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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Butley

March 2014

Food Standards Agency

Cover photo: Shellfish harvesting on the Butley estuary

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds at Butley, 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

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Final	Final report post consultation	Simon Kershaw	25/04/2014

Consultation

Consultee	Date of consultation	Date of response
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Dissemination

Food Standards Agency, Suffolk Coastal District Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2014. Sanitary survey of Butley. 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 in humans (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis). 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 anticipated 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 (*Crassostrea gigas*) within the Butley River. The area was prioritised for survey in 2013-14 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2. Area description

The Butley survey area is situated on the east coast of England, in Suffolk and forms part of the Alde/Ore estuary complex which discharges to the Southern North Sea (Figure 1.1).

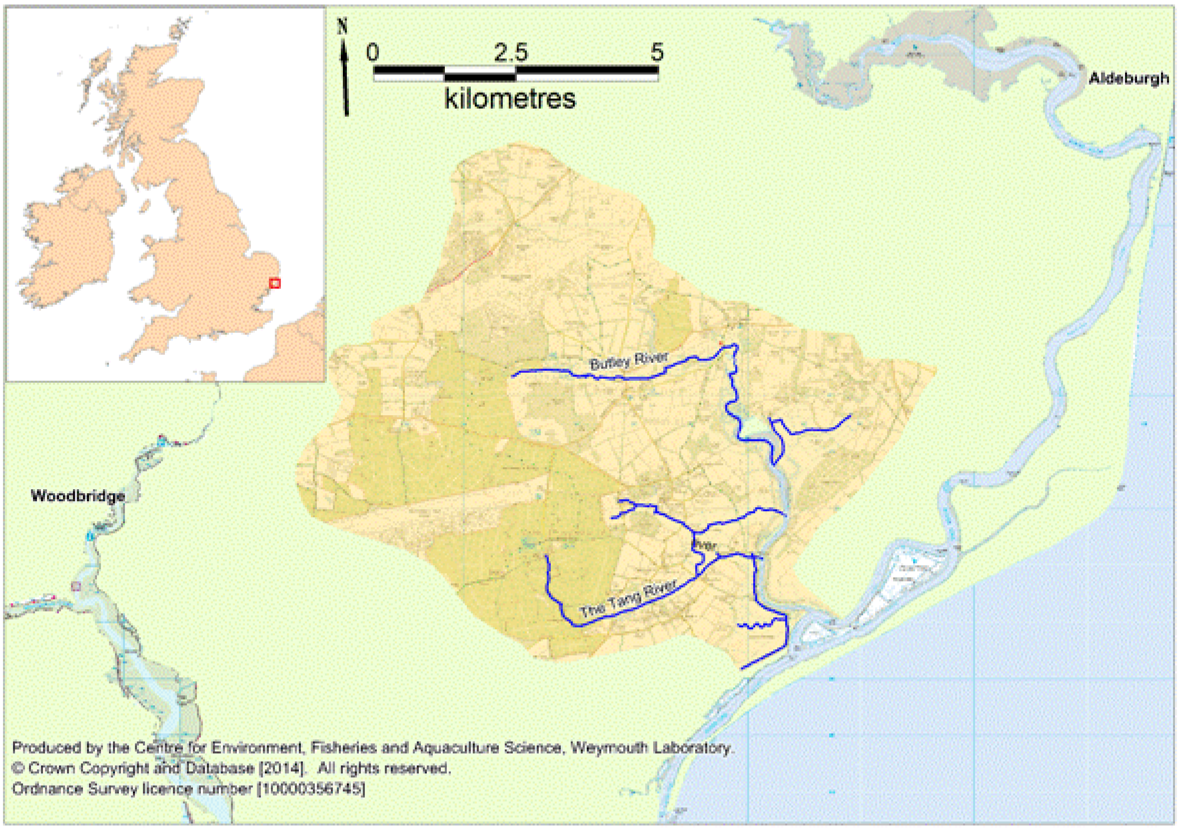


Figure 1.1 Location of the Butley survey area

The Butley is a narrow meandering estuary comprised of a central sub-tidal channel, flanked by intertidal mudflats and saltmarsh. It is surrounded by low lying reclaimed land, which lies behind sea banks. There are two principal freshwater inputs: the Butley River discharges to the head of the estuary and the River Tang discharges to the west bank of the outer estuary. It has a quiet, rural backdrop with no significant settlements on its banks and little boat traffic. The estuary has supported the current Pacific oyster culture fishery for several decades.

1.3. Catchment

Figure 1.2 illustrates landcover within the hydrological catchment of the Butley estuary, which covers an area of 60 km². The catchment is rural in character, principally comprised of arable farmland with large expanses of forest in the west of the catchment and some areas of pasture adjacent to the shoreline of the Butley estuary. A small proportion of the catchment is urbanised, limited to the north of the catchment. There are two disused airfields in the north and west of the catchment.

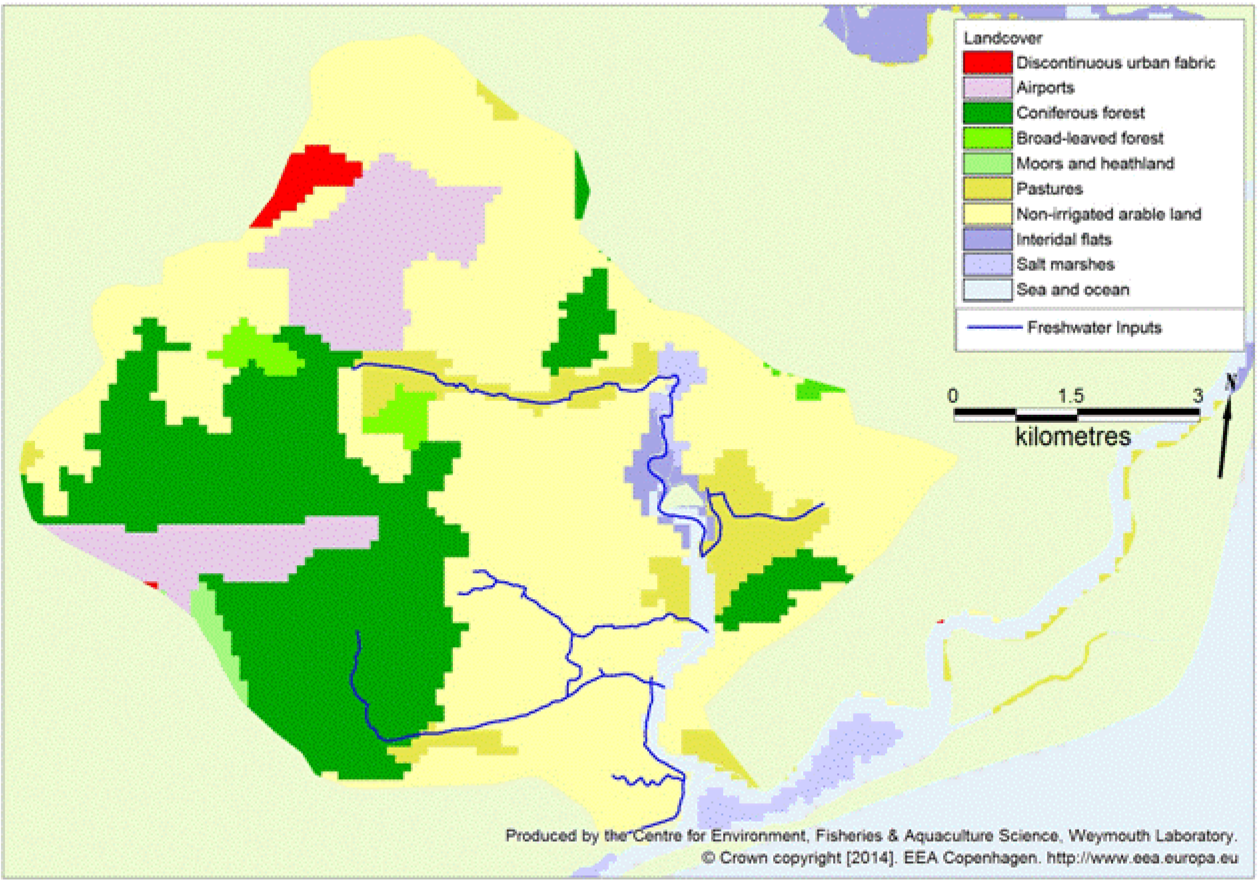


Figure 1.2 Landcover in the Butley survey area

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. The hydrogeology of the catchment is described as being of moderate permeability (NERC, 2012) so there will be both groundwater and surface water flows.

2. Recommendations

It is recommended that one zone is defined which encompasses the entire oyster growing and nursery area (Figure 3.1). No significant point sources of contamination discharging directly to this zone have been identified. Land runoff enters the estuary via the River Butley, 4 km upstream of the zone, the Chillesford Pumping Station about 2 km upstream of the zone, the Butley Pumping Station on the southern boundary of the zone, and the River Tang about 400 m downstream of the zone. There may be occasional overboard discharges made by boats in the estuary, and this is more likely to occur in its lower reaches. The Hollesley STW discharges to the outer reaches of the Ore channel via a drain 6 km from this zone, and contamination from it may be carried as far as the zone on a flooding tide although this will be subject to considerable dilution *en route*. Whilst birds may be a significant influence, particularly during winter, they are a diffuse source so it is not possible to set an RMP specifically to capture their peak influence. No spatial patterns in levels of faecal indicator bacteria were observed across the multiple seawater samples taken during the shoreline survey. It is therefore recommended that the RMP be located on the west bank at the downstream end of the zone (Pumping Station Outfall) to best capture contamination delivered by the River Tang and the Butley PS.

The species sampled should be Pacific oysters of a market size. A tolerance of 50 m applies for dredge sampling. Alternatively, bagged shellfish may be used to ensure a regular supply of stock for sampling. If this is the case they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling and a tolerance of 10m applies. Sampling should be on a monthly, year round basis.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Butley
Cefas Main Site Reference	M009
Ordnance survey 1:25,000 map	Explorer 212
Admiralty Chart	2693

Shellfishery

Species/culture	Pacific oysters (*Crassostrea gigas*)	Bed culture
Seasonality of harvest	No closed season	

Local Enforcement Authority

Name & Address	Suffolk Coastal District Council Council Offices Melton Hill Woodbridge Suffolk IP12 1AU
Environmental Health Officer	V Johnston
Telephone number	01394 444 629
E-mail	v.johnston@suffolkcoastal.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 2020. 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 at Butley

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Butley Oysterage	B009E	Pumping Station Outfall	TM 3943 4850	52° 04.982'N 01° 29.589'E	Pacific oysters	Bed culture	Dredge	Dredge or hand	50 m or 10 m	Monthly	Can be sampled via dredge, or by hand from deployment bag if required to guarantee stock availability

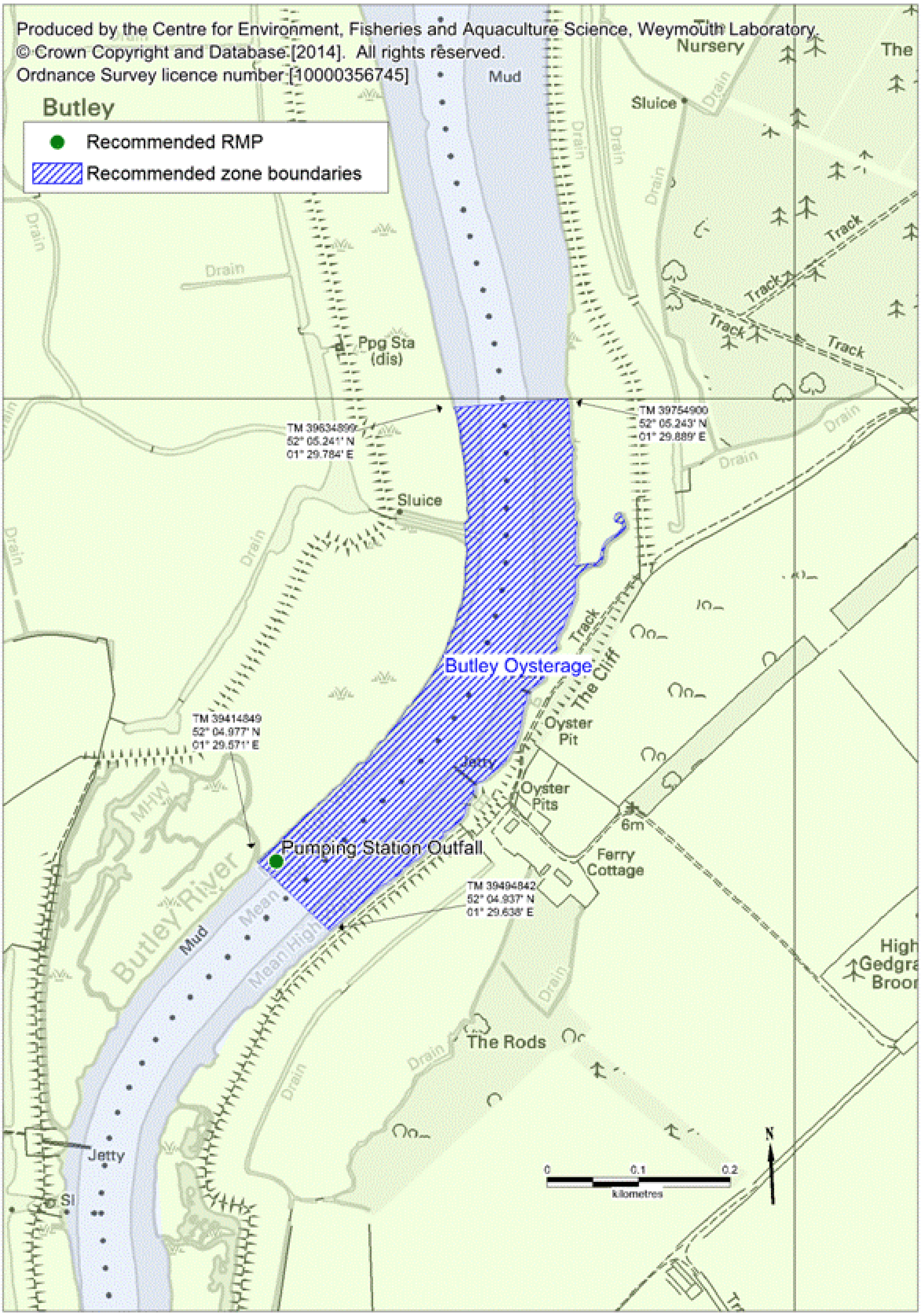


Figure 3.1: Recommended zoning and monitoring arrangements (Pacific oysters)

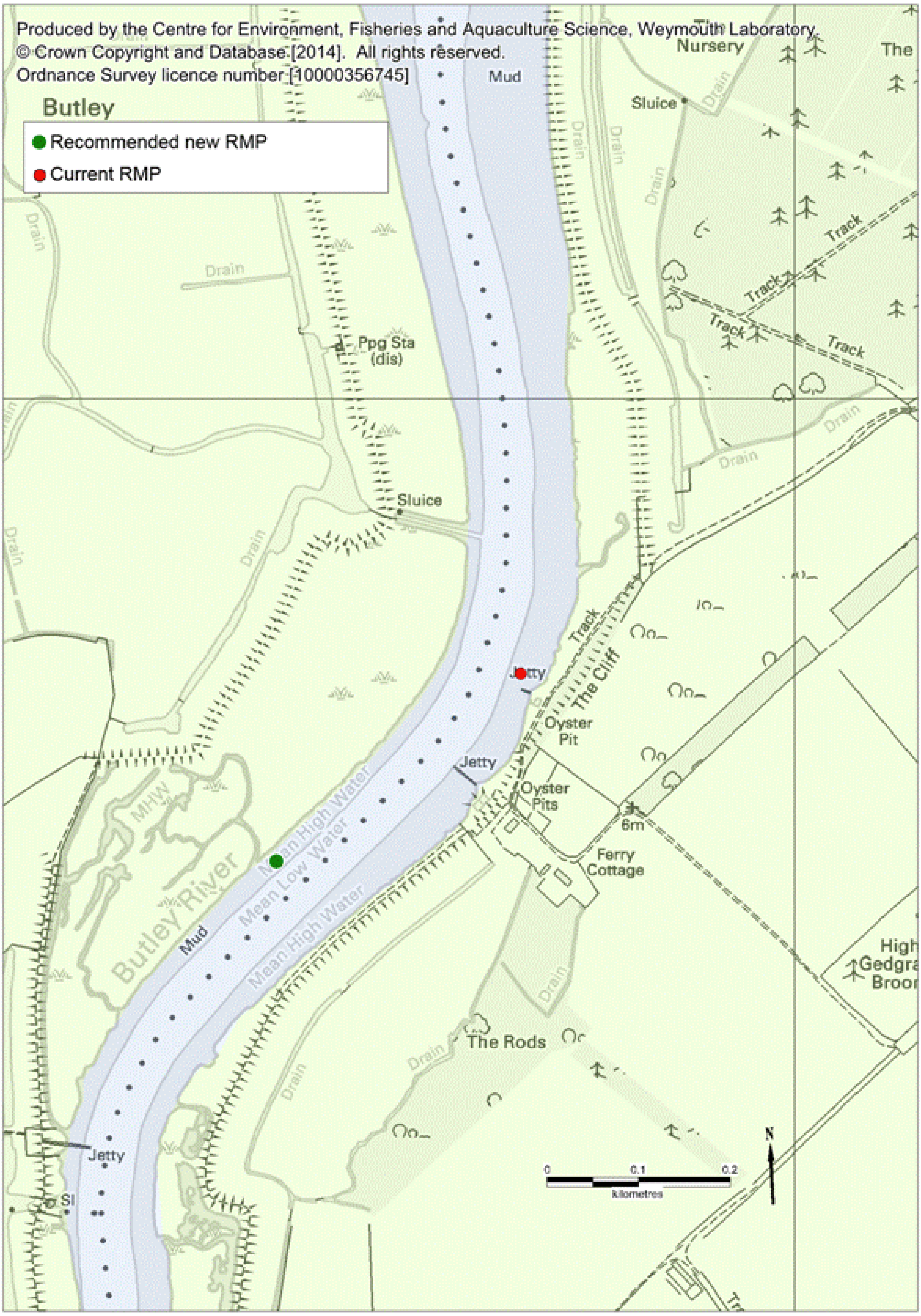


Figure 3.2: Location of current and recommended RMPs (Pacific oysters)

4. Shellfisheries

4.1. Species, location and extent

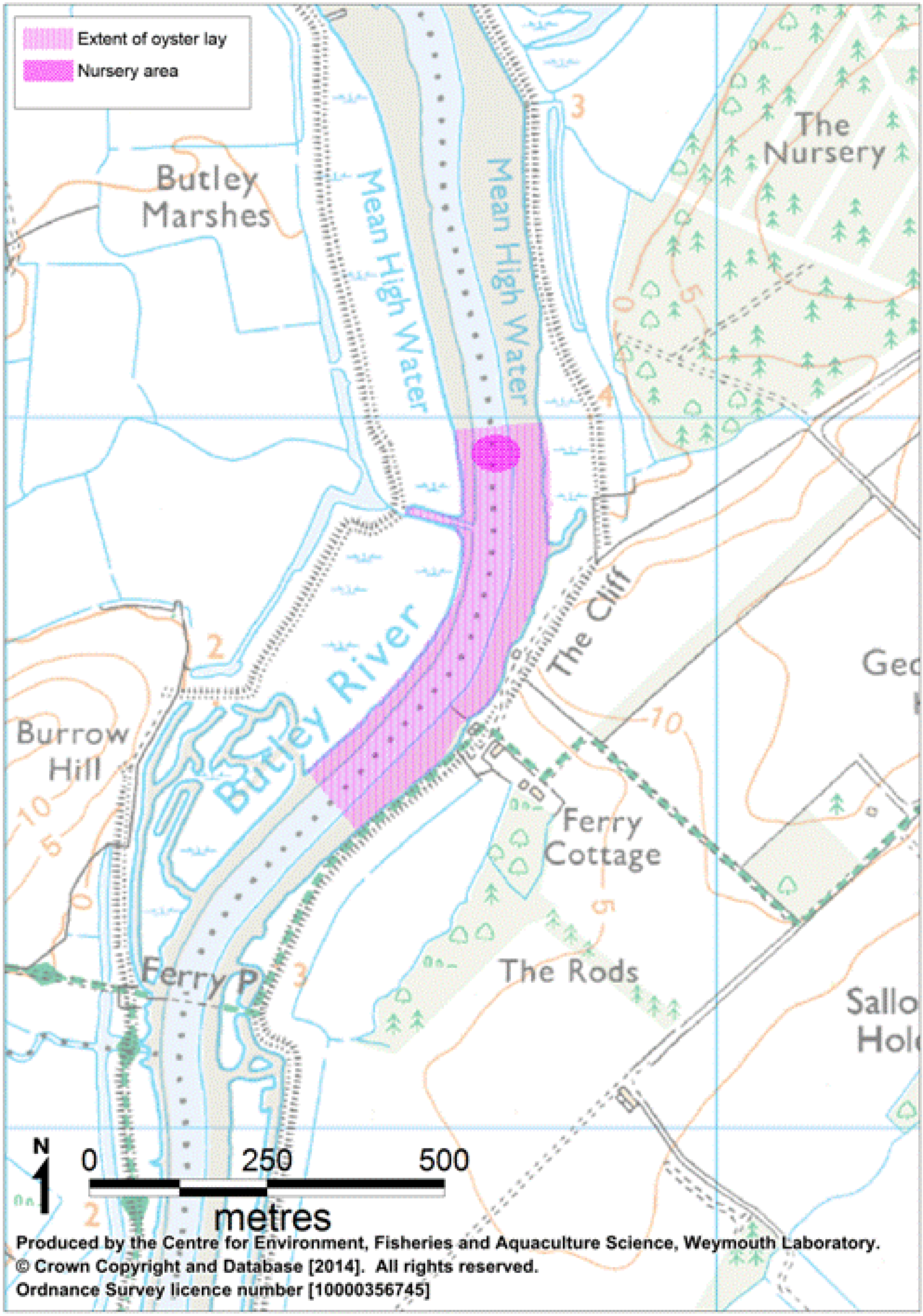


Figure 4.1: Location of oyster lays at Butley

Pacific oysters are cultured within a 600 m stretch of the Butley estuary, which is approximately centred around Ferry Cottage, from where the operation is run.

