RMPs active since 2003

Figure XI.2: Mussel RMPs active since 2003

Figure XI.3: Native oyster RMPs active since 2003

Figure XI.4: Pacific oyster RMPs active since 2003

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

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Scrapsgate	Cockle	45	14/01/2003	05/06/2007	162.5	<20	3500	33.3	0.0
Minster Car Park	Cockle	2	14/01/2003	23/04/2003	697.1	90	5400	50.0	50.0
Kentish Flats	Cockle	1	09/05/2005	09/05/2005	310.0	310	310	100.0	0.0
Ham Ground	Cockle	1	16/05/2005	16/05/2005	10.0	<20	20	0.0	0.0
Swale BC/7	Cockle	107	11/03/2003	11/09/2013	757.6	40	9200	78.5	7.5
Pollard 2	Cockle	9	12/02/2013	08/10/2013	362.0	<20	5400	55.6	11.1
Pollard	Cockle	66	24/11/2003	14/01/2013	593.1	20	16000	68.2	7.6
Minster Car Park	Mussel	6	13/03/2003	02/12/2003	119.2	40	750	33.3	0.0
Pollard	Mussel	7	17/01/2005	11/05/2009	97.6	40	750	14.3	0.0
Sheppey Barton Point	Mussel	118	14/01/2003	25/09/2013	85.0	<20	16000	23.7	0.8
Minster Foreshore	Mussel	5	09/06/2003	22/03/2004	426.2	110	1100	80.0	0.0
Swale BC/1	Mussel	107	11/03/2003	11/09/2013	782.9	40	16000	82.2	18.7
Swale BC/2	Mussel	19	11/03/2003	01/03/2005	421.8	90	3500	63.2	0.0
Swale BC/6	Mussel	106	11/03/2003	11/09/2013	368.9	<20	24000	67.9	4.7
Swale BC/8	Mussel	105	11/03/2003	11/09/2013	246.0	<20	28000	46.7	4.8
South Oaze 2	Mussel	7	16/04/2013	08/10/2013	193.1	50	1700	42.9	0.0
South Oaze	Mussel	65	12/11/2003	12/11/2012	220.4	20	3100	46.2	0.0
Pollard	Native oyster	2	15/12/2003	09/02/2004	147.3	70	310	50.0	0.0
Swale BC/4	Native oyster	89	11/03/2003	11/09/2013	457.5	20	24000	68.5	4.5
Whitstable Bay	Native oyster	5	11/02/2013	18/09/2013	39.6	<20	220	0.0	0.0
Whitstable Oyster Co.	Native oyster	58	17/11/2003	12/12/2012	66.1	<20	1700	13.8	0.0
Pollard	Pacific oyster	101	24/11/2003	14/01/2013	141.2	<20	9100	35.6	2.0
Swale BC/4	Pacific oyster	1	16/10/2003	16/10/2003	500.0	500	500	100.0	0.0
Whitstable Oyster Co.	Pacific oyster	72	17/11/2003	25/09/2012	47.6	<20	5400	18.1	1.4

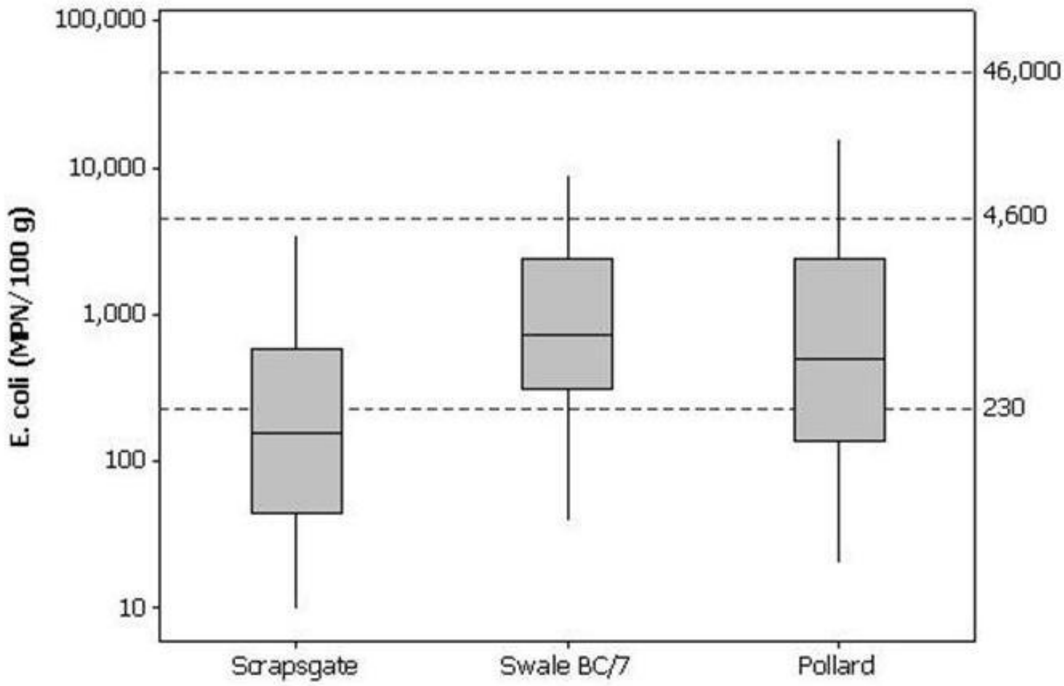


Figure XI.5: Boxplots of *E. coli* results from cockle RMPs from 2003 onwards.

E. coli levels exceeded 230 MPN/100 g at all cockle RMPs with 10 or more samples. *E. coli* levels did not exceed 4,600 MPN/100g in more than 10% of samples and site, and no samples exceeded 46,000 *E. coli* MPN/100g at any site. One way ANOVA tests showed that there was a significant difference in *E. coli* levels between cockle sites (p<0.001) and post ANOVA Tukey tests revealed that Scrapsgate had lower levels of *E. coli* than Swale BC/7 and Pollard.

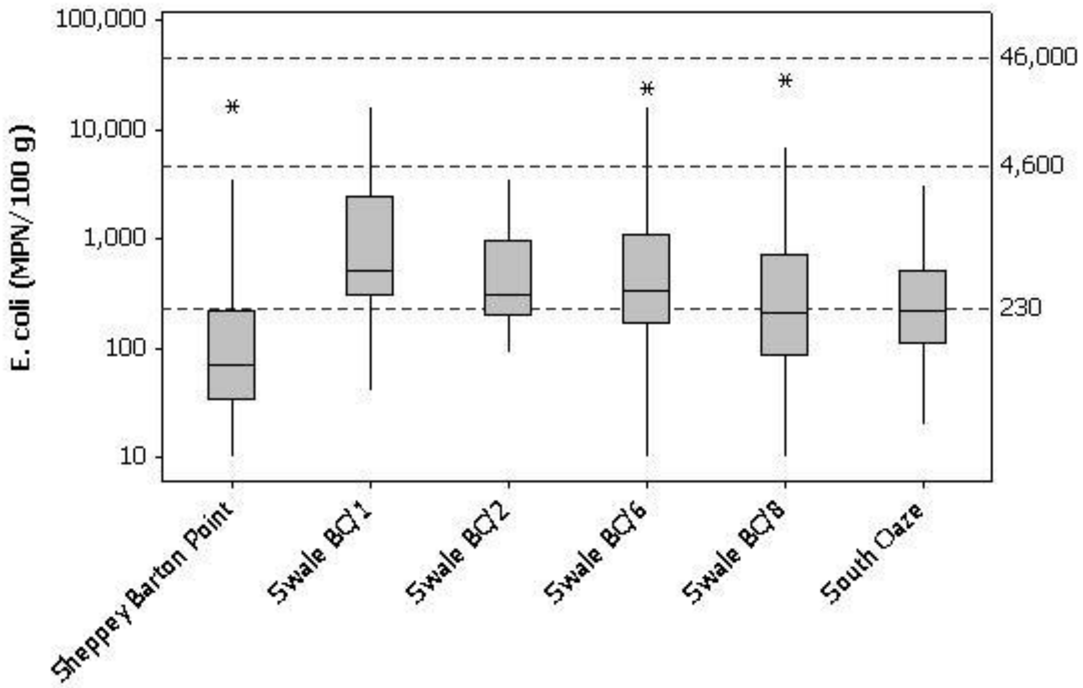


Figure XI.6: Boxplots of *E. coli* results from mussel RMPs from 2003 onwards.

E. coli levels exceeded 230 MPN/100 g at all mussel RMPs with 10 or more samples. *E. coli* levels only exceeded 4,600 MPN/100g in more than 10% of samples at Swale BC/1 (18.7%), and no samples exceeded 46,000 *E. coli* MPN/100g at any site. One way ANOVA tests showed that there was a significant difference in *E. coli* levels between mussel sites ($p < 0.001$) and post ANOVA Tukey tests revealed that Sheppey Barton Point had lower levels of *E. coli* than all other sites. Swale BC/1 had higher levels of *E. coli* than all sites except Swale BC/2.

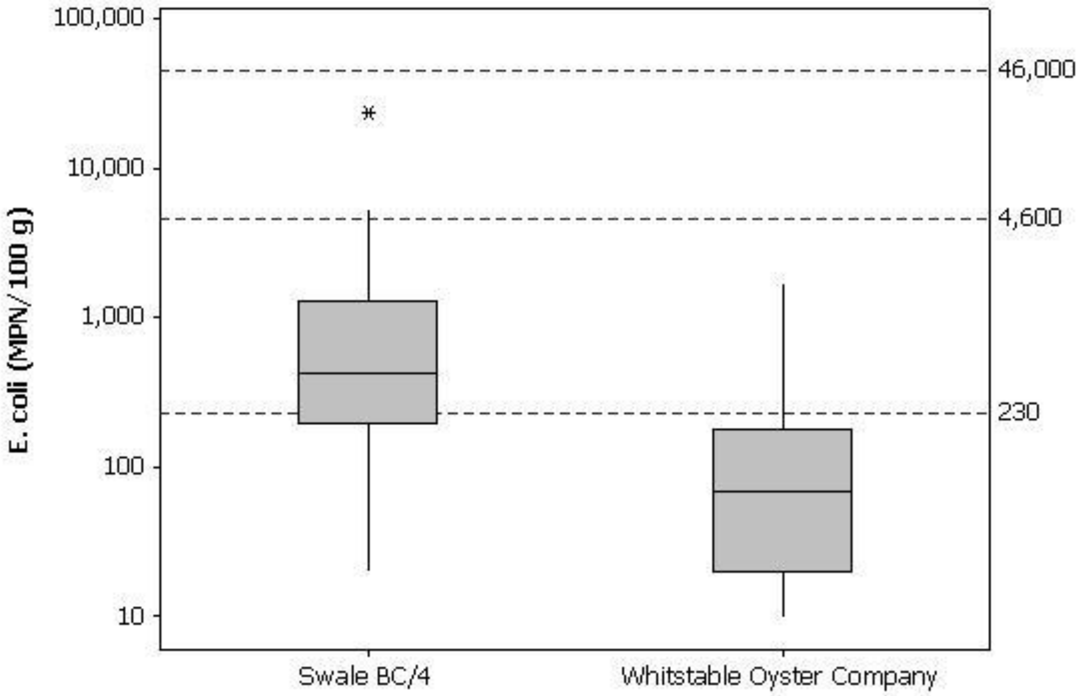


Figure XI.7: Boxplots of *E. coli* results from native oyster RMPs from 2003 onwards.

