Cefas

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

St Austell Bay

2010

Cover photo: Underwater view of mussel lines in St. Austell Bay.

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

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency		
Local Enforcement Authority		
Sea Fisheries Committee		

DISSEMINATION: Food Standards Agency, Cornwall Port Health Authority, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2010. Sanitary survey of St Austell Bay. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC Regulation No. 854/2004.

CONTENTS

1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

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

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

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

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

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

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

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

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

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

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

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

This report documents information relevant for a sanitary survey of cultured mussels (*Mytilus sp.*) at the Ropehaven Outer site owned by Westcountry mussels of Fowey in St Austell Bay, and is largely based on a recent sanitary survey undertaken at the adjacent St Austell Bay – Ropehaven mussel site (Cefas, 2009).

1.2 Site Description

St Austell Bay

St. Austell Bay is situated in Cornwall on the South West coast of England (Figure 1.1).

Figure 1.1 Location of St. Austell Bay and its river catchments.
Google Earth ™ mapping service.

This bay is approximately 6km wide and recessed by 3.6km. It is bounded by maritime cliffs and slopes and beaches (Figure 1.4). The towns of Par and St Austell border its north shore. The bathymetry is uncomplicated, gently sloping to a depth of about 20m in the centre.

Catchment

A series of watercourses drain to St Austell Bay. The St. Austell sub-catchment borders the western coast, the Crinnis and Par sub-catchments border the northern central coast. The Par drains a catchment of 67 km^2, the Crinnis drains a catchment of 20 km^2, and the St Austell River drains an area of about 43 km^2. The larger Fowey catchment borders the east shore of the bay, and runoff from this catchment enters the sea in the Fowey estuary, about 3km to the east of St Austell Bay (Figure 1.1). Therefore, sources within this catchment are unlikely to be of significance to the fishery in St Austell Bay, and so are not considered in this report.

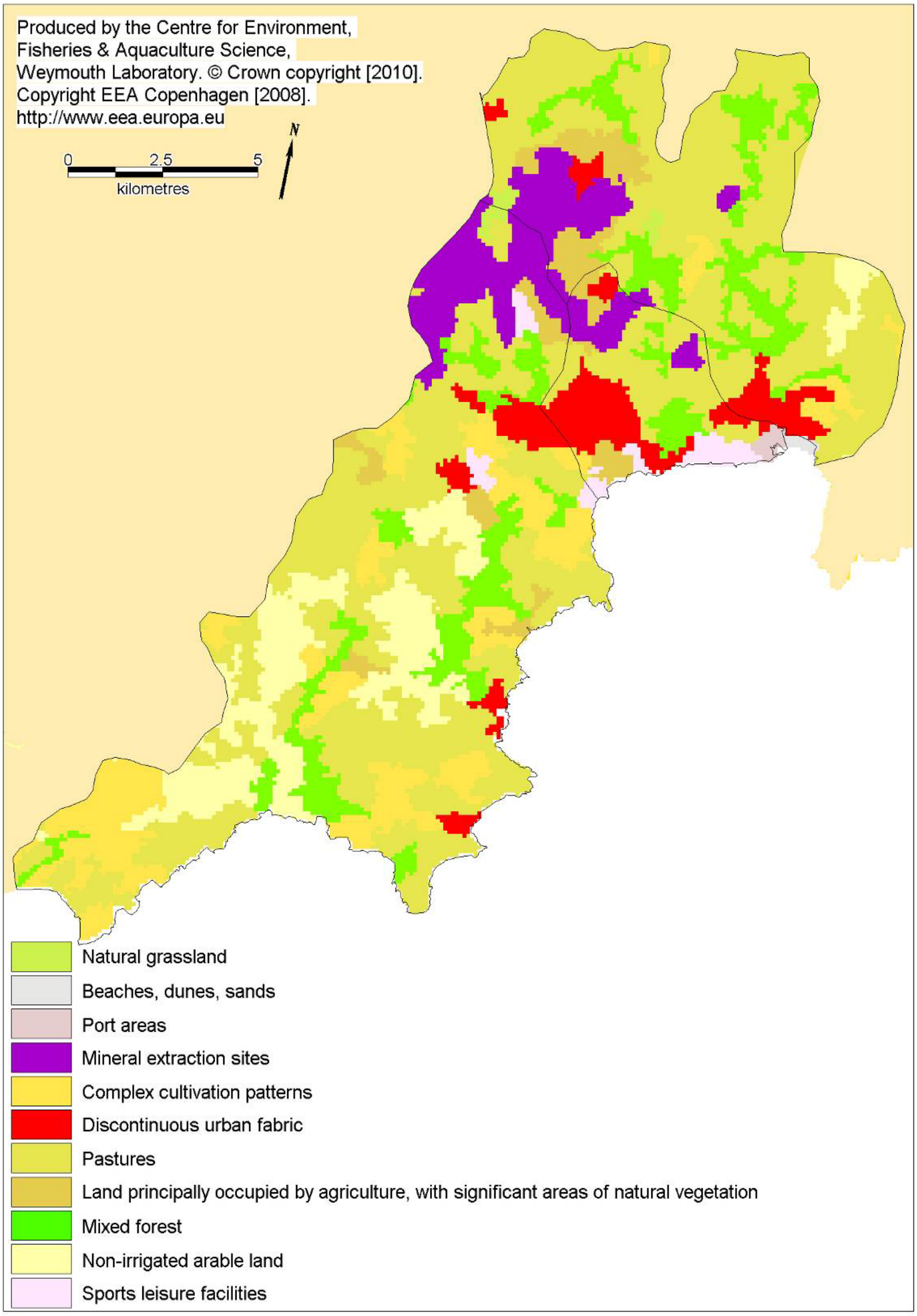

Figure 1.2 Land cover in catchments bordering St. Austell Bay.

Soil permeability within the catchments draining to St Austell Bay is generally high in the lower reaches where acid loamy soils predominate. There are some areas of poorly draining peaty soils in the upper Par and St Austell catchments so a higher proportion of rainfall will run off from these areas (National Soil Resources Institute, 2010).

Figure 1.3 Views of St. Austell catchment showing grazing land (A) and steep-sided topography of the catchment (B).

Figure 1.4 Maritime cliff at Phoebe's Point (A) and Porthpean Beach (B) on the western side of St. Austell Bay.

Agricultural land dominates within the catchments, most of which is pasture used for livestock production (Figure 1.3A) although there are some areas of arable farmland. There is a significant proportion of deciduous woodland along the steep and undulating river valley sides (Figure 1.2) and areas of mineral extraction to the north of St. Austell. There are also significant urban areas mainly at the head of St. Austell Bay.

2. SHELLFISHERIES

This updated sanitary survey of St Austell Bay was prompted by an application made by Westcountry mussels of Fowey for the classification of a new mussel lease area at Ropehaven outer. These are situated adjacent to the currently classified Ropehaven site, but fall outside the current classification zone.

2.1 SPECIES, LOCATION AND EXTENT

Mussels (*Mytilu*s sp.) are cultured on ropes at both sites. The new Ropehaven outer lease covers an area of about 0.34km^2, and has permission for the installation of 3 longlines of about 400m in length. At the time of shoreline survey (May 2010) the two outer lines were being installed, and at the time of writing the inner line was yet to be installed. The Ropehaven lease area covers an area of about 0.28km^2, on which there are only two mussel longlines, each about 110m in length. These lines fall within a classified zone of about 0.022km^2. The deployment of further lines at this site is anticipated in late 2010, and these will almost certainly fall outside the currently classified zone. Figure 2.1 shows the locations of the mussel lines and lease areas.

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

Both sites operate longlines with droppers suspended from a headline submerged at about 2m depth to minimise disturbance from wave action. A schematic diagram of the system employed at Ropehaven is shown in Figure 2.1. A similar arrangement is used at the Ropehaven outer site. This design is more resistant to wave action than the more commonly used surface headline.

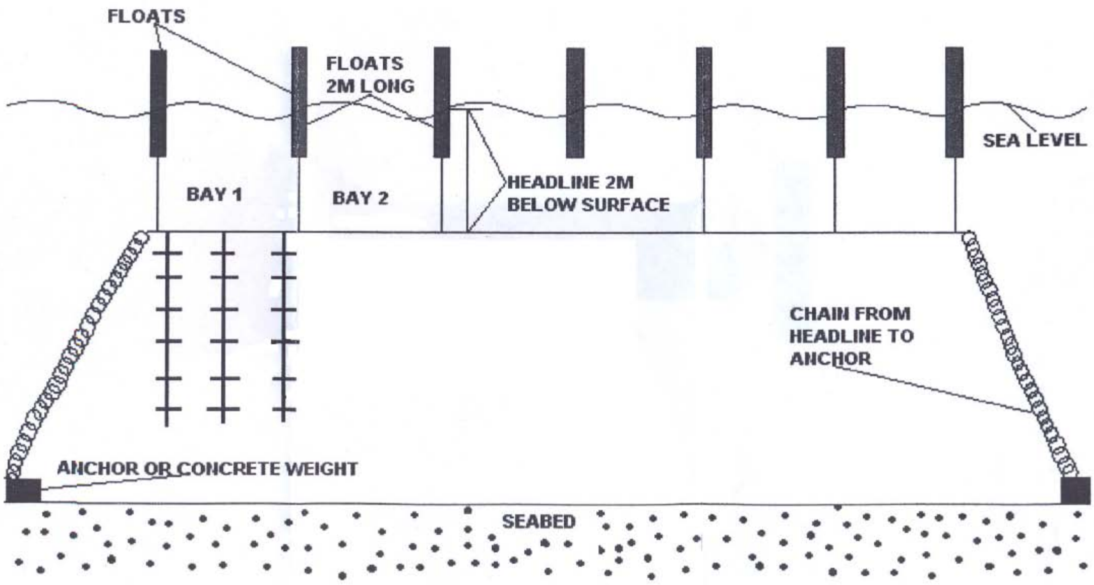

Figure 2.2 Diagram of mussel longline design at Ropehaven.

At the Ropehaven site, the droppers are 6m in length. Adult mussels will be harvested by hand using a boat to recover the ropes. At the Ropehaven outer site, longer (9m) droppers are used. At the time of the last shoreline survey (May 2010) the two outer longlines were being deployed. Both sites are dependent on natural spatfalls. Satisfactory spatfalls were reported at the

Ropehaven site in 2009 and 2010. As the lines at the Ropehaven outer site were only deployed in May 2010 they are yet to experience a spatfall, but given their relative proximity to the Ropehaven site, similar satisfactory spatfalls are anticipated here in 2011.

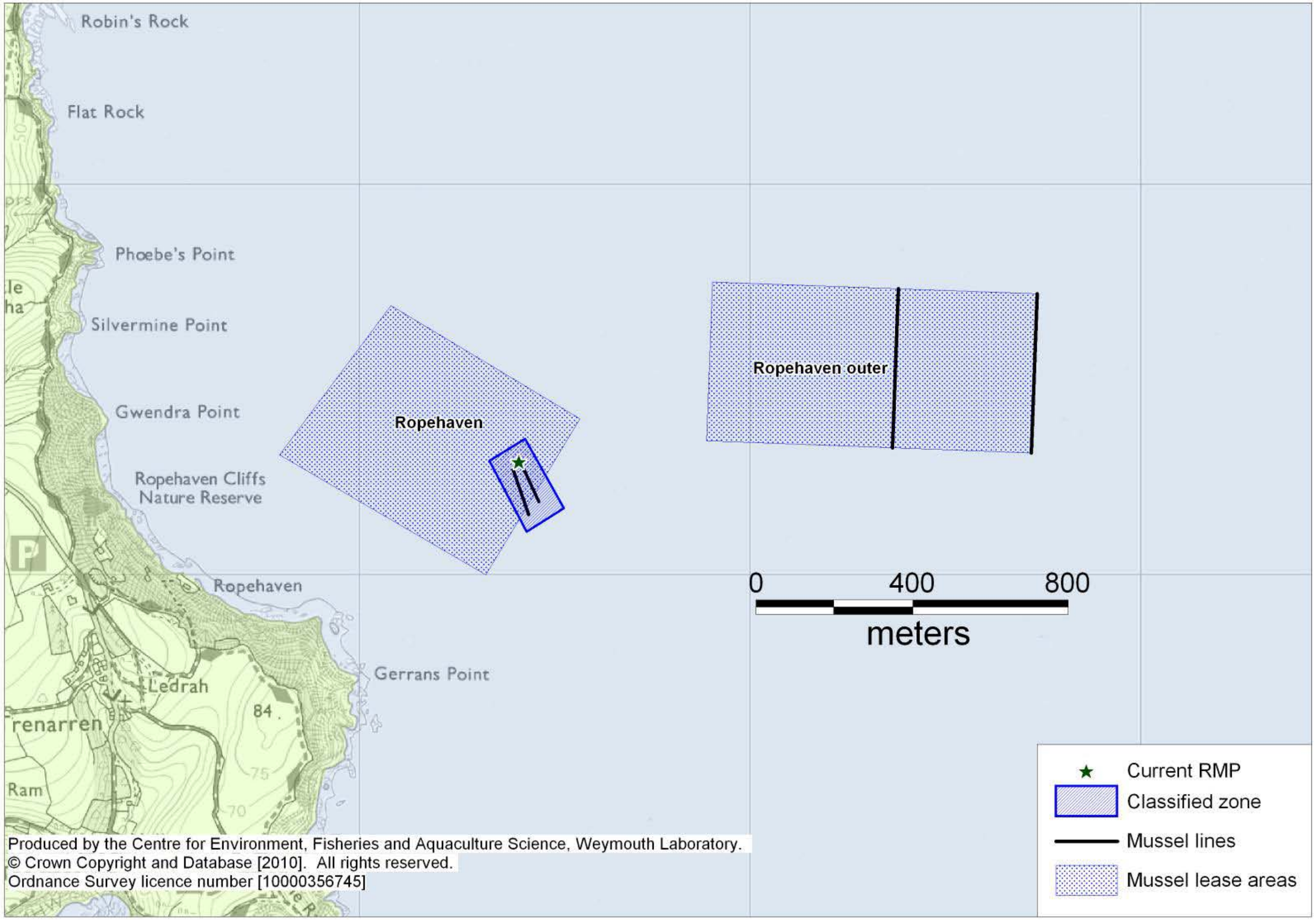

Figure 2.1 Location of mussel sites, lease areas, current classification zone, and RMP within St Austell Bay.

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

The estimated production for the two longlines at Ropehaven is approximately 30 tonnes. The tackle on this site only occupies a small proportion of the lease area, and so significant expansion within this lease area is possible. At the Ropehaven outer site, permission for the installation of a total of three 400m longlines has been granted. The applicant indicated that annual production at this site would be about 50 tonnes. No conservation controls apply to either of these sites, and harvest may occur at any time of the year.

2.4 HYGIENE CLASSIFICATION

The two Ropehaven mussel lines lie within a small classified zone which was awarded a provisional B classification on 15th September 2009. This has subsequently been revised to a full B classification. The Ropehaven outer site and most of the Ropehaven lease area lie outside this classification zone. Table 2.1 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 1.3 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 100g^{-1} Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* 100g^{-1} FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100g^{-1} FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* 100g^{-1} FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* 100g^{-1} FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds.

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of the impacts of pollution sources on the microbiological contamination of the mussel sites within St Austell Bay as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of the bivalve mollusc production area (BMPA) in this geographical area.

SHELLFISHERIES

There are now two separate lease areas within St Austell Bay on which rope mussels are cultured. Only a small part of one of the lease areas (Ropehaven) is classified at present. Currently not all of these lease areas are in use, but the sites are likely to expand to fill them in the future. The Ropehaven site lies in depths of between about 8-14m below chart datum, and mussels are cultured at depths of 2-8m below the surface. The Ropehaven outer lease lies in a depth of about 14-16m below chart datum, and mussels are cultured between 2 and 11m below the surface. The total distance between the most inshore point of the Ropehaven lease and the most offshore point of the Ropehaven outer site is about 2km. Over this distance there are potentially significant differences in levels of contamination, depending on the nature of contamination sources within the bay, so it is possible that these two sites may require separate monitoring and classification.

The sampling officer for this area advises that as the two sites are under different ownership, separate visits are required to sample each site directly from the mussel lines. Therefore, a more efficient approach would be to deploy independent sampling installations where bagged mussels could be held, so that samples representing both sites could be taken on one visit. These sampling installations would have to be secured to anchors at the end of the lines.

POLLUTION SOURCES

FRESHWATER INPUTS

There are three main freshwater inputs to the area. The Par drains a catchment of 67 km^2 and discharges to the north eastern corner of the bay, the Crinnis drains a catchment of 20 km^2 and discharges to the center of the north coast of the bay, and the St Austell River drains an area of about 43 km^2 and discharges at Pentawan, about 3-4km south of the mussel lease areas and outside of St. Austell Bay. There are also a number of much smaller streams discharging around the bay, including some small spring fed watercourse on the shoreline adjacent to the mussel leases. Pasture used for livestock production is the principal land use, but there are also significant urban areas lying within the catchments of all three of the largest watercourses. Given that urban areas and pastures tend to produce more heavily contaminated runoff, significant transport of contamination into St Austell Bay via these watercourses may be anticipated.

Flow gauging records from the St. Austell River at Molingey indicate that river discharge averages about 1 m^3/sec and is considerably higher during the winter months. High flow events can occur at any time of the year although are least likely during the months of April, May and June. During peak events, discharge can increase up to about 10 times base flow. As the characteristics of these other watercourses are fairly similar, this pattern is likely to be broadly representative of other watercourses discharging to St Austell Bay, and their discharge volumes will be roughly in proportion to their catchment areas.

Levels of faecal coliforms (presumptive) within the Par River ranged from 8 to 150,000 cfu/100ml with a geometric mean of 1,974 cfu/100ml indicating very high levels of contamination within this watercourse at times. Within the Crinnis, they ranged from 2 to 26,000 cfu/100ml with a geometric mean of 393 cfu/100ml indicating it is less contaminated than the Par River. Rainfall resulted in increases in levels of faecal coliforms within these watercourses, presumably as well as an increase in discharge volume, so their significance in transporting contamination into St Austell Bay increases in wet weather. No sampling was undertaken on the St. Austell River, but a similar pattern may be expected.

Therefore, it may be expected that the Par River carries the highest bacterial loading, followed by the St Austell River, then the Crinnis and then the other minor watercourses. The influence of the Par River will be strongest in the north eastern corner of the bay. The extent of their influence will depend on patterns of circulation within St Austell Bay as w ell as the amount of rainfall in the preceding few days. The small spring fed streams issuing on the shore adjacent to the mussel leases are probably too small to be a significant contaminating influence.

AGRICULTURE

There are significant numbers of livestock within the St Austell Bay catchment area, and so livestock are likely to constitute a significant source of contamination. There is likely to be significant temporal variation in impacts attributable to season and rainfall. As numbers of grazing animals on pasture are likely to be highest during the summer months, wet weather at this time of year following a dry period in which faecal matter may build up on pastures will probably result in peak fluxes into coastal waters. Slurry is most likely to be spread on fields during the winter, so more localised impacts may arise at this time of year in areas where spreading occurs just before a period of wet weather.

