Cefas

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Oxwich Bay

2013

Cover photo: Oxwich Bay.

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

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency	14/01/2013	No comment received
Local Enforcement Authority	14/01/2013	19/02/2013
Welsh Government Fisheries	14/01/2013	14/01/2013
Dŵr Cymru - Welsh Water	14/01/2013	No comment received
Countryside Council for Wales	14/01/2013	04/02/2013

DISSEMINATION: Food Standards Agency, Swansea Council, Welsh Government Fisheries, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2013. Sanitary survey of Oxwich 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 of EC Regulation No. 854/2004.

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1. INTRODUCTION

1.1 Legislative Requirement

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

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

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

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

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

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

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

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

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

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

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

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

This report documents the information relevant to undertake a sanitary survey for razor clams (*Ensis* spp.) from Mumbles Head to Oxwich Point, and other species if required.

1.2 AREA DESCRIPTION

The survey area (Oxwich Bay to Mumbles Head) is situated in the outer reaches of the Bristol Channel in South Wales, on the south shore of the Gower Peninsula (Figure 1.1).

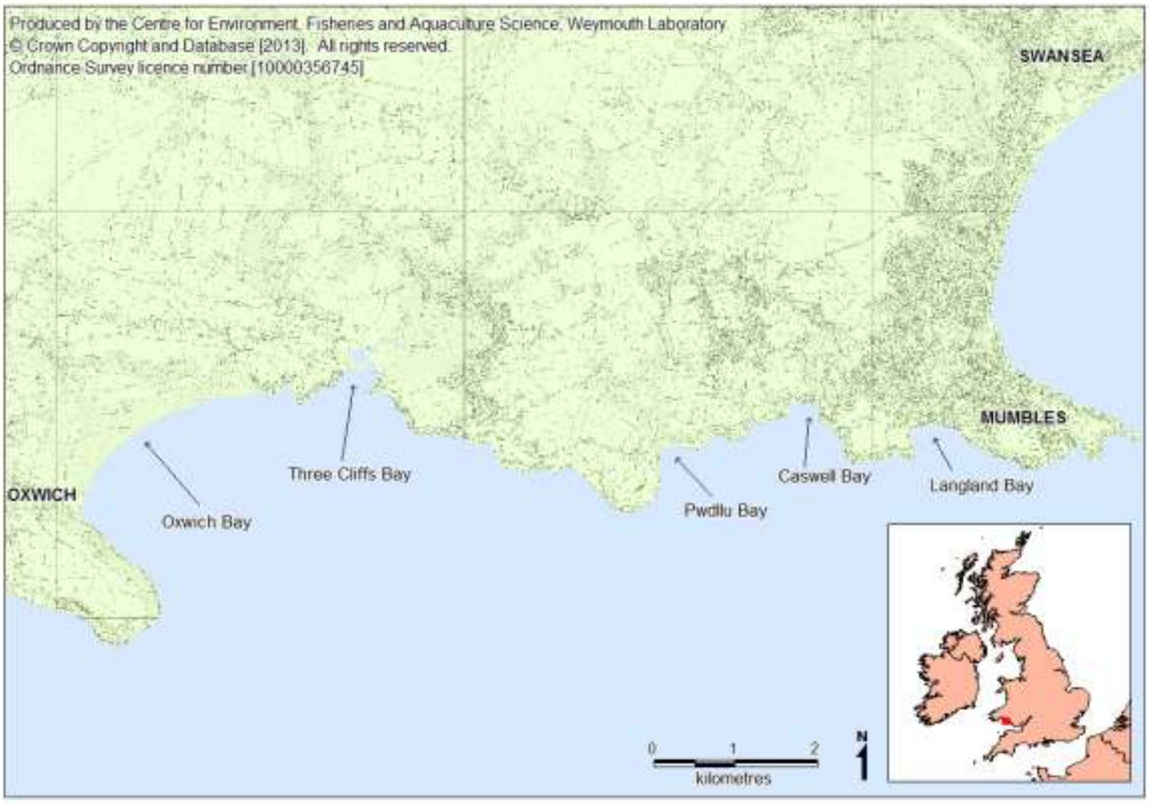

Figure 1.1 Location of the Oxwich Bay survey area

The area is a stretch of south facing open coast approximately 12 km in length. It comprises of a series of carboniferous limestone cliffs and embayment's, including; Oxwich, Threecliff, Pwdllu, Caswell and Langland Bays. The seabed along this coastline is mainly sandy although there are rocky reefs extending into the subtidal areas throughout the eastern half. There are a variety of different coastal habitats such as oak woodland, sandy beaches, dunes and salt marsh. The main town is Mumbles, which lies at the eastern end of the survey area. Further east the city of Swansea borders Swansea Bay. Tourism is a key contributor to the area's economy with beaches at Oxwich, Langland and Caswell Bays, coastal footpaths, and the seaside town of Mumbles being popular with tourists.

CATCHMENT

Figure 1.2 shows the land cover within the hydrological catchment draining to the survey area.

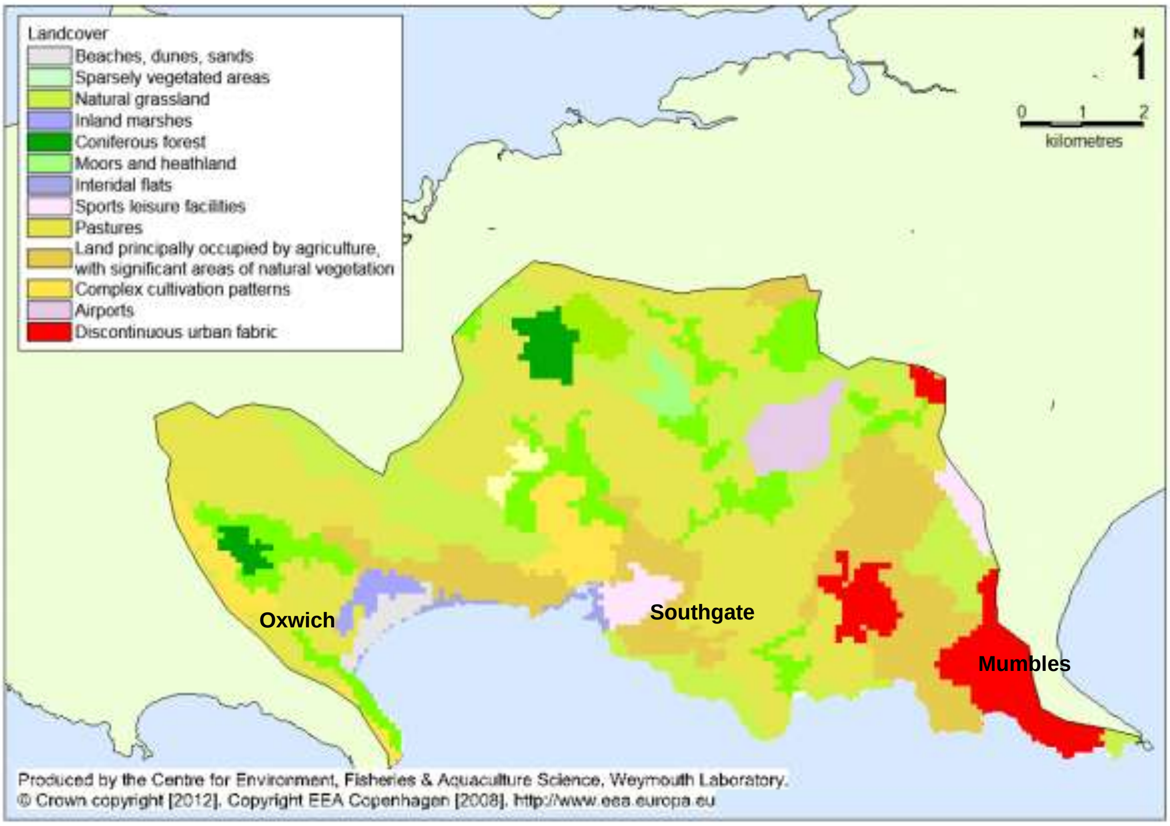

Figure 1.2 Land cover in the Oxwich Bay catchment area

The catchment covers an area of only 68km^2 and is largely rural in character, with pasture and natural grassland the principal land cover types. The outskirts of Mumbles lie at the eastern end. The small villages of Southgate and Oxwich also lie adjacent to this shoreline, although they are not apparent on the land cover dataset used in Figure 1.2. Highest faecal coliform contributions arise from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land cover types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which may increase up to 100 fold.

2. RECOMMENDATIONS

DREDGE FISHERY AND INTERTIDAL FISHERIES

2.1 There is the possibility for two types of commercial fisheries with the survey area. Electrofishing and possibly clam dredge fishery could take place across the whole survey area. A commercial scale hand gathering fishery could take place within the Oxwich Bay intertidal area, it is believed that the main concentrations of intertidal shellfish occur here, particularly towards its western end.

It is recommended that the area requiring classification for razors should be split into the following five zones, each with its own single RMP (Figure 3.1).

- Oxwich Bay. This zone includes Oxwich Bay and Threecliff Bay. The largest identified source of contamination to this zone is likely to be the Pennard Pill. Consistent westerly tidal flows are predicted along the shore here due to a flood tide gyre. Therefore, the RMP should be set at Threecliff Bay, just to the west of where the Pennard Pill enters coastal waters.
- Oxwich intertidal. This zone includes the whole of Oxwich Bay, but not Threecliff Bay. Within this, predictable sources likely to impact on intertidal shellfisheries are the Oxwich Stream and the Pennard Pill. As the Oxwich Stream is direct to the area whereas the Pennard Pill is not, the path that this follows across the intertidal is likely to represent the most noticeable hotspot in the area. It is therefore recommended that the RMP be set within the path of this stream in order to capture this most effectively
- Off Southgate. This zone extends from the eastern end of Threecliff Bay through to Pwlldu Head. The main source of contamination to this zone is the Southgate STW outfall. The RMP should therefore be set as close as possible to this outfall, and within the plume it generates, which will travel parallel to the coast.
- Pwlldu and Caswell. This zone extends from Pwlldu Head to Whiteshell Point. Whilst this zone does include the Bishopston STW outfall and the Caswell Bay stream, the Bishopston stream is likely to generate the highest bacterial loading on average. Therefore, the RMP should be set within Pwlldu Bay, as close as possible to where the Bishopston stream enters coastal waters.
- Off Mumbles. This zone extends from Whiteshell Point to Mumbles Head. The main source of contamination is likely to be the Mumbles pumping station, and although it discharged only about 14.4% of the time over the last two years, when it does significant impacts are anticipated. Sources within Swansea Bay may also be of some influence. The RMP should be therefore set as close as possible to (and within the ebb plume of) the Mumbles PS outfall, which lies at the eastern end of the zone, so would also be effective in capturing contamination from Swansea Bay.

2.2 There is considerable uncertainty about the distribution of stocks of the species requiring classification for the possible dredge fishery. As such, it may not be possible to sample at the exact locations defined in Table 3.1. Therefore, there is some flexibility about the final RMP locations, which should be situated according to the principles defined in the comments column of Table 3.1. The exact locations sampled should be recorded by GPS to 10m accuracy and written on the sample submission form.

2.3 Dredge fisheries. The species sampled should be the species for which classification is required, apart from in the case of razors, where any *Ensis* spp. can be sampled. A tolerance of 100m should be set around the RMPs to allow for repeated sampling, once suitable locations have been confirmed. Sampled stock should be of a market size and collected using the commercial harvesting technique.

2.4 Oxwich intertidal. The species sampled should be the species for which classification is required, apart from in the case of razors, where any *Ensis* spp. can be sampled. A tolerance of 50m should be set around the RMPs to allow for repeated sampling. Sampled stock should be of a market size and collected by hand. The use of salting is appropriate for razors, and the use of rakes will be suitable for cockles and clams.

2.4 Sampling should be on a monthly basis for full classification. If classification is required more rapidly, 10 samples taken at least 1 week apart would be needed before a provisional classification can be awarded. Monthly sampling will be required thereafter to maintain this classification.

3. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Oxwich Bay
Cefas Main Site Reference	TBA
Ordnance survey 1:25,000 map	Explorer 164
Admiralty Chart	1165

Shellfishery

Species/culture	Razors (*Ensis* spp.)	Wild
	Possibly other clam species	Wild
	Cockles (*Cerastoderma edule*)	Wild
Seasonality of harvest	No formal closed season for any species	

Local Enforcement Authority

Name	Environmental Health Department Swansea City & County Council The Guildhall Swansea SA1 4PE

Environmental Health Officer	Keith James
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REQUIREMENT FOR REVIEW

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

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

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Oxwich Bay	TBA	Threecliff Bay	SS 5349 8764	51° 34.11' N 04° 06.92' W	Any species as required	Wild	Various	Same method as for any commercial harvesting	100m	Monthly	To be located as close as possible, but to the west of the Pennard Pill outlet
Off Southgate	TBA	Southgate Outfall	SS 5528 8701	51° 33.80' N 04° 05.36' W	Any species as required	Wild	Various	Same method as for any commercial harvesting	100m	Monthly	To be located as close as possible to (and within the plume of) the Southgate STW outfall. The plume will travel parallel to the shore.
Pwlldu and Caswell	TBA	Pwlldu Bay	SS 5762 8696	51° 33.81' N 04° 03.33' W	Any species as required	Wild	Various	Same method as for any commercial harvesting	100m	Monthly	To be located as close as possible to the Bishopston stream outlet.
Off Mumbles	TBA	Mumbles	SS 6347 8690	51° 33.86' N 03° 58.27' W	Any species as required	Wild	Various	Same method as for any commercial harvesting	100m	Monthly	To be located as close as possible to (and within the ebb plume of) the Mumbles PS outfall. The plume will travel in an approximately WSW direction.
Oxwich Bay intertidal	TBA	Oxwich stream	SS 5185 8741	51° 33.96' N 04° 08.33' W	Any species as required	Wild	Hand/Dredge	Hand (salting for razors, rake for cockles or clams)	50m	Monthly	To be located in the path of the Oxwich Stream, as far up the beach as the species can be reliably sampled

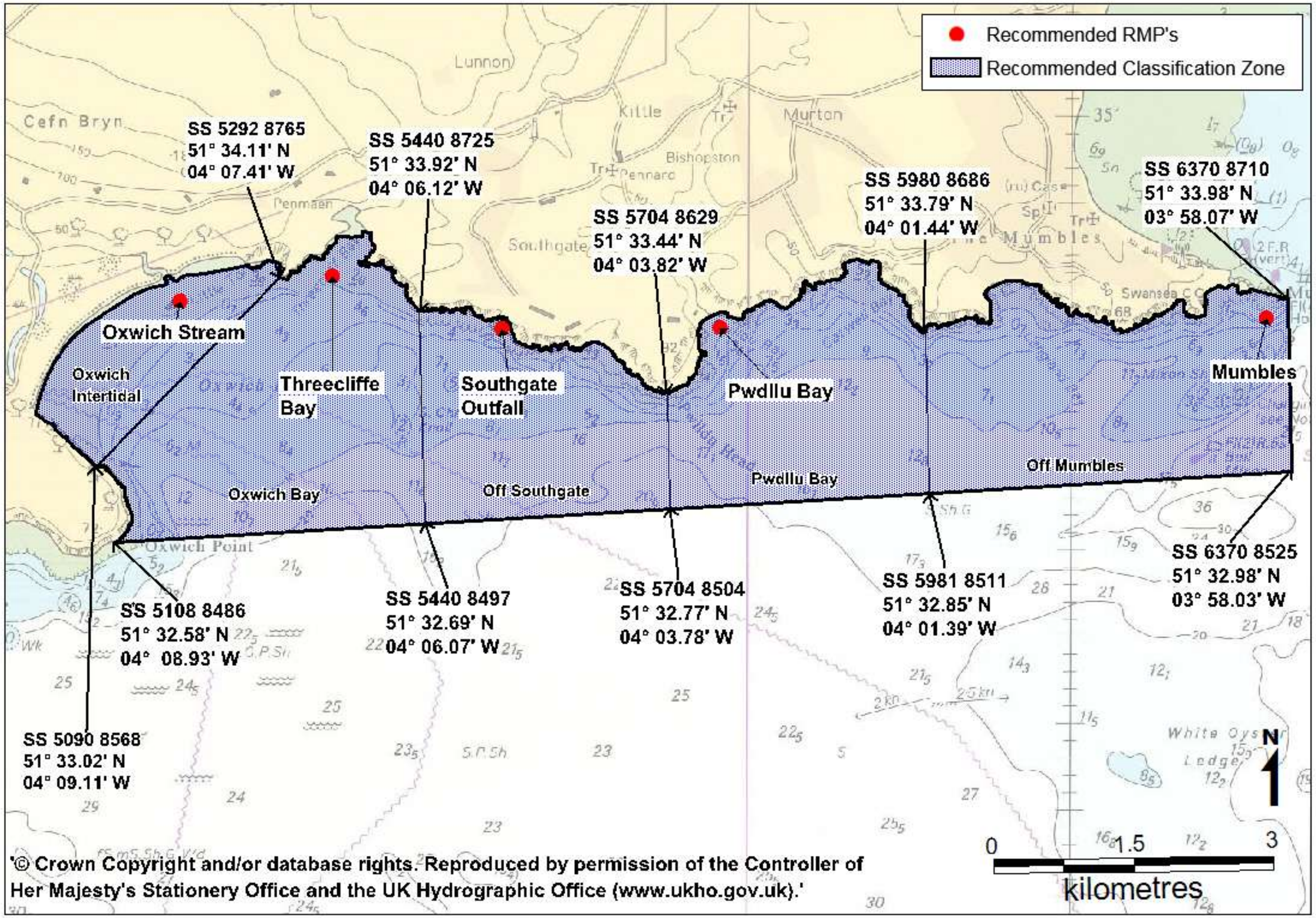

Figure 3.1 Recommended classification zone boundaries and RMP locations (all species by dredge and intertidal areas)

4. SHELLFISHERIES

4.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for classification of an area of 28km^2 off the south coast of the Gower Peninsula for the harvest of razor clams (*Ensis* spp.) (Figure 4.1). As well as this species, there are other stocks of potential commercial interest within the survey area. The applicant subsequently identified an interest in harvesting surf clams (*Spisula solida*) and possibly other clam species in the area.