4.2. Growing Methods and Harvesting Techniques

The oysters grown are bought in from the hatcheries at a small size (<10 g) and are initially held in bags suspended from floats in a nursery area at the northern end of the fishery. Once they reach sufficient size they are then laid on the seabed until they have grown to market size. This process takes around 2 years in total. They are then harvested via dredge, and depurated at the harvesters own facilities. The vast majority of oysters produced are sold by a restaurant in Orford, which is under the same ownership. There are two holding ponds by Ferry Cottage which are used for holding lobsters. Occasionally they may be used to hold seed oysters for short periods before they are laid on the seabed for ongrowing, but they are not used for holding market sized oysters between harvest and depuration.

4.3. Seasonality of Harvest, Conservation Controls and Development Potential

Harvesting occurs throughout the year to maintain steady a supply to the restaurant. No conservation controls such as minimum landing size apply to this culture fishery. Annual production is about 5 tonnes, and it is anticipated that similar volumes will continue to be produced.

Culture of mussels was attempted within the estuary about a decade ago, but this was subsequently abandoned and there is no intention to restock with this species.

4.4. Hygiene Classification

Table 4.1 lists all classifications at Butley from 2004 onwards.

Table 4.1: Classification history for Butley, 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Butley Creek	Pacific oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Butley Creek	Mussel	B	B-LT	-	-	-	-	-	-	-	-

LT denotes long term classification

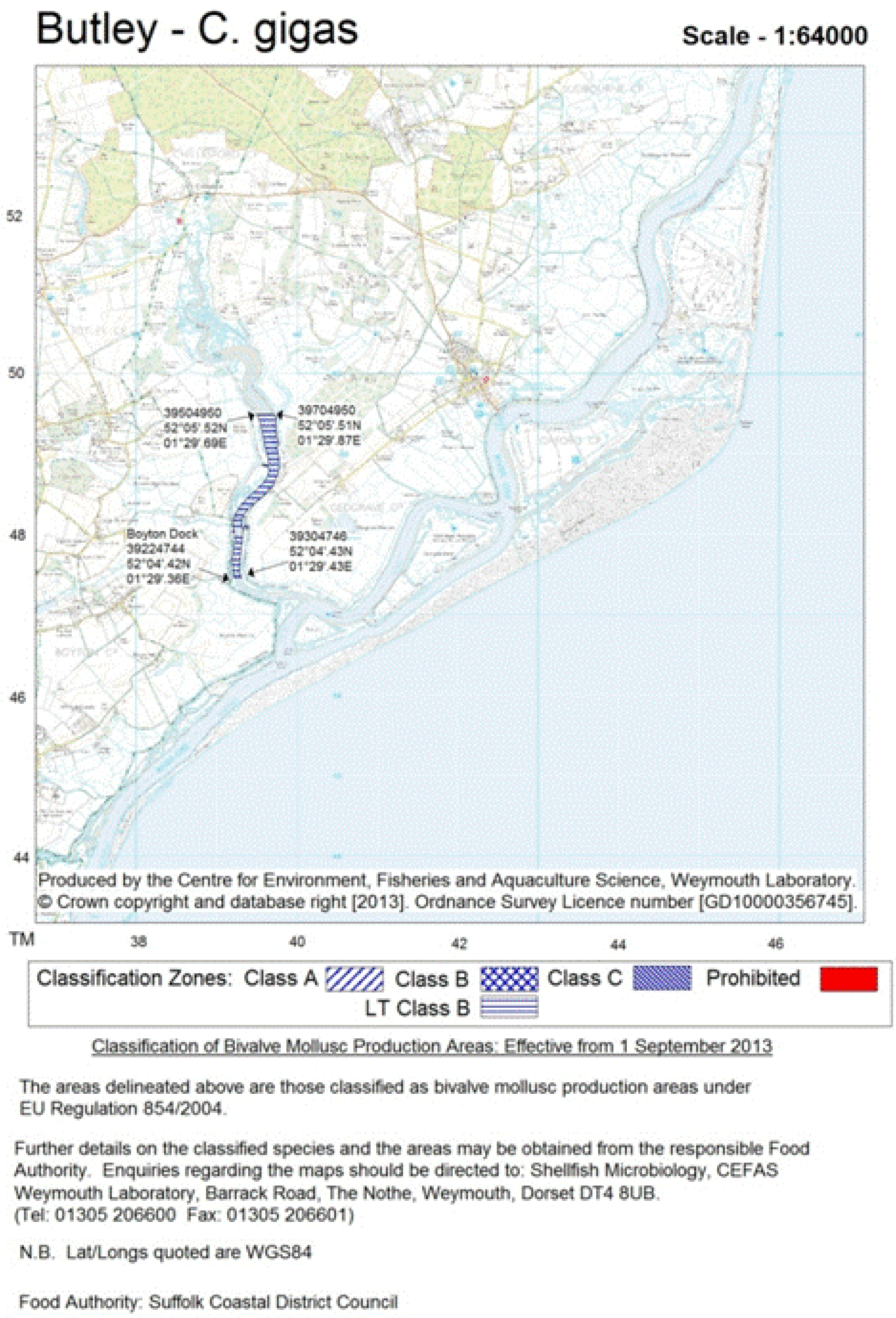


Figure 4.2: Current Pacific oyster classification

The area currently classified for Pacific oysters extends about 500 m farther north and 1 km further south than is actually required.

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 supports a well established Pacific oyster culture fishery, where seed is initially grown in suspended culture, then transferred to the river bed where it is grown on to a market size then harvested via dredge. The fishery lies within a 600m stretch of the estuary, which is centred approximately around Ferry Cottage from where the operation is run. The nursery area lies at the northern end of this stretch, and the ground lays are present throughout it. As harvesting occurs throughout the year, continued year round classification of this fishery is required.

5.3. Pollution Sources

Freshwater Inputs

The Butley estuary has a hydrological catchment of only 60 km^2 draining to it, so freshwater inputs direct to the estuary are limited. There are four freshwater inputs, two of which are minor rivers (Butley and Tang) and two of which are pumping stations draining the reclaimed land adjacent to the estuary (Chillesford PS and Butley PS). The catchment they drain is largely arable farmland, but there are pastures bordering the River Butley, as well as in some areas adjacent to the estuary, so they are likely to be subject to some agricultural inputs. The hydrogeology is of moderate permeability, so a proportion of rainfall will infiltrate the soil rather than entering watercourses.

There are no gauging stations on any of the watercourses within the catchment, so it was not possible to evaluate the volumes of runoff the estuary receives. However, it can be assumed that flows will generally be higher in the winter months, as although rainfall does not vary much through the year, there is less evaporation and transpiration during the colder months, leading to a higher water table. The Butley and Chillesford pumping stations do not have particularly large pumping capacities (0.5 and 0.2 m^3/sec respectively) and will only pump for a small fraction of the time. It is likely that they operate for a much higher proportion of the time during the colder months, and during the warmer months water will be held back for irrigation.

Although there was no information on discharge volumes of the watercourses, the results of repeated bacteriological testing of the four freshwater inputs were available. The average and maximum levels of faecal indicator bacteria in all four freshwater inputs were broadly similar and quite low (geometric means ranging from 36 to 75, and maximums ranging from 640 to 3800 faecal coliforms/100 ml). All freshwater inputs tend to carry lower levels of faecal coliforms during the spring. Their geographical distribution suggests there may be a tendency for increasing levels of runoff borne contamination towards the upper reaches, with a second possible hotspot in the vicinity of the River Tang outfall and the Butley PS.

Human Population

Results of the 2011 census were not available for part of the survey catchment, but in 2001 the total population in census areas contained within or partially within the catchment area was approximately 8,600. A large increase in population (~20%) across the wider area was reported between 2001 and 2011, although it is uncertain whether there was a significant increase within the Butley catchment. There is little in the way of tourist attractions in the survey area, so significant seasonal fluctuations in population are not anticipated.

Sewage Discharges

There are no water company sewage works discharging directly to the Butley estuary or its hydrological catchment. There are however two sewage works which discharge to the Alde/Ore channel via short watercourses which may have some influence. The largest of these is Hollesley STW, which provides secondary treatment for a consented dry weather flow of 1400 m^3/day, and generates an estimated bacterial loading of 4.6×10^{12} faecal coliforms/day. The watercourse to which it discharges feeds into the main Ore channel about 3.8 km to the west of the mouth of the Butley. Contamination from this source may therefore be carried into the Butley channel during the flooding tide, assuming the tide carries it this far before reversing. Gedgrave STW provides secondary treatment for a dry weather flow of 188 m^3/day, and generates an estimated bacterial loading of 6.2×10^{11} faecal coliforms/day. This discharges to the network of field drains on the Gedgrave Marshes, which feed into the Ore channel to the east of the mouth of the Butley. Whilst this will contribute to faecal indicator concentrations in the Ore channel, it will not impact directly on the shellfishery as effluent will be carried towards Butley on the ebb tide, at which time water will be flowing out of the Butley channel as well. As both of these works discharge to field drains in low lying reclaimed farmland where flows are likely to be sluggish for most of the time, some bacterial dieoff is anticipated before the effluent reaches tidal waters.

There are no intermittent discharges associated with the water company owned sewerage infrastructure either discharging directly to the Butley estuary, or to its hydrological catchment.

There are 19 permitted private sewage discharges within the survey catchment. Of these, five discharge to soakaway so should be of no impact to coastal waters assuming they are functioning correctly. Of the 14 discharging to water, 8 discharge to the Tang and tributaries, with a consented maximum flow totalling about 20 m^3/day and three (combined maximum flow of 7 m^3/day) discharge to the Butley River and tributaries within 500 m of the tidal limit. The largest private discharge is from Sudbourne Hall (18 m^3/day) and this is to an unnamed drain which ultimately feeds into the estuary via the Chillesford PS. These sewage discharges will make a relatively minor contribution to the bacterial loading carried by these watercourses. There is some uncertainty as to the course followed by the two remaining private discharges to water, which are located in the north of the catchment, as there are no surface watercourses visible in their vicinity on the Ordnance Survey maps.

Agriculture

The majority of the land within the survey catchment is used for agriculture, although there are significant parts of the western catchment which are occupied by forestry and two disused airfields. Most agricultural land is in arable use, but there are some areas of pasture, most of which lie on the banks of the River Butley and the upper reaches of the estuary.

Livestock census data from 2010 indicates that large numbers of poultry and pigs (~300,000 and ~18,000) are farmed in the catchment. There are also significant numbers of grazing animals (~3,000 cattle and ~5,000 sheep). Contamination of livestock origin will either be deposited directly on pastures by grazing animals, or collected from operations such as cattle sheds and poultry houses and spread on farmlands. This in turn may enter watercourses which will carry it to coastal waters. As the primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, fluxes of agricultural contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). The geographical distribution of pasture suggests that the River Butley and the field drains served by Chillesford PS may be most heavily impacted by grazing animals. The extent of these impacts will be influenced by the amount of access livestock have to these watercourses. The spatial pattern of application of organic fertilisers (manures, slurries and sewage sludge) to arable crops is uncertain, but arable land is widespread throughout the catchment so most, if not all, watercourses may be impacted at times.

There is likely to be some seasonality in fluxes of agricultural contamination. Numbers of sheep and cattle will increase in the spring with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Livestock are likely to access watercourses to drink and cool off more frequently during the warmer months. The seasonal pattern of application of manures and slurries to farmland is uncertain, although as the area is within a nitrate vulnerable zone spreading is not permitted during the winter. Therefore peak levels of contamination from livestock 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 and possibly more intense basis if wet weather follows a slurry application, which is not permitted during the winter.

Boats

Boat traffic within the Alde/Ore estuary complex is limited to pleasure craft such as sailing dinghies, yachts and cabin cruisers, and a handful of fishing boats. Most of these are associated with Orford Quay and Slaughden Quay, both of which are on the main Alde/Ore channel, and so are unlikely to enter the Butley estuary. There are a few boat moorings on the Butley estuary which are mainly located within the central reaches of the area classified for oysters, and an anchorage area from the mouth of the Butley channel up to the southern end of the classified area.

Relatively small numbers of boats will use the lower reaches of the Butley for anchoring and mooring, so impacts from boats are likely to be minor within this area. Only private vessels such as yachts, motor cruisers and fishing vessels of a sufficient size are likely to make overboard discharges. 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 area. As such, the Alde/Ore channel and to a lesser extent the lower reaches of the Butley channel are most at risk. 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.

Wildlife

The Butley estuary and the wider Alde/Ore estuary complex encompasses a variety of habitats, and these support significant aggregations of wildlife. The most important of these from a shellfish hygiene perspective are likely to be overwintering waterbirds (wildfowl and waders). Over the five winters up until 2011/2012 an average maximum count of 33,908 overwintering waterbirds were recorded within the Alde/Ore complex, and during the shoreline survey (February) flocks of birds were observed throughout but in particular large numbers around Havergate Island. Inputs from these birds may be considered as diffuse, but some areas may be subject to a higher intensity of bird presence. Waders feeding on intertidal invertebrates may seek aggregations of their preferred prey, although this will depend on species and will likely vary over time. Grazers will frequent saltmarsh and coastal grasslands, so drainage from such areas will carry contamination from these into the estuary. All species are likely to have preferred roosting areas, which will typically be remote areas inaccessible to humans and predators, such as Havergate Island. It is therefore concluded that the inputs from overwintering waterbirds are generally diffuse and whilst they may be a significant contaminating influence they will have little bearing on the sampling plan. One possible exception is the grazing birds, and contamination from these may be best captured by RMPs in saltmarsh or watercourse drainage channels through the intertidal.

Whilst most of these birds migrate elsewhere to breed, there are significant resident and breeding populations of seabirds (gulls, terns etc) in the area. A census of these in the early summer of 2000 recorded 6,919 pairs within a 5 km radius of the Butley estuary, the vast majority of which form a major colony at Orford Ness. A smaller breeding colony of 612 pairs of gulls and terns was reported on Havergate Island, but there were only four pairs of gulls recorded within the Butley estuary. 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. As there are not significant breeding colonies within the Butley estuary, their impacts here will be diffuse and will not influence the sampling plan.

Aside from birds, it is likely that seals enter the area from time to time, but not in great numbers, and no regular haulout sites were identified in the Butley estuary. There are reported to be a few otters in the area as well. Both these species will only be present in small numbers, and their impacts will be unpredictable in spatial terms so they will have no bearing on the sampling plan

Domestic animals

Dog walking takes place on 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 accessible paths. 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.

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												
Continuous sewage discharges												
Intermittent sewage discharges												
Urban runoff												
Waterbirds												
Boats												

Red - high risk; orange - moderate risk; yellow - lower risk; white - little or no risk.

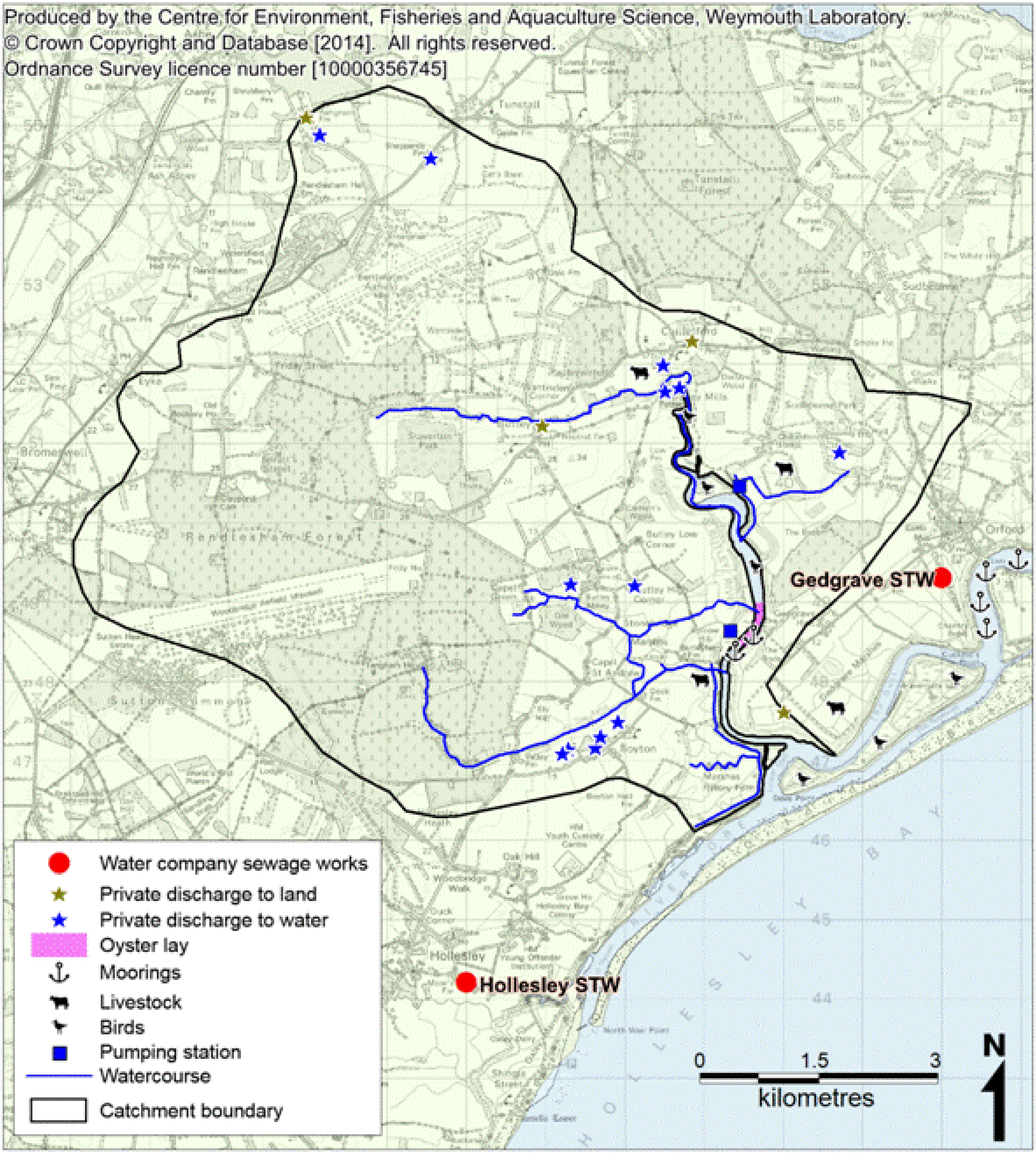


Figure 5.1: Summary of main contaminating influences

Hydrography

The Alde/Ore has a relatively long and narrow main channel of about 26 km from mouth to tidal limit. This channel averages about 5 m in depth and the intertidal areas are limited. It runs parallel to the coast behind a shingle bar for most of its length before heading inland and opening out into a wider, shallower tidal basin with more extensive intertidal areas. The Butley estuary forms a relatively small sidearm that branches off from the main channel about 5 km from the mouth, where it splits into two around Havergate Island. The Butley estuary is about 6 km in length and meanders in a northerly direction. Again, this is a relatively narrow channel, but the central subtidal channel is shallower and does not generally exceed 2 m in depth relative to chart datum. Intertidal areas cover a larger proportion of the Butley channel than the Alde/Ore channel, with mud and saltmarsh, and are backed by earth dykes that protect the adjacent reclaimed land. The subtidal channel becomes narrower, shallower and more meandering in its upper reaches, where the estuary widens slightly and the saltmarsh becomes more extensive. Its shallow nature will promote tidal exchange but will limit dilution potential.

Water circulation in the estuary is primarily driven by tides. The tidal range at the mouth of the Ore is 2.8 m and 1.6 m on spring and neap tides respectively. This decreases to 2.2 m and 1.2 m at Orford Quay, where high water arrives about an hour later. No firm information on current speeds of relevance to the survey could be found, so it was not possible to estimate tidal excursions and hence the approximate distances contamination may be carried from its source during the course of a flood or ebb tide. Tidal streams will flow up the estuary on the flood tide and back down the estuary on the ebb. Therefore contamination from shoreline sources will travel up or down estuary with the tide, impacting either side along the same shore, and the magnitude of their impacts will decrease with increasing distance as the plume spreads. On the flood tide, contamination from sources discharging to the north shore of the outer Alde/Ore channel will be carried up this channel and into the Butley. The Hollesley STW discharges to the north shore of the Ore channel about 3.5 km from the mouth of the Butley, so contamination from this may reach the shellfishery towards the end of a flood tide, albeit subject to significant dilution and mixing. Sources discharging to the Alde/Ore channel up-estuary from the Butley confluence, such as the Gedgrave STW will not impact directly within the Butley channel as contamination from them will be carried out past it on the ebbing tide.

Freshwater inputs to the Butley estuary are minor in relation to tidal exchange so the system can be considered well mixed, and density driven circulation is unlikely to be of significance. Repeated surface salinity measurements taken at the Butley Oysterage shellfish waters monitoring point showed an average salinity of 26.8 ppt, with the minimum recorded being 12 ppt. There is therefore a significant freshwater influence in the vicinity of the fishery at times, and decreased salinity was correlated with increased levels of faecal coliforms here. This suggests that land runoff is a significant contaminating influence.

Winds may modify circulation patterns, as they drive surface currents which in turn create return currents at depth or along sheltered margins. Southerly winds for example will tend to push surface water up the estuary. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended, although given the enclosed nature of the estuary strong wave action is not generally anticipated.

5.4. Summary of Microbiological Data

The survey area has been subject to limited microbiological monitoring over recent years, deriving from the Shellfish Waters monitoring programme, and 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 these analyses.