HUMAN POPULATION

The total resident human population within catchment areas bordering St. Austell Bay is ~59,000, the majority of which are concentrated within the towns of St. Austell and Par. Large influxes of tourists are expected primarily during the summer. Population increases of around 50% during the peak tourist season were assumed by South West Water for areas served by the Par STW so higher inputs of human sewage are expected at this time.

Sewage Discharges

The most significant continuous sewage discharge is the Par STW in terms of both the estimated bacterial loading it generates and its proximity to the fisheries. It lies about 1.5km to the ENE of the closest part of the Ropehaven outer lease, and 2.5km from the closest part of the Ropehaven lease, so greater impacts from this discharge may be expected at Ropehaven outer. RMPs should be set to best capture contamination from this source. The Polkerris STW discharge, whilst of relatively low volume, has been estimated to produce a bacterial loading of about half that of the Par STW as it is not subject to biological treatment or disinfection. As it also lies to the ENE of the two lease areas it may have a similar spatial pattern of impacts as the Par STW, but is about twice as far away and is located in much shallower water. The other two continuous discharges which may impact on St. Austell Bay are both UV treated discharges to watercourses (the St. Austell and the Par) generating estimated loadings of 3 or more orders of magnitude lower than that of Par STW. Any contaminating impacts they may have on the shellfishery will have the same spatial profile as described for these rivers. A bacteriological survey demonstrated that the smaller of these (Luxulyan) had no appreciable impact on levels of faecal coliforms in the receiving watercourse (Par River), and it is probable that the impacts of the larger of these (St. Austell Mengawins) are minor at most.

The pumping station overflows at Porthpean and Charlestown are within less than 2 km of both mussel leases and so could be a significant contaminating influence, particularly at the nearer Ropehaven site in the event of a spill. No information on the frequency of spills from these discharges was available however. Par STW and Par No 2 overflows are designed so the spill frequency does not exceed an average of three per bathing season, so occasional impacts from these may be expected.

Overall, the most significant sewage discharges to the mussel lease areas are Par STW (continuous and emergency overflow) and Polkerris STW, which are located to the ENE of the lease areas. An RMP at the ENE extremity of the lease area may best capture contamination from these depending on water circulation patterns. The pumping station overflows at Porthpean and Charlestown may also be of significance and are located to the NW of the lease areas, but information on spill frequency and/or spill volumes were not available at the time of writing. An RMP at the NW extremity of the lease area may best capture contamination from these.

Boats

The main port in the area is located at Mevagissey, over 5km to the south of the mussel lease areas from which 63 small fishing vessels operate. There are other minor ports within the bay such as Charlestown and Polkerris, and small sailing clubs at Porthpean and Pentewan. Overall, boating activity is relatively minor and any impacts would be unpredictable spatially and so has no influence on the sampling plan.

BIRDS

Wild birds, including seabirds are present in the area, but not in great numbers. The relative instability of the floats used at the mussel sites deters seabirds from roosting on them. Therefore, diffuse but very minor impacts are anticipated from seabirds, and this will have no influence on the sampling plan.

DOMESTIC ANIMALS

The beaches at St. Austell Bay are popular for dog walking, although dogs are banned from some during the summer months, and so is a relatively minor diffuse input direct to the intertidal area. Whilst this may potentially have some impacts on water quality in nearshore regions in the vicinity of the more popular beaches, significant impacts from dog faeces on the mussel lease areas are not anticipated.

SUMMARY OF POLLUTION SOURCES

An overview of sources of pollution likely to affect the levels of microbiological contamination at the mussel sites in St Austell Bay is shown in Table 3.1 and Figure 3.1.

Table 3.1 Qualitative assessment of changes in pollution load in St. Austell Bay.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sewage treatment works	Red	Red	Red	Red	Red	Red +	Red +	Red +	Red	Red	Red	Red
Pasture runoff	Orange	Orange	Orange	Orange	Red	Red	Red	Red	Red	Red	Orange	Orange
Rainfall-dependent discharges	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Red
Urban runoff	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Red
Slurry application to land	Red	Red	Orange									Orange

Red - high risk; orange - moderate risk; + - peak tourist season

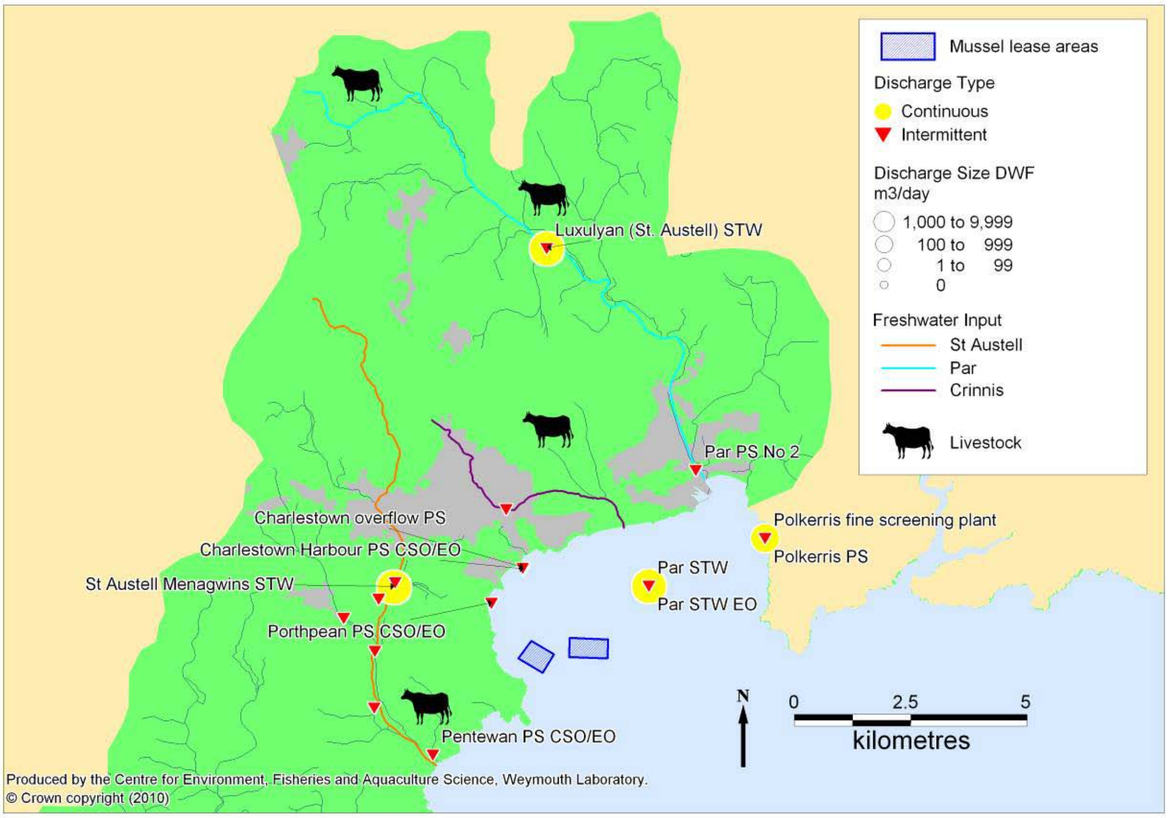

Figure 3.1 Significant sources of microbiological pollution to St Austell Bay.

HYDRODYNAMICS

Tidally driven circulation within the bay is almost negligible, so circulation is primarily driven by wind and density effects. Wind and density driven currents are dependent on meteorological conditions and are therefore quite variable in nature, and the speed and direction of circulation driven by these forces will vary significantly with depth.

Thermal stratification has been reported to occur in the summer and it is possible that some salinity related stratification may occur under high rainfall and calm conditions. Density driven currents are likely to also be quite weak and most apparent in the near shore regions. Under calm conditions contamination from shoreline sources such as freshwater inputs may tend to be most concentrated towards the surface and slowly move offshore. For example, the presence of a density gradient extending offshore from the mouth of the Par River was reported in one study. Therefore, if any vertical differences in levels of contamination are found, it is expected that shellfish are more contaminated towards the top of the lines, and if this is the case RMPs should be set towards the surface. Contamination carried towards the lease areas via this mechanism may be expected to impact most heavily nearer the shore where they originate, and an RMP set at the most inshore point of the Ropehaven lease would be best placed to capture this.

Contamination from the Par STW outfall is reported to rise to the surface in the vicinity of the outfall but be carried away from the lease areas under conditions of light wind. A persistent easterly flow of 0.06m s^{-1} in the vicinity of this outfall has been reported but it is unclear how this arises. Therefore, in the absence of significant winds, contamination from this outfall would tend to be slowly carried away from the lease areas.

Wind driven currents are likely to dominate circulation within the bay under windy conditions, as well as disrupting any stratification. South westerly winds prevail, and strong winds from this direction would induce a north eastward flow at the surface, possibly increasing the importance of sources to the south west of the lease areas such as the St. Austell River, but further decreasing the importance of the Par STW outfall. Under stronger winds from the north east or east any contamination from the Par STW outfall rising to the surface may be carried directly towards the lease areas, as would any carried by the Par River, probably resulting in highest levels of contamination being found at the north easterly extremes of the lease areas. Contamination from the Polkerris STW outfall may also be of significance under these conditions.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

There are several bathing waters sites in the vicinity. Sample results indicate higher levels of contamination within the north eastern corner of the bay at Par and Polkerris compared to its north western corner and western shore, suggesting that the Par River and the Polkerris STW outflow may be significant contaminating influences and/or that contamination from the Par STW outfall impacts most heavily in this area. Sites nearest to freshwater inputs tended to show the strongest correlations between levels of indicator bacteria and rainfall. Strong correlations with rainfall were also found at Polkerris, which is not immediately adjacent to any freshwater inputs but may be influenced by the Par River or by an intermittent sewage discharge at here. All but one of the sites showed some correlations with rainfall or river flow, indicating widespread but somewhat spatially variable impacts from rainfall related sources in the inshore areas at least. This implies that land runoff and/or storm overflows are significant sources at times. Pentewan, which is located adjacent to where the St Austell River discharges was the only site for which no significant correlations were found with rainfall.

Only one location within St. Austell Bay has been monitored for *E. coli* levels in shellfish flesh. A total of 34 valid samples have been taken, of which 10 were taken from a depth of 6m and 24 were taken from a depth of 2m, so sample numbers were low and any analyses of results should be treated with some caution. A comparison of results from different depths on the 10 occasions when both depths were sampled reveals that results were higher at 2m, supporting the assertion that RMPs should be set towards the surface.

Positive correlations were found between *E. coli* results and rainfall for the samples taken at 6m depth, but no correlations were found for those taken at 2m depth. This is surprising as freshwater borne contamination may be expected to float on the surface above more dense salt water in the absence of mixing forces, and it must be noted that only 10 samples were taken from 6m depth, but it does tentatively suggest that rainfall dependent sources may impact as far offshore as the mussel lines. No correlations between *E. coli* results and the high/low or spring/neap tidal cycles were found at either depth, which is consistent with the weakness of tidal effects within the Bay.

4. RECOMMENDATIONS

4.1 The two mussel sites are owned by two different harvesters. To remove the need for separate sampling visits to the two sites and the associated time and expense, bagged mussels should be hung from installations deployed at the RMPs rather than mussels sampled direct from the lines.

4.2 Production area boundaries should be set to encompass the full extent of the lease areas so further revision of the sampling plan is not necessary as these operations expand.

4.3 As the lease areas cover a distance of about 2km from the inshore corner of Ropehaven to the offshore corner of Ropehaven outer, it is quite likely there will be noticeable spatial variation in levels of contamination on this scale. Therefore, separate classification zones and RMPs should be established for the two sites.

4.4 Classification zone boundaries at Ropehaven should be the lease area boundaries, extended by 100m to allow for movement of the lines and any small inaccuracies in their deployment. The representative monitoring point should be moved to an installation deployed at SX 0397 4945 to best capture contamination originating from both the near shore region and the Par STW, as described in the previous sanitary assessment of this area.

4.5 Should the operator of the Ropehaven site decide not to expand, the existing monitoring point (B070W) and classification zone may be used as it will be more representative of the existing fishery. These arrangements would however leave most of this lease area unclassified, and to classify the larger area the monitoring arrangements indicated in 4.4 would have to be used.

4.6 Classification zone boundaries at Ropehaven outer should be the lease area boundaries, extended by 100m to allow for movement of the lines and any small inaccuracies in their deployment. The Ropehaven outer RMP should be set at the north east corner of the zone to best capture any contamination from the main sources to the north east (Par STW, Par River).

4.7 All RMPs should be set at a depth of 2m below the surface. A tolerance of 10m should be applied to allow for the movement of sampling installations with wind and tide.

4.8 The requirement for separate monitoring and classification of these two sites should be reviewed on completion of one years parallel monitoring. Should there prove to be no consistent difference between the two sites the classification zones could be combined and the RMP set at the point yielding the highest individual result.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	St Austell Bay
Cefas Main Site Reference	M070
Cefas Area Reference	FDR 3529
Ordnance survey 1:25,000 map	OS Explorer 105 (Falmouth & Mevagissey)
Admiralty Chart	Admiralty 148 (Dodman Point to Looe Bay) Admiralty 442 (Lizard Point to Barry Head)

Shellfishery

Species/culture	Mussels (*Mytilus* spp.)	Cultured
Seasonality of harvest	Year round	

Local Enforcement Authority

Name	Cornwall Port Health Authority The Docks Falmouth TR11 4NR
Environmental Health Officer	Terry Stanley
Telephone number ☎	01326 211581
Fax number	01326: 211548
E-mail	t.stanley@cieh.org.uk

REQUIREMENT FOR REVIEW

The need for this sampling plan to be reviewed will be assessed by the competent authority within six years or in light of any obvious known 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 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones in St. Austell Bay.

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Ropehaven (entire lease area)	B070Y	Ropehaven (West corner)	SX 0397 4945	50° 18.74'N 4°45.28'W	*Mytilus* spp.	Rope	Hand	Hand (bagged mussels)	10m	Monthly	Classified zone expanded to include entire lease area. RMP to be moved to bagged mussel installation at most inshore point of lease area. May be merged with Ropehaven outer zone following one years parallel monitoring should similar results be obtained at both.
Ropehaven (existing zone)	B070W	St Austell	SX 2044 4929	50° 18.66'N 4°44.90'W	*Mytilus* spp.	Rope	Hand	Hand (bagged mussels)	10m	Monthly	Existing RMP if only small area is to be classified.
Ropehaven outer	B70AE	Ropehaven outer (NE corner)	SX 0574 4972	50°18.92'N 4°43.80'W	*Mytilus* spp	Rope	Hand	Hand (bagged mussels)	10m	Monthly	New classification zone and RMP. May be merged with Ropehaven zone following one years parallel monitoring should similar results be obtained at both.

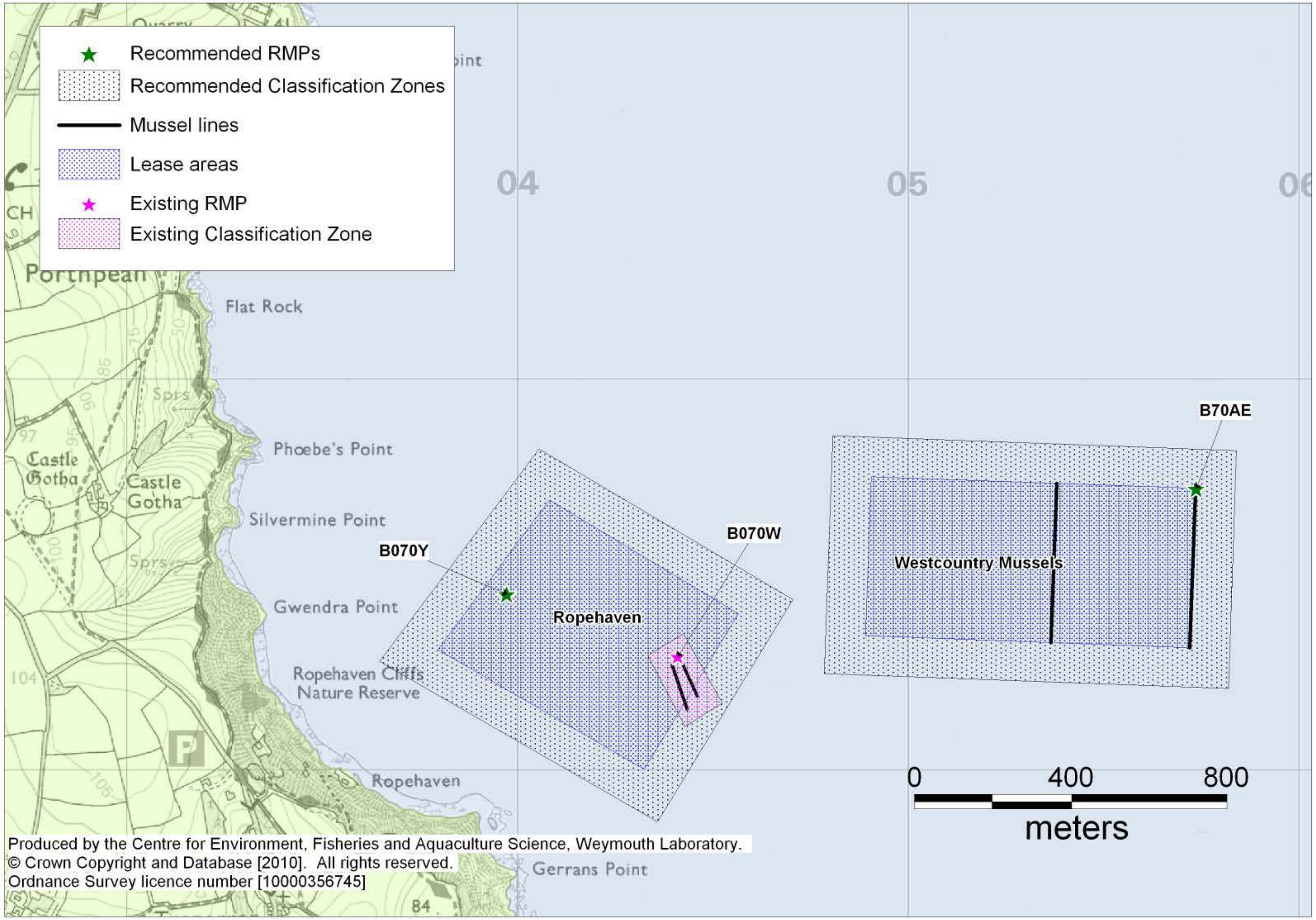

Figure 5.1 Classification monitoring recommendations for mussels in St. Austell Bay.

APPENDICES

APPENDIX I
HUMAN POPULATION

Table I.1 shows total resident human population in catchments bordering St. Austell Bay. Human population density reaches a maximum of 63 inhabitants per hectare in Restormel, St. Austell town (Figure I.1), and overall population densities are highest in the Crinnis catchment.

Table I.1 Resident population in St. Austell river catchment areas.

Sub catchment	Resident human population
St. Austell	15,593
Crinnis	21,379
Par	14,511
Fowey (tidal)	7,934
Total	59,417

Data from Office for National Statistics, 2001 census.