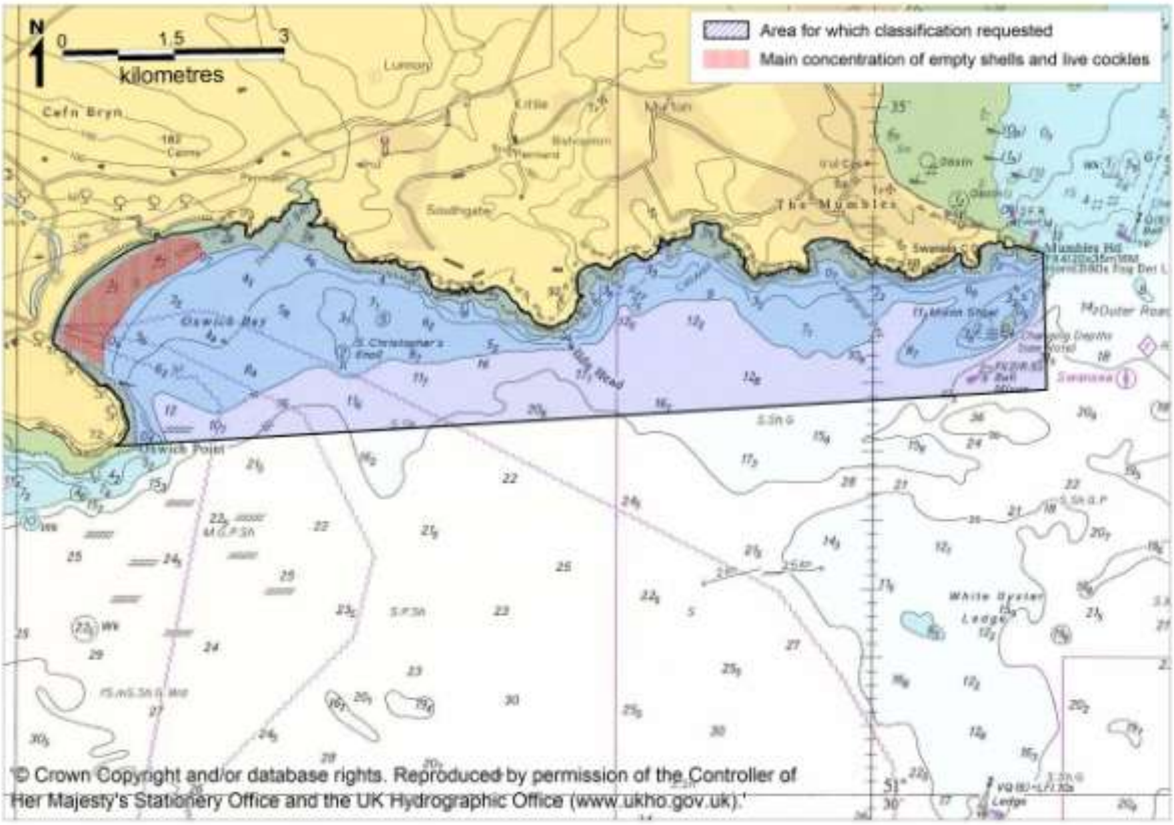

Figure 4.1. Area for which classification has been requested and area where high numbers of empty bivalve shells and live cockles were seen during the shoreline survey

The application indicated that razors are present throughout area from the low water mark for spring tides down to a depth of about 15m below chart datum. Within Oxwich Bay, the applicant reports that densities of up to 5 animals per m^2 are present around the extreme low water mark. Further information on the distribution and densities of these stocks within the wider area is not available. They occur within sandy substrates and are likely to be scarcer in the more exposed areas subject to energetic wave action. UK distribution maps indicate that *Ensis siliqua* (pod razor), *Ensis arcuatus (*curved razor) *and Ensis Ensis* (common razor) are all present off the south coast of the Gower peninsula (Marine Scotland, 2011). For classification purposes no distinction is made between them, so any razor species may be sampled to classify all razor species, with the resulting classification for *Ensis* spp. Surf clams are more tolerant of wave action and occur in sandy substrates from the low intertidal zone to offshore.

Although part of the eastern end of the survey area was formerly classified for native oysters, a sanitary survey (Cefas, 2011) identified stocks of commercial interest which did not extend south of Mumbles Head, but were confined within Swansea Bay. Now even these are no longer sufficient to support a fishery. A recent underwater camera survey did record a 'possible live oyster' on the White Oyster Ledge, about 2km southwest of Mumbles Head (Woolmer, 2011) but did not find significant quantities of this species within the survey area. The study report did however note that large oysters have been caught by [whitefish] trawlers here.

Oxwich Bay formerly supported a significant cockle population which was eradicated by an oil spill in 1945. In the last decade it is reported that cockles have become re-established here, and now some casual gathering of cockles occurs (This is South Wales, September 2011). No interest has been expressed to the FSA or CEFAS in classifying any part of the survey area for cockles.

During the shoreline survey, significant quantities of dead shells from burrowing molluscs were recorded within Oxwich Bay but not in the more exposed bays/beaches to the east. Species observed included pod razors, cockles (*Cerastoderma edule*), softshell clams (*Mya arenaria*), hard clams (*Mercenaria mercenaria*) and very occasional native oysters. The greatest concentrations were towards the western end of Oxwich Bay where it is more sheltered from westerly winds and waves. Here, live cockles were also observed on the surface of the sand. Very few shells were seen to the east of this area perhaps suggesting commercial concentrations of the various burrowing species within the intertidal and nearshore zones may only be present in Oxwich Bay.

Some patches of mussels were observed on intertidal rocks at Caswell Bay, and possibly at the bottom of cliffs in other locations, but these were undersized and barnacle encrusted and as such unlikely to be of commercial interest.

4.2 Growing methods and harvesting techniques

All stocks are wild. The commercial harvesting technique to be used by the applicant for razors is an electric fishing technique which has been refined for efficiency, operator safety and to minimise damage to both the razors and to other fauna and flora. Electrodes are towed slowly across the seabed, which induces the razors to leave their burrows. They are subsequently collected from the surface of the substrate by a dredge/collection box towed just behind the electrode array. Towed gear such as this will need to be operated on clean sandy areas only.

The less mobile clam species such as surf clams are incapable of exhibiting the escape response shown by razors. Therefore, dredges capable of mechanically extracting them from the substrate, such as hydraulic or toothed dredges will be required to harvest them, should such a fishery be developed.

Razor clams and other species (cockles and various clams) are also gathered by hand at Oxwich Bay and possibly from other beaches within the survey area by private individuals for personal consumption. Hygiene classifications are not required for casual gathering.

4.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

Razors are subject to a statutory MLS of 100mm and there is no formal closed season for this species. There is a blanket ban on marine electrical fishing of any form under EC 850/98, Article 31 (EC, 1998). Some initial experimental trials were permitted by Welsh Government Fisheries, and these concluded that that the technique does not appear to cause serious negative effects on benthic (sea bottom dwelling) communities (Woolmer *et al*, 2011). Following on from this a more rigorous trial was planned over a three year period in the Oxwich Bay area, during which the catches were to be marketed to help offset the costs of the development work.

In December 2011, CEFAS were advised by Welsh Government Fisheries that they would issue permission for this second trial, and so the classification application was progressed by CEFAS on this basis. However, during the sanitary survey process it became apparent that the Countryside Council for Wales (CCW) was not entirely satisfied with the evidence provided by the initial trial. As statutory consultees on such applications their advice to Welsh Government Fisheries was that the applicant would need to address some evidence gaps before a commercial fishery could be pursued. It is uncertain whether the applicant will wish to proceed further under these terms. It is also possible that future trials may reveal unacceptable impacts. As such, the prospects and timescales for the establishment of a commercial fishery for razors are now uncertain.

If and when a classification is issued, a public fishery will be created and other operators may fish the area commercially using any acceptable method. It is possible that there will be additional commercial interest as there are few areas classified for this species within England and Wales and first sale prices are from £2-4 per kg (Gray, 2008). The use of hydraulic or toothed dredges to extract razors will require permission from Welsh Government Fisheries, and may not be acceptable as they can cause high levels of damage to the target species and the seabed. There are no restrictions on harvesting by hand either from the beach or by divers. Given the large area for which classification has been requested, a considerable amount of stock may be present, even if densities are relatively low and occurrence is patchy. Therefore a potentially lucrative public fishery may be created. However, razors are long lived, slow growing and late maturing so stocks subject to overexploitation may be rapidly depleted and take several years to recover, as has occurred in some other razor fisheries (Fahy, 2006).

Prior written approval from Welsh Government Fisheries is required for the use of (conventional) shellfish dredges in the district. It is uncertain whether a dredge fishery targeting other species of clams would be acceptable in the area. The use of hydraulic dredges is unlikely to be approved, but box dredges with relatively short teeth (15cm) are more likely to be acceptable. There are no formal closed seasons for surf clams, hard clams or softshell clams.

No specific byelaws apply to hand gathering of cockles within the survey area, aside from a minimum size of 19mm. Should a commercial fishery develop in the future, it is likely some management measures would be imposed.

4.4 Hygiene Classification

Until 2012, part of the classification zone for native oysters within Swansea Bay extended out past the Mumbles head (Figure 4.2) and overlapped with the area for which classification has been requested. This classification was based on monitoring results from within Swansea Bay, to the north and east of Mumbles Head and outside of the area now requiring classification for razors, and so is not directly relevant to the present sanitary survey. When classified within the last decade it has held a B classification (Table 4.1). The entire area has now been declassified due to lack of commercial interest.

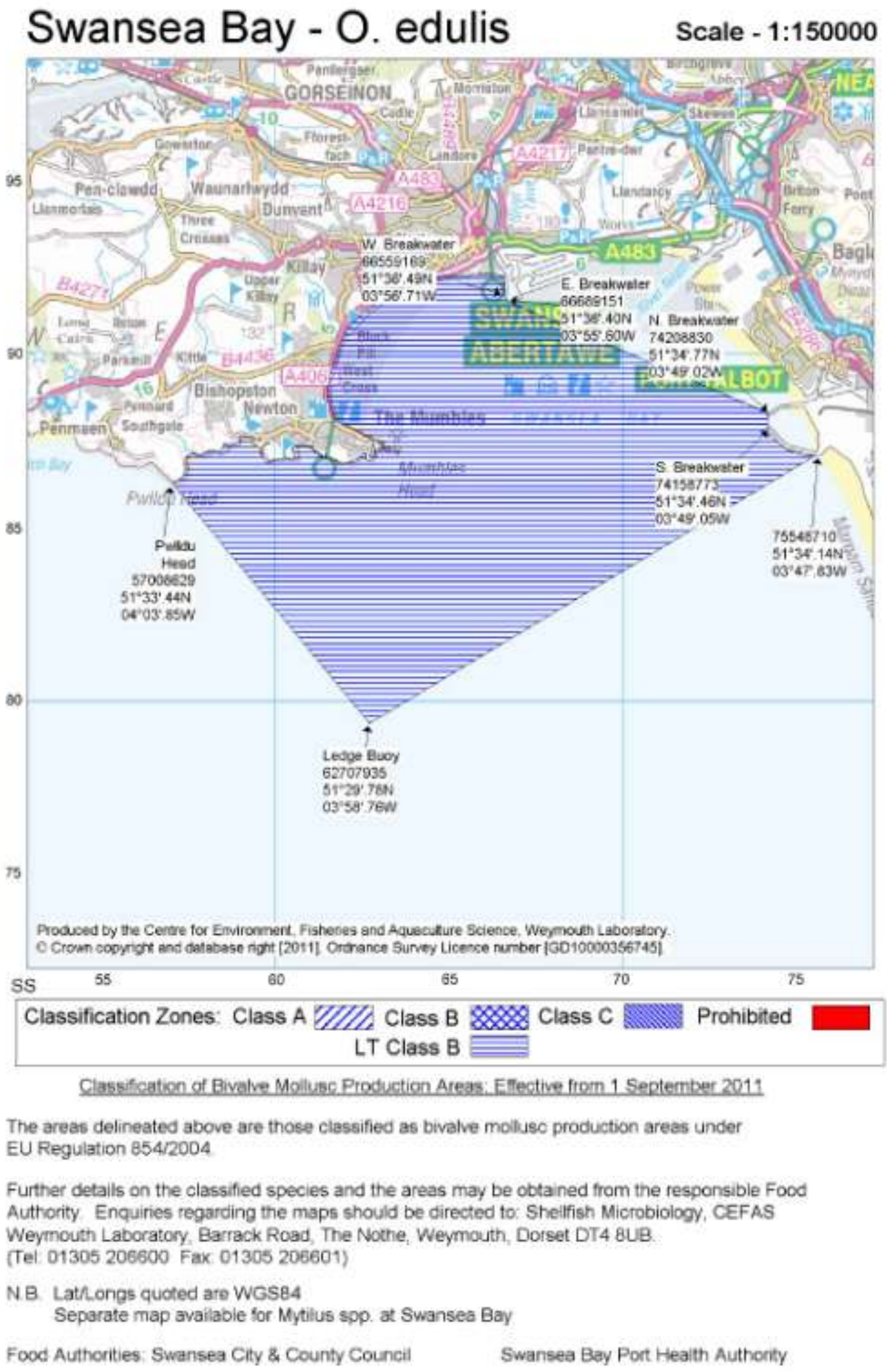

Figure 4.2 Swansea Bay native oyster classification zone, 2011-2012 (now declassified).

Table 4.1 Criteria for classification of bivalve mollusc production areas.

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

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

5. OVERALL ASSESSMENT

AIM

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

SHELLFISHERIES

The application requested classification of the area from Mumbles Head to Oxwich Point for razors, extending about 2-3km offshore to about the 15m depth band. A three year experimental electrofishing trial was intended here to assess the environmental impacts of the method, with the catch to be marketed to help offset the costs of the trial. As marine electrofishing is banned in the EU, permission to undertake the trial (and fishery) is required from Welsh Government Fisheries. A smaller scale initial trial had concluded that the method did not cause unacceptable damage, and Welsh Government Fisheries initially indicated that they were content for the larger trial and fishery to proceed. However, during subsequent consultations, Countryside Council for Wales identified some evidence gaps in the initial trial which would need addressing. As a consequence they were not content for the main trial to proceed before these issues were satisfactorily resolved. Therefore the prospects and timescales for the development of a commercial fishery are presently uncertain. It is not clear if the catch from further trials can be marketed. If not then this may render further trials unviable. Nevertheless, a sampling plan will be provided for when and if operations commence.

The distribution of razors within the area requiring classification is uncertain. Observations of dead shells during the shoreline survey suggest stocks may only be present within the more sheltered waters of Oxwich Bay. Here, relatively high densities of razors (5 per m^2) are reported around the extreme low water mark. In the absence of assistance from the harvester, these stocks represent the only known intertidal area where razor samples can be collected. When further electrofishing trials get underway in the area, even if the catch cannot be marketed, the harvester should be able to collect samples for classification monitoring from both intertidal and subtidal areas where stocks are present. There is no closed season for razors, so any classification should be year round.

In order for a sustainable fishery to become established, CCW have advised that a thorough and scientific assessment of targeted shellfish stocks, the surrounding environment and likely impacts takes place in order to avoid adverse affects on the shellfish species themselves but also on the wider ecosystem.

The applicant has also expressed an interest in harvesting surf clams using a conventional shellfish dredge in the area. No solid information on the abundance and distribution of these stocks is available, but they occur in sandy substrates from the low intertidal to offshore and are tolerant of more high energy environments. It is likely that they would have to be sampled by dredge, which would require the assistance of the harvester. There is no closed season for this species so any classification monitoring should be undertaken on a monthly, year round basis.

There is a significant population of cockles in the intertidal zone at Oxwich Bay, which is subject to casual gathering and may potentially be of commercial interest in the future. A sampling plan will be provided for this species to cover for this eventuality, and as there is no closed season classification monitoring should be undertaken on a monthly, year round basis.

Other species thought to be present in the area include several other clam species, a few patches of mussels on intertidal rocks, and occasional specimens of native oysters further offshore. None of these is understood to be of commercial interest or even subject to casual gathering.

Sampling for all species should be via an approved technique.

POLLUTION SOURCES

FRESHWATER INPUTS

The hydrological catchment of the survey area covers approximately 68km^2 and is rural in character. It is drained by a series of small watercourses which discharge to the various embayments along the coast. All watercourses will carry some contamination from land runoff and so will require consideration in this assessment. All significant watercourses and surface water outfalls were sampled and measured during the shoreline survey, allowing a 'snapshot' estimation of their bacterial loading to be made (Figure 5.1). This revealed that the highest *E. coli* loading by far was carried by the Pennard Pill, which discharges to Threecliff Bay, although some of the other watercourses will still be of local significance. The survey was undertaken during a high flow event, so the *E. coli* loadings recorded are likely to be considerably higher than average.

Insufficient measurements exist for these watercourses to make an estimate of seasonality in discharge volumes and concentrations of faecal indicator bacteria. Local rainfall records indicate higher rainfalls in the winter, and during the colder months a much higher proportion of rainfall is likely to run off. Stream discharges are therefore likely to be highest on average during the colder months of the year, although high flow events may occur at any time of the year. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters, particularly as stream levels rise when heavy rain occurs following a dry period (the ‘first flush’).

Monitoring points should be set to best capture contamination from land runoff, which is likely to be of relatively high importance along this stretch of coast. Their impacts will be greatest where they enter coastal waters, particularly within or immediately adjacent to any drainage channels they follow across the intertidal area.

As a consequence of the geology there are flows of groundwater through the catchment as well as the surface water streams. These generally re-emerge via numerous small freshwater springs on the beaches. High nitrate levels have been found in the aquifers here, although it is uncertain to what extent bacterial contamination survives passage. A sample of groundwater taken from a small spring on the beach at Brandy Cove contained only 16 *E. coli* cfu/100ml, suggesting groundwater's in this area at least, were relatively uncontaminated with bacteria. Whilst they may convey bacterial contamination to coastal waters, their small discharge volumes and frequent occurrence make them impractical to consider in terms of the sampling plan.

Human Population

The catchment area considered is largely rural, supporting a population of 27,191 at the time of the 2001 census. The highest population density is found at the eastern end, on the outskirts of the town of Mumbles, with other settlements at Bishopston and Southgate. Most of the rest of the catchment supports population densities of less than 250 persons per km^2, so impacts from sewage discharges should be relatively light. The spatial pattern of impacts from human sources will of course depend on the nature of the sewage treatment infrastructure in the area.

Significant numbers of tourists are attracted to the area primarily for the pursuit of outdoor activities such as walking and watersports. Consequently, population within the survey area is likely to increase significantly during the peak holiday season. Therefore, an increase in the volumes of effluent received by sewage works serving the area is anticipated at these times.

Sewage Discharges

There are two continuous water company discharges direct to the survey area (Bishopston and Southgate STWs). The former provides UV disinfection of the effluent, whilst the latter provides secondary treatment only. As a consequence, only a very small bacterial loading is generated under normal conditions by Bishopston STW. The bacterial loading generated from Southgate STW is estimated to be more than two orders of magnitude higher than this on average. The effluent from Bishopston STW is regularly subjected to bacteriological testing, and this did highlight considerable variation in faecal coliform concentrations. It is however concluded that the Southgate STW is likely to create the most significant and consistent sewage related hotspot of contamination within the area requiring classification. There is another small sewage works about 2km west of Oxwich Point (Oxwich STW) which receives secondary treatment and generates an estimated bacterial loading of about half of that generated by Southgate STW. This may be of some limited influence primarily towards the western end of the survey area. For these three works, there was a slight tendency for higher flow during the autumn and winter. No seasonal pattern in faecal coliform content was found for the Bishopston STW.

Further afield, but of potential significance there are two major sewage works (Swansea and Afan) to Swansea Bay. They discharge 5 and 10km east of Mumbles Head respectively. The former receives UV treatment and as such is not likely to generate a large bacterial loading, and the latter is perhaps too far away for the plume to reach Mumbles during the course of an ebb tide. Nevertheless, their combined effects may be of some influence towards the eastern end of the shellfishery.

As well as the continuous discharges, there are nine intermittent overflow discharges which may impact on the area. Six of these are only consented to discharge in an emergency (e.g. blockage, pump failure), which is likely to be a rare event. Three of the intermittent discharges are consented to discharge under storm conditions, when the sewers become inundated with surface water. This is likely to occur more frequently than emergency discharges. One of these discharges to the Oxwich Stream and two discharge to coastal waters (Bishopston STW and Mumbles Pumping Station). The former passes through a reed bed before discharging and the latter only discharges during the ebb tide. Both Bishopston STW and Mumbles SPS discharging to coastal waters have spill event monitoring, and records of spill durations for the last two years were provided by Dŵr Cymru Welsh Water. These showed that the Bishopston STW was only active for 1.0% of this period, so any impacts will be relatively minor and infrequent. The Mumbles outfall was active for 14.4% of this period, and has a large catchment area so spills from here may be of a relatively high volume. The outfall is tidally phased and is mainly active during the ebb tide, when the plume would be carried along the south Gower coast. It must be noted that only event durations were recorded rather than actual volumes spilled and no bacteriological testing data was available for storm sewage from these outfalls.

There are about 150 small private discharges within the catchment area, the vast majority of which are to soakaway with a few discharging to watercourses. These are all small relative to the three sewage works which serve most of the area, typically consisting of a septic tank or package treatment plant serving one or a small number of properties. It is uncertain whether the bacterial content of those discharging to soakaway survives to reach coastal waters. As discussed above, the groundwater re-emerges on the beaches as a series of springs which are too small and numerous to influence the sampling plan. Those discharging to watercourses will make some contribution to levels of *E. coli* within these watercourses, but overall impacts are likely to be minor.

As well as consented discharges, it is thought there may be some sewage misconnections in the area, where domestic sewage from properties has been mistakenly routed into surface water drains rather than sewers. This may have occurred in Limeslade Bay, and possibly in other areas, although it could only be confirmed by investigative work.