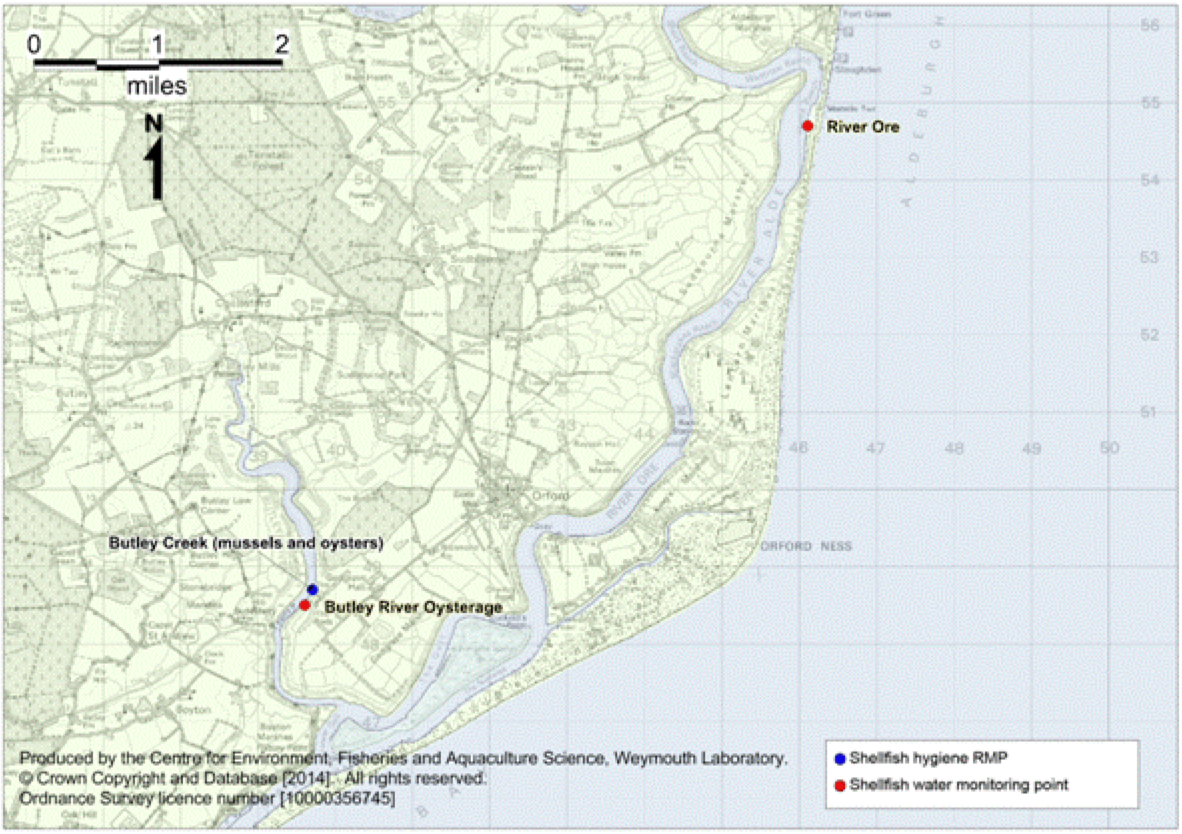


Figure 5.2: Location of microbiological sampling sites.

Shellfish Waters

There are two shellfish waters monitoring points within the Alde/Ore system, where water has been sampled and enumerated for faecal coliforms just over 100 times at each since 2003. One is located at Slaughden in the Ore Channel and so is of minor relevance to the fishery in the Butley. At the Butley River Oysterage the geometric mean result was 18.5 faecal coliforms/100 ml, with a maximum result of 909 faecal coliforms/100 g. The mean result was significantly lower (8.3 faecal coliforms/100 g) at River Ore. The results of paired (same day) samples were weakly correlated suggesting the system as a whole is under broadly similar influences.

Since 2003, results at Butley River Oysterage have fluctuated with time, and were more stable at River Ore. Statistically significant seasonal variation was found at both points, with lowest results in the spring. A statistically significant influence of tides across both the high/low and spring/neap tidal cycle was found for Butley River Oysterage only. Results here were higher on average around low water, and higher results tended to occur as tide size decreased from springs to neaps. Significant correlations with antecedent rainfall were found at both. At Butley River Oysterage the response was rapid (1-3 days after a rainfall event) whereas at River Ore the influence was significant 3-5 days after a rainfall event. A significant correlation between faecal coliform levels and salinity was found only at Butley River Oysterage. These findings suggest that the Butley River Oysterage is more influenced by land runoff than River Ore.

Shellfish Hygiene monitoring

Only two RMPs have been sampled within the Butley since 2003, one of which is for mussels and the other of which is for Pacific oysters. They are both in the same location. The mussel RMP was sampled on 28 occasions from 2003 to 2005, and the Pacific oyster RMP was sampled on 134 occasions from 2003 to present. The geometric mean results for the two species were similar (255 *E. coli* MPN/100 g for mussels, and 206 *E. coli* MPN/100 g for Pacific oysters) as were the proportions of results exceeding 4600 *E. coli* MPN/100g (3.6 and 3.0 % respectively). The results for Pacific oysters did not show an increasing or decreasing trend since 2003. Some seasonality was observed in both species, with highest results on average during the summer, and lowest results on average during the spring, although this was only statistically significant for Pacific oysters.

A statistically significant influence of tidal state across the high/low cycle was detected for oysters. A plot of this data showed a tendency for higher results during the later stages of the ebb tide and around low water, which is consistent with up-estuary sources being an influence. No significant influence of the spring/neap tidal cycle was found, and it was not possible to conduct tidal analyses for mussels due to the lower number of samples. No statistically significant influence of rainfall was found for either species. Given the associations found here between faecal coliform concentrations in the water column and both salinity and rainfall, this difference between flesh and water may be due to reduced feeding rates in the oysters at times of lowered salinity.

Bacteriological survey

In order to further investigate spatial variation in levels of contamination across the fishery a series of additional seawater and sediment samples were taken during the shoreline survey. The seawater samples all contained 10 or <10 *E. coli* cfu/100 ml, perhaps due to the conditions at the time. The sediment samples contained from <20 to 800 cfu/100 g, with no consistent spatial pattern, although the highest result was recorded in the vicinity of the River Tang outfall.

Appendices

Appendix I. Human Population

The population data for the majority of the catchment were missing from the 2011 census dataset, so Figure I.1 shows population densities in census output areas within or partially within the Butley catchment area derived from data collected from the 2001 census.

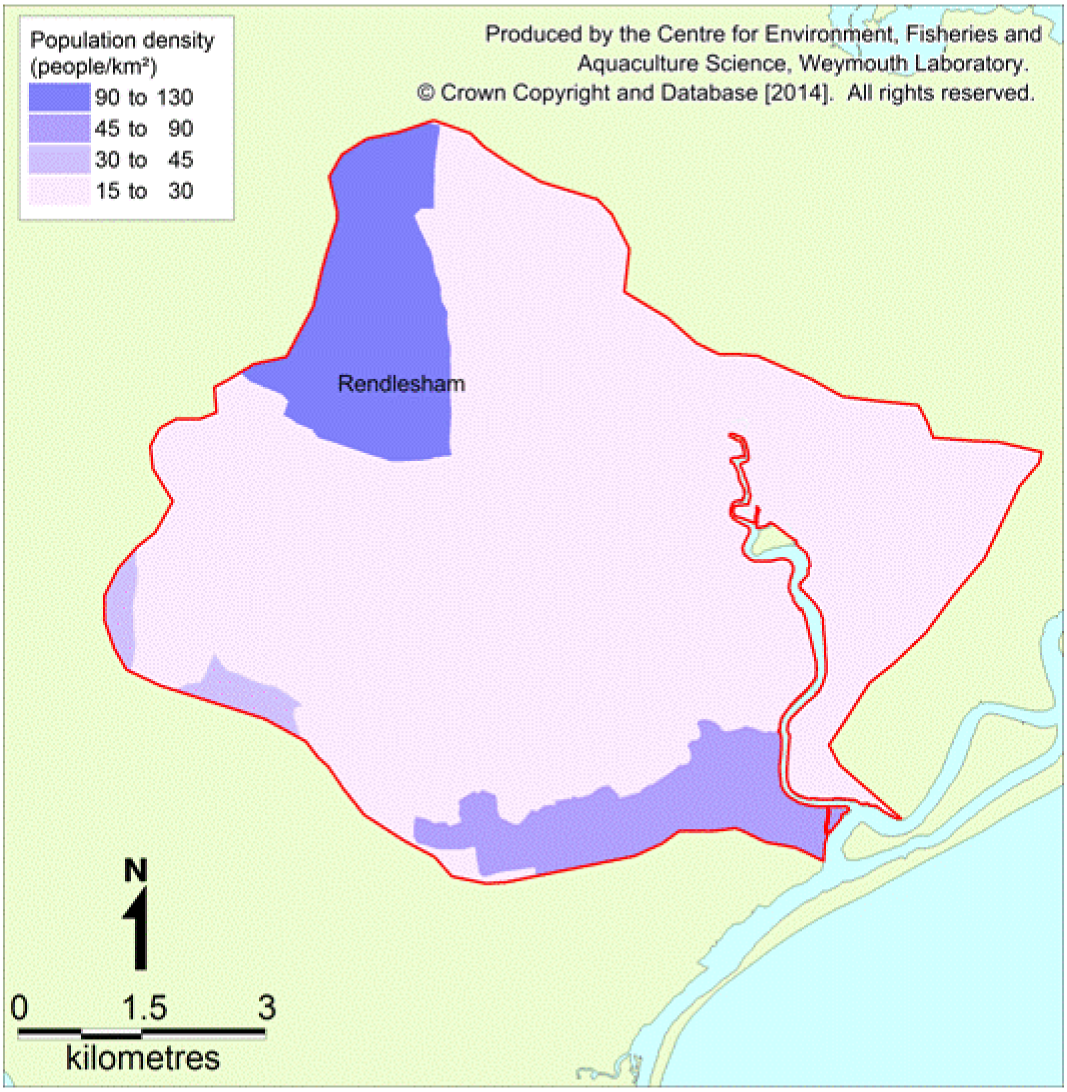


Figure I.1: Human population density in census areas in the Butley catchment.

Total resident population within the census areas contained within or partially within the catchment area was approximately 8,600 at the time of the 2001 census. However, the 2011 population in the wider area increased by 20% between 2001 and 2011, which means that the total population for this area may be more in the order of 10,000 in 2011, assuming that these increases were evenly distributed. There are few tourist attractions in the Butley catchment, and so it would not be expected that there would be a major seasonal fluctuation in population size.

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

Details of all sewage treatment works in the hydrological catchment, and two potentially relevant discharges just outside the catchment were taken from the most recent update of the Environment Agency national permit database (October 2013). These are mapped in Figure II.1, and details are presented in Table II.1 and Table II.3.

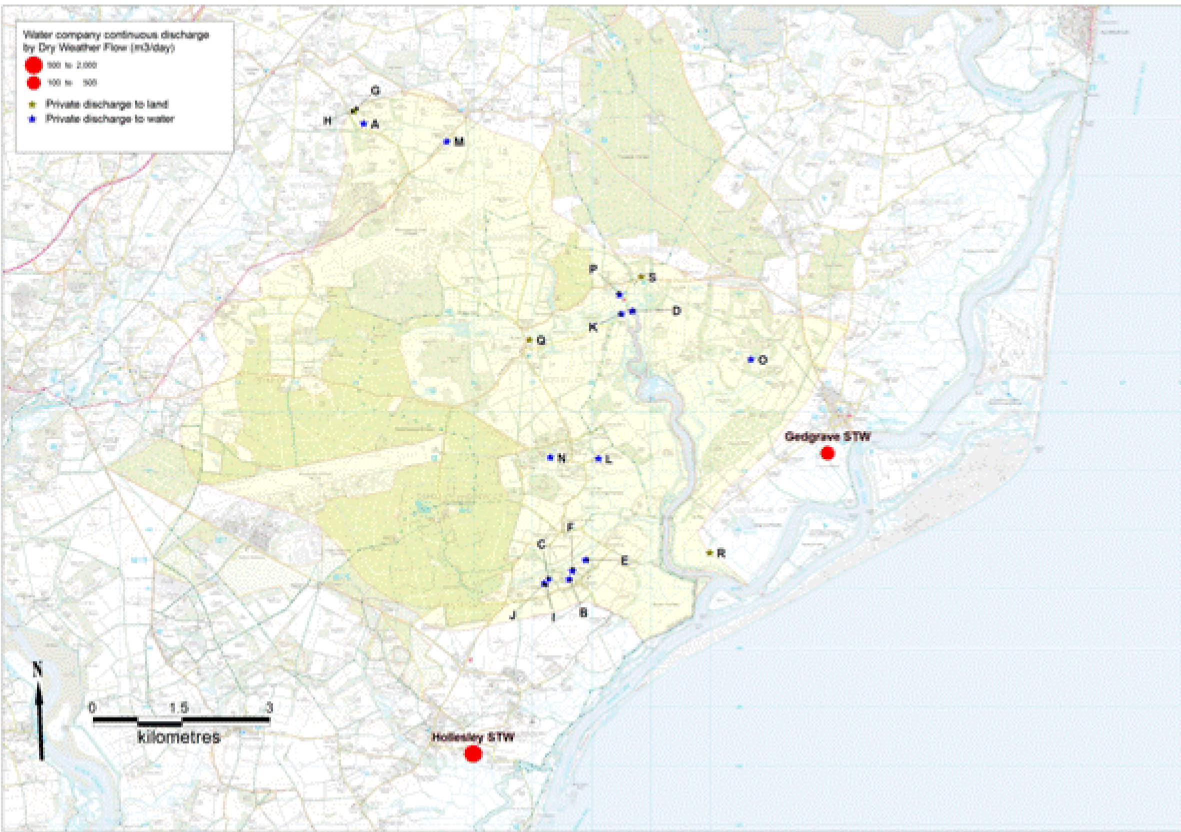


Figure II.1: Sewage discharges to the Butley catchment and nearby waters
Data from the Environment Agency

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
Gedgrave STW	TM 42000 49300	Biological Filtration	188	6.24×10^{11}	Marsh Drain River Ore Trib
Hollesley STW	TM 36000 44200	Biological Filtration	1400	4.62×10^{12}	Black Ditch, River Ore

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

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

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

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

There are no continuous water company discharges within the Butley catchment itself but there are two water company discharges, Gedgrave STW and Hollesley STW just outside the catchment that will contribute to bacterial indicator concentrations within the Ore channel. Gedgrave STW has a consented Dry Weather Flow (DWF) of 188 m^3/day and it discharges biologically treated effluent to a marsh drain entering the River Ore, approximately 5.6 km east of the nearest shellfishery. Depending on water movement locally this discharge may have limited impact at the southern end of the shellfishery in the River Butley. Hollesley STW discharges to Black Ditch approximately 2.7 km inland from the River Ore. The point where the ditch enters the River Ore is then a further 3.8 km southwest of the confluence of the Ore and the Butley. This sewage works has a consented DWF of 1400 m^3/day, discharging biologically treated effluent. The effluent will contribute bacterial loading to the River Ore, and during a flood tide this may impact on water quality at the shellfisheries in the River Butley. There are no intermittent discharges in the Butley catchment.

Although the majority of the survey area is served by water company sewerage infrastructure, there are also several 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 a small number of properties. Details of the private discharges are presented in Table II.3 and illustrated in Figure II.1.

Table II.3: Details of private sewage discharges

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Ashe Green Cottage	TM3414054900	Unspecified	2	Butley tributary
B	Bellfield	TM3762047170	Unspecified	0.81	Tang tributary
C	Boyton House	TM3727247156	Package Plant	1	Tang tributary
D	Butley Mills Complex	TM3868051720	Unspecified	5	Butley River at tidal limit
E	Cottons Acre Boyton	TM3790047500	Unspecified	4	Tang tributary
F	Crag Farm	TM3768047310	Unspecified	1	Tang tributary
G	Hall Barn	TM3400055128	Package Plant	1	Soakaway
H	Little Barn	TM3397455114	Package Plant	1	Soakaway
I	Mary Warner Almshouses	TM3722047090	Unspecified	7	Tang tributary
J	Mary Warner Homes	TM3720047100	Package Plant	4	Tang tributary
K	Miller's Cottage	TM3850051670	Unspecified	1	Butley River
L	Ocean View	TM3811149222	Unspecified	1.08	Tang tributary
M	Sheppards Farm House	TM3554554600	Package Plant	1.3	Butley tributary
N	Waterwood Cottage	TM3730649240	Package Plant	1	Tang tributary
O	Sudbourne Hall	TM4070050900	Unspecified	18	Unnamed drain (Chillesford PS)
P	The Old School House	TM3847052000	Unspecified	1	Butley tributary
Q	45 & 46 Mill Lane	TM3694751235	Package Plant	3	Soakaway
R	Ferry Farm	TM4000047620	Unspecified	5	Soakaway
S	1-3 Meadow Crescent	TM3883952300	Package Plant	2.6	Soakaway

Data from the Environment Agency.

There are 19 permitted private discharges within the survey catchment. Of these, five discharge to soakaway so should be of no impact to coastal waters assuming they are functioning correctly. Of the 14 discharging to water, 8 discharge to the Tang and tributaries, with a consented maximum flow totalling about 20 m^3/day and five (combined maximum flow of 10.3 m^3/day) discharge to the Butley River and tributaries within 500 m of the tidal limit. The largest private discharge is from Sudbourne Hall (18 m^3/day) and this is to an unnamed drain which ultimately feeds into the estuary via the Chillesford PS. Private discharges to watercourse will contribute to the bacterial loading they carry into coastal waters, but given their small sizes and numbers their overall influence of these discharges on shellfish hygiene within the estuary is likely to be minor at most.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

The majority of the land within the survey catchment is used for agriculture, although there are significant parts of the western catchment which are occupied by forestry and two disused airfields. Most agricultural land is in arable use, but there are some areas of pasture, most of which lie on the banks of the River Butley and the upper reaches of the estuary (Figure 1.2). Manure is either deposited directly on land by grazing animals or collected from cattle, pig or poultry units, and spread on farmland. This may in turn be washed into watercourses by rain which will carry it to coastal waters. As the primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, fluxes of agricultural contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush').

Table III.1 presents livestock numbers and densities for the catchment. These data were provided by Defra and are derived from the June 2010 census, as more recent censuses were less detailed. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, Table III.1 should give a reasonable indication of the numbers and types of livestock within the catchment.

Table III.1: Summary statistics from 2010 livestock census for the Butley catchment

Cattle		Sheep		Pigs		Poultry	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
2,950	49	5,057	84	18,141	303	311,956	5212

Data from Defra

The concentration of faecal coliforms excreted in the faeces of animals and humans 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 wet weight)	Excretion rate (g/day wet weight)	Faecal coliform load (No./day)
Chicken	1,300,000	182	2.3×10^8
Pig	3,300,000	2,700	8.9×10^9
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).

Large numbers of poultry and pigs are farmed in the catchment, as well as some grazing animals (cattle and sheep). During the shoreline survey around 30 sheep were observed on Gedgrave marshes and around 30 cows were observed at Chillesford. The geographical distribution of pasture suggests that the River Butley and the field drains served by Chillesford PS may be most heavily impacted by grazing animals. The extent of these impacts will be influenced by the amount of access livestock have to these watercourses. The spatial pattern of application of organic fertilisers (manures, slurries and sewage sludge) to arable crops is uncertain, but arable land is widespread throughout the catchment so most, if not all, watercourses may potentially be impacted at times.

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Livestock are likely to access watercourses to drink and cool off more frequently during the warmer months. In 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 the survey area is a nitrate vulnerable zone so spreading is not permitted during the winter. Therefore peak levels of contamination from grazing livestock 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 not permitted during the winter.

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is a potential source of bacterial contamination to shellfisheries within the Butley survey area. The Alde/Ore entrance is shallow, constantly changing, is potentially hazardous to navigate and is only buoyed from April to October. Boat traffic in the area is limited to fishing and recreational craft such as yachts, sailing dinghies and kayaks. 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 Butley survey area

There are no commercial ports, marinas or facilities for visiting yachtsmen within the Butley survey area, so merchant shipping is unlikely to enter the area. There are a few boat moorings on the Butley estuary which are mainly located within the central reaches of the area classified for oysters. The nautical chart of the area also shows anchorages from the mouth of the Butley channel up to the southern end of the classified area. There are numerous moorings in the Alde/Ore channel at Orford around Orford Quay, and also farther up this channel around Slaughden Quay. Both these quays provide some facilities for visiting yachtsmen, but no sewage pump-out services (The Green Blue, 2010). There is a small fishing fleet in the area, of which 5 fishing vessels under 10 metres are listed as having Orford Quay as their home port (MMO, 2013). Their fishing patterns are uncertain but in general they fish outside of the estuary complex (MCS, 2012).

It is therefore concluded that boat traffic within the estuary complex is limited to pleasure craft and a few fishing vessels, and most of these will be associated with Orford and Slaughden so will not generally enter the Butley arm. Relatively small numbers of boats will use the lower reaches of the Butley for anchoring and mooring. Smaller pleasure craft such as kayaks and sailing dinghies will not have onboard toilets and so are unlikely to make overboard discharges. 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 area. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the moorings and the main navigation routes through the area are most at risk of contamination from this source. 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 Butley estuary encompasses a variety of habitats including intertidal mudflats and sandflats, lagoons and saltmarsh which in turn attracts aggregations of wildlife. Consequently, alongside the rest of the Alde/Ore estuary complex, the Butley estuary has been classified as a Special Area of Conservation (SAC) and a RAMSAR site. The survey area is also protected by several other international and national environmental legislations including: a Site of Special Scientific Interest (SSSI) and a couple of RSPB reserves including Havergate Island and Boyton and Hollesley Marshes.