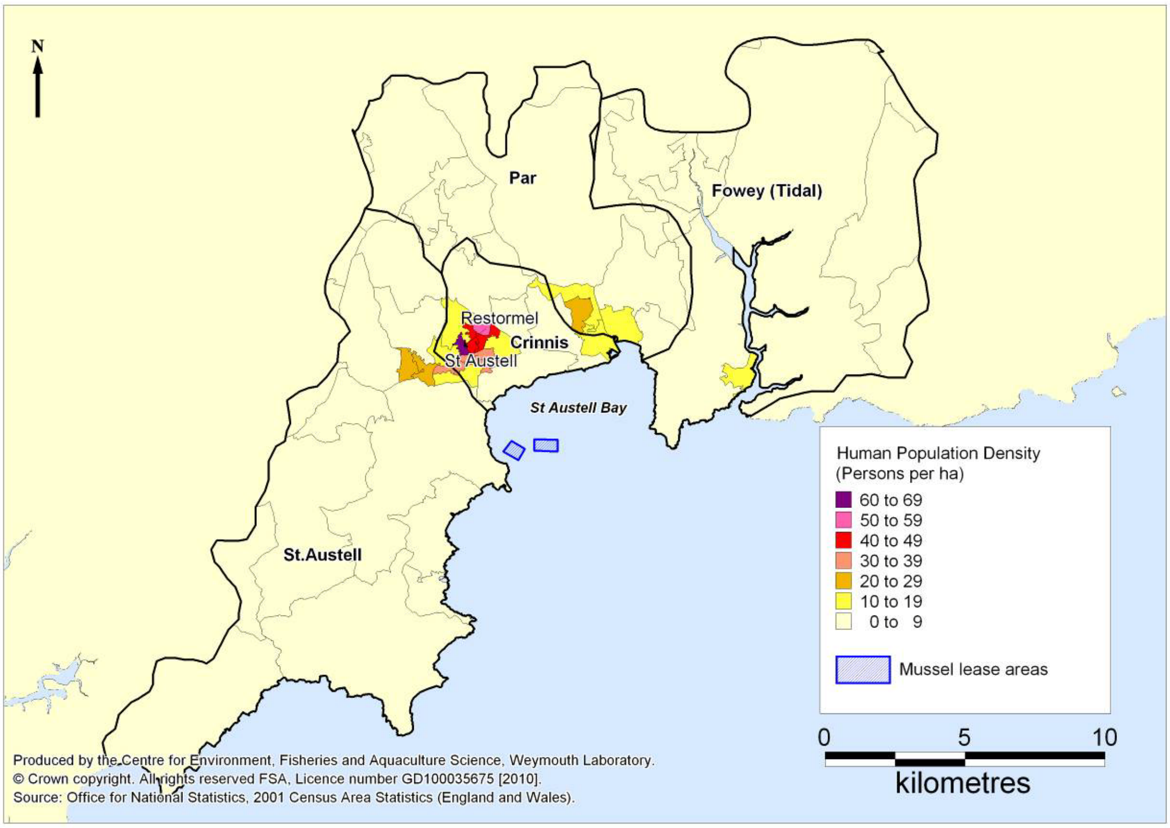

Figure I.1 Human population density in Census Areas bordering St. Austell Bay.

Tourism is significant to the local economy, and will result in significant increases in population during the summer months. An indication of the scale of these increases is the design population equivalent for the Par STW in the peak tourist season, which is about 50% higher than the resident population. The main tourist attractions are represented in Figure I.2.

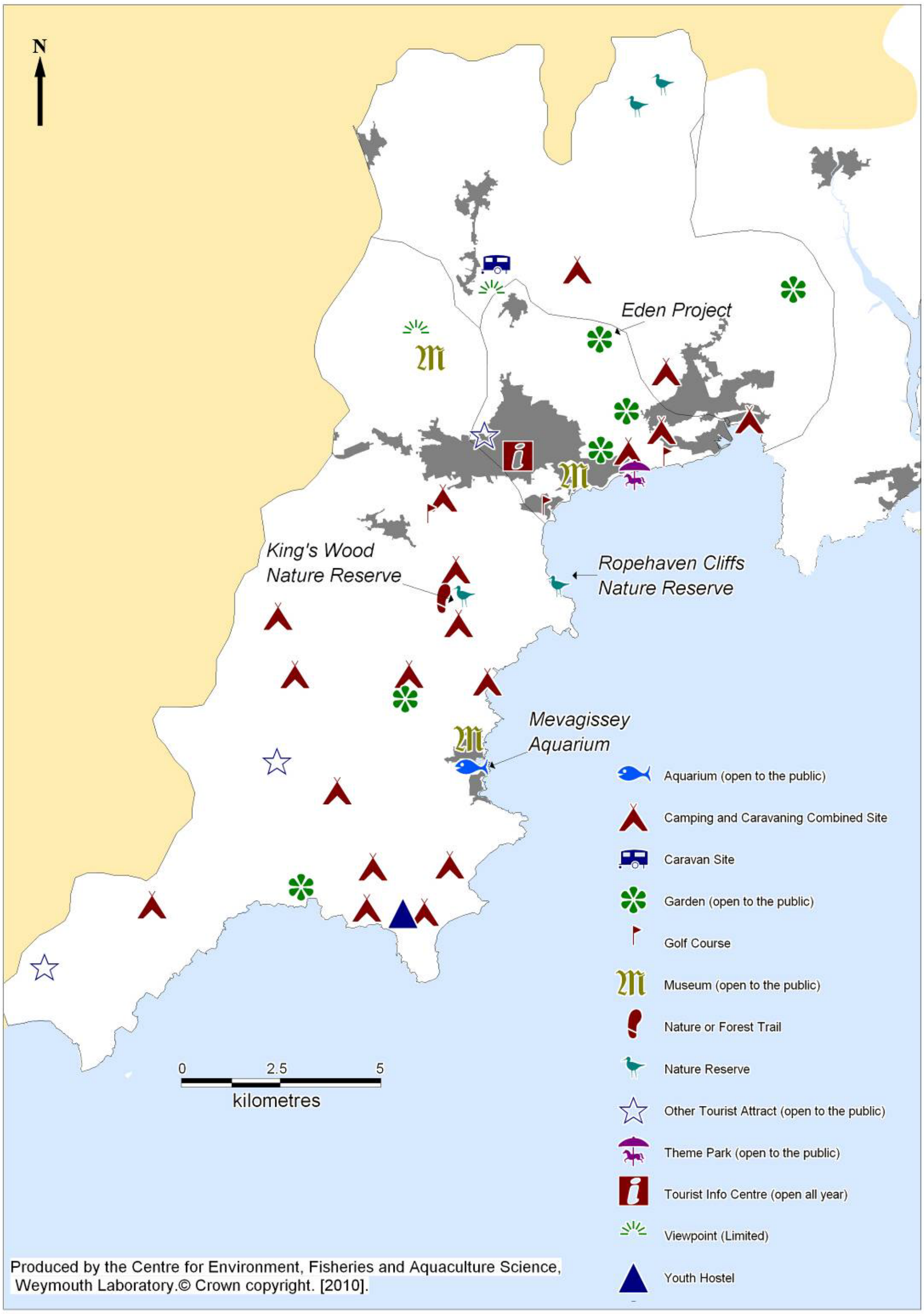

Figure I.2 Tourist attractions in catchments bordering St. Austell Bay.

There are several camping and caravan parks at Carlyon Bay (180 pitches) and Pentewan Sands (500 pitches) (UK Campsite, 2009).

Kings Wood, an Area of Outstanding Natural Beauty on the west facing valley of the Pentewan Valley adjacent to St. Austell River, is used by locals and visitors for walking, horse riding and mountain biking (Woodland Trust, 2005).

Both local residents and tourists make recreational use of the beaches in the bay throughout the year. The Mevagissey harbour area also has a public aquarium, which receives approximately 35,000 visitors per year (Mevagissey Harbour, 2008).

St. Austell has been mentioned as the seventh preferred tourism destination in Cornwall (Visit Cornwall, 2005). The Eden Project is the most popular tourism attraction in the catchment, with over 1.1M visitors in 2007 (South West Tourism, 2007).

Over two thirds of the total number of tourists visit the county between June and August (Visit Cornwall, 2005; South West Tourism Research Department, 2007). About three quarters of visits last for seven nights or less and over 60% of trips are short breaks and extra holidays (Visit Cornwall, 2005).

Deteriorated microbiological quality of water and bivalve molluscs is frequently detected in urbanised coastal areas impacted by pollution sources from tourism related activities (see Campos and Cachola, 2007).

In many areas, the deterioration may result from increased loads from sewage treatment plants. Increased microbiological contamination of water in St. Austell Bay is expected during the tourism season. The northern edge of the BMPA would be the most vulnerable area to contamination from pollution sources derived from tourism activities. The potential contributions of continuous and intermittent sewage discharges to the bay are analysed in detail in Appendix VII.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

The southwest of England is one of the wettest regions in the UK. Annual precipitation totals in the district have been increasing in recent years to nearly 1,300mm (Perry, 2006). The pattern is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall throughout the upper reaches of the catchments. The rainfall pattern varies greatly throughout the catchments bordering St. Austell Bay. The coastal areas of these catchments receive 900–1,000mm of rain per year (Met Office, 2007). Figure II.1 presents box and whisker plots of daily rainfall values at the Luxulyan weather station (Figure III.1 for location) recorded between 2003 and 2010. Only 57% of these records were fully validated, and only the fully validated records are used, but nevertheless this should give a broad indication of rainfall patterns in the area.

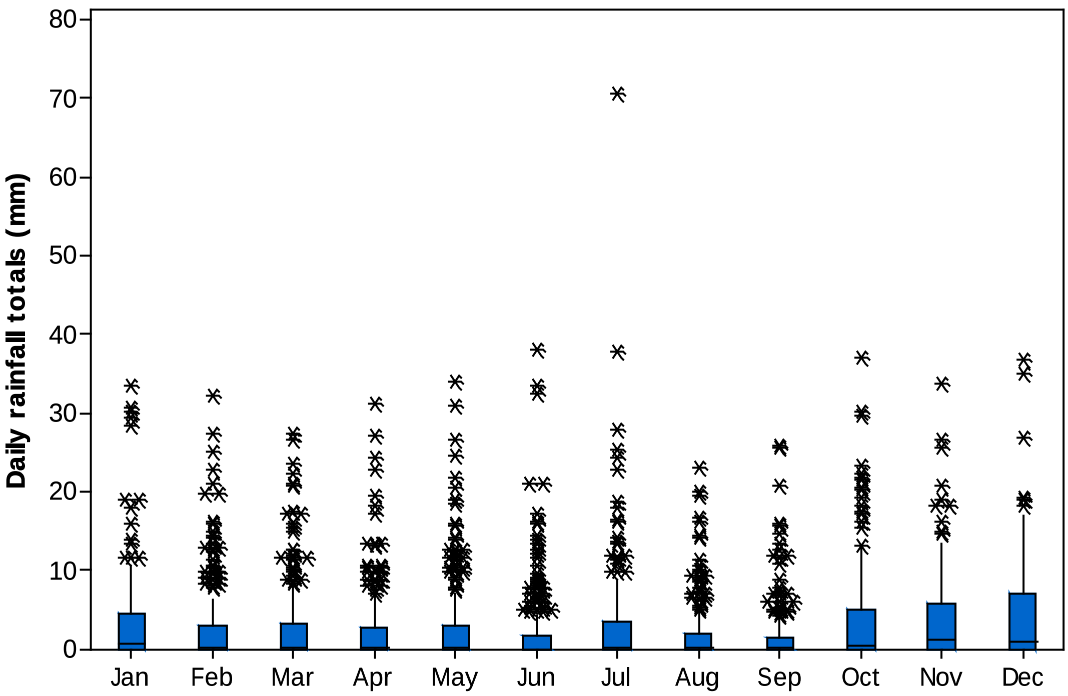

Figure II.1. Box and whisker plot of total daily rainfall values 2003-2010 at Luxulyan (validated values only).
Data from the Environment Agency (2010).

Rainfall is generally highest from October through to January, and lowest from June to September. Therefore, river discharge and volumes of runoff from pastures are likely to be highest from October to January. High rainfall events of over 20mm in a day were recorded in every month of the year, and so sewer overflows may happen at any time of the year. High rainfall events following a period of dry weather may generate a ‘first flush’ of more contaminated runoff from pastures.

An examination of the relationship between levels of faecal coliforms in designated bathing waters in the vicinity of St. Austell Bay and recent rainfall is given in Appendix XI, and similar evaluations of shellfish hygiene flesh monitoring data and Environment Agency bacteriological monitoring of streams in the area are presented in Appendix XII and XIII respectively.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

Figure III.1 shows the most significant freshwater inputs to St. Austell Bay. The River Par flows over land with very little fall in landform [130m Above Ordnance Datum (AOD) at the northern boundary of the river catchment to 110 m AOD at Luxulyan] (Environment Agency, 2006). Then, the river enters the steep sided Luxulyan valley and drops to 20 m AOD, flowing within wide flood plains from this point to the bay at Par Sands. Levels of faecal coliforms (presumptive) within samples taken by the Environment Agency from the Par River near where it discharges to St Austell Bay ranged from 8 to 150,000 cfu/100ml with a geometric mean of 1974 cfu/100ml (Appendix XIII).

Figure III.1 Freshwater inputs to St. Austell Bay and location of hydrometric gauges referred in the report.

The St. Austell River rises at 220m relative to OD near Carthew and flows to the south through areas of flood plain for much of its course and discharges to the sea at Pentewan Beach (Environment Agency, 2006). No microbiological testing has been carried out by the Environment Agency on this watercourse. There is a flow gauging station on the St Austell River at Molingey, which is about 5km upstream of the mouth of the river so does not represent the full catchment area. Figure III.2 shows that the river discharge is generally considerably higher during the winter months. High flow events can occur at any time of the year although the magnitude and frequency of these events are lowest during the months of April, May and June. During peak events, discharge can increase up to about 10 times base flow. This general pattern is likely to be broadly representative of other watercourses discharging to St Austell Bay such as the Par River.

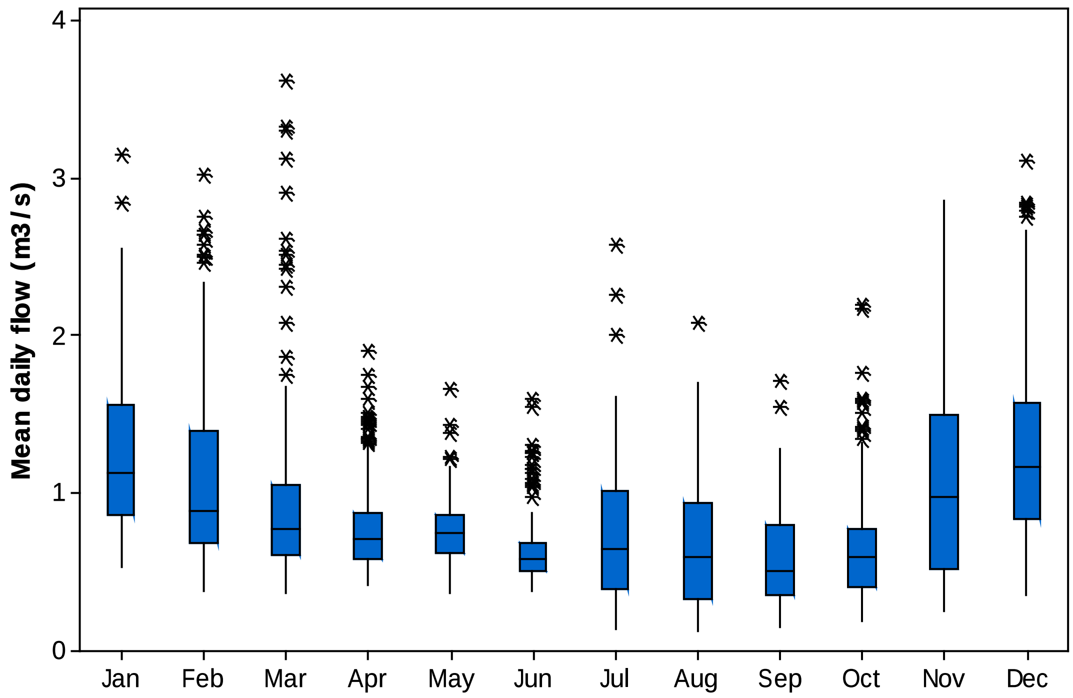

Figure III.2. Box and whisker plot of mean daily flows recorded at Molingey from June 2004 to June 2010.
Data from the Environment Agency (2010).

Several smaller watercourses also discharge to St Austell Bay. A small stream discharges at the eastern end of Par Sands. Levels of faecal coliforms (presumptive) within samples taken by the Environment Agency from this watercourse ranged from 66 to 280,000 cfu/100ml with a geometric mean of 899 cfu/100ml (Appendix XIII). A slightly larger stream discharges to the beach at Crinnis. Levels of faecal coliforms (presumptive) within samples taken by the Environment Agency from this watercourse ranged from 2 to 26,000 cfu/100ml with a geometric mean of 393 cfu/100ml (Appendix XIII).

A number of small springs issue along the west shore of St Austell Bay. Water samples taken from two of these during the 2008 shoreline survey carried moderate levels of *E. coli* (300 and 620 *E. coli* cfu/100ml).

All three streams sampled by the Environment Agency for faecal coliforms showed increased levels of contamination with higher levels of rainfall in the few days prior to sampling (Appendix XIII). Greater volumes will be discharged under wet conditions further increasing their importance as a source of contamination. It is expected that the other watercourses discharging to St Austell Bay would also respond in a similar manner to rainfall.

Kay *et al*. (2008a) investigated catchment export coefficients for faecal indicator bacteria (cfu km^{-2} hr^{-1}) in a range of river catchments in the UK under a range of conditions, and found that these increased by roughly 2 orders of magnitude from base to high flow conditions in both summer and winter. Whilst catchment export coefficients were not significantly different at base flow conditions between summer and winter, at high flow conditions they were significantly higher in summer than in winter. This seasonal difference was attributed to lower faecal input to pasture land and more frequent flushing under the generally wetter conditions experienced during winter.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

St Austell Bay is an open, south facing shallow bay with an uncomplicated bathymetry (Figure IV.1). Intertidal areas are generally small, with the exception of Par Beach. The bottom gently slopes down to about 20m below chart datum in the centre of the bay. Contours are slightly steeper at the south western part of the bay near where the mussel leases are located. The Ropehaven lease area lies in a depth of about 8-14m below chart datum, and the Ropehaven outer lease are in about 14-16m below chart datum. Therefore, as the Ropehaven lease lies in shallower water closer to the shore, the potential for dilution of contamination is likely to be slightly lower at this site particularly towards its inshore limits, although of course the levels of contamination experienced within the two lease areas will be mainly determined by the location of sources and patterns of circulation within the bay.

