EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Salcombe - Kingsbridge Estuary

2009

Cover photo: Pacific oysters in bags on trestles at Geese Quarries.

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STATEMENT OF USE: This report provides information from a desk study evaluation of the information available relevant to perform a sanitary survey of bivalve mollusc harvesting areas in the Salcombe-Kingsbridge Estuary. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, determined in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

DISSEMINATION STATUS: Food Standards Agency, South Hams District Council, Devon Sea Fisheries Committee, Environment Agency.

CONTENTS

EXECUTIVE SUMMARY

Under EC Regulation 854/2004, there is a requirement for competent authorities intending to classify bivalve mollusc production and relaying areas (BMPAs) to undertake a number of tasks collectively known (in England and Wales) as ‘sanitary surveys’. The main purpose of these surveys is to inform the sampling plans for the microbiological monitoring programme and classification of BMPAs. Other wider benefits of these surveys include the potential to improve identification of pollution events and the sources of those events such that in the future remedial action can be taken to the benefit of the fisheries.

This report documents the qualitative assessment made of the levels of microbiological contamination in mussels (*Mytilus* spp.) and Pacific oysters (*C. gigas*) in Frogmore Creek at Geese Quarries classification zone and presents the recommended sampling plan as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency (FSA).

The assessment is supported by published relevant information for the Salcombe catchment and new information obtained from a shoreline survey performed in the estuary. Statistical analysis of historical data from the Shellfish Hygiene, Shellfish Waters and Bathing Waters monitoring programmes was also undertaken. The sampling plan presents information on the recommended location of representative monitoring points (RMPs) and sampling frequency for bivalve molluscs.

The main sources of microbiological contamination potentially affecting bivalve molluscs at Geese Quarries are continuous effluent discharges from Frogmore & Chillington and Sherford sewage treatment works (STW) and intermittent sewage discharges in Frogmore, Charleton, Chillington and Sherford. Other potential sources of contamination in the estuary include birds, dogs and sewage discharges from moored boats.

Inputs of contamination from agricultural land to the estuary via watercourses are thought to be a significant source of microbiological contamination. This hypothesis is corroborated by the high levels of faecal coliforms and *E. coli* enumerated in freshwater water samples from Tacketwood Creek and Kingsbridge at Squares Quay and considerably high levels of the microbiological indicators in freshwater samples from Batson Creek, Balcombe Creek, Collapit Creek and Frogmore Creek collected on 1 September 2008 under dry weather conditions.

Approximately 90% of the farms in the catchment spread manure; about 40% apply slurry (biosolids). Most spreading occurs during the spring. Some biosolids are also applied during the autumn. Lesser amounts are spread in late spring and summer. Sewage sludge is also applied to land during spring and in September. Manure and slurry applied shortly before/during rainfall events poses a significant risk of pollution which can be delivered to the estuary via small watercourses.

The macro-tidal regime and low residence time suggest that the estuary is able to quickly disperse microbiological contaminants especially in deeper areas. Well flushed areas such as Frogmore Creek may be more vulnerable to contamination transported during neap tides. Contaminated water and sediments transported down the creek on the ebb tide is considered to be the dominant microbiological impact on the BMPA at Geese Quarries. However, the bivalve molluscs are grown on trestles above the riverbed and will therefore only be immersed over part of the tidal cycle and not during the low water period, which is the worst case scenario.

Recommendations are made for one RMP for Pacific oysters located in the eastern bed at Geese Quarries and one RMP for mussels located in the western bed at Geese Quarries. The later reflects the very limited extent of the bed requiring classification for mussels, the absence of any other nearby mussel beds and the fact that the industry had emphasised that they do not anticipate to expand the production area in the future.

1 INTRODUCTION

This report documents information from a sanitary survey undertaken following an application for classification of farmed mussels at Geese Quarries (Salcombe-Kingsbridge Estuary), within the classified zone for Pacific oysters.
A desk based assessment of existing information has been made and the results are presented in sections 2 to 5. The results from a shoreline survey undertaken along the coastal area of the estuary are set out in the Appendix I. In section 6, the results of the desk study and shoreline survey are drawn together in an overall assessment of the potential sources of pollution likely to constitute sources of microbiological contamination for the bivalve mollusc classification zones. The sampling plan for microbiological monitoring, derived from the overall assessment, is set out in Appendix II. The sampling plan includes the location of representative monitoring points (RMPs) and required sampling frequency for mussels and pacific oysters in the production area.

1.1 Background

Filter feeding, bivalve molluscan shellfish (e.g. mussels, Pacific 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 (Bell, 2006).

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

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

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

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

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

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

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

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

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

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as 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. However, the standard test[1] used to enumerate *E. coli* does not differentiate between contamination of animal and human origins.

Both sewage discharges and agricultural inputs to river systems discharging into estuaries are thought to significantly impact on a number of coastal and estuarine BMPAs in England and Wales (Younger *et al*., 2003). Other potentially significant source of contamination for the production areas is waste discharges from boats (Sobsey *et al*., 2003).

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and better analyse their effects to BMPAs. 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 proactive changes in land management practices.

[1] ISO TS 16649-3: Microbiology of food and animal feeding stuffs – Enumeration of β-Glucuronidase positive *Escherichia coli* – part 3: Most Probable Number (MPN) technique using 5-Bromo-4-Cloro-3-Indolyl-β-D-Glucuronide Acid. International Organization for Standardization, Geneva.

1.1 Site description

SALCOMBE-KINGSBRIDGE ESTUARY

Salcombe-Kingsbridge Estuary (Eastings/Northings: 274,700/40,500) is situated in Devon, south west coast of England (Figure 1.1). The estuary is sheltered, branching and relatively narrow (Figure 1.1).

Figure 1.1 Location of Salcombe-Kingsbridge Estuary with inset showing Frogmore Creek.
Google Earth ™ mapping service.

The lower reaches are bordered by steep cliffs, whilst the upper reaches contain numerous creeks. From its tidal limit at Kingsbridge, the estuary extends for approximately 8km to Salcombe. The mouth width is low relative to the main channel length, narrowing from 1km wide at the area where the estuary meets with the sea to approximately 230m wide at Salcombe. The main morphological characteristics of the estuary are summarised in Table 1.1.

Table 1.1 Main characteristics of Salcombe-Kingsbridge Estuary.

Geomorphological classification	Type 3b Ria (drowned river valley)
Shoreline length (km)	c. 49
Core area (ha)	c. 674
Intertidal area (ha)	446

Data compiled from the Estuary Guide (ABPmer and HR Wallingford, 2008).

The intertidal is bordered by beaches and rocky shores and includes sandflats, mudflats and saltmarsh.

CATCHMENT CHARACTERISATION

Commercial uses of the estuary include shipping, marine services, fishing and tourism. Tourism-related activities are both water-based (e.g. boating, fishing, canoeing) and land-based (e.g. walking, bird-watching, cultural). The estuarine area at Salcombe is lined by slipways, moorings, boatyards and a fishing dock (Figure 1.2).

Figure 1.2 View of Salcombe from East Portlemouth.
Courtesy of Richard Weymouth.

The estuary's river catchment covers an area of 85km^2 and is largely rural in character. Dominant land cover is improved grassland (52%), most of it supporting livestock production (Figures 1.3, 1.4A). Arable land constitutes 32% of the catchment (Pilbeam, 2008; Figure 1.3). Significant woodland areas occur on steep valley sides (Figure 1.3).

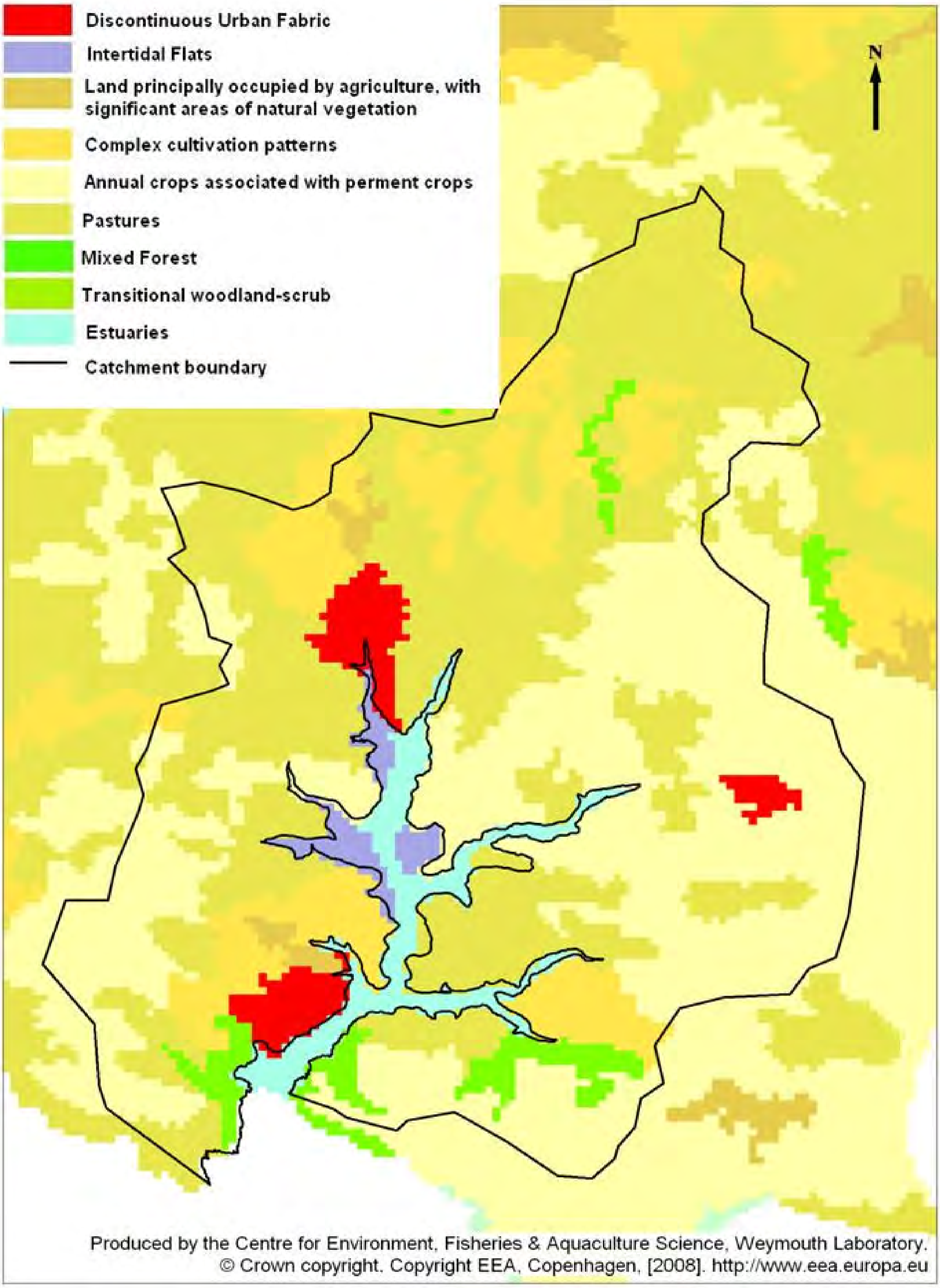

Figure 1.3 Land cover in the Salcombe catchment.

The catchment contains a variety of habitats supporting very rich fauna and flora. These are recognised by a number of nature conservation designations: the estuary constitutes a designated Site of Special Scientific Interest (SSSI) and a Local Nature Reserve. The site also lies within the South Devon Area of Outstanding Natural Beauty (Figure 1.5).

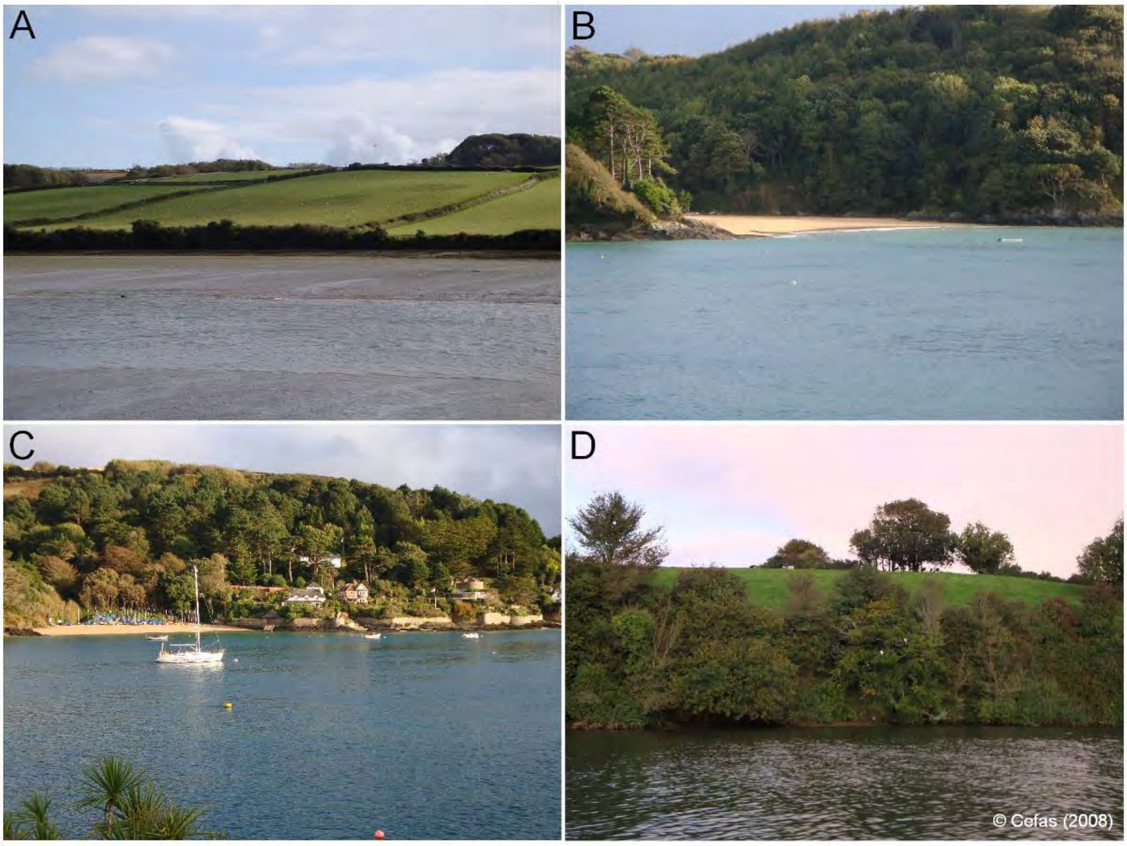

Figure 1.4 Views of Salcombe catchment: grassland south of Frogmore Creek (A), beaches at Mill Bay (B) and Small's Cove (C) and woodland South of Charletown (D).

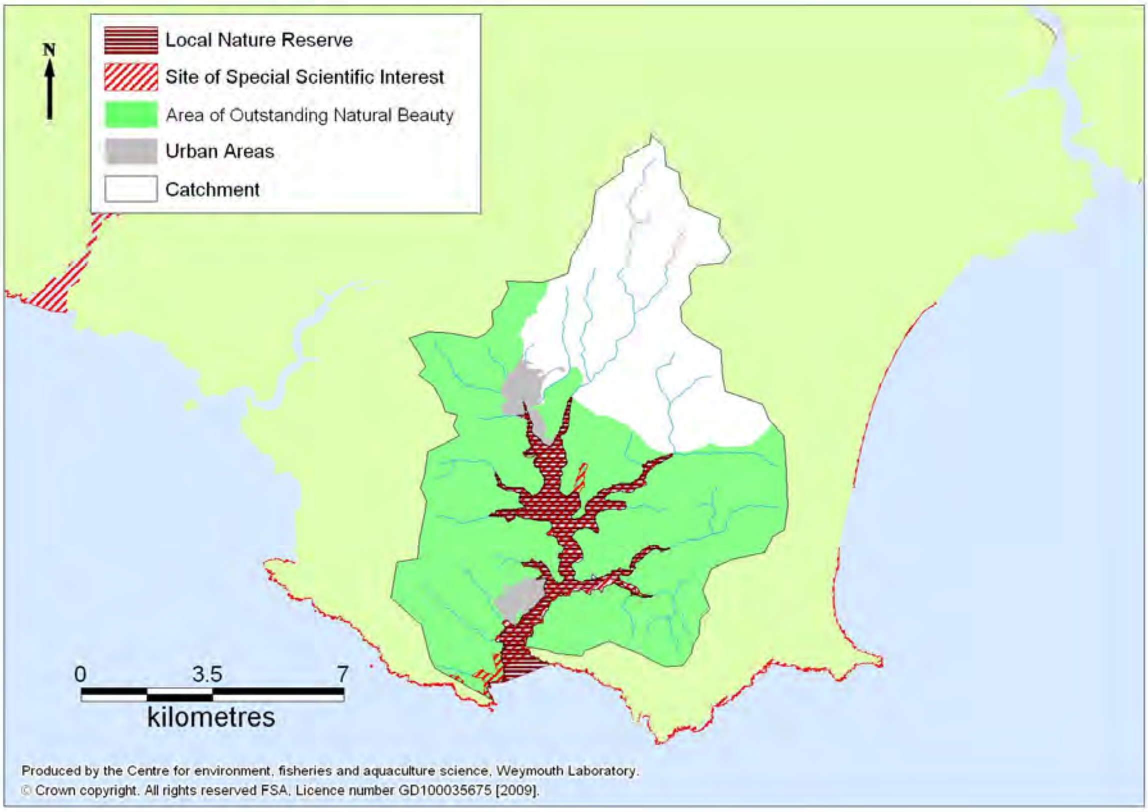

Figure 1.5 Nature conservation designations in the Salcombe-Kingsbridge Estuary.

Total resident human population within the catchment is 19,208 (Office for National Statistics, 2007). Its distribution is shown in Figure 1.6. Population density by Super Output Area Boundary[2] has its maximum value at the urban area of Kingsbridge (11 people per hectare). In the lower catchment, maximum human population densities are 6 people at the urban area of Salcombe.

The most significant urbanised areas are Kingsbridge (3,999) inhabitants in Kingsbridge East and West wards) and Salcombe (3,269 inhabitants in Salcombe and Marlborough ward), situated at the head and the mouth of the estuary, respectively (Office for National Statistics, 2008). In recent years, Kingsbridge has seen a significant population growth (15.4% change over the period 1991–2004) (Devon County Council, 2006).

[2] Super Output Area (SOA) boundaries are in part derived from Ordnance Survey information and some SOA boundaries which follow ward or parish boundaries reproduce limited parts of the OS Boundary-Line product.

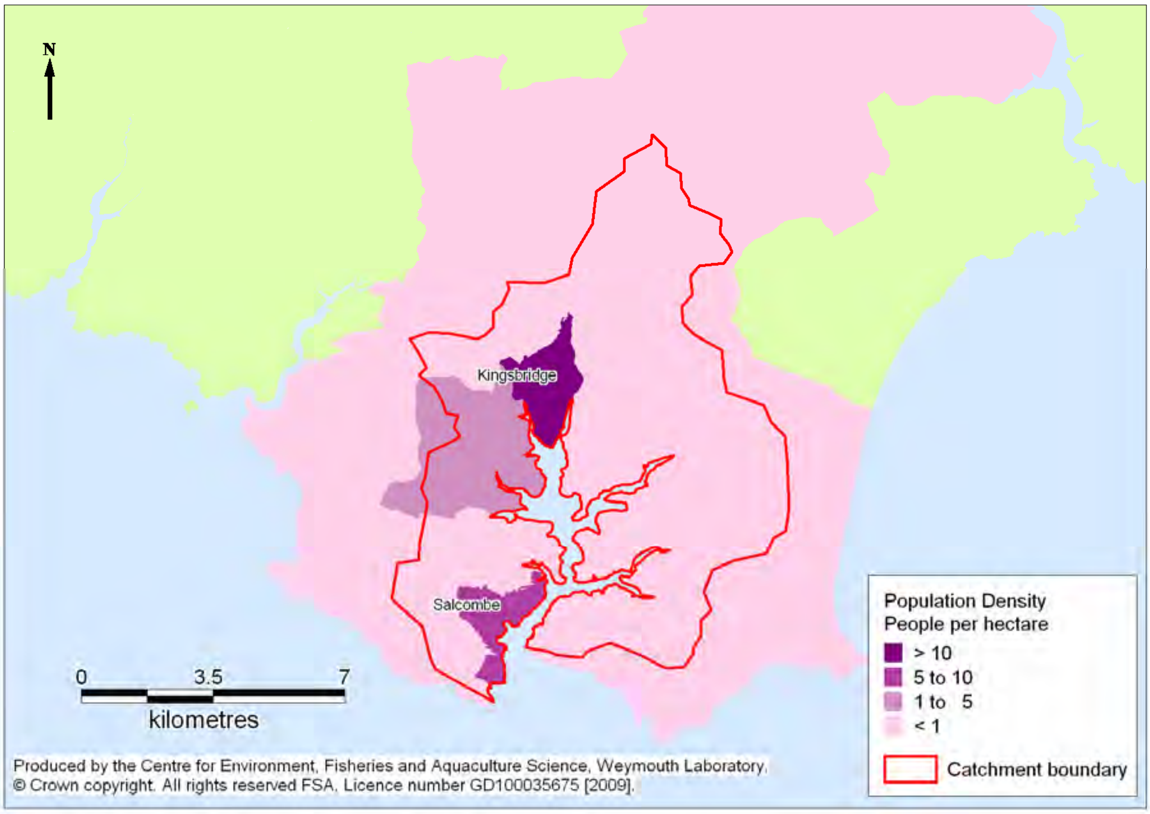

Figure 1.6 Human population density in the Salcombe catchment.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Urban areas will be the source of sewage discharges and impervious surfaces[3] (e.g. roads, parks, pavements), which are known to contribute significant loads of microbiological contaminants to watercourses (see Ellis and Mitchell, 2006)[4]. Microbiological loads from the urbanised areas of Salcombe and Kingsbridge will therefore represent potential sources of pollution to the estuary.