The most significant wildlife aggregation in terms of shellfish hygiene is likely to be overwintering waterbirds (waders and wildfowl). 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 2011/2012 an average maximum count of 33,908 overwintering waterbirds were recorded within the Alde/Ore complex (Austin *et al*, 2014). On the shoreline survey flocks of birds were observed throughout the area, and in particular large numbers around Havergate Island RSPB Reserve.

Grazers, such as 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 are likely to be a significant influence during the winter months.

Whilst most of these birds migrate elsewhere to breed, there are significant resident and breeding populations of seabirds (gulls, terns etc) in the area. A census of these in the early summer of 2000 recorded 6,919 pairs within a 5 km radius of the Butley estuary (Mitchell *et. al,* 2004). The vast majority of these were in the vicinity of Orford Ness (approximately 5 km north east of the survey area) where a total of

6,200 pairs of gulls were reported. A smaller breeding colony of 612 pairs of gulls and terns was reported on Havergate Island, but there were only four pairs of gulls within the Butley estuary. 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. As there are not significant breeding colonies within the Butley estuary, their impacts here will be diffuse and will not influence the sampling plan.

Whilst there are major seal colonies on the North Norfolk coast, and the Essex estuaries support about 100 harbour seals (MMO, 2011), there are no seal colonies within the Alde/Ore estuary complex. Small numbers are likely to forage in the area from time to time, their impacts will be minor at most and spatially unpredictable, and so will have no bearing on the sampling plan. Otters are present within the survey area and have been sighted at Boyton Marshes (RSPB, 2013b) however no information on numbers was available but the population is likely to be small. Otters generally tend to favour the more secluded areas with access to watercourses. However, given their wide distribution and small numbers otters have no influence on the sampling plan.

Appendix VI. Meteorological Data: Rainfall

The Woodbridge weather station, received an average of 416 mm per year between 2003 and 2012. Figure VI.1 presents a boxplot of daily rainfall records by month at Woodbridge.

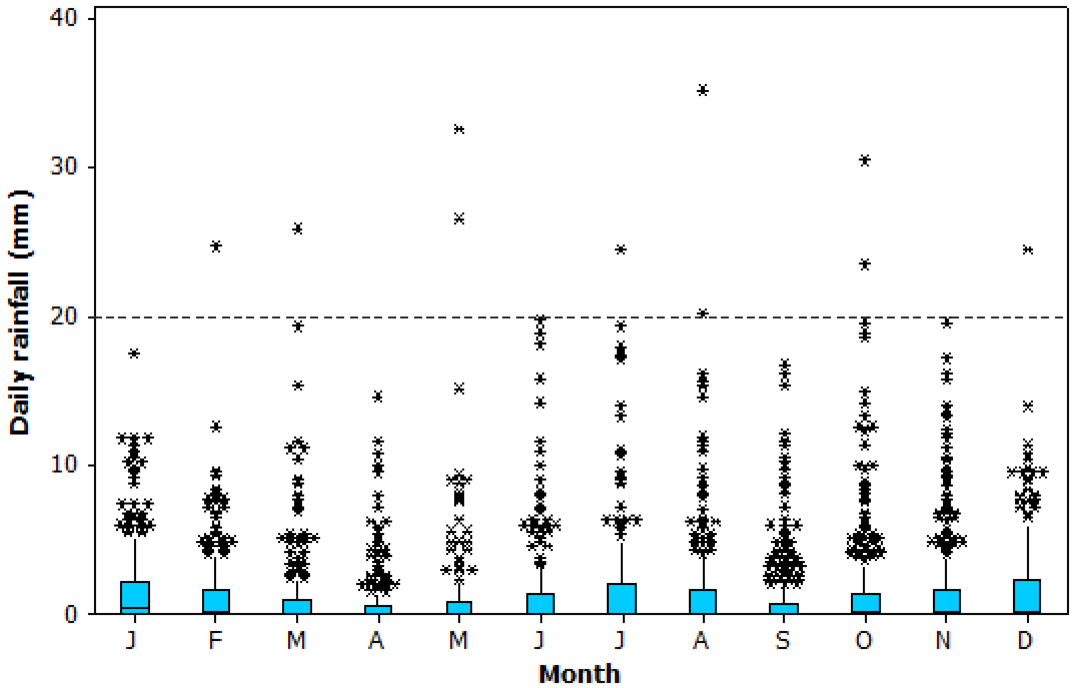


Figure VI.1: Boxplot of daily rainfall totals at Woodbridge, January 2003 to December 2012.
Data from the Environment Agency

Rainfall records from Woodbridge, which is representative of conditions in the vicinity of the shellfish beds, indicate some seasonal variation in average rainfall with slightly more rainfall through the period October to January, and a secondary peak during the summer. Rainfall was lowest on average in February and highest on average in June. Daily totals of over 20 mm were only recorded on 0.3 % of days and were recorded in every season, and 49 % 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

Eastern England is one of the more sheltered parts of the UK, since the windiest 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).

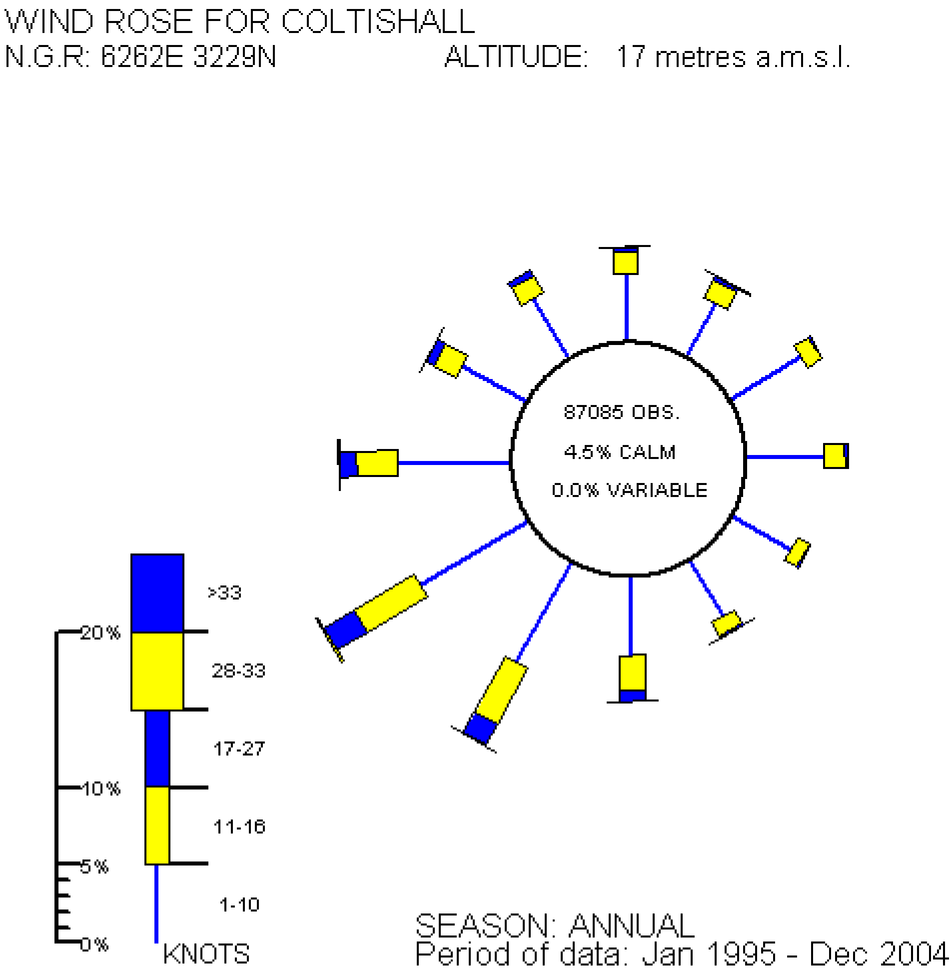


Figure VII.1 Wind Rose for Coltishall
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Coltishall is typical of open, level locations across the region. There is a prevailing south-westerly wind direction throughout the year. During spring there is also a high frequency of north-easterly winds due to a build up of high pressure over Scandinavia. Periods of very light or calm winds are more prevalent inland, with coastal areas having similar wind directions to inland locations but higher wind speeds. The Butley estuary has a north west to south east orientation and is therefore afforded some shelter from the prevailing south westerly winds, although it is surrounded by low lying land which offers limited protection. Orford Ness Spit runs parallel to the shore and shields the entrance of the Butley estuary from North Sea swells.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The Butley estuary has a hydrological catchment of only 60 km² draining to it, so freshwater inputs direct to the estuary are limited. There are two main freshwater inputs; the Butley River and the Tang River (Figure VIII.1), one of which enters at the head of the channel, and the other drains to the west shore of the lower reaches. Both enter the estuary via sluice gates. There are also two pumped outfalls (Chillesford PS and Butley PS) which drain the reclaimed land bordering the estuary.

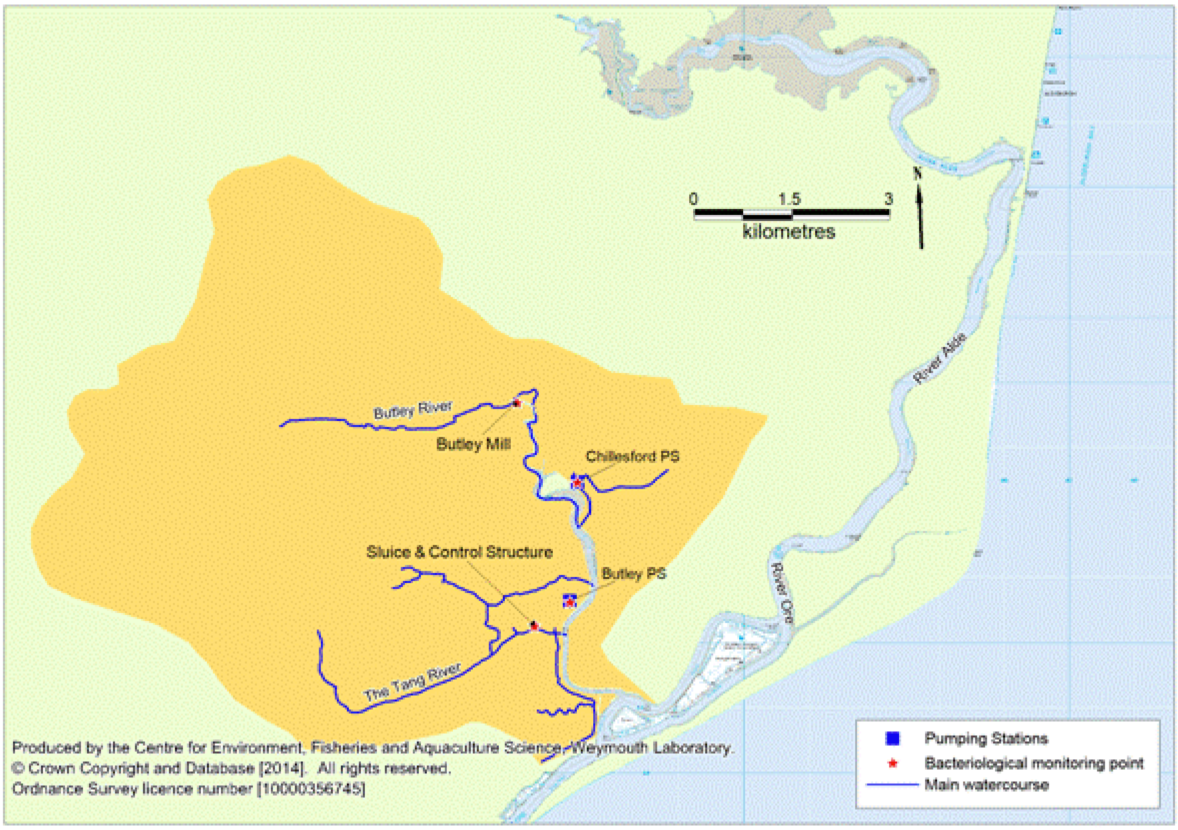


Figure VIII.1 Main watercourses and pumping stations in the Butley catchment

Both the River Butley and River Tang originate from and flow through rural land, principally arable and horticultural land, with around 30% woodland. The River Butley, and the upper reaches of its estuary are flanked by strips of pasture. Urbanised land is limited to the north of the catchment representing the village of Rendlesham and two disused airfields. A large proportion of the land bordering the estuary has been reclaimed for agriculture and is around or below sea level and is drained by a network of ditches. The majority of the estuary is enclosed by manmade embankments.

The catchment is of moderately permeable hydrogeology (NERC, 2012) so a proportion of rainfall will infiltrate the soil. There are no gauging stations on any of the watercourses within the catchment, so it was not possible to evaluate the volumes of runoff the estuary receives. However, it can be assumed that flows will generally be higher in the winter months, as although rainfall does not vary much through the year, there is less evaporation and transpiration during the colder months, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. The Butley and Chillesford pumping stations have maximum capacities of 0.5 and 0.2 m^3/sec respectively (Solomon and Wright, 2012), although they will only pump for a small fraction of the time. It is likely that they operate for a much higher proportion of the time during the colder months, and during the warmer months water will be held back for irrigation.

Although there was no information on discharge volumes of the watercourses, the results of repeated bacteriological testing from the two main rivers and the two pumping stations were available. Table VIII.1 and Figure VIII.2 summarise the results of repeated sampling from the two watercourses and from the drains at the two pumping stations.

Table VIII.1: Summary statistics for faecal coliform monitoring results (2003-2013) from principle freshwater inputs

	Faecal coliforms results (cfu/100ml)			
Site	**No. samples**	**Geometric mean**	**Minimum**	**Maximum**
Butley Mill	58	75	4	1080
Butley PS	18	44	<10	1818
Chillesford PS	20	36	<10	3800
Sluice & Control Structure (River Tang)	20	37	<10	640

Data from the Environment Agency

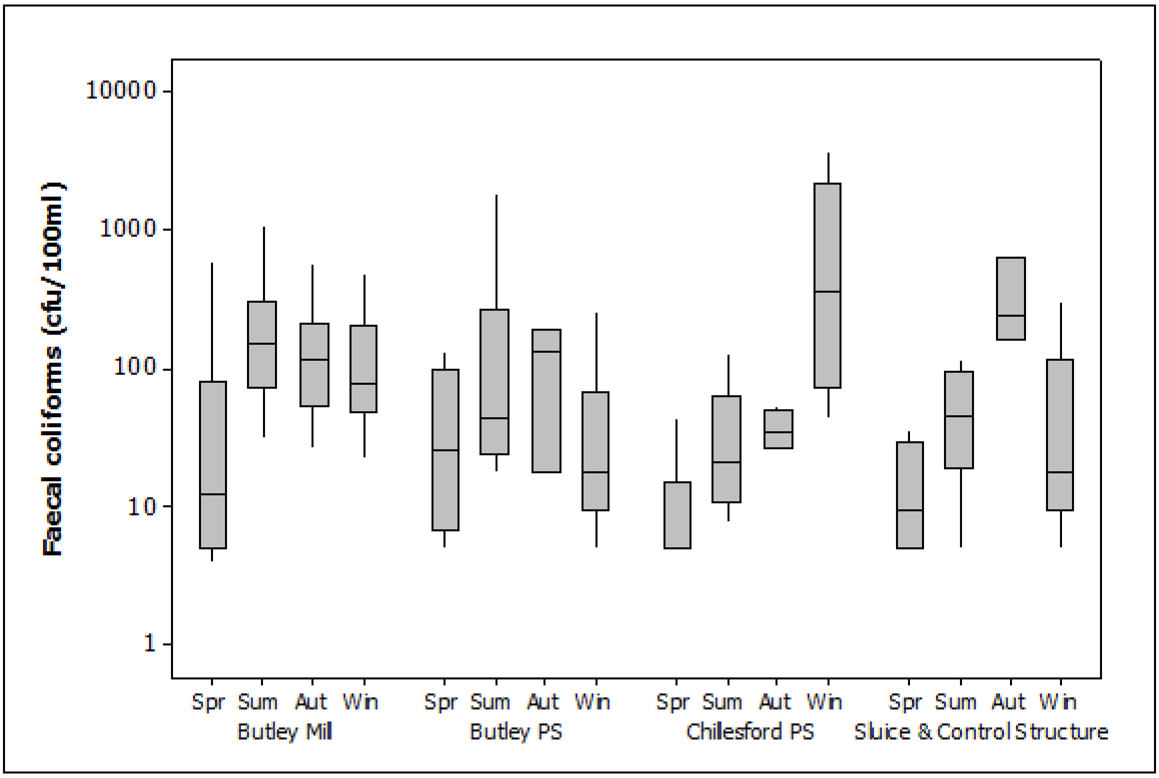


Figure VIII.2: Boxplots of faecal coliform concentrations by season in the principle freshwater inputs
Data from the Environment Agency

The average and maximum levels of faecal indicator bacteria in all four freshwater inputs were broadly similar and quite low. Faecal coliform concentrations tended to be lowest on average in the spring. Their relative importance will therefore largely depend on the volumes of water they discharge. During the shoreline survey, which was undertaken following a prolonged wet spell, the only freshwater input sampled was the Butley River and this only contained 20 *E. coli* cfu/100 ml.

It is therefore concluded that there are only four freshwater inputs to the Butley estuary, two of which are minor rivers of a similar size, and two of which are pumped outfalls with a relatively low pumping capacity. The geographical distribution of these suggests there may be a tendency for increasing levels of runoff borne contamination towards the upper reaches, and a second hotspot around the River Tang outfall. The pumped outfalls will operate more during the colder months of the year, and river flows will also be higher at these times. All freshwater inputs tend to carry lower levels of faecal coliforms during the spring. Their overall influence is likely to be limited as all four of these freshwater inputs generally contain relatively low levels of faecal indicator bacteria.

Appendix IX. Hydrography

IX.1. Bathymetry

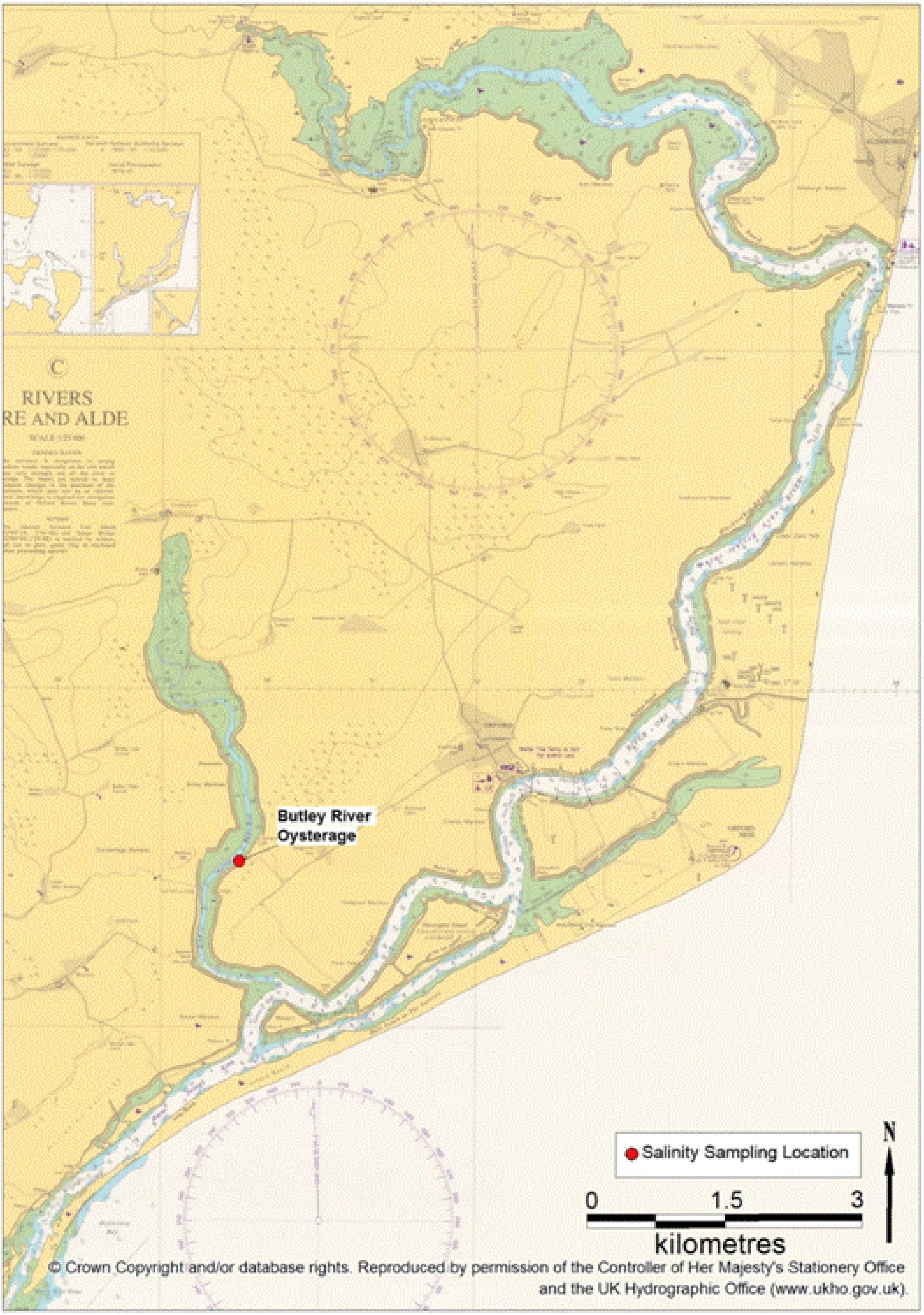


Figure IX.1 Bathymetry of the Alde/Ore estuary complex

The Alde/Ore has a relatively long and narrow main channel of about 26 km from mouth to tidal limit. This channel averages about 5 m in depth and the intertidal areas are limited. It runs parallel to the coast behind a shingle bar for most of its length before heading inland and opening out into a wider, shallower tidal basin with more extensive intertidal areas. The Butley estuary forms a relatively small sidearm that branches off from the main channel about 5 km from the mouth, where it splits into two around Havergate Island. The Butley estuary is about 6 km in length and meanders in a northerly direction. Again, this is a relatively narrow channel, but the central subtidal channel is shallower and does not generally exceed 2 m in depth relative to chart datum. Intertidal areas cover a larger proportion of the Butley channel than the Alde/Ore channel, with mud and saltmarsh, and are backed by earth dykes that protect the adjacent reclaimed land. The subtidal channel becomes narrower, shallower and more meandering in its upper reaches, where the estuary widens slightly and saltmarsh becomes more extensive. Its shallow nature will promote tidal exchange but will limit dilution potential. The estuary receives land runoff via two minor rivers, one of which drains to its head, and the other of which drains to the west shore about 1.7 km from its mouth, as well as a few minor field drains.