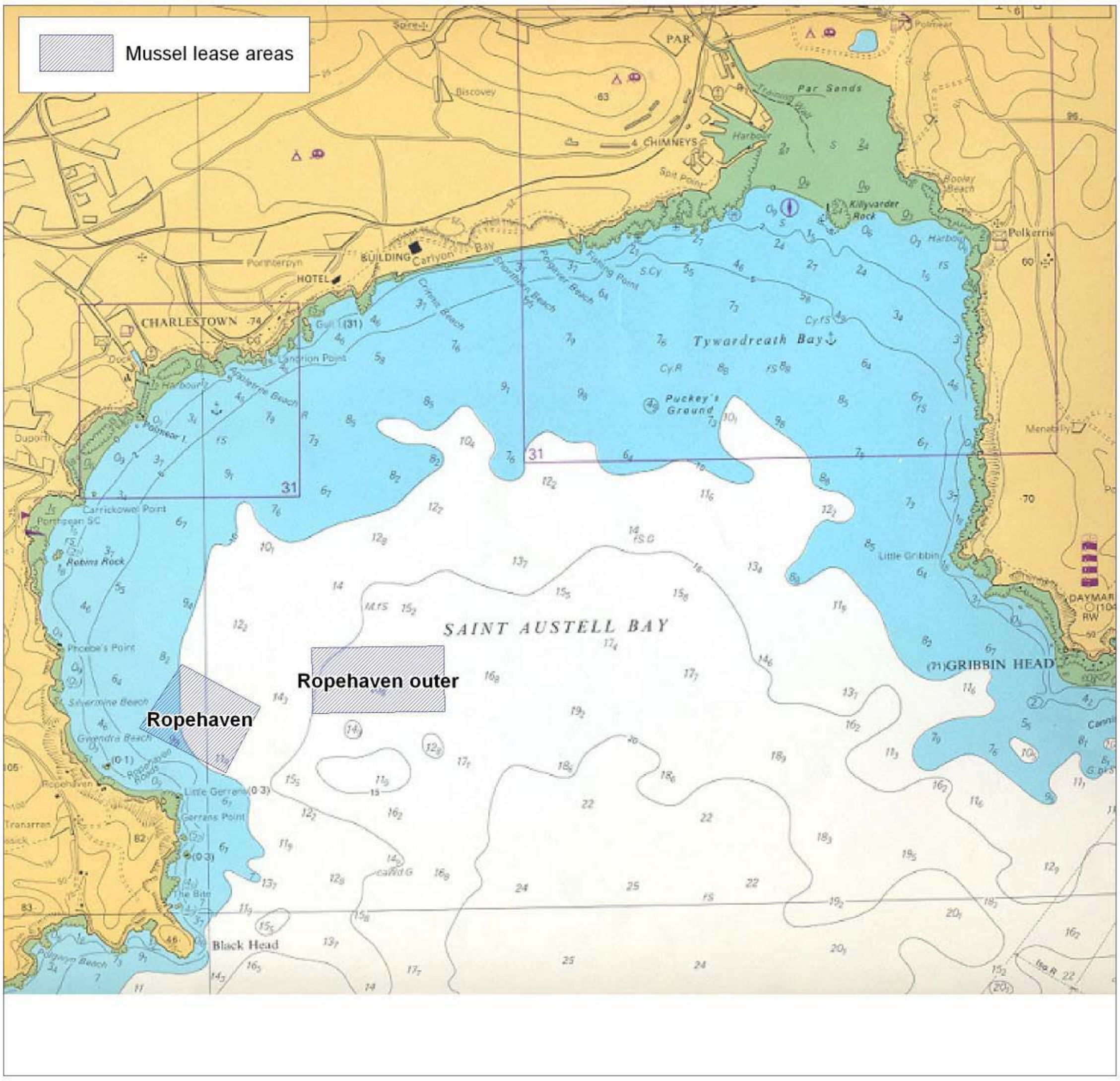

Figure IV.1 Bathymetry of St. Austell Bay.

APPENDIX V
HYDRODYNAMIC DATA: WATER CIRCULATION PATTERNS

TIDALLY DRIVEN CIRCULATION

Mean high and low water levels and the spring and neap tidal range are shown for the nearest ports to the proposed new harvesting area in St Austell Bay in Table V.1.

Table V.1 Tide levels and ranges in St Austell Bay.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Mevagissey	5.4	4.3	2.0	0.7	4.7	2.3
Charlestown	5.4	4.3	No data	No data	No data	No data
Par	5.1	4.0	1.8	0.6	4.5	2.2

Predictions for these secondary ports are based on Plymouth (Devonport). Data from Imray (2003).

Tidal currents on the inner continental shelf off Fowey Estuary mouth are generally bi-directional along the east-west plane, running parallel to the coast (Friend *et al*., 2006). Fennessy (1990) describes a maximum spring tide surface current velocity of approximately 0.4m s^{-1} a few kilometres offshore from the Fowey Estuary mouth.

Despite the moderately large tidal range in the area, tidal currents within St Austell Bay itself are very small. Sherwin and Jonas (1994) reported that currents exceed 0.25m s^{-1} near Gribbin Head and Black Head, at the south east and south west extremities of the bay. However, inside the bay tidally driven currents are so small (0.024m s^{-1}) that they can be effectively ignored (Sherwin and Jonas, 1994). There is a more significant and persistent eastward flow of unknown origin of about 0.06m s^{-1} along the 10m depth contour in the vicinity of the Par STW outfall (Sherwin *et al.*, 1997). This would carry contamination from the Par STW outfall away from the mussel lease areas.

No correlation was found between shellfish hygiene flesh sampling results from the Ropehaven mussel site and tidal state on either the spring/neap or high/low cycles at either depth sampled, although it must be noted that number of samples used in the analysis was low (Appendix XII).

Negligible tidal currents will mean that density effects (thermal and freshwater driven stratification) and wind driven currents will tend to predominate circulation in the area. These are more variable and less predictable than tidally driven currents as they depend on amount of heating and freshwater inputs and wind strength and direction. Also, patterns of circulation driven by these forces are likely to vary significantly through the water column.

DENSITY EFFECTS

In general terms, both warmer water and less saline water will originate at/near the shore from either freshwater inputs or the heating of shallow waters. As they are more buoyant they will form a seaward moving surface layer, in turn driving return flows in the opposite direction towards the bottom of the water column. Any thermal stratification is more likely to occur during summer, whereas salinity stratification may be expected more during the winter when freshwater inputs are generally higher. Sherwin and Jonas (1997) report the presence of very weak thermal and salinity stratification in St Austell Bay during summer, with decreasing density of surface water along transects heading north and east from the outfall (i.e. towards Par Beach and the head of the Bay).

WIND EFFECTS

Strong winds will modify surface currents within St Austell Bay. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2m s^{-1}) would drive a surface water current of about 1 knot or 0.5m s^{-1}. Therefore, under conditions of moderate to strong winds, wind driven currents are likely to dominate circulation within the bay, as well as inducing mixing and thereby reducing stratification. Sherwin and Jonas (1994) report that wind speeds of over 3-5m s^{-1} the top 5-8 m of the water column become mixed. Wind speeds of over 5m s^{-1} were recorded for just over half the time at Polruan in 2007. The prevailing wind direction is from the south west (Appendix VI).

PAR OUTFALL DYE RELEASE STUDY

Sherwin *et al.* (1997) report the results of a dye tracing study carried out in St Austell Bay where dye was released from the Par STW outfall for a period of 12 hours in August 1993 under conditions of light winds. As this is the most significant sewage discharge to the fishery, this study is of particular interest, although it only relates to the conditions experienced on the day. The dye plume was buoyant, and rose to the surface in the immediate vicinity of the outfall (although the plume did not always remain at the surface) and headed slowly northwards, away from the lease areas, at about 0.09m s^{-1} spreading as it progressed.

SUMMARY

Tidally driven circulation within the bay is almost negligible, so circulation is primarily driven by wind and density effects. Wind and density driven currents are dependent on meteorological conditions and are therefore quite variable in nature, and the speed and direction of circulation driven by these forces will vary significantly with depth. Therefore, it can be concluded that circulation within the bay is complicated, variable, and difficult to predict, and generally weak with strongest circulation under windy conditions.

APPENDIX VI
METEOROLOGICAL DATA: WIND

The southwest is one of the more exposed areas of the UK. The strongest winds are associated with the passage of deep depressions and the frequency and strength of depressions is greatest in the winter so mean wind and maximum gust speeds are strongest at this time of year. As Atlantic depressions pass the UK, the wind typically starts to blow from the south or southwest, but later comes from the west or northwest as the depression moves away. The frequency and strength of depressions is greatest in the winter half of the year and this is when mean speeds and gusts are strongest (Met Office, 2007). Another seasonal pattern noted was the increased prevalence of winds from the north east during spring.

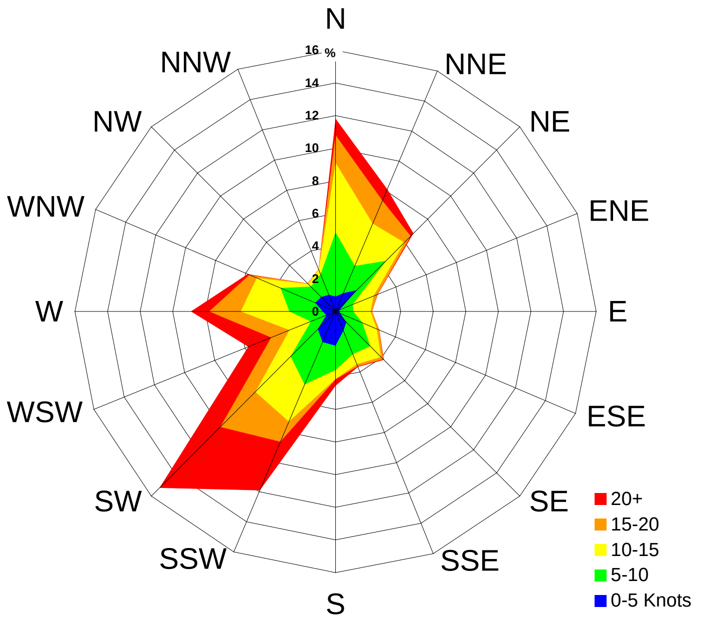

Figure VI.1 Percentage of wind speed and direction at Polruan for 2007.
Data provided by NCI Polruan meteorological station (2008).

Figure VI.1 shows that winds between SSW and W predominate and the strongest winds usually blew from these sectors. This weather station is located in the outer reaches of the Fowey estuary, which is a narrow steep sided valley with a north east to south west aspect at this point. Local topography would tend to funnel winds up and down the valley, so wind patterns are likely to be more skewed along this axis than they would be at St Austell Bay.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Continuous sewage discharges to St Austell bay are listed in Table VII.1.

Table VII.1 Continuous sewage discharges to St Austell Bay.

Name	Treatment	DWF (m^3/day)	Estimated bacterial loading (faecal coliforms/day)*	NGR of outfall	Distance (km via water) from	
					Ropehaven lease	Ropehaven outer lease
Par STW	Secondary	8,414	$2.8x10^{13}$	SX 0662 5088	2.5	1.5
Polkerris STW	Primary (screened)	117	$1.2x10^{13}$	SX 0912 5191	5.2	4.0
St Austell Menagwins STW	Tertiary (UV)	9,707	$2.7x10^{10}$	SX 0113 5086	8.1	8.5
Luxulyan (St Austell) STW	Tertiary (UV)	2,728	$2.2x10^{9}$	SX 0442 5814	12.4	11.4

*Based on dry weather flow and geometric mean concentrations of faecal coliforms in different effluent types from Table VII.2 except for Luxulyan STW where geometric mean faecal coliform concentration in samples of final effluent (Table XIII.1) was used.

The most significant of these is the secondary discharge from Par STW, which discharges to St Austell Bay via a sea outfall 2.5 and 1.5km to the northeast of the Ropehaven and Ropehaven outer Mussel leases respectively. An estimated loading of $4.2x10^{13}$ faecal coliforms/day is discharged to the bay through a 1.25km pipe with a 45m long diffuser head to a depth of 12m relative to Chart Datum. The design population equivalent for this discharge is 22,877 (resident) and 35,162 (resident and peak tourist).

There is a relatively small screened (primary) discharge at Polkerris on the Eastern part of St Austell Bay which generates an estimated bacterial loading about half that from Par STW. St Austell (Menagwins) STW discharges to the St Austell River which enters the sea to the south west of the new bed. The effluent from this STW receives year round UV disinfection and its estimated bacterial loading is about 3 orders of magnitude lower than that from Par STW. Finally, there is a small UV treated continuous discharge at Luxulyan STW to the Par River about 7.5 km upstream of its mouth, generating an estimated loading about 4 orders of magnitude less than Par STW. On the basis of a bacteriological survey undertaken by the Environment Agency, no impacts on the mussel lease areas are anticipated from this latter discharge (Appendix XIII). Reference concentrations of faecal coliforms in sewage discharges, subject to differing degrees of treatment, under low and high flow conditions are given in Table VII.2.

Table VII.2 Summary of reference faecal coliform levels for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

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

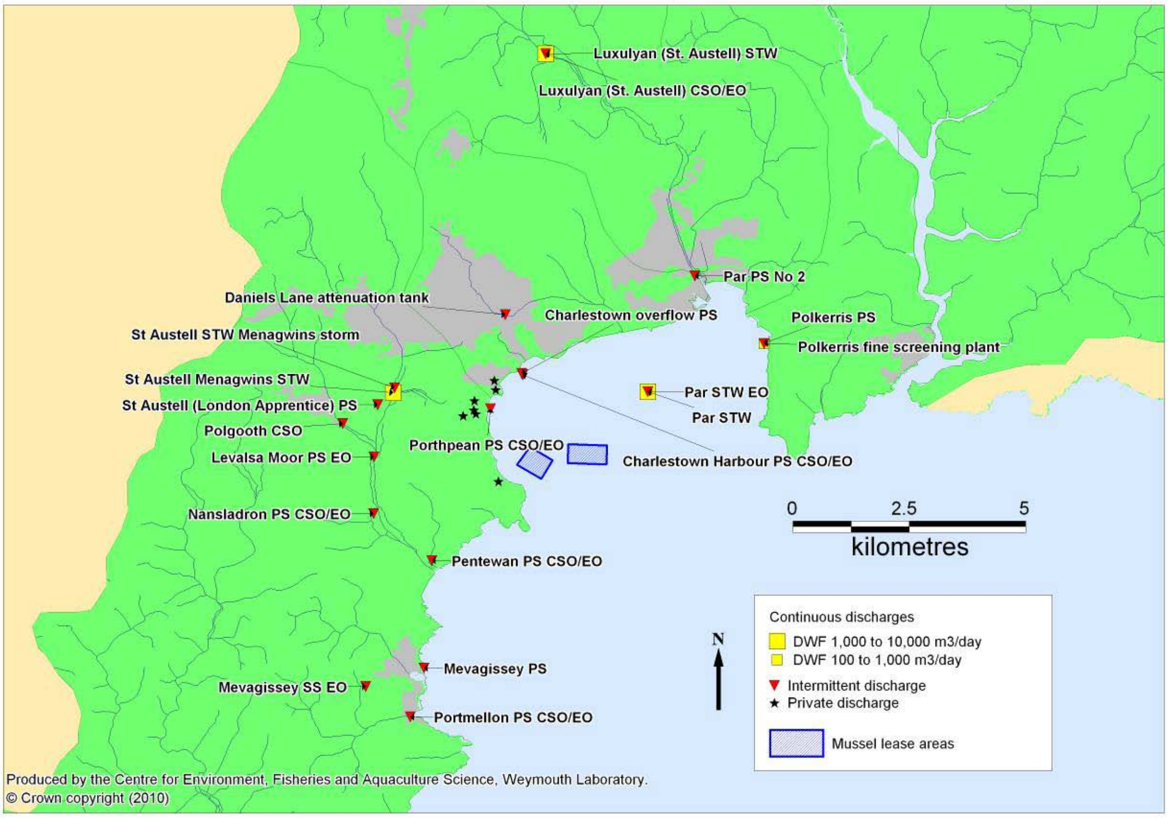

Figure VII.1 Sewage discharges to St Austell Bay.

As part of the dye tracing study on the dispersion of the effluent plume from Par STW, Sherwin *et al.* (1997) collected water samples for faecal coliform determination at various depths throughout the day of 13 August. The highest concentrations (up to 1,600 cfu/100 ml) were detected in the vicinity of the outfall, but diminished along the axis of the plume to levels below 100 cfu/100ml.

Intermittent sewage discharges can deliver highly contaminated water to coastal areas resulting from the rapid flushing of stored contaminants during storm conditions and/or the overloading during periods of heavy rainfall (Lee and Morgan, 2003). Contaminant microorganisms in these discharges can be rapidly accumulated by bivalves and deteriorate the microbiological quality of BMPAs (Younger *et al.*, 2003). Intermittent sewage discharges (emergency overflows and combined sewer overflows) directly to St Austell Bay and indirectly via St. Austell River are listed in Table VII.3.

Table VII.3 Intermittent sewage discharges to St Austell Bay.

Name	Receiving water	NGR of outfall	Distance (km via water) from Ropehaven lease	Ropehaven outer lease
Porthpean PS CSO/EO	St Austell Bay	SX 0323 5051	1.2	1.8
Charlestown Harbour PS CSO/EO	St Austell Bay	SX 0387 5120	1.5	1.8
Charlestown overflow PS	St Austell Bay	SX 0387 5120	1.5	1.8
Par STW EO	St Austell Bay	SX 0662 5088	2.5	1.5
Pentewan PS CSO/EO	St Austell River	SX 0197 4725	3.6	4.0
Mevagissey PS	Mevagissey Bay	SX 0180 4494	4.9	5.4
Par PS No 2	River Par	SX 0763 5337	4.9	3.9
Nansladron PS CSO/EO	St Austell River	SX 0071 4826	5.1	5.5
Polkerris PS	St Austell Bay	SX 0912 5191	5.2	4.0
Portmellon PS CSO/EO	Portmellon Stream	SX 0150 4389	5.9	6.5
Daniels Lane attenuation tank	Unnamed stream	SX 0355 5253	6.1	5.6
Levalsa Moor PS EO	St Austell River	SX 0072 4948	6.3	6.7
St Austell (London Apprentice) PS	St Austell River	SX 0080 5060	7.4	7.8
Polgooth CSO	Trib. of St Austell River	SX 0005 5019	7.4	7.8
Mevagissey SS EO	Portmellon Stream	SX 0054 4454	8.1	8.7
St Austell STW Menagwins storm	St Austell River	SX 0116 5096	8.1	8.5
Luxulyan (St. Austell) CSO/EO	River Par	SX 0442 5814	12.4	11.4

PS - pumping station
CSO - combined storm overflow
EO - emergency overflow
STW - sewage treatment works.
NGR - national grid reference.

The pumping station overflows at Porthpean and Charlestown are less than 2 km of both mussel leases and could contribute to background levels of contamination in the event of a storm or emergency sewage spill. No information on the frequency of spills from these discharges is available. The storm overflows from Par STW and Harbour Road (Par No 2) CSO were improved under AMP4 in 2006 to reduce spill frequency to an average of three spills per bathing season (May to September). There are several consented sewage discharges (soakaways) from domestic properties on the coast in the vicinity of Ropehaven. These discharges are to ground and are unlikely to have an impact on the levels of microbiological contamination in the bay.