In 2006, the South Hams district recorded over 2.7M overnight visitors. Although a significant number (43,000) of visitors used boat moorings (South West Tourism, 2006), the vast majority used serviced (473,000), self catering (470,000) and caravans/tents (545,000) accommodation. Tourism occupancy rates for serviced accommodation generally increase from January to peak in August (South West Tourism, 2007).

In 2007, a survey undertaken in the district by South West Tourism highlighted that 70% of visitors stayed four or more nights (South West Tourism, 2007a).

Deterioration in the microbiological quality of water and bivalve molluscs is frequently detected in coastal areas impacted by pollution sources associated with tourism activities. This may result from increased loads from sewage

[3] In the context of the present report, impervious surfaces are any surface in the urban landscape that does not infiltrate rainfall.
[4] Concentrations of *E. coli* (MPN $100ml^{-1}$) quoted in literature are: $10–10^3$ for residential areas and highways and $10^2–10^4$ for roof runoff and commercial areas (Ellis and Mitchell, 2006).

treatment plants (Younger *et al.*, 2003). Increased microbiological contamination of water in Salcombe-Kingsbridge Estuary is therefore expected to be significantly higher during the tourism season. Section 4.1 summarises the assessment made to the potential contributions of continuous and intermittent sewage discharges to levels of contamination within the estuary.

2 SHELLFISHERIES

2.1 Species, location and extent

The harvesting of mussels (*Mytilus* spp.) and Pacific oysters (*Crassostrea gigas*) for human consumption has had some tradition in the Salcombe-Kingsbridge Estuary. In the past, commercial operations were established for mussels in Collapit Creek and for Pacific oysters in Charleton Creek and Frogmore Creek (Figure 2.1C). Literature indicates that these operations were affected by TBT and were financially unviable (MacAlister, Elliot & Partners, 2003). In recent years, the commercial interest has been restricted to Frogmore Creek, where Pacific oysters have been farmed by Bigbury Bay Oysters and Limosa Farms Ltd.

The Pacific oyster (*C. gigas*) is a non-native species in the UK (Spencer *et al.*, 1994). No natural spatfalls of this species have been reported within the Salcombe-Kingsbridge Estuary. The existing operations are dependent on the regular supply of juveniles (seed) from commercial hatcheries. Locations of Pacific oyster beds are shown in Figure 2.1A.

The sanitary survey was prompted by an application for classification of a small area (130m^2) of farmed mussels within the area currently classified for Pacific oysters (Figure 2.1B). Following completion of the sanitary survey assessment, the mussel bed at Geese Quarries was classified during the production of this final report. The very limited extent of the bed, the absence of any other nearby mussel beds and the fact that the industry had emphasised that they do anticipate requiring the area of bed to be extended in the future[5], there is limited scope for the location of a representative sampling point and closely defined limits on the boundary of the production area. This report however also reviews the wider Salcombe BMPA, which includes the area classified for Pacific oysters shown in Figure 2.2[6].

Initial classifications at Geese Quarries were initially given for mussels in 2000 (class C) and for Pacific oysters in 2004 (class B). Farmed mussels were classified until 2003, when the commercial interest for this species at this bed was lost and classification allowed to lapse. Oysters have maintained long-term class B[7] since 2005. The criteria for classifying bivalve molluscs are summarised in Table 2.1. Historical classifications for beds in Salcombe BMPA are summarised in Table 2.2 below.

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[5] During the consultation stage of the sanitary survey, Cefas has been informed by the applicant that an agreement has been made between Limosa Farms Ltd and Natural England that mussel farming would be allowed in the restricted area of Frogmore Creek as shown in Figure 2.1.

[6] During the consultation stage of the sanitary survey, Cefas has been informed by the applicant that although there is no stock on the western part of the classified area, Limosa Farms Ltd wishes to retain classification for Pacific oysters in case of the need to transfer stock from the Yealm at some point in the future.

[7] LT - Long-Term classification system applies. Note: Long-Term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification.

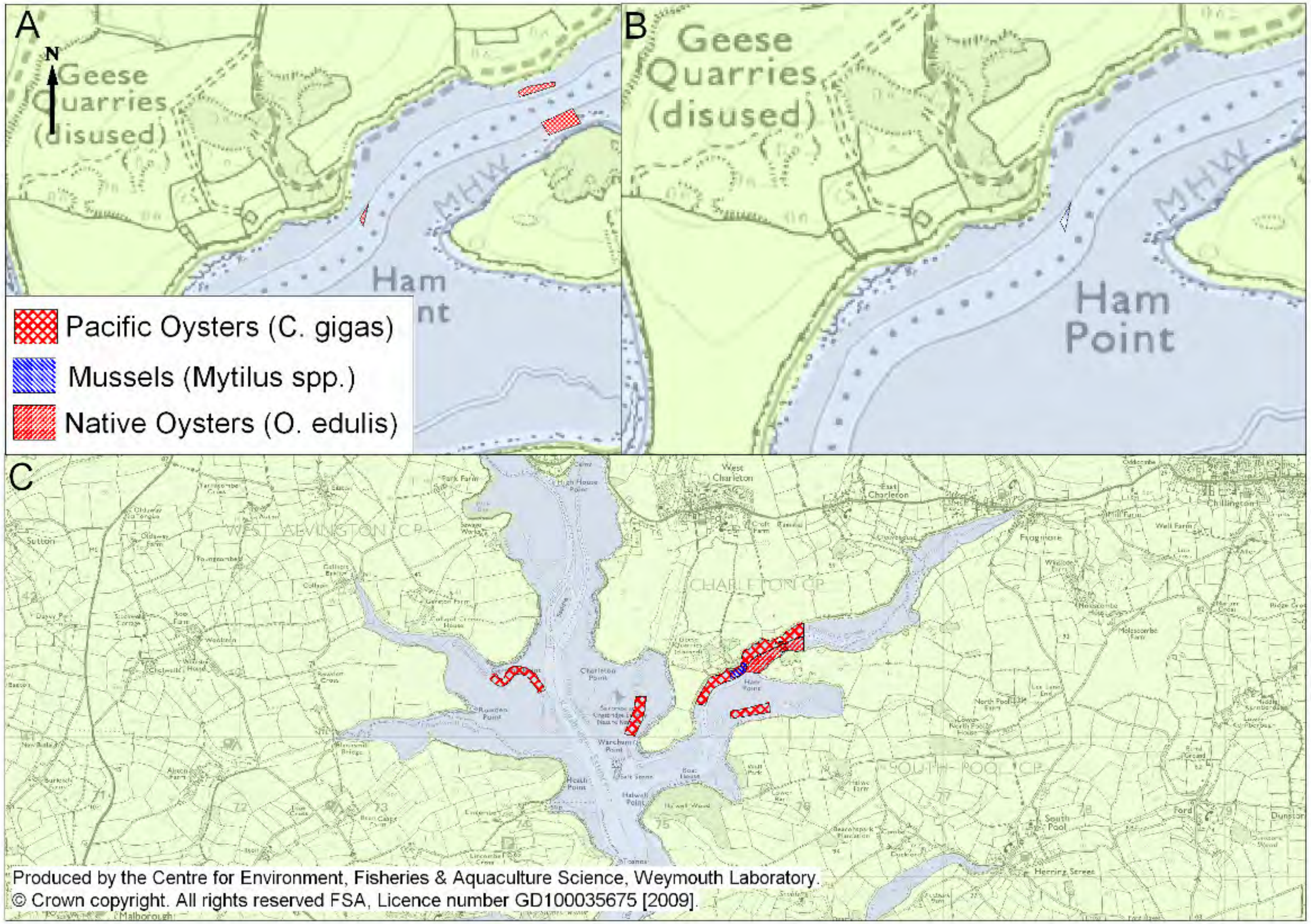


Figure 2.1 Location of currently classified Pacific oyster beds (A), proposed/recently classified mussel bed (B) in Frogmore Creek and (C) historical bivalve mollusc beds in Frogmore, Collapit and Charleton Creeks.

Table 2.1 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 MPN *E. coli* 100g^{-1} FIL[2]	None
B	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (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[3]	Purification, relaying or cooking by an approved method
C	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[4]	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited	>46,000 *E. coli* 100g^{-1} FIL[5]	Harvesting not permitted

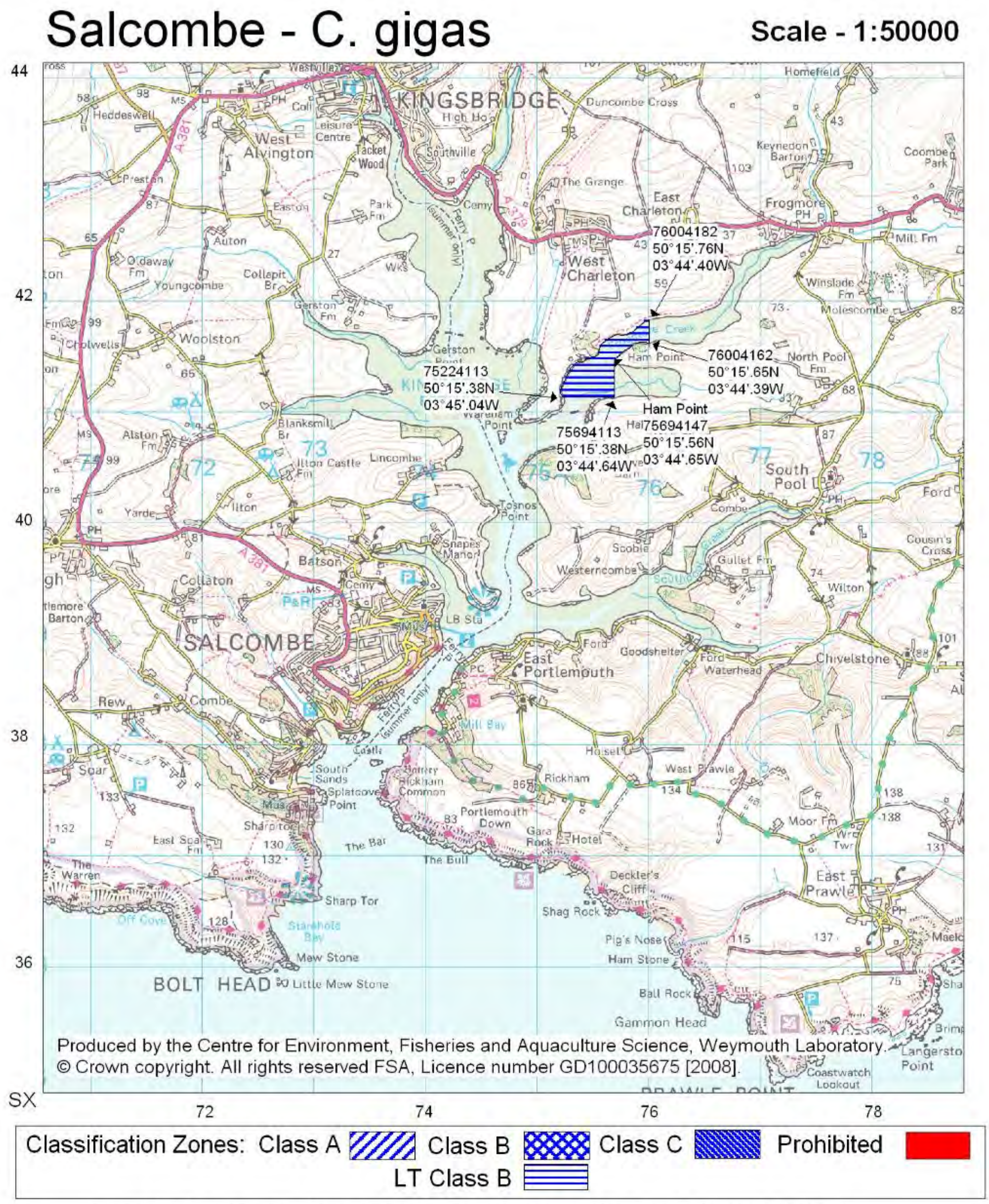
[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply 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.

The classification zone and current classification status is shown in Figure 2.2.

Table 2.2 Historical bed classifications in Salcombe BMPA.

Bed Name	RMP ID	Species	1992–1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Geese Quarries	B029D	C. gigas	n/c	n/c	n/c	n/c	n/c	B[1]	B-LT	B-LT	B-LT	B-LT
	B029E	*Mytilus* spp.	n/c	C	C	B	C	n/c	n/c	n/c	n/c	n/c

n/c - not classified.
1 - Classification is provisional due to insufficient sample results, either in number or period of time covered.
LT - Long-Term classification system applies. N.B. Long-Term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2008

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

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

N.B. Lat/Longs quoted are OSGB 36

Food Authority: South Hams District Council

Figure 2.2 Existing classification zone and current classification status for Pacific oysters (*C. gigas*) in Salcombe-Kingsbridge Estuary.

2.2 Growing methods and harvesting techniques

Mussels and oysters are grown in bags supported above the riverbed on trestles. Both species are harvested by hand (Figure 2.3).

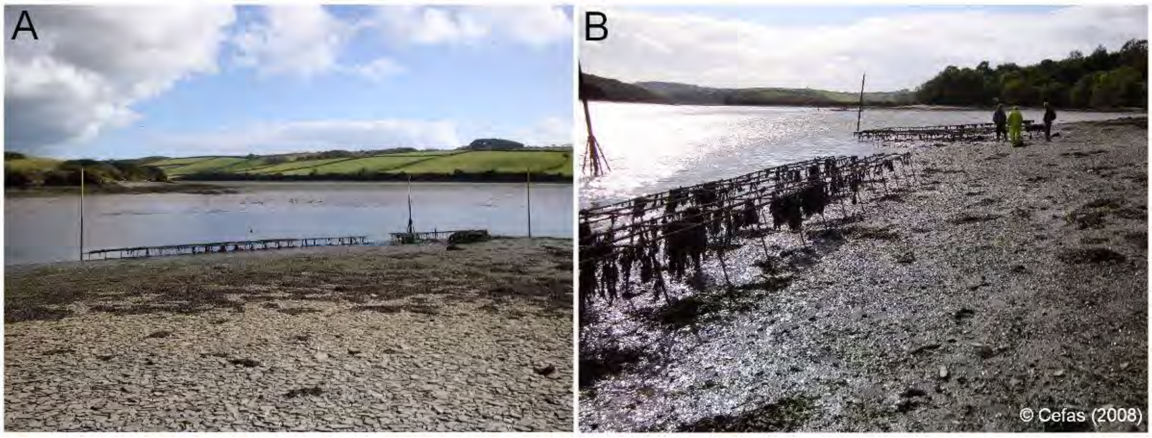


Figure 2.3 Pacific oysters in bags on trestles at Geese Quarries.

2.3 Seasonality of harvest, conservation controls and development potential

All bivalve molluscs in the Salcombe-Kingsbridge Estuary are harvested on a year-round basis.

The anticipated annual production of mussels for the re-instated operation at Geese Quarries is approximately 5 tonnes. Maximum oyster production in the south bed is estimated to be approximately 2 tonnes (100 bags assuming 20kg each).

The estuary bed is owned by the Duchy of Cornwall, of which the majority is leased to South Hams District Council and the Salcombe Harbour Authority.

MacAlister, Elliot & Partners (2003) considered that the deeper areas of the estuary are suitable for floating aquaculture production systems. Both Bigbury Bay Oysters and Limosa Farms Ltd informed Cefas that they do not intend to expand the existing operations in the foreseeable future. Owing to the very restricted extent of the existing operations, limited scope exists for the location of a representative monitoring points and closely defined limits on the boundary of the production area.

The commercial production of bivalve molluscs on the Salcombe-Kingsbridge Estuary is not covered by Several, Regulating or Hybrid Order.

The Devon Sea Fisheries Committee (SFC) regulates harvesting of bivalve molluscs in the estuary. Under Byelaw 26th February 1998, the SFC is responsible for issuing temporary harvesting closures of beds or parts of beds which contain immature and undersized shellfish[8].

[8] In the context of the Byelaw, the term “shellfish” means mussels, oysters, clams and periwinkles.

3. Hydrometrics and hydrodynamics

The southwest of England is one of the wettest regions in the UK. The rainfall pattern throughout the Salcombe river catchment is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall throughout the upper reaches of the catchment. Figure 3.1 shows the location of watercourses and rain-gauge stations in the Salcombe-Kingsbridge Estuary catchment.

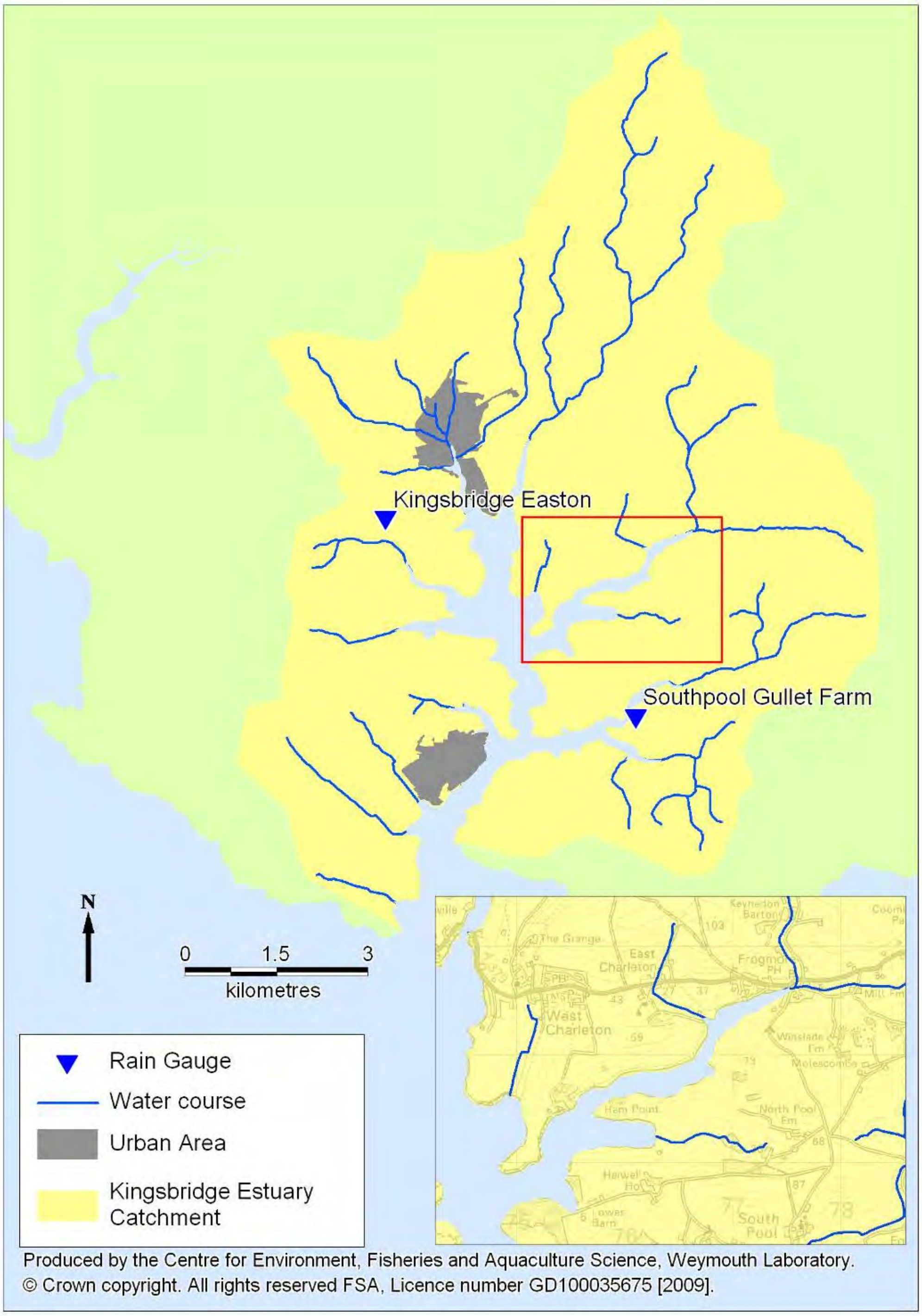


Figure 3.1 Location of watercourses and rain-gauge stations in the Salcombe catchment.