In conclusion, the main consistent hotspot of sewage related contamination is at the Southgate STW outfall. A second hotspot will arise at the Bishopston STW outfall, which will be much smaller on average, but at times when the UV plant is not operating efficiently or when storm discharges are being made here, will be of greater significance. Some impacts to the western end may arise from Oxwich STW, and the eastern end may be impacted by discharges to Swansea Bay. The intermittent discharge at Mumbles, spills regularly in wet weather, and is generally active during the ebb tide so most impacts will be felt along the south Gower coast. There may be some impacts from multiple small private discharges to groundwaters, but there is some uncertainty about whether the bacterial content of these survives passage through the aquifers. Also, as the groundwaters re-emerge as a series of many small springs, they may almost be considered a diffuse input.

AGRICULTURE

Agricultural land within the catchment area is mainly pasture, and although the catchment is quite small it does support significant numbers of grazing livestock (9055 sheep and 2760 cattle). There are also large numbers of poultry farmed here. Contamination of livestock origin will either be deposited directly on pastures by grazing animals, or collected from operations such as cattle sheds and poultry houses and spread on agricultural land. This, in turn will enter watercourses which will carry it to coastal waters. Given the ubiquity of pasture in the area and the large numbers of livestock all watercourses are likely to carry some contamination of agricultural origin into coastal waters. It is likely that the aquifers are also subject to some agricultural contamination. Fluxes of livestock related contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush').

Of particular interest livestock are grazed on the saltmarsh adjacent to Pennard Pill, which flows into Threecliff Bay, so tidal inundation of saltmarsh here is likely to result in significant fluxes of faecal indicators into Threecliff Bay. This will add further to the loadings carried by land runoff from the Pennard Pill catchment. Significant poaching of river banks has been recorded in the Bishopston Stream, which discharges to Pwlldu Bay. This indicates that livestock have access to this watercourse and so are likely to deposit directly within it which will result in elevated levels of faecal indicators. Therefore, Threecliff Bay and Pwlldu Bay may be particularly susceptible to contamination of agricultural origin.

The spatial pattern of manure spreading within the catchment is uncertain. Since 2009 sewage sludge has been applied to land at three farms at Knelston, two of which are in the Pennard Pill catchment and one of which is in the Oxwich Stream catchment. There is anecdotal evidence of poor slurry management at some farms, which may allow slurry to escape into watercourses and aquifers.

There is likely to be some seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry manure and sewage sludge may be spread at any time of the year. Peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring.

BOATS

The discharge of sewage from boats is a potential source of bacterial contamination to shellfisheries on the south Gower coast. Boat traffic in the area includes fishing boats, yachts and cabin cruisers which are likely to have on-board toilets, as well as smaller leisure craft such as sailing dinghies and kayaks which are unlikely to make overboard discharges. There are no marinas within the survey area, but there are a few moorings within Oxwich Bay and a slipway at its western end for launching small boats. There is another recognised anchorage with Pwlldu Bay. These two locations are perhaps at most risk of regular impacts from overboard discharges, although they may be made at any location.

The volumes of boat traffic are likely to be higher during the summer months when more yachts and pleasure craft take to the seas. The seasonal pattern of fishing activity is uncertain, but is likely to be on a more year round basis although poor weather is more likely to curtail fishing during the autumn and winter months. There is considerable uncertainty regarding the extent to which overboard discharges are made and their impacts on shellfish hygiene. Monitoring points within the moorings at Oxwich Bay and within the anchorage at Pwlldu Bay would probably be best situated to capture any such impacts.

WILDLIFE

The survey area contains a diversity of habitats which attract a variety of wildlife which may potentially contribute to levels of contamination found in shellfish here, including waterbirds, seabirds, seals and porpoises.

There are no major estuaries or large areas of saltmarsh supporting overwintering waterbirds (wildfowl and waders) in numbers of national importance. It is likely that the saltmarsh habitat found around the tidal reaches of Pennard Pill does attract some waterbirds, and intertidal areas with large invertebrate populations are likely to support foraging waders. Numbers of such birds in the area will be much higher during the winter. Contamination from wildfowl on the salt marshes will be carried into Pennard Pill either via tidal inundation or runoff, so will further contribute to the bacterial loadings carried by this watercourse. Foraging waders will deposit directly on the intertidal area, and so represent a diffuse source which will not influence the sampling plan.

The rocky headlands of Mumbles and Pennard Point are used by breeding seabirds (gulls, cormorants etc.). Seabirds will forage widely around the area and are likely to be present all year round. On the shoreline survey small aggregations of gulls were recorded foraging on the intertidal area at Threecliff Bay and at Oxwich Bay, in close proximity to where streams flow across the beach in both cases.

Harbour porpoises are a regular presence within the survey area and are sighted throughout the year. Seals are found foraging throughout the south Gower coastline all year round. A small colony is also found on Worm’s Head, approximately 6 miles from Oxwich Bay (CCW pers. comm.). One seal was seen during the shoreline survey. Porpoises and seals forage widely so will be present within the survey area from time to time but their numbers are likely to be small and their presence will be unpredictable both spatially and temporally. Due to their low numbers and high mobility the presence of porpoises and seals will not influence the sampling plan.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified.

Domestic Animals

Dogs are exercised along the coastal footpaths and beaches within the survey area. They are banned from Bracelet, Caswell, Langland and Rotherslade Bays (but not Oxwich Bay) between May to September. Dogs represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on beaches near easy access points.

Summary of Pollution Sources

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

Table 5.1 Qualitative assessment of seasonality of important sources of contamintion.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff												
Continuous sewage discharges												
Intermittent sewage discharges												
Waterbirds and seabirds												
Boats on moorings/anchorages												
Dogs												

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

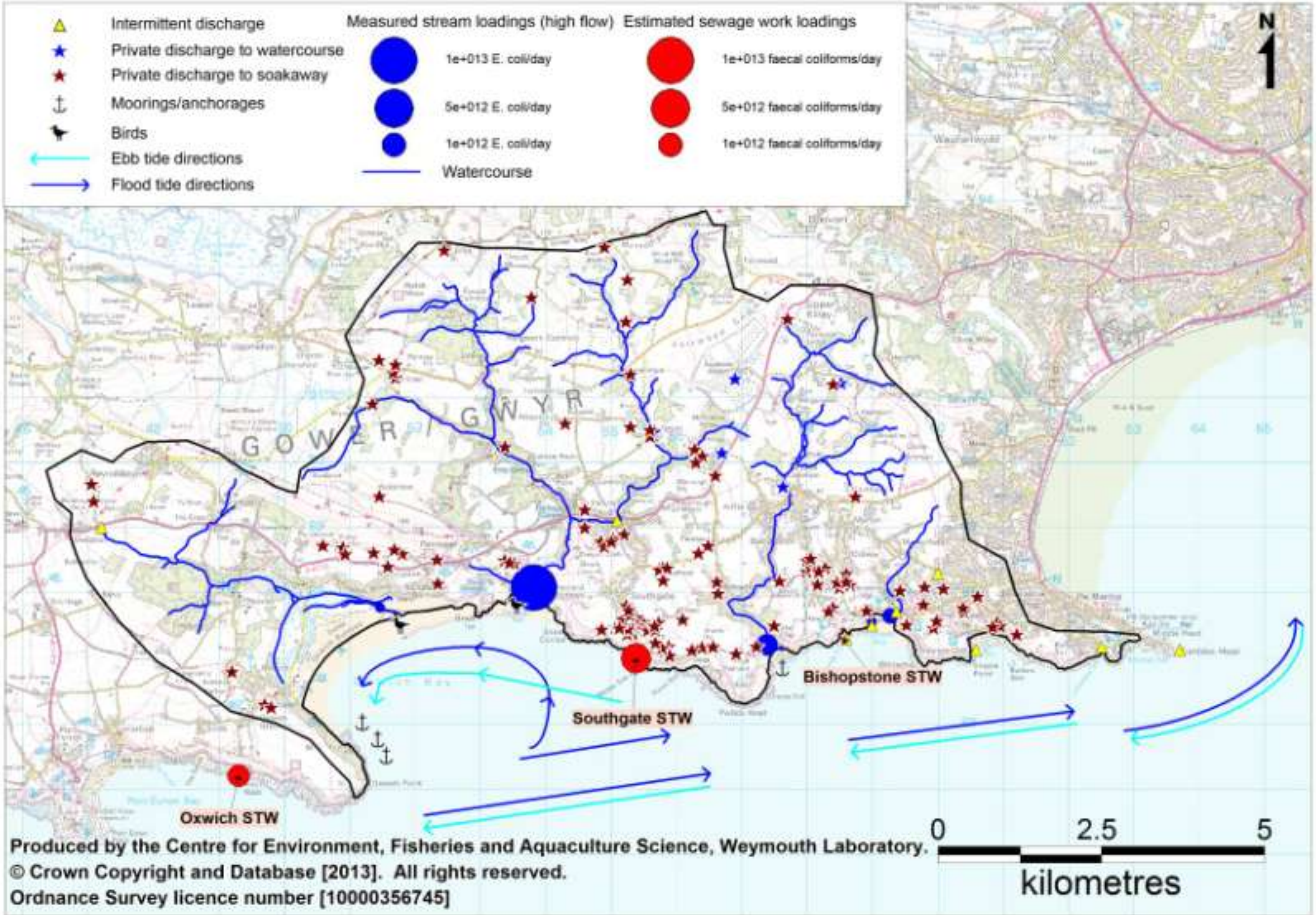

Figure 5.1 Summary of significant sources of microbiological pollution to the survey area.

HYDROGRAPHY

The survey area is an open coast location on the north shore of the approaches to the Bristol Channel. The bathymetry is relatively uncomplicated, gradually sloping away to depths of over 15m. The depth drops away more steeply at the eastern end of the area, with a shallower gradient and more extensive intertidal areas within Oxwich Bay. Oxwich Point provides Oxwich Bay with shelter from the prevailing south westerly winds and swells. There are a series of smaller bays backed by cliffs to the east of Oxwich Bay, where the intertidal area is rockier. At the eastern end of the survey area a reef lies about 1km to the south of Mumbles Head. Tidal streams are likely to accelerate and become more turbulent over this reef, and at Oxwich Point, which will promote mixing of the water column.

Tidal amplitude is large, and tidal streams dominate patterns of water circulation in the area. A bi-directional tidal regime prevails, with the tide flooding in an easterly direction, and ebbing in a westerly direction, so the plumes emanating from shoreline sources will tend to travel along the coastline. Within Oxwich Bay, a gyre forms on the flood tide. As a consequence flows along the shore at Oxwich Bay are usually in a westwards direction irrespective of state of tide, which may have the consequence of increasing the impacts of Pennard Pill on intertidal fisheries within Oxwich Bay. Other sources to the east of Threecliff Bay, such as the Southgate sewage works will impact both to the east and west of their locations. As the Mumbles Head pumping station only discharges during the ebb tide, all effluent from this outfall will be carried in a westerly direction along the south Gower coast. Modelling has indicated the plume can reach as far as Oxwich Bay on Spring tides.

Approximate estimates for tidal excursions along this stretch of coast, based on a tidal diamond by Mumbles Head, are about 10km on spring tides and 5km on neap tides. As a consequence, the (UV treated) Swansea STW discharge may impact on the eastern and of the survey area during larger tides, although the UV treatment should mean the bacterial concentrations within the effluent should be very low. Modelling studies have indicated that effluent from this STW would be carried about as far as Pwlldu Head during a spring ebb tide, but would remain at least 1km offshore even under southerly winds. The plume from the (secondary treated) Afan STW discharge, which will generate a much larger bacterial loading, will only just reach Mumbles Head on spring tides before the tidal stream reverses and carries it back eastwards. Whilst the direction of flows in the nearshore and intertidal areas to the east of Oxwich Bay are likely to be similar to offshore, the rates of travel will be slower due to friction. The plume from Oxwich STW may impact on the western end of the survey area, and it is likely that more of it will reach the shore during larger tides.

As freshwater inputs are relatively small, and the survey area is along an open coastline, density effects are unlikely to modify tidal streams in any noticeable way. Salinity levels at various points consistently average around 32.5ppt confirming there is little freshwater influence throughout this stretch of coast.

Winds will modify circulation patterns within the survey area at times. The survey area is most exposed to winds from the south, and the prevailing wind direction is from the south west. Exact effects are dependent on the wind speed and direction and the state of the tide at the time and so a great range of scenarios may arise. Winds with a southerly element will tend to advect contamination in the upper part of the water column towards the shore.

As well as driving surface currents, onshore winds will create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. The western end of Oxwich Bay is much more protected from the prevailing swells by Oxwich Point and so may represent a more stable environment for bivalve molluscs compared to the more open coast to the east.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

No samples of shellfish flesh from the survey area have been tested for bacteriological content as it is neither a classified harvesting area nor a shellfish growing water. Water samples have been regularly tested for faecal coliform content from seven sites within the area under the bathing waters monitoring programme.

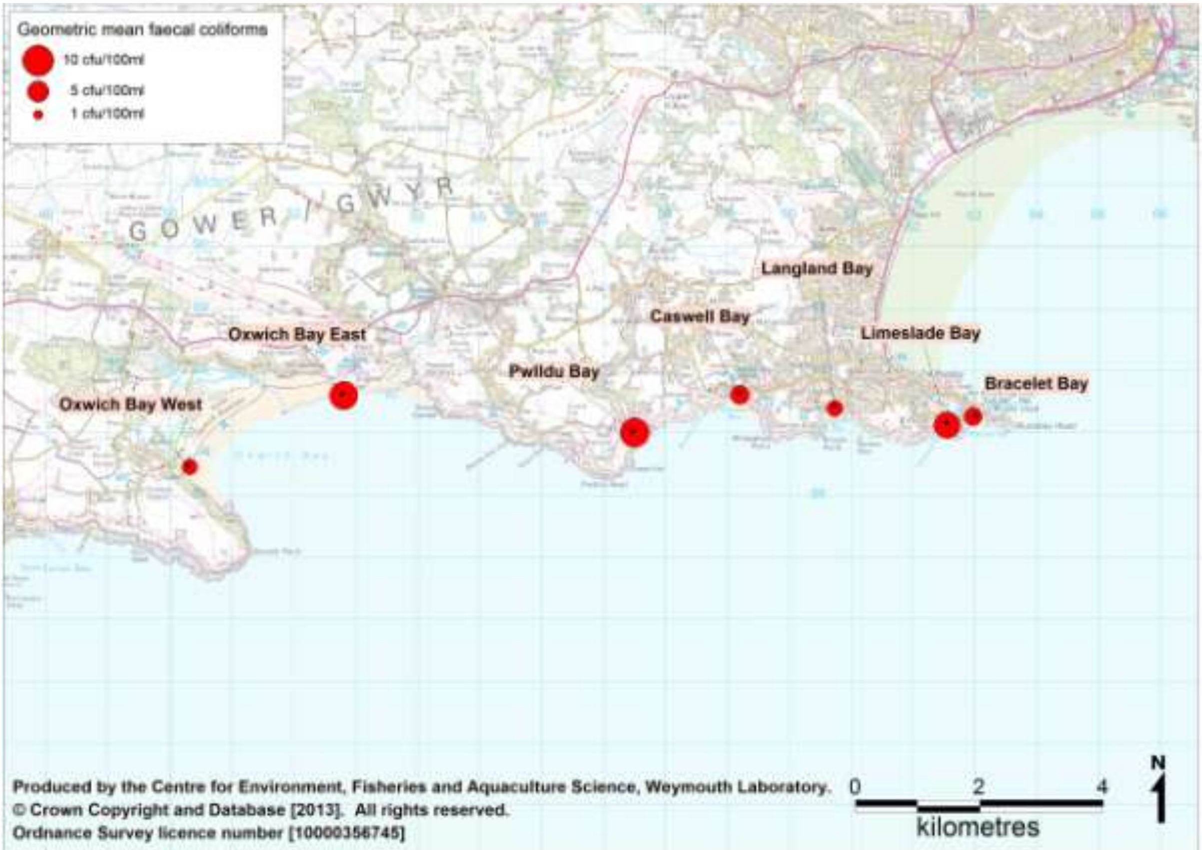

Figure 5.2. Location of bathing waters sampling points referred to in this assessment

Every bathing season (May-September) around 20 samples were taken from each location. Oxwich Bay East and Pwlldu Bay were only monitored until 2004 and 2005 respectively, but the other sites were sampled every year from 2003-2011 Levels of faecal coliforms are generally low throughout the area, with average concentrations of less than 10 cfu/100ml at all locations. No overall pattern of increasing or decreasing levels of contamination was observed along the coast as a whole suggesting large sources outside of the survey area (e.g. sewage discharges to Swansea Bay) are not of major significance.

Some spatial variation was observed, with higher average results at Pwlldu Bay, Oxwich Bay East and Limeslade Bay compared to the other sites. The first two are close to significant freshwater inputs, and lie either side, but a considerable distance from, the Southgate STW outfall. Alternatively, the higher average results may potentially be a consequence of the shorter period over which they were sampled. Limeslade Bay may be impacted by sewage misconnections, but there are no significant streams here and the emergency overflow from the Limeslade Bay pumping station is not thought to have made a discharge during the bathing season for several years. Paired (same-day) sample comparisons of the five sites sampled throughout the period (Oxwich Bay West, Caswell Bay, Langland Bay, Limeslade Bay and Bracelet Bay) revealed significant correlations between each site pairing. This suggests that the whole stretch is influenced by a similar profile of sources, or sources which react in a similar manner to environmental conditions.

Some relatively weak correlations between faecal coliform results and state of tide were detected at the three most easterly sites. Correlations were found between the high/low tidal cycle at Langland and Limeslade Bays. When this data was plotted, a vague tendency for fewer low results around high water was seen at Langland Bay, but no pattern was apparent at Limeslade Bay. Langland, Limeslade and Bracelet Bays all showed correlations with the spring/neap tidal cycle, but no obvious pattern in results was seen at any of these sites when the data was plotted. Overall, this suggests there is some influence of tide at the eastern end, perhaps implying that sources within Swansea Bay have some underlying influence. However, the general lack of clear patterns when the data was plotted indicates that any such influence is a weak one and is not the main source of variation in levels of indicator bacteria at these locations.

Very few correlations were found between faecal coliform concentrations and rainfall over a variety of periods before sampling, suggesting that rainfall dependent sources do not cause major deteriorations in water quality along this stretch of coast. Significant positive correlations were found at Oxwich Bay West, Pwlldu Bay and Caswell Bay. Pwlldu Bay and Caswell Bay are both have watercourses draining into them. Oxwich Bay West may be influenced by the Oxwich Stream, and possibly also the Pennard Pill. No correlation with rainfall was found for Oxwich Bay East, which is just under 1km to the west of the Pennard Pill. This may suggest the plume emanating from Pennard Pill is not a major influence here, although it must be noted that this site was sampled on considerably fewer occasions than most of the other sites.

During the shoreline survey, five water samples were taken, and of these most returned relatively low results (less than 30 *E. coli* cfu/100ml). The exception to this was a sample from the western end of Oxwich Bay, which contained 2,200 *E. coli* cfu/100ml. The reason for this high result is unclear as no significant point sources were observed in the vicinity.

APPENDICES

APPENDIX I
HUMAN POPULATION

Figure I.1 shows population densities in census output areas within or partially within the hydrological catchment, derived from data collected at the time of last census (2001). The equivalent data from the 2011 census was not yet published at the time of writing.