E. coli levels exceeded 230 MPN/100g at all native oyster RMPs with 10 or more samples. *E. coli* levels did not exceed 4,600 MPN/100g in more than 10% of samples at any site, and no samples exceeded 46,000 *E. coli* MPN/100g at any site. A two sample T-test showed that Swale BC/4 had significantly higher *E. Coli* levels than Whitstable Oyster Company ($p < 0.001$).

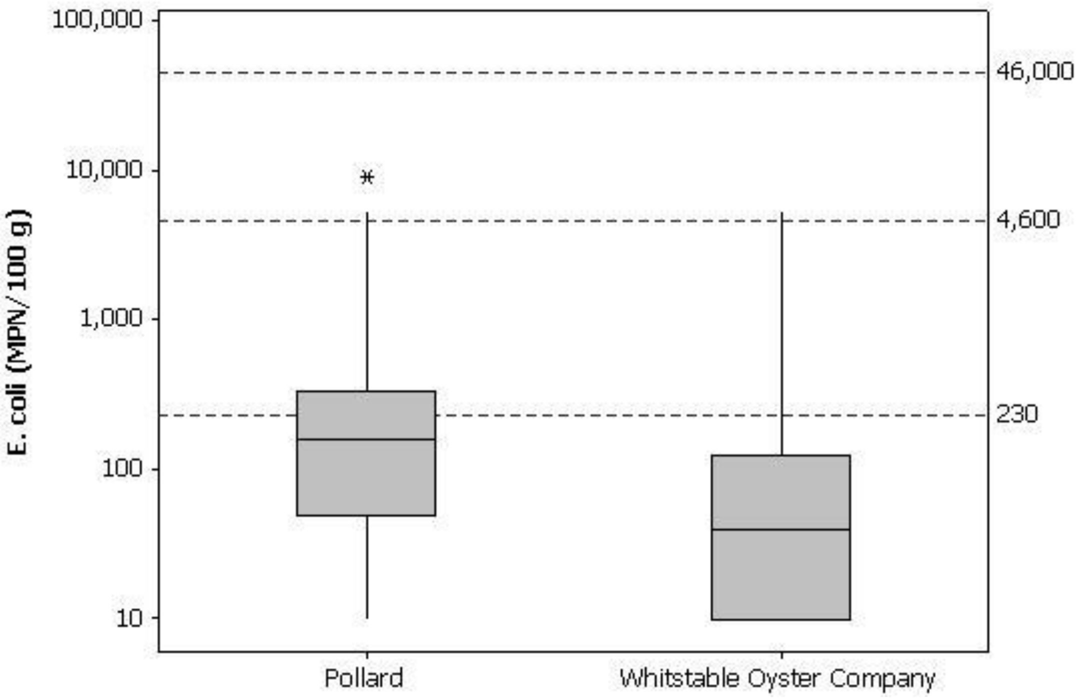


Figure XI.8: Boxplots of *E. coli* results from Pacific oyster RMPs from 2003 onwards.

E. coli levels exceeded 230 MPN/100g at all Pacific oyster RMPs with 10 or more samples. *E. coli* levels did not exceed 4,600 MPN/100g in more than 10% of samples at any site, and no samples exceeded 46,000 *E. coli* MPN/100g at any site. A two sample T-test showed that there were significantly higher levels of *E. coli* at Pollard than at Whitstable Oyster Company ($p < 0.001$).

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. There were not enough matching sampling days between any cockle, native oyster and Pacific oyster sites for correlations to be run. For mussels, correlations could only be run between Swale BC/1, Swale BC/2, Swale BC/6 and Swale BC/8. Swale BC/1 correlated significantly with Swale BC/2 and Swale BC/6. However Swale BC/6 did not correlate significantly with Swale BC/2. Additionally there were significant correlations between Swale BC/8 and Swale BC/6 which are both at the eastern end of the Swale. These results suggest that these sites share similar contamination sources.

XI.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves at sites sampled for two years or longer is shown in Figure XI.9 to Figure XI.12.

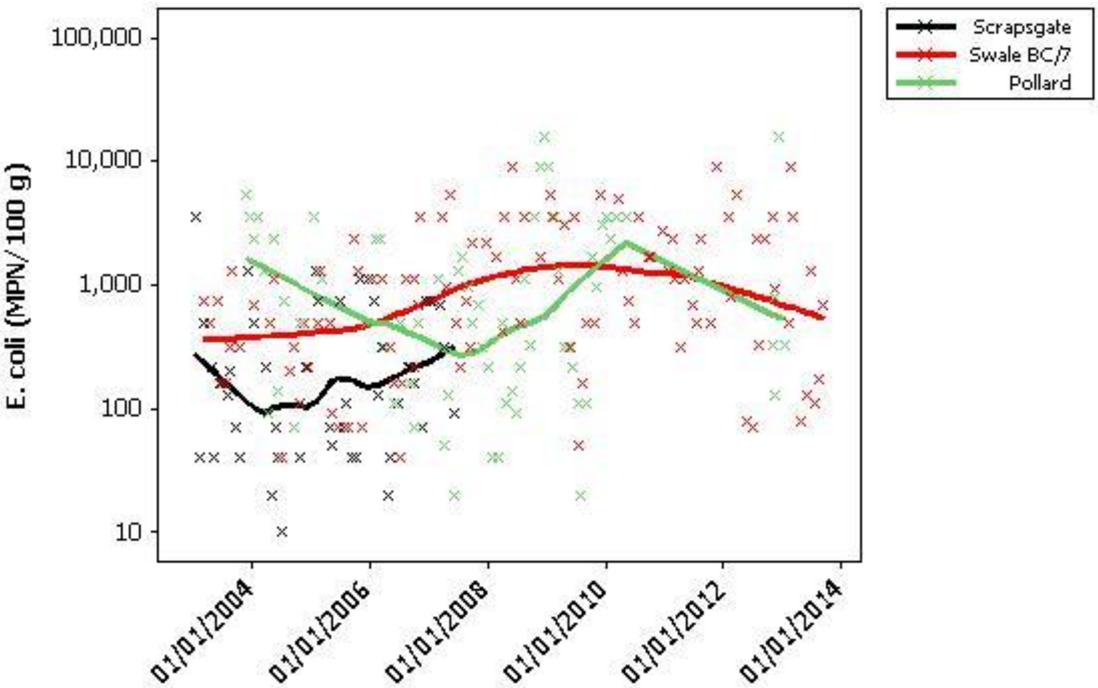


Figure XI.9: Scatterplot of *E. coli* results for cockles overlaid with loess lines.

E. coli levels in cockles increased at Swale BC/7 from 2006 to 2010 but appear to have been declining since. At Pollard, *E. coli* levels increased between 2007 and 2010 and began to decline until January 2013.

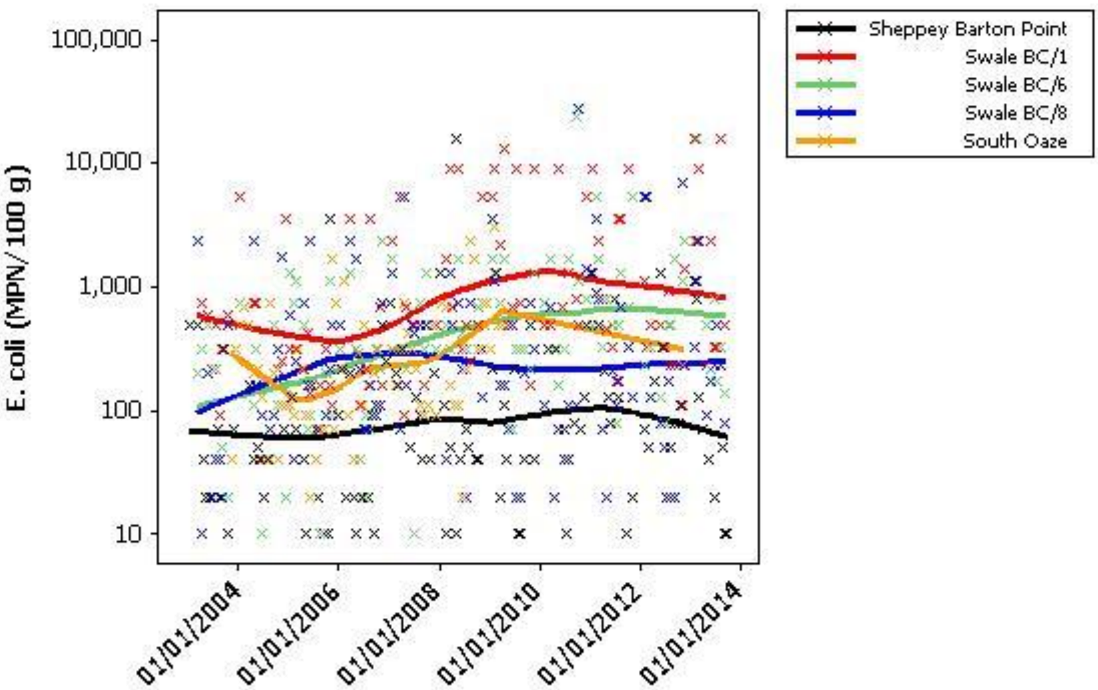


Figure XI.10: Scatterplot of *E. coli* results for mussels overlaid with loess lines.

E. coli levels at most mussel RMPs have remained stable since 2003. At South Oaze, there was an increase of almost an order of magnitude between 2005 and 2009 but levels remained stable after this time until the end of sampling in November 2012.

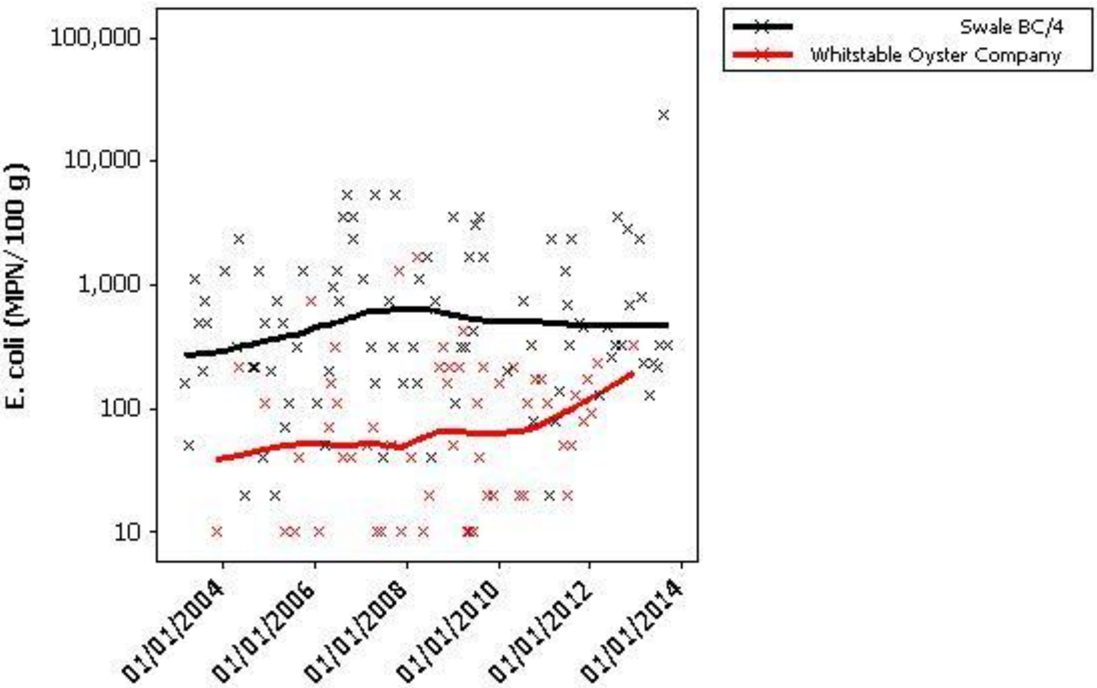


Figure XI.11: Scatterplot of *E. coli* results for native oysters overlaid with loess lines.