3.1 Rainfall

Figure 3.2 shows monthly averaged and monthly total rainfall monitored daily at two gauges (Kingsbridge Easton: (Latitude/Longitude: 50°16.16.'/3°47.26') and Southpool Gullet Farm: 50°14.34'/3°55.17') representative of the mid and lower catchment for the period 2004–2007. The magnitude of rainfall levels indicates that rainfall does not vary significantly throughout the catchment. On average, a significant decrease in rainfall levels occurs from July to September. The wettest period is October–December (Figure 3.2).

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) as well as runoff from faecally contaminated land (Younger *et al*., 2003). An inventory of the most significant sewage discharges to the Salcombe-Kingsbridge Estuary is listed in section 4.1.

Levels of microbiological contamination are therefore expected to increase during autumn-winter months. The effect of rainfall on the levels of *E. coli* in bivalve molluscs on the Salcombe-Kingsbridge Estuary was analysed and the results are given in section 5.2.

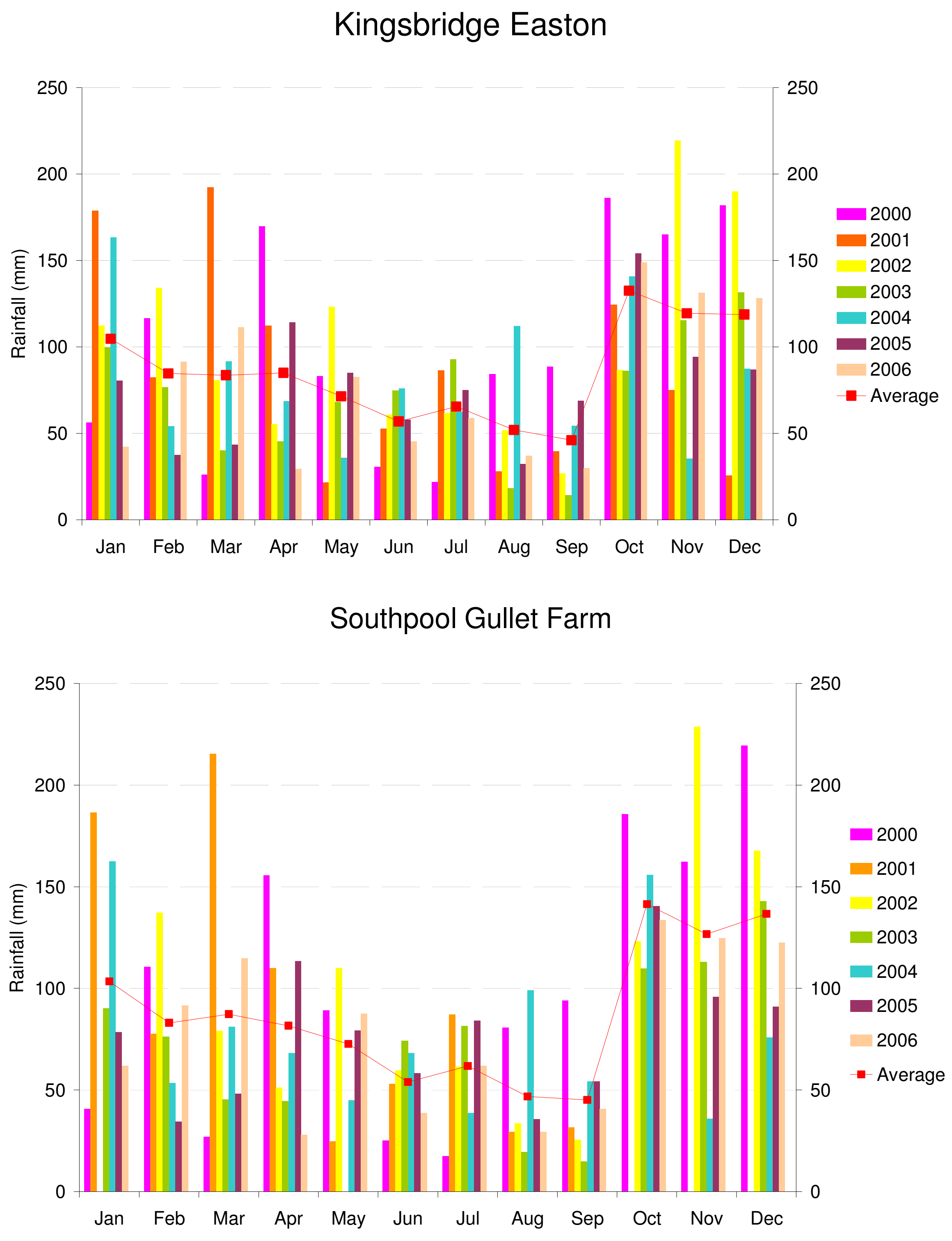


Figure 3.2 Monthly variation of rainfall in two gauging stations in the Salcombe catchment for the period January 2004–December 2006.
Data from the Environment Agency (2007).

3.2 River inputs

The Salcombe-Kingsbridge Estuary is a ria and therefore no significant rivers discharge to the estuary. Transport of contamination with and out of the estuary will therefore be mostly dependent on tidal processes.

There are however several small streams (shown in Figure 3.1) which potentially contribute to microbiological loads to the estuary. No continuous flow monitoring is undertaken in these watercourses.

Several streams were sampled for enumeration of faecal indicator microorganisms as part of the shoreline survey on 1–2 October 2008 (see Appendix I). Samples from Tacketwood Creek and Kingsbridge at Squares Quay were found to be heavily contaminated with faecal coliforms and *E. coli* suggesting significant contributions from these watercourses to levels of contamination in the estuary.

3.3 Bathymetry

The estuary is mainly shallow, dendritic, with several creeks and significant areas drying at Low Water springs (Figure 3.3A). Around low water, flows occur through one main deeper channel which extends from the tidal limit at Kingsbridge to the mouth of the estuary at Salcombe. Each creek has one secondary channel. Of these, Frogmore Creek is the deepest and is where bivalve mollusc beds have been established.

Chartered depths in Frogmore Creek and the wider estuary are shown in Figure 3.3. Maximum charted depth within Frogmore Creek at the intersection point with the main channel is 2.4m relative to Chart Datum (CD) (Figure 3.3B). A maximum charted depth of 12.5m relative to CD is found in the deeper channel leading to Salcombe in the area known as The Bag, just north of Snapes Point.

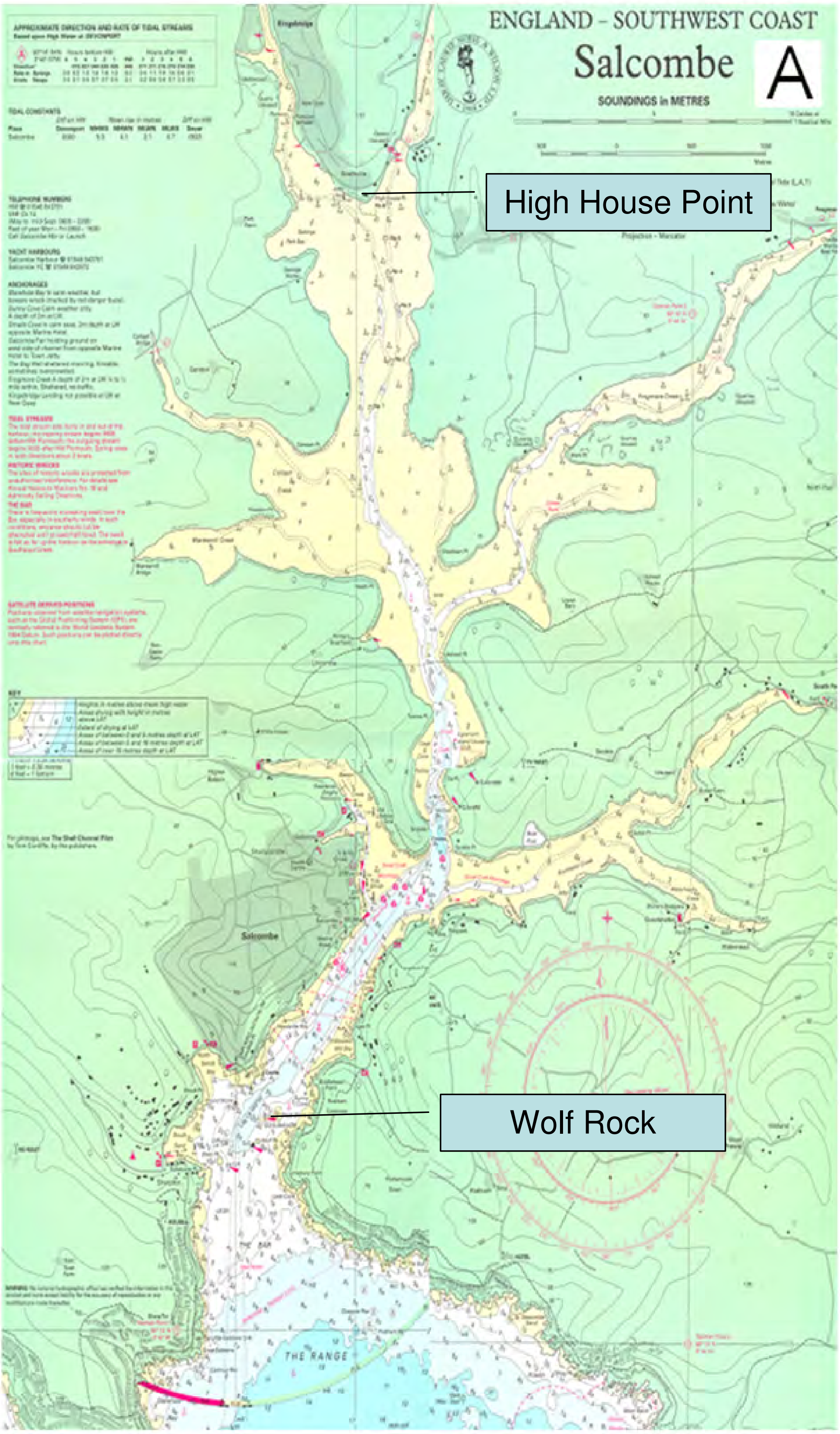


Figure 3.3A Bathymetry of the Salcombe-Kingsbridge Estuary.
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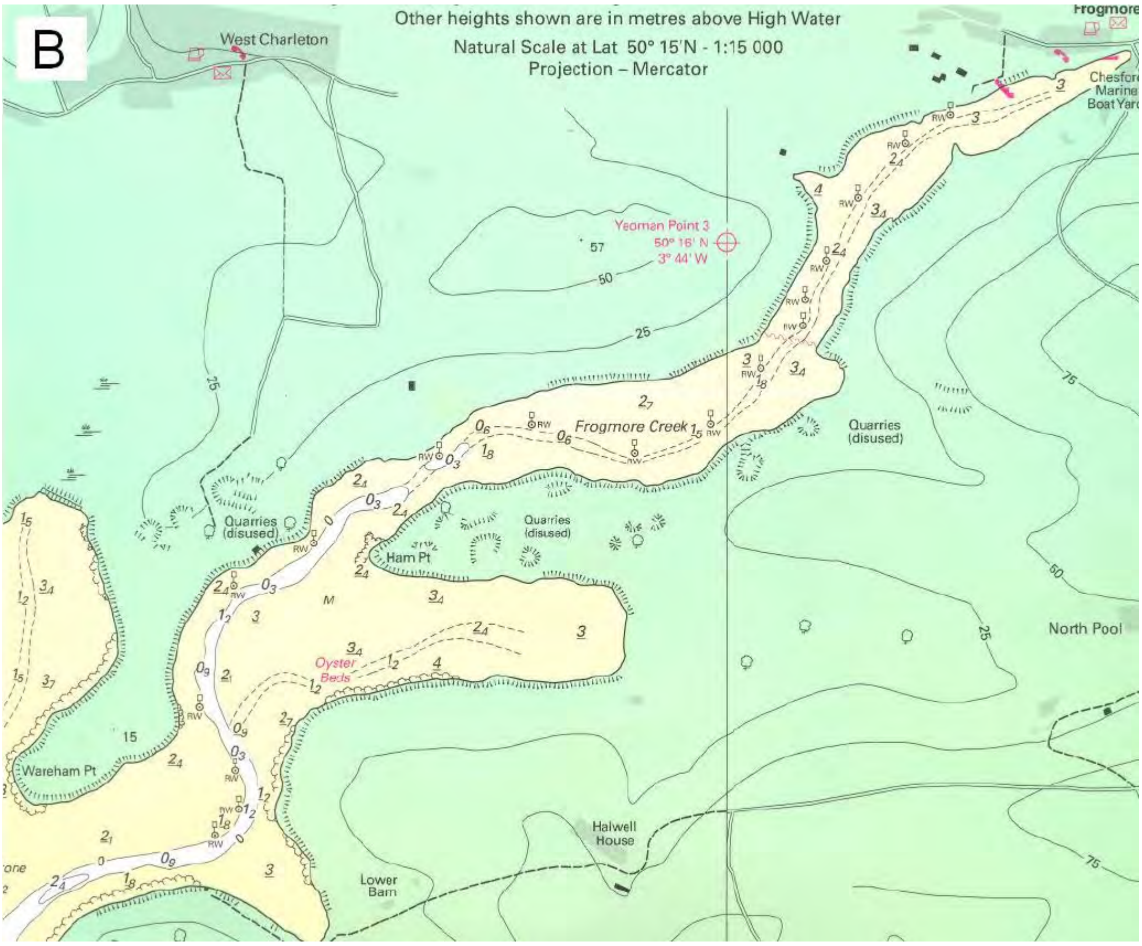

Figure 3.3B Bathymetry of Frogmore Creek.

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The dendritic structure of many estuaries, with muddy shallow creeks of varying sizes, often result in a continued flow long after the tide has receded and the mudflats are exposed (Whitehouse *et al*., 2000). Contaminated runoff from retained seawater and/or from rainfall falling on the surface of mudflats at Frogmore Creek (particularly the area marked as "Oyster Beds" in Figure 3.3B) and other creeks of the upper estuary will be conveyed along the main channel of Frogmore Creek.

Sedimentation of microbiological contaminants and re-suspension of contaminated sediment is expected to occur in the shallow intertidal areas where less water for dispersion and dilution is available.

3.4 Tides and tidal currents

The estuary has an asymmetrical macro-tidal regime with semi-diurnal tides (i.e. two tidal cycles per day). At Salcombe, the mean spring tide range is 4.6m and the mean neap tide range is 2.0m (Table 3.1).

Table 3.1. Mean sea level and tidal constants for Salcombe.

		Height (m) above Chart Datum				Range (m)	
Port	Mean Sea Level (m)	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Salcombe	3.1	5.3	4.1	2.1	0.7	4.6	2.0

Predictions for this secondary port is based on Plymouth (Devonport)
Admiralty © TotalTide (The UK Hydrographic Office)

The Salcombe-Kingsbridge Estuary is ebb dominant (Halcrow Group Ltd., 2002), the flood being of shorter duration than the flood. The tidal length (mouth to limit of reversing tidal currents) is estimated to be 7.5km and the estimated residence (flushing) time[9] is estimated to be approximately 3.5 days (Uncles *et al.*, 2002). It is estimated that approximately 79% and 50% of the total High Water volume of water is exchanged during spring and neap tides, respectively (Kinetics Ltd, 1992). Tidal currents would therefore constitute the main factor that contributes to the transport of microbiological contamination in the estuary.

The maximum depth averaged suspended particulate matter on the Salcombe-Kingsbridge Estuary is low (8.4mg l^{-1}) when compared with that of other estuaries in the Southwest UK, such as for example Helford (17mg l^{-1}) and Dart (12mg l^{-1}) (Uncles *et al.*, 2002). This factor, coupled with the low residence time, indicates that the behaviour of the turbidity maximum in the Salcombe-Kingsbridge Estuary is controlled mainly by tidal processes on short-time scales (see Jay and Musiak, 1994).

Within the estuary, tidal effects will be greatly modified by the friction of the bed and by the funnelling effect of the convergence of the estuary sides (Dyer, 1995). Figures 3.4A–B show tidal vectors for a spring tide at mid ebb and mid flood stages, respectively. These highlight the general increasing gradient of tidal flushing toward the mouth of the estuary during spring tides and decreasing gradient towards the head of the estuary during the flood. Of particular relevance for bivalves at Geese Quarries are the relative strong flows (≈1m s^{-1}) in Frogmore Creek at Ham Point. Locally, these will promote rapid dispersion of contamination suspended in the water column. The model resolution does not allow an assessment of whether secondary currents (e.g. significant back eddies, etc.) are present at Geese Quarries that may be of local importance.

[9] The residence time is the ratio between the tidal volume and the freshwater input to the estuary.

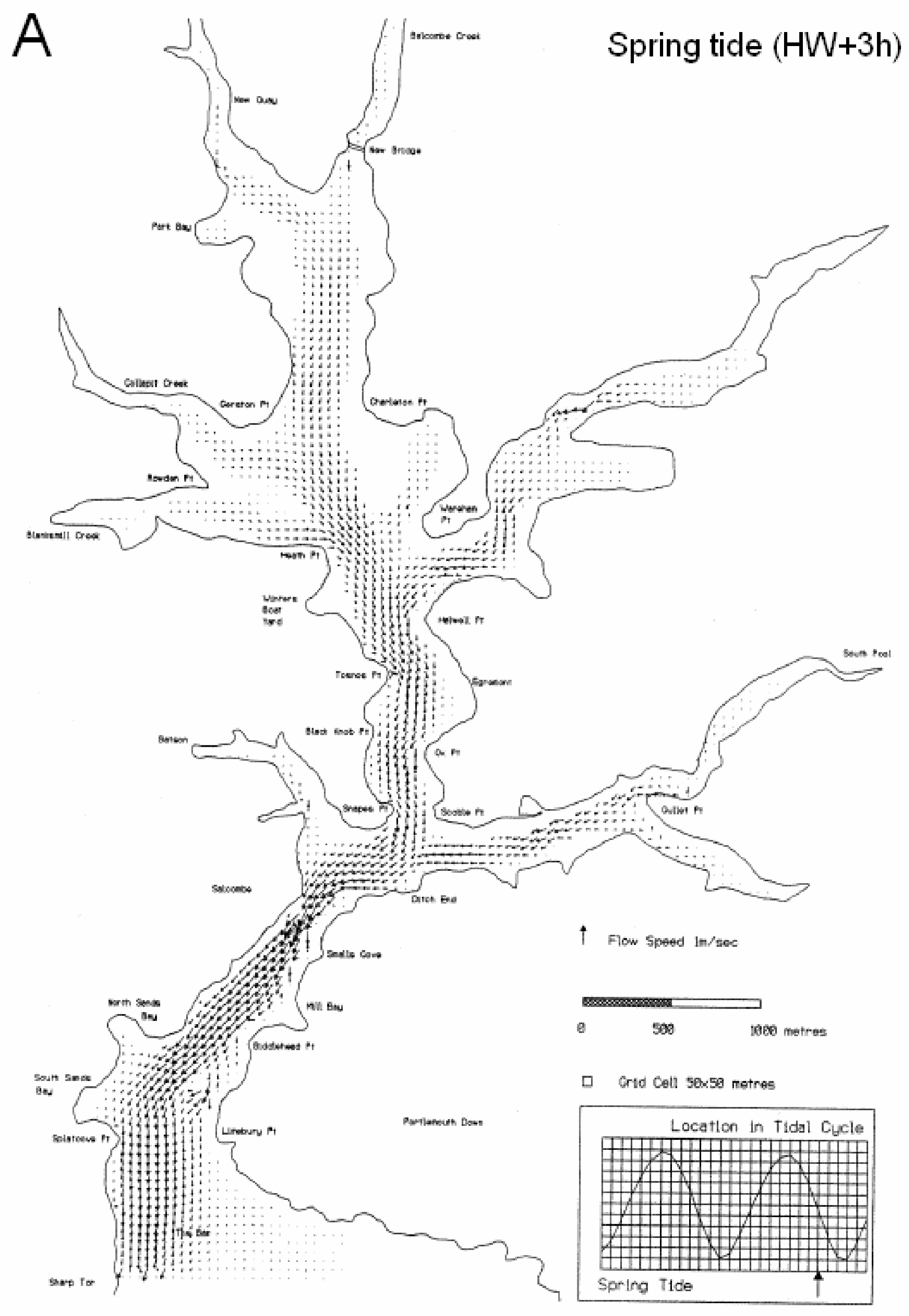

Figure 3.4A Flow speeds and directional vectors for a spring tide at mid ebb in the Salcombe-Kingsbridge Estuary.