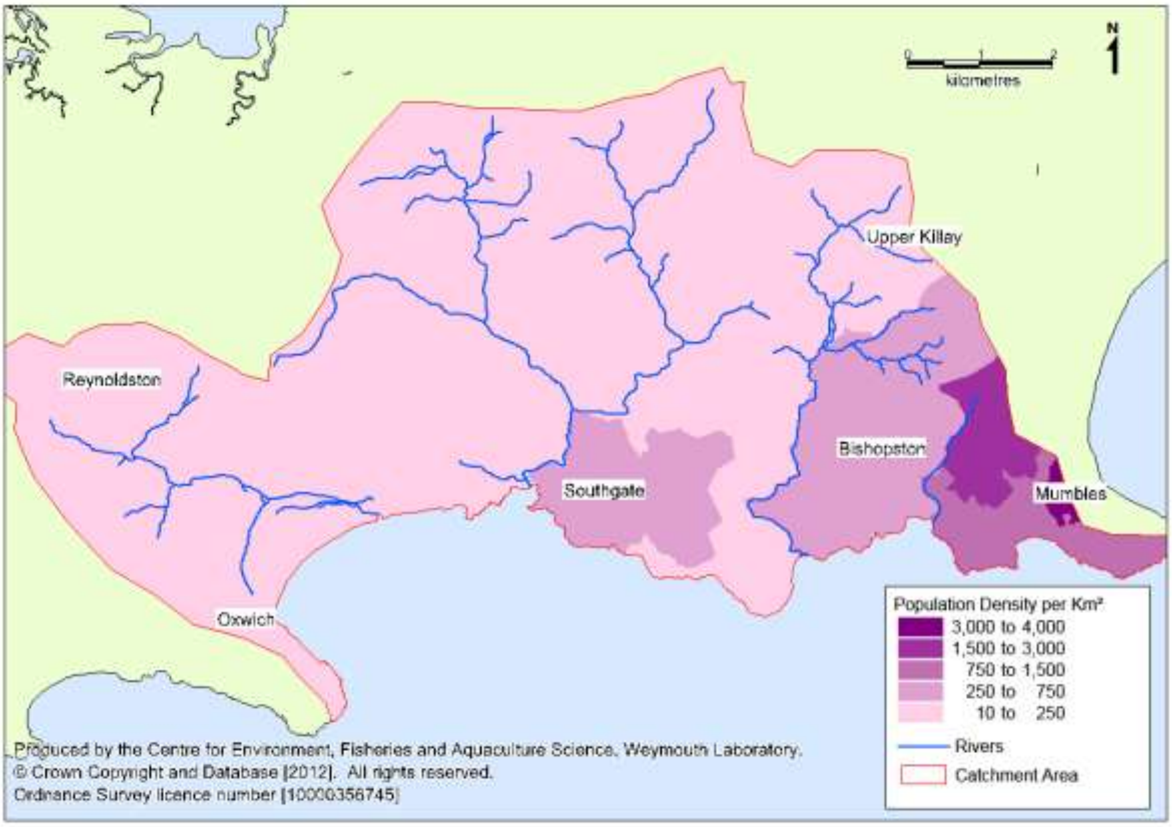

Figure I.1 Population densities in the catchment area

Source: ONS, Super Output Area Boundaries (Lower layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Total resident population of the survey area was about 27,191 at the time of the 2001 census. Figure I.1 indicates that the highest density within the catchment was in the south eastern corner on the outskirts of the town of Mumbles. The majority of the survey area is rural comprising of woodland, pasture, agricultural and common land; this is reflected in the low population density in the majority of the catchment which falls between 10 and 250 persons per km². Oxwich on the western side of the survey area has a resident population of less than 200.

Significant numbers of tourists are attracted to the area because of the attractive scenery and sandy beaches, where various watersports, coastal walks and other outdoor activities are pursued. Visitors to the area tend to stay in the various guesthouses, B&B's, caravan and camping sites. Consequently, population within the survey area will increase during peak months. Tourism contributes to a large proportion of the income in the sea side villages, in particular Mumbles. In 2011 Swansea attracted over 4.2 million tourists; this brought an expenditure of £335 million to the region and supported 5,602 jobs (City and Council of Swansea, 2011). Due to the close proximity of Swansea, it can be assumed that a high proportion of day visitors from Swansea visit the south Gower coast. During the summer the Swansea Bay Rider (a tourist train) runs from the outskirts of Swansea into Mumbles village.

In conclusion, the area is mainly rural with a relatively small population, which is most concentrated at the eastern end. During the summer months when tourism is at its peak the total population will be higher and bacterial loadings from sewage treatment works serving the area will increase accordingly. Deterioration in the microbiological quality of water and bivalve molluscs is frequently detected in coastal areas that are impacted by pollution sources associated with tourism activities, possibly due to increased loads from sewage treatment plants (Younger et al., 2003). .

APPENDIX II
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges within the hydrological catchments draining to the survey area were taken from the Environment Agency's national discharge database (July 2012). The Environment Agency also provided locations of recently registered private discharges which were yet to be added to the national database. Their locations are shown in Figure II.1.

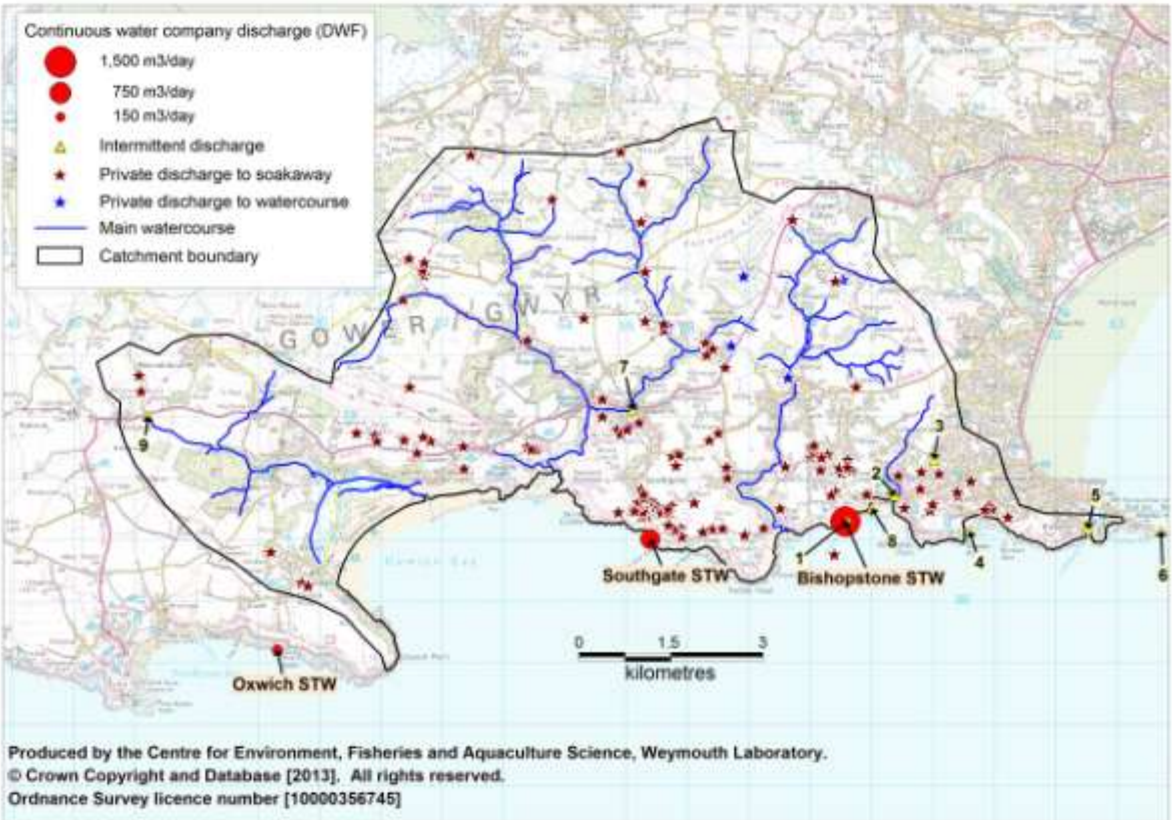

Figure II.1 Sewage discharges to the survey area

There are two continuous water company owned sewage discharges direct to the fishery area, and another one about 2km to the west. Details of these are presented in Table II.1.

Table II.1 Details of the continuous water company sewage discharge to the area

Name	Bishopston STW	Oxwich STW	Southgate STW
Outfall location	SS 58560 87287	SS 49300 85200	SS 55380 87000
Receiving Water	Brandy Cove	Port Enyon Bay	Oxwich Bay
Consented dry weather flow (m^3/day)	1,406	Not stated	682
Population equivalent	Not stated	1349	Not stated
Treatment Level	Tertiary (UV)	Secondary	Secondary
Mean sampled flow	916 m^3/day	261 m^3/day	677 m^3/day
Maximum sampled flow	7,361 m^3/day	812 m^3/day	1,425 m^3/day
No flow samples	136	39	41
Geometric mean feacal coliforms in final effluent	853 cfu/100ml	Not tested	Not tested
Maximum faecal coliforms in final effluent	260,000 cfu/100ml	Not tested	Not tested
Average bacterial loading (faecal coliforms/day)	6.4×10^9	8.6×10^{11}	2.2×10^{12}
No. bacteriological samples	136	Not tested	Not tested
Period of sampling	2006-2011	2006-2009	2006-2009
Method of loading calculation	Geometric mean of all occasions where flow and concentration of faecal coliforms were measured.	Reference values (Table II.2) for bacterial indicator concentration and average measured flow	

Data from the Environment Agency

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

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

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

The largest of the three sewage works (Bishopston STW) receives UV disinfection and so its effluent generally contains low concentrations of indicator bacteria and the bacterial loading it generates is very low. The other two works, although smaller in terms of the volumes of effluent discharged receive only secondary treatment so are likely to generate much larger bacterial loadings. Therefore, the Southgate sewage works is likely to create the most significant sewage related hostpot of contamination within the area requiring classification.

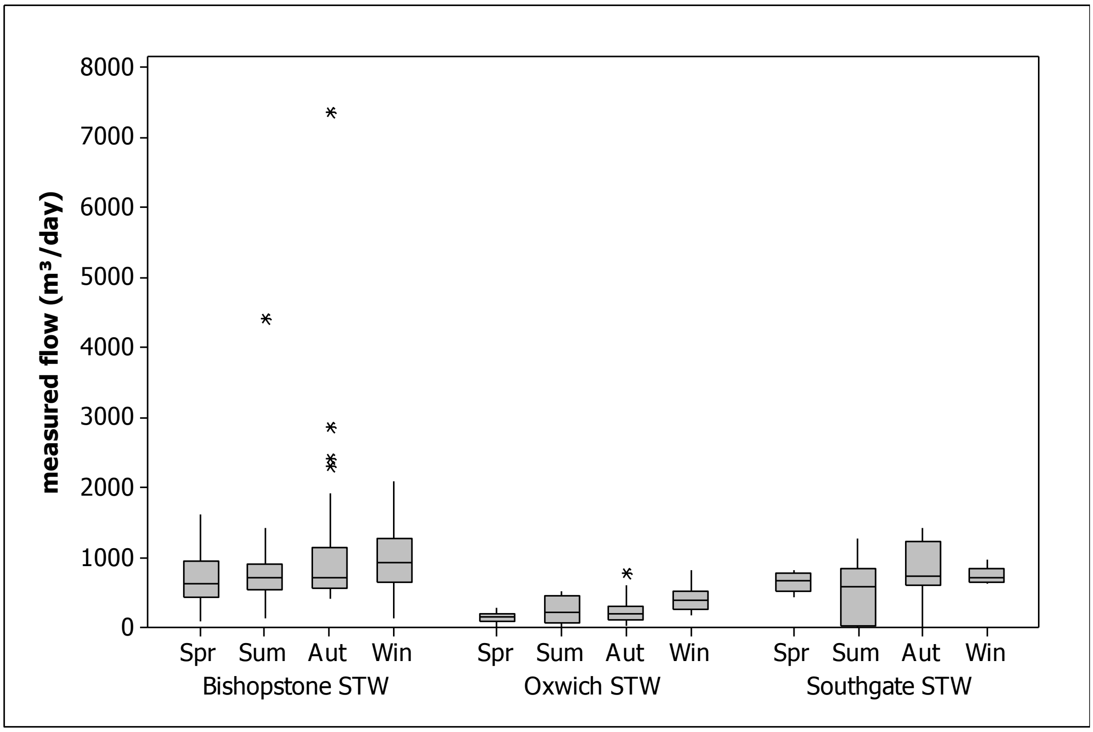

Figure II.2 Boxplot of flow measurements by season at the three sewage works
Data from the Environment Agency

No significant seasonal variation in measured flows was found at any of the sewage works (One-way ANOVA, p=0.064 to 0.375) but a slight tendency for higher flows during the autumn and winter is apparent in Figure II.2. This is perhaps a consequence of increased surface water infiltration rather than increased volumes of sewage. No seasonal variation in concentrations of faecal coliforms in the final effluent from Bishopston STW was found (One-way ANOVA, p=0.993).

As well as the discharges listed in Table II.1 there are two major sewage works (Swansea and Afan) to Swansea Bay which may be of significance to Oxwich Bay. They serve populations of 184,921 and 125,462 and discharge 5 and 10km east of Mumbles Head respectively (CEFAS, 2011). Although the former receives UV treatment their combined effects may be of some influence, particularly towards the eastern end of the shellfishery.

In addition to the continuous discharges, there are nine water company owned intermittent discharges within the survey area. Some are permitted to make storm discharges, which may occur when the sewers become overloaded following heavy rainfall. Others are only permitted to discharge in an emergency, for example following a pump failure or a blockage. Details are shown in Table II.3.

Table II.3. Intermittent discharges to the survey area

No.	Name	Location	Receiving water	Type
1	Bishopston STW	SS 58600 87300	Brandy Cove	Storm
2	Caswell Bay SPS	SS 59367 87711	Caswell Bay	Emergency
3	Woolacot SPS	SS 60000 88300	Watercourse	Emergency
4	Langland SPS	SS 60589 87127	Langland Bay	Emergency
5	Limeslade SPS	SS 62508 87168	Limslade Bay	Emergency
6	Mumbles (Knab Rock) SPS	SS 63700 87130	Coastal waters	Storm
7	Pennard SPS	SS 55094 89102	Watercourse	Emergency
8	Redcliffe SPS	SS 58990 87500	Caswell Bay	Emergency
9	Knelston SWO	SS 47200 89000	Watercourse	Storm

Outfalls highlighted in yellow have spill event recording

Spills from storm overflows will mainly be associated with wet weather events, particularly if the sewerage networks collect significant amounts of surface water. Storm overflows from Bishopston STW pass through a reed bed before being discharged to coastal waters (Environment Agency, 2012a) which will reduce its impacts to some extent. Records of spill events from Bishopston STW and Mumbles SPS were provided by Welsh Water for the period covering 01/12/2010 to 27/11/2012. These are presented in Figure II.3.

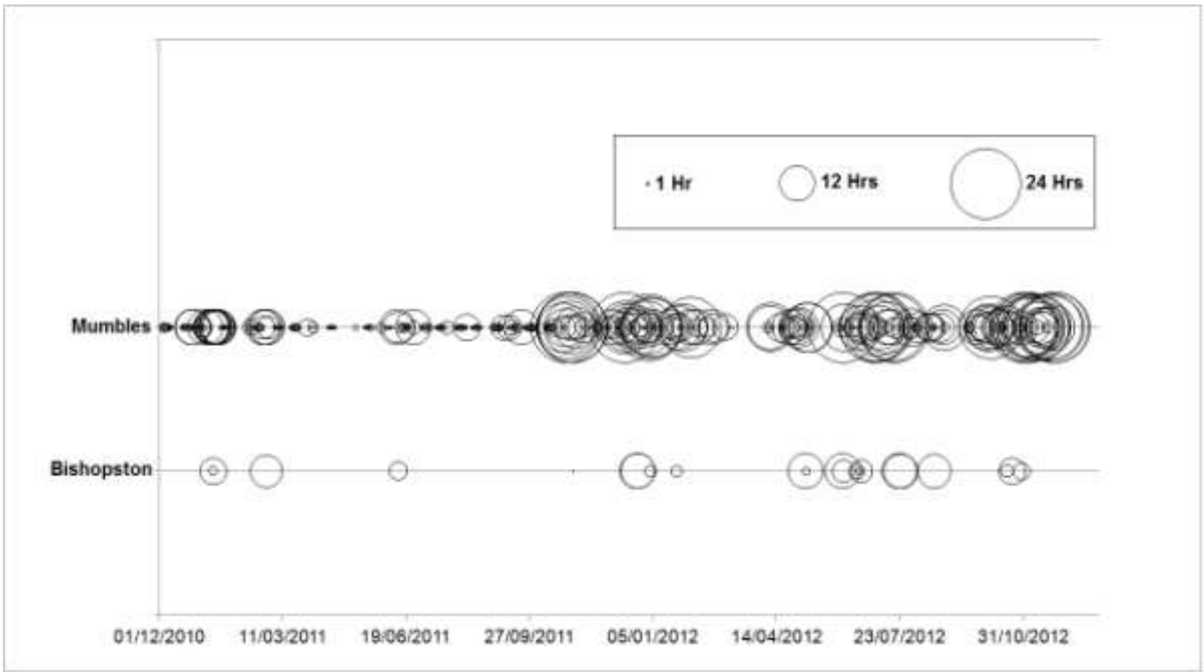

Figure II.3 Bubble plot of spill records from the monitored storm outfalls.
Data from DCWW.

The Bishopston STW overflow only spilled occasionally, and was only active for 1.0% of the period covered, and so is not likely to be a major contaminating influence. The Mumbles STW spilled much more frequently, and was active for 14.4% of the period covered. This pumping station serves a large catchment and has a consented dry weather flow of 6930 m^3/day so spills from here are potentially of a high volume. Discharges from this outfall are tidally phased, and are supposed to be made between 1 and 5 hours post high water to help protect the bathing and shellfish waters in Swansea Bay. Whilst the vast majority of recorded events started shortly after high water, some were of longer duration than 4 hours and so continued outside of this window. Therefore, the majority of activity from this outfall occurs during the ebb tide, at which time contamination will be carried westwards towards Oxwich Bay.

Spills from the emergency overflows associated with mechanical failures or blockages may occur at any time but are likely to be much rarer events. For example, bathing waters profiles indicate that Caswell Bay, Limeslade and Redcliffe SPSs have not spilled during the bathing waters season in the last 5 years (Environment Agency 2012a, b). Neither Southgate nor Oxwich STWs are permitted to make storm or emergency discharges.

In addition to water company sewerage networks, there are about 150 private sewage discharges, the vast majority of which are to soakaway with a few discharging to watercourses. These are all small relative to the three sewage works which serve most of the area, typically consisting of a septic tank or package treatment plant serving one or a small number of properties. The groundwater's to which most of these discharges are made re-emerge at various points along the shore, but the travel time and extent of bacterial die off which occurs underground is uncertain. Those discharging to watercourse will make some contribution to levels of *E. coli* within these watercourses, but overall impacts are likely to be minor.

As well as consented discharges, it is thought there may be some sewage misconnections in the area, where domestic sewage from properties has been mistakenly routed into surface water drains rather than sewers. At Limeslade Bay some evidence of this was observed during the shoreline survey, where toilet paper was seen in the mouth of a surface water outfall pipe. It is uncertain how many properties may be misconnected but it is assumed that the vast majority are properly connected. Any surface water drains in built up areas may potentially be subject to contamination from such sources.

APPENDIX III
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Agricultural land within the Oxwich Bay catchment area is mainly pasture, although there is a pocket of land where crops are cultivated around Parkmill (Figure 1.2). Table VIII.1 presents livestock numbers and densities for the entire catchment area draining directly to the shellfishery. This data was provided by Welsh Government and is based on the June 2011 census. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, Table VII.1 should give a reasonable indication of the numbers and types of livestock within the catchment.

Table VIII.1 Summary statistics from 2011 livestock census for the survey catchment

	Sheep	Cattle	Pigs	Horses	Goats	Poultry
Total number	9,055	2,760	16	342	12	368,991
Density (animals/km^2)	134.0	40.9	0.2	5.1	0.2	5,462.5

There are significant numbers of grazing animals (both sheep and cattle) within the catchment. There are also large numbers of poultry farmed here. Contamination of livestock origin will either be deposited directly on pastures by grazing animals, or collected from operations such as cattle sheds and poultry houses and spread on agricultural land. This, in turn will enter watercourses which will carry it to coastal waters. 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).