Overall, the most significant sewage discharges to the mussel lease areas are Par STW (continuous and emergency overflow) and the pumping station overflows at Porthpean and Charlestown. Information on spill frequency and/or spill volumes were requested from the Environment Agency, but were not available at the time of writing.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Diffuse contamination from livestock will be carried into the bay via watercourses draining areas of pasture. The extent of this will depend not only on the numbers and distribution of livestock, but also rainfall patterns, soil permeability, slope, and the degree of separation between livestock and watercourses. To capture contamination of livestock origin RMPs should be set in a position which most exposes them to plumes originating from these watercourses. The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.1.

Table VIII.1 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Farm Animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^{8}
Pig	3,300,000	2,700	8.9×10^{8}
Human	13,000,000	150	1.9×10^{9}
Cow	230,000	23,600	5.4×10^{9}
Sheep	16,000,000	1,130	1.8×10^{10}

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

Livestock production is one of the main activities taking place in catchments bordering St. Austell Bay. Figure VIII.1 shows the numbers of farmed animals by category and catchment area from the June 2008 agricultural survey undertaken by Defra. As the tidal Fowey catchment drains through the Fowey estuary and not to St Austell Bay it is unlikely that livestock within this and the wider Fowey catchment are a significant contaminating influence on St Austell Bay. A total of 20,897 cattle, 1,862 pigs and 17,407 sheep were recorded in the three catchments with direct hydrological connections to St Austell Bay. Overall numbers and densities of cattle, pigs and sheep were lowest within the Crinnis catchment (2,309 at 113 animals km^{-2}). Densities were similar within the Par and St Austell catchments (192 and 208 animals km^{-2} respectively) but overall numbers were higher in the St Austell catchment (24,975) than in the Par catchment (12,881). On this basis the overall *E. coli* loading generated by the St Austell catchment is likely to be highest, and that generated by the Crinnis catchment lowest.

During the shoreline survey, approximately 25 cattle were recorded on pasture at Castle Gotha on the west shore of St Austell Bay so some contaminated runoff from pastures may be expected along the shore adjacent to the mussel leases. However, the presence of buffer strips and fences along watercourses was noted during the shoreline survey that farms located along the west shore of St Austell Bay, which would reduce their impacts. Cattle were also recorded in the vicinity of Tregaminion, by Polkerris.

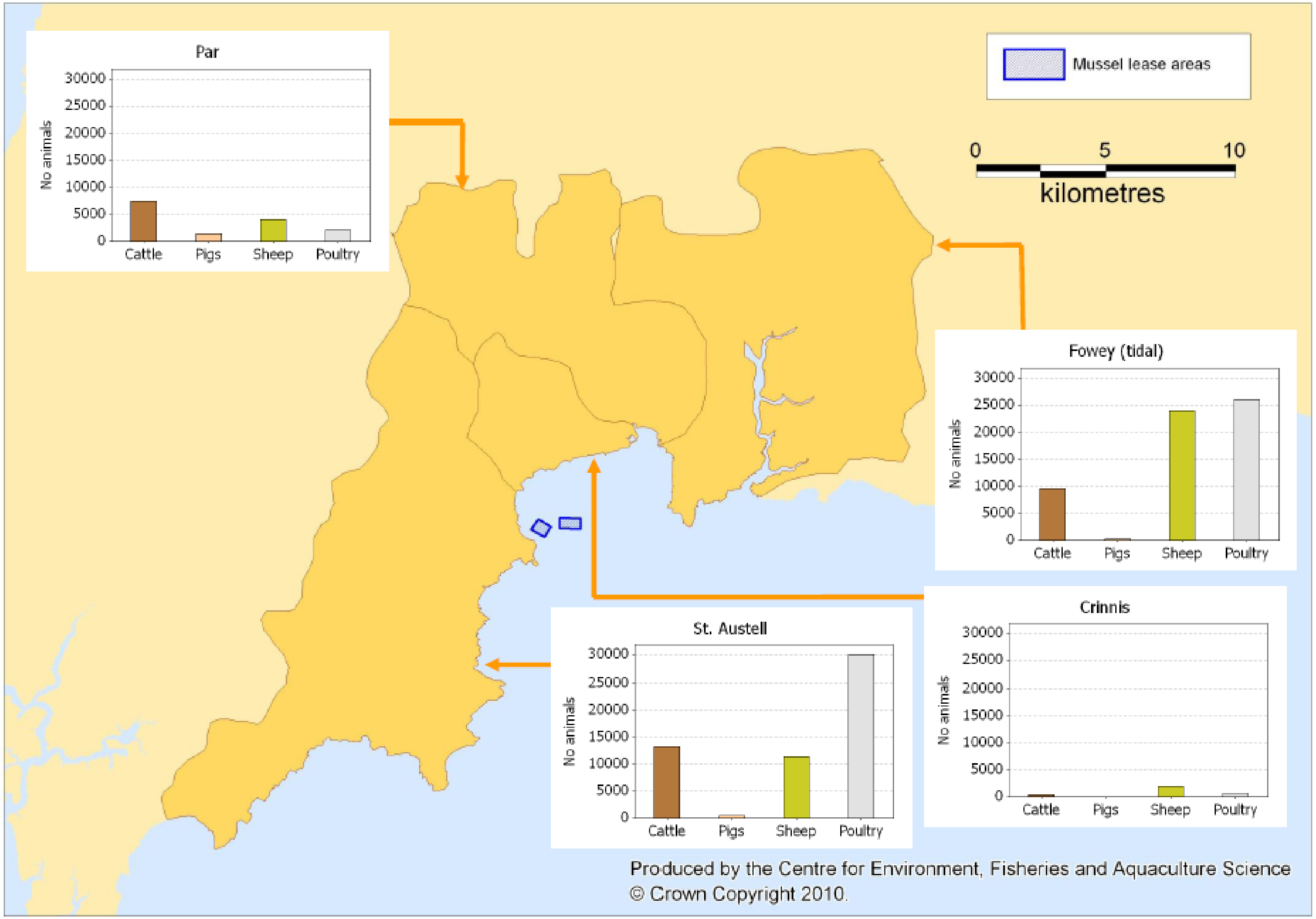

Figure VIII.1 Livestock numbers in river catchments bordering St Austell Bay

There is likely to be seasonality in levels of contamination originating from livestock. Numbers will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During winter livestock may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Therefore it is likely that peak levels of contamination from livestock on pastures will arise in the bay following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a buildup of faecal material on pastures.

Many farms in Cornwall do not have long-term storage capacity for slurries and manure and, therefore, maintain these as a pile in fields (Roderick and Burke, 2004; Lizbe Pilbeam, Natural England, pers. comm.). For this reason, most farmers frequently apply manure and slurries during the winter, throughout the spring (February–March) for spring growth and some are applied in the autumn for winter cereals. Winter spreading is usually more frequent as farmers try to avoid over-topping their slurry stores. Fewer quantities are retained for the late spring and summer for second and third cut silage applications. Sewage sludge is usually applied to land in February–March and in September (Lizbe Pilbeam, Natural England, pers. comm.).

In conclusion, there are significant numbers of livestock within the St Austell Bay catchment area, and so livestock are likely to contribute a proportion of the indicator bacteria found within shellfish here. The magnitude of the flux of contamination from livestock to coastal waters is likely to be dependent on rainfall. Some seasonality is expected, possibly with greatest impacts following summer storms when numbers of grazing animals on pastures are likely to be highest, or in wet weather during the winter and spring in more localised areas where slurry or manure has recently been applied.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

Boating activities in St. Austell Bay are represented in Figure IX.1. Mevagissey is the main harbour in St. Austell catchment. There are other minor ports within the bay such as Charlestown and Polkerris. The port of Mevagissey has supported an important traditional fishing industry and presently there are 63 registered fishing vessels in the harbour, most of them under 10m length (Mevagissey Harbour, 2008).

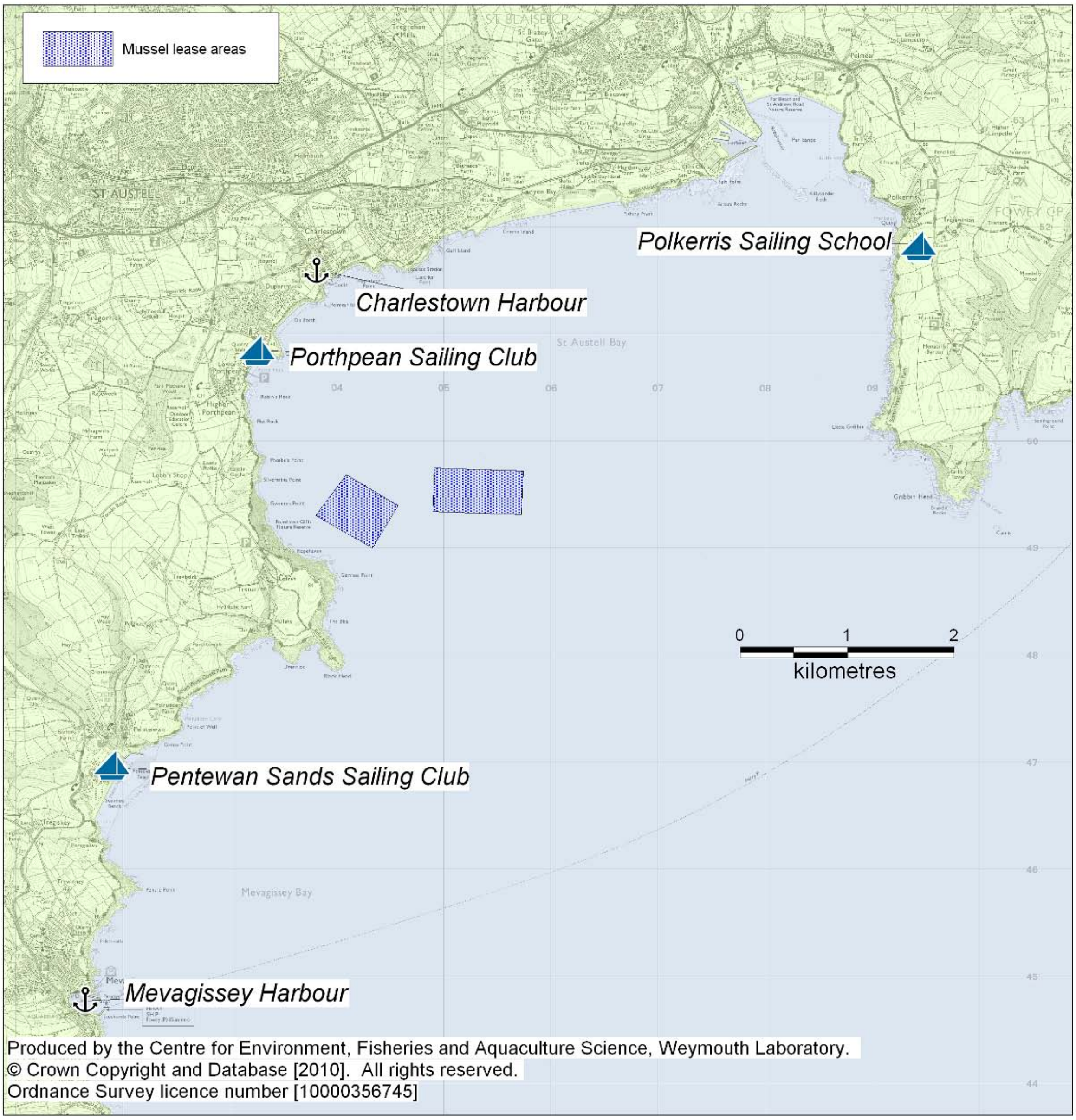

Figure IX.1 Boating activities in St. Austell Bay.

Locally, Porthpean Sailing Club has approximately 80 members and Pentewan Sands SC has 110 members. There is also a sailing school at Polkerris offering a number of water-based recreational activities on a seasonal basis and accommodation in 7 caravans (Polkerris Beach Co, 2009).

The low overall boating activity in St. Austell Bay, boats are not considered to represent a significant risk of microbiological contamination to the proposed BMPA.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

The whole coastal area of St. Austell Bay supports a significant community of birds, particularly woodland, farmland and coastal species in the Cornwall Area of Outstanding Natural Beauty, on the West facing valley of the Pentewan Valley adjacent to St. Austell River.

The Ropehaven Cliffs Nature Reserve includes an area (approximately 20 hectares) of cliffs and woodland and is the nearest most important habitat for birds to the mussel production area. This nature reserve is important for nesting birds and Fulmars (*Fulmarus glacialis*) which use the cliffs as a nesting area (RSPB, 2008; Cornwall Wildlife Trust, 2009). Table X.1 summarises counts of seabirds in four coastal sites in the bay during the breeding season (lat spring/early summer).

Table X.1 Number of occupied nests by seabird species monitored in four sites in St. Austell Bay.

Species	Common name	Number of occupied nests per site (site counts per 1km length)			
		Par SX 077533	Carlyon Bay SX 055521	St. Austell SX 025525	Black Head SX 041479
Phalacrocorax carbo	Great Cormorant	-	1	-	1
Phalacrocorax aristotelis	European Shag	-	2	-	31
Larus marinus	Great Black-Backed Gull	-	1	-	4
Larus fuscus	Lesser Black-Backed Gull	-	-	-	-
Larus argentatus	Herring Gull	12	46	11	-
Fulmarus glacialis	Northern Fulmar	-	7	-	-

Data supplied by Seabird 2000 (Joint Nature Conservation Committee).

Bird faeces deposited directly onto the rocky shores at Robin's Rock (Porthpean Beach) were observed during the shoreline survey. Previous studies have indicated significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) in intertidal sediment samples in the Northwest UK supporting large communities of birds (Obiri-Danso and Jones, 2000).

Literature also indicates that bird abundance is inversely correlated with the total roosting area made available by the floating gear and that floater instability is an important factor determining the presence of birds on longline systems (Comeau *at al*., 2009).

Plastic floats supporting the two longlines at Ropehaven offer a small area where birds could rest. From the observations made during the shoreline survey, the plastic floats seemed to be sufficiently unstable to deter the presence of birds and this could be the reason why no bird faeces were seen on the floats. Given the arguments above, the diffuse nature of contamination from birds and the small scale of the operation, it is considered that birds roosting on floats located along the longline do not present a risk of contamination.

The beaches in St. Austell Bay are very popular for dog walking. Dog walking is allowed throughout the year in Par Beach. Polkerris and Porthpean beaches have a seasonal dog ban from Easter day to 1 October. Dog walking is not allowed throughout the year in Crinnis, Duporth and Charlestown beaches (Visit Cornwall *et al*., 2007). Dog faeces therefore present a potential source of contamination to nearshore shellfish beds especially those on intertidal areas. The location of the mussels lines in St Austell Bay are not considered vulnerable in this respect.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are twelve bathing waters sites within 10 km of the fishery, designated under the Directive 76/160/EEC (Council of the European Communities, 1976) (Figure XI.1). Around 20 samples were taken from each of these sites during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples.

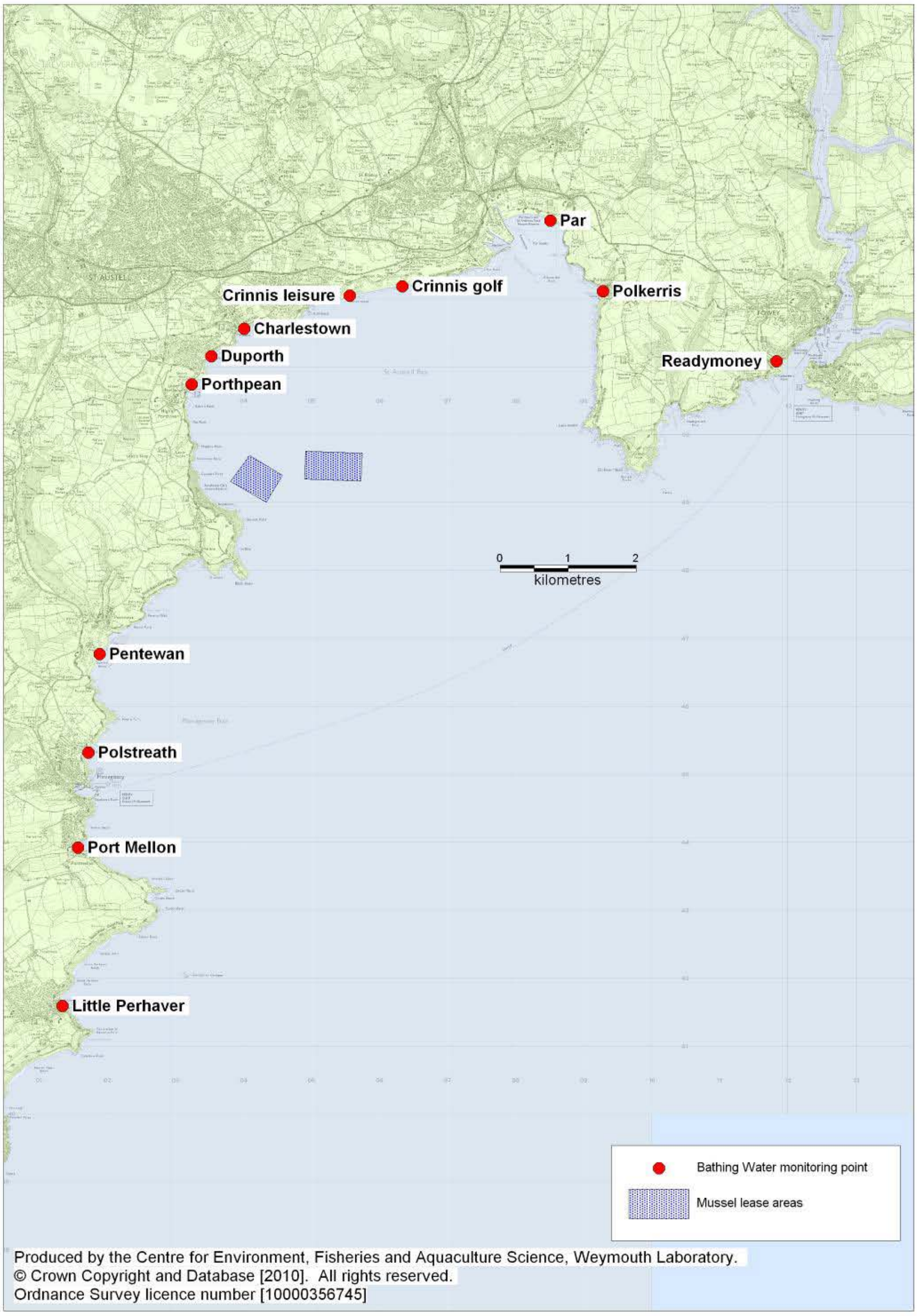

Figure XI.1 Location of bathing waters monitoring points

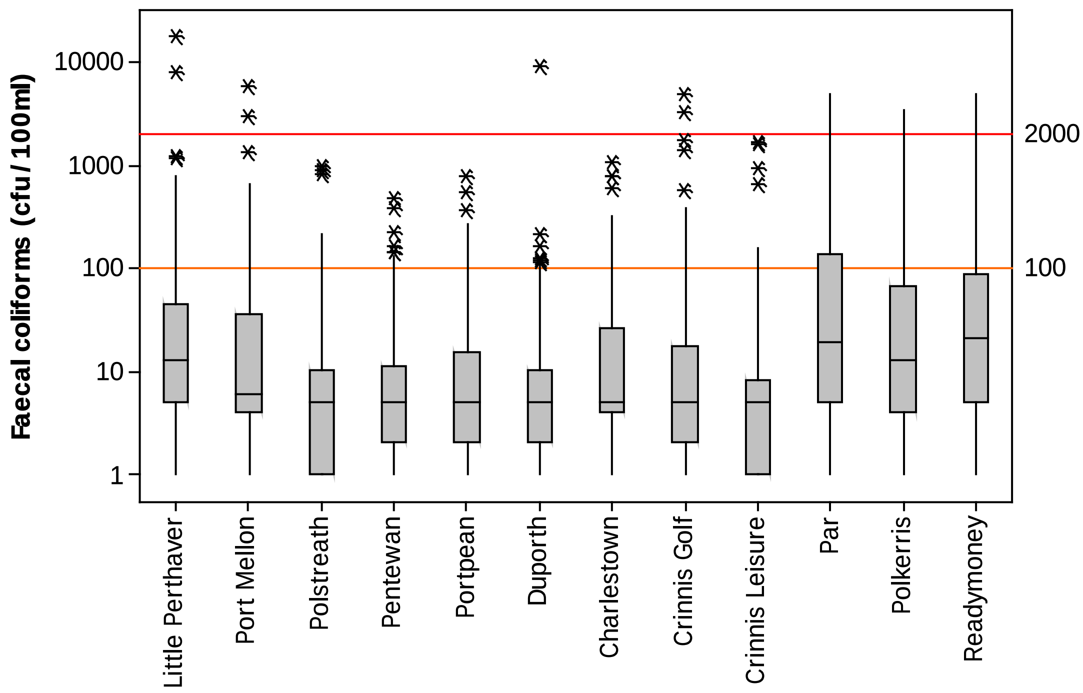

Figure XI.2 Box and whisker plot of faecal coliforms in the twelve designated bathing waters in the vicinity of St Austell Bay.