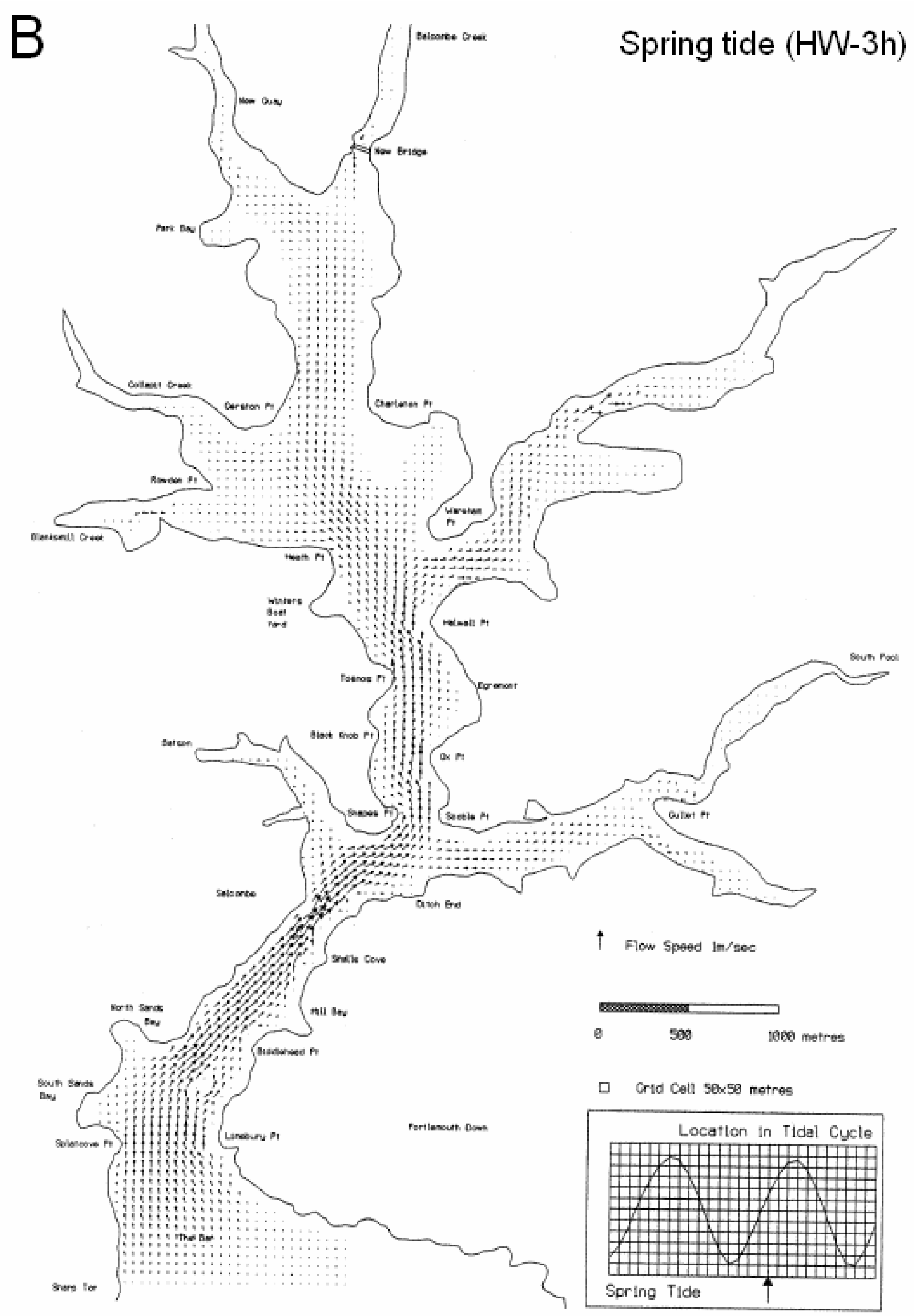

Figure 3.4B Flow speeds and directional vectors for a spring tide at mid flood in the Salcombe-Kingsbridge Estuary.

Results from two dye tracing exercises undertaken by InstallOcean Ltd in May 1991 (first release at High Water (HW): spring tide of 17 May 1991; second release at HW: neap tide of 21 May 1991) evidenced the differences in tidal excursion on spring and neap tides. The stronger spring tide currents promoted the dispersion of the dye from the release point in the vicinity of High House Point (Kingsbridge) to Wolf Rock, at the mouth of the estuary by Low Water (LW)-2h. A substantial amount of dye was probably flushed from the estuary and did not return in the following flood tide. During the neap tide, tidal flows are weaker and the leading edge of the dye only reached Wolf Rock at around LW, suggesting that the complete dye patch would have returned up the estuary on the following flood tide (InstallOcean Ltd, 1991).

This suggests that sewage discharges in Kingsbridge area could potentially impact on the water quality of the whole Salcombe-Kingsbridge Estuary. Bivalve molluscs at Frogmore Creek would be particularly impacted when there is less tidal flushing (during neap tides) and when contamination from discharges at Kingsbridge and/or Salcombe is likely to be transported up the estuary during the flood tide. The dye tracing exercise also showed that dilution rates are highly variable.

Pacific oysters and mussels growing above the river-bed will be out of the water over a significant proportion of the tidal cycle. Figure 3.5 shows the relative position of Pacific oyster bags relative to the main channel of Frogmore Creek at Geese Quarries during the first moments of the flood tide.

Figure 3.5 Water flow along the main channel of Frogmore Creek at Geese Quarries during the flood tide.

Arrow indicates direction of tidal flows.

In general, the macro-tidal regime and low residence time suggest that, for most of the time, the estuary is able to quickly disperse microbiological contaminants in well flushed areas such as those along the main deeper channel. Higher impact of contamination from pollution sources located at the head of the estuary are expected to occur during neap tides due to effective lack of tidal flushing, particularly in tidal creeks such as Frogmore Creek. Contaminated water and sediments transported down the creek on the ebb tide is considered to be the most significant process acting on the transport of microbiological contamination impacting the BMPA at Geese Quarries.

4 SOURCES OF MICROBIOLOGICAL POLLUTION

4.1 Sewage discharges

Sewage discharges pose a significant risk of contamination of faecal origin to bivalve molluscs. The risk is diverse and depends from contributing human population and volume of discharge. Sewage effluents in the catchment draining to Salcombe-Kingsbridge Estuary are treated in a number of sewage treatment works (STW). The larger STW are associated with the urbanised areas of Kingsbridge and Salcombe. Smaller discharges are in the vicinity of Sherford, Frogmore, Chillington, West Charlton and Woolston villages.

Of those identified in the Environment Agency Pollution Reduction Plans (PRPs) (Environment Agency, 2007, 2008) as having a significant or potentially significant impact on the Shellfish Water, only Frogmore & Chillington STW and Sherford STW discharge to Sherford Stream, a tributary of Frogmore Creek.

Effluents from Salcombe, Gerston, West Charlton and Frogmore & Chillington STW receive ultraviolet (UV) disinfection. Effluents from Sherford STW and Woolston STW receive secondary treatment.

The sewerage infrastructure is also served by a number of combined sewer overflows (CSO), emergency overflows (EO) and overflows from sewage pumping stations (PS). Of particular significance to bivalve mollusc beds are East Charlton PS CSO, Frogmore & Chillington STW storm tank, Frogmore No 1 PS, Frogmore No 2 PS, Sherford STW SO, Chillington SSO, Rear of (R/o) 7 Meadowside and Home Close PS CSO/EO, which discharge directly to Frogmore Creek or its tributaries.

Figure 4.1 shows the numbered locations of continuous and intermittent sewage discharges likely to be a source of microbiological contamination to bivalve molluscs. The fluvial distances from these sewage discharges to bivalve mollusc beds are summarised in Tables 4.1 and 4.2. Black asterisks represent discharges not identified in the EA PRP that may impact on parts of the wider estuary/contribute to overall background microbiolgical levels.

In the past, there was particular concern about the impact of sewage treatment works on the microbiological quality of water in the estuary (South Hams District Council, 2005a). The bivalve mollusc beds at Frogmore Creek are particularly vulnerable to receive contamination from Sherford STW (secondary; 4km from nearest bivalve bed) and Woolston STW (secondary treatment; 5.5km from nearest bivalve bed). Effluents from the intermittent discharges East Charlton PS CSO, Frogmore & Chillington STW storm tank, Frogmore No 1 PS, Frogmore No 2 PS, Sherford STW SO, Chillington SSO, R/o 7 Meadowside and Home Close PS CSO/EO discharge directly to Frogmore Creek or its tributaries and could represent a negative impact during/following rainfall events.

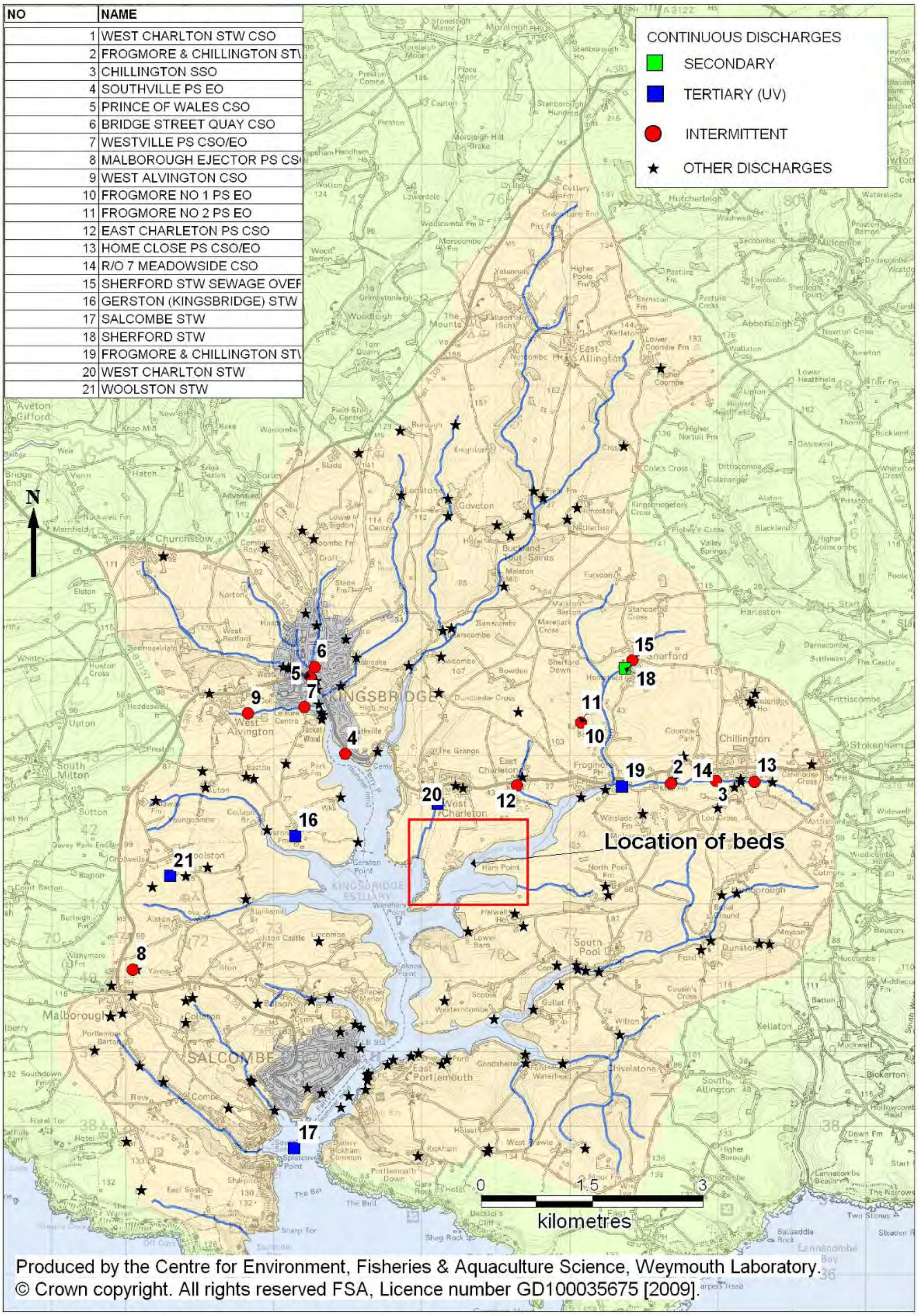

Figure 4.1 Location of significant sewage discharges to Salcombe-Kingsbridge Estuary.

Table 4.1 Significant continuous sewage discharges to Salcombe-Kingsbridge Estuary.

Discharge	treatment	DWF ($m^3\ d^{-1}$)	Population Equivalent (annual)	Approximate (fluvial) distance from nearest oyster bed (km)
Gerston (Kingsbridge) STW	UV	5,530	-	4.0
Salcombe STW	UV	1,814	3,962*	5.0
Sherford STW	Secondary	1,210	225	4.0
Frogmore & Chillington STW	UV	458	-	2.3
West Charlton STW	UV	112	520	3.6
Woolston STW	Secondary	4	-	5.5

DWF - dry weather flow.
STW - sewage treatment works
UV - ultra-violet disinfection.
** Information from Ofwat (2004).*

Table 4.2 Significant intermittent sewage discharges to Salcombe-Kingsbridge Estuary.

Discharge Name	Type	Approximate (fluvial) distance from nearest oyster bed (km)
Bridge Street Quay	CSO	7.4
West Alvington	CSO	6.2
Malborough Ejector PS	CSO	5.7
Prince of Wales Road	CSO	5.6
Westville PS	CSO/EO	5.4
Southville PS	EO	4.3
Sherford STW	SO	4.2
Home Close PS	CSO/EO	4.1
West Charlton STW	CSO	3.6
Chillington	SSO	3.6
R/o 7 Meadowside	CSO	3.6
Frogmore No 1 PS	EO	3.4
Frogmore No 2 PS	EO	3.4
Frogmore & Chillington STW	STO	2.9
East Charlton PS	CSO	2.0

CSO - combined sewer overflow.
EO - emergency overflow.
PS - pumping station.
SSO - sewage storm overflow
STO - storm tank overflow
STW - sewage treatment works.

Table 4.3 presents summary statistics for levels of faecal coliforms monitored in the final UV-treated effluent in four sewage treatment works discharging to the Salcombe-Kingsbridge Estuary. Geometric means of faecal coliforms in effluent discharges from Salcombe STW and Frogmore & Chillington STW are higher than the average levels given in the literature for a range of UV-treated effluents in the UK (Kay *et al*., 2008). Maximum levels of the microbiological indicator indicate the existence of periods when the quality of the final effluent had deteriorated. This is particularly evident in the quality of the effluent from Frogmore & Chillington STW during summer months (Figure 4.2).

Table 4.3 Summary statistics of presumptive levels of faecal coliforms in the final effluent post UV disinfection monitored in four sewage treatment works discharging to Salcombe-Kingsbridge Estuary.

STW Name	Number of samples	CFU Faecal coliforms 100ml^{-1}					
		Minimum	Maximum	Median	Geometric mean	95% CI for mean Lower	Higher
Gerston (Kingsbridge)	46	11	1,700	110	105	75	150
Salcombe	101	80	360,000	1,600	1,801	1,200	3,050
Frogmore & Chillington	25	25	41,000	320	375	180	780
West Charlton	53	5	10,000	69	103	58	180

N.B. monitoring periods:
Gersaton (Kingsbridge) STW (Jan 2005–Sep 2006);
Salcombe STW (Jan 2003–Sep 2006);
Frogmore & Chillington STW (Oct 2005–Sep 2006);
West Charlton STW (Oct 2004–Sep 2006).

Side-by-side box-and-whisker plots[10] of levels of faecal coliforms grouped by season (Figure 4.2) show deteriorated quality of the effluent discharge (as evidenced by median values) from Salcombe STW throughout the year. The quality of the effluent from Kingsbridge STW is below the typical levels in UV-treated effluents as mentioned in the literature.

One-way ANOVA combined with Tukey HSD post-hoc test (95% confidence level) revealed statistically significant differences in the levels of faecal coliforms detected in the effluent of Gerston (Kingsbridge) STW ($F_{(3,42)}$=7.94; p=0.000) and West Charlton STW ($F_{(3,49)}$=7.91; p=0.000) between winter and those detected in the other seasons. Statistically significant differences were also found in the levels of the microbiological indicator in the effluent from Salcombe STW ($F_{(3,97)}$=7.97; p=0.000) between the summer and those detected in autumn-winter months. Levels of the microbiological indicator in the effluent discharge from Frogmore & Chillington STW were not statistically different between seasons.

Deterioration in microbiological quality of effluent discharges from Gerston (Kingsbridge), West Charlton and Salcombe STW during summer may contribute to seasonal variations in the levels of microbiological contamination retained and accumulated by bivalve molluscs. Analysis of historical *E. coli* data in Pacific oysters and mussels is given in section 5.2.

[10] Box-and-whisker plots depict the distribution (central tendency and spread) of a data set. These plots show (a) the centre or median of the data (centre line of the box), (b) the spread or inter-quartile range (box height), (c) quartile skew (relative size of box halves) and (d) the presence of extreme values or outliers (asterisks).

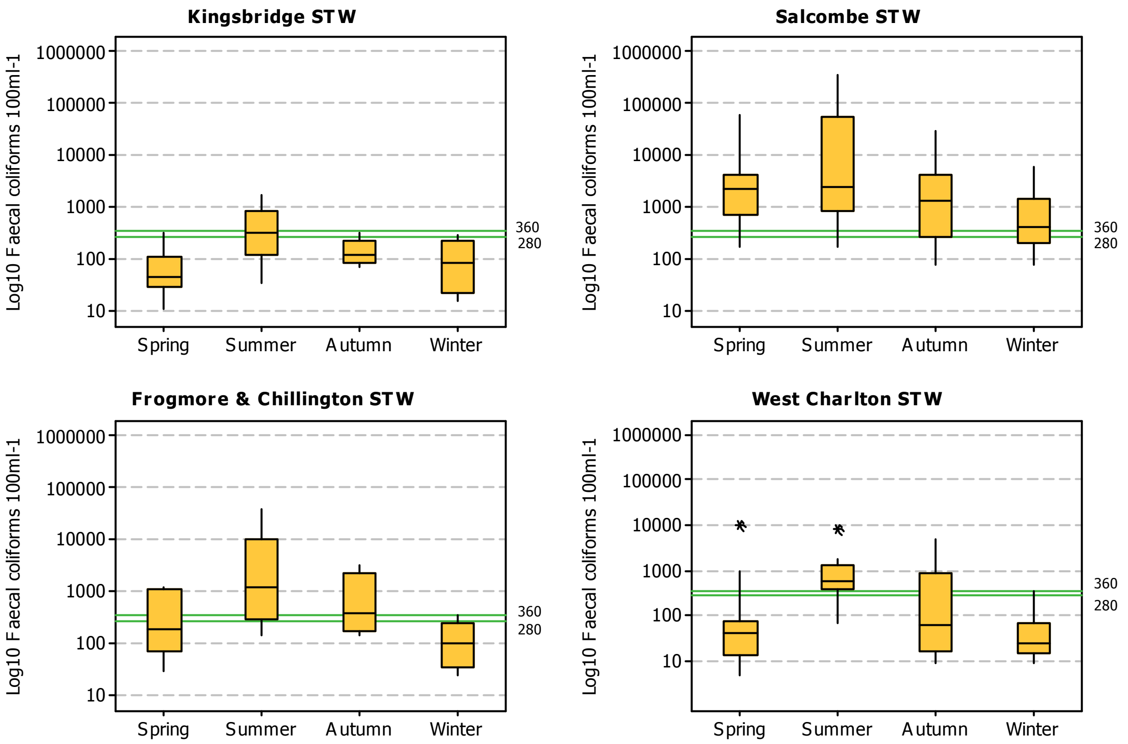

Figure 4.2 Box-and-whisker plots of seasonal presumptive levels of faecal coliforms in the final effluent post UV disinfection monitored in four sewage treatment works discharging to Salcombe-Kingsbridge Estuary.
N.B. Spring: March–May; Summer: June–August; Autumn: September–November; Winter: December–February.
N.B. monitoring periods:
Gerston (Kingsbridge) STW (Jan 2005–Sep 2006; n=46);
Salcombe STW (Jan 2003–Sep 2006; n=101);
Frogmore & Chillington STW (Oct 2005–Sep 2006; n=25);
West Charlton STW (Oct 2004–Sep 2006; n=53).
Reference lines correspond to typical levels of faecal coliforms in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents by Kay et al. (2008).