At Whitstable Oyster Company, levels of *E. coli* in native oysters remained stable from 2004 to 2010 when there was an increase until the end of sampling in December 2012. At Swale BC/4, *E. coli* levels have remained stable since 2003.

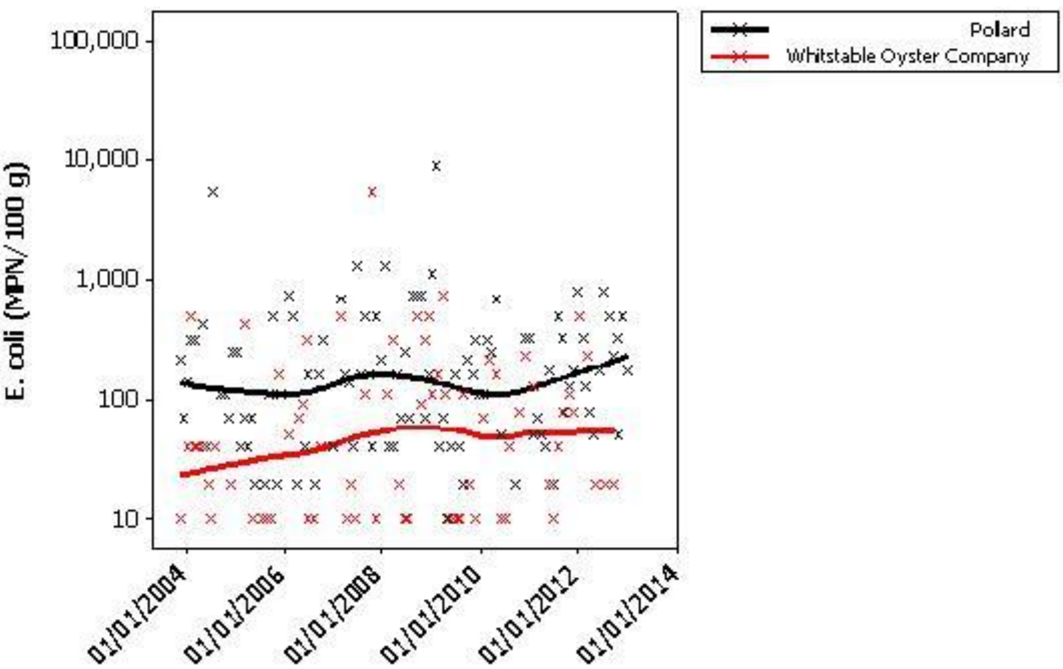


Figure XI.12: Scatterplot of *E. coli* results for Pacific oysters overlaid with loess lines.

E. coli levels in Pacific oysters sampled at both Pollard and Whitstable oyster Company remained relatively stable between 2003 and the end of sampling in January 2013 and September 2012 respectively.

XI.3. Seasonal patterns of results

The seasonal patterns of results from 2003 to 2013 were investigated by species and RMP. Figure XI.13 to Figure XI.16 show the variation in *E. coli* levels between seasons at different RMPs sampled for two years or longer.

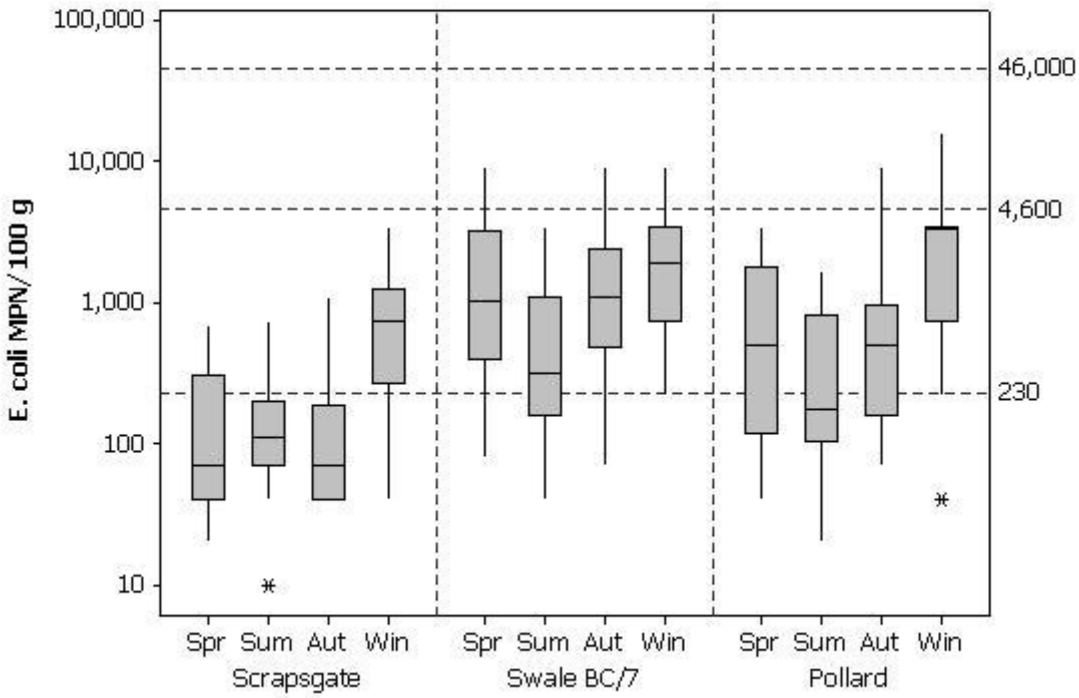


Figure XI.13: Boxplot of *E. coli* results in cockles by RMP and season

At all cockle RMPs tested (One-way ANOVA), there were significant differences in *E. coli* levels between seasons (p <0.001 to 0.001). Post ANOVA Tukey tests showed that at Scrapsgate and Pollard, there were higher levels of *E. coli* found in winter than during any other season. At Swale BC/7 *E. coli* levels were lower in summer than any other season.

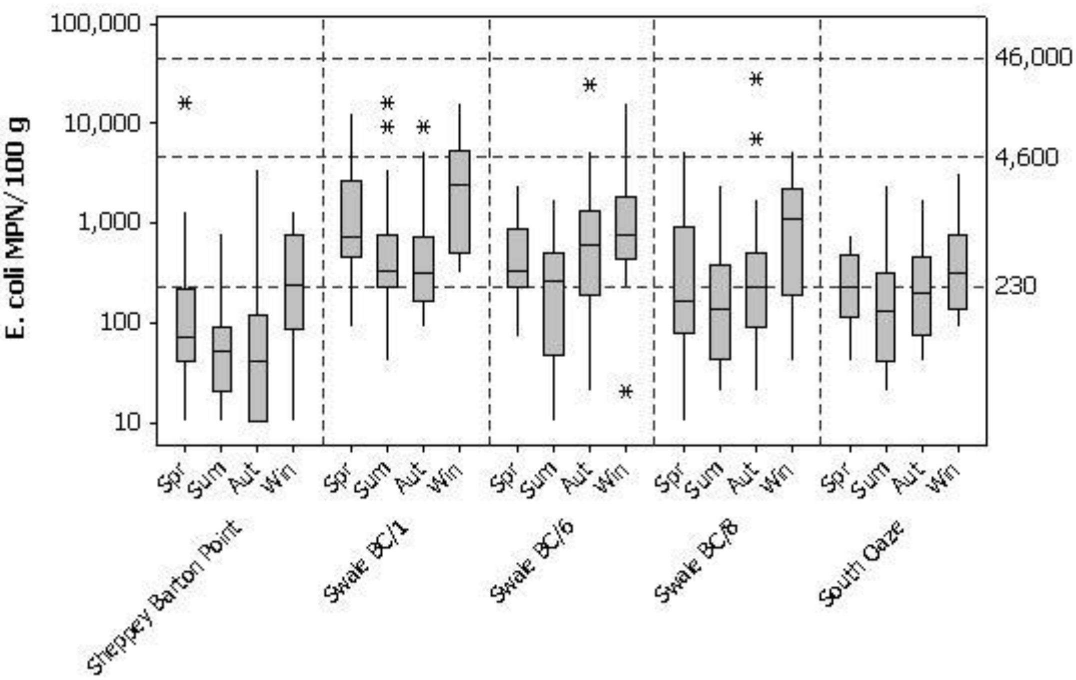


Figure XI.14: Boxplot of *E. coli* results in mussels by RMP and season

One way ANOVA tests showed that other than South Oaze (p = 0.099), there were significant differences in *E. coli* levels between seasons at all mussel sites tested (p<0.001 to 0.004). Post ANOVA Tukey tests showed that at Sheppey Barton Point, *E. coli* levels were higher in winter than during summer and autumn. At Swale BC/1 *E. coli* levels were higher in spring and winter than during summer and autumn. At Swales BC/6, *E. coli* levels were higher winter *E. coli* levels were higher than in spring and summer; and spring and autumn levels were higher than the summer. At Swale BC/8 *E. coli* levels were higher in winter than summer.

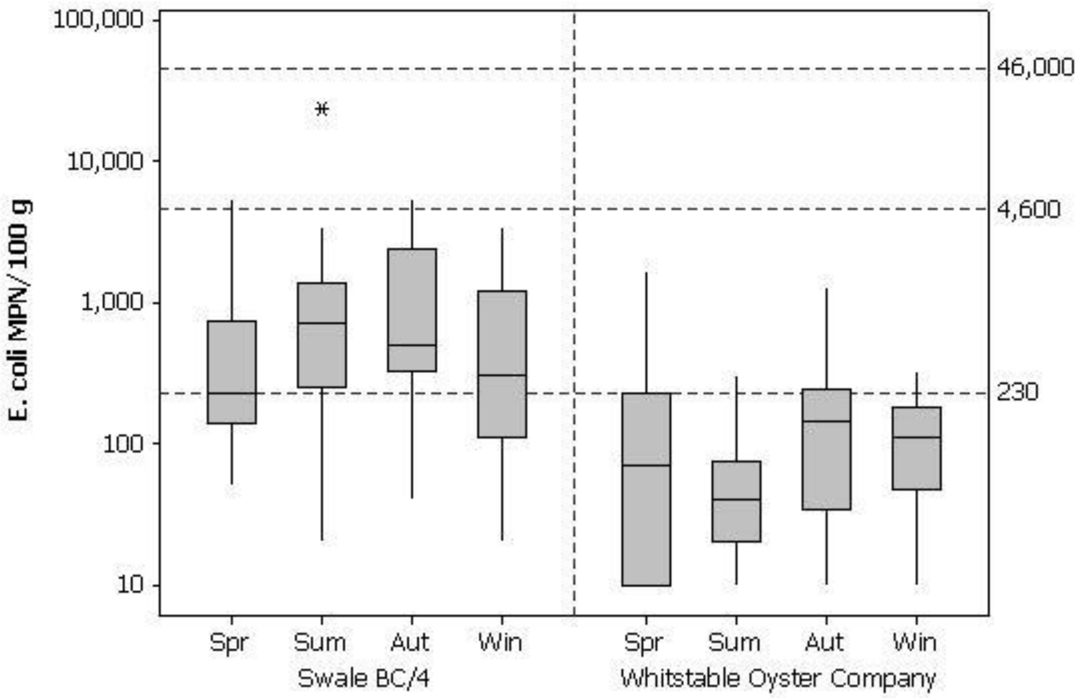


Figure XI.15: Boxplot of *E. coli* results in native oysters by RMP and season

One way ANOVA tests showed that there were no significant differences in *E. coli* levels between seasons at either of the native oyster RMPs tested (p = 0.148 and 0.134 for Swale BC/4 and Whitstable Oyster Company respectively).