IX.2. Tides and Currents

Water circulation patterns within estuaries and coastal waters are driven by tides, which are regular and predictable, with more dynamic and unpredictable effects from freshwater inputs, barometric pressure and winds superimposed on this.

Table IX.1 Tidal levels and ranges within the Butley survey area

Port	Height above chart datum (m)				Range (m)	
	MHWS	**MHWN**	**MLWN**	**MLWS**	**Spring**	**Neap**
Orford Haven Bar	3.2	2.6	1.0	0.4	2.8	1.6
Orford Quay	2.8	2.3	1.1	0.6	2.2	1.2

Data from the Proudman Oceanographic Laboratory

The Alde/Ore estuary can be described as meso tidal, with a tidal range of 2.8 m and 1.6 m at its mouth (Orford Haven Bar) on spring and neap tides respectively. This decreases to 2.2 m and 1.2 m at Orford Quay which is about 5 km further up the Alde/Ore channel than the mouth of the Butley. High water arrives at Orford Quay just over an hour after it arrives at Orford Haven Bar. There are no tidal diamonds within the estuary complex. The maximum current velocity at the mouth of the Ore is reported to be 1.63 m/s (Royal Haskoning, 2009). No further firm information on current speeds or direction was found during the literature search. It was therefore not possible to make estimates of the tidal excursion and hence the approximate distances over which contamination will be carried during the course of a tide.

Tidal streams are likely to dominate patterns of circulation within the estuary, and will flow up the estuary on the flood tide and back down the estuary on the ebb.

Therefore contamination from shoreline sources will travel up or down estuary with the tide, impacting either side along the same shore, and the magnitude of their impacts will decrease with increasing distance as the plume spreads. On the flood tide, contamination from sources discharging to the north shore of the outer Alde/Ore channel will be carried up this channel and into the Butley. Sources discharging to the Alde/Ore channel up-estuary from the Butley confluence will not impact directly within the Butley channel as contamination from these will be carried out past it on the ebbing tide.

In addition to tidally driven currents are the effects of freshwater inputs and wind. Freshwater inputs are very low relative to tidal exchange and the system as a whole is considered well mixed (Futurecoast, 2002). As such, density effects are unlikely to significantly modify tidal circulation patterns. Vertical salinity profiles taken during the shoreline survey confirmed that this was the case within the Butley estuary (Figure XII.6 – XII.10).

Repeated salinity measurements taken between 2003 and 2013 at one point within the Butley River show an average surface salinity of 26.8 ppt, with salinities as low as 12 ppt recorded (Figure IX.2). These measurements suggest that there is a significant freshwater influence within the Butley channel.

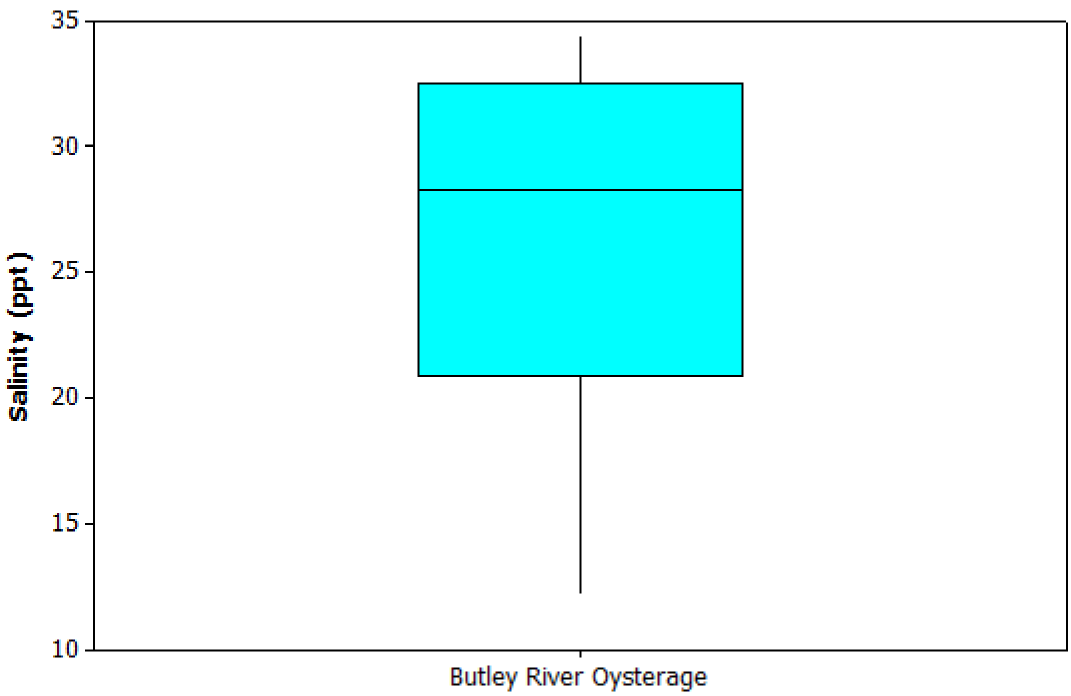


Figure IX.2: Boxplot of salinity measurements at Butley River Oysterage, 2003-2013.
Data from the Environment Agency

During the shoreline survey surface salinity remained at 31 ppt throughout the lower estuary and through the fishery, but dropped to 24 ppt about 700 m upstream of it. Water samples taken from these locations all contained low levels of *E. coli* (10 or

<10 cfu/100 ml) irrespective of salinity. A strong negative correlation between salinity and levels of faecal indicator bacteria was found at the Butley River Oysterage shellfish waters monitoring point (Figure X.7) suggesting that land runoff is a significant contaminating influence. The spatial patterns in salinity are therefore likely to reflect to some extent spatial variation in the levels of faecal indicator organisms in the water column. However, the freshwater influence and hence salinity profile at the time of shoreline survey may not be typical as the survey followed a prolonged period of wet weather.

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive surface water currents of about 0.5 m/s. These create return currents which may travel lower in the water column or along sheltered margins. Southerly winds will tend to push surface water up the estuary. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended, although given the enclosed nature of the estuary strong wave action is not generally anticipated.

Appendix X. Microbiological Data: Seawater

Summary statistics and geographical variation

The only microbiological monitoring of seawaters in the survey area derives from the Shellfish Waters monitoring programme. There are two Shellfish Waters monitoring sites designated under Directive 2006/113/EC (European Communities, 2006) relevant to the Butley production area. Figure X.1 shows the location of these sites. Table X.1 presents summary statistics for bacteriological monitoring results and Figure X.2 presents a boxplot of faecal coliform levels from the monitoring points.

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

Table X.1: 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
Butley River Oysterage	101	17/02/2003	23/07/2013	18.5	<2	909	14.9
River Ore	102	22/01/2003	23/07/2013	8.3	<2	144	4.9

Data from the Environment Agency

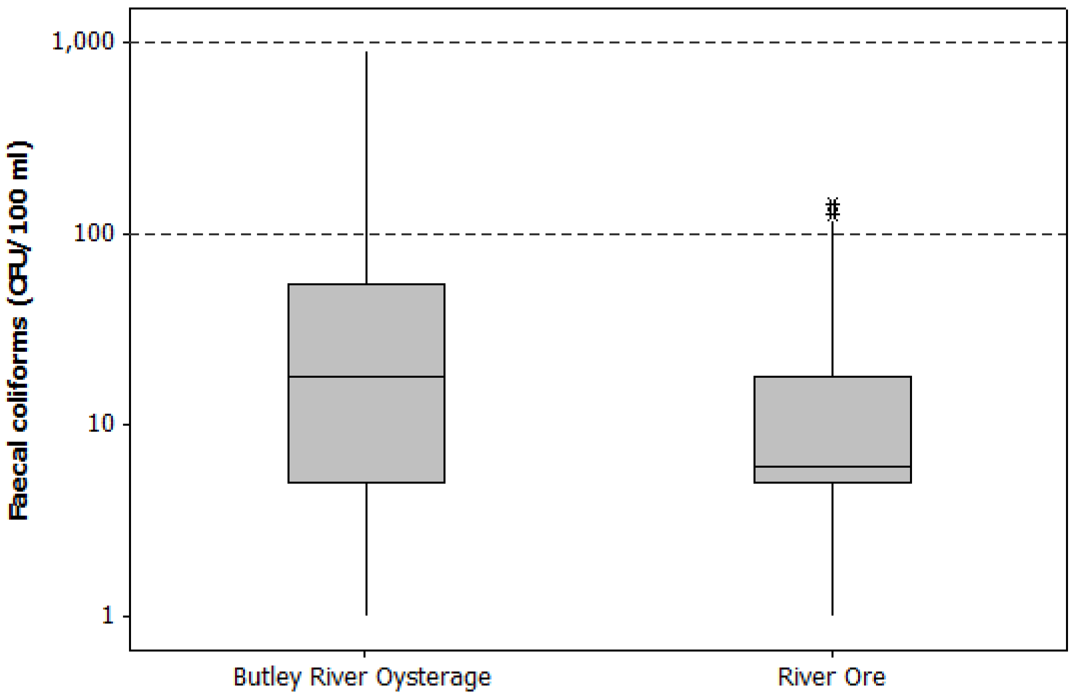


Figure X.2: Box-and-whisker plots of all faecal coliforms results
Data from the Environment Agency

Both sites had samples with more than 100 faecal coliform CFU/100 ml, but neither site had samples that exceeded 1,000 faecal coliform CFU/100 ml. A two-sample T-test showed that Butley River Oysterage had significantly higher faecal coliform levels than River Ore ($p<0.001$).

Comparisons of sites were carried out on a pair-wise basis by running correlations (Pearson's) between samples that shared sampling dates, and therefore environmental conditions. A significant but relatively weak correlation ($p=0.025$) was found between Butley River and River Ore suggesting that they share contamination sources that respond to environmental variables in a similar manner.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at Shellfish Water sites over time is shown in Figure X.3.

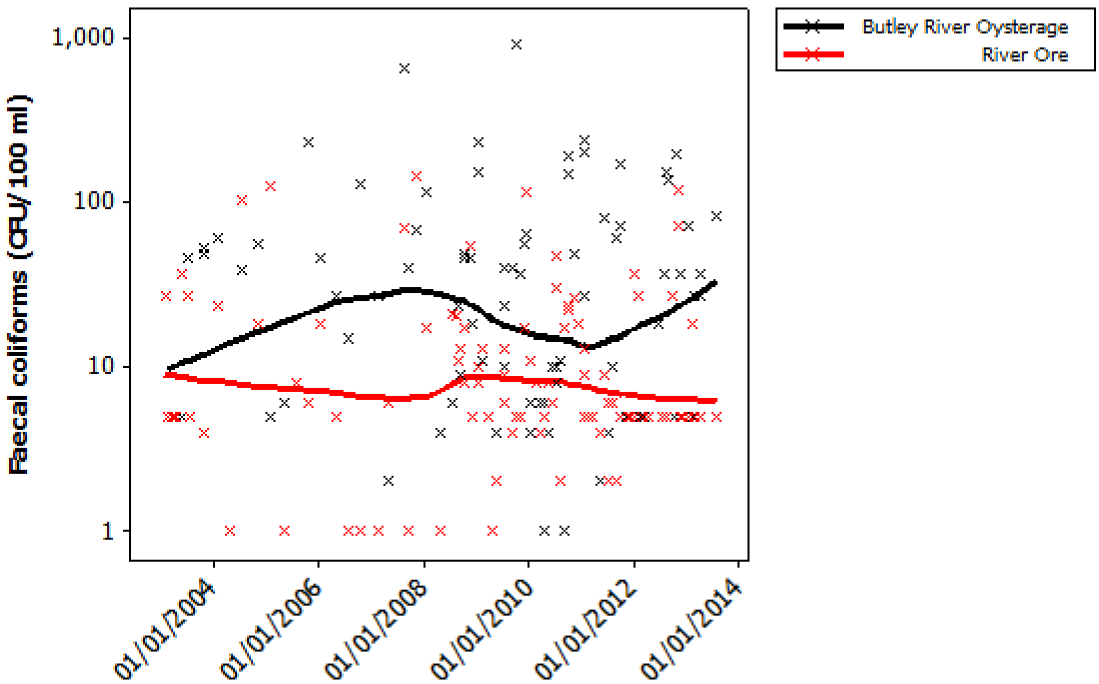


Figure X.3: Scatterplot of faecal coliform results by date, overlaid with loess lines
Data from the Environment Agency

In 2003 both sites had similar levels of faecal coliforms but have since diverged. Faecal coliform levels at River Ore have remained stable, but at Butley River Oysterage, there have been some slight fluctuations.

Seasonal patterns of results

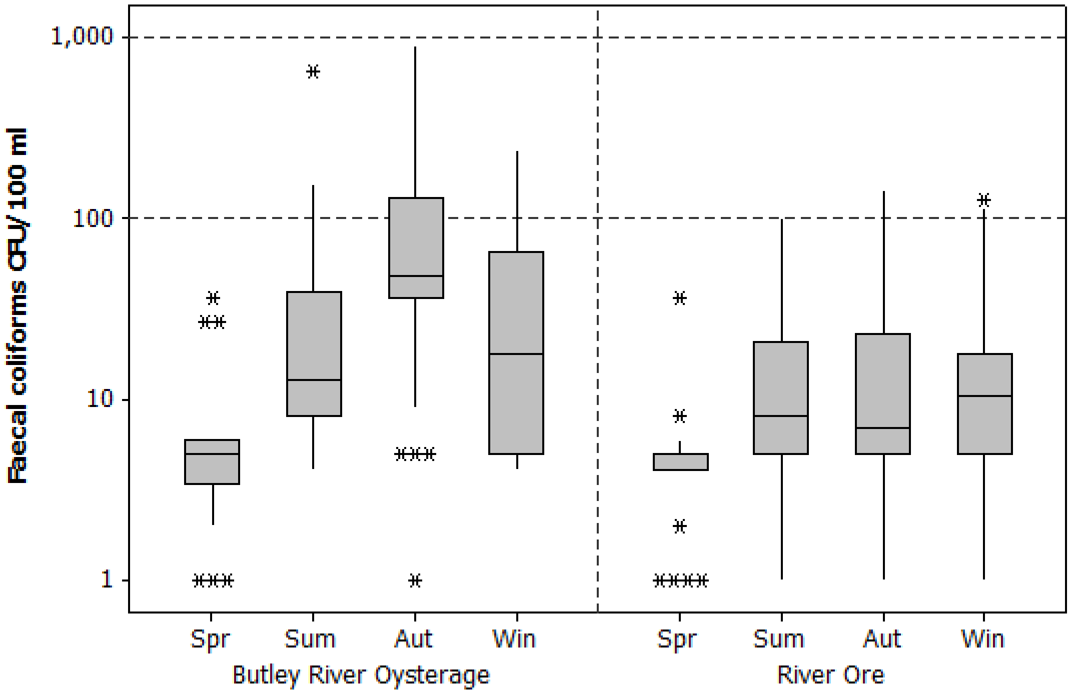


Figure X.4: Boxplot of faecal coliform results by site and season
Data from the Environment Agency

One-way ANOVA tests showed that there were significant variations in faecal coliform levels between seasons at both sites (p<0.001 and 0.004 at Butley River Oysterage and River Ore respectively). Post ANOVA Tukey tests showed that at both sites, there were significantly lower levels of faecal coliforms in spring than during any other season.

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.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**
Butley River Oysterage	0.424	<0.001	0.346	<0.001
River Ore	0.139	0.149	0.094	0.413

Data from the Environment Agency

Figure X.5 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle. High water at Orford Quay 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.

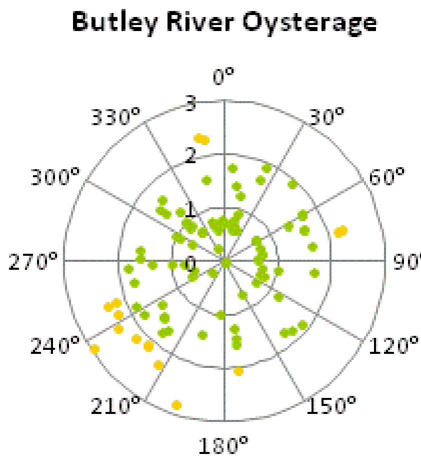


Figure X.5: Polar plots of log10 faecal coliforms against tidal state on the high/low tidal cycle for shellfish waters monitoring points with significant correlations
Data from the Environment Agency

At Butley River Oysterage, higher results tended to occur around low water.

Figure X.6 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.

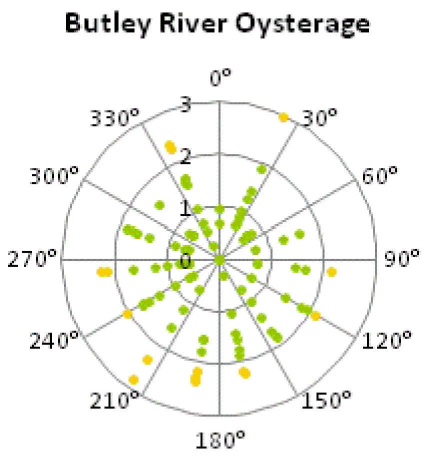


Figure X.6: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At Butley River Oysterage, higher results tended to occur as tide size decreased from springs to neaps.

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 Woodbridge 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 coliform results against recent rainfall

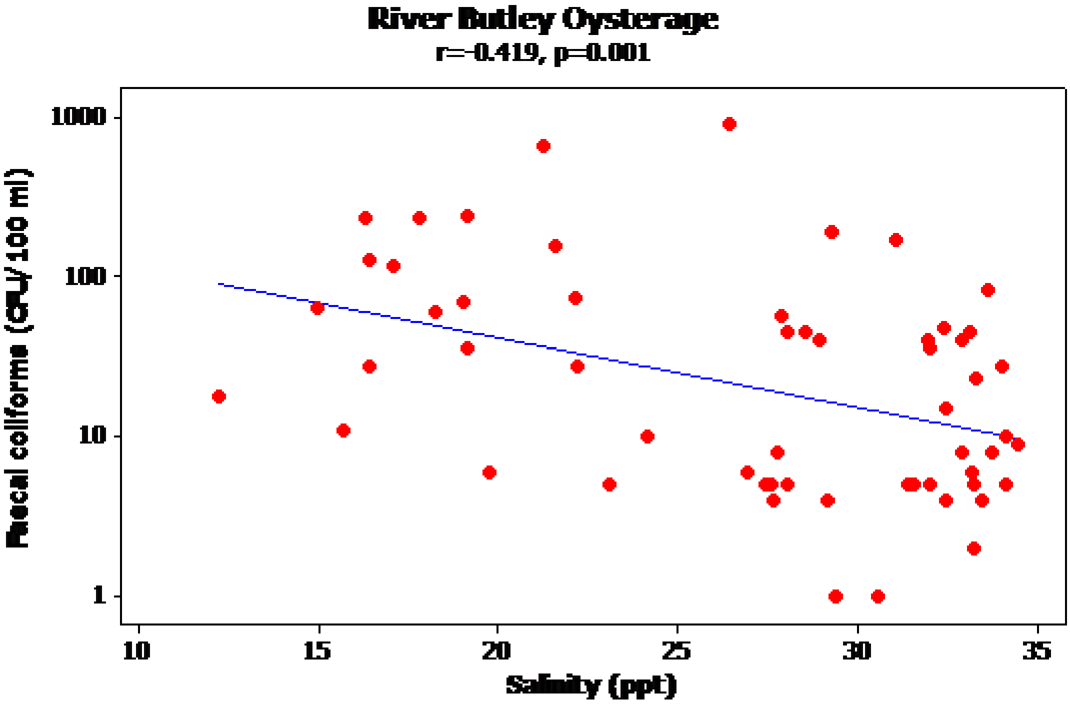
	Site	Butley River Oysterage	River Ore
	n	71	71
24 hour periods prior to sampling	1 day	0.210	0.114
	2 days	0.207	0.094
	3 days	0.237	0.237
	4 days	0.078	0.209
	5 days	-0.007	0.252
	6 days	0.024	0.133
	7 days	0.171	0.095
Total prior to sampling over	2 days	0.203	0.113
	3 days	0.232	0.184
	4 days	0.168	0.176
	5 days	0.128	0.187
	6 days	0.129	0.212
	7 days	0.152	0.217

Data from the Environment Agency

At Butley River Oysterage, rainfall affected faecal coliform levels immediately and the effect persisted for three days, whereas at River Ore it took 3 days before rainfall had a significant effect on faecal coliform levels.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.7 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.