4.2 Boats and marinas

The potential for sewage discharges from boats to constitute sources of microbiological contamination for bivalve molluscs has received a great deal of attention. Most of the studies demonstrating positive associations between the percentage of boating occupancy and the levels of contamination have been undertaken in partially enclosed water bodies, such as ports and marinas (see Sobsey *et al.*, 2003).

The harbour has several visitor moorings, deep water moorings and pontoon berths and dinghy storage sites (Table 4.4).

Table 4.4 Number and types of moorings in the Salcombe-Kingsbridge Estuary.

Mooring type	Number
Deep water swinging moorings	215
Deep water pontoon berths	60
Deep water visitor moorings	25
Deep water visitors' pontoon	25
Foreshore moorings	630
Pontoon Berths	Number
Victoria Quay	76
Shadycombe	33 (of which 7 are business berths)
Batson	246
Kingsbridge	37
Dinghy storage	Number
Whitestrand	27
Batson	172
New Bridge	98
Kingsbridge	11

Data from South Hams District Council (2007).

The location of moorings and anchorage points in the Salcombe-Kingsbridge Estuary in relation to shellfish beds is shown in Figure 4.3. Salcombe Harbour Authority acknowledges that Collapit Creek, Blanksmill Creek, Lower Frogmore Creek and Widegates should be kept free of moorings. The head of Frogmore Creek is however considered by the authority an area where vessels may lay-up (South Hams District Council, 2004).

Salcombe Harbour has a commercial fleet of about 15 registered potting boats, half of which are over 10m in length (Pawson *et al.*, 2002). Salcombe Harbour Authority recommends that the total number of fishing vessels on deep water moorings shall not exceed 25 (South Hams District Council, 2007).

The Harbour Office provides a number of waste disposal facilities, including a sewage pump-out facility for boats (South Hams District Council, 2009).

Being ebb-dominant and macro-tidal, the Salcombe-Kingsbridge Estuary is generally able to disperse contamination from moored boats towards the mouth of the estuary under most conditions. Strong southerly winds coincident with the flood stage of the tide may however promote retention of contaminants within the estuary with the potential to increase negative impacts on bivalve mollusc beds. Given the high number of moorings used on a seasonal basis, the risk would be particularly evident during summer months.

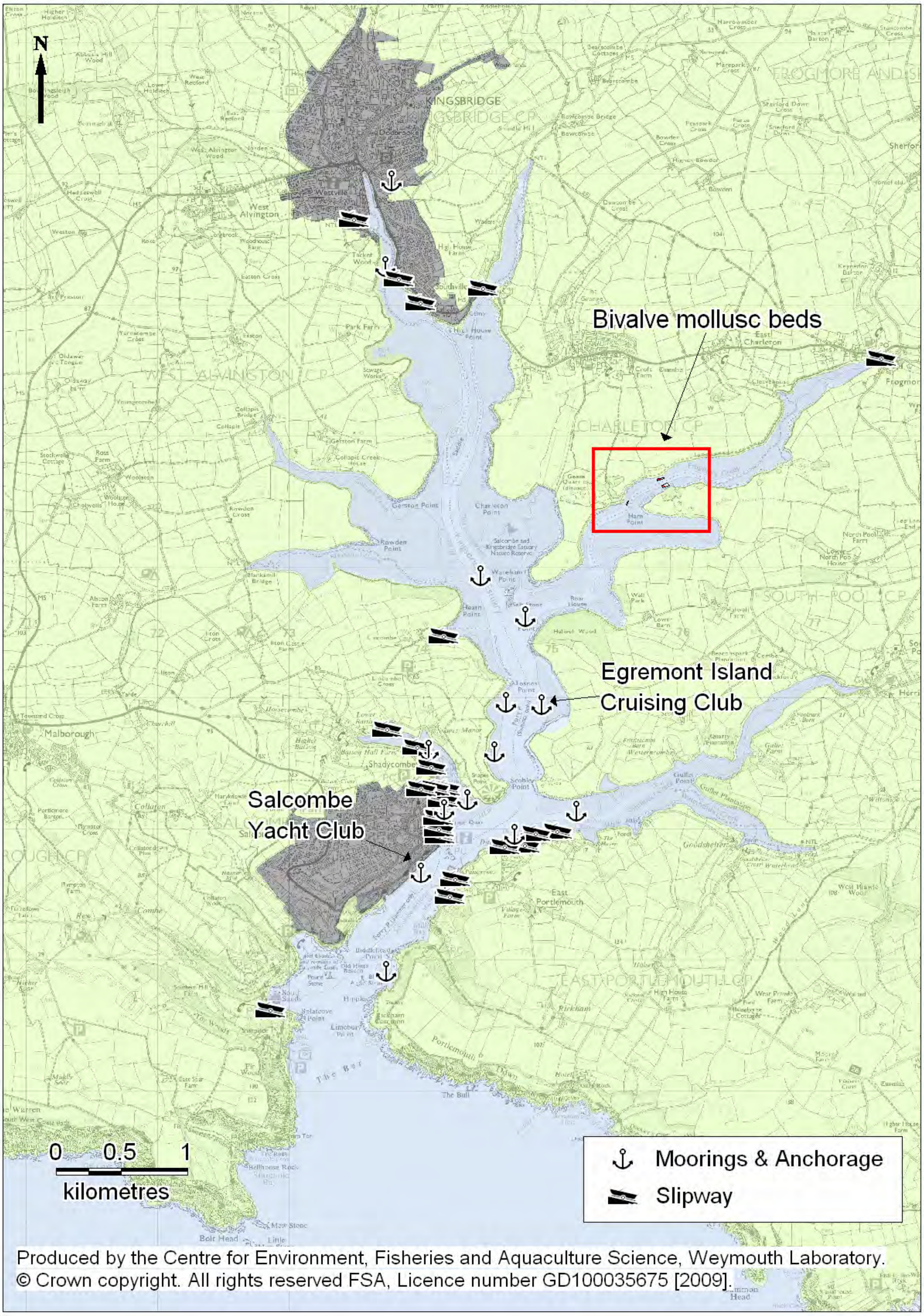

Figure 4.3 Location of slipways, moorings and anchorage points in Salcombe-Kingsbridge Estuary.

4.3 Farm animals

Agriculture is one of the main activities within the Salcombe catchment. Mixed farming systems in small holdings are present throughout the catchment. There are approximately 230 farms spread throughout the catchment (Figure 4.4).

In total, there are approximately 65,858 farmed animals in these catchments (Table 4.5), of which 29.7% are cattle and 58.7% sheep.

Table 4.5 Livestock numbers in the Salcombe catchment.

Area (km^2)	Cattle	Pigs	Sheep	Poultry	Other livestock*
226	19,582	3,172	38,627	3,886	591

Data from June Agricultural Survey (Defra, Farming Statistics, 2008).
** Other livestock include horses, deer, donkeys, llamas, mules.*

The Salcombe-Kingsbridge Estuary and the land draining into it are within a priority area identified by Defra under their Catchment Sensitive Farming Delivery Initiative to reduce diffuse water pollution from agriculture. Soil compaction, bank-side soil erosion, poor management of wastes and nutrients and defecation of livestock in watercourses potentially leading to elevated concentrations of *E. coli* were also among the problems identified.

Watercourses throughout the entire catchment are also classified as being at high risk of sedimentation. The range of annual total sediment at the head of Frogmore Creek (>19,000kg $year^{-1}$) considerably exceeds that detected in other creeks of the estuary (<14,000kg $year^{-1}$) (Defra Rural Development Service *in* Pilbeam, 2008a).

Literature indicates that farmyards can significantly contribute to loads of faecal indicator microorganisms (e.g. faecal coliforms, verotoxin-producing *E. coli*[11], *Salmonella enterica*) to watercourses or coastal waters when they have a ready and renewable source of faecal material, a direct hydrological connection with open water channels exists and a sufficient proportion of livestock farms are present in the catchment (see Vernozy-Rozand *et al.*, 2002; You *et al.*, 2006; Edwards *et al.,* 2008). Concentrations of faecal coliforms detected in typical UK farmyards are summarised in Table 4.6.

High density areas for cattle and sheep are distributed across the catchment (Defra Rural Development Service *in* Pilbeam, 2008, 2008a) indicating potential high risk of contamination from these animals. Inputs of contaminated water can be delivered directly to the estuary or via small watercourses. These watercourses were sampled during the shoreline survey for enumeration of indicators of faecal contamination and the results are shown in the Appendix I.

[11] A serotype of *E coli* that has been responsible for outbreaks of hemorrhagic diarrhea due to undercooked food, in people of all ages.

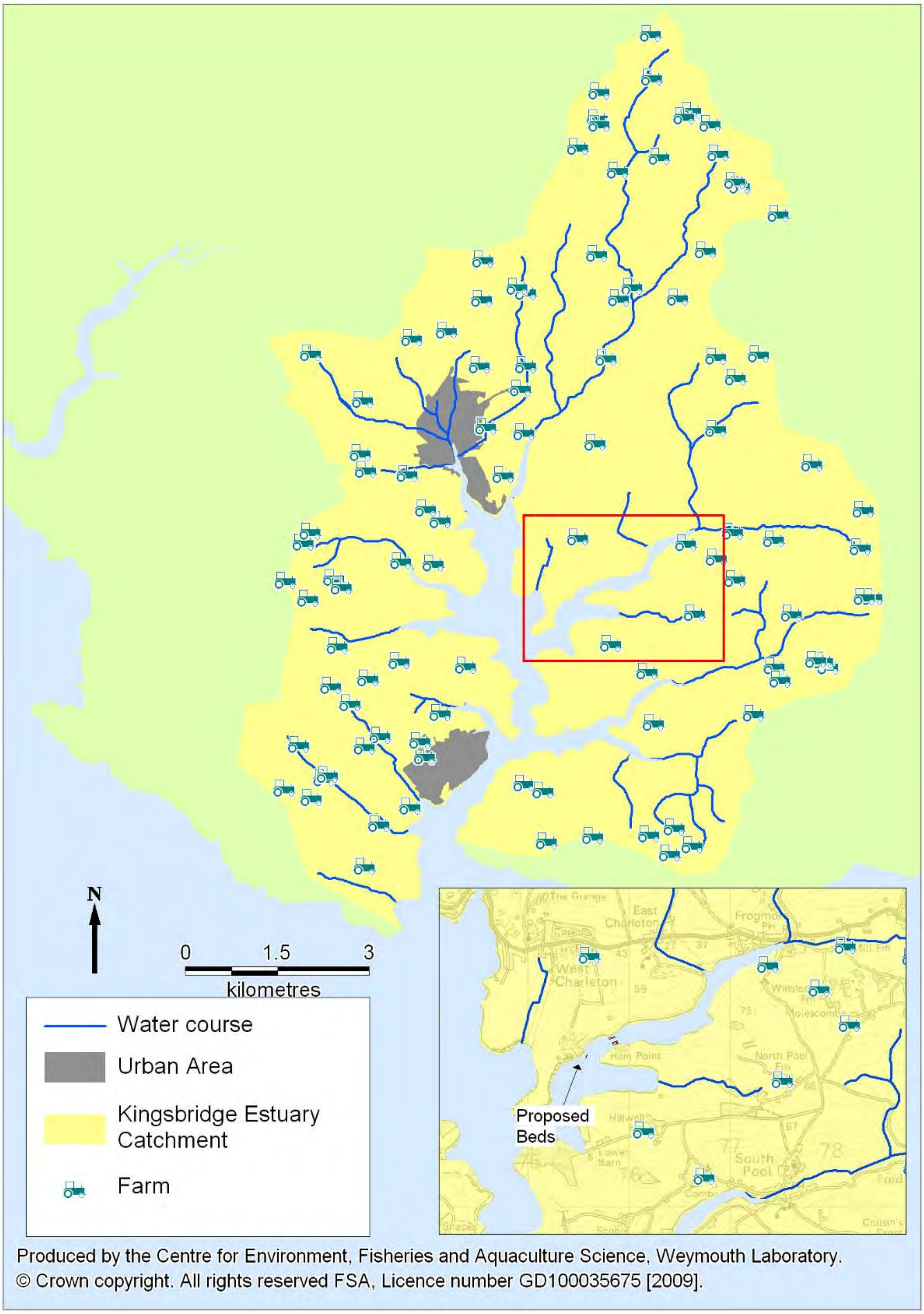

Figure 4.4 Location of farms in the Salcombe catchment.
Only those highlighted in the Ordnance Survey map are represented.

Figure 4.5 shows soil 'poaching' by livestock in lower fields of a farm in the vicinity of Frogmore Creek.

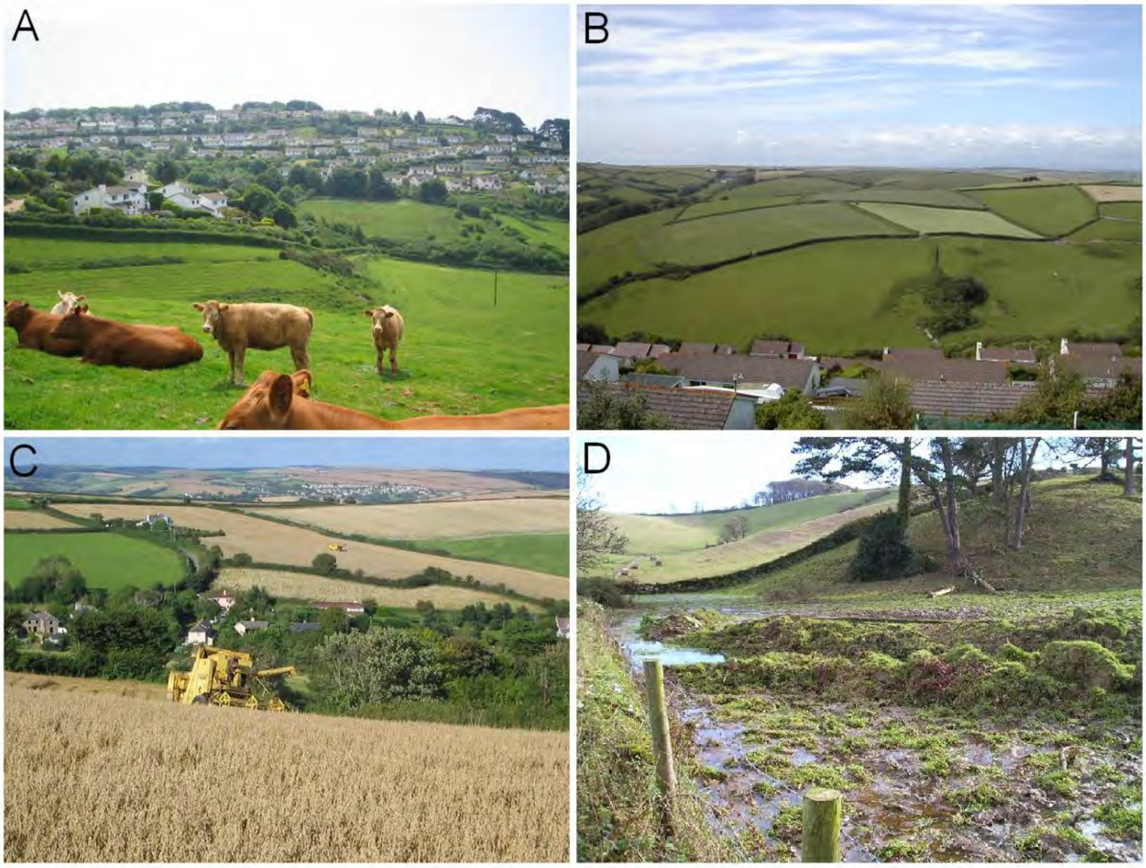

Figure 4.5 Views of farmland in the Salcombe catchment at Salcombe (A, B), West Charlton (C) and soil poaching by livestock in one tributary of the Salcombe-Kingsbridge Estuary.
Photos A, B and C courtesy of Richard Weymouth.
Photo D courtesy of Nigel Mortimer (Estuaries Officer - South Devon AONB Unit).

Some farms adjacent to Frogmore Creek inspected during the shoreline survey on 1–2 October 2008 did not have fences or buffer strips (see Appendix I).

Table 4.6 Mean concentrations of faecal coliforms in farmyard manure.

	Concentration of faecal coliforms ($CFU\ 100ml^{-1}$)
Roof runoff samples	1,974
Hardstanding runoff	77,362–13,948,933
Rising storm	106,091
Peak storm	122,129

Data from Edwards et al. (2008).
N.B. These indicative concentrations referred to samples from 4 farms situated in the River Irvine catchment (Scotland) taken during the summer.

Approximately 90% of the farms in the Salcombe catchment spread manure and a lower number (about 40%) apply slurry. Most spreading occurs during the spring (February–March) prior to the growing season and some biosolids are applied during the autumn for winter cereals. Large quantities of slurry are applied during the winter because many dairies have short capacity for storage and therefore need to spread on a frequent basis to avoid over-topping the slurry stores. Lesser amounts are retained for the late Spring and Summer for second and third cut silage applications. Sewage sludge is also applied to land during spring and in September (Lizbe Pilbeam, Natural England, pers. com.).

Manure and slurry applied shortly before/during rainfall events poses a significant risk of pollution which can be delivered to the estuary via watercourses.

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table 4.7.

Table 4.7 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Farm Animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^{8}
Pig	3,300,000	84,000,000	8.9×10^{8}
Human	13,000,000	3,000,000	1.9×10^{9}
Cow	230,000	23,600	5.4×10^{9}
Sheep	16,000,000	38,000,000	1.8×10^{10}

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

4.4 Birds

The Salcombe-Kingsbridge Estuary supports important populations of overwintering wildfowl such as Wigeon (*Anas penelope*), Teal (*A. crecca*) and Shelduck (*Tadorna tadorna*) (English Nature, 1987). The intertidal mudflats are also important feeding areas for passage waders. The mudflat lying just South of Ham Point is particularly important for Shelduck (*Tadorna tadorna*), Eurasian Oystercatcher (*Haematopus ostralegus*), Wigeon (*Anas penelope*) and Curlew (*Numenius arquata*) (Figure 4.6). The head of Frogmore Creek tends to provide habitat for Kingfisher (*Alcedo atthis*), Little Egret (*Egretta garzetta*) and Greenshank (*Tringa nebularia*), whilst Goldeneye (*Bucephala clangula*) and Red Breasted Merganser (*Mergus serrator*) are more commonly found at its mouth (Figure 4.6). Ham Point is a roosting site for waders at high tide.

Previous studies in the UK have indicated 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). For example, geometric means of *E. coli* detected in faecal samples of Starling (*Sturnus vulgaris*) can be 4.6×10^{7}CFU $100g^{-1}$ (Environment Agency, 2003; Whither *et al*., 2003). Feare (2001) suggests that approximately 10% of the faecal matter could be deposited under a roost, suggesting the potential significant contribution of contamination in these areas.

Birds therefore, will contribute to the background levels of contamination in Frogmore Creek. Autumn-winter months would be the period of higher impact from this source. The most vulnerable areas are the mudflats in the upper estuary, particularly those numbered as 2, 3, 6 and 4 as these are feeding areas for wildfowl during the low water and roosting areas for waders during the high tide, which are in the vicinity of bivalve mollusc beds.

Figure 4.6 Location of main roosting areas for wildfowl and waders in Salcombe-Kingsbridge Estuary.

Data from South Hams District Council (2005).

Permitted use by Nigel Mortimer (South Devon AONB Unit).

5. MICROBIOLOGICAL DATA

5.1 Water

This assessment reviews relevant microbiological data in surface waters obtained from the Bathing Waters and Shellfish Waters monitoring programmes to support the overall assessment of pollution sources impacting on the water quality of the estuary. Locations of sampling points are represented together with those from the Shellfish Hygiene monitoring programme in Figure 5.1.