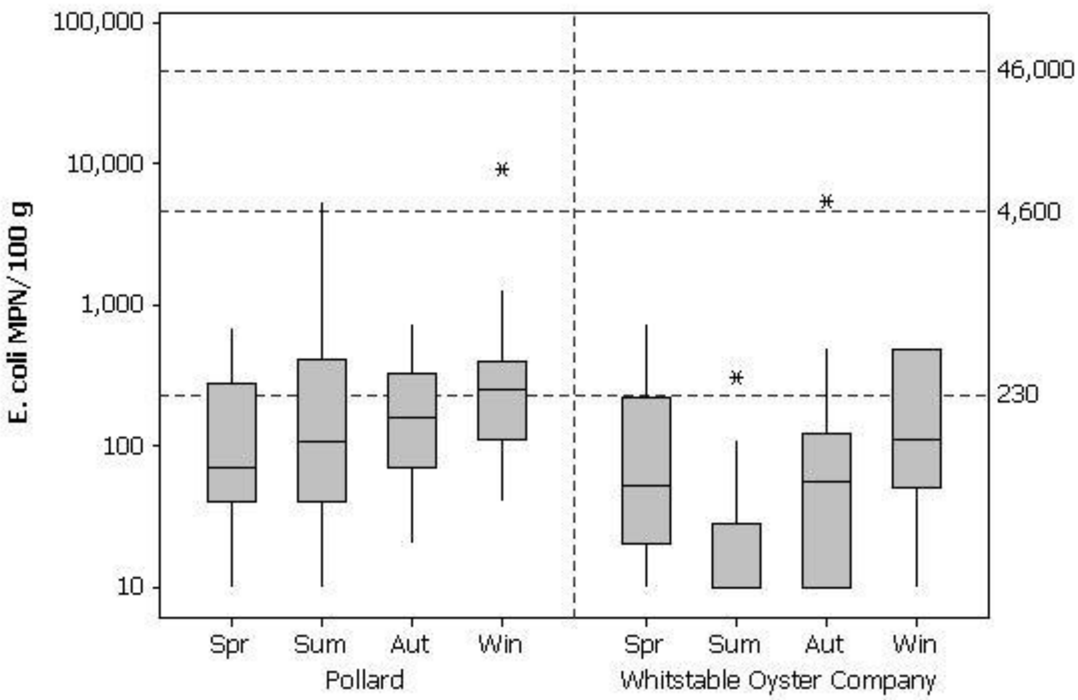


Figure XI.16: Boxplot of *E. coli* results in Pacific oysters by RMP and season

One way ANOVA tests showed that there were significant differences in *E coli* levels in Pacific oysters between seasons at Whitstable Oyster Company (p = 0.001) but not at

Pollard (p = 0.064) Post ANOVA Tukey tests showed that at Whitstable Oyster Company *E. coli* levels were higher in winter than summer, and were lower in summer than spring.

XI.4. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low and spring/neap tidal cycles for each RMP where more than 30 samples had been taken. Results of these correlations are summarised in Table XI.2, and significant results are highlighted in yellow.

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

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Scrapsgate	Cockle	0.179	0.259	0.216	0.141
Swale BC/7	Cockle	0.114	0.065	0.160	0.004
Pollard	Cockle	0.207	0.002	0.334	0.000
Sheppey Barton Point	Mussel	0.214	0.005	0.249	0.001
Swale BC/1	Mussel	0.092	0.168	0.170	0.002
Swale BC/6	Mussel	0.152	0.008	0.320	0.000
Swale BC/8	Mussel	0.148	0.010	0.050	0.590
South Oaze	Mussel	0.170	0.014	0.145	0.045
Swale BC/4	Native oyster	0.083	0.551	0.123	0.273
Whitstable Oyster Company	Native oyster	0.077	0.722	0.105	0.545
Pollard	Pacific oyster	0.161	0.004	0.070	0.354
Whitstable Oyster Company	Pacific oyster	0.306	0.000	0.188	0.005

Figure XI.17 to Figure XI.19 present polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

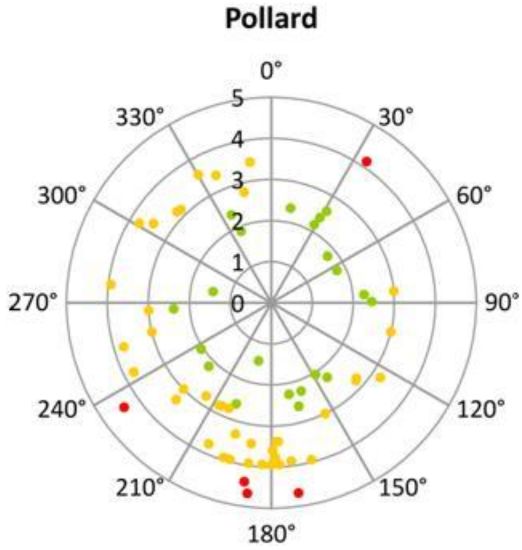


Figure XI.17: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) from cockle RMPs against high/low tidal state.

At the Pollard cockle RMP, higher *E. coli* results tended to occur around low tide.

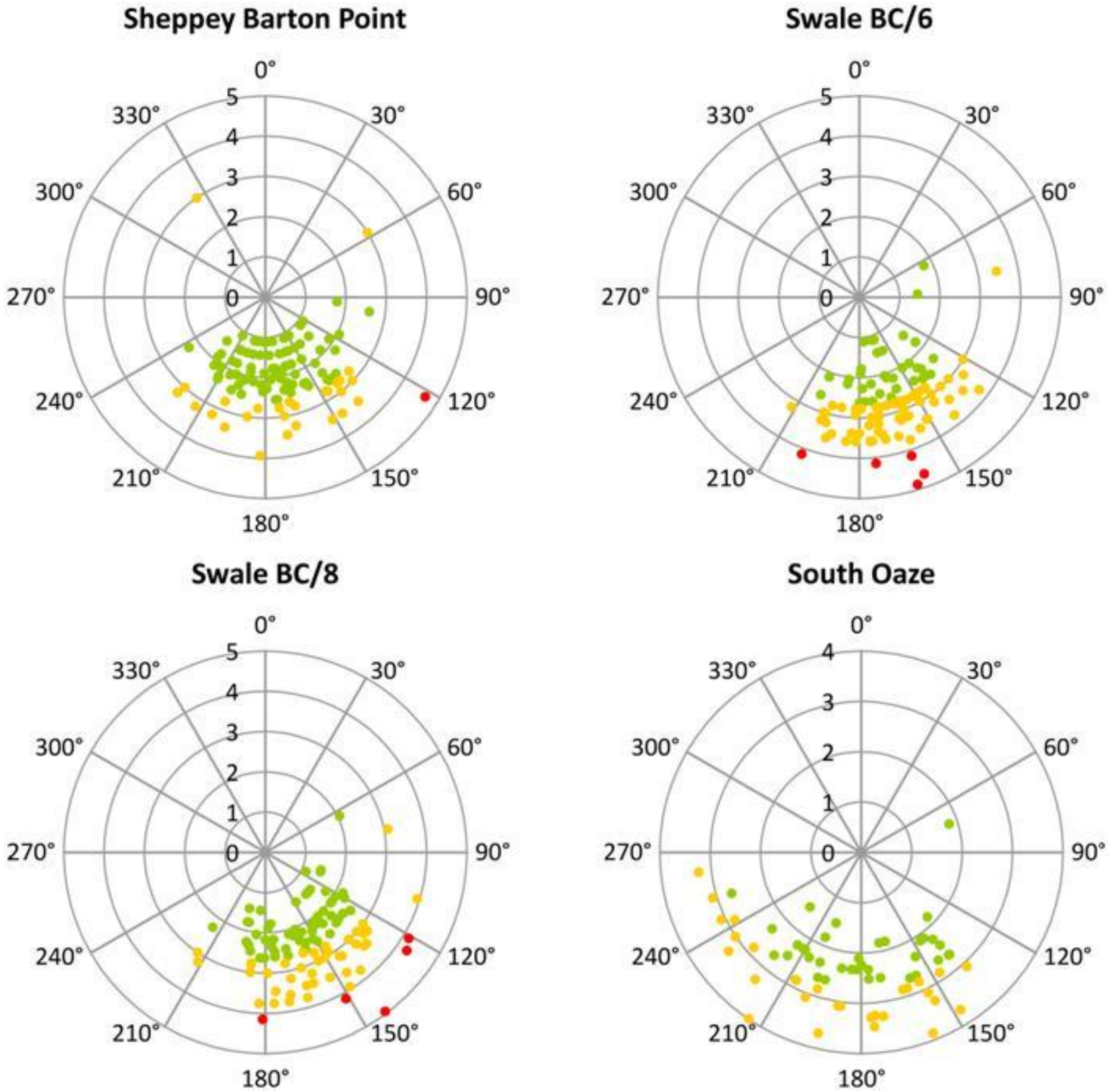


Figure XI.18: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) from mussel RMPs against high/low tidal state.

Although significant correlations were detected for the data presented in the above four plots, sampling was targeted towards low water and no obvious patterns are apparent.