Geometric mean results were relatively low overall. Higher levels of faecal coliforms were found at the western end of the bay (Polkerris and Par), with lower levels of contamination generally found between Crinnis Leisure and Polstreath, and increasing again at the two most south western sites (Port Mellon and Little Perthaver). The highest recorded result arose at Little Perhaver.

Table XI.1 Summary statistics of faecal coliforms in the twelve designated bathing waters in the vicinity of St Austell Bay

Bathing Water	Date of first sample	Date of last sample	n	Min.	Max.	Median	Geometric mean
Little Perhaver	04 May 2000	22 Sep 2009	199	<2	18,000	13	15
Port Mellon	04 May 2000	22 Sep 2009	199	<2	6,000	6	11
Polstreath	04 May 2000	22 Sep 2009	199	<2	973	5	4
Pentewan	03 May 2000	22 Sep 2009	199	<2	480	5	5
Porthpean	03 May 2000	22 Sep 2009	199	<2	786	5	6
Duporth	03 May 2000	22 Sep 2009	180	<2	9,200	5	5
Charlestown	03 May 2000	24 Sep 2009	196	<2	1056	5	9
Crinnis golf	03 May 2000	24 Sep 2009	200	<2	39,000	5	10
Crinnis leisure	03 May 2000	24 Sep 2009	200	<2	1,656	5	5
Par	03 May 2000	24 Sep 2009	200	<2	5,000	20	23
Polkerris	03 May 2000	24 Sep 2009	200	<2	3,462	13	14
Readymoney	03 May 2000	24 Sep 2009	200	<2	5,000	21	23

To investigate the effects of land runoff on levels of contamination in mussels Spearman's rank correlations were carried out between flows recorded at the

Molingey gauging station on the St Austell River and rainfall recorded at the Luxulyan weather station over various periods running up to sample collection. These are presented in tables XI.2 and XI.3 respectively. Statistically significant correlations ($p<0.05$) are highlighted in yellow. Continuous flow data from Molingey was available for 2004 to 2009, and rainfall data from Luxulyan was available for the majority of bathing waters samples taken from 2003 to 2009.

Tables XI.2 and XI.3 suggest that Luxulyan rainfall is a better general predictor of levels of contamination at these bathing waters sites than flows recorded at Molingey. Rainfall recorded more than 4 days prior to sampling was not correlated with increased levels of contamination, which is consistent with the relatively small catchment area of St. Austell Bay. Sites nearest to freshwater inputs tended to show the strongest correlations with rainfall (Readymoney, Par, Crinnis golf, Crinnis Leisure) as may be expected. Strong correlations with rainfall were also found at Polkerris, which is not immediately adjacent to any freshwater inputs but may be influenced by the Par River, which discharges about 1.5km from this site. There is also an intermittent sewage discharge at Polkerris which may operate in wet weather. All but one of the 12 sites showed some correlations with rainfall or river flow, indicating widespread but somewhat spatially variable impacts from rainfall related sources in the inshore areas at least. Surprisingly, Pentewan, which is located adjacent to where the St Austell River discharges was the only site for which no significant correlations were found either with rainfall or flow data.

Table XI.2 Spearman's Rank correlations between mean daily flows recorded at the Molingey gauging station and Bathing Waters sample results from St Austell Bay (2004-2009)

		24 hour periods prior to sampling								Total prior to sampling over					
	No.	Day of sampling	1 day	2 days	3 days	4 days	5 days	6 days	7 days	2 days	3 days	4 days	5 days	6 days	7 days
Charlestown	103	0.171	0.138	0.140	0.108	0.087	0.073	0.031	0.044	0.165	0.157	0.15	0.135	0.126	0.117
Crinnis golf	107	0.248	0.24	0.231	0.140	0.153	0.124	0.102	0.117	0.255	0.249	0.228	0.214	0.207	0.191
Crinnis leisure	107	0.079	0.069	0.062	0.013	-0.012	-0.031	-0.050	-0.030	0.076	0.071	0.057	0.04	0.033	0.014
Duporth	87	0.239	0.207	0.169	0.166	0.172	0.174	0.106	0.133	0.236	0.214	0.203	0.201	0.2	0.189
Little Perhaver	106	0.152	0.115	0.078	0.056	0.034	0.056	0.026	0.061	0.136	0.126	0.1	0.093	0.086	0.086
Par	107	0.364	0.338	0.317	0.241	0.237	0.192	0.196	0.154	0.359	0.35	0.328	0.311	0.299	0.280
Pentewan	106	-0.073	-0.023	-0.018	-0.069	-0.083	-0.057	-0.128	-0.123	-0.051	-0.037	-0.035	-0.049	-0.045	-0.050
Polkerris	107	0.315	0.287	0.26	0.213	0.172	0.138	0.129	0.132	0.308	0.299	0.286	0.261	0.246	0.230
Polstreath	106	0.125	0.116	0.085	0.031	0.062	0.048	-0.066	-0.049	0.128	0.118	0.094	0.091	0.088	0.075
Port Mellon	106	0.017	-0.02	-0.006	-0.059	-0.078	-0.096	-0.175	-0.118	0.002	0.000	-0.015	-0.028	-0.035	-0.047
Porthpean	106	0.145	0.075	0.06	0.035	0.030	0.035	-0.035	0.002	0.123	0.100	0.084	0.079	0.074	0.060
Readymoney	107	0.399	0.401	0.372	0.340	0.308	0.28	0.283	0.251	0.405	0.402	0.394	0.378	0.371	0.359

Table XI.3 Spearman's Rank correlations between rainfall recorded at the Luxulyan weather station and Bathing Waters sample results from St Austell Bay (2003-2009)

		24 hour periods prior to sampling								Total prior to sampling over					
	No.	Day of sampling	1 day	2 days	3 days	4 days	5 days	6 days	7 days	2 days	3 days	4 days	5 days	6 days	7 days
Charlestown	121	0.259	0.227	0.175	0.192	0.089	-0.031	-0.028	-0.025	0.282	0.292	0.311	0.31	0.266	0.198
Crinnis golf	125	0.407	0.295	0.292	0.244	0.067	0.061	-0.026	-0.015	0.394	0.407	0.394	0.379	0.340	0.290
Crinnis leisure	125	0.440	0.375	0.224	0.254	-0.019	-0.048	-0.090	-0.032	0.445	0.396	0.371	0.325	0.296	0.227
Duporth	103	0.247	0.235	0.047	0.139	0.041	0.142	-0.016	0.074	0.247	0.194	0.195	0.169	0.191	0.168
Little Perhaver	126	0.205	0.230	0.118	-0.113	0.043	-0.019	-0.024	0.008	0.241	0.224	0.160	0.164	0.158	0.138
Par	125	0.457	0.327	0.317	0.275	0.264	0.109	0.139	-0.017	0.426	0.473	0.428	0.447	0.428	0.400
Pentewan	126	-0.079	-0.031	-0.024	0.094	0.000	-0.023	-0.049	-0.003	-0.111	-0.026	0.028	0.037	0.023	0.024
Polkerris	125	0.545	0.453	0.350	0.405	0.196	-0.019	0.047	-0.009	0.533	0.543	0.553	0.542	0.503	0.447
Polstreath	126	0.327	0.278	0.258	0.071	0.239	0.044	0.088	0.007	0.306	0.387	0.345	0.357	0.363	0.325
Port Mellon	126	0.242	0.272	0.232	0.130	0.055	-0.014	-0.035	0.086	0.266	0.298	0.294	0.266	0.24	0.199
Porthpean	126	0.288	0.208	0.124	0.128	0.003	0.055	-0.110	-0.087	0.221	0.228	0.230	0.183	0.202	0.160
Readymoney	126	0.409	0.333	0.257	0.348	0.115	-0.039	0.118	0.007	0.396	0.415	0.439	0.454	0.414	0.402

Shellfish Waters

St Austell Bay does not coincide with any Shellfish Growing Waters designated under the Shellfish Water Directive (2006/113/EC, European Communities, 2006b).

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

At the time of writing (Aug 2010) shellfish hygiene monitoring results for one mussel sampling location within St Austell Bay were listed on the SHS database. This RMP (B070W) is within the Ropehaven mussel site (Figure XII.1) and a total of 34 valid samples have been taken from here since March 2008. Of these samples six had a reported result of <20 *E. coli* MPN/100g, and these were assigned a nominal value of 10 for the following analyses.

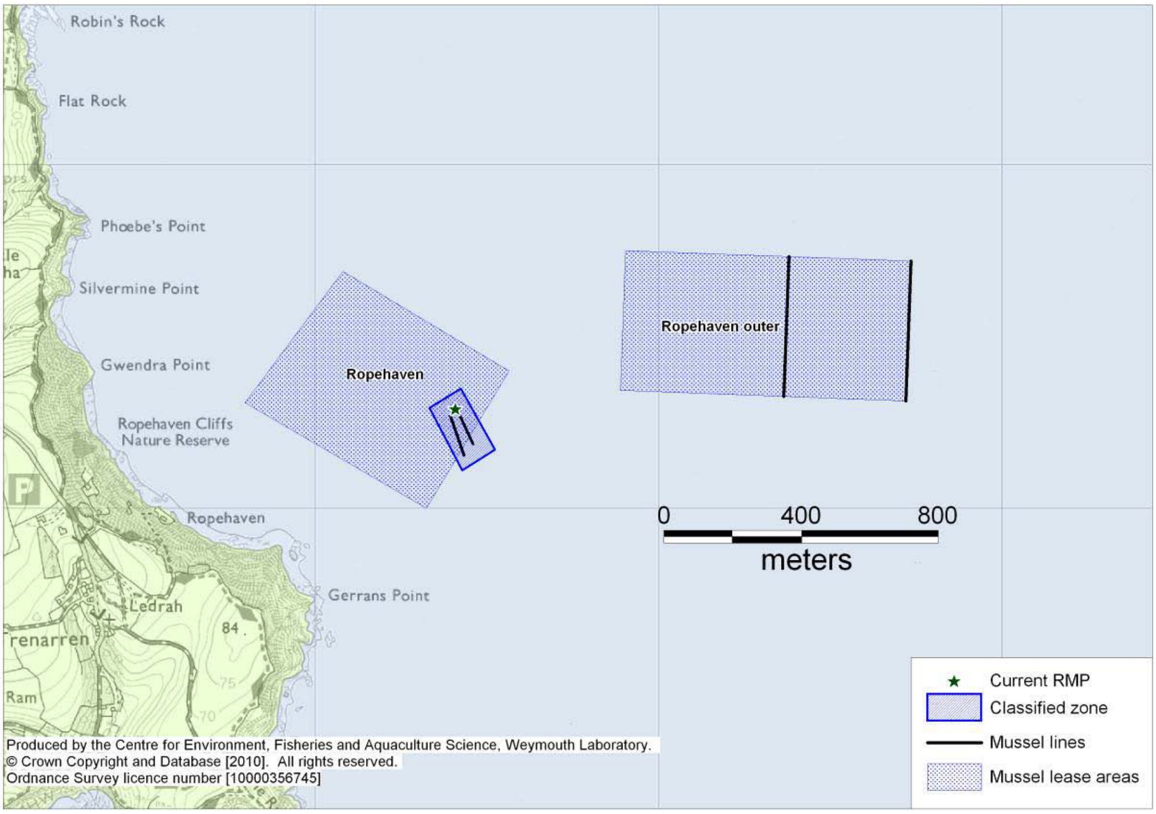

Figure XII.1 Location of St Austell Bay - Ropehaven shellfish hygiene monitoring point

Of these 34 samples, 20 were taken during the course of a bacteriological survey instigated during the course of the previous sanitary survey of this area. These 20 samples were taken on 10 occasions, with one sample taken from 2m depth and one from 6m depth each time, and were subsequently used for classification purposes so are presented in this section together with the other hygiene monitoring results. Table XII.1 shows summary statistics by sampling depth.

Table XII.1 Summary statistics for all mussel samples taken from St Austell Bay (B070W)

Depth	Date of first sample	Date of last sample	No.	*E. coli* result (MPN/100g) Min.	Max.	Median	Geometric mean
2m	26 Mar 2008	06 Jul 2010	24	<20	790	50	54
6m	30 Mar 2009	13 Aug 2009	10	<20	130	45	33

As only one location was sampled, this dataset did not allow the investigation of geographical patterns in levels of contamination. The 10 occasions when samples were taken from 2m and 6m depth allow a direct comparison of levels of contamination at these two depths. Figure XII.2 presents a box and whisker plot of these paired results.

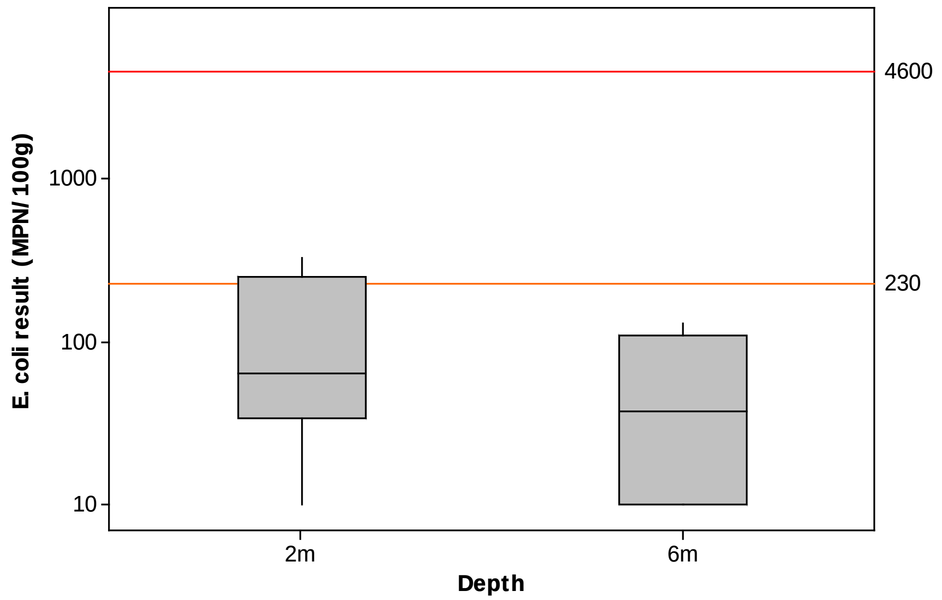

Figure XII.2 Box and whisker plots of paired mussel sample results from St Austell Bay at 2 and 6m depth

Of these 10 sampling occasions results were higher at 2m depth on 8 occasions, identical on one occasion, and lower at 2m depth on one occasion. Results were higher on average at 2m depth (geometric mean = 71 *E. coli* MPN/100g) than at 6m depth (geometric mean = 33 *E. coli* MPN/100g). The difference in mean result was not quite statistically significant (paired T-test, t=2.05, p=0.071). No samples contained more than 230 *E. coli* MPN/100g at 6m depth, whereas results for 2 of 10 samples at 2m depth exceeded this. Therefore it is concluded that levels of contamination were slightly higher towards the surface, and that this effect was fairly consistent so on this basis an RMP set at 2m depth would be best protective of public health.

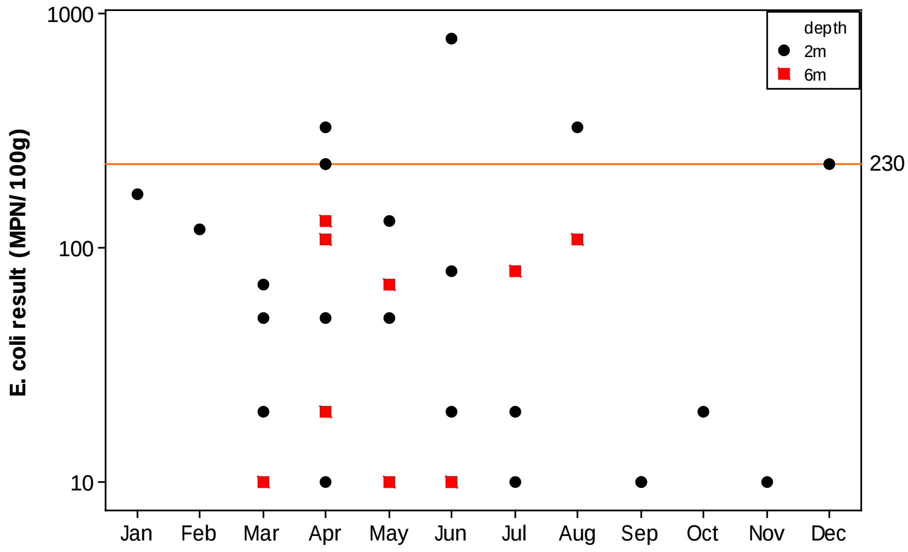

Figure XII.3 Scatter plot of all mussel sample results from St Austell Bay by month

The results presented here very tentatively suggest highest levels of contamination during the winter, and lowest levels during the autumn. However, sample numbers are too low to draw any firm conclusions regarding seasonality in levels of contamination here, with only 3 samples taken during the autumn and 3 during the winter.

To investigate the effects of land runoff on levels of contamination in mussels Spearman's rank correlations were carried out between flows recorded at the Molingey gauging station on the St Austell River and rainfall recorded at the Luxulyan weather station over various periods running up to sample collection. Statistically significant correlations ($p<0.05$) are highlighted in yellow in table XII.2.