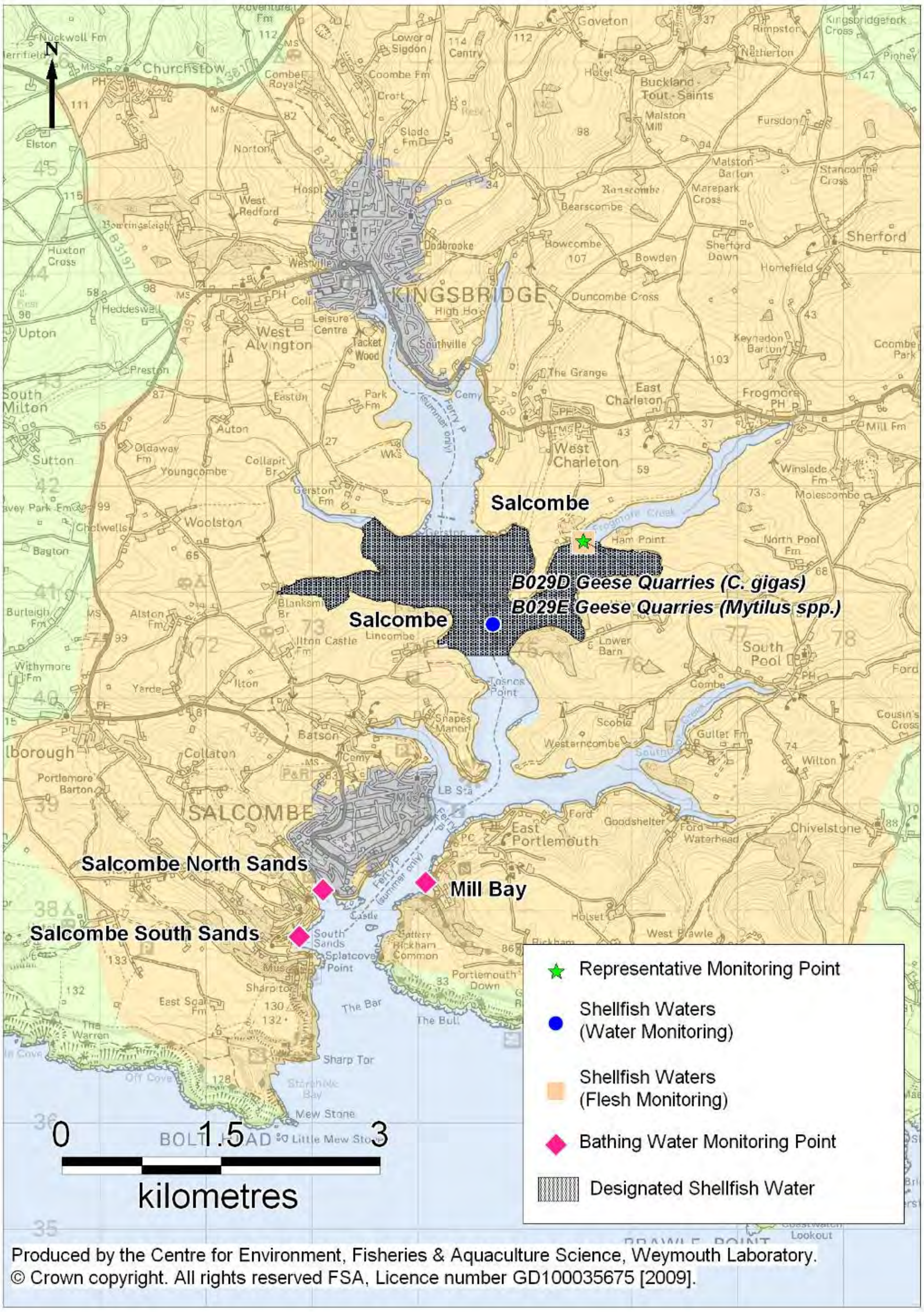

Figure 5.1 Location of sampling points for designated Bathing Waters, Shellfish Waters and Shellfish Hygiene monitoring programmes in Salcombe-Kingsbridge Estuary.

BATHING WATERS

Three bathing waters are designated within the Salcombe-Kingsbridge Estuary and approaches under the Directive 2006/7/EC (European Communities, 2006) concerning the quality of bathing water: North Sands, South Sands and Mill Bay (Figure 5.1)[12].

The overall quality of these bathing waters is summarised in Tables 5.1 and 5.2.

Table 5.1 Descriptive statistics of annual variation in levels of faecal coliforms in three designated Bathing Waters in the Salcombe-Kingsbridge Estuary (North).

		CFU Faecal coliforms 100ml^{-1}			
Bathing Water	Year	Minimum	Maximum	Geometric mean	Median
Salcombe (North Sands)	2005	<2	430	13	24
	2006	<2	347	8	5
	2007	<2	972	15	16
	2008	<2	1,960	16	11
Salcombe (South Sands)	2005	<2	2,484	35	31
	2006	<2	117	12	15
	2007	<2	8,000	32	23
	2008	<2	1,620	19	15
Mill Bay	2005	<2	82	8	11
	2006	<2	70	5	6
	2007	<2	370	7	8
	2008	<2	78	8	9

Data provided by the Environment Agency (2008).
Total number of samples per year=20.

Table 5.2 Quality of designated bathing waters in the Salcombe-Kingsbridge Estuary for the period 2005–2008.

	Bathing season			
Bathing water	2005	2006	2007	2008
North Sands	Good	Excellent	Excellent	Excellent
South Sands	Good	Excellent	Good	Good
Mill Bay	Excellent	Excellent	Excellent	Excellent

Information from the Environment Agency (2008).

Results from Mill Bay do not suggest any appreciable impact by sources of pollution on the eastern side of the mouth of the estuary. Geometric means of faecal coliforms in surface water from North Sands and South Sands however have been consistently higher than those at Mill Bay indicating prevalence of some contamination from pollution sources associated with the urbanised area of Salcombe.

[12] The bathing season runs from 15 May to 30 September. Water is sampled approximately weekly throughout the season. Levels of bacteria must not exceed the Imperative (I) value (2000 for faecal coliforms 100 ml^{-1}) and the Guideline (G) value (100 for faecal coliforms 100 ml^{-1}) represents the ideal maximum value. Bathing waters in England and Wales are classified as:
Poor - fails at least one coliform I standard;
Good - passes coliform I standards but fails at least one coliform G standard;
Excellent - passes coliform G standard and national faecal streptococci standard.

SHELLFISH WATERS

The mid estuarine area between Gerston Point-Charleton Point to Halwell Point has been designated under Directive 2006/113/EC as Shellfish Water since 1999 (European Communities, 2006). Summary statistics of levels of faecal coliforms in the water column for the period 2005–2007 are given in Table 5.3.

Table 5.3. Descriptive statistics of annual variation in presumptive levels of faecal coliforms in designated Shellfish Waters in the Salcombe-Kingsbridge Estuary.

Year	CFU Faecal coliforms 100ml^{-1}			
	Minimum	Maximum	Geometric mean	Median
2005	10	175	41	41
2006	15	1,240	128	212
2007	6	72	17	11
2005–2007	6	1,240	49	38

Data provided by the Environment Agency (2008).

The magnitude of the levels of the microbiological indicator in the Shellfish Water suggests an impact from pollution sources at the head of the estuary. The high geometric mean obtained for 2006 is due to the maximum level of 1,240CFU 100ml^{-1} obtained in December. High levels of faecal coliforms have been detected in previous years: 2,200ml^{-1} in October 2003, 1,273ml^{-1} in November 2001 and 2,000 in March 2000, representing occasional deterioration of the microbiological quality of the water column in the upper estuary.

5.2 Bivalve mollusc flesh

Analysis of historical data from the Shellfish Hygiene monitoring programme has been undertaken for samples collected from 2005 to 2008, i.e. it is restricted to the period following the programme of upgrading sewage discharges prior to 2005.

Table 5.3 summarises the results in terms of sampling effort, range, median, geometric mean, standard deviation of Log_{10}-transformed concentrations and the 95% confidence interval for the mean of *E. coli* levels in bivalves at each.

Due to low number of mussel results, no inter-species comparison can be made. None of the samples of Pacific oysters returned a result above the limit of detection. In 2008, the geometric mean of *E. coli* decreased to the lowest value (229) since 2005 (Figure 5.2).

Table 5.3. Summary statistics of* E. coli *levels in bivalve molluscs from two RMPs in Geese Quarries, Salcombe-Kingsbridge Estuary for the period July 2004–December 2008.

					MPN *E. coli* 100g^{-1} FIL						
										95% CI for mean	
RMP	Species	n	Date of first sample	Date of last sample	Min.	Max.	Median	GM	Log_{10} SD	Lower	Upper
B029E	*Mytilus* spp.	2	24/04/2006	11/11/2008	130	5,400	2,765	838	0.15	-	-
B029D	*C. gigas*	40	27/01/2005	15/12/2008	<20	7,500	500	422	0.52	300	642

N.B. Analysis of historical microbiological data confined to the period following UV installation at Wadebridge STW.
CI - confidence interval. N.B. Confidence intervals for less than 10 samples are not reported.
FIL - flesh and intravalvular liquid.
GM - geometric mean
n - number of samples.
SD - standard deviation.
Less-than E. coli *results were assigned half the numerical value before transformation.*

The maximum concentration of *E. coli* corresponds to the outlier (top asterisk) represented in the box-and-whisker plot (Figure 5.3).

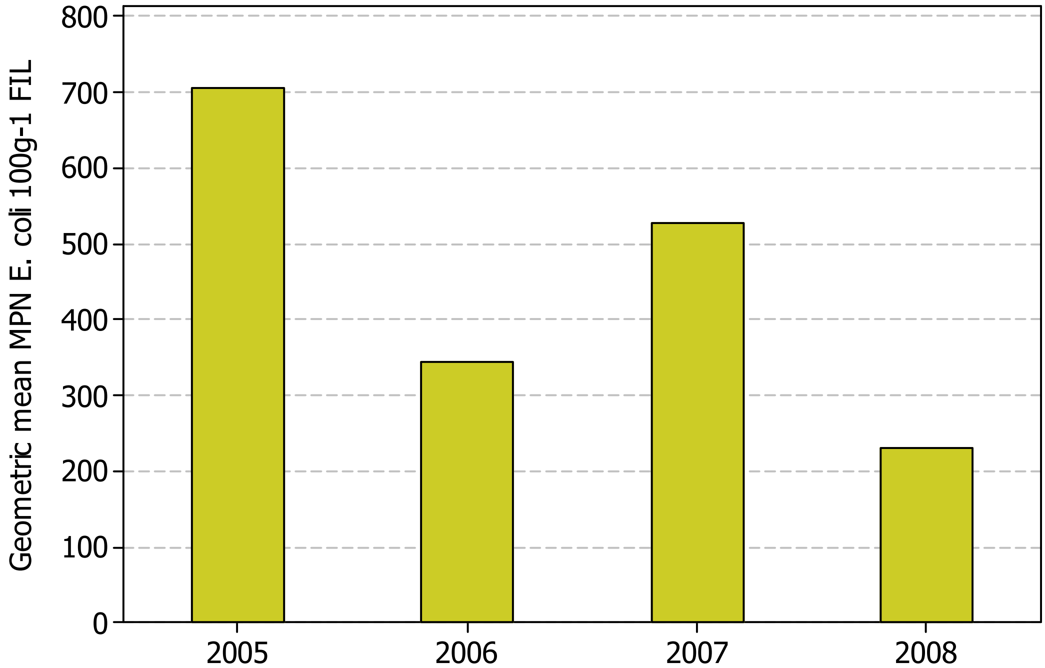

Figure 5.2. Annual geometric means of levels of E. coli in Pacific oysters from Geese Quarries in Salcombe-Kingsbridge Estuary.

The taller bottom box halve indicates a left-skewed distribution of the data or higher number of results below the median (50th percentile) than the results above the median value (790). This suggests that, for most of the time, levels of *E. coli* in Pacific oysters tend to be below the median.

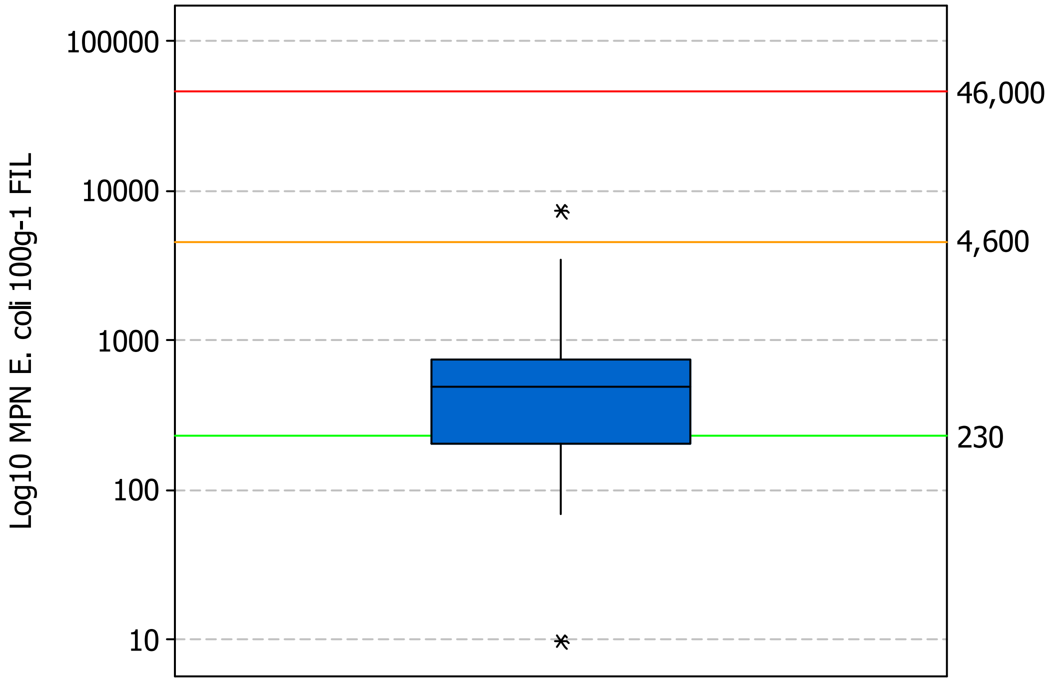

Figure 5.3 Box-and-whisker plot of levels of* E. coli *in Pacific oysters from Geese Quarries (B029D) in Salcombe-Kingsbridge Estuary for the period 2005–2008.

Table 5.4 summarises the results of *E. coli* levels in mussels from Geese Quarries in Salcombe-Kingsbridge Estuary during the period of preliminary monitoring.

The geometric mean is considerably higher than that detected in Pacific oysters. This is consistent with the pattern of variation found in *E. coli* levels between species in other BMPAs in England and Wales (Younger *et al*., 2003).

Table 5.4. Summary statistics of* E. coli *levels in mussels from Geese Quarries in Salcombe-Kingsbridge Estuary during the period of preliminary monitoring.

RMP	Bed name	Species	n	Date of first sample	Date of last sample	MPN *E. coli* 100g^{-1} FIL						
						Min.	Max.	Median	Geometric mean	Log_{10} St. Dev.	95% CI for mean Lower	95% CI for mean Upper
B029E	Geese Quarries	*Mytilus* spp.	12	11/11/2008	09/03/2009	130	5,400	790	839	0.412	460	1,533

Note: analysis to historical microbiological data confined to the period following UV installation at Wadebridge STW.
n - number of samples.
CI - confidence interval.
St. Dev. - standard deviation.
FIL - flesh and intravalvular liquid.

Ten samples returned *E. coli* levels within the range attributed to class B.

The association of *E. coli* levels in Pacific oysters from Geese Quarries (B029D) with rainfall data from Kingsbridge Easton and Southpool Gullet Farm rain-gauge stations were examined for the period June 2005–September 2007.

Spearman's rank correlation coefficient (*rho*) was used to estimate correlations between MPN *E. coli*100g^{-1} FIL and individual /total accumulated rainfall up to seven days prior to sampling (Table 5.5). This method was used because neither of the variables met the assumption of normality determined by the Anderson-Darling statistic.

Table 5.5 Spearman's rank correlation coefficients (*rho*) between rainfall recorded at two rain-gauge stations and levels of* E. coli *in Pacific oysters from Geese Quarries (B029D) for the period June 2005–September 2007.

			Rain-gauge station	
			Kingsbridge Easton	Southpool Gullet Farm
Daily rainfall	Day of sampling	*rho*	-0.180	-0.049
		p	0.308	0.793
	-1 day	*rho*	0.183	0.207
		p	0.252	0.225
	-2 days	*rho*	0.186	0.290
		p	0.277	0.107
	-3 days	*rho*	0.054	0.207
		p	0.751	0.218
	-4 days	*rho*	**0.334**	-0.188
		p	**0.035**	0.296
	-5 days	*rho*	**0.348**	**0.385**
		p	**0.040**	**0.030**
	-6 days	*rho*	0.067	-0.052
		p	0.700	0.763
	-7 days	*rho*	**0.376**	0.205
		p	**0.026**	0.245
Total rainfall	-2 days	*rho*	0.069	0.276
		p	0.653	0.070
	-3 days	*rho*	0.130	**0.437**
		p	0.372	**0.001**
	-4 days	*rho*	0.241	**0.411**
		p	0.119	**0.002**
	-5 days	*rho*	0.107	**0.422**
		p	0.484	**0.001**
	-6 days	*rho*	0.236	**0.453**
		p	0.111	**0.000**
	-7 days	*rho*	0.271	**0.421**
		p	0.059	**0.001**

Spearman's correlation coefficient (*rho*) ranges between +1 and -1.
The significance of *r* is tested by determining whether its value differs from 0.
A correlation of +1 means that there is a perfect positive linear relationship between rainfall and Log_{10} MPN of *E. coli* 100g^{-1} FIL.
A correlation of -1 means that there is a perfect negative linear relationship between rainfall and Log_{10} MPN of *E. coli* 100g^{-1} FIL.
A correlation of 0 means that there is no linear relationship between rainfall and Log_{10} MPN of *E. coli* 100g^{-1} FIL.
* Statistically significant (p<0.05).
Correlation analysis performed using Log_{10}-transformed *E. coli* concentrations.
Less-than *E. coli* results were assigned half the numerical value before transformation.

Statistically significant positive correlations were obtained between levels of *E. coli* and daily rainfall recorded at Kingsbridge Easton on the fourth, fifth and seventh days before sampling. Statistically significant positive correlations were also obtained between levels of *E. coli* and daily rainfall recorded at Southpool

Gullett Farm on the fifth day before sampling and total rainfall between the third and seventh days before sampling.

The relationship between variables was further explored and is graphically represented by scatterplots with superimposed Locally Weighted Scatterplot Smoothing (LOWESS) lines for statistically significant relationships (Figures 5.4, 5.5).

Despite the relative small data set, the curvature of LOWESS lines clearly illustrate that levels of the microbiological indicator in Pacific oysters increase with increasing rainfall. Scatterplots also highlight the stronger relationship between variables in rainfall recorded at Southpool Gullet Farm than that recorded at Kingsbridge Easton. Considering the similar magnitude of rainfall between gauging stations described in Section 3.1, the differences in correlation suggest a degree of spatial variation in the relationship, likely to be associated with proximity of Southpool Gullet Farm to watercourses discharging to Southpool Creek. Given the similar characteristics of Southpool Creek and Frogmore Creek it is therefore expected that sampling between the third and seventh days after rainfall may better reflect the worst-case scenario of microbiological contamination in bivalve molluscs at Frogmore Creek, if this aspect of the *European Union Good Practice Guide for Microbiological Monitoring of Bivalve Mollusc Harvesting Areas* (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007) is adopted in the UK at some time in the future.

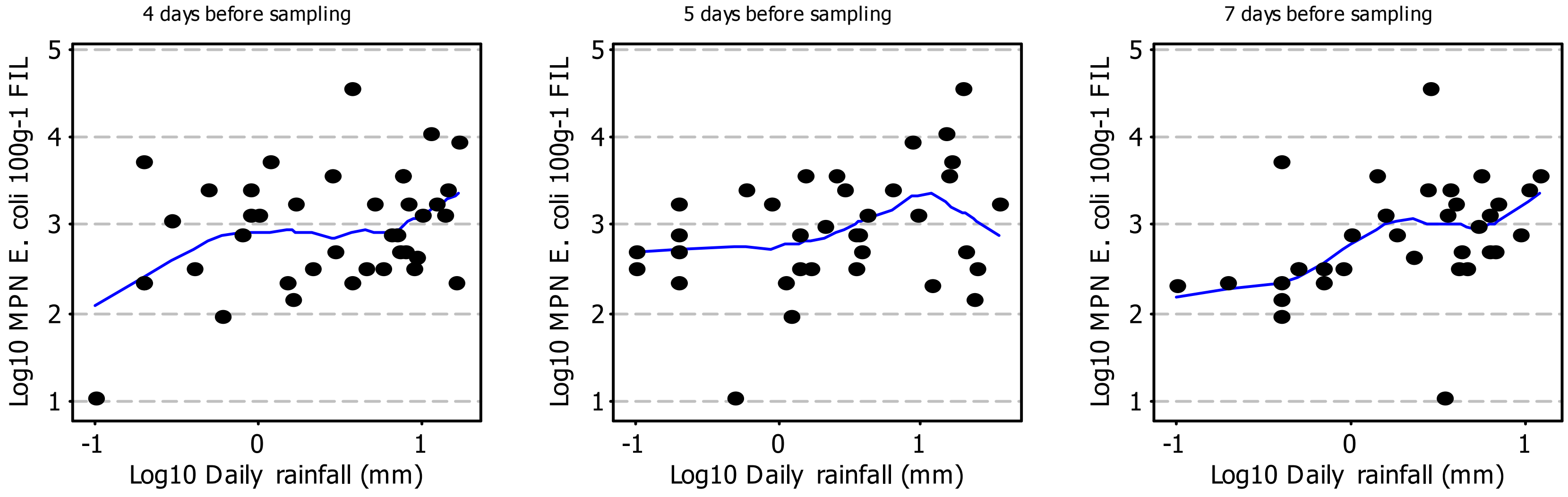

Figure 5.4 Scatterplots of rainfall recorded at Kingsbridge Easton and levels of E. coli in Pacific oysters from Geese Quarries (B029D).