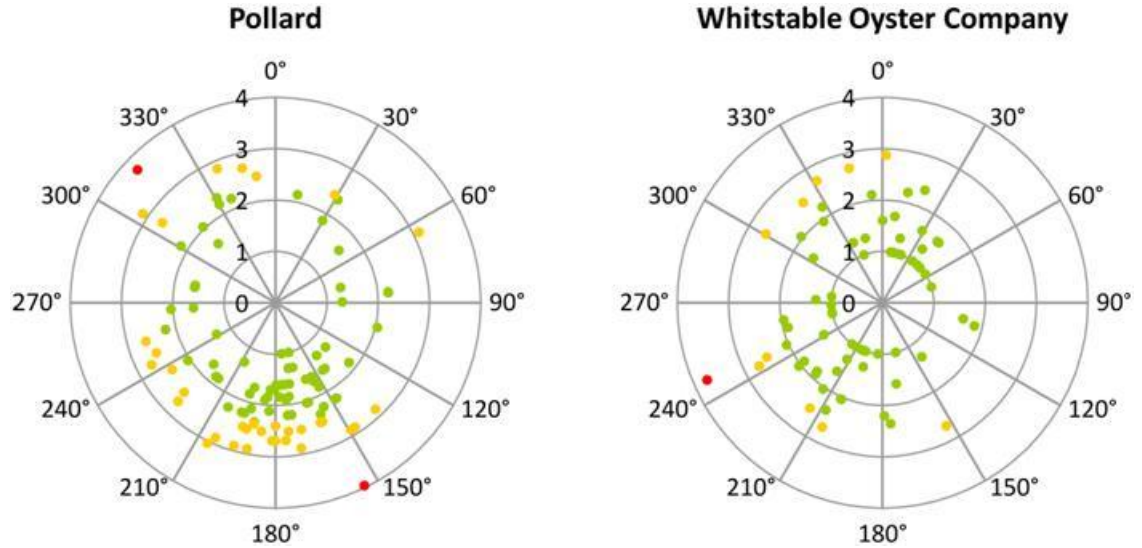


Figure XI.19: Polar plot of log_{10} *E. coli* results (MPN/100g) from Pacific oyster RMPs against high/low tidal state.

No obvious pattern is apparent for Pollard, but there does appear to be a tendency for lower results during the ebb tide at Whitstable Oyster Company.

Figure XI.20 to Figure XI.22 present polar plots of log_{10} *E. coli* results against the spring/ neap tidal cycle for each RMP. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

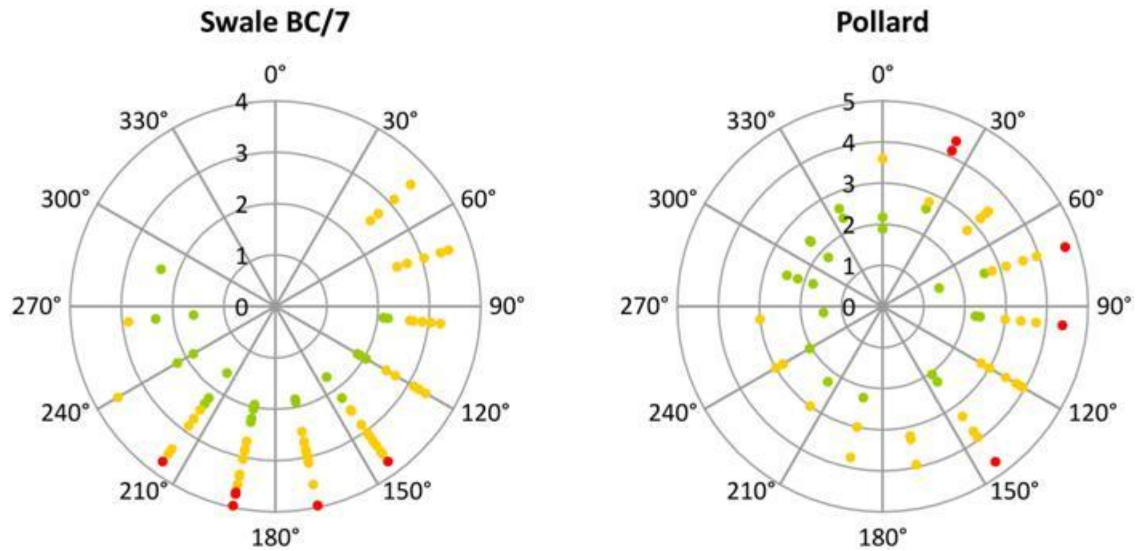


Figure XI.20: Polar plot of log_{10} *E. coli* results (MPN/100g) from cockle RMPs against spring/neap tidal state.

At Pollard a tendency for higher results during neap tides and tides of increasing size is apparent. No patterns are apparent for Swale BC/7 although the entire tidal cycle is not represented.

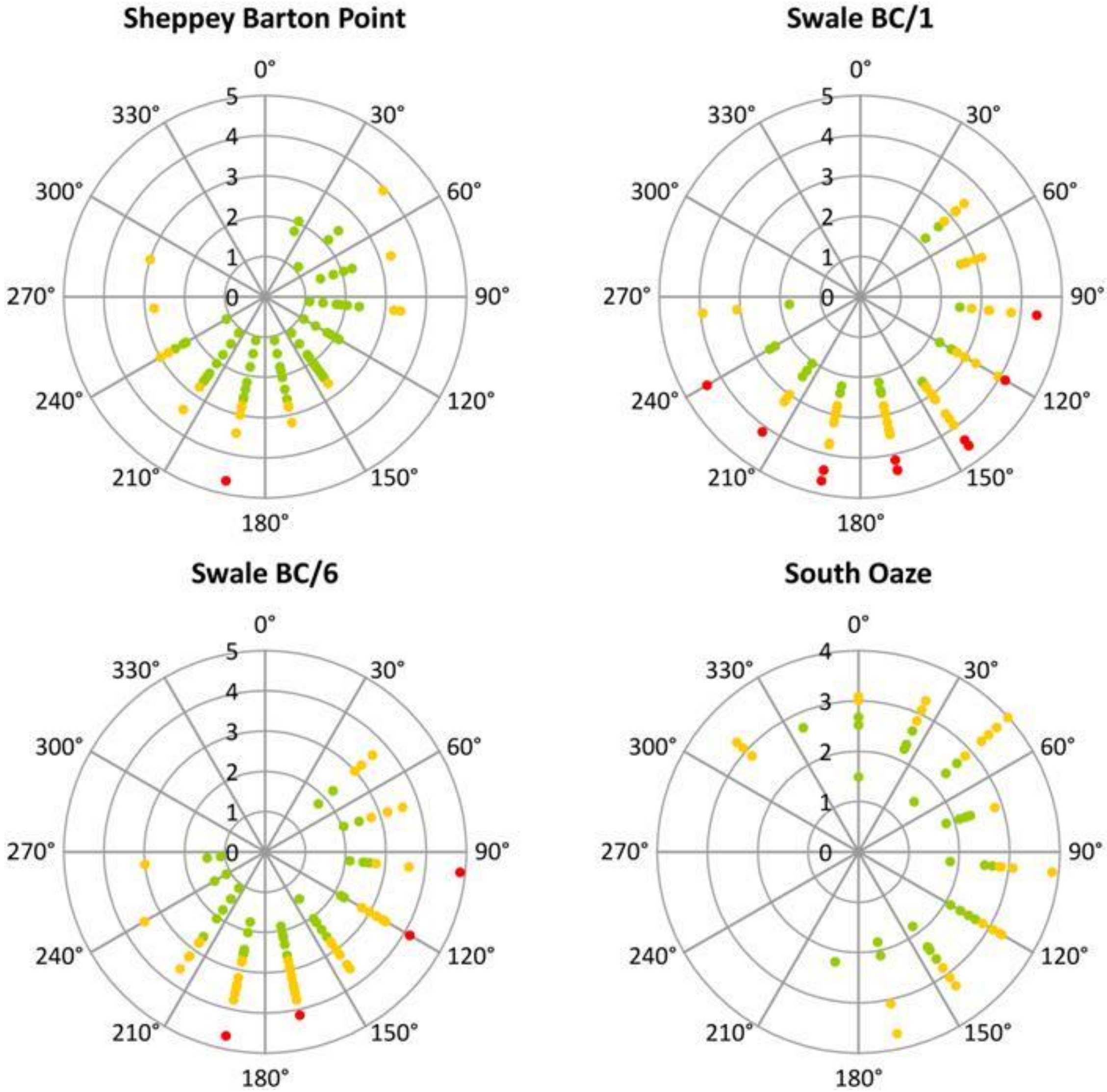


Figure XI.21: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) from mussel RMPs against spring/neap tidal state

Despite the significant correlations, no strong patterns are apparent in the plots, apart from a possible tendency for lower results during neap tides at Swale BC/6.

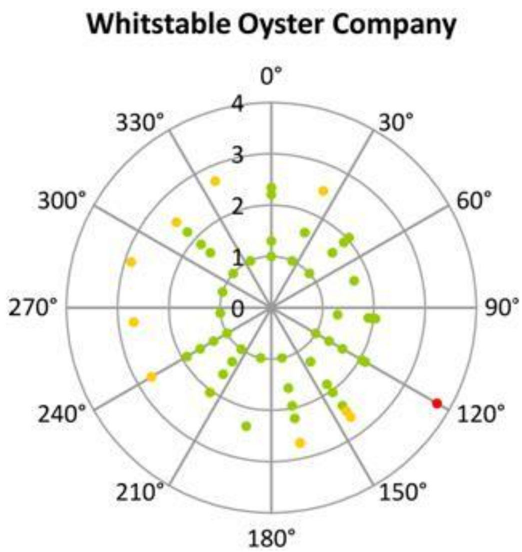


Figure XI.22: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) from Pacific oyster RMPs against spring/neap tidal state

No patterns are apparent in the polar plot for Whitstable Oyster Company.

XI.5. Influence of rainfall

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Sheerness Golf Course weather station (Appendix II for details) over various periods running up to sample collection. Only those sites with ten or more samples corresponding to dates for which rainfall data were available were analysed. Correlation results are presented in Table XI.3, and statistically significant positive correlations ($p<0.05$) are highlighted in yellow and significant negative correlation are highlighted in blue. It should be noted that on average, one in twenty correlations will return a significant r value by chance alone.

Table XI.3: Spearman's Rank correlations between rainfall recorded at Sheerness Golf Course and shellfish hygiene results

Site		Scrapsgate	Swale BC/7	Pollard	Sheppey Barton Point	Swale BC/1	Swale BC/2	Swale BC/6	Swale BC/8	South Oaze	Swale BC/4	Whitstable Oyster Company	Pollard	Whitstable Oyster Company
Species		Cockle			Mussel						Native oyster		Pacific oyster	
n		45	101	66	112	100	19	100	99	65	83	58	101	70
24 hour periods prior to sampling	1 day	0.000	0.133	0.156	0.048	0.139	0.488	0.202	0.149	0.081	-0.093	-0.223	0.132	-0.208
	2 days	-0.046	0.198	0.183	0.197	0.104	0.539	0.130	0.142	-0.042	0.184	-0.037	0.156	-0.102
	3 days	0.007	-0.007	0.212	0.129	0.098	0.299	0.005	-0.041	0.234	0.328	-0.112	0.001	-0.112
	4 days	0.208	0.100	0.139	0.135	0.075	0.101	0.165	0.165	0.258	0.228	0.013	-0.014	0.028
	5 days	0.076	-0.038	-0.109	0.044	0.127	0.129	0.014	0.167	-0.164	0.114	0.024	-0.080	-0.151
	6 days	0.061	-0.015	0.145	0.125	0.148	0.058	0.087	0.066	0.123	0.158	-0.096	0.117	-0.191
	7 days	0.215	-0.149	-0.120	0.173	-0.094	-0.079	-0.176	0.122	-0.130	0.081	-0.097	0.109	-0.064
Total prior to sampling over	2 days	-0.021	0.174	0.203	0.123	0.119	0.581	0.171	0.174	0.021	0.089	-0.147	0.149	-0.243
	3 days	-0.083	0.118	0.285	0.116	0.151	0.298	0.120	0.113	0.145	0.219	-0.196	0.143	-0.252
	4 days	-0.084	0.117	0.281	0.115	0.121	0.348	0.150	0.124	0.203	0.263	-0.101	0.113	-0.182
	5 days	-0.062	0.121	0.220	0.127	0.172	0.273	0.155	0.136	0.118	0.293	-0.117	0.043	-0.240
	6 days	-0.075	0.113	0.228	0.120	0.193	0.225	0.146	0.116	0.150	0.320	-0.091	0.067	-0.241
	7 days	-0.019	0.036	0.168	0.139	0.116	0.100	0.014	0.134	0.058	0.214	-0.148	0.058	-0.298

The influence of rainfall on *E. coli* levels on shellfish was very limited. Most of the positive correlations were detected within the Swale Channel and around its mouth, with some influence also detected in mussels at Barton Point. At Whitstable Oyster Company, increased rainfall was weakly associated with decreased levels of *E. coli* in both oyster species. The reasons for this are unclear given that there are limited freshwater inputs and so large and abrupt changes in salinity which may cause the oysters to cease feeding are not anticipated here.