Table XII.2 Spearman's Rank correlations between flows recorded at the Molingey gauging station and rainfall recorded at the Luxulyan weather station and mussel sample results from St Austell Bay

Sampling depth		2m	6m	2m	6m
Variable		Molingey flow	Molingey flow	Luxulyan rainfall	Luxulyan rainfall
No. samples		23	10	22	10
24 hour periods prior to sampling	Day of sampling	-0.058	0.477	-0.116	0.094
	1 day	0.306	0.577	0.124	0.696
	2 days	0.229	0.458	0.026	0.583
	3 days	0.056	-0.119	-0.104	0.104
	4 days	0.077	-0.213	-0.272	-0.201
	5 days	-0.012	-0.069	-0.278	-0.22
	6 days	0.154	0.006	-0.083	-0.068
	7 days	0.231	0.088	-0.098	-0.253
Total prior to sampling over	2 days	-0.026	0.646	-0.146	0.551
	3 days	-0.013	0.690	-0.157	0.525
	4 days	-0.001	0.540	-0.235	0.393
	5 days	0.028	0.533	-0.230	0.408
	6 days	-0.004	0.527	-0.281	0.409
	7 days	0.034	0.533	-0.252	0.389

Significant positive correlations were found between hygiene results and both river flow and rainfall for the samples taken at 6m depth, but no correlations were found for those taken at 2m depth. This is surprising as freshwater borne contamination may be expected to float on the surface above more dense salt water in the absence of mixing forces. These correlations must be treated with some caution however due to the small numbers of samples involved.

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase. Figure XII.4 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

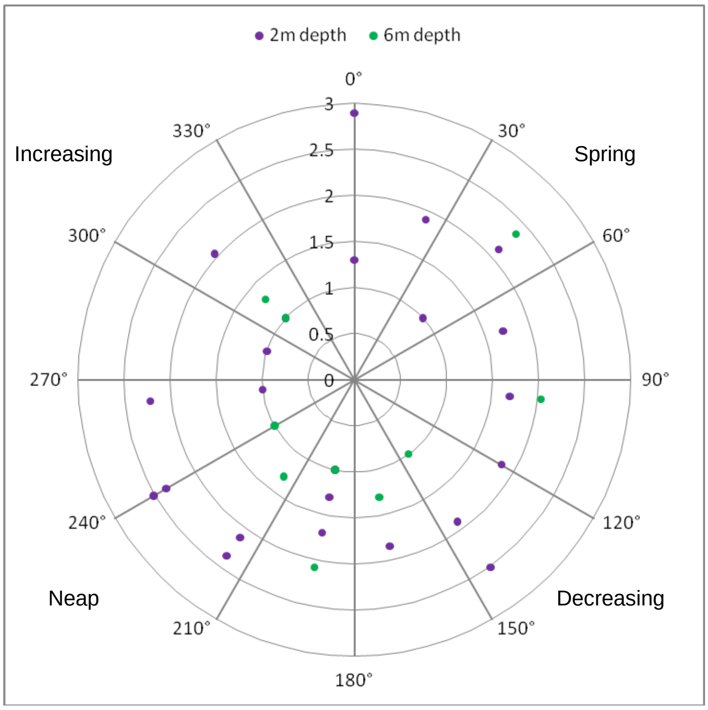

Figure XII.4 Polar plot of log_{10} E. coli result against tidal state on the spring/neap tidal cycle

No correlation between *E. coli* results and tidal state on the spring neap cycle was found for samples collected from 2m depth (circular-linear correlation, r=0.169, p=0.549) or from 6m depth (circular linear correlation, r=0.635, p=0.050). No strong patterns are apparent in Figure XII.4, although for samples from 6m depth higher results arose around spring tides and lower results arose during neap tides. This tentative observation must be treated with caution however due to the low sample numbers.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure XII.5 presents a polar plot of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is at 0º, and low water is at 180º.

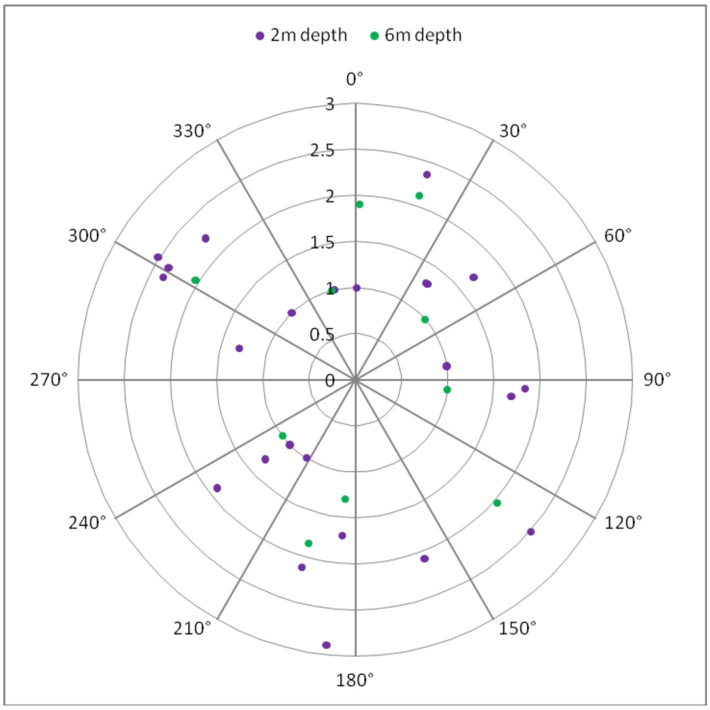

Figure XII.5 Polar plot of $\log_{10}$ E. coli result against tidal state on the high/low tidal cycle

No correlation between *E. coli* results and tidal state on the high low cycle was found for samples collected from 2m depth (circular-linear correlation, r=0.193, p=0.458) or from 6m depth (circular linear correlation, r=0.070, p=0.957). No strong patterns are apparent in Figure XII.4

APPENDIX XIII
MICROBIOLOGICAL DATA: BACTERIOLOGICAL SURVEYS

INVESTIGATIONS UNDERTAKEN BY THE ENVIRONMENT AGENCY – BACTERIOLOGICAL SURVEY OF WATERCOURSES DISCHARGING TO ST AUSTELL BAY

From 2004 to the time of writing, the Environment Agency had taken multiple water samples from selected locations within some of the watercourses draining into St Austell Bay. These were taken alongside the bathing waters samples reported in Appendix XI (i.e. from May to September) and tested for faecal coliforms (presumptive). As faecal coliforms were not confirmed by the testing laboratory these results are not directly comparable with the bathing waters results. Presenting and interpreting this dataset in its entirety is beyond the scope of this report, but some of the sampling results are of relevance and are discussed below.

Three streams discharging to the north shore of St Austell Bay were sampled on multiple occasions – the Crinnis stream, the Par and an unnamed stream at the eastern end of Par Beach (Figure XIII.1). Also of interest are samples taken from upstream and downstream of the Luxulyan (St Austell North) STW. Samples of final effluent from the works were also taken on these occasions, permitting a robust assessment of the impact of these works on water quality within the Par River. Summary statistics for these sampling locations are presented in Table XIII.1.

Table XIII.1 Summary statistics for selected locations sampled by the Environment Agency

				Faecal coliforms presumptive (cfu/100ml)			
Site	Date of first sample	Date of last sample	No.	Min.	Max.	Median	Geometric mean
Crinnis stream	01 May 2004	28 Jun 2010	118	2	26,000	346	393
Par River (A3082)	11 Mar 2004	04 Jul 2010	222	8	150,000	1,500	1,974
Par beach stream	11 Mar 2004	04 Jul 2010	226	66	280,000	800	899
Par River u/s STW	12 Jul 2006	29 Jun 2010	64	4	100,000	1,980	2,081
Par River d/s STW	12 Jul 2006	29 Jun 2010	64	154	100,000	2,180	2,913
STW effluent	12 Jul 2006	29 Jun 2010	64	2	30,000	40	79

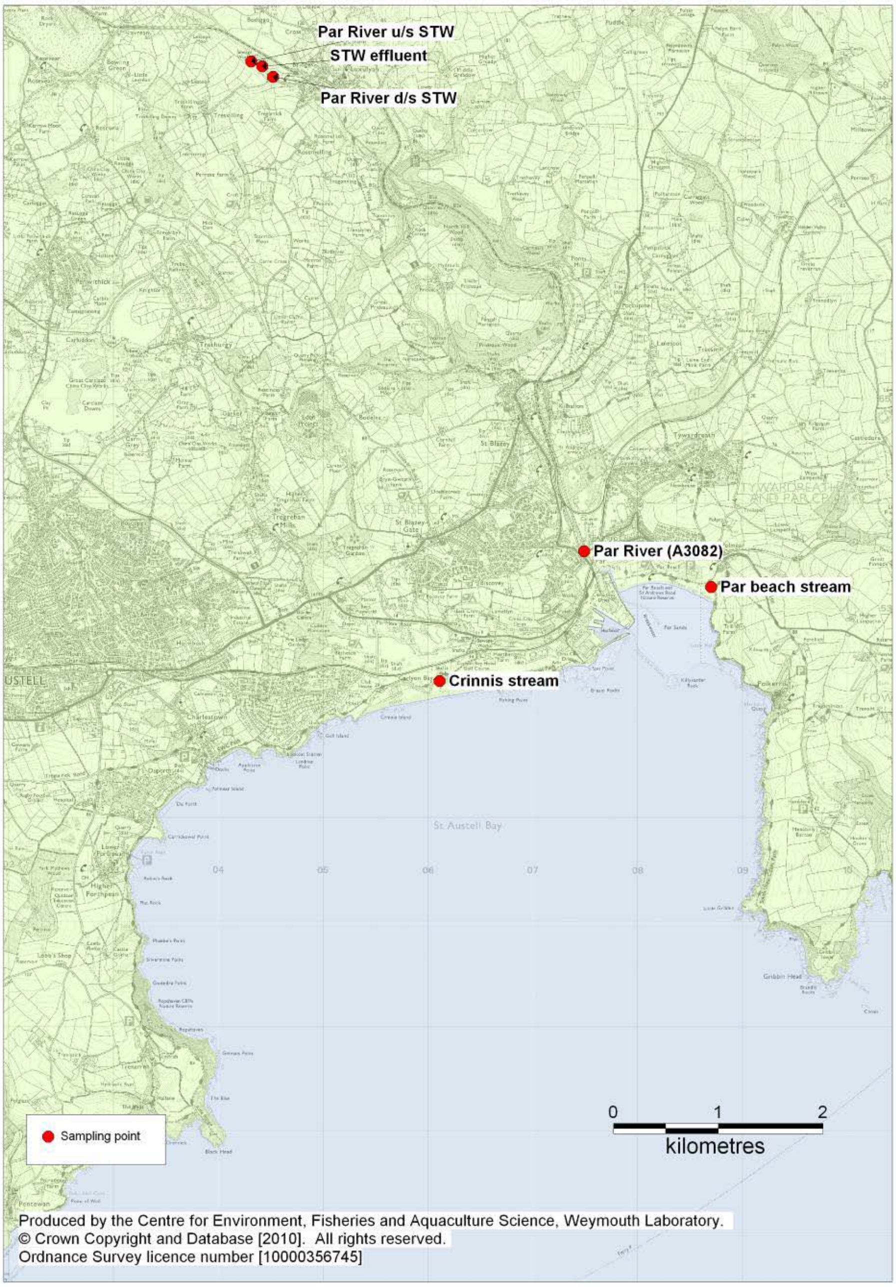

Figure XIII.1 Selected locations sampled by the Environment Agency

Geometric mean levels of faecal coliforms ranked as Par River (A3082) > Par Beach Stream > Crinnis Stream and results from these three sites all differed significantly from each other (One-way ANOVA, p=0.000, Tukeys comparison). All of these watercourses were found to carry very high levels of contamination (>10,000 faecal coliforms/100ml) on several occasions.

Although levels of faecal coliforms were slightly higher on average downstream of the St Austell North STW compared to upstream, the final effluent from this works contained much lower levels of faecal coliforms than that in the Par River upstream of the works, and the geometric mean levels of faecal coliforms were lower than those indicated for UV treated discharges in Table VII.2, so it may be concluded that the UV treatment is effective and this discharge has a negligible impact on levels of contamination within St Austell Bay.

To investigate the effects of recent rainfall on the concentration of faecal coliforms in these watercourses Spearman's rank correlations were carried out between these results and rainfall recorded at the Luxulyan weather station over various periods running up to sample collection. Statistically significant correlations ($p<0.05$) are highlighted in yellow in table XIII.2.

Table XIII.2 Spearman's Rank correlations between rainfall recorded at the Luxulyan weather station and water sample results from three streams draining to St Austell Bay

	Watercourse	Par River	Crinnis Stream	Par Beach Stream
	No. samples	198	103	199
24 hour periods prior to sampling	Day of sampling	0.304	0.441	0.343
	1 day	0.329	0.508	0.311
	2 days	0.161	0.274	0.159
	3 days	0.107	0.279	0.076
	4 days	0.122	0.287	0.053
	5 days	0.105	-0.067	-0.061
	6 days	0.066	-0.049	0.038
	7 days	-0.079	0.037	-0.021
Average prior to sampling over	2 days	0.384	0.501	0.418
	3 days	0.376	0.497	0.376
	4 days	0.352	0.49	0.341
	5 days	0.343	0.491	0.304
	6 days	0.343	0.43	0.267
	7 days	0.324	0.376	0.247

Table XIII.2 indicates that levels of faecal coliforms carried by these three streams increase in response to rainfall on the day of sampling and up to 4 days prior to sampling. Discharge volumes will also increase with increasing rainfall.

INVESTIGATIONS UNDERTAKEN BY THE ENVIRONMENT AGENCY – INVESTIGATIONS IN RESPONSE TO HIGH BATHING WATERS RESULTS

On some occasions when high results were obtained for bathing water samples, recent rainfall and spill records from nearby sewage infrastructure was examined. Locations of the bathing waters monitoring points are presented in Figure XI.1, and locations of sewage pumping stations and works are presented in Figure VII.1.

Samples investigated arose from Charlestown, Par, Polkerris, Port Mellon, Crinnis Golf, Little Perhaver, Pentewan and Polstreath. In all cases some heavy rainfall had occurred in the previous 7 days, and at Par and Pentewan sewage spills had been recorded shortly before at nearby outfalls.

BACTERIOLOGICAL SURVEY RECOMMENDED BY CEFAS

After reviewing the conclusions of the previous sanitary survey of St Austell Bay and a second shoreline survey, the location of two potential representative monitoring points within the new Ropehaven outer site were identified. It was recommended that these points should be sampled once a month during August, September and October alongside the classification monitoring at the adjacent Ropehaven site, with samples collected from depths representing the top and bottom of the lines (2m and 8m) at both points.

Unless the ongoing sanitary survey assessment identifies otherwise, the results of the bacteriological survey may be used for the preliminary classification at this site.

The points identified were at the north eastern and north western extremities of the Ropehaven outer lease area indicated in the application. No samples had been taken from either point at the time of writing of this report.

APPENDIX XIII
SHORELINE SURVEY(S)

Date (time): 14 July 2008 (14:30-16:30 BST)
15 July 2008 (08:00-11:00 BST)
12 May 2010 (09:45−17:00 BST)
Applicant: Mr Hancock (Fowey River Oysters LLP, 2008 survey)
Mr Rawle (Westcounrty Mussels of Fowey Ltd, 2010 survey)
Cefas Officers: Carlos Campos; Simon Kershaw (2010 only)
Local Enforcement Authority Officer: Terry Stanley (Cornwall Port Health Authority).
Area surveyed: Two separate shoreline surveys were carried out in response to two separate classification applications. The total area surveyed included the coastal area between Porthpean Beach and Gwendra Point and parts of St. Austell Bay from Lower Porthpean to Polkerris (Figure XIII.2).

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

The predicted times and heights of high and low waters and tidal curve on the day of the survey are given in Figure XIII.1 and Table XIII.1.

Table XIII.1 Predicted high and low water times and heights for Par during shoreline surveys.

	Date and time (height)
High Water	14 Jul 2008 02:57 (3.9m)
Low Water	14 Jul 2008 09:17 (1.7m)
High Water	14 Jul 2008 15:33 (4.1m)
Low Water	14 Jul 2008 21:53 (1.7m)
High Water	15 Jul 2008 04:02 (4.0m)
Low Water	15 Jul 2008 10:21 (1.6m)
High Water	15 Jul 2008 16:28 (4.3m)
Low Water	15 Jul 2008 22:52 (1.5m)
High Water	12 May 2010 05:06 (4.5m)
Low Water	12 May 2010 11:23 (1.0m)
High Water	12 May 2010 17:29 (4.6m)
Low Water	12 May 2010 23:44 (1.0m)

Predicted heights are in metres above Chart Datum.
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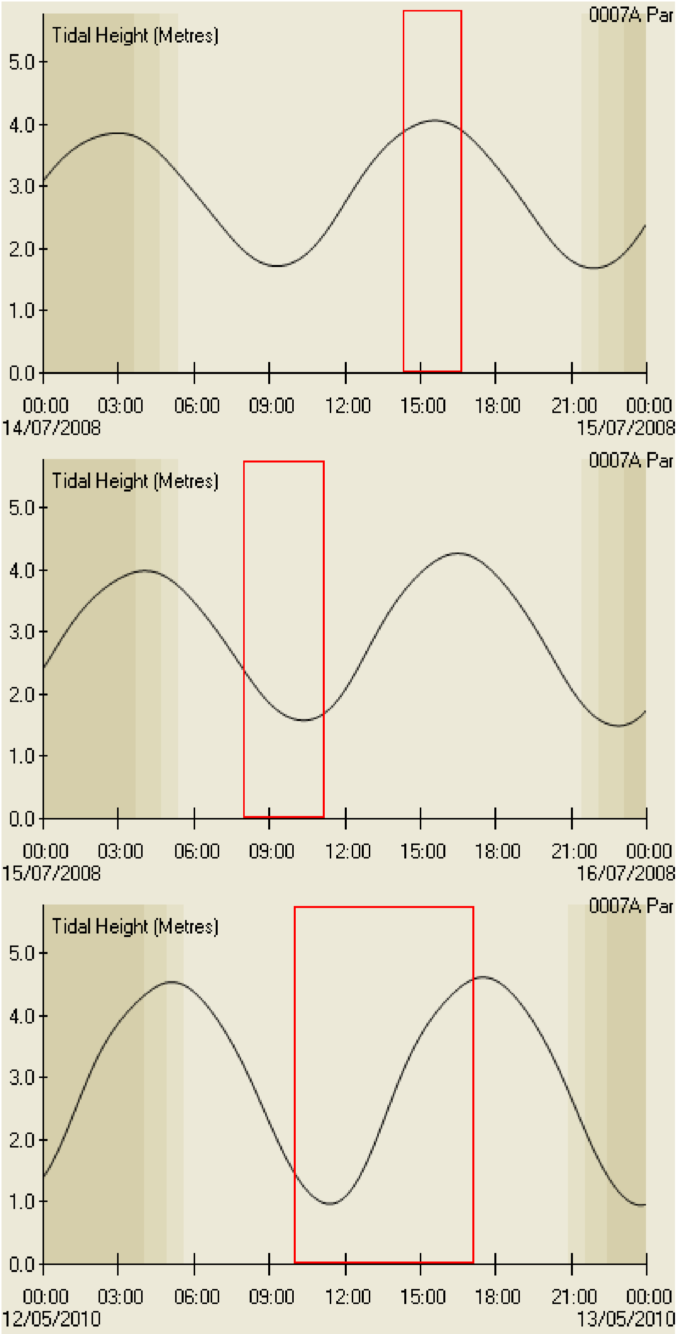

Figure XIII.1 Tidal curve at Par during the shoreline surveys.
Red line indicates the period surveyed.
Predicted heights are in metres above Chart Datum Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office.