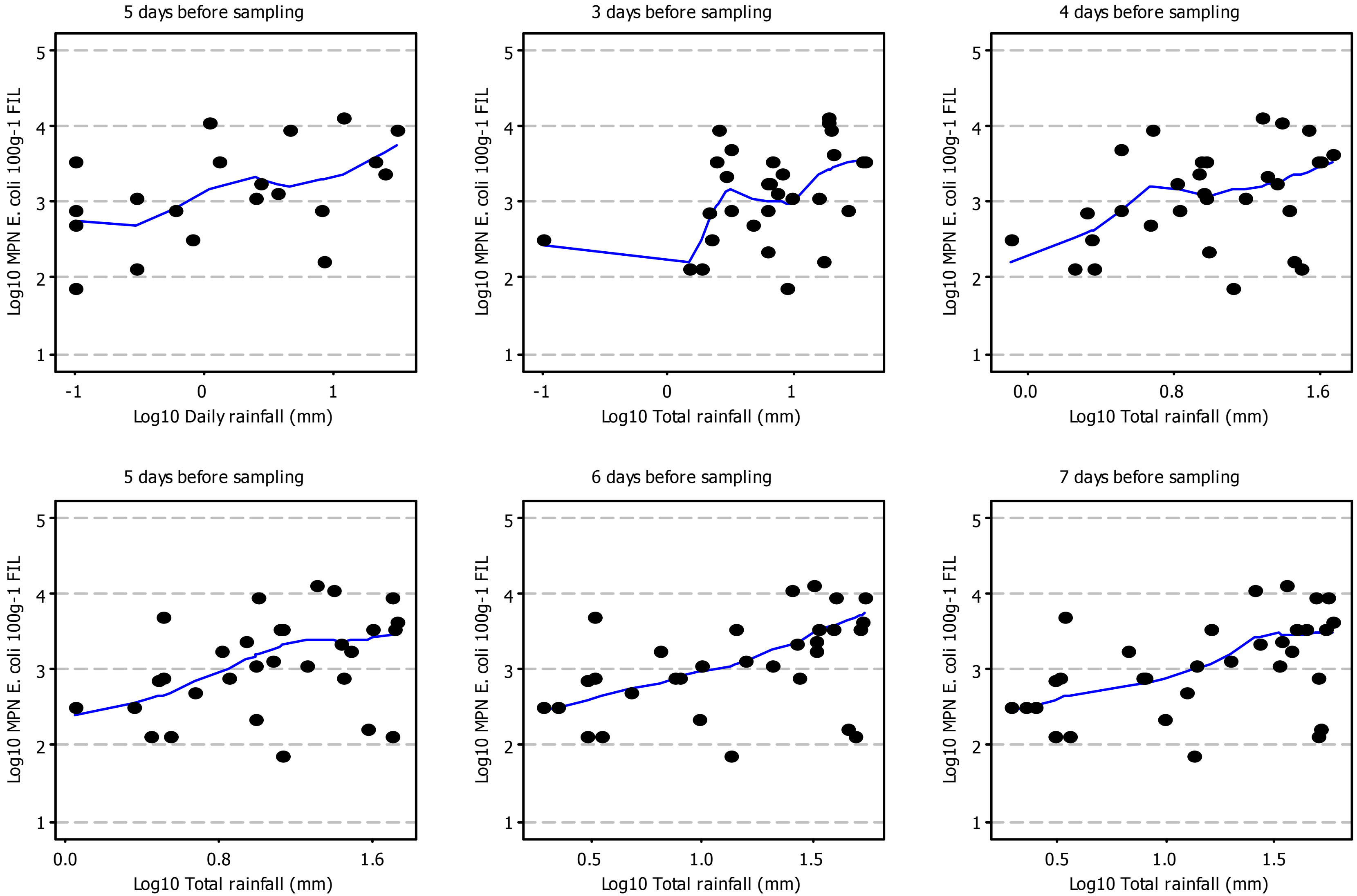

Figure 5.5 Scatterplots of rainfall recorded at Southpool Gullet Farm and levels of E. coli in Pacific oysters from Geese Quarries (B029D).

6 OVERALL ASSESSMENT

The mussel bed requiring classification in Frogmore Creek at Geese Quarries is located within a rural catchment, predominantly used for agriculture. On average, human population density is relatively low when compared to an average of 246 for the U.K.). The most significant urbanised areas are Kingsbridge wards (3,999 inhabitants) and Salcombe and Marlborough wards (3,269) situated at the head and the mouth of the estuary, respectively. Total resident human population in the catchment is 19,208 people. The numbers of livestock (65,858 farmed animals in the catchment) suggest potential for a high microbiological load from livestock production areas.

The Salcombe-Kingsbridge Estuary is peculiar in the fact that no significant rivers discharge to it. Runoff from agricultural land occurs via numerous small watercourses. The periods of higher risk of microbiological contamination occur when manure is spread shortly before/during rainfall events, when there is insufficient storage of slurry or when manure is spread near a watercourse, which prevail in the catchment.

A number of continuous and intermittent sewage discharges were identified to represent a significant or potentially significant impact on the levels of microbiological contamination to bivalve mollusc beds. Those representing the highest risk are continuous discharges from Sherford STW (secondary treatment; 4km from nearest bed) and Woolston STW (secondary; 5.5km from nearest bed). Effluents from the intermittent discharges East Charlton PS CSO, Frogmore & Chillington STW storm tank, Frogmore No 1 PS, Frogmore No 2 PS, Sherford STW SO, Chillington SSO, R/o 7 Meadowside and Home Close PS CSO/EO discharge directly to Frogmore Creek or its tributaries and could represent a significant source of contamination during rainfall events.

It is considered that, for most of the time, the contribution of tertiary (UV)-treated effluents from Salcombe, Gerston (Kingsbridge), West Charlton and Frogmore & Chillington Sewage Treatment Works will be low when compared with the discharges mentioned above. However, analysis to historical levels of faecal coliforms in the effluent from these sewage works evidenced statistically significant (ANOVA; p=0.000) deteriorations in the microbiological quality of the effluent from Salcombe, Gerston (Kingsbridge), West Charlton during summer months. These deteriorations are interpreted to be the result of higher human presence in tourism season, including increased overnight boat usage. The short-time dataset on historical *E. coli* levels in mussels and Pacific oysters does not allow assessment of whether seasonality is also evident in bivalves.

Approximately 90% of the farms in the Salcombe catchment spread manure and a lower number (about 40%) apply slurry (biosolids). Most spreading occurs during the spring (February–March). Large quantities of slurry are also applied during winter months. Sewage sludge is also applied to land during spring and in September. These practices, when undertaken shortly before/during rainfall events, can pose significant risk of pollution which could be discharged to the estuary via watercourses.

The Salcombe-Kingsbridge Estuary supports important populations of overwintering wildfowl. The intertidal mudflats of the estuary are also important feeding areas for passage waders. High abundance of birds was observed at Frogmore Creek during the shoreline survey. Bird faeces deposited onto mudflats would contribute to background levels of contamination in the seawater and be retained by bivalves during the time when bags are immersed.

A schematic representation of the most significant pollution sources likely to cause microbiological contamination to the BMPAs is shown in Figure 6.1.

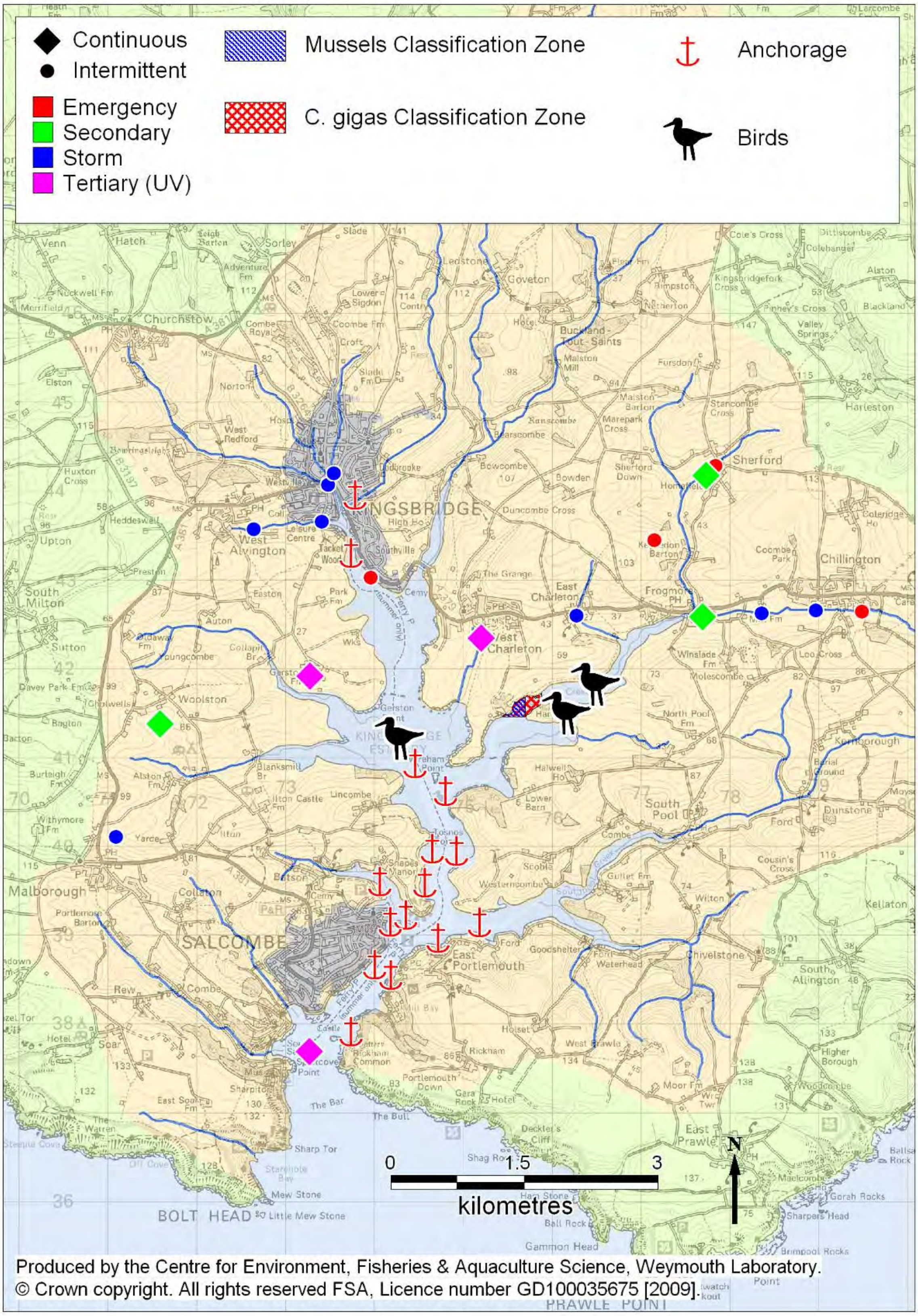

Figure 6.1 Overview of sources of pollution likely to affect the levels of microbiological contamination in bivalve molluscs in Salcombe-Kingsbridge Estuary.

Results from the Bathing Waters monitoring programme indicate the lack of significant impact by sources of pollution on the eastern side of the estuary.

Levels of faecal coliforms in surface water from designated bathing waters on the western side have been consistently higher indicating prevalence of contamination from pollution sources associated with the urbanised area of Salcombe.

Historical levels of faecal coliforms quantified in the scope of the Shellfish Waters monitoring programme have occasionally been high indicating potential deterioration of the microbiological quality of the water column.

Levels of *E. coli* in Pacific oysters from Geese Quarries for samples collected during the period 2005–2008 (period following the programme of upgrading sewage discharges) in the scope of the Shellfish Hygiene monitoring programme have showed a decreasing tendency since 2005, with high frequency of results below the median value. After a period of preliminary monitoring, mussels at the same location consistently showed higher levels of the microbiological indicator relative to those in Pacific oysters. This is consistent with the pattern of contamination found between species in England and Wales.

The macro-tidal regime and relatively short residence time in the Salcombe-Kingsbridge Estuary suggest that, in general, the estuary is able to quickly disperse microbiological contaminants in well flushed areas of the lower estuary such as those where high densities of boats occur.

The upper reaches of the estuary are however very shallow, with significant areas of the creeks drying at Low Water spring tides. In these muddy creeks, water continues to flow long after the tide has receded and the mudflats are exposed. Sedimentation of microbiological contaminants and re-suspension of contaminated sediment is expected to occur as a result of less water being available for dispersion and dilution. In Frogmore Creek, where bivalve mollusc beds are established, water flows along one main channel.

Tidal advection is the main process determining the transport of contamination in the estuary. Tidal excursion in the estuary is however significantly different on spring and neap tides. During spring tides, tidal currents are stronger and can promote the dispersion of contaminants between the tidal limit at Kingsbridge to the mouth of the estuary from High Water to Low Water-2h. On spring tides therefore microbiological contaminants are likely to be flushed from the estuary and not return in the following flood tide. During neap tides, tidal flows are weaker and may lead to retention of contamination inside the estuary over the tidal cycle. Under these circumstances, classified zones at Frogmore Creek would be vulnerable to contaminants transported from the wider estuary during the flood stage of neap tides and contaminants transported down the creek from Frogmore during the ebb tide.

Tidal flows in Frogmore Creek are low (<0.5m s^{-1}) both on ebb and flood tides. Flows are however accelerated (up to 1m s^{-1}) as they pass through Ham Point, and could contribute to dispersion of contaminants during the period when bags of mussels and Pacific oysters are immersed.

6.1 Recommendations for classification zone boundaries, location of monitoring points and sampling frequency

- Owing to the small scale of the aquaculture operation required to be classified for mussels, it is recommended that one Representative Monitoring Point in the western bed at Geese Quarries (SX 7556 4148) should adequately reflect the impact of pollution sources of human and animal origin from the catchment discharged to Frogmore Creek and contamination from the wider estuary.

- It is recommended that a new Representative Monitoring Point for Pacific oysters (SX 7585 4168) should replace the existing point (B029E). This should be relocated at the edge of the eastern bed at Geese Quarries to better reflect the impact of contamination from the catchment discharged to Frogmore Creek and its tributaries.

- The recommended sampling tolerance for the recommended monitoring points for mussels and Pacific oysters is 10m. It is considered that this tolerance minimises the effect of spatial variability in the extent of contamination whilst preserves the concept of sampling at fixed geographical points, i.e. reflecting levels of contamination over time rather than use of non-fixed points which do not allow differentiation of temporal and spatial differences.

- Boundaries of the classification zone for Pacific oysters should encompass the area currently classified in Frogmore Creek, as required by the applicant.

- Boundaries of the classification zone for mussels in Frogmore Creek should be defined by enforceable lines approximately 10m around the edge of the area where trestles are established. This restricted area reflects the absence of any other nearby mussel beds and the fact that the applicant had emphasised that they do not anticipate to expand the production area in the future.

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List of abbreviations

AMPs	Asset Management Plans
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
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
HAT	Highest Astronomical Tide
ISO	International Organization for Standardization
km	Kilometre
LFA	Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MPN	Most Probable Number
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
OSGB36	Ordnance Survey Great Britain 1936
PS	Pumping Station
RMP	Representative Monitoring Point
SO	Storm Overflow
SSO	Sewage Storm Overflow
STO	Storm Tank Overflow
STW	Sewage Treatment Works
SSSI	Site of Special Scientific Interest
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated or those waters specified in Section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
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.
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.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of a skewed data such as one following a log-normal distribution.
Hepatitis A	Hepatitis A virus is a RNA virus that has a single strand of RNA surrounded by a protein capsid. It is classified with the Picornaviridae

	family of the enterovirus group. Hepatitis A virus infection is transmitted through contaminated water and foods via the faecal-oral route. Outbreaks associated with the consumption of bivalve molluscs have been reported since the 1950s. The infectious dose is low (10-100 viruses) and the incubation period is 3-6 weeks. The clinical disease is generally mild, characterised by prodrome of fatigue, myalgias, anorexia, nausea, and upper abdominal discomfort.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Norovirus	Noroviruses (previously called Norwalk-like viruses or small round-structured viruses) have single-strand RNA with positive polarity and show non-distinct capsid edges on microscopy. Norovirus has been referred as the leading cause of gastroenteritis associated with the consumption of raw bivalve molluscs. Noroviruses infect people of all ages, a feature that distinguishes them from other agents of acute viral gastroenteritis. The infectious dose is low (<100 viruses). Norovirus infection usually presents as acute-onset vomiting, watery non-bloody diarrhoea with abdominal cramps and nausea. Symptoms usually begin about 18–48h (average of approximately 33h), but they can appear as early as 12h after exposure.
Ria	Drowned river valley in origin, with exposed rock platform and no linear banks.
Salmonellosis	Salmonellae are Gram-negative, non-spore forming, facultatively anaerobic bacilli that ferment glucose and reduce nitrates. The disease caused by salmonella may be broadly categorised into two syndromes: enteric (or typhoid) fever and gastroenteritis. Enteric fever is a systemic infection characterised by high fever, abdominal cramps in the first week of illness followed by watery diarrhoea. Non-typhoidal salmonella causes a syndrome of gastroenteritis, after an incubation period of 8–72h, but is usually about 12–36h.
Secondary Treatment	Treatment 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.
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.
TBT	Tributyltin (TBT) is a chemical used for a long time as one of the components of antifouling paints, applied on boats to prevent the attachment of algae, barnacles and other marine invertebrates. It has been demonstrated that TBT can alter the development and functioning of the endocrine system and affect reproduction of marine invertebrates at very low concentrations. For this reason, it is also called an "endocrine disruptor". The use of TBT is now prohibited in most countries.
Waste water	Any waste water but see also "sewage".

APPENDIX I - SHORELINE SURVEY

GENERAL

Date (time): 1 October 2008 (10:20–16:30 BST)
Applicant: Steve Allen (Limosa Farms Ltd)
Local Enforcement Authority: Peter Wearden (South Hams District Council)
Cefas Offficers: Simon Kershaw, Carlos Campos
Estuaries Officer - South Devon AONB Unit: Nigel Mortimer

Areas surveyed: inspection to stream inputs to the estuary and sewage discharge points at several locations between Salcombe and Frogmore, followed by shoreline walk over low water period (Figure A1; Table A1) along the north side of Frogmore Creek (red line in Figure S2). The area surveyed encompassed the site of the proposed mussel bed at Geese Quarries and existing Pacific oyster beds in the creek.

Date (time): 2 October 2008 (06:40–11:00 BST)
Local Enforcement Authority: Peter Wearden (South Hams District Council)
Cefas Offficers: Simon Kershaw, Carlos Campos

Map/chart references: OS Explorer OL20. Admiralty Chart 28 - Salcombe Harbour

Met Office inshore waters forecast:

	1 October 2008 (13:00)	2 October 2008 (07:00)
Wind	West veering northwest 6 or 7, occasionally gale 8	West veering northwest 6 to gale 8
Sea state	Moderate or rough, occasionally very rough in west	Moderate or rough, occasionally very rough in west
Weather	Occasional rain then showers	Showers
Visibility	Moderate or good	Moderate or good, occasionally poor

Air temperature (measured): 20.3°C (1 October 2008; 15:10)
Wind (measured): 5 knots (9.1knots maximum)
Precipitation: occasional showers on 2 October 2008

Areas surveyed: boat survey in the estuary, from Frogmore Creek to the lower Southpool Creek and the mouth of the estuary at Splatcove Point (blue line in Figure A2).

Objectives: (a) confirm the existence of pollution sources identified during the desk study likely to constitute sources of microbiological contamination for the bivalve mollusc beds, (b) identify any additional pollution sources in the area and (c) confirm the extent of the new and existing production areas.