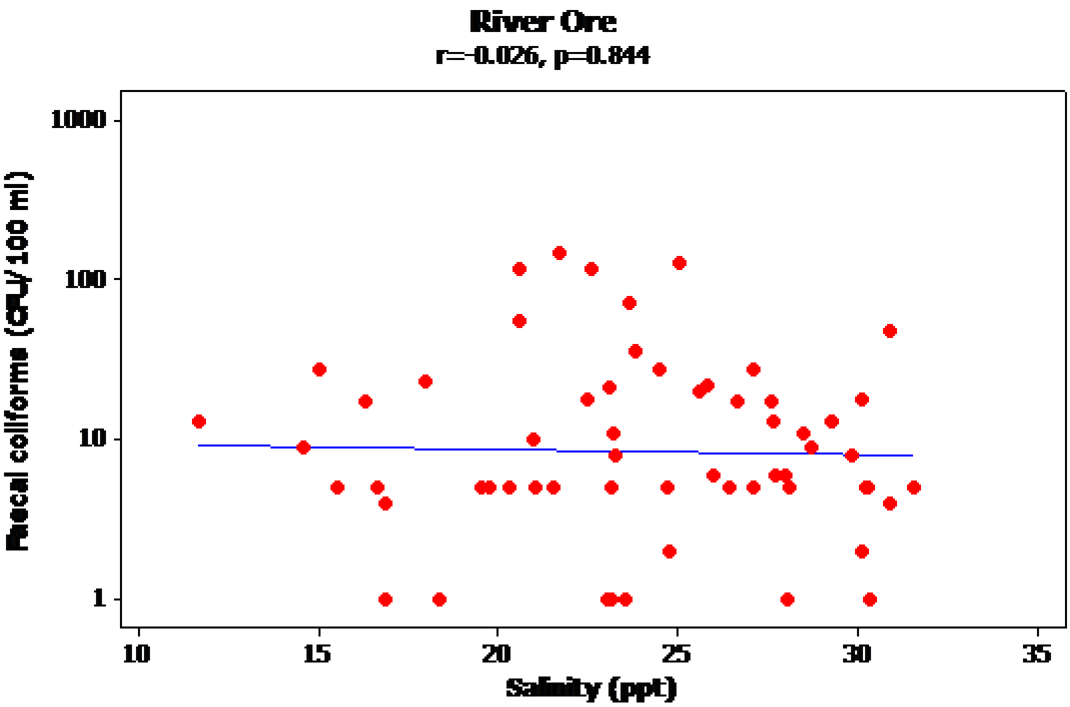


Figure X.7: Scatter-plots of salinity against faecal coliforms.
Data from the Environment Agency

There was a significant correlation between faecal coliform levels and salinity at River Butley Oysterage, but not River Ore.

Appendix XI. Microbiological Data: Shellfish Flesh

XI.1. Summary statistics and geographical variation

There are a total of two RMPs in the Butley production area that have been sampled between 2003 and 2013. One of these RMPs is for mussels and one is for Pacific oysters. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites are show in Figure XI.2 to Figure XI.3.

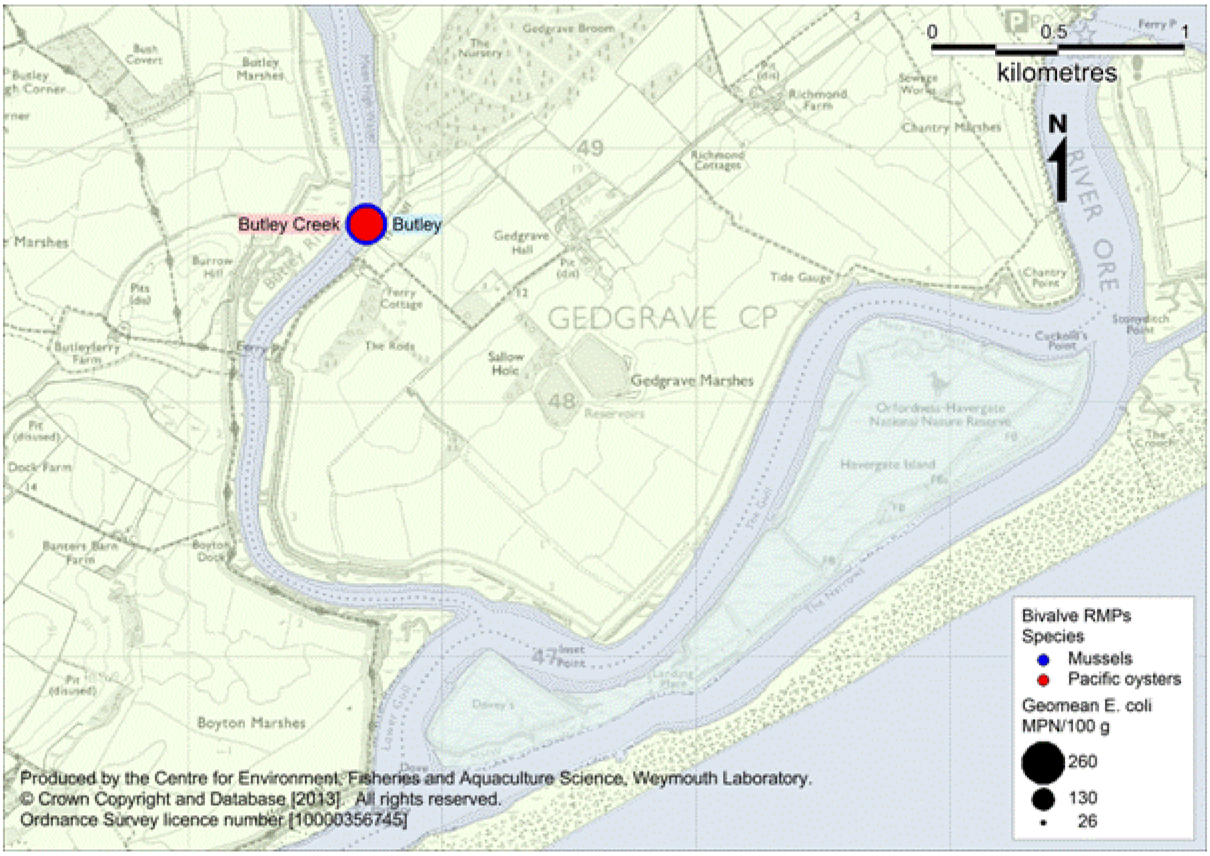


Figure XI.1: Bivalve RMPs active since 2003

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from 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
Butley	Mussel	28	20/01/2003	11/04/2005	255.0	20	>18000	57.1	3.6
Butley Creek	Pacific oyster	134	20/01/2003	22/10/2013	206.0	<20	>18000	40.3	3.0

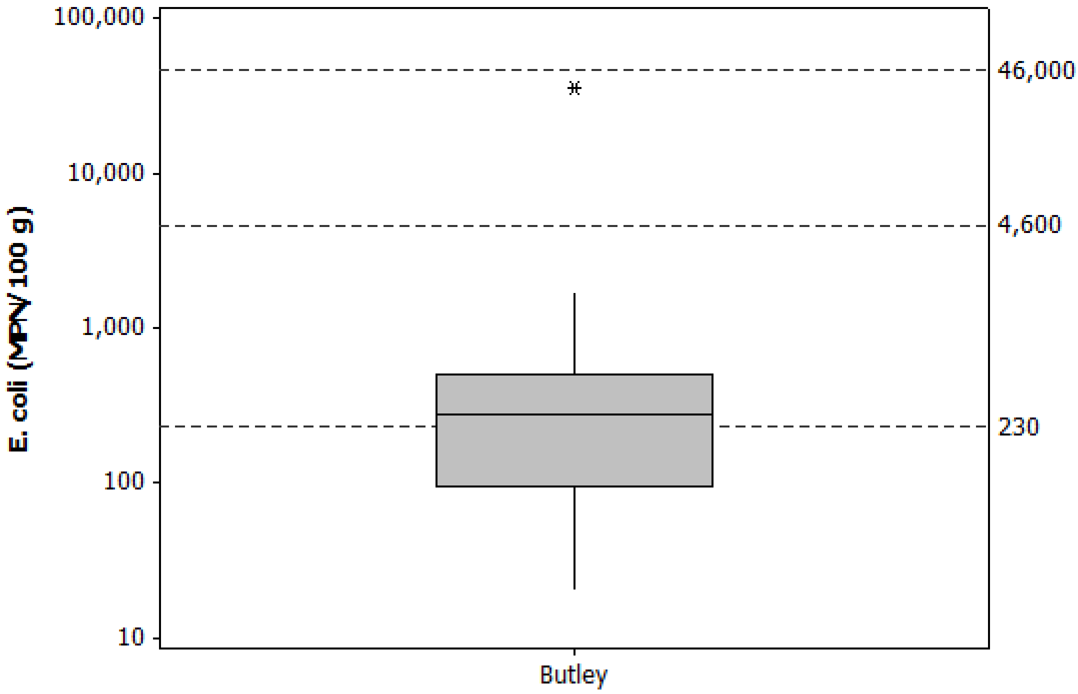


Figure XI.2: Boxplots of *E. coli* results from mussel RMPs from 2003 onwards.

At the Butley mussel RMP, 3.6 % of samples exceeded 4,600 *E. coli* MPN/100 g, but none exceeded 46,000.

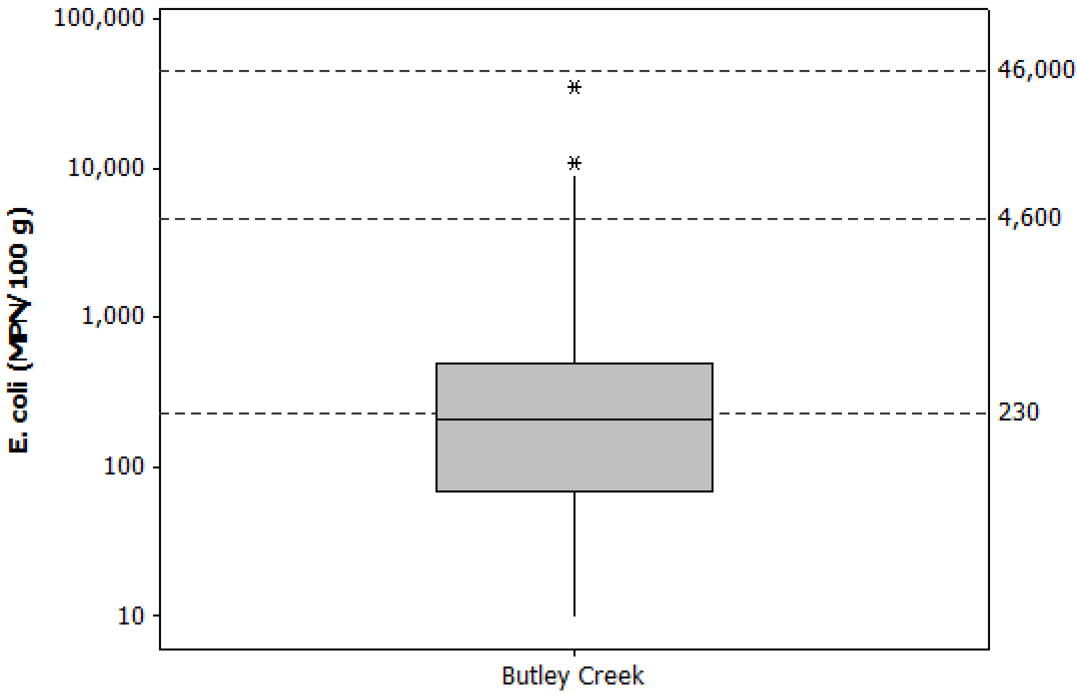


Figure XI.3: Boxplots of *E. coli* results from Pacific oyster RMPs from 2003 onwards.

At the Butley Creek Pacific oyster RMP, 3 % of samples exceeded 4,600 *E. coli* MPN/100g, but none exceeded 46,000 *E. coli* MPN/100 g.

XI.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves is shown in Figure XI.4.

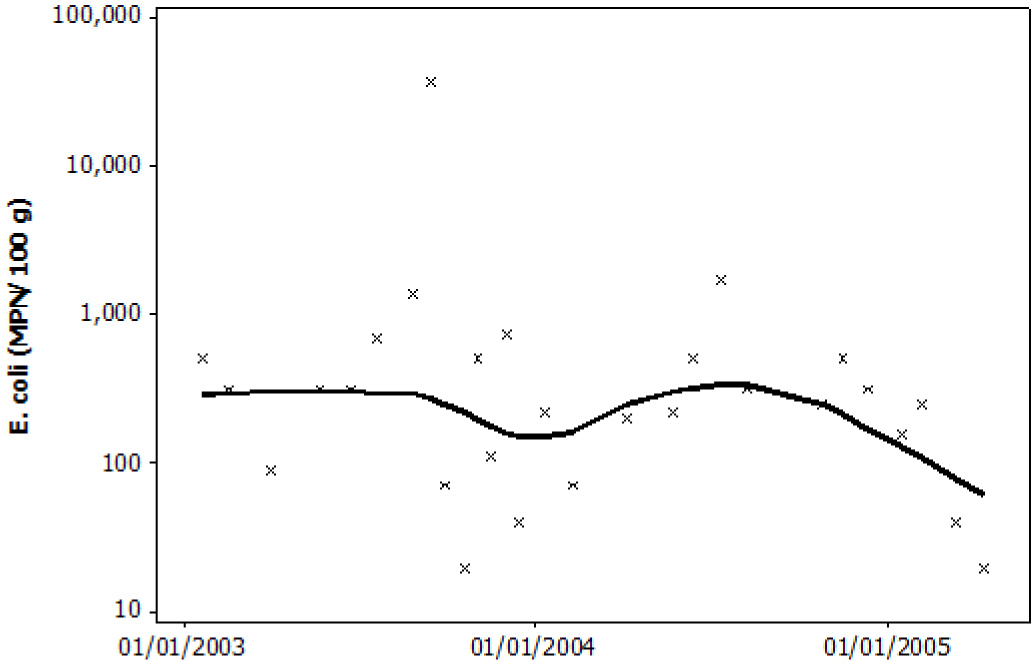


Figure XI.4: Scatterplot of *E. coli* results for mussels overlaid with loess line.

Figure XI.4 suggests that there was an improvement in 2005, but whether this is a genuine trend or just a short run of relatively low sample results is uncertain.

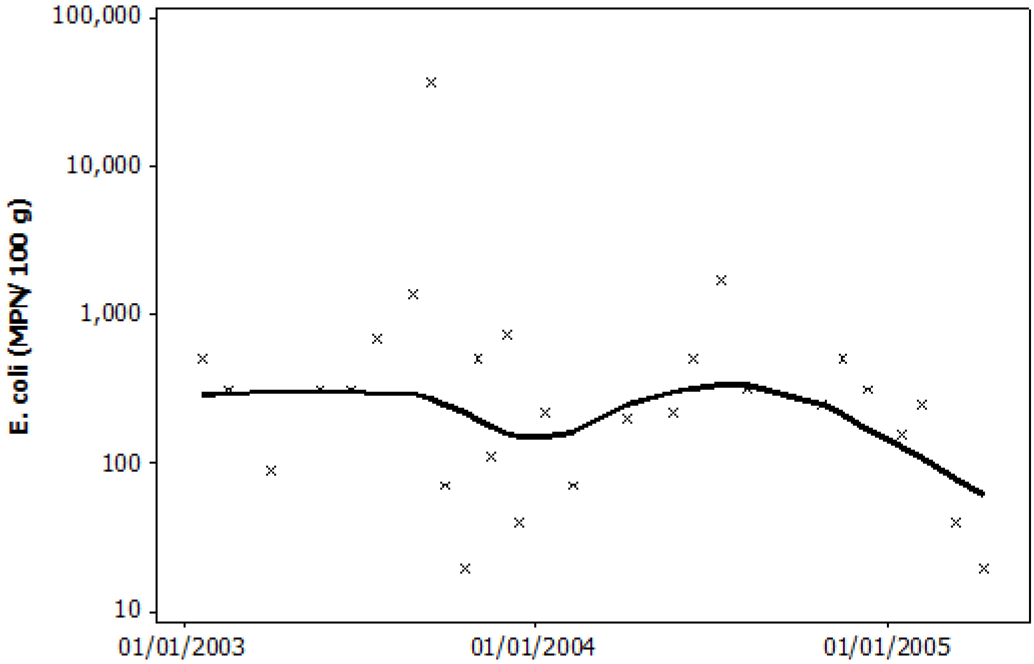


Figure XI.5: Scatterplot of *E. coli* results for Pacific oysters overlaid with loess line.

E. coli levels have remained stable in Pacific oysters since 2003.

XI.3. Seasonal patterns of results

Figure XI.6 and Figure XI.7 show the variation in *E. coli* levels between seasons in mussels and Pacific oysters respectively.

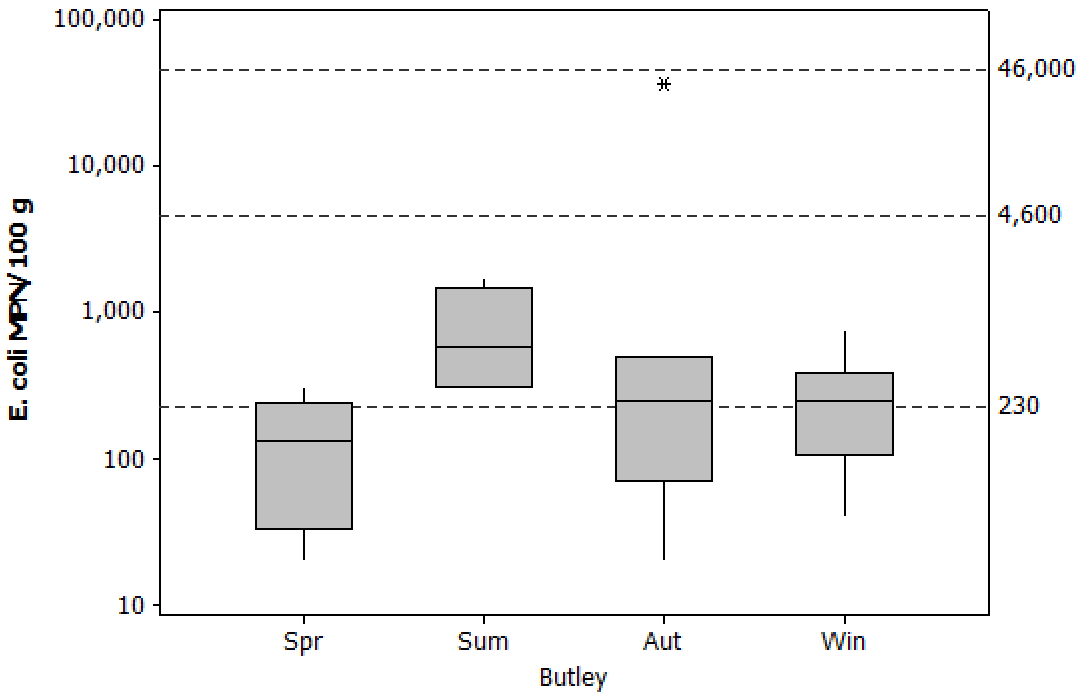


Figure XI.6: Boxplot of *E. coli* results for mussels by RMP and season

Although results were noticeably higher on average during the summer, a one- way ANOVA showed that there were no significant differences between seasons in mussels (p=0.166).

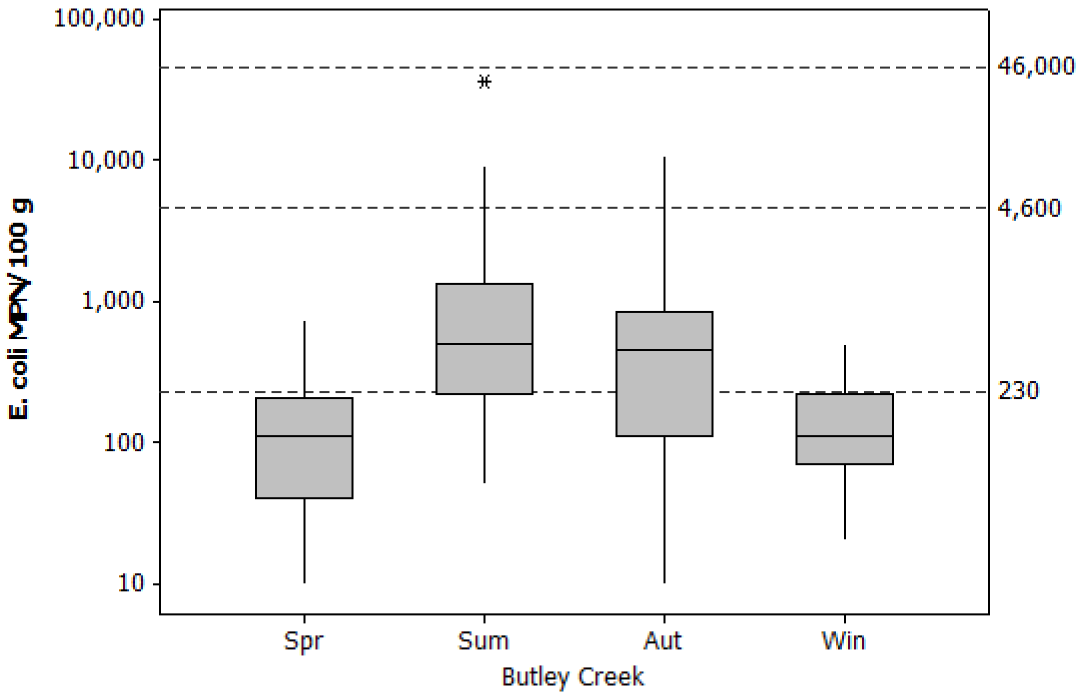


Figure XI.7: Boxplot of *E. coli* results for Pacific oysters by RMP and season

One-way ANOVAs showed that there were significant differences in *E. coli* levels between seasons in Pacific oyster ($p<0.001$). Post ANOVA Tukey tests revealed that summer and autumn had higher *E. coli* levels than spring and winter.