Given the ubiquity of pasture in the area and the large numbers of livestock all watercourses are likely to carry some contamination of agricultural origin into coastal waters. The main watercourses discharging to the coast here are Pennard Pill, Bishopston stream and the Oxwich Stream, although there are several smaller watercourses which may also be of some significance. Groundwaters, which re-emerge at numerous places along the shoreline are also likely to receive contamination from agriculture. Elevated nitrate levels have been recorded in groundwaters around Oxwich (Environment Agency, pers comm.) although the extent to which bacterial indicators survive passage through the aquifers is uncertain.

Two specific areas of potential concern were identified by the Environment Agency. Livestock are grazed on the saltmarsh adjacent to Pennard Pill, which flows into Threecliff Bay, so tidal inundation of saltmarsh here is likely to result in significant fluxes of faecal indicators into Threecliff Bay. This is a particularly direct and predictable mechanism which may result in large amounts of faecal matter being washed into coastal waters during spring tides. An Environment Agency study conducted in the Ribble estuary found a significant increase in levels of faecal coliforms within saltmarsh creeks in grazed areas as the tide started to ebb following tidal inundation (Dunhill, 2003). Significant poaching of river banks has been recorded in the Bishopston Stream, which discharges to Pwlldu Bay. This indicates that livestock have access to this watercourse and so are likely to deposit directly within it which will result in elevated levels of faecal indicators. Therefore, Threecliff Bay and Pwlldu Bay may be particularly susceptible to contamination of agricultural origin.

The spatial pattern of manure spreading within the catchment is uncertain. Since 2009 sewage sludge has been applied to land at three farms at Knelston, two of which are in the Pennard Pill catchment and one of which is in the Oxwich Stream catchment (Environment Agency, pers comm.). No major incidents arising from the spreading of organic fertilisers have been recorded by the Environment Agency within the survey area in recent years, although they report anecdotal evidence of poor slurry management at some farms.

The primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, so fluxes of livestock related contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’).

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During the summer months animals may access watercourses more frequently to drink. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring. However, at present an accurate assessment on the effects of sewage sludge in the survey catchment cannot be made, as Defra/water company field level information on sewage sludge is unavailable to Cefas.

APPENDIX IV
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

The discharge of sewage from boats is a potential source of bacterial contamination to shellfisheries on the south Gower coast. Boat traffic in the area includes fishing boats, yachts, cabin cruisers and smaller leisure craft such as sailing dinghies and kayaks.

There are no marinas within the survey area, the closest being at Burry Port (450 berths) within the Burry Inlet, and Swansea Marina (390 berths) in Swansea Bay (Reeds, 2011). Swansea Marina has a sewage pumpout facility but Burry Port does not. Angling charters and commercial fishermen operate out of Swansea and Burry Port so some associated boat traffic is anticipated within the survey area.

There are a few moorings within Oxwich Bay and a slipway at its western end for launching small boats. Three fishing boats were observed on moorings here during the shoreline survey. It is likely that yachts and cabin cruisers use the more sheltered bays as anchorages from time to time. A local watersports company website lists Pwlldu Bay and Oxwich Bay as recognised anchorages for visiting yachts (Euphoria Sailing, 2012). Around 40 yachts at anchor within Pwlldu Bay were visible on satellite imagery (Google Earth, accessed 24/10/2012), although it is uncertain whether their presence in such numbers is a regular occurrence. Only five craft were visible moored/anchored within Oxwich Bay on the same images.

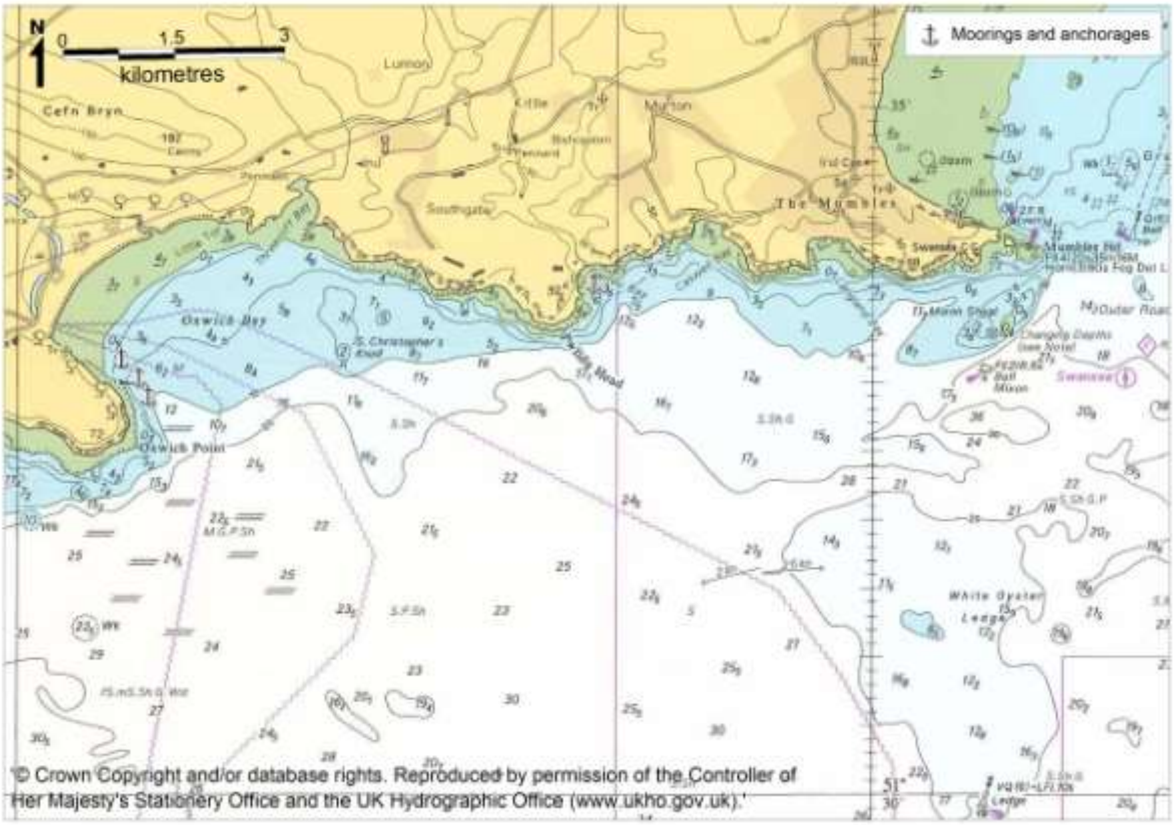

Figure IV.1 Location of moorings and recognised anchoring areas

Private vessels such as yachts, pleasure craft and fishing vessels are not covered by the specific sewage disposal regulations for commercial shipping, and so those with onboard toilets are likely to make overboard discharges. This may occur whilst boats are on passage, but it is quite likely that boats in overnight occupation on the anchorages will make a discharge at some point during their stay. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the anchorages at Oxwich Bay and Pwlldu Bay are most at risk of contamination from this source. Smaller pleasure craft such as kayaks and sailing dinghies will not have onboard toilets and so are unlikely to make overboard discharges.

The volumes of boat traffic are likely to be higher during the summer months when more yachts and pleasure craft take to the seas. The seasonal pattern of fishing activity is uncertain, but is likely to be on a more year round basis although poor weather is more likely to curtail fishing during the autumn and winter months.

To conclude, the areas used as anchorages at Oxwich Bay and Pwlldu Bay are likely to receive overboard discharges on the most regular basis, and the summer months will see higher numbers of craft at these locations. However, overboard discharges from boats may occur at any location within the survey area, at any time of the year, and there is considerable uncertainty about the extent of their impacts on water quality and shellfish hygiene.

APPENDIX V
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

The survey area which includes Oxwich Bay and a series of small bays east to Mumbles Headland, contains one of the richest and diverse coastal habitats in the UK ranging from woodland to sandy beaches, dunes, saltmarsh and a freshwater lake which in turn attracts a variety of wildlife. It is because of these diverse habitats and their biological importance that Oxwich Bay and the surrounding areas have been designated as conservation areas. Oxwich Bay National Nature Reserve protects the sand dunes and saltmarsh area which is important for wildfowl and winter wading birds. Oxwich Bay, Pwlldu Head and Minchin Hole have been designated as SSSI's and Gower Ash Wood as a Special Area of Conservation (SAC).

Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Estuarine and saltmarsh habitats such as that found at the mouth of Pennard Pill tend to attract overwintering waterbirds (wildfowl and waders). There are no sites within the survey area where the British Trust for Ornithology undertakes counts of overwintering waterbirds (Holt *et al*, 2011) so it is concluded that there are no major aggregations where peak numbers of thousands of birds occur. Nevertheless it is likely that some overwintering waterbirds frequent the saltmarsh area by Pennard Pill and the more sheltered intertidal areas where there are sufficient invertebrates for them to forage on.

The rocky headlands of Mumbles and Pennard Point are used by breeding seabirds (gulls, cormorants etc.). A survey of breeding seabirds in 2001 recorded 92 pairs of Black-legged kittiwake at Mumbles headland and 2 pairs of Herring Gull at Pennard (Mitchell *et al*, 2004). Seabirds will forage widely around the area and are likely to be present all year round. On the shoreline survey small aggregations of gulls were recorded foraging on the intertidal area at Threecliff Bay and at Oxwich Bay, in close proximity to where streams flow across the beach in both cases. This tentatively suggests that such areas may represent richer bird foraging prospects and be subject to higher levels of contamination of avian origin.

Harbour porpoises are a regular presence within the survey area and are sighted throughout the year (Baines & Evans, 2012). Although summer peaks in abundance have been reported, these may be a consequence of increased counting effort and more favourable surveying conditions at this time of year. There are about 5000 grey seals in west Wales and their main stronghold is the Pembrokeshire coast. The nearest colony to Oxwich Bay is at Caldey Island (Kiely *et al*, 2000) about 30km to the west. No formal count data for this colony could be found, but anecdotal information from a tour boat operators website indicated a year round presence. Whilst undertaking the shoreline survey one seal was spotted just offshore from Pwdllu Bay. Porpoises and seals forage widely so will be present within the survey area from time to time but their numbers are likely to be small and their presence will be unpredictable both spatially and temporally. Due to their low numbers and high mobility the presence of porpoises and seals will not influence the sampling plan.

Otters are present within the survey area (www.forestry.gov.uk). No information on numbers was available but the population is likely to be small. Otters generally tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers otters have no material bearing on the sampling plan.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified. Dogs are exercised along the footpaths that run around the coastline of the survey area and along the beaches. Four of the more popular lifeguarded beaches (Bracelet, Caswell, Langland and Rotherslade Bays) ban dogs between May to September. Dogs represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on areas of foreshore near the more populated areas and easier access points.

APPENDIX VI
METEOROLOGICAL DATA: RAINFALL

The Southgate weather station, which has a coastal location within the catchment area, received an average of 1024 mm of rain per year between 2003 and 2012. Figure II.1 presents a boxplot of daily rainfall records by month at Southgate.

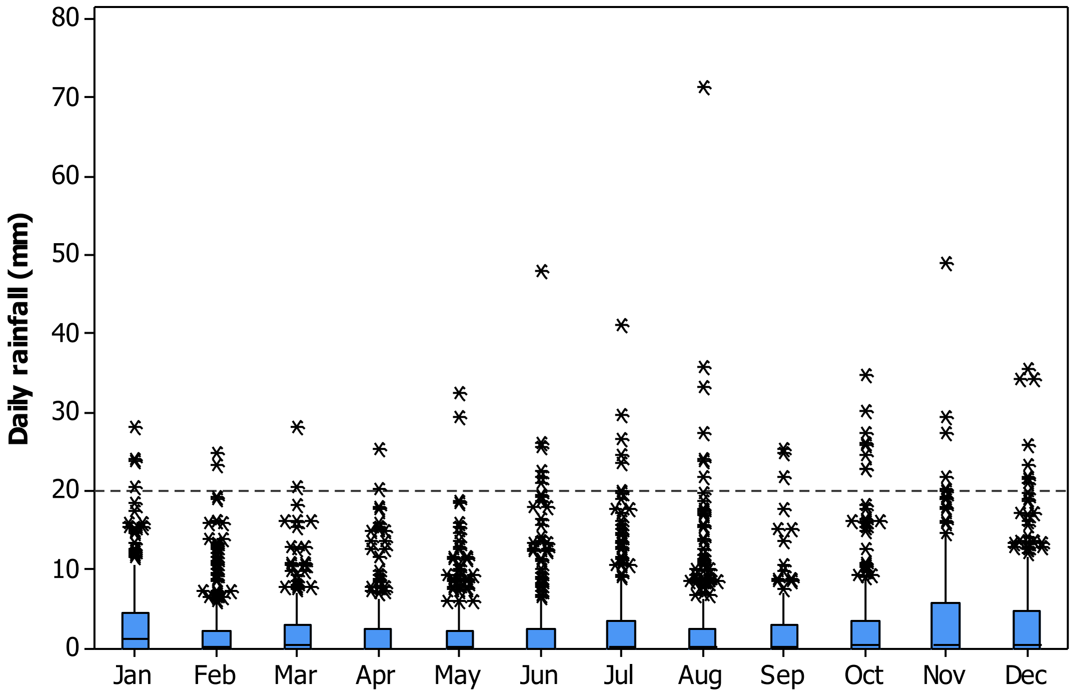

Figure II.1 Boxplot of daily rainfall totals at Southgate, January 2003 to September 2012.
Data from the Environment Agency

Rainfall records from Southgate, which is representative of conditions in the vicinity of the shellfish beds indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average in September and highest on average in November. Daily totals of over 20mm were recorded on 1.8% of days and 42.1% of days were dry. High rainfall events were recorded throughout the year, but highest daily rainfall totals tended to arise during the second half of the year.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). Representative monitoring points located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of faecal indicator bacteria in water samples and recent rainfall are investigated in detail in Appendices XI.

APPENDIX VII
METEOROLOGICAL DATA: WIND

Wales is one of the windier parts of the UK, particularly its west facing coasts (Met Office, 2012). The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to February, and this is when mean speeds and gusts are strongest (Met Office, 2012).

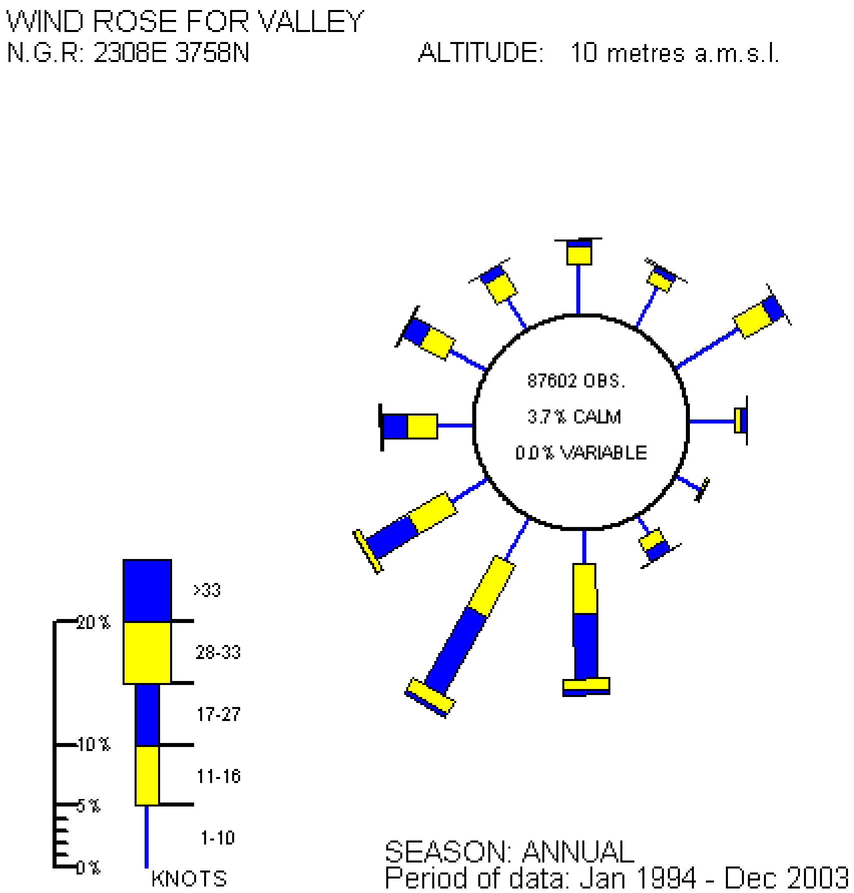

Figure VI.1 Wind rose for Valley.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Valley (Anglesey) is typical of coastal locations in Wales. The prevailing wind direction is from the south west and the strongest winds usually blow from this direction. A higher frequency of north easterly winds occurs during spring. The headland situated on the western end of Oxwich Bay provides good protection from the prevailing south westerly winds. However, the majority of the coast through to Mumbles headland through to Threecliff Bay will be exposed to south westerly winds and swells.

APPENDIX VIII
HYDROMETRIC DATA: FRESHWATER INPUTS

The catchment area draining into the shellfishery around Oxwich Bay is approximately 68 km^2 and is illustrated in Figure VIII.1. There are four principal watercourses which drain into the shellfisheries area, the largest of which is Pennard Pill. The majority of the catchment is rural and there are no large urban areas through which the watercourses flow. The underlying bedrock within the catchment is mainly moderately permeable Carboniferous limestone and Namurian millstone grit, with some smaller areas of very low permeability Devonian sandstones (British Geological Society, 2012). The soils over which the main water channels flow in this catchment are mostly easily drained brown earths although some of the surrounding soils are less porous (Bridges, 1967). As a consequence of the geology there are flows of groundwater through the catchment as well as the surface water streams, and a series of small freshwater springs were seen on the beaches during the shoreline survey.

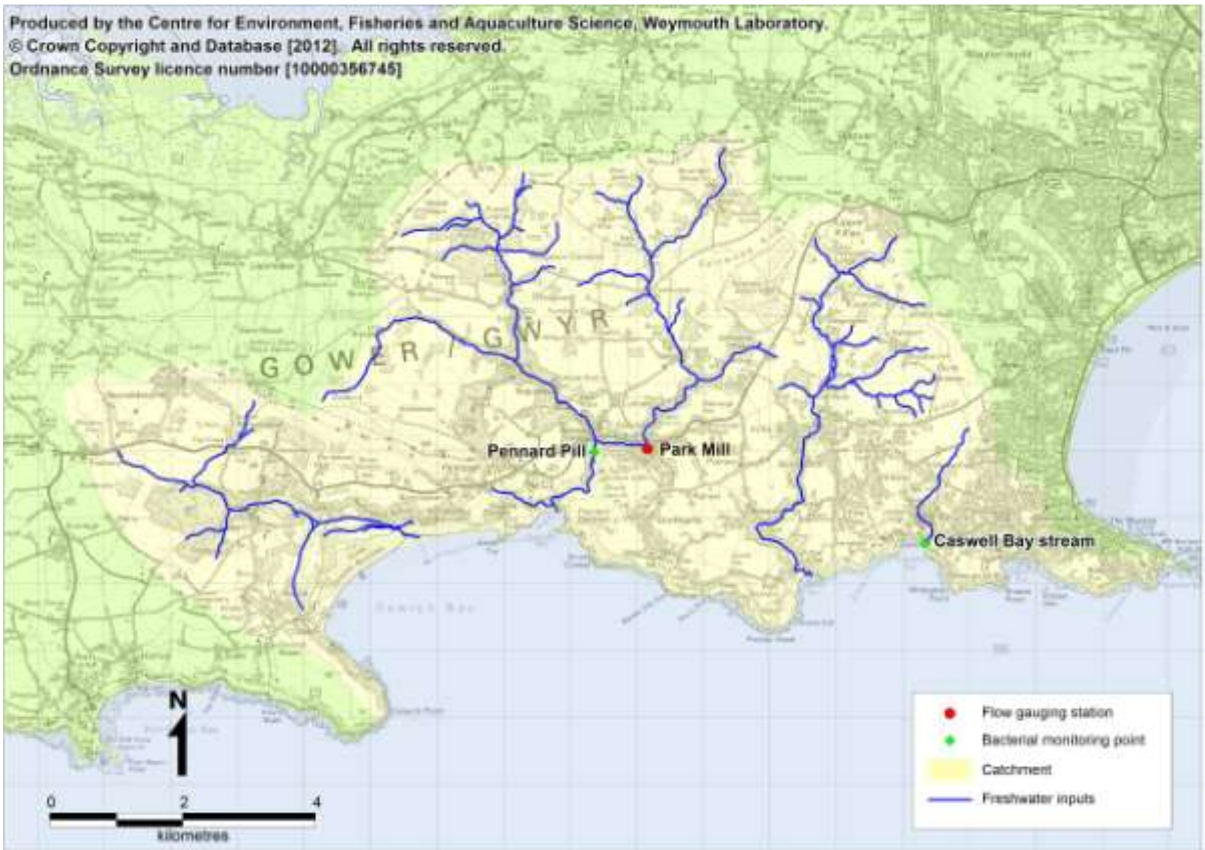

Figure VIII.1: Watercourses within the survey catchment area

All water courses will probably carry some microbiological pollution from sources such as agricultural runoff and private sewage discharges. They are all therefore a potential source of microbiological contamination for the shellfishery, although their impacts will be in proportion to both their discharge volume and the levels of contamination they carry.