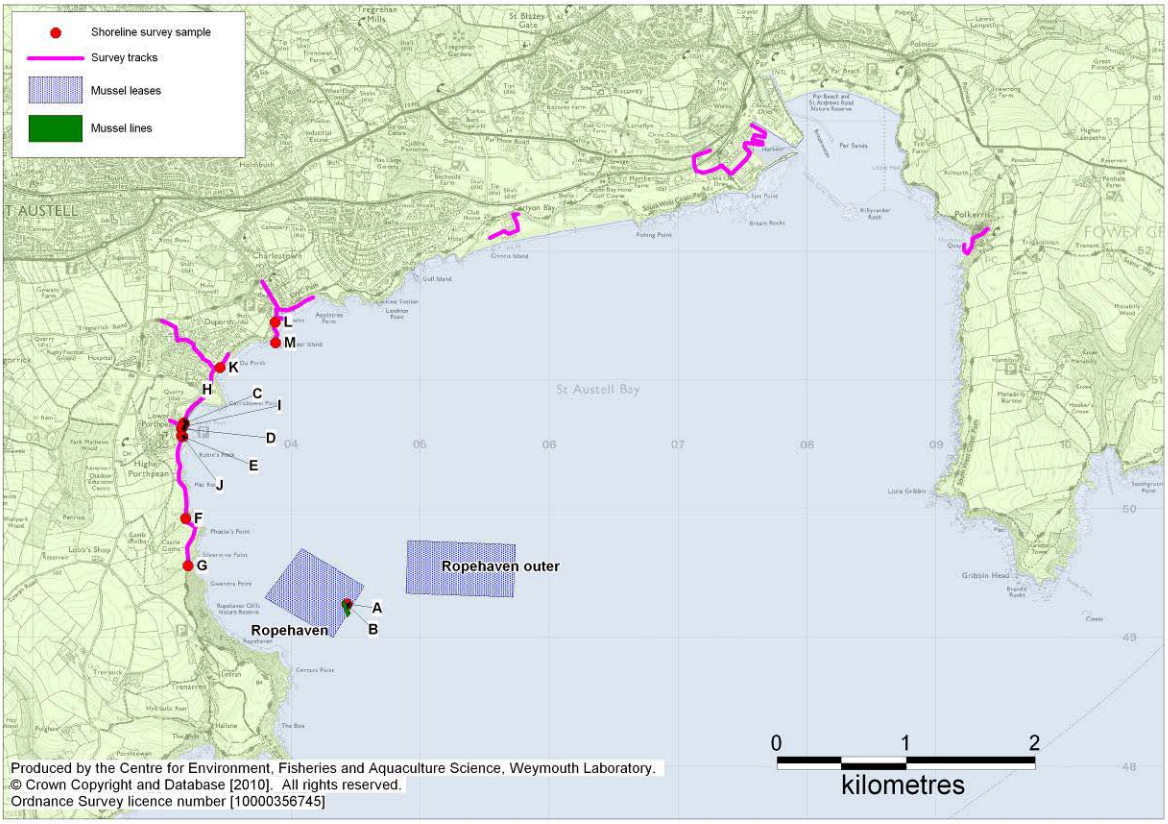

Figure XIII.2 Location of sites sampled in St. Austell Bay during the shoreline surveys.

Table XIII.2 summarises the observations made during the survey.

Table XIII.2 Results and observations made during the shoreline survey.

Production area	St. Austell Bay (M070)
Classification zones and ID/species	Ropehaven - mussels (*Mytilus* spp.)
Area of beds (Cefas database)	Ropehaven mussel lines = 0.0036km^2 Ropehaven lease area = 0.275km^2 Ropehaven outer lease area = 0.338km^2
SWD Flesh Point	No designated Shellfish Water
SWD Water Point	
BWD Sampling points (Easting, Northing)	Little Perhaver (201328,41588) Port Mellon (201558, 43917) Polstreath (201710, 45314) Pentewan (201879, 46766) Porthpean (203232, 50734) Duporth (203518, 51147) Charlestown (204003, 51552) Crinnis leisure (205553, 52040) Crinnis golf (206328, 52178) Par (208507, 53145) Polkerris (209281, 52105) Readymoney (211831, 51078)
Applicant's details	Mr D. J Hancock (Fowey River Oysters LLP) Lamorna 30 Lankelly Lane Fowey Cornwall PL23 1HN 01726 832475 Gary Rawle (Westcountry Mussels of Fowey Ltd) Old Bath House Fowey Docks Fowey Cornwall PL23 1AL Tel: 01726 832693/01726 832333
Map/Chart references	Imray C6 (Salcombe to Lizard Point) Admiralty 148 (Dodman Point to Looe Bay) Admiralty 442 (Lizard to Berry Head) OS Explorer 105 (Falmouth & Mevagissey) - Truro & St. Mawes

Recorded air temperature	17°C (15/7/2008 at 10:00) 19.2°C (12/5/2010 at 10:13)
Recorded wind	Max 21 km h^{-1} W-SSW (14/7/2008) Max 21 km h^{-1} W-SSW (15/7/2008) Max 11 km h^{-1} SW (12/5/2010)
Precipitation	Sunny (14/7/2008) Sunny (15/7/2008) Showers 12/5/2010 pm
Streams/springs	Springs at southern Lower Porthpean beach from high, vertical masonry wall retaining a slipway (203169/50665; sampled) (Figure XIII.3A) Springs at southern Lower Porthpean beach from high wall retaining a slipway (2031157/50632; sampled) (Figure XIII.3B) Springs at southern Lower Porthpean beach (Robin's Rock) from maritime cliff (203159/50558; sampled) (Figure XIII.3C) Springs at Duporth beach running to beach from blue PVC pipe (203448/51092; sampled) (Figure XIII.3D) Springs at western Charlestown cliff/breakwater (203875/51445) River running into inner Charlestown Harbour (not sampled) River Par (not sampled)
River flows (gauged)	All streams trickle flow
Significant sewage discharges (Cefas database)	Porthpean PS CSO/EO (observed at the entrance; 203167/50678. Discharge point not observed) (Figure XIII.4) Charlestown overflow (outfall observed on the western side of the harbour. Discharge point not observed) Charlestown Harbour PS CSO/EO (outfall observed on the western side of the harbour ; 203355/51156) (Figure XIII.5) Par STW (offshore marine outfall) Par PS No. 2 (not observed) Workshops Port of Par (outfall observed, no sign of discharge at time of survey; 207608/52881) (Figure XIII.6) Par driers control point (discharge point observed, trickle flow at time of survey; 207510/52820) (Figure XIII.7) Land at Par Harbour CP (observed) (Figure XIII.8) Polkerris PS/Polkerris fine screening plant (not observed)
Other discharges	PVC pipe from Porthpean Sailing Club (203188/50729). It appeared this may be used to drain off storm water (Figure XIII.9). Iron piped outfall (203917/51549) at Par Docks (Figure XIII.10). No sign of discharge at time of survey. Black PVC pipe about 15 inches diameter at 203448/51092. Discharge point protected by masonry culvert. No sign of discharge at time of survey (Figure XIII.11). Group of three manhole covers at footpath around Porthpean Sailing Club. Imerys consented water discharge identified as "Par Effluent Site/No. 1 Sea Discharge" with turbidity meter at Par Docks (207135/52605) (Figure XIII.12). Culvert at Duporth woodland south of new Holiday Village (203157/51197). No sign of discharge at time of survey (Figure XIII.13).

Boats/port	Canoeing & Jetskiing at Porthpean Beach One boat observed off Silvermine Point One fishing boat operating off Gerrans Point. Three fishing boats moored within Charlestown Harbour Walls. Two old ships moored within the inner Charlestown Harbour Walls. Four boats moored at Par Docks, one of them an Halmatic working boat with ramp "Spirit of Cornwall" used by the applicant. Small dinghies stored in Porthpean Sailing Club. Small dinghies off Polkerris beach. Slipway at Lower Porthpean Beach. Slipway at Par Docks. Slipway at Polkerris Harbour.
Dogs	One dog at Duporth beach. Dog faeces at Lower Porthpean Beach (203178/50691). Porthpean and Polkerris, have seasonal (Easter–1 October) dog ban. Duporth and Crinnis have year-round dog ban. Par beach and Charlestown are open to dog walking all year.
Other animals	Seabirds at Lower Porthpean beach and Charlestown (Adits headland and Polmear island rocky shores) (Figure XIII.14). Bird droppings at Polmear Island rocky shores (03878/51285). Cattle grazing in farm at Castle Gotha (Higher Porthpean) and in fields in the vicinity of Tregaminion. Most farms are fenced and no direct access of livestock to watercourses was observed. Rabbits in Par Docks.
Sewage related debris	None. Lower Porthpean, Duporth, Crinnis Golf and Polkerris beaches were noted to be very clean.
Samples taken	See Table XIII.2.
Bivalve harvesting activity	Ropehaven – two longlines installed in area indicated on Figure XIII.2. 6m droppers suspended from headline 2m below surface. Location recorded by GPS on 2008 survey. Ropehaven outer - installing two sets of mussel longlines within the area requiring classification at time of 2010 survey (Figure XIII.15). Seeded droppers 9m in length to be deployed with a view of obtaining harvestable stock by December.
Capacity of harvesting area	30 tonnes (Ropehaven) 50 tonnes (Ropehaven outer)
Water appearance	Water appeared clear in the bay and Charlestown Harbour.
Hydrodynamics	Western part of St. Austell Bay would be vulnerable to swell waves driven by the dominant westerly winds. Winds with a dominant east/south-east component blowing over the English Channel can promote transport of microbial contamination from sources in the eastern part of the bay. The applicant confirmed that tidal current velocities inside the bay are low.
Human population	Coastal settlements depend largely on tourism. The region is a popular destination for walking, bathing, sailing, golf and caravanning.
Topography	Topography of the area surveyed increases to 50m in places at Porthpean and Duport.

Land Use	Agricultural, mostly arable land, interspersed by areas used for horticulture/gardening and woodland. Urban and suburban areas in Lower/Higher Porthpean, Duport, Charlestown, St. Austell and Par. Coastline exposed and rugged, with small coves, headlands and high maritime cliffs. Sandy beaches present throughout the bay.
Other comments/observations	At time of survey, Duporth village was experiencing significant urban development. A local resident informed Cefas/LEA Officers that significant volumes of runoff water had reached the beach via the public access footpath. Three apparently newly settled PVC pipes to drain off surface water and a new piped outfall discharging to the beach was identified at time of the survey.

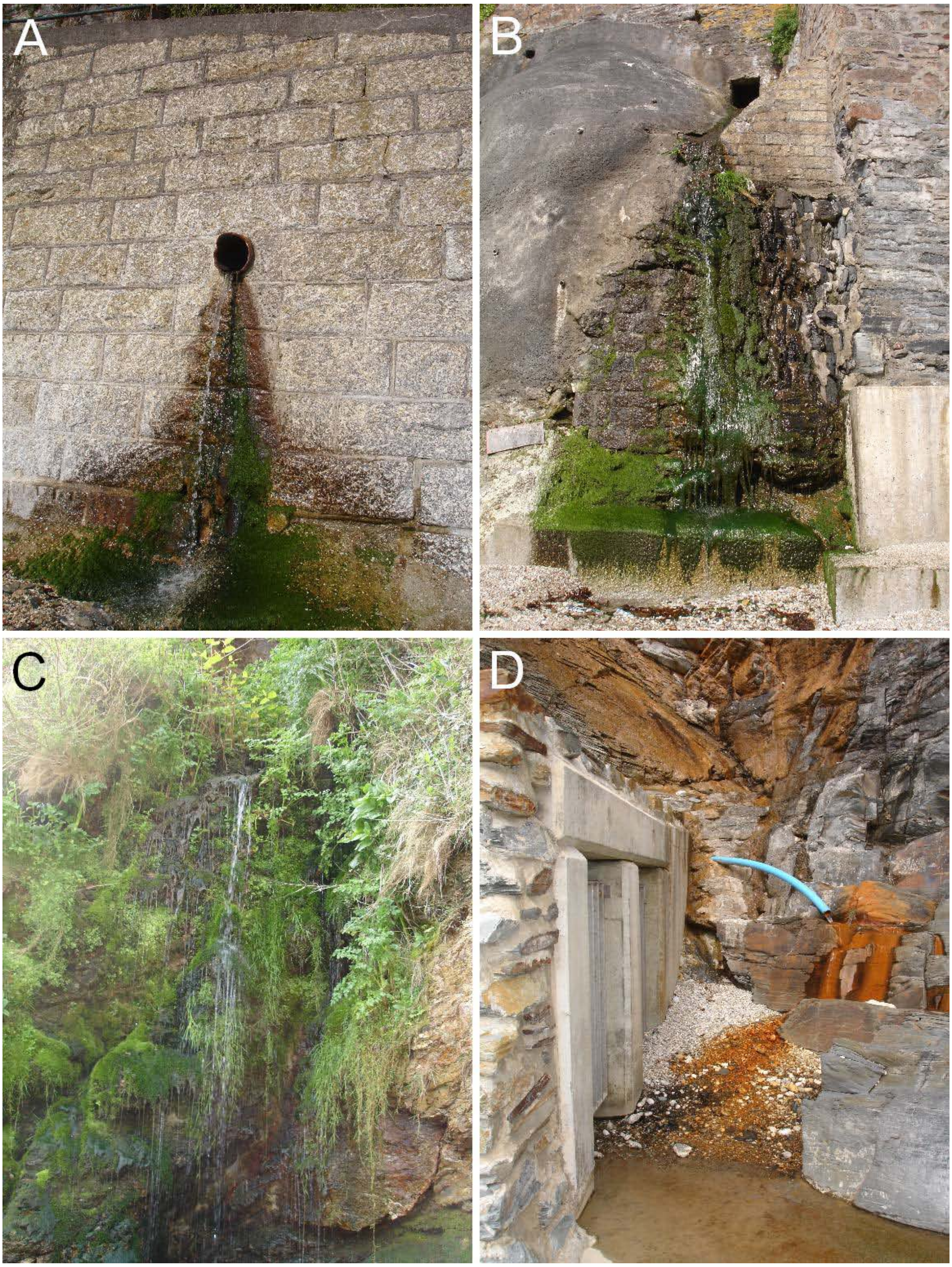

Figure XIII.3 Sites sampled during the shoreline survey.

Figure XIII.3 (cont.) Sites sampled during the shoreline survey.

Figure XIII.4 Porthpean Pumping Station entrance.

Figure XIII.5 Manhole cover at Charlestown Harbour PS CSO/EO.

Figure XIII.6 Workshops Port of Par overflow.

Figure XIII.7 Par Driers Control Point 33.

Figure XIII.8 Land at Par Harbour CP.

Figure XIII.9 PVC pipe from Porthpean Sailing Club

Figure XIII.10 Unidentified piped discharge at Par Docks (03917/51549).

Figure XIII.11 Unidentified pipe at Duporth Beach (03448/51092).

Figure XIII.12 Imerys consented water discharge identified as "Par Effluent Site/No. 1 Sea Discharge" at Par Docks (07135/52605).

Figure XIII.13 Culvert at Duporth woodland south of new Holiday Village (03157/51197).

Figure XIII.14 Seabirds in rocky shores at Polmear Island, Charlestown.

Figure XIII.15 Mussel longlines installed by Westcountry Mussels of Fowey Ltd in St. Austell Bay showing yellow plastic floats (buoys), main headropes and concrete blocks (weights) (A), marker buoys (B) and concrete blocks for marker buoys (C).

Table XIII.2 Results of samples collected during the shoreline surveys.

Sample ID	Matrix	Date	Time	Easting	Northing	*E. coli* result	Comments
A	Seawater	14 July 2008	15:20	204430	49260	0 cfu/100ml	Mid western boundary of production area
B	Mussels	14 July 2008	15:20	204430	49260	50 MPN/100g	Mid western boundary of production area
C	Freshwater	15 July 2008	08:45	203170	50657	160 cfu/100ml	Pipe in sea wall adjacent to sailing club
D	Freshwater	15 July 2008	08:49	203150	50619	220 cfu/100ml	Pipe under sea wall adjacent to sailing club
E	Freshwater	15 July 2008	08:54	203150	50562	230 cfu/100ml	Stream into Robin’s Rock (Lower Porthpean)
F	Freshwater	15 July 2008	09:23	203180	49923	620 cfu/100ml	Stream at Phoebe’s Point
G	Freshwater	15 July 2008	09:34	203200	49556	300 cfu/100ml	Stream at Silvermine Point
H	Freshwater	12 May 2010	10:09	203169	50665	280 cfu/100ml	Water clear
I	Freshwater	12 May 2010	10:10	203157	50632	40 cfu/100ml	Water clear
J	Freshwater	12 May 2010	10:15	203159	50558	120 cfu/100ml	Water clear
K	Freshwater	12 May 2010		203448	51092	0 cfu/100ml	Water clear
L	Freshwater	12 May 2010	11:30	203875	51445	0 cfu/100ml	Water clear
M	Seawater	12 May 2010		203878	51285	90 cfu/100ml	Water turbid, contained bird faeces

CONCLUSIONS

The following conclusions can be drawn from the shoreline surveys:

1. St. Austell Bay is bounded by areas of mixed land uses and steep sloping topography, being subjected to significant urban development. The River Par constitutes the main freshwater input into the bay. Freshwater samples collected from small streams indicate low to moderate levels of contamination in these watercourses.

2. Par STW could be considered the most significant source of contamination of faecal origin to St. Austell Bay.

3. Sewage discharges from pumping station overflows at Porthpean, Charlestown and Par represent potentially significant sources of contamination during wet weather.

4. No major harbours/fishing ports/marinas occur throughout the bay and therefore waste discharges from boats are not considered to be a significant source of contamination to mussel fisheries.

5. Faecal matter from birds and dogs deposited onto sandy beaches and intertidal rocky shores represent potentially significant sources of contamination.

6. The overall bathymetric profile encompassing the Ropehaven outer lease is deeper and less prone to thermal stratification than that encompassing Ropehaven classified area. This will markedly influence the total initial dilution available. However, the new area is closer to Par STW marine outfall. Under wind driven currents from east, the mussel fishery could be impacted by contamination from this source.

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List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (E. coli)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. *coli* O157 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer, goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygiene Regulations, Shellfish and Bathing Water Directives, *E. coli* is the most common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44°C as well as 37°C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and

	preceding the ebb tide.
Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of a skewed data such as one following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	LOcally WEighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given data set, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the *n* data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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