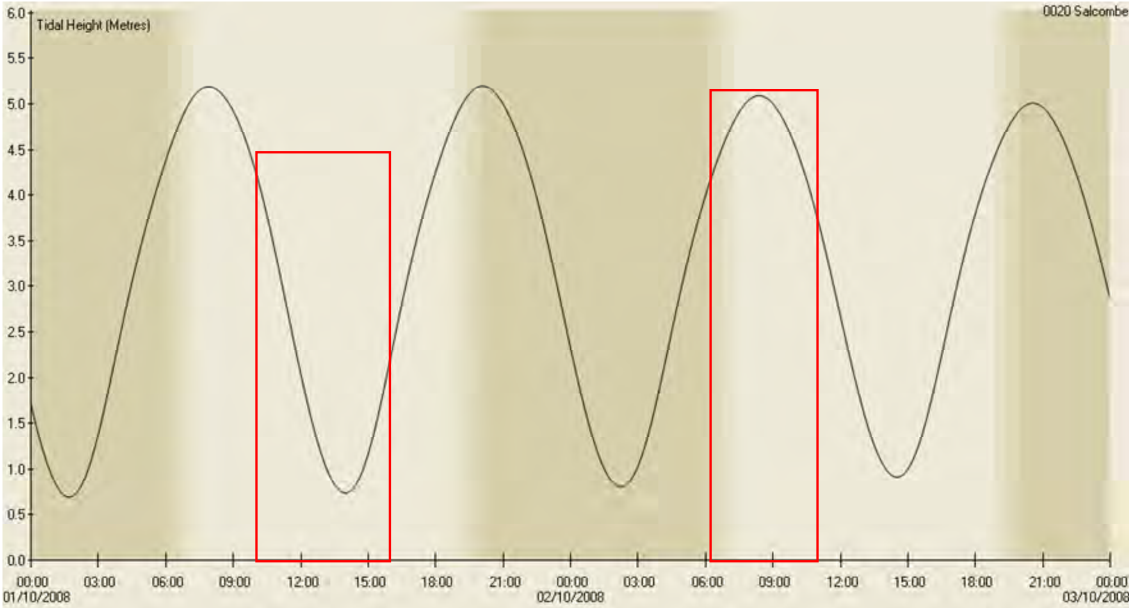

Figure A1. Tidal curves at Salcombe on 1 and 2 October 2008.
N.B. Red lines indicate periods surveyed.
Salcombe is a Secondary Harmonic port.
Predicted heights are in metres above Chart Datum
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Table A1 Predicted high and low water times and heights for Salcombe (50°13'N 3°47'W) on 1 and 2 October 2008.

01/10/2008			02/10/2008		
Low	01:41	0.7 m	Low	02:14	0.8 m
High	07:54	5.2 m	High	08:22	5.1 m
Low	13:58	0.7 m	Low	14:30	0.9 m
High	20:05	5.2 m	High	20:33	5.0 m

Predicted heights are in metres above Chart Datum
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Figure A2. Areas surveyed on 1 (red line) and 2 (blue line) October 2008.

OBSERVATIONS AND RESULTS

Stream inputs to Salcombe-Kingsbridge Estuary were inspected and sampled for microbiological analysis. The locations of these are given in Figures A2–A3. The results are summarised in Table A2. Water from springs was clear in appearance. Seawater from Balcombe Creek was very turbid.

Levels of *E. coli* in mussels and Pacific oysters correspond to class B.

Figure A2. Sites sampled during the shoreline survey on 1 October 2008.

Figure A3 shows unidentified pipe discharges observed during the survey. Sewage discharges inspected during the survey are shown in Figure A4. Locations of these are shown in Tables A3 and A4.

Table A2 Levels of faecal indicator microorganisms in samples collected during the shoreline survey on 1 October 2008.

Fig. A2 ref.	Matrix	Site sampled	Location (NGR) (Eastings/Northings)	Time of collection (h:min.)	Weather conditions	Salinity (ppt)	Faecal coliforms	Unit	*E. coli*	Unit
Photo not available	Freshwater	Tappers Quay – end of Thorning Street (Batson Creek)	274,148/39,269	10:49	Dry	0	5,800	MPN $100ml^{-1}$	1,900	MPN $100ml^{-1}$
A	Freshwater	Blanksmill Bridge	272,676/40,982	11:23	Dry	0	17,000	MPN $100ml^{-1}$	820	MPN $100ml^{-1}$
B	Freshwater	Collapit Bridge	272,860/42,161	11:33	Dry	0	13,000	MPN $100ml^{-1}$	1,400	MPN $100ml^{-1}$
C	Freshwater	Tacketwood Bridge	272,860/42,161	11:49	Dry	0	>24,000	MPN $100ml^{-1}$	>24,000	MPN $100ml^{-1}$
D	Freshwater	Kingsbridge at Squares Quay (pipe 1)	273,559/44,011	12:05	Dry	0	>24,000	MPN $100ml^{-1}$	24,000	MPN $100ml^{-1}$
D	Freshwater	Kingsbridge at Squares Quay (pipe 2)	273,572/44,011	12:08	Dry	0	8,200	MPN $100ml^{-1}$	160	MPN $100ml^{-1}$
E	Seawater	Balcombe Creek at Southville (A379) New Bridge	274,535/43,107	12:31	Dry	2.2	6,500	MPN $100ml^{-1}$	1,600	MPN $100ml^{-1}$
F	Mussels (*Mytilus* spp.)	Geese Quarries (B029D)	275,564/41,478	14:36	Dry	-	-	-	1,700	MPN $100g^{-1}$ FIL[a]
F	Pacific oysters (*C. gigas*)	Geese Quarries (B029D)	275,564/41,478	14:35	Dry	-	-	-	500	MPN $100g^{-1}$ FIL[a]
G	Seawater	Geese Quarries (East)	275,820/41,667	15:08	Dry	2.2	2,100	MPN $100ml^{-1}$	260	MPN $100ml^{-1}$
G	Pacific oysters (*C. gigas*)	Geese Quarries (East)	275,819/41,671	15:01	Dry	-	-	-	500	MPN $100g^{-1}$ FIL[b]
H	Freshwater	Frogmore Creek at Bridge	277,510/42,601	15:08	Dry	0	13,000	MPN $100ml^{-1}$	1,400	MPN $100ml^{-1}$

NGR - national grid reference system.
N.B. all samples were submitted to the laboratory within 6 hours of collection.
[a] *Sample temperature=8.7℃.*
[b] *Sample temperature=8.1℃.*

Figure A3–1 Unidentified piped discharges inspected during the shoreline survey on 1 October 2008.

Figure A3–2 Unidentified piped discharges inspected during the shoreline survey on 1 October 2008.

Figure A3–3 Unidentified piped discharge inspected during the shoreline survey on 1 October 2008.

Figure A3. Sewage discharges identified during the shoreline survey on 1 October 2008.

Table A3 Unidentified discharges inspected during the shoreline survey.

Fig. A3 ref.	Name	Location (NGR) Eastings/Northings	Obs.
A	Unidentified pipe at Island Quay	274,100/39,340	Pipe under wall in residential area at Island Quay (Salcombe). Not discharging at time of survey.
B	Unidentified discharge at Lower Batson Creek	273,890/39,294	Pipe in muddy area. Trickle flow of clear water. Inaccessible from car park.
C	Two iron pipes at Lower Batson Creek adj. Yeoward & Dowie Boatyards	273,890/39,294	Pipe under wall in boatyard. Not discharging at time of survey.
D	Unidentified PVC pipe in grassland adj. Frogmore Creek	277,312/42,466	Discharge point submerged at high water. Not discharging at time of survey. Apparently recently introduced.
E	Unidentified iron pipe on rocky cliff adj. Fort Charles, Salcombe	273,443/38,181 (approximate location)	Submerged discharge point submerged at high water.
F	Pipe on rocky cliff	273,802/38,539 (approximate location)	Discharge point above MHW mark. Not discharging at time of survey.
G	Pipe on rocky cliff at East of Splatcove Point		
H	PVC pipe on rocky cliff		
I	PVC pipe on rocky cliff		

NGR - national grid reference system.

Table A4 Sewage discharges inspected during the shoreline survey.

Fig. A4 ref.	Name	Location (NGR) Eastings/Northings	Obs.
A, B	Frogmore No.1 PSO/EO	277,615/42,619	Freshwater sample taken at Frogmore Creek at bridge
C	Frogmore No.2	Not recorded	Discharge point not located
D	Prince of Wales CSO	273,525/44,001	Discharge point possibly leading to pipe shown in figure, inaccessible from quay. Not sampled.

No sewage related debris was observed by shellfish beds in Frogmore Creek or by slipway by bridge in Frogmore.

Agricultural activities

The vast majority of the lower catchment was noted to be improved grassland, but general cropping, arable and horticultural areas were also observed. Woodland bordered a significant proportion of the low lying areas of the catchment.

Several farms were observed along the surveyed area. Cattle were seen grazing in the fields at Frogmore. Sheep was seen grazing in the fields adjacent to the southern side of Frogmore Creek. No direct access of these farms to watercourses was observed.

Dogs and birds

Two dogs were being exercised on the north shore of Frogmore Creek in the vicinity of the shellfish beds in the first day of the survey.

Very high numbers of birds were in evidence in Frogmore Creek during both days of the survey.

Figure A Birds in Frogmore Creek, in the village of Frogmore (A) and Geese Quarries (B).

BOATS

Two small open boats moored on the intertidal in the vicinity of the shellfish beds. No other moorings are established in Frogmore Creek in the vicinity of the shellfish beds, although there are several drying moorings for small boats at the head of the Creek by Frogmore Village.

SHELLFISHERIES

The location and extent of the area requiring classification for mussels and the areas being used for Pacific oysters at Geese Quarries were updated by Global Positioning System (GPS) on the first day of the survey during the low water period. On the second day, the location of the area being used for Pacific oysters by Bigbury Bay Oysters in Frogmore Creek was also updated. Further information on location and extent of the bed was received from the Local Enforcement Authority.

CONCLUSIONS

The extent of the areas requiring classification for mussels and Pacific oysters was re-defined following on-site inspection and discussion with the industry. Levels of faecal coliforms and *E. coli* in water samples collected from small watercourses discharging to the estuary highlighted the potential high contribution of contamination from Tacketwood Creek and Kingsbridge and, to a lesser degree, from Batson Creek, Balcombe Creek and Collapit Creek. Levels of the microbiological indicator in water from Frogmore Creek were however lower than those in samples from other creeks. Levels of *E. coli* in mussels from Geese Quarries were consistent with those obtained during the preliminary monitoring, which corresponded to the range of concentrations equivalent to class B.

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SAMPLING PLAN

Salcombe-Kingsbridge Estuary

2009

GENERAL INFORMATION

Location Reference

Production Area	Salcombe-Kingsbridge Estuary
Cefas Main Site Reference	M029
Cefas Area Reference	FDR4037
Ordnance survey 1:25000 map	Explorer OL20
Admiralty Chart	Admiralty 28 (Salcombe Harbour) Imray 2400.5 (Salcombe River)

Shellfishery

Species/culture	Mussels (*Mytilus* spp.) Pacific oysters (*C. gigas*)	Farmed Farmed
Seasonality of harvest	Year round	

Local Enforcement Authority

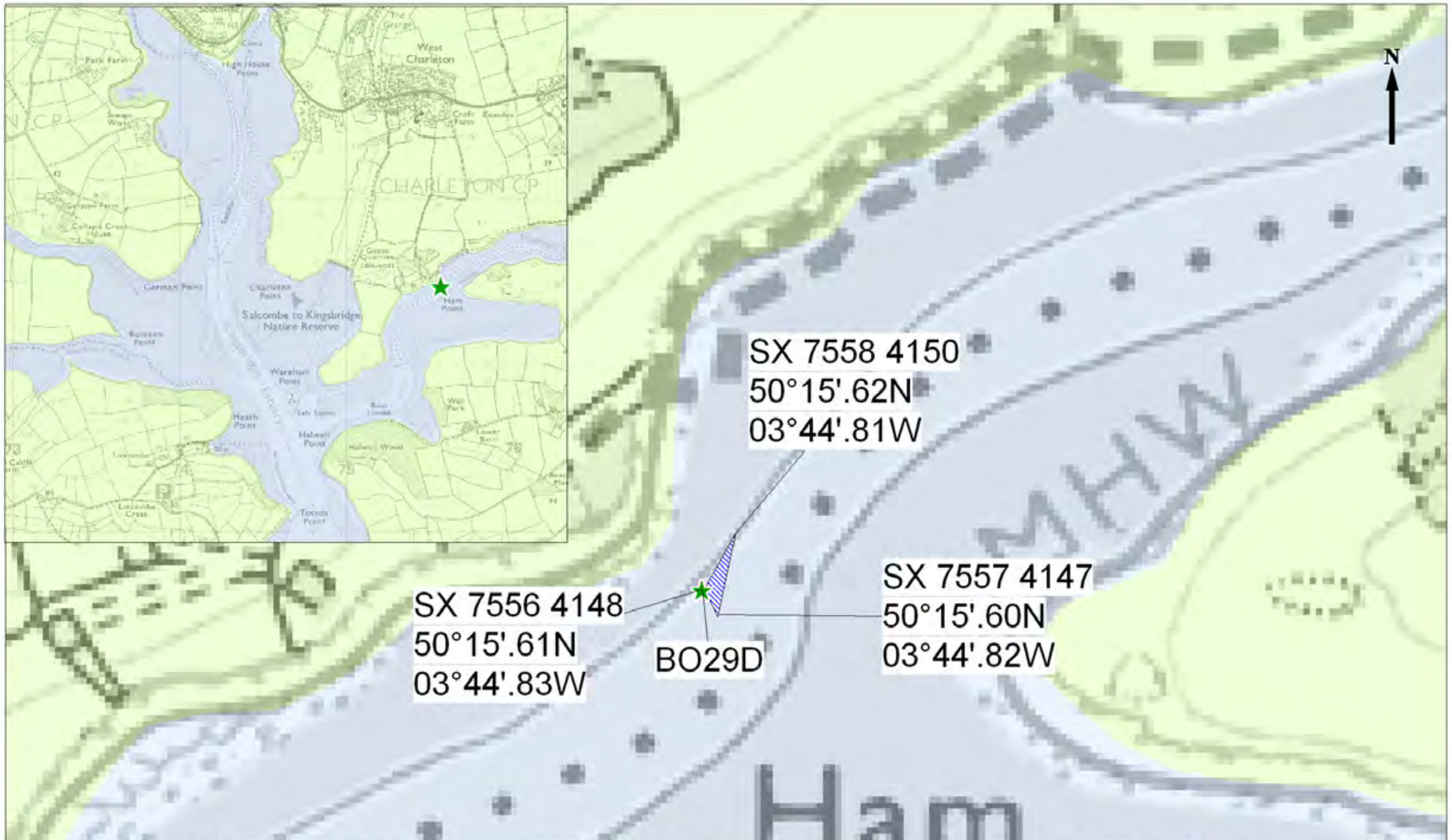
Name	South Hams District Council
Address	Environmental Health, Technical Services Dept. Follaton House, Plymouth Road, TOTNES, Devon, TQ9 5NE
Telephone number ☎	01803 861234
Environmental Health Officer	Mr. Peter Wearden
Fax number	0183 861294
E-mail	peter.wearden@southams.gov.uk
Sampling Officer	Mr. Jim Kershaw

REQUIREMENT FOR REVIEW

This sampling plan will be reviewed by the competent authority within six years or in light of any obvious known changes in the extent of the production area or changes in sources of pollution of human (e.g. improvements in sewage treatment works) or animal origin likely to be a source of contamination for the bivalve mollusc production area.

Table S1. Number and location of representative monitoring point (RMPs) and frequency of sampling.

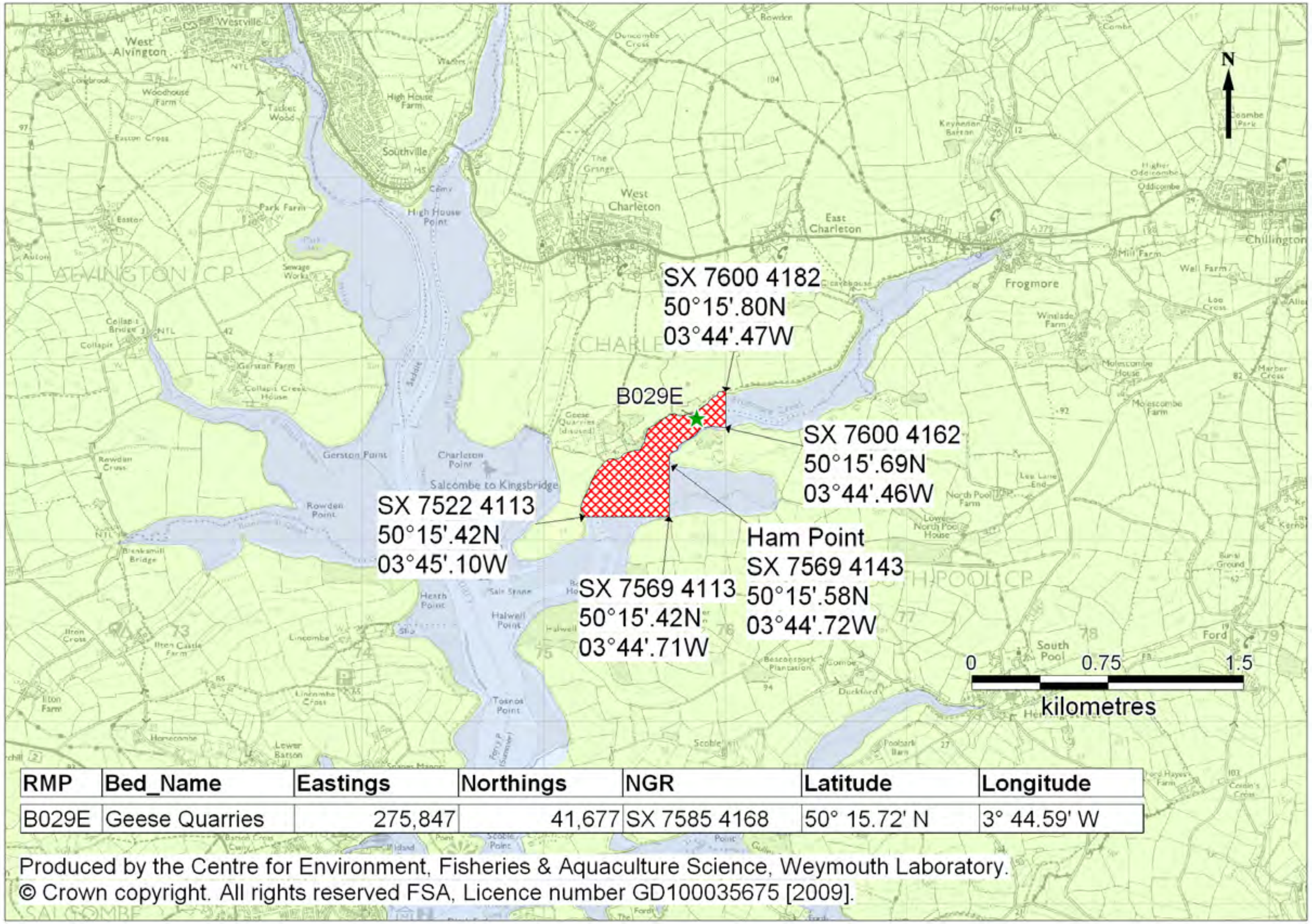
Production area			Salcombe-Kingsbridge Estuary	
Classification zone			Geese Quarries	
RMP			B029D	B029E
Geographic grid references (datum) of sampling points	**OSGB36**	**Eastings** **Northings**	275560 41480	275847 41677
	NGR		SX 7556 4148	SX 7585 4168
	WGS84	**Latitude** **Longitude**	50° 15.61' N 3° 44.83' W	50° 15.72' N 3° 44.59' W
Species			Mussels (*Mytilus* spp.)	Pacific oysters (*C. gigas*)
Growing method			Bags on trestles	Bags on trestles
Harvesting technique			Hand-picked from bags via shore	Hand-picked from bags via shore
Sampling method			Hand-picked from bags via shore	Hand-picked from bags via shore
Depth (m)			Depth of bags	Depth of bags
Tolerance for sampling points (m)			10	10
Frequency of sampling (PRELIMINARY Classification)			10 samples taken over at least 3 months (interval between sampling not less than 1 week).	-
Frequency of sampling (FULL Classification)			at least monthly over one year	at least monthly over one year



RMP	Bed_Name	Eastings	Northings	NGR	Latitude	Longitude
B029D	Geese Quarries	275,560	41,480	SX 7556 4148	50°15'.61N	03°44'.83W

Produced by the Centre for Environment, Fisheries & Aquaculture Science, Weymouth Laboratory.

Figure A1 Location of Representative Monitoring Point (RMP) and Classification Zone boundaries for mussels.



RMP	Bed_Name	Eastings	Northings	NGR	Latitude	Longitude
B029E	Geese Quarries	275,847	41,677	SX 7585 4168	50° 15.72' N	3° 44.59' W

Produced by the Centre for Environment, Fisheries & Aquaculture Science, Weymouth Laboratory.

Figure A1 Location of Representative Monitoring Point (RMP) and Classification Zone boundaries for Pacific oysters.