At Park Mill on Pennard Pill, spot flow measurements were taken on 32 occasions from 2002 to 2007. The mean discharge was 0.179 m³/s, and the Q95 (the discharge exceeded 95% of the time) and Q10 (the flow that is exceeded 10% of the time) were estimated at 0.240 m³/s and 0.409 m³/s respectively (data supplied by the Environment Agency). Insufficient numbers of measurements were taken to allow a meaningful analysis of seasonality. Local rainfall records indicate higher rainfalls in the winter (Appendix VI), and during the colder months there is less evaporation and transpiration and soils are more likely to be saturated. As a consequence, stream discharges are likely to be highest on average through the late autumn and winter, as was reported for the neighbouring Burry Inlet catchment (CEFAS, 2012). High flow events may however happen at any time of the year. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters. They will also decrease residence time in rivers so contamination from more distant sources may have an increased impact during high flow events.

As well as the main four watercourses, some smaller freshwater inputs were seen during the shoreline survey. All watercourses which could be safely accessed were sampled for *E. coli* and spot flow measurements were made. The survey was undertaken in wet conditions so flows were likely to be higher than normal. For example, the measured discharge at Park Mill (Table 1, line 4) was almost double the highest recorded by the Environment Agency over 32 occasions indicating that a significant high flow event was underway. The results are presented in Table 1 and Figure 2.

Table 1: **E. coli** ***sample results, measured discharge and calculated E. coli loadings***

Ref.	Watercourse name	Date and Time	NGR	*E. coli* (cfu/ 100ml)	Measured discharge (m³/s)	Loading (*E. coli*/day)
1	Oxwich stream	03/10/2012 11:33	SS 51464 87772	130	0.46	4.9×10^{10}
2	Pennard Pill trib.	03/10/2012 10:29	SS 53591 88255	560	0.023	1.1×10^{10}
3	Pennard Pill trib.	03/10/2012 12:53	SS 54341 89270	720	0.89	5.5×10^{11}
4	Pennard Pill trib.	03/10/2012 13:05	SS 54502 89148	>10,000	1.62	$>1.4 \times 10^{13}$
5	Bishopston stream	02/10/2012 10:20	SS 57385 87204	1,900	0.48	7.9×10^{11}
6	Unnamed stream	02/10/2012 11:34	SS 58992 87555	820	0.069	4.9×10^{10}
7	Caswell Bay stream	02/10/2012 11:48	SS 59273 87646	2,100	0.15	2.7×10^{11}
8	Unnamed stream	02/10/2012 12:31	SS 60472 87290	400	0.0056	1.9×10^{9}
9	Unnamed stream	02/10/2012 14:00	SS 62517 87093	>10,000	0.0007	$>5.9 \times 10^{9}$

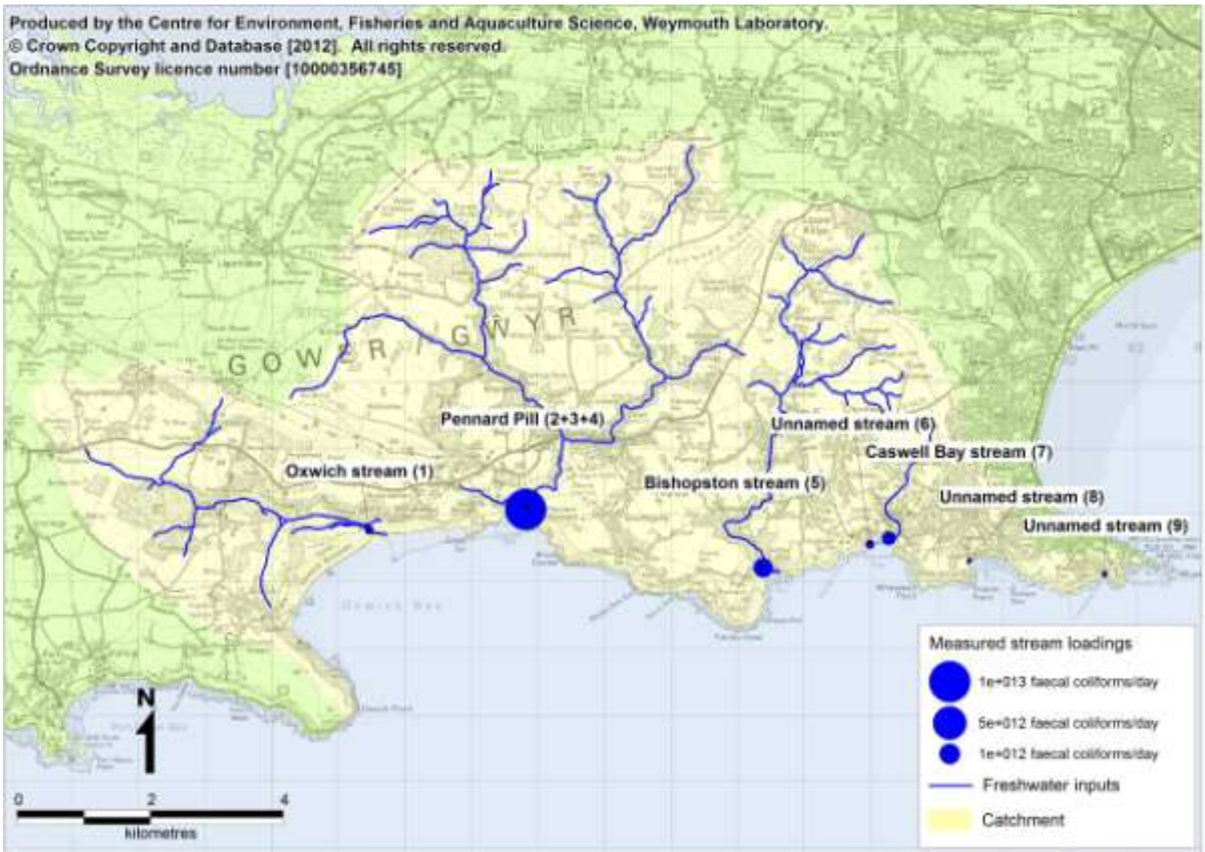

Figure 2: Measured stream loadings from shoreline survey

The combined *E. coli* loadings from the three Pennar Pill tributaries were much higher than any of the other watercourses that drain into the area, so shellfisheries in and around Threecliff Bay are likely to be subject to highest levels of runoff borne contamination. The other streams, including the Oxwich Bay stream, only carried relatively small *E. coli* loadings and as such are likely only to be of localised significance. A sample of groundwater taken from a small spring on the beach at Brandy Cove contained only 16 *E. coli* cfu/100ml, suggesting groundwaters in this area at least were relatively uncontaminated with bacteria.

Selected watercourses draining to the Oxwich Bay area have been sampled by the Environment Agency and tested for faecal coliforms. Summary statistics of these results are presented in Table 2. Results were reported here as faecal coliforms (presumptive), and so are not directly comparable with the results presented in Table 1. Also, Pennard Pill was only sampled in the late winter of 2000.

Table 2: Summary statistics for freshwater faecal coliforms results (cfu/100ml).

Watercourse	n	Geo-mean	Min.	Max.	Date of 1st sample	Date of last sample
Caswell Bay stream	63	955	40	17,273	03/09/2008	08/05/2012
Pennard Pill	20	845	73	4,900	10/01/2000	16/02/2000

The results of these samples indicate the two watercourses carried just under 1000 faecal coliforms/100ml on average, although they were more variable with a higher maximum result at Caswell Bay stream which may simply be a consequence of greater sampling effort over a longer period.

In conclusion, there are a series of small watercourses which drain the relatively small and rural catchment area considered in this survey. They will all carry some contamination from catchment sources, principally agriculture, but also sewage discharges in some cases. Of these, the most significant was the Pennar Pill, which was carrying a very high *E. coli* loading (>1.4×10^{13} cfu/day) at the time of shoreline survey, albeit under high flow conditions. Under such conditions, this watercourse may have a major influence within Threecliff Bay and beyond. The other freshwater inputs were likely to be of more local significance within the bays to which they discharge. There is likely to be significant variation in the bacterial loading carried by these watercourses on both a day to day and seasonal basis. Flows are likely to be higher on average in the winter, although high flow events may occur at any time of the year. There are significant flows of groundwater through the catchment, which typically emerge as springs on the beaches, and these may be subject to contamination from private sewage discharges to soakaway and agricultural sources.

APPENDIX IX
BATHYMETRY AND HYDROGRAPHY

BATHYMETRY

Source data for part of the admiralty chart presented in Figure IV.1 was mainly gathered in the 1980's so the bathymetry may be slightly different now, however important features discussed below are unlikely to have changed significantly.

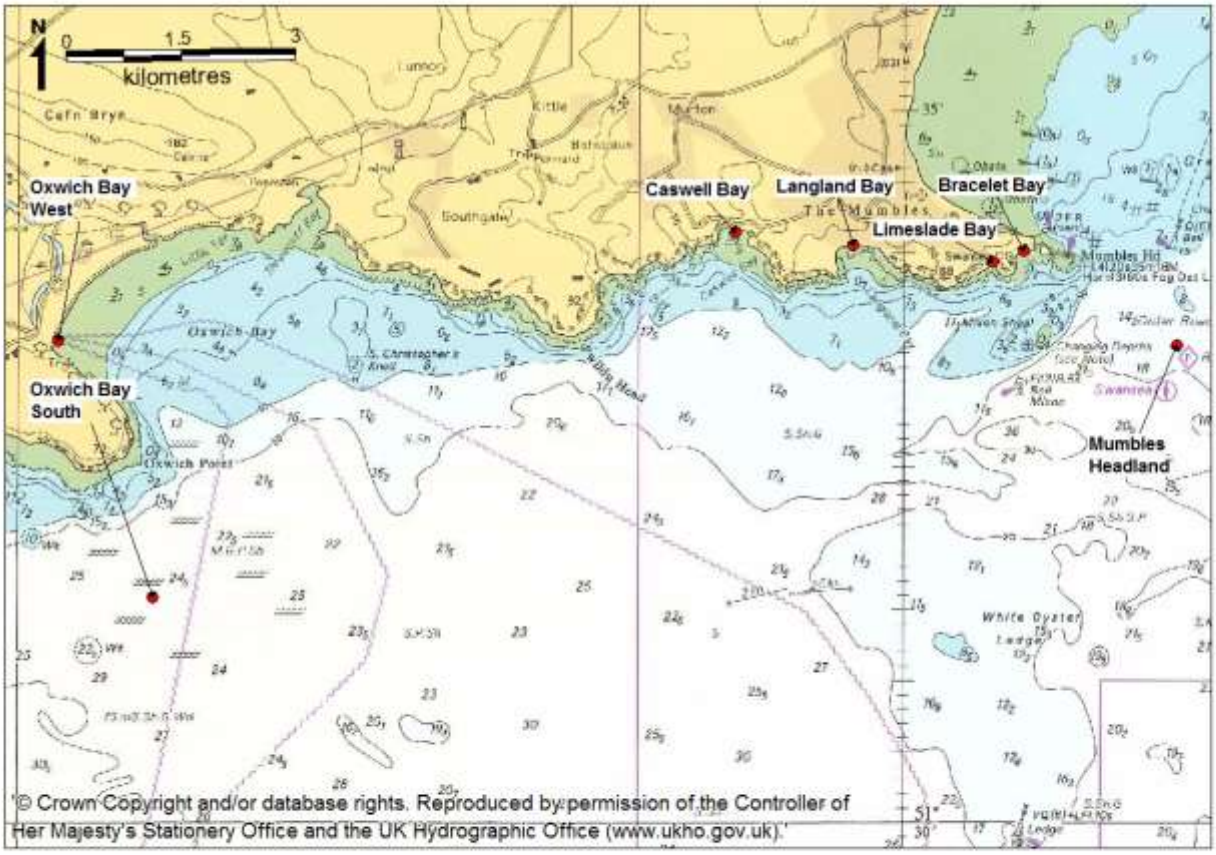

Figure IX.1 Bathymetry chart of Oxwich Bay and salinity sampling locations

The stretch of coastline encompassing Oxwich Bay is relatively uncomplicated in terms of its bathymetry. The bays Oxwich through to Langland Bay have a gradual sloping gradient and are shallow reaching a maximum depth of 12m. The gradient is slightly steeper on the west side of Oxwich Bay falling to 12m at CD in a distance of 1km, on the east a similar depth is reached in 3km. Razor clams are found up to the 15m depth mark. The gradient surrounding the headlands drops off more sharply, at Pwlldu Head the depth drops down to 10 metres in less than 1km.

Approximately 1km south of Mumbles headland there is a rocky reef (Mixon Shoal) which is 0.4m above CD at its highest point. Water will move over this shallow reef at faster speeds than the surrounding deeper waters. To the south of the reef, the depth drops rapidly to 9m and then down to 36m. There is also a subtidal sandbank (St. Christopher's Knoll) just to the east of Threecliff Bay.

WATER CIRCULATION PATTERNS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large, and tidal streams are likely to dominate patterns of water circulation in the area under most conditions.

Table IX.1 Tide levels and ranges at Mumbles

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Mumbles	9.46	7.22	3.22	0.98	8.48	4.00

Data from the UK Proudman Oceanographic Laboratory.

Table IX.2 presents the direction and rate of tidal streams at a station off Mumbles Headland on spring and neap tides at hourly intervals before and after high water. This station is located approximately 2.5km south east of Mumbles Headland (Figure IX.1, diamond F).

Table IX.2 Tidal stream predictions for the Oxwich Bay Survey Area

Time before /after High Water	Station F		
	Direction	Rate (m/s)	
		Spring	Neap
HW-6	ESE	0.05	0.00
HW-5	NE	0.26	0.15
HW-4	ENE	0.51	0.26
HW-3	ENE	0.72	0.31
HW-2	ENE	0.67	0.31
HW-1	ENE	0.51	0.26
HW	E	0.26	0.10
HW+1	SW	0.36	0.21
HW+2	WSW	0.72	0.36
HW+3	WSW	0.82	0.41
HW+4	WSW	0.57	0.26
HW+5	SW	0.36	0.21
HW+6	SW	0.10	0.05
Excursion (flood)		10.7km	5.0km
Excursion (ebb)		10.5km	5.4km

Data summarised from the Admiralty Chart 1165

The tides flood along the survey area in a north easterly direction parallel to the shore, and ebb in the opposite direction. This represents a clear bi-directional pattern of tidal streams. The flow rates indicate that the tidal excursion (the distance water travels during the course of a flood or ebb tide) is approximately 10km on spring tides, and 5km on neap tides. Tidal current at this tidal diamond is likely to be slightly skewed as the water is diverted around the prominent Mumbles headland. Further west along the coast towards Oxwich Bay, the tidal flow is likely to flood along the survey area in a more easterly direction parallel to the shore, and ebb in the opposite direction. Whilst the direction of flows in the nearshore and intertidal areas are likely to be similar to offshore, the rates of travel will be slower due to friction. Near bed flows are also likely to be slower than surface flows for the same reason. It is likely that flows are slower within Oxwich Bay than in the more open coastal locations to the east, and it is possible that eddies form here at certain states of the tide. One study suggests that an anticlockwise gyre forms during the flood tide from Threecliff Bay westwards, and on the ebb tide water also flows along the shore in a westerly direction before flowing south past Oxwich Point (Tyler and Banner, 1976). This gyre is likely to cause a dead spot to some extent in the centre of Oxwich Bay.

Contamination from shoreline sources will therefore travel parallel to the coast, impacting either side of their locations, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. Within Oxwich Bay itself, tidal flows along the shore are westwards on both flood and ebb due to the formation of a gyre on the flood tide. Contamination from shoreline sources may be carried several km along the shore during the course of a flood or ebb tide, so impacts may potentially be felt a considerable distance away. Contamination from more offshore sources such as long sea sewage outfalls may be carried up to10km on spring tides.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. There is little in the way of freshwater inputs along the coast between Oxwich Bay and Mumbles headland, and the coastal waters here are unenclosed so density effects are unlikely to modify water circulation here. A density related effect of potential relevance to the fishery is that sewage discharged from long sea outfalls, being less dense than the receiving seawater, will tend to rise to the surface and this will limit their impacts on any benthic shellfish beds in their vicinity to some extent. Figure IX.2 and Table IX.3 reveal that the salinity levels consistently average around 32.5ppt indicating little freshwater influence throughout this stretch of coast.

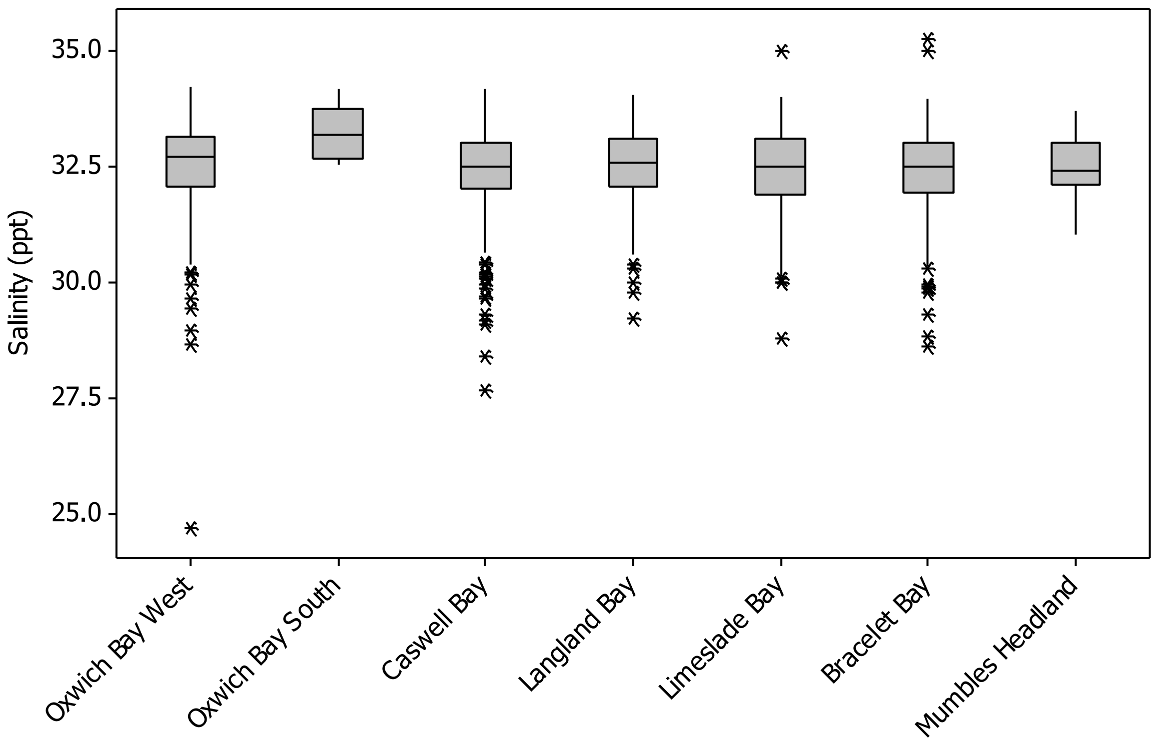

Figure IX.2 Box-and-whisker plots of levels of salinity readings taken between May and September (for the period 2000 – 2012) *Data from the Environment Agency.*

Table IX.3 Summary statistics for salinity measurements

Location	N	Mean	Minimum	Maximum
Oxwich Bay West	262	32.5	24.7	34.2
Oxwich Bay South	15	33.2	32.6	34.2
Caswell Bay	260	32.4	27.7	34.2
Langland Bay	258	32.5	29.2	34.1
Limeslade Bay	263	32.4	28.8	35.0
Bracelet Bay	266	32.4	28.6	35.3
Mumbles Headland	15	32.5	31.0	33.7

Data from the Environment Agency

Strong winds will modify surface currents on the Oxwich Bay coast. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m s^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. These currents will create return currents, either lower down the water column or along sheltered margins. The survey area is most exposed to winds from the south, and the prevailing wind direction is from the south west. Exact effects are dependent on the wind speed and direction and the state of the tide at the time and so a great range of scenarios may arise. South westerly winds will tend to advect contamination in the upper part of the water column towards the shore, and may tend to encourage the formation of eddy currents within Oxwich Bay, which is partially sheltered. As well as driving surface currents, onshore winds will create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. The western end of Oxwich Bay is much more protected from the prevailing swells by Oxwich Point and so may represent a more stable environment for bivalve molluscs compared to the more open coast to the east.