Appendix XII. Shoreline Survey Report

Date (time):
30th September 2013 (0900-15:45)
1st October 2013 (0900-15:00)

Cefas Officers:
David Walker, Louise Rae & Owen Morgan

Local Enforcement Authority Officers:
David Carter, Swale Borough Council (North Kent Shore, 30/09/13 – 01/10/13)
Keith Wilson, London Port Health Authority (Isle of Sheppey, 01/10/13)

Area surveyed:
North and East shore of the Isle of Sheppey; North Kent Shore from just west of Seasalter, to Conyer Creek.

Weather:
30th September 12:00, partially cloudy, dry, 23°C, wind bearing 351° at 5 km/h
1st October 2013 12:00, partially cloudy, dry, 17°C, wind bearing 291° at 5 km/h

Tides:
Admiralty Totaltide predictions for Sheerness (51°27'N 0°45'E). All times in this report are BST.

30/09/2013			01/10/2013		
High	09:33	4.6 m	High	10:42	5.0 m
High	22:18	4.8 m	High	23:16	5.2 m
Low	03:13	1.9 m	Low	04:25	1.7 m
Low	16:03	1.5 m	Low	17:03	1.2 m

XII.1. Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are shown in Figure XII.1.

The shoreline survey was undertaken over two days by two teams on foot. Every effort was made to ensure the entire shoreline was surveyed. However, the southern shore of the Isle of Sheppey was largely inaccessible due to private land. In addition, the stretch of coast between Minster and Warden on the north of the Isle of Sheppey was inaccessible. This was because the wind was blowing towards the coast, keeping the tide in for longer than predicted. This meant that it was not safe to walk along this stretch of shoreline, which is backed by cliffs with no access inland.

XII.2. Description of Fishery

It was not possible to meet with harvesters during this survey to determine the extent of the shellfish beds due to time constraints. However, dead shells of Pacific oyster, cockle, mussel, *Tapes spp.* and razor clams (*Tapes* spp.) were observed on the east coast of the Isle of Sheppey around Warden (observation 1). Dead shells of cockles, *Tapes spp.* and Pacific oysters were seen on the North Kent coast at observation 27. A cockle dredger (Abbie Jayne) was observed harvesting cockles in an unclassified area off Minster (observation 19).

XII.3. Sources of contamination

Sewage discharges

Three intermittent water company consents were confirmed on the Isle of Sheppey (observations 3, 22 and 24) but none of the intermittent water company consents on the North Kent Shore were observed.

The Faversham Abbey Field Sewage Treatment Works was observed and the continuous discharge measured. It was found to discharge an instantaneous bacterial loading equivalent to approximately 2.6×10^{12} *E. coli* CFU/day.

One private consent was observed (observation 41). However, at the actual location of the consent there was a Liquid Petroleum Gas (LPG) container. Two inspection covers in the garden of this property suggest that there may be a discharge nearby, and observation 40 which was in the adjacent field looked like it could have been a septic tank vent (Figure XII.14)

Freshwater inputs

There were five culverted streams observed on this survey, two of which were on the Isle of Sheppey and three on the north Kent shore. The stream at observation 18 had 23,000 *E. coli* CFU/100 ml which is high for surface runoff, and may suggest some sewage input. One possible source of this contamination is the Sheerness East Waste Water Pumping Station consent, which is located approximately 1.8 km (fluvial distances) away from the stream outlet. The stream was not accessible, and it was therefore not possible to measure its flow.

The culverted streams at observations 34 and 47 both contained approximately 500 *E. coli* CFU/100 ml. No flow reading was possible for observation 34, but at observation 47 a total of approximately 2×10^{13} *E. coli* CFU per day was calculated. This represents the highest *E. coli* loading for any of the observations on this survey.

There were several pipes throughout the survey area which were not listed in the EA consent database (including current and revoked consents), and are therefore assumed to be ground/surface water drainage. Observations 6 and 8 were found to have *E. coli* levels of 7,200 and 7,400 CFU/100 ml respectively, indicating possible faecal contamination.

Boats and Shipping

There were very few boats observed across the survey. However there were approximately 20 house boats at observations 37 and 38 and a marina at the southern end of Conyer Creek.

Livestock

There was very little livestock on the Isle of Sheppey except at observation 12 and 13, where approximately 50 and 60 cows were observed respectively. On the north Kent shore, around 20 to 30 cows were observed at observations 26 and 33, both toward the east of the survey route. Between Faversham Creek and Conyer Creek, there were upwards of 1,000 sheep observed.

Wildlife

Most birds were observed in the Swale (no observations in the north of Sheppey). The main concentrations of birds were at the Sheerness Nature Reserve on the Isle of Sheppey (observation 11) and along most of the shoreline from observation 26 to 30.

Dog walking and dog excrement was frequently observed at all points which had footpath access. Horse faeces were also observed on the beach at observation 1 and on the promenade at observation 4.

Bacteriological survey

As well as the standard practice of sampling and measuring freshwater inputs where possible, a total of 18 additional seawater samples were taken to assist in understanding the spatial profile of contamination across the survey area. The results of these are presented in Table XII.3. These indicate generally low levels of *E. coli* along the north/east shore of Sheppey, with a localised hotspot towards the western end of Minster. They also indicate that levels of contamination increase to high levels within the confines of Faversham and Oare Creek.

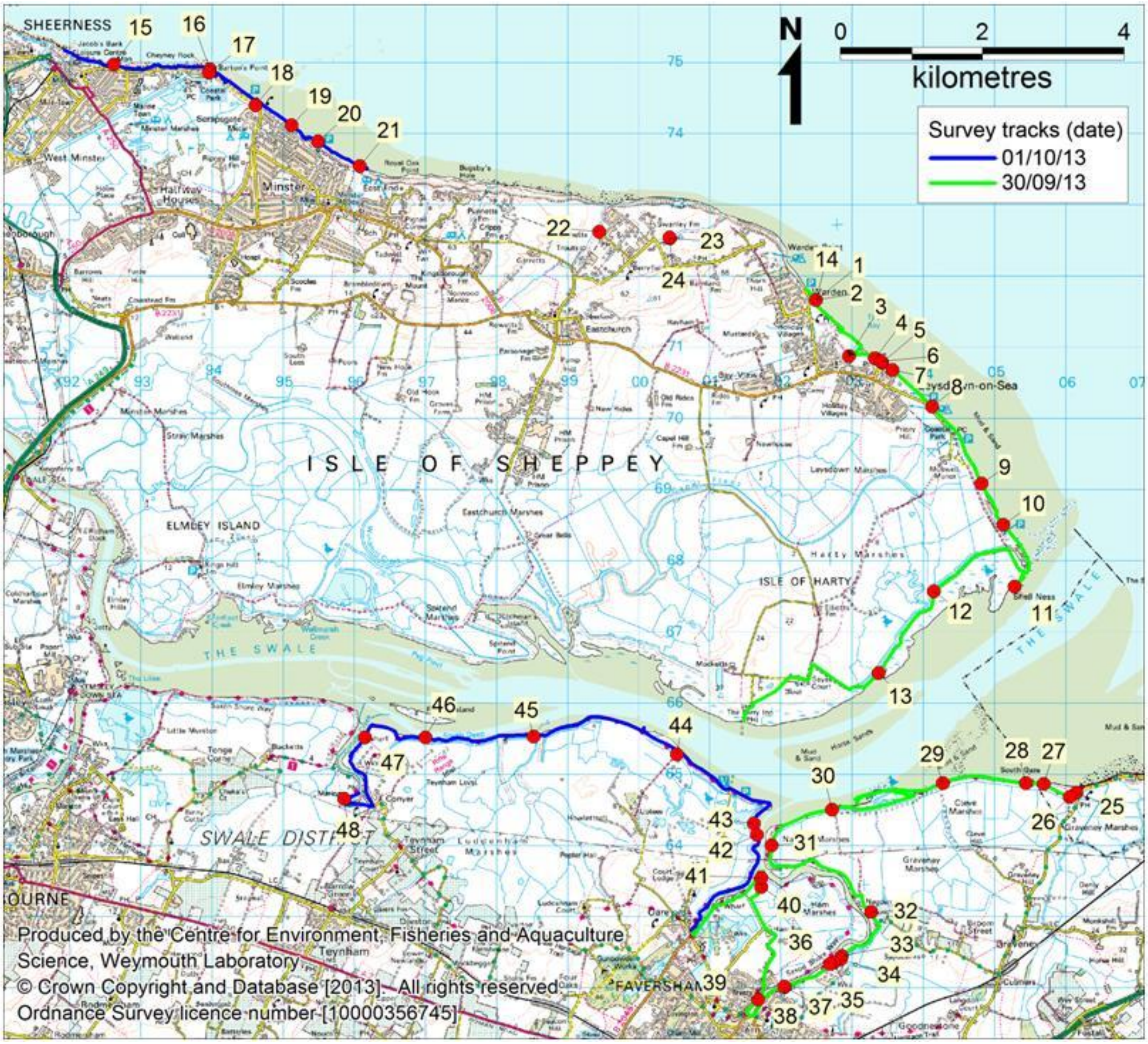


Figure XII.1: Locations of Shoreline Observations (Table XII.1 for details)

Table XII.1: Details of Shoreline Observations

Obs. no.	NGR	Date	Time	Description	Photo
1	TR0248571660	30/09/2013	09:08	Dog and horse faeces along beach. Pacific oyster, cockle, mussel, clam and razor clam dead-shell.	
2	TR0248571660	30/09/2013	09:08	Outfall pipe with sanitary debris, seawater sample as covered by the tide (sample BS02).	Figure XII.4
3	TR0295170876	30/09/2013	09:37	Little Groves storm overflow, 50 cm black plastic pipe to ditch. Neither pipe nor ditch flowing. Sample taken from ditch (Sample SS02).	Figure XII.5
4	TR0331370842	30/09/2013	09:48	Horse faeces along promenade.	
5	TR0341270782	30/09/2013	09:54	Pipes from concrete sea wall.	Figure XII.6
6	TR0339870801	30/09/2013	09:59	Valved pipe (~20 cm diameter), (Sample SS03, spot flow estimate).	Figure XII.7
7	TR0355970678	30/09/2013	10:05	Ground water drainage.	
8	TR0411370162	30/09/2013	10:25	Iron pipe (~50 cm diameter) from sea wall. Broken and spilling onto foreshore (Sample SS05, spot flow estimate).	
9	TR0480969083	30/09/2013	10:56	Cockle dead-shell pile.	
10	TR0511768502	30/09/2013	11:11	300 birds.	
11	TR0527667634	30/09/2013	11:43	3000 birds in reserve.	
12	TR0414167568	30/09/2013	12:17	50 cows on landward side of dyke. Hoofprints and pats on seaward side.	
13	TR0336266422	30/09/2013	12:38	60 cows on landward side of dyke. Hoofprints and pats on seaward side.	
14	TR0248571660	30/09/2013	14:37	Resample of observation number 2 when uncovered by the tide, 2 pipes side by side, one with gentle flow (sample SS08, measured by recording time taken to fill jar), other not flowing.	Figure XII.8
15	TQ9261474969	01/10/2013	10:02	Sanitary waste on strandline. Pacific oyster dead shell.	
16	TQ9396774903	01/10/2013	10:39	End of mussel bed.	
17	TQ9395174855	01/10/2013	10:47	Possible drain for seawater impoundment (Sample SH05).	Figure XII.9
18	TQ9460374396	01/10/2013	11:10	Culverted stream (Sample SH06). Not possible to measure due to fence.	Figure XII.10
19	TQ9511274114	01/10/2013	10:31	Cockle dredger (Abbie Jayne).	Figure XII.11
20	TQ9548873891	01/10/2013	12:13	Pipe on beach with inspection covers - one approximately every 50 metres along promenade.	
21	TQ9607073545	01/10/2013	12:25	Small outfall pipe, not flowing.	
22	TQ9943772623	01/10/2013	13:12	Hens Brook Pumping station.	