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**
Butley Creek	Pacific oyster	0.163	0.030	0.073	0.500

Figure XI.8 presents 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 at Orford Quay is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

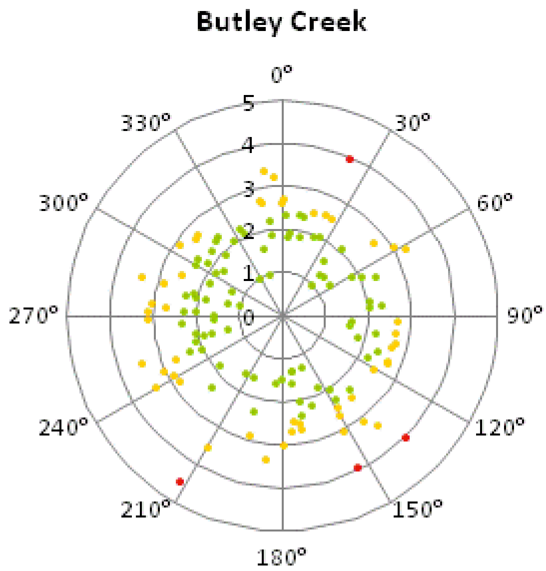


Figure XI.8: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) at Pacific oyster RMPs against high/low tidal state

The polar plot shows a tendency for higher results during the later stages of the ebb tide and around low water. This suggests that up-estuary sources may be of influence, or that the reduced dilution potential at lower states of the tide results in higher concentrations of faecal indicator organisms.

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 Woodbridge weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XI.3, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.3: Spearman's Rank correlations (r) between rainfall recorded at Johnstown and shellfish hygiene results

Site		Butley	Butley Creek
Species		Mussel	Pacific oyster
n		21	99
24 hour periods Prior to sampling	1 day	-0.097	0.045
	2 days	-0.017	-0.112
	3 days	0.179	-0.141
	4 days	-0.243	0.004
	5 days	0.288	0.047
	6 days	0.213	-0.149
	7 days	0.316	0.029
Total prior to sampling over	2 days	-0.116	-0.033
	3 days	-0.053	-0.050
	4 days	-0.119	-0.080
	5 days	n/a	-0.022
	6 days	n/a	-0.025
	7 days	n/a	-0.002

No significant correlations between antecedent rainfall and *E. coli* levels in either species were found. The range of r values in Table XI.3 suggest that rainfall is of no influence at all at these two RMPs.

Appendix XII. Shoreline Survey Report

Date (time):
17 February 2014 (08:45 -15:15)

Cefas Officers:
Rachel Parks, Simon Kershaw

Survey Partner:
Harry Tice (Suffolk Coastal DC)

Area surveyed:
Orford Quay to the mouth of the River Ore and the Butley estuary.

Weather:
17 February 2014, sunny spells and overcast, 10°C, wind bearing 151° at 12.39 km/h.

The survey was undertaken following a prolonged spell of unusually wet weather. This may have resulted in atypical conditions of increased freshwater influence in the system. It may also have resulted in lower than usual concentrations of faecal indicator organisms in the freshwater inputs as the prolonged high rainfall event would have had the effect of washing much of the contamination away during its earlier stages.

Tides:
Admiralty TotalTide© predictions for Walton on the Naze (52°05'N 0°32'E). All times in this report are GMT.

17/02/2014		
High	01:35	2.8 m
High	13:51	2.8 m
Low	07:56	0.5 m
Low	19:59	0.8 m

Objectives:

The shoreline survey aimed 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.

XII.1. Fishery

The extent of the oyster fishery is shown in Figure XII.1. Oyster seedlings are placed in floating cages in the northern section of the fishery area (Figure XII.11) and then transferred to the river bed until they are a harvestable size. The oysters are harvested by dredge and harvesting takes place year round. Two holding ponds are located on the eastern shore adjacent to the depuration facility. These are used for holding lobsters, and may occasionally be used for holding seed oysters prior to laying on the river bed for ongrowing (observation 11, Figure XII.17). They are not used for the storage of market sized oysters. The area is harvested by one company, Pinneys of Orford and was being dredged for oysters at the time of the survey (Figure XII.12).

XII.2. Sources of contamination

Sewage discharges

No sewage discharges were observed on the shoreline survey. Water samples were taken downstream of what was assumed to be the Gedgrave STW discharge point (observation 3 and 4) but, *E. coli* concentrations were low at these locations (10 CFU/100ml). The watercourse to which Hollesbury STW discharges was not accessible at the time of the survey due to sea conditions at the mouth of the Ore.

Freshwater inputs

There are two pumping stations within the survey area (Butley and Chillesford) but neither were observed on the shoreline survey as they are situated within the marshes and consequently inaccessible by boat. The majority of freshwater inputs observed during the survey were marsh drainage (observation 1, 7 and 20). Flow readings were not possible due to inaccessibility. The River Butley was flowing at the time of the survey; it discharges to the Butley estuary via the Butley Mills sluice gate, *E. coli* concentrations were low at 20 CFU/100ml. The River Tang (Observation 9) discharges to the south west Butley also via a sluice gate. It was difficult to assess whether the Tang River was flowing at the time of the survey as it was submerged. Flow readings were not taken for any freshwater inputs due to inaccessibility

Livestock

Around 30 sheep were observed on Gedgrave marshes close to the entrance of Butley (observation 8 and 9) and around 30 cows were observed at Chillesford (observation 25).

Wildlife

Birds were observed throughout the survey area (observations 5, 6, 10, 12, 14, 15 & 17). The largest aggregation, around 500 was observed at Dovey's on Havergate Island (observation 17).

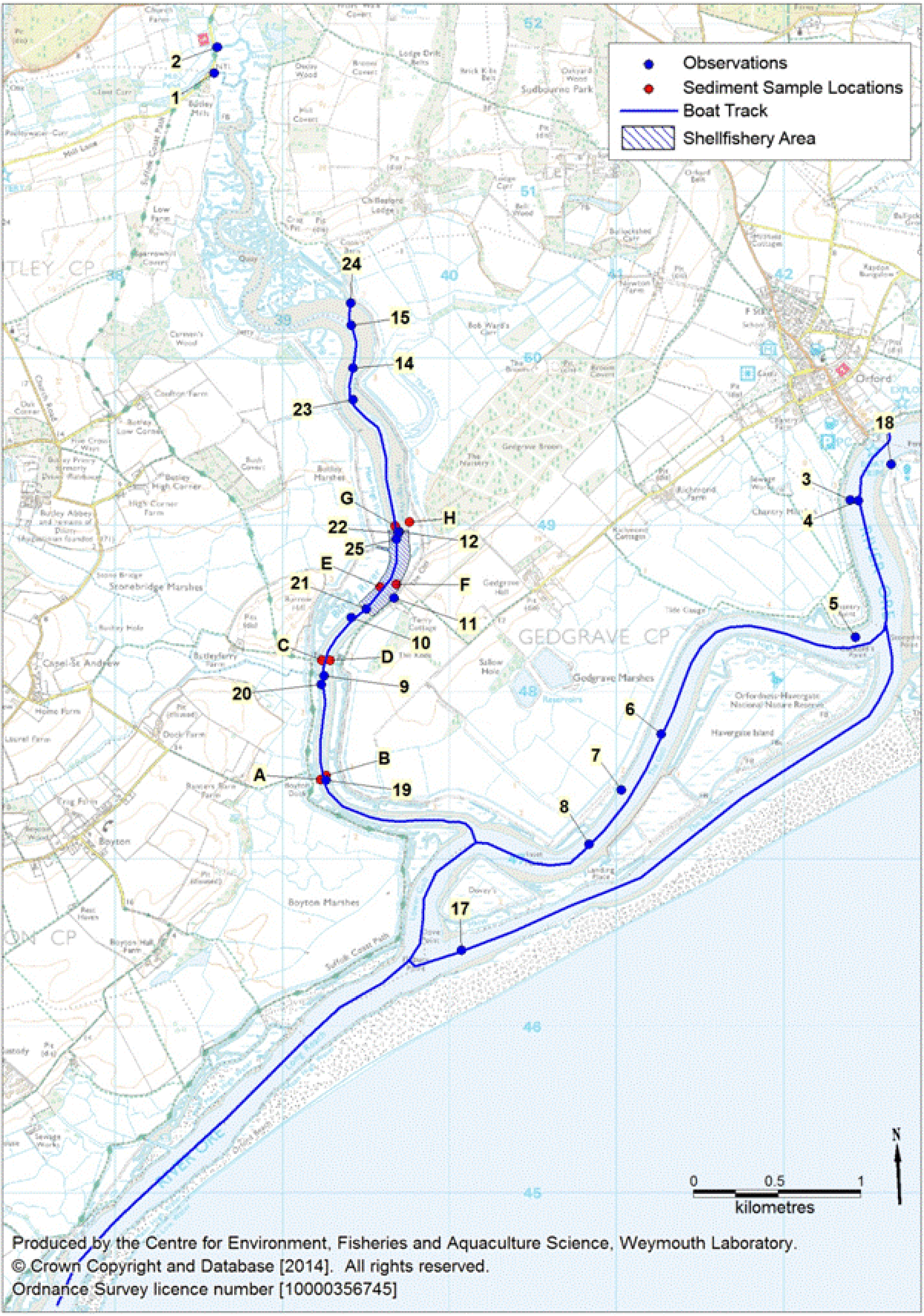


Figure XII.1: Locations of shoreline observations (Table XII.1 and for details).

Table XII.1: Details of Shoreline Observations

Observation no.	NGR	Date	Time	Description	Photo
1	TM3859251709	17/02/2014	07:49	Butley Mills Sluice - Not Flowing	Figure XII.13
2	TM3860951864	17/02/2014	07:51	Butley Mills Sluice - Flowing (not accessible for flow reading)	Figure XII.14
3	TM4239849151	17/02/2014	09:20	Possible sewage discharge (0.6m depth) CTD 1 Measurement	Figure XII.15
4	TM4244549146	17/02/2014	09:25	Middle of Channel (7 m depth) CTD 2 measurement	
5	TM4242948329	17/02/2014	09:31	5 oystercatchers	
6	TM4126647748	17/02/2014	09:35	10 geese	
7	TM4102847412	17/02/2014	09:37	Drainage sluice from Gedgrave marshes - (not flowing)	Figure XII.16
8	TM4083447089	17/02/2014	09:4	~ 30 sheep on Gedgrave Marshes	
9	TM3924948098	17/02/2014	09:59	The River Tang and ~ 5 sheep	
10	TM3940948445	17/02/2014	10:14	~ 30 birds	
11	TM3966548562	17/02/2014	10:31	Sample from holding tank	Figure XII.17
12	TM3969648960	17/02/2014	11:09	~ birds on the flats (including shelduck)	
14	TM3942049942	17/02/2014	11:13	~ 400 birds on marsh	
15	TM3941050197	17/02/2014	11:15	~ 100 birds on flats	
17	TM4007246451	17/02/2014	12:03	~ 500 birds on Havergate Island	Figure XII.18
18	TM4264249367	17/02/2014	13:56	Pipe Flowing on Kings Marshes (reddy brown colour)	Figure XII.19
19	TM3925747473	17/02/2014	14:16	CTD 3 measurement and sample - Boyton Dock (5 m depth)	
20	TM3923148045	17/02/2014	14:22	CTD 4 measurement and sample - downstream of the River Tang (3.1 m depth)	Figure XII.20
21	TM3950048499	17/02/2014	14:28	CTD 5 measurement and sample - South end of fishery (2.8 m depth)	
22	TM3969148951	17/02/2014	14:36	CTD 6 measurement and sample - North End of fishery (2.1 m depth)	
23	TM3942049751	17/02/2014	14:42	CTD 7 measurement and sample - (1.9 m depth)	
24	TM3940650328	17/02/2014	14:48	Water sample - Chillesford (0.3 m depth)	
25	TM3968148915	17/02/2014	14:55	30 cows on the fields at Chillesford	Figure XII.21

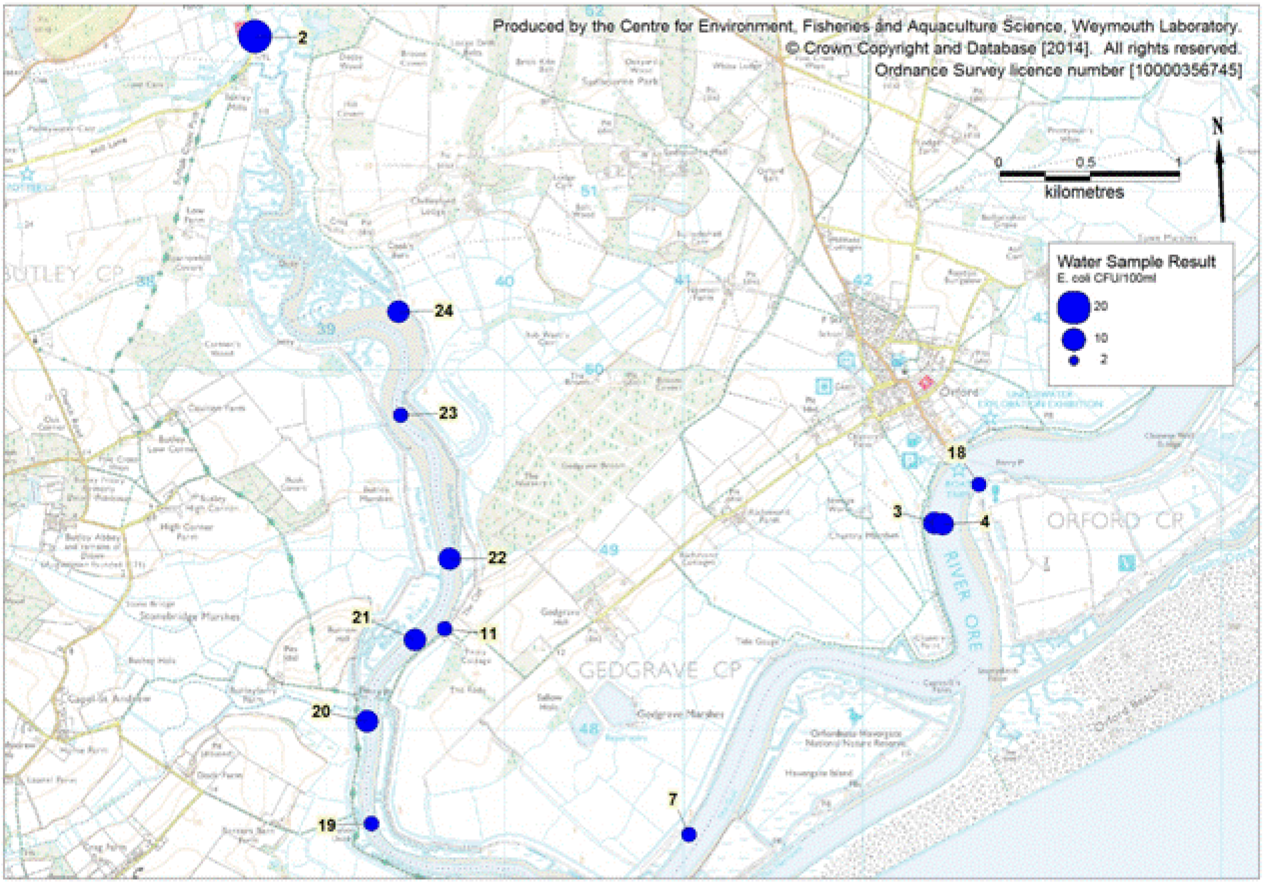


Figure XII.2: Water sample results (Table XII.2 for details)

Table XII.2: *E. coli* results

Sample ID	Observation number	Water type	Description	*E. coli* concentration (CFU/100 ml)
BY01	2	FW	Butley Mills Sluice	20
BY02	3	BW	Sample close to possible sewage discharge	10
BY03	4	BW	Sample in deepwater channel & close to possible sewage discharge	10
BY04	7	BW	Sample adjacent to drainage sluice	<10
BY05	11	BW	Sample from holding tank	<10
BY06	18	FW	Marsh drainage	<10
BY07	19	BW	Sample from Butley channel	<10
BY08	20	BW	Sample from Butley channel	10
BY09	21	BW	Sample from Butley channel	10
BY10	22	BW	Sample from Butley channel	10
BY11	23	BW	Sample from Butley channel	<10
BY12	24	BW	Sample from Butley channel	10

XII.3. Sediment Samples

Sediment samples were taken at eight locations on the Butley estuary, Figure XII.3 illustrates their locations. Samples of surface sediments were taken on both banks adjacent to the main Butley channel. Table XII.3 details the *E. coli* concentrations within the sediment samples, which were low and ranged from between <20 CFU/100 ml to 800 CFU/100 ml. The highest concentration was found on the west bank just north of the River Tang outfall.

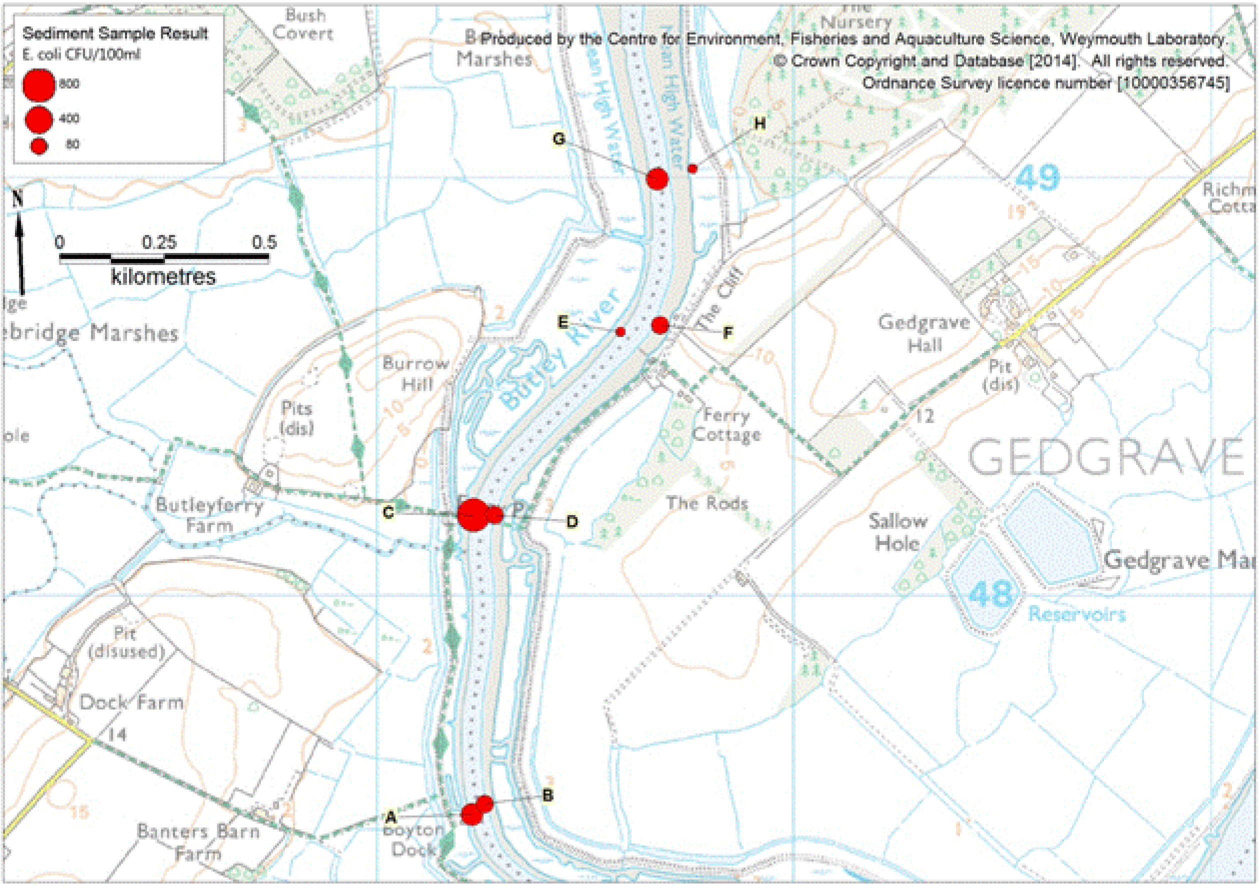


Figure XII.3 Sediment Sample results (Table XII.3 for details)

Table XII.3 Details of Sediment samples

No	NGR	Sample ID	*E. coli* concentration (CFU/100 g)
A	TM3922847475	BYS01	200
B	TM3925947500	BYS02	100
C	TM3923348192	BYS03	800
D	TM3928248191	BYS04	100
E	TM3958448631	BYS05	<20
F	TM3967948646	BYS06	100
G	TM3967348996	BYS07	200
H	TM3967348996	BYS08	<20

XII.4. Conductivity Temperature Depth (CTD) Measurements

Conductivity (practical salinity scale, which is effectively the same as ppt), temperature (degrees Celsius) and depth (metres) [CTD] measurements were taken at seven locations within the Butley and Ore/Alde, Figure XII.1 illustrates their locations. Temperature and salinity profiles for these locations are shown in Figure XII.4 – Figure XII.10.

CTD 1 and CTD 2 (observations 3 and 4) were taken on the late flood tide in the main Ore/Alde. At CTD 1 the salinity and temperature measurements are fairly constant throughout the water column whereas in the middle of the channel where the depth is about double there is a slight increase in the salinity with depth (14.99 PSS at the surface to 19.71 PSS at 8 metres).

CTD 3 – CTD 7 were taken just after high water at five locations within the Butley estuary (observations 19 – 23). Measurements were taken against the ebbing tide starting south of the fishery and working upstream (observations 19 – 23). Temperature and salinity profiles for CTD 3 – CTD 6 salinity was about 31 PSS throughout the whole water column. At CTD 7 (observation 23) in the upper estuary above the shellfishery surface salinity was considerably lower, with a very slight increase lower down (24.05 PSS increasing to 25.91 at 6.6 metres).