Some modelling of plume dispersal from the Mumbles sewer overflow has been undertaken (Wallace Evans, 1994). Figure IX.3 shows results for what was considered a high volume discharge from this outlet. The following conditions were applied: *E. coli* concentration = 1 x 10^6 $100ml^{-1}$; total volume discharged = 38,578m³ between 1 and 5 hours post high water (spring tides) with 10m s^{-1} southerly winds.

Figure IX.3A shows the plume from Mumbles 2h after the storm discharge started. This shows that the wind pushes the plume towards the shore as the ebb tide draws it westwards along the coast. Two hours later (Figure IX.3B), as the discharge ceases (about an hour before low water) the plume extends almost to Oxwich Point, but only comes into contact with intertidal areas at the eastern end. Concentrations of indicator bacteria are highest in the immediate vicinity of the outfall. After the tide has turned, the plume starts moving back towards Swansea Bay (Figure IX.3C). At this stage remnants of the plume can be seen over subtidal areas in Oxwich Bay (which is consistent with the formation of a gyre within Oxwich Bay) and along much of the shoreline east of Pwlldu Head. By the middle of the flood tide (Figure IX.3D), the plume is advected around Mumbles Head into the inner Swansea Bay and very little remains along the south Gower shore.

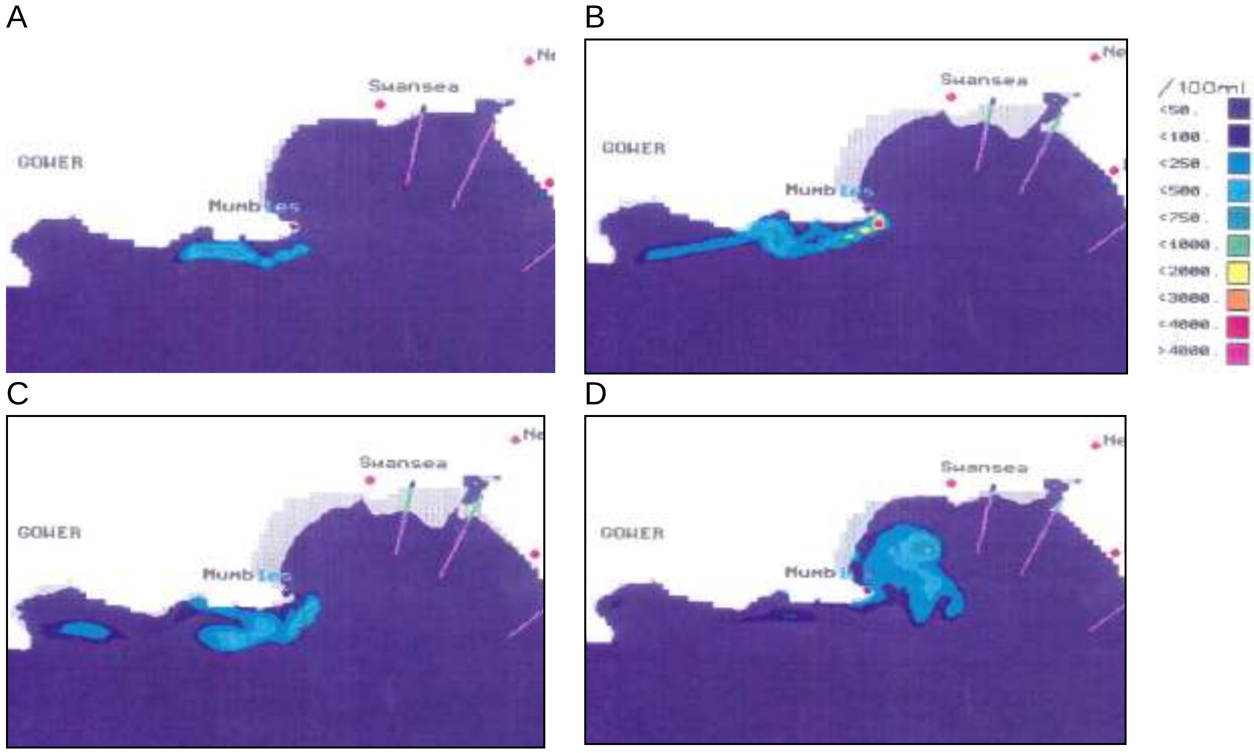

Figure IX.3 Modelled plume dispersion from Mumbles (4h duration storm discharge from HW+1 to HW+5, spring tide, 10m s^{-1} southerly winds). A is 2 hrs into release, B is at end of release, C is 2 hours post release and D is 4 hours post release.
Modified from Wallace Evans Ltd (1994).

Other modelling results from the same study indicate that the plume from the Swansea STW, which discharges to the middle of Swansea Bay, would be carried about as far as Pwlldu Head during the ebb tide, but would remain at least 1km offshore even under southerly winds.

In conclusion, tides drive water circulation in the area, and flow along the coast in an easterly direction on the flood and westerly direction on the ebb. The tidal excursion is up to about 10km on spring tides, which means sources of contamination within Swansea Bay may impact on the eastern end of the survey area. Within Oxwich Bay, the situation is different, with generally slower currents and a gyre forming on the flood tide that results in westerly flows along the shore from Threecliff Bay westwards throughout the tidal cycle. Winds may modify circulation patterns at times, with a southerly wind for example pushing the plume from the Mumbles sewage overflow towards the shore. More energetic wave action occurs at the eastern end of the survey area away from the shelter of Oxwich Point.

APPENDIX X
MICROBIOLOGICAL DATA: SEAWATER

BATHING WATERS

There are 7 bathing waters within the survey area, 5 of which are designated under the Directive 76/160/EEC (Council of the European Communities, 1975). Oxwich Bay East and Pwlldu Bay are not designated under this directive and were only monitored until 2004 and 2005 respectively.

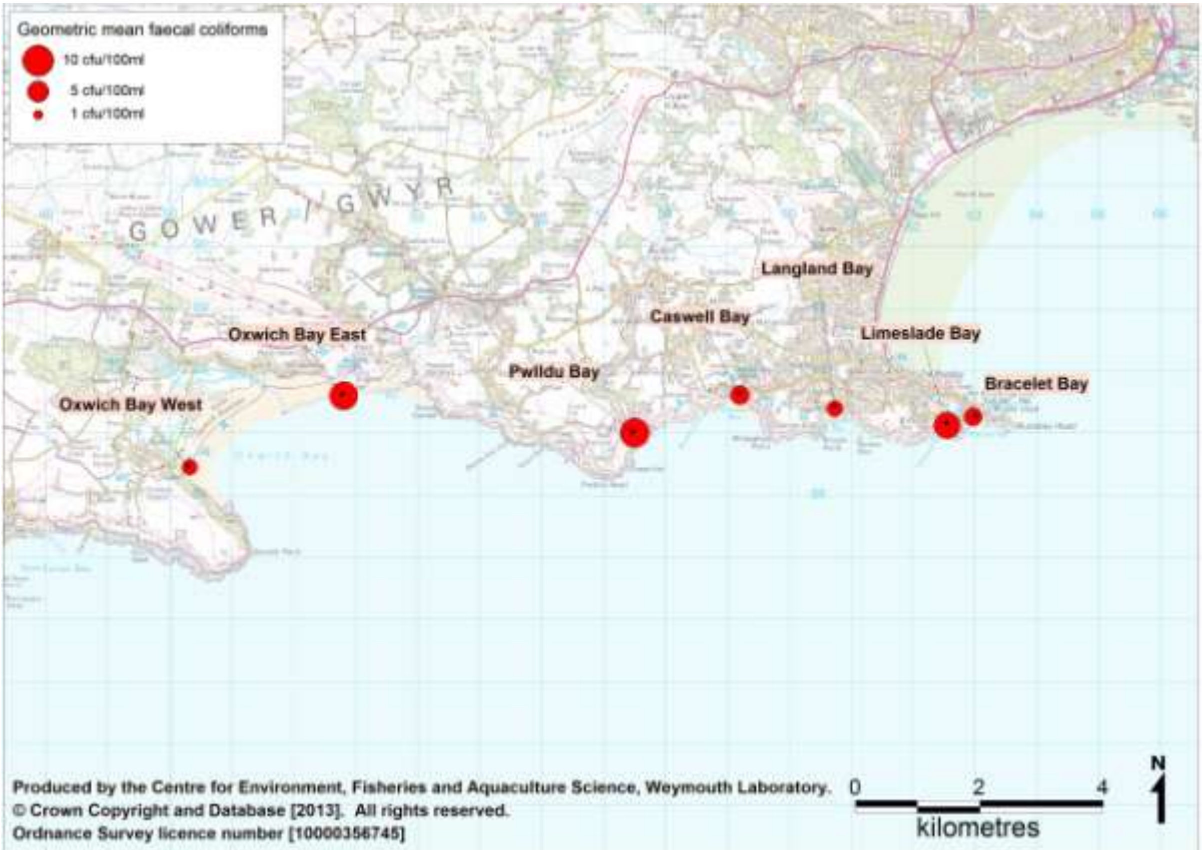

Figure X.1 Location of designated bathing waters monitoring points at Oxwich Bay.

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

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

Site		Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Oxwich Bay West	180	3.0	<2	654	3.3	0.0
Oxwich Bay East	40	8.6	0	12,200	5.0	2.5
Pwlldu Bay	61	9.0	0	500	4.9	0.0
Caswell Bay	180	4.3	<2	1,680	2.8	0.6
Langland Bay	180	3.2	<2	154	0.6	0.0
Limeslade Bay	180	7.5	<2	2,440	8.9	1.1
Bracelet Bay	180	3.8	<2	1,800	2.8	0.6

Data from the Environment Agency

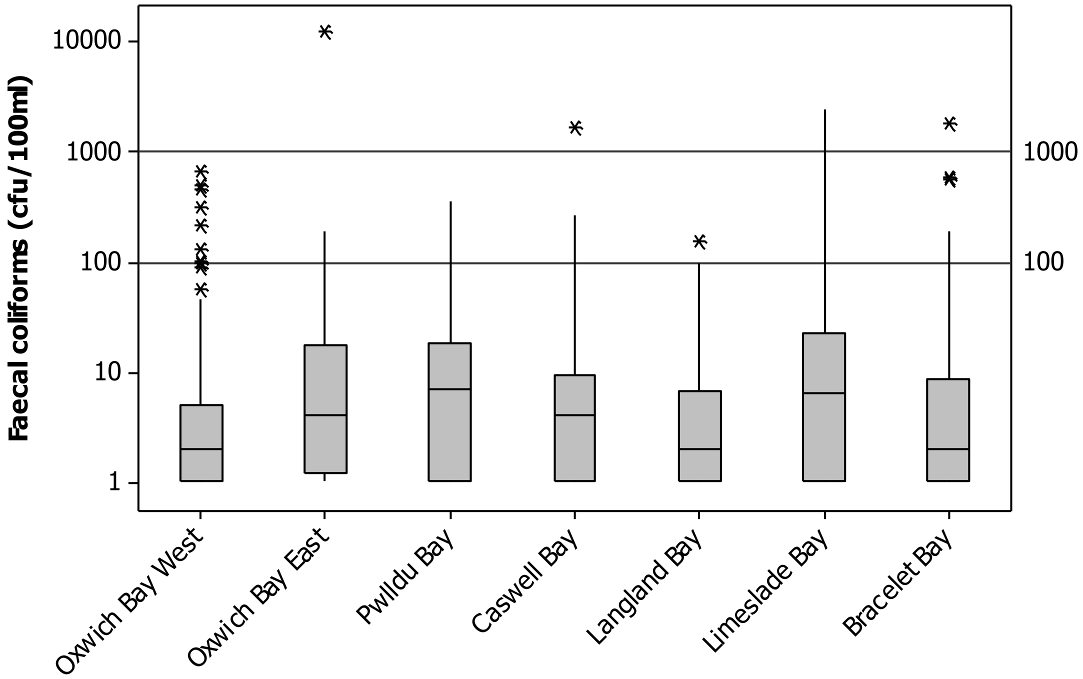

Figure X.2 Box-and-whisker plots of all faecal coliforms results by site
Data from the Environment Agency

Across the seven locations monitored, levels of contamination were generally low, averaging less than 10 faecal colfirms/100ml at all sites. Levels of contamination were highest on average at Pwlldu Bay. Results were similar for Oxwich Bay West, Langland Bay and Bracelet Bay. The highest proportions of results over 1000 cfu/100ml arose at Oxwich Bay East, which also returned the highest individual result by quite a large margin.

Comparisons of results from all 7 sites showed a significant difference between sites (One-way ANOVA, p<0.001), indicating that there are spatial influences on the levels of faecal coliforms in the Oxwich Bay area. Post ANOVA tesing (Tukey) showed that the results for Limeslade Bay were significantly higher than all sites except Oxwich Bay East and Pwlldu Bay. Results for Pwlldu Bay were significantly higher than for Oxwich Bay West, but no other significant differences were found.

Oxwich Bay East and Pwlldu Bay were excluded from the following analyses because they did not share many sampling dates with the other sites. Paired comparisons of the results from the 175 occasions when the remaining 5 monitoring points were sampled on the same day found a significant difference by both site and sampling date (2-way ANOVA, $p<0.001$ for both). This indicates that not only do the sites differ significantly in the average level of contamination but also that levels of contamination tend to vary in a similar way temporally across the general area.

Post ANOVA testing (Tukey's comparison) indicated that results for Limeslade Bay were significantly higher than all other sites. Caswell Bay was significantly higher than Oxwich Bay.

Significant correlations were found on a sample by sample basis for each site pairing (Pearson's correlation, $r \geq 0.180$, $p \leq 0.017$). This suggests all sites are influenced by similar profiles of sources or sources which react in a similar manner to environmental conditions.

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

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

		high/low		spring/neap	
Site	n	r	p	r	p
Oxwich Bay West	180	0.119	0.082	0.077	0.350
Oxwich Bay East	40	0.177	0.316	0.199	0.232
Pwlldu Bay	61	0.107	0.516	0.135	0.346
Caswell Bay	180	0.108	0.128	0.044	0.711
Langland Bay	180	0.144	0.025	0.202	0.001
Limeslade Bay	180	0.130	0.049	0.170	0.006
Bracelet Bay	180	0.066	0.463	0.161	0.010

Data from the Environment Agency

Figure X.3 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Mumbles Head is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

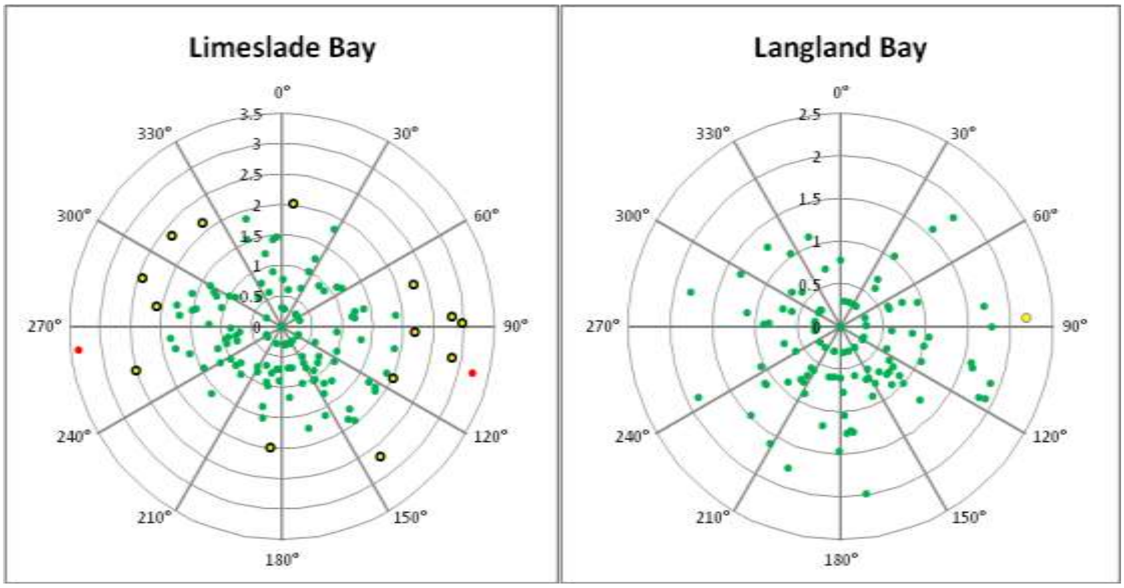

Figure XI.3. Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

Although correlations were found with the high/low cycle at these two sites, they were weak and no clear patterns are apparent in Figure X.3, apart from perhaps a slight tendency for fewer low results around high water at Langland Bay.

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

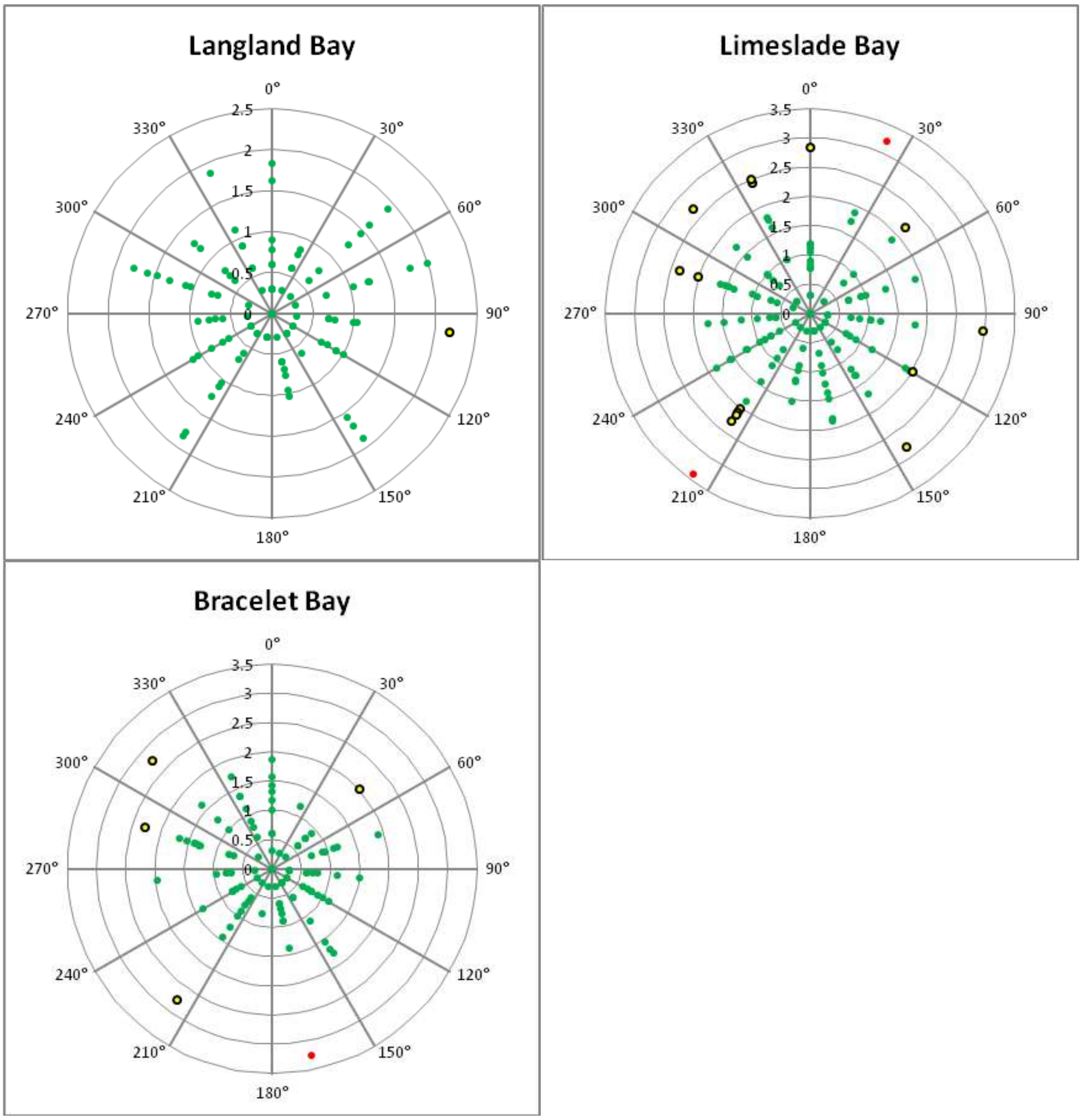

Figure X.4. Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

Although correlations were found, no clear patterns are apparent in Figure X.4.