23	TR0043072531	01/10/2013	13:18	Southern water enclosure.	
24	TR0042872541	01/10/2013	13:18	Barrows Brook CEO pumping station.	
25	TR0614464740	30/09/2013	09:25	Holiday hut and ~150 birds.	
26	TR0605264679	30/09/2013	09:28	~30 cows.	
27	TR0568564863	30/09/2013	09:35	Cockle, clams and Pacific oyster dead shell.	
28	TR0543364874	30/09/2013	09:39	Oyster bag.	
29	TR0426564874	30/09/2013	10:01	Birds throughout shoreline (thousands).	
30	TR0271064501	30/09/2013	10:57	EA sluice for marsh drainage - not flowing (Sample NK03).	Figure XII.12
31	TR0185964004	30/09/2013	11:21	Old boats, possible dredger.	
32	TR0326163068	30/09/2013	12:11	Three horses.	
33	TR0284762445	30/09/2013	12:26	20 cows on opposite bank.	
34	TR0283062404	30/09/2013	12:28	Culverted stream/sluice - not flowing (Sample NK05).	
35	TR0273762354	30/09/2013	12:34	Sewage treatment works.	
36	TR0267862337	30/09/2013	12:38	Outfall from STW (Sample NK06).	Figure XII.13
37	TR0204362010	30/09/2013	12:59	Houseboats.	
38	TR0203962015	30/09/2013	13:00	Houseboats.	
39	TR0167361836	30/09/2013	13:35	Pipe - opposite bank.	
40	TR0171563417	30/09/2013	14:03	Possible cess pit.	Figure XII.14
41	TR0171863543	30/09/2013	14:06	LPG container where discharge consent marked. Two inspection covers visible in garden.	Figure XII.15
42	TR0165564149	01/10/2013	10:17	Sluice. Draining marsh. Sample taken from ditch behind sluice (Sample SS13). Not possible to access for measurement.	
43	TR0161064307	01/10/2013	10:28	Around 500 birds on marsh. Draining via above sluice.	
44	TR0053365276	01/10/2013	11:05	Sluice draining from stagnant pond. No safe access.	Figure XII.16
45	TQ9851365532	01/10/2013	11:47	Concrete enclosure with 10cm diameter orange pipes draining onto ditch. Around 100 sheep and 100 cattle. Water sample taken from ditch (SS15). No outfall to shore.	Figure XII.17
46	TQ9699465517	01/10/2013	12:17	Sluice and around 1,000 sheep (Sample SS16)	
47	TQ9614465514	01/10/2013	13:03	Culverted stream, draining into marina. Around 6 horses and 50 sheep (Sample SS17, spot flow measurement).	
48	TQ9585064654	01/10/2013	14:14	Culverted stream, draining into marina. Larger than observation 47. Water sample taken (Sample SS18) but not possible to access for flow measurement	Figure XII.18

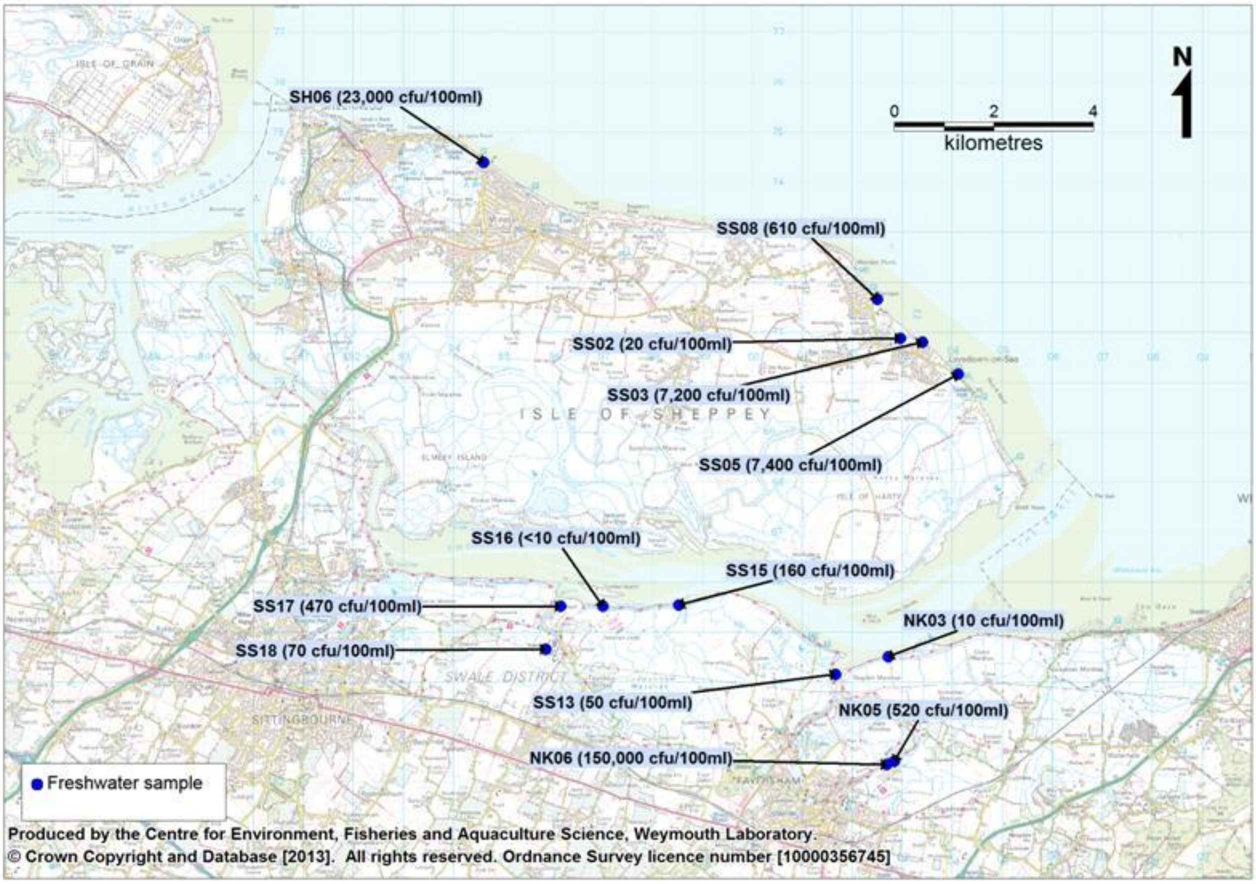


Figure XII.2: Freshwater sample results (Table XII.2 for details)

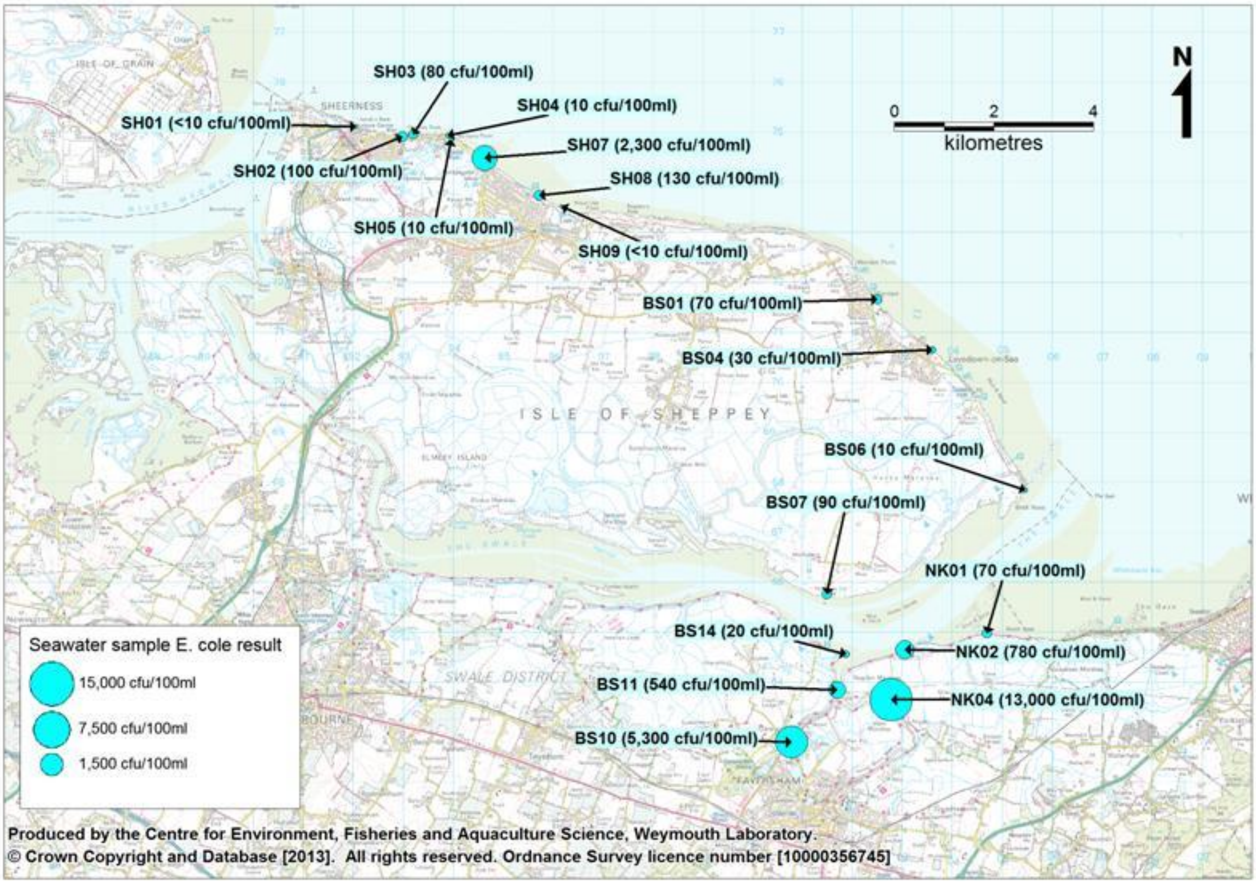


Figure XII.3: *E. coli* stream loadings (Table XII.3 for details).