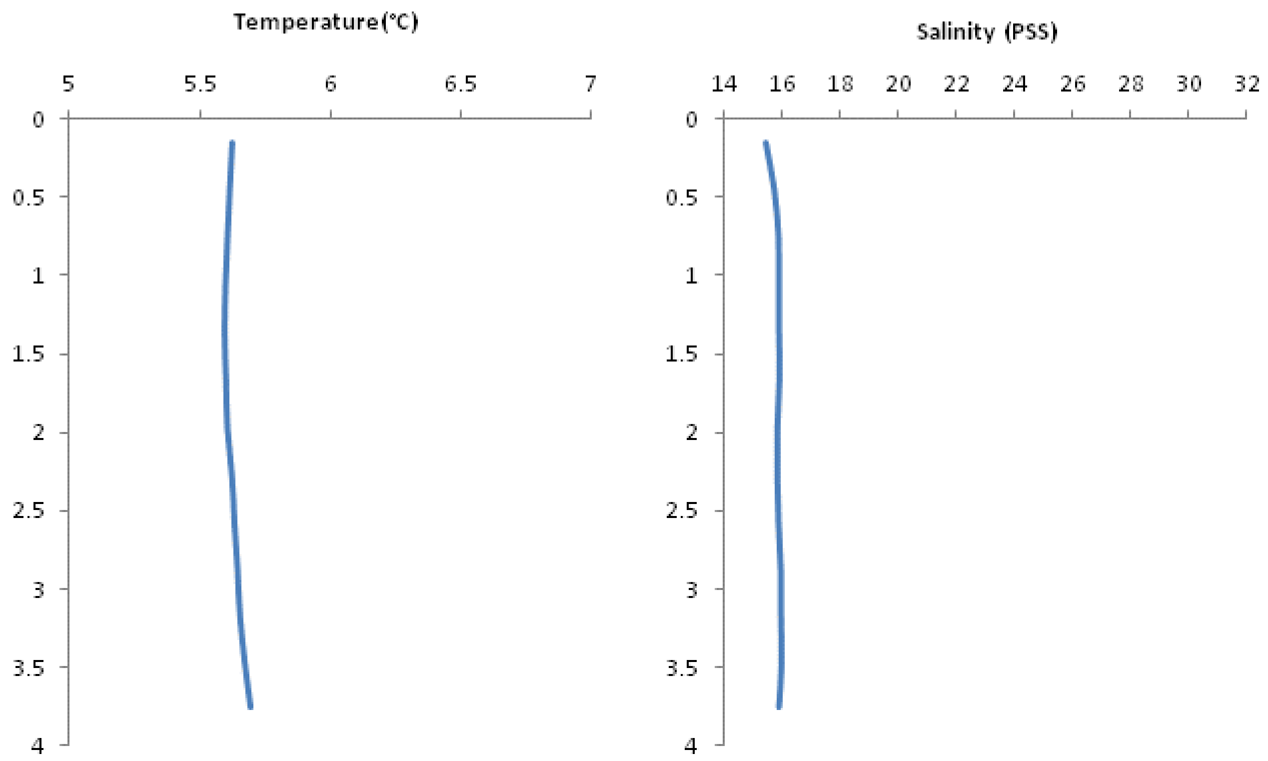


Figure XII.4 Temperature and salinity profiles CTD 1 (observation 3)

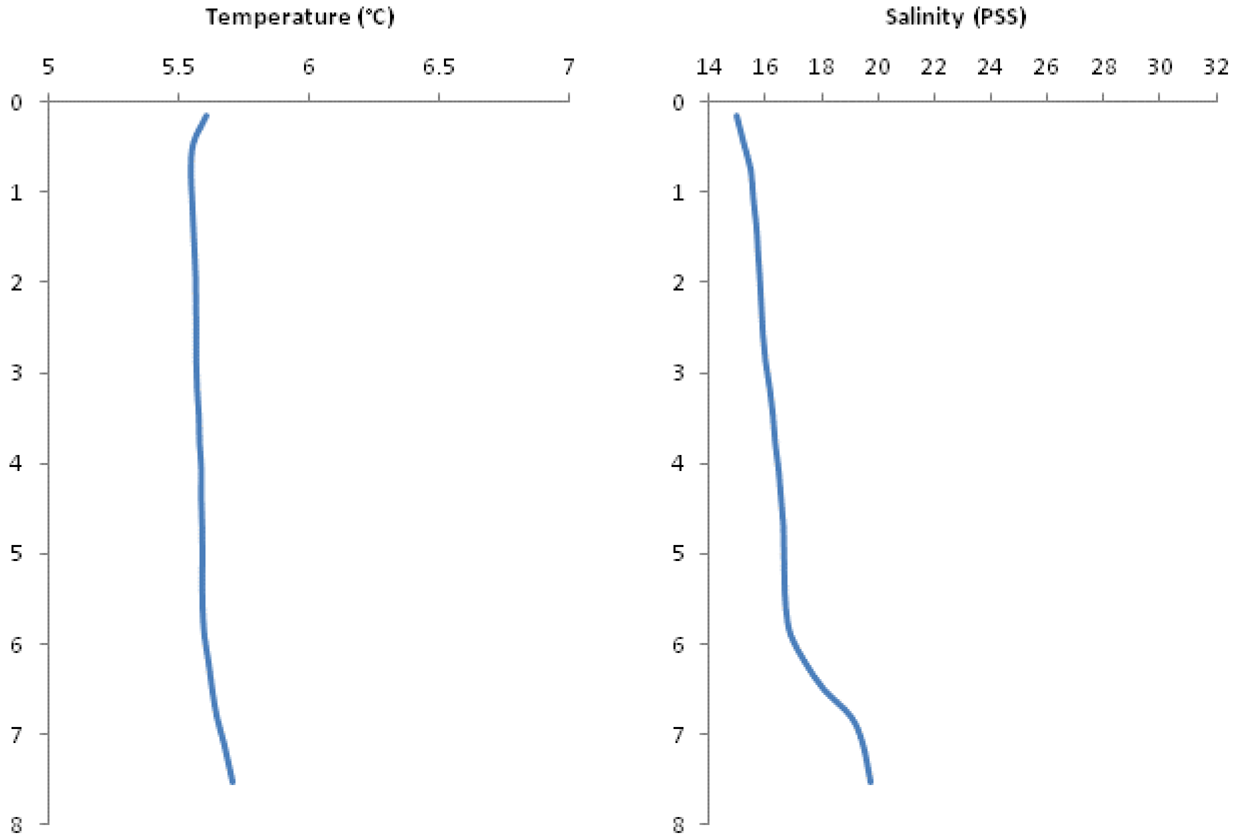


Figure XII.5 Temperature and salinity profiles CTD 2 (observation 4)

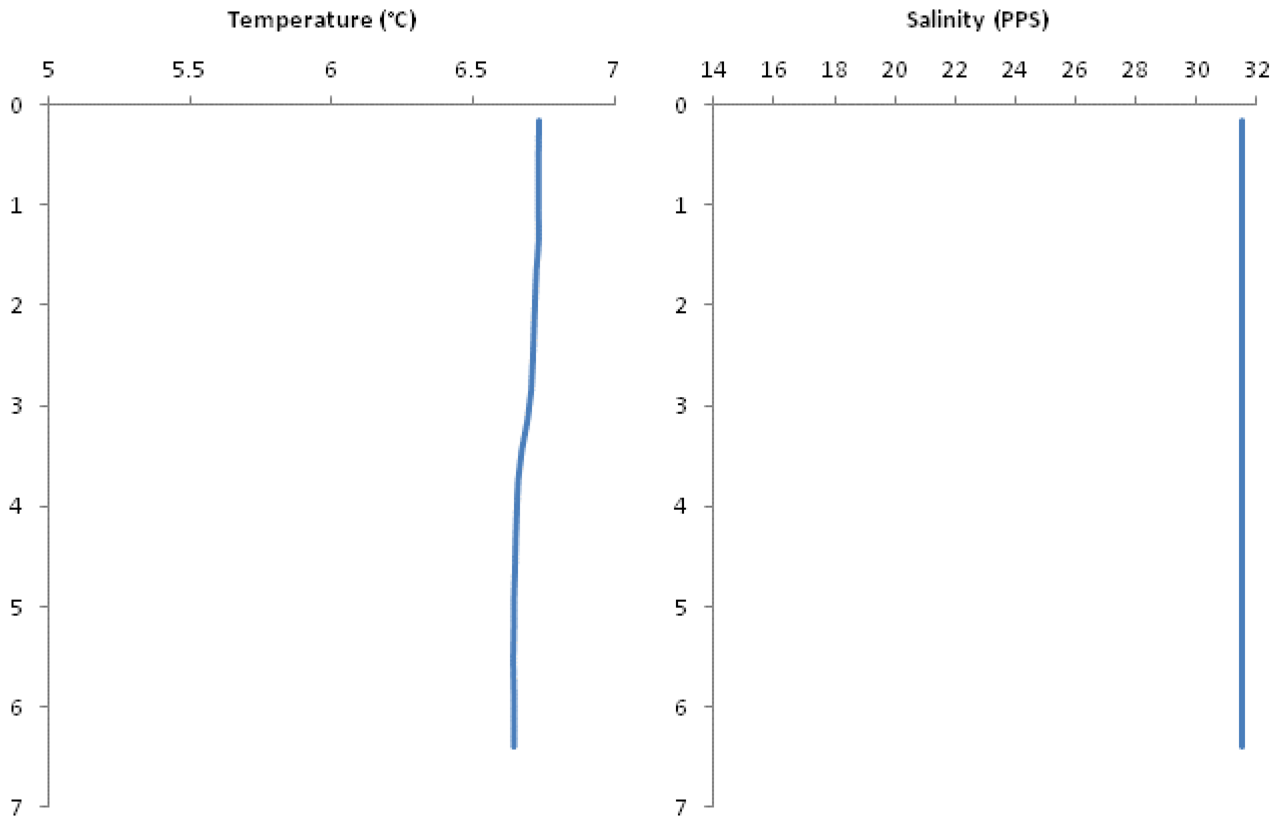


Figure XII.6 Temperature and salinity profiles CTD 3 (observation 19)

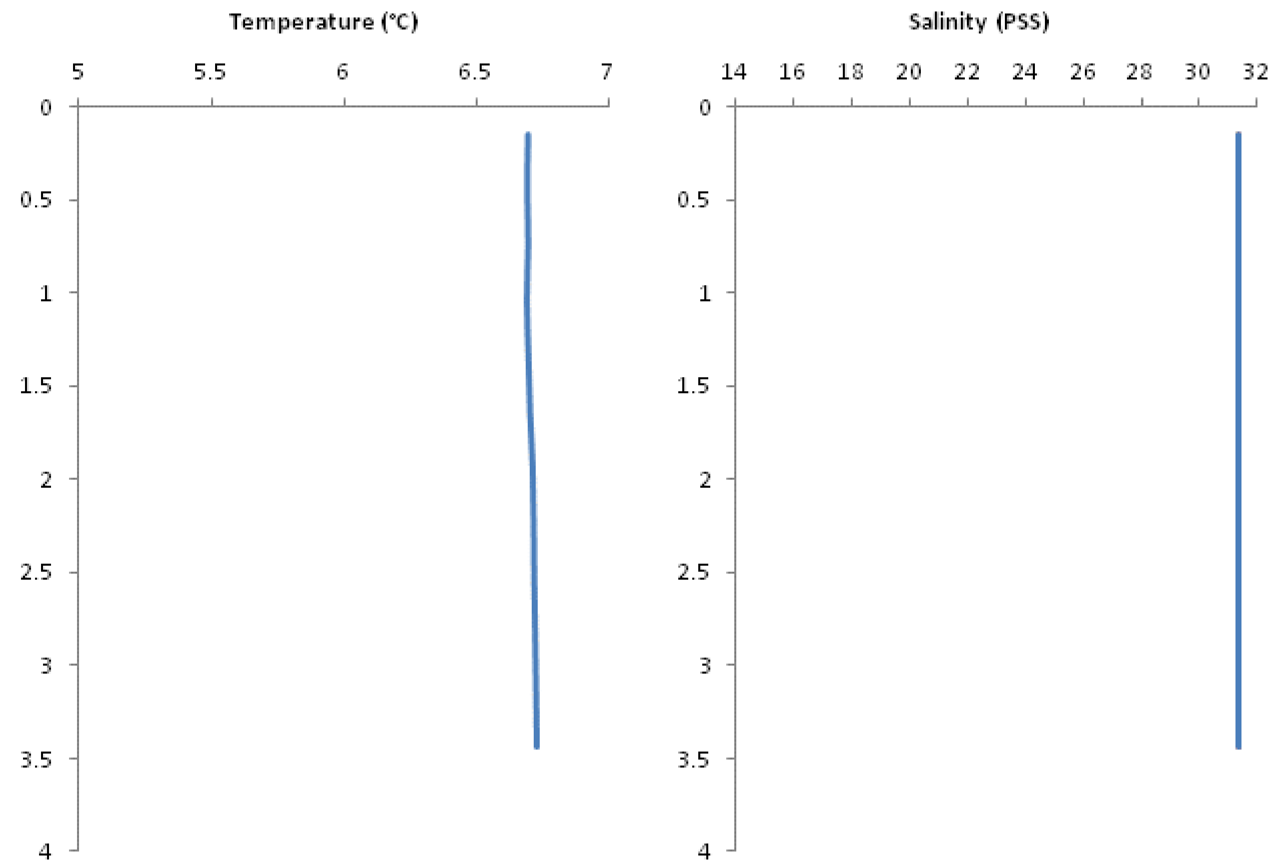


Figure XII.7 Temperature and salinity profiles CTD 4 (observation 20)

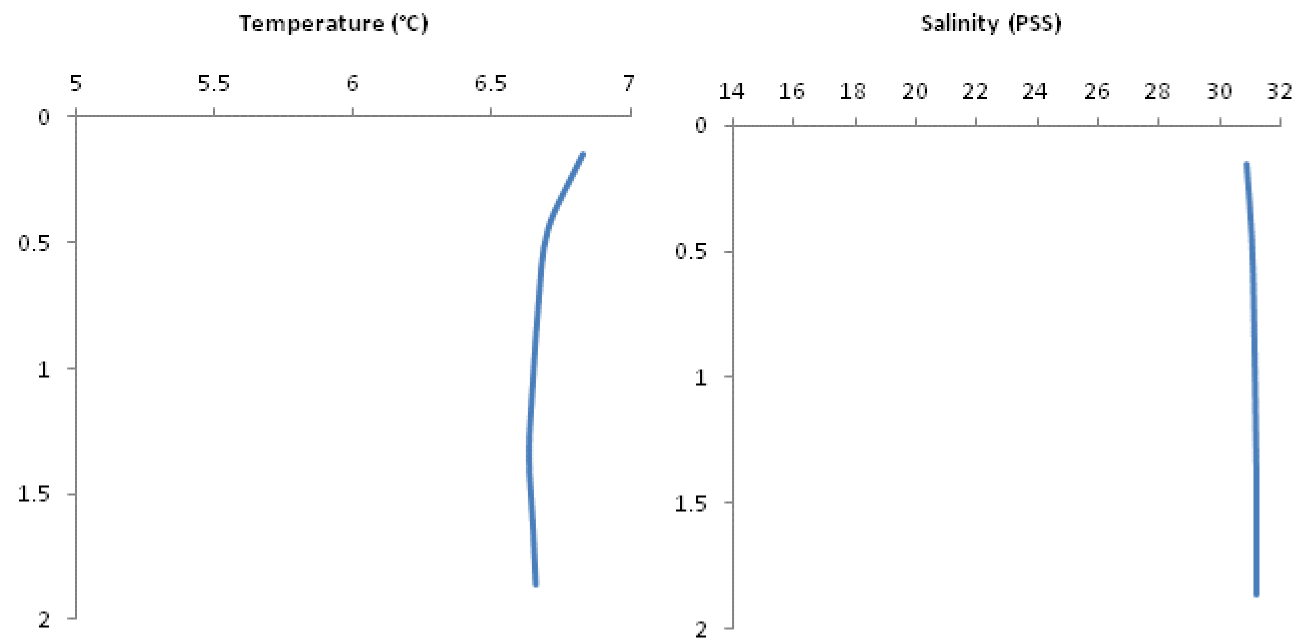


Figure XII.8 Temperature and salinity profiles CTD 5 (observation 21)

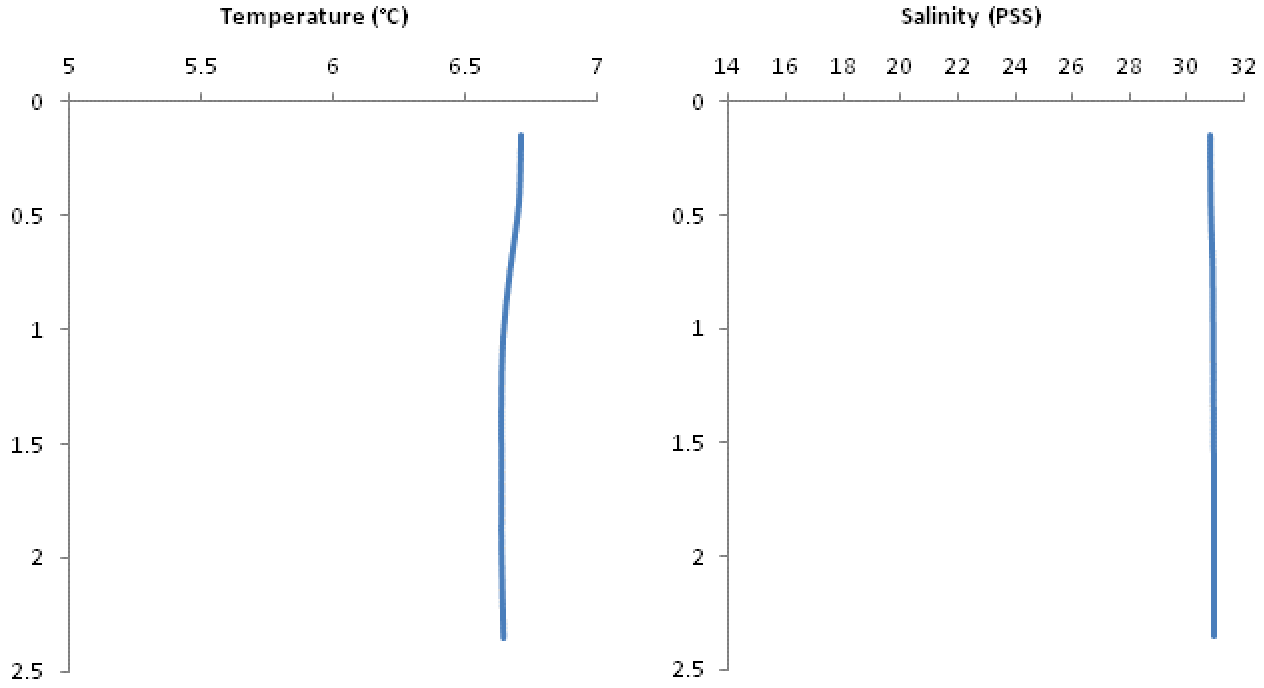


Figure XII.9 Temperature and salinity profiles CTD 6 (observation 22)

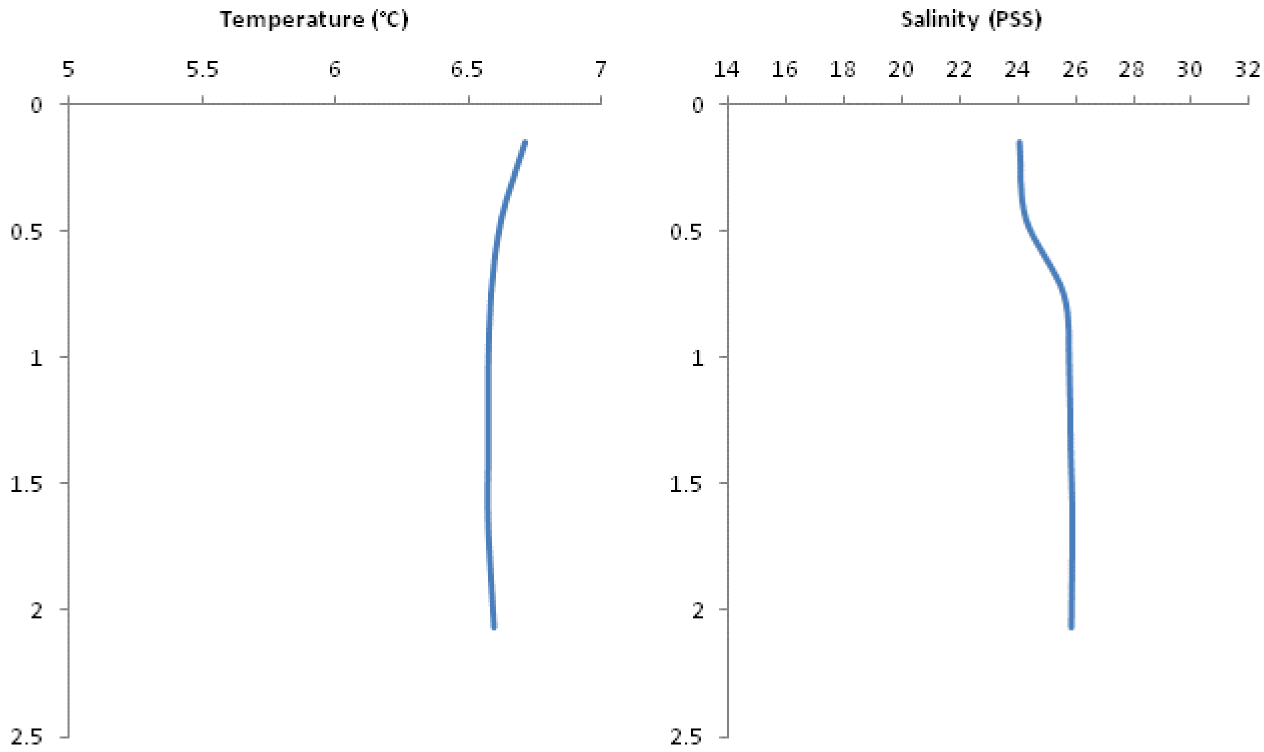


Figure XII.10 Temperature and salinity profiles CTD 7 (observation 23)

Figure XII.11

Figure XII.12

Figure XII.13

Figure XII.14

Figure XII.15

Figure XII.16

Figure XII.17

Figure XII.18

Figure XII.19

Figure XII.20

Figure XII.21

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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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