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

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

		Oxwich Bay West	Oxwich Bay East	Pwlldu Bay	Caswell Bay	Langland Bay	Limeslade Bay	Bracelet Bay
	No.	180	40	60	180	180	180	180
24 hour periods prior to sampling	1 day	-0.058	-0.03	0.216	0.006	0.028	0.020	-0.058
	2 days	0.050	0.151	-0.198	-0.132	-0.082	-0.063	-0.217
	3 days	0.180	0.074	0.102	-0.090	0.093	0.083	0.070
	4 days	-0.005	-0.042	-0.015	0.154	0.146	0.079	0.120
	5 days	0.091	-0.057	-0.157	0.074	0.123	-0.027	0.136
	6 days	0.045	0.154	-0.104	0.043	0.053	0.010	0.075
	7 days	0.053	0.071	0.061	0.061	0.032	0.055	0.032
Total prior to sampling over	2 days	-0.040	0.050	-0.041	-0.084	-0.059	-0.068	-0.179
	3 days	0.079	0.128	0.105	-0.096	0.007	0.025	-0.091
	4 days	0.037	0.064	0.160	-0.048	0.031	0.047	-0.030
	5 days	0.052	0.062	0.131	-0.015	0.064	0.036	-0.014
	6 days	0.072	0.079	0.033	-0.011	0.063	0.011	0.000
	7 days	0.077	0.083	0.038	-0.023	0.030	0.040	0.014

Data from the Environment Agency

Table XI.4 shows that there is very little influence of recent rainfall on the levels of faecal indicator bacteria at bathing water sites along the south of the Gower. Significant positive correlations were found at Oxwich Bay West, Pwlldu Bay and Caswell Bay but not consistently. It must however be noted the laws of probability dictate a false positive will be found on 5% of occasions where correlations are undertaken. A relatively large watercourse discharges at Pwlldu Bay, which may contribute to the higher faecal coliform levels only 1 day after rainfall.

At Oxwich Bay East however, no correlation was found between rainfall and faecal coliform levels. Given the close proximity of the Pennard Pill watercourse to the Oxwich Bay East bathing water site, the lack of any influence of rainfall here suggests that the plume emanating from this watercourse is not a major source of contamination at the monitoring point, just under 1km to the west.

APPENDIX XI
MICROBIOLOGICAL DATA: SHELLFISH FLESH

No samples of shellfish flesh from within the survey area have been subject to microbiological testing either under the shellfish hygiene or shellfish waters monitoring programmes.

APPENDIX XII
SHORELINE SURVEY

Date (time): 2 October 2012
3 October 2012

Applicant: Andy Woolmer (unable to attend)

Cefas Officers: Alastair Cook, David Walker, Rachel Parks

Local Enforcement Authority Officers:
Keith James (Swansea City Council, 2nd October only)
Owen Caughlin (Environment Agency, 2nd October only)
Sarah Bennet (Environment Agency, 3rd October only)

Area surveyed: South Gower (Oxwich Bay to Mumbles Head)

Weather: 2 October 2012 - Wind SW force 5, 14°C, Rain
3 October 2012 - Wind SW force 5, 13°C, Sunny

Tidal predictions for Mumbles (Admiralty TotalTide):

Mumbles, 51°34’ N 3°58’ W, Wales. Times GMT+0100. Predicted heights are in metres above chart datum.

02/10/2012			03/10/2012		
Low	01:52	1.3 m	Low	02:21	1.4 m
High	08:11	9.4 m	High	08:41	9.2 m
Low	14:06	1.4 m	Low	14:34	1.6 m
High	20:29	9.4 m	High	20:59	9.1 m

Objectives:

This sanitary survey was initiated by Dr. Andy Woolmer in order to obtain classification for razor clam stocks between Oxwich Bay and Mumbles Head. The shoreline survey aims to obtain samples of seawater and freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown; find out more information about the fishery. A full list of recorded observations is presented in Table XII. and the locations of these observations are mapped in Figure XII.1. Photographs referenced in Table XII. are presented in Figure XII.3 - Figure XII.26.

Description of Fishery

A full shellfish stock survey was beyond the scope of the shoreline survey, and this report only presents observations made during the survey. Wild stocks of common cockles (*Cerastoderma edule*), American clams (*Mercenaria mercenaria*), soft clams (*Mya arenaria*), native oysters (*Ostrea edulis*), common razor clams (*Ensis siliqua*) and several other non-marketable species of bivalves were observed along the sandy beaches of Oxwich Bay and Threecliff Bay to the west of the survey area. However, most of shellfish found were dead shells. On the west-most end of Oxwich Bay, populations of common cockles were particularly dense. Small populations of undersized common mussels (*Mytilus edulis*) were observed along the coast on rocks. No evidence of razor clams was present west of Threecliff Bay.

Sources of contamination

Sewage discharges

There are several sewage outlets along the survey area. At Brandy Cove there was a sewerage treatment pipeline running under the beach, but the outlet was not visible. A similar pipe was observed at Langland Bay (point 18). At Caswell Bay there was a private pumping station for the Redcliff Apartments. No outfall was visible for this pumping station, and the Environment Agency were unable to locate the outfall following this survey. At Langland Bay there was a pipe outlet below the high tide line that was exposed at the time of survey. According to the Environment Agency this pipe is authorised for use as an emergency overflow for a pumping station which is inland from the bay. There is also a separate private pumping station on the shore which may overflow into this pipe. The effluent from this pipe had a sulphurous smell and a sample was taken for *E. coli* enumeration.

In Langland Bay, there was also a rock pool with dirty water next to a rocky outcrop. Behind this outcrop there was concrete that looked like it might be covering a pipe. Investigations by the Environment agency have found that this is likely to be left over from improvements to the sewer system which removed an outfall. It is possible that some misconnections in the newer pipe work are still having an effect. The Environment Agency is investigating this further. There were many other private discharges in the catchment that have only recently been registered and are not recorded in the EA Permitting database[1]. Details of these were subsequently provided by the Agency.

Freshwater inputs

There were several freshwater inputs across the survey area, including large streams at Oxwich Bay, Pennard Pill and Pwlldu Bay. At the western end of Caswell Bay there was a concrete structure which, according to the Environment Agency, may be a disused structure for abstracting surface water. A stream of water was seen to be flowing from the bottom of this structure, but the water was grey and had a stale odour. Further to the east of Caswell Bay was a culverted stream outlet. Just to the north of this outlet was a pumping station which discharges into the stream as an emergency storm overflow.
At the top of Limeslade Bay there were two pipes which carry surface water. According the Environment Agency this is a known area for misconnections, which may explain the presence of toilet paper in one of these pipes. There were also

[1] EA Public Register Consented Discharges to Controlled Waters data, July 2012

several ground water springs along the survey site. At Limeslade Bay and Brandy Cove, these groundwater springs contained large amounts of macro algae, indicating the presence of nutrients.

Livestock

Large areas of the land along the south coast of the Gower peninsula are used for grazing livestock. Cattle, sheep and horses were seen in farms around Pwlldu Head. However, along the majority of the coastal path there was evidence (faecal) of recent use by livestock.

Wildlife

Moderately sized (~30 individuals) flock of seagulls were observed at two points along the survey route, however the numbers of birds present is likely to vary throughout the year due to migrations. A seal was seen off the coast of Pwlldu Bay. Burrows in the ground across the survey area suggest that there are populations of burrowing animals such as rabbits, however no direct observation was made of any such animals.

Several domestic dogs were seen throughout the area. However, signage indicates that dogs are banned between 1st May and 30th September at Bracelet Bay, Limeslade Bay, Langland Bay, Rotherslade Bay and Caswell Bay.

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

Table XII.1: Details of shoreline observations

No.	Date and Time	Position	Photograph	Details
1	02/10/2012 08:37	SS 55452 87246		Dairy cattle
2	02/10/2012 09:31	SS 56884 86833		29 sheep
3	02/10/2012 09:42	SS 56951 87140		35 sheep
4	02/10/2012 09:44	SS 56947 87145		3 horses
5	02/10/2012 10:05	SS 57399 87055		Seawater sample 1
6	02/10/2012 10:20	SS 57385 87204		Stream 270cm x 24cm x 0.661 m/s, 25cm x 0.787 m/s. Freshwater sample 2
7	02/10/2012 10:40	SS 57838 87109		Seal offshore
8	02/10/2012 10:47	SS 58141 87290		Mussels possibly on rocks at bottom of cliff
9	02/10/2012 10:59	SS 58534 87465	Figure XII.3 & Figure XII.4	Cotton buds on tide line, sewage treatment pipeline under beach. Outfall not visible
10	02/10/2012 11:04	SS 58559 87428		Seawater sample 3
11	02/10/2012 11:07	SS 58558 87443		Freshwater sample 4, groundwater
12	02/10/2012 11:31	SS 58977 87569	Figure & Figure XII.6	Concrete box with manhole on top, water flowing out of bottom
13	02/10/2012 11:34	SS 58992 87555	Figure	Stream flowing from point 12, 45cm x 20cm x 0.764 m/s. Freshwater sample 5, mussels on rocks
14	02/10/2012 11:48	SS 59273 87646	Figure	Stream, 200cm x 10cm x 0.751m/s. Freshwater sample 6
15	02/10/2012 11:54	SS 59377 87748	Figure	Pumping station enclosure
16	02/10/2012 12:31	SS 60472 87290	Figure 3	Stream, 20cm x 5cm x 0.559 m/s. Freshwater sample 7
17	02/10/2012 12:41	SS 60578 87133	Figure 4 & Figure XII.12	Pipe from sewage pumping station with grey water, 15cm x 5 cm x 0.335m/s. Freshwater sample 8
18	02/10/2012 12:53	SS 60661 87268	Figure XII.14	Cast iron pipe going to ground
19	02/10/2012 13:00	SS 60998 87325	Figure XII.14	Cast iron pipe going down cliff
20	02/10/2012 13:05	SS 61026 87313		Rock pool with dirty water next to rocky outcrop with concrete structure. Suspected pipe. Freshwater sample 9
21	02/10/2012 13:12	SS 61041 87359		Surface water outfall
22	02/10/2012 13:54	SS 62557 87152	Figure XII.15	Two surface water outfalls, toilet paper in one

23	02/10/2012 14:00	SS 62517 87093	Figure XII.16	Stream or spring possibly flowing from nearby road. Lots of algal growth present. 11 cm x 6 cm x 0.103m/s. Freshwater sample 10
24	02/10/2012 14:15	SS 62966 87314	Figure XII.17	Sewage tunnel (Mumbles main outfall), pumping station enclosure (no outfall at Bracelet Bay)
25	03/10/2012 09:14	SS 55355 87378	Figure XII.18	Heatherslade pumping station box (this pumping station has no outfall)
26	03/10/2012 09:50	SS 54012 87822	Figure	Cotton buds and other litter
27	03/10/2012 09:53	SS 54005 87822		Seawater sample 11
28	03/10/2012 10:13	SS 53867 88202	Figure XII.20	A flock of seagulls
29	03/10/2012 10:22	SS 53797 88334	Figure 5	Cotton buds
30	03/10/2012 10:29	SS 53591 88255		Stream 180cm x 8cm x 0.156m/s. Freshwater sample 12
31	03/10/2012 11:01	SS 52839 87853	Figure	Cotton buds
32	03/10/2012 11:08	SS 52555 87738		Seawater sample 13
33	03/10/2012 11:33	SS 51464 87772		Stream 380cm wide. 17cm (1m across) x 0.604m/s, 22cm (1.9m across) x 0.697m/s, 20cm (2.8m across) x 0.547 m/s. Freshwater sample 14, flock of seagulls
34	03/10/2012 12:22	SS 50466 86270		Seawater sample 15
35	03/10/2012 12:53	SS 54341 89270	Figure XII.23	Stream 286cm x 22cm (1m across) x 1.655m/s, 28cm (1.4m across) x 0.869, 30 cm (1.86m across) x 0.972m/s. Freshwater sample 16
36	03/10/2012 12:59	SS 54387 89266	Figure XII.24	Parkmill sewage pumping station (this pumping station has no outfall)
37	03/10/2012 13:05	SS 54502 89148	Figure XII.25	Stream 750cm x 15cm (1m across) x 0.836m/s, 25cm (3.7m across) x 0.768m/s, 45cm (6.5m across) x 0.689m/s. Freshwater sample 17
38	03/10/2012 13:22	SS 55094 89113	Figure XII.26	Outfall from Pennard pumping station.

Sample results

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

Table XII.2: Water sample* E. coli *results

No.	Date and Time	Position	Type	*E. coli* (cfu/100ml)	Flow (m³/day)	*E. coli* (cfu/day)*
1	02/10/2012 10:05	SS 57399 87055	Seawater	28		
2	02/10/2012 10:20	SS 57385 87204	Stream	1900	41379	7.86×10^{11}
3	02/10/2012 11:04	SS 58559 87428	Seawater	18		
4	02/10/2012 11:07	SS 58558 87443	Groundwater	16		
5	02/10/2012 11:34	SS 58992 87555	Stream	820	5941	4.87×10^{10}
6	02/10/2012 11:48	SS 59273 87646	Stream	2100	12977	2.73×10^{11}
7	02/10/2012 12:31	SS 60472 87290	Stream	400	483	1.93×10^{9}
8	02/10/2012 12:41	SS 60578 87133	Pipe	5600	217	1.22×10^{10}
9	02/10/2012 13:05	SS 61026 87313	Rock pool	3		
10	02/10/2012 14:00	SS 62517 87093	Stream	>10000	59	$>5.87 \times 10^{9}$
11	03/10/2012 09:53	SS 54005 87822	Seawater	25		
12	03/10/2012 10:29	SS 53591 88255	Stream	560	1941	1.09×10^{10}
13	03/10/2012 11:08	SS 52555 87738	Seawater	20		
14	03/10/2012 11:33	SS 51464 87772	Stream	130	39775	4.92×10^{10}
15	03/10/2012 12:22	SS 50466 86270	Seawater	2200		
16	03/10/2012 12:53	SS 54341 89270	Stream	720	76787	5.53×10^{11}
17	03/10/2012 13:05	SS 54502 89148	Stream	>10000	140330	$>1.4 \times 10^{13}$

*Numbers of *E. coli* per day introduced to coastal waters from each freshwater input, calculated from spot gauging of discharges and corresponding water sample *E. coli* results.

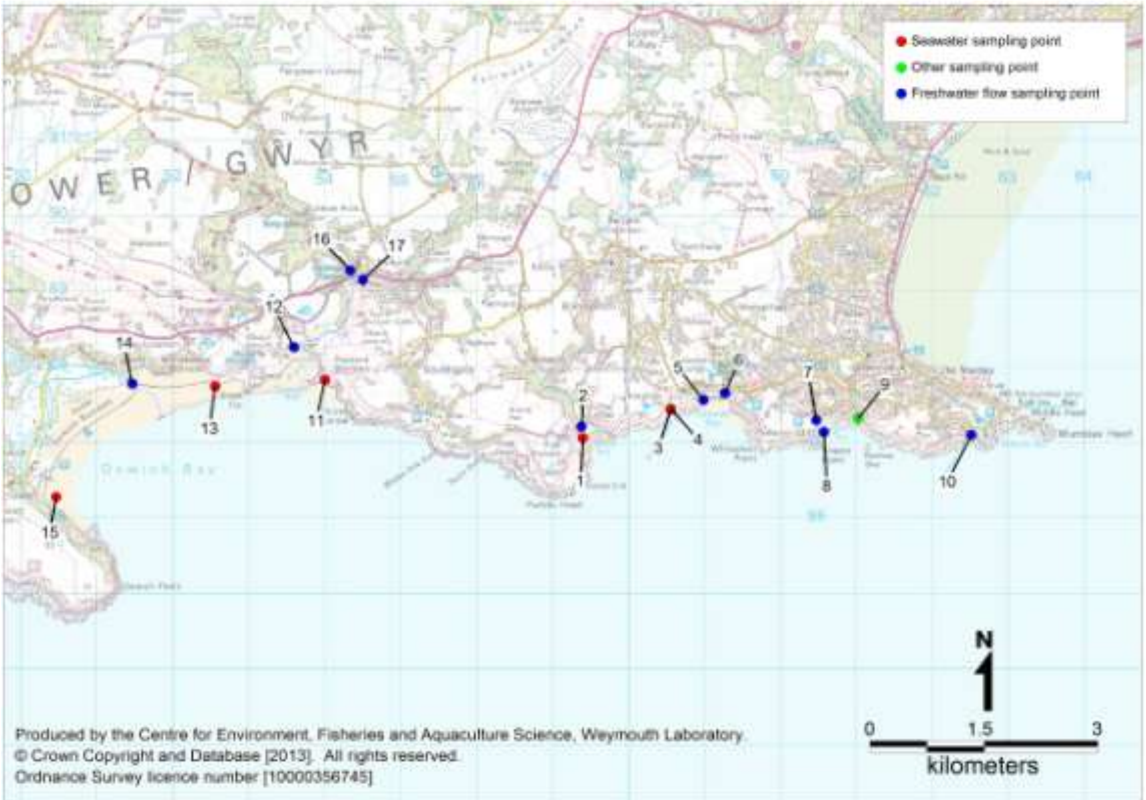

Figure XII.2: Water sampling locations on the Oxwich Bay shoreline survey

Seawater samples indicated moderate levels of contamination throughout this stretch of coast. However sample 15 (western end of Oxwich Bay) had unusually high levels of *E.coli*, with results of 2200 cfu/100ml. The reasons for this are unclear.

Two freshwater samples contained more than 10,000 *E. coli* cfu/100ml. The first of these was taken from what appeared to be a stream or spring possibly flowing from a road adjacent to Limeslade Bay. This source does not appear on any maps and judging from the very high levels of *E. coli*, may originate from a broken sewerage pipe. The large amount of algae that was found around this stream indicates that there was a high nutrient load which would also be consistent with sewage. The presence of this source may partially explain the relatively high levels of faecal coliforms found in this bathing water. The second site that had more than 10,000 *E. coli* cfu/100ml was on the Pennard Pill water course behind the Maes-Yr-Haf holiday home in Park Mill. Adjacent to the sampling point, there was an overflow outlet (Figure XII.25) which may have contributed to the high *E. coli* loads.

Conclusions

There are several small ground water springs and 4 larger streams that output into the Oxwich Bay area. Several sewage pumping station discharges input directly into the Bay, but most are only permitted to discharge under emergency conditions such as power failures, equipment failures, blockages or main failures. The overflows at Bishopston STW and Mumbles Head are however consented to discharge under storm conditions