Table XII.2: Freshwater sample *E. coli* results, spot flow gauging results and estimated stream loadings.

Sample ID	Observation number	Date and time	Description	Flow (m^3/s)	*E. coli* concentration (CFU/100 ml)	*E. coli* loading (CFU/day)	NGR
SS02	3	30/09/2013 09:37	Surface water pipe	0.00013	20	$2.30x10^6$	TR0295170876
SS03	6	30/09/2013 09:59	Surface water pipe	0.00002	7,200	$1.38x10^8$	TR0339870801
SS05	8	30/09/2013 10:25	Surface water pipe	0.0001	7,400	$6.39x10^{10}$	TR0411370162
NK03	30	30/09/2013 10:57	Marsh drainage sluice		10		TR0271064501
NK05	34	30/09/2013 12:28	Culverted stream		520		TR0283062404
NK06	36	30/09/2013 12:38	Sewage works outfall	0.02	150,000	$2.61x10^{12}$	TR0267862337
SS08	14	30/09/2013 14:37	Culverted stream		610		TR0248571660
SS13	42	01/10/2013 10:17	Marsh drainage sluice		50		TR0165564149
SH06	18	01/10/2013 11:10	Culverted stream		23,000		TQ9460374396
SS15	45	01/10/2013 11:47	Ground water		160		TQ9851365532
SS16	46	01/10/2013 12:17	Marsh drainage sluice		<10		TQ9699465517
SS17	47	01/10/2013 13:03	Culverted stream	0.16	470	$6.44x10^{10}$	TQ9614465514
SS18	48	01/10/2013 14:14	Culverted stream		70		TQ9585064654

Table XII.3: Seawater sample *E. coli* results.

Sample ID	Obs. no.	Date and time	Description	*E. coli* concentration (CFU/100 ml)	NGR
BS01	2	30/09/2013 09:08	By freshwater outfall (covered by tide)	70	TR0248571660
NK01	n/a*	30/09/2013 09:53		70	TR0468164975
BS04	n/a*	30/09/2013 10:08		30	TR0359170646
NK02	n/a*	30/09/2013 10:20		780	TR0303664646
BS06	n/a*	30/09/2013 11:28		10	TR0545567834
NK04	n/a*	30/09/2013 11:54		13000	TR0276763635
BS07	n/a*	30/09/2013 13:36		90	TR0147465758
BS10	n/a*	01/10/2013 09:40		5300	TR0077462787
SH01	n/a*	01/10/2013 09:50		<10	TQ9204475112
BS11	n/a*	01/10/2013 10:10		540	TR0168263835
SH02	n/a*	01/10/2013 10:11		100	TQ9296974919
SH03	n/a*	01/10/2013 10:19		80	TQ9319074963
SH04	n/a*	01/10/2013 10:33		10	TQ9388374935
BS14	n/a*	01/10/2013 10:35		20	TR0186064549
SH05	17	01/10/2013 10:47	Drainage from seawater impoundment	10	TQ9395174855
SH07	n/a*	01/10/2013 11:15		2300	TQ9462974484
SH08	n/a*	01/10/2013 12:18		130	TQ9571473738
SH09	n/a*	01/10/2013 12:27		<10	TQ9617273522

**Sample taken as part of bacteriological survey of the area. Not associated with any specific shoreline observations.*

Figure XII.4

Figure XII.5

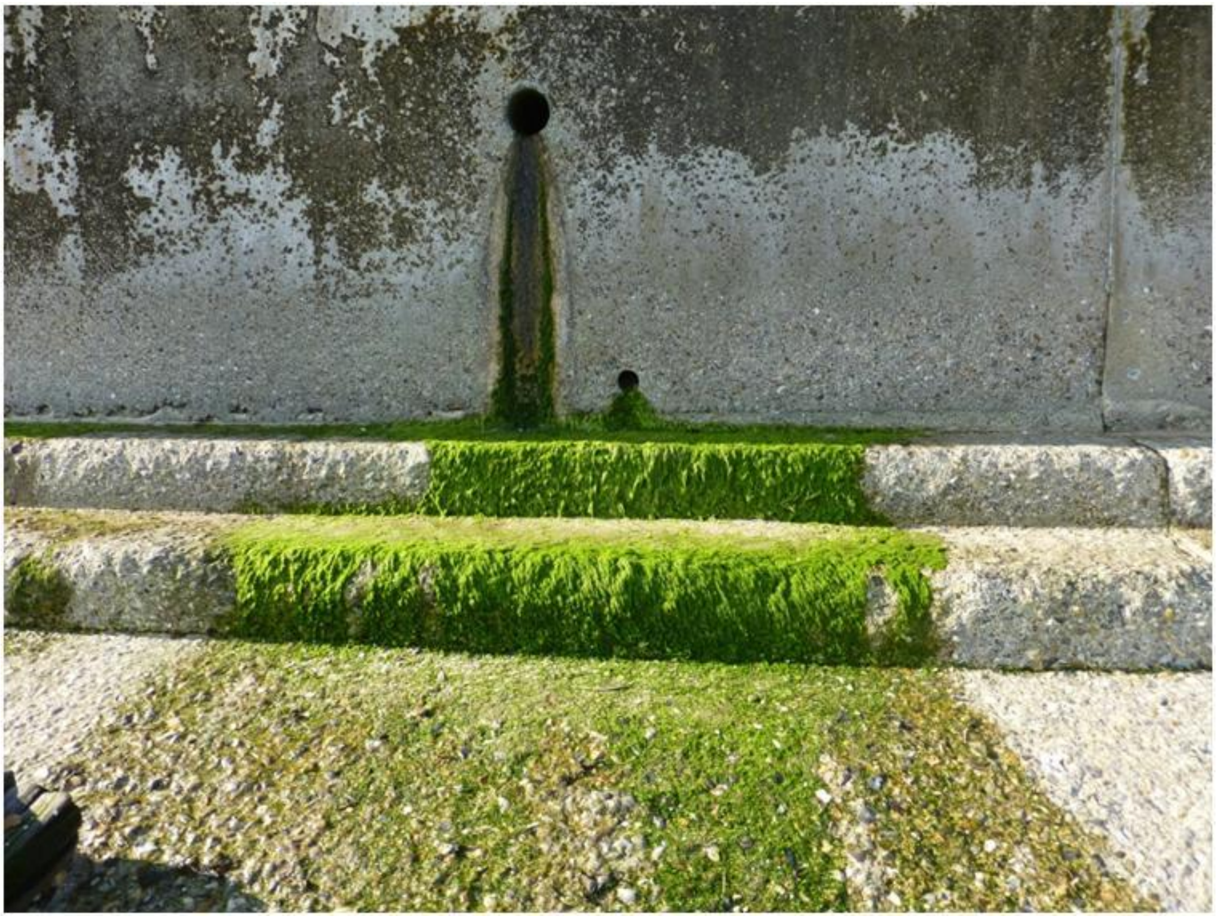


Figure XII.6

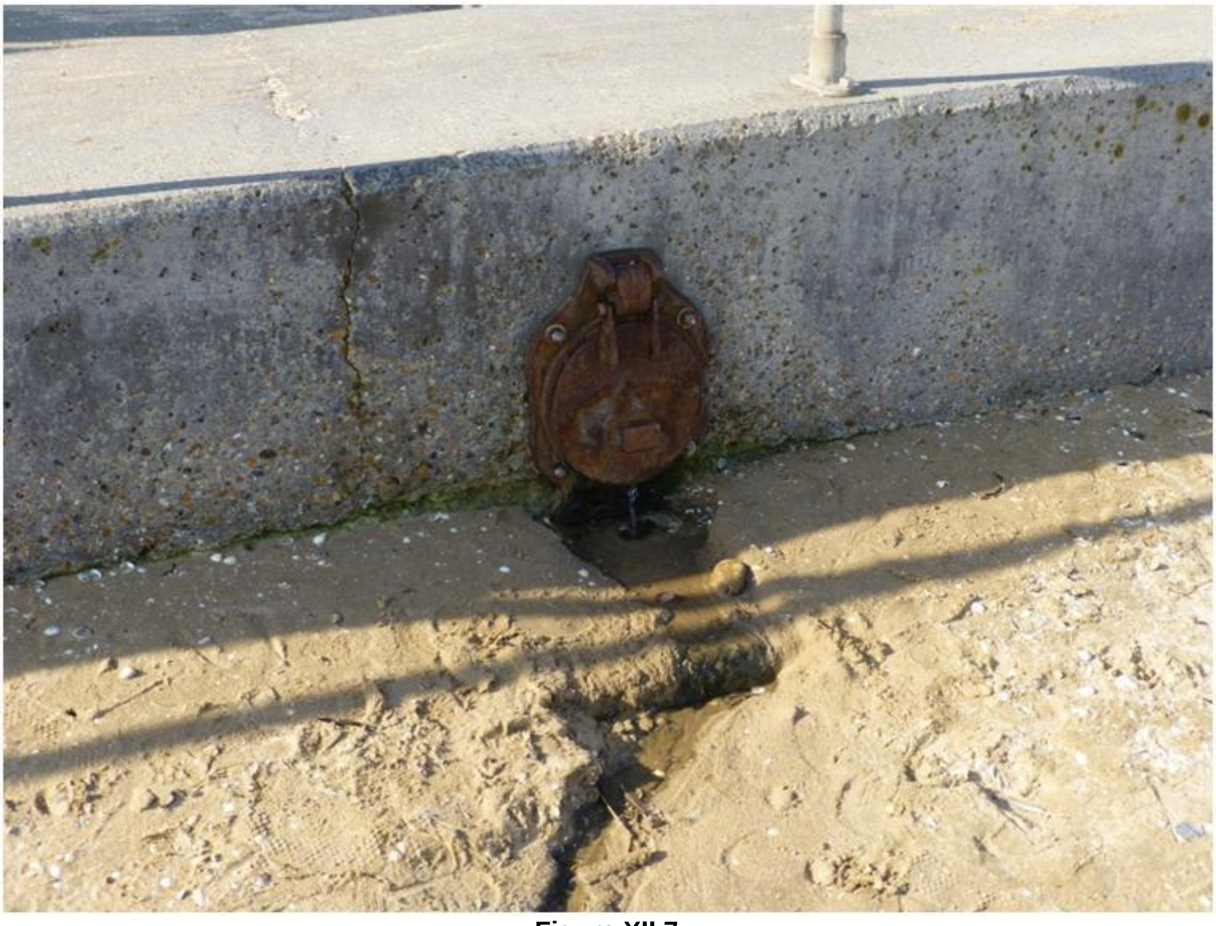


Figure XII.7

Figure XII.8

Figure XII.9

Figure XII.10

Figure XII.11

Figure XII.12

Figure XII.13

Figure XII.14

Figure XII.15

Figure XII.16

Figure XII.17

Figure XII.18

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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
IFCA	Inshore Fisheries and Conservation Authority
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
NM	Nautical Miles
NRA	National Rivers Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
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.
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 Nth root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	Locally Weighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the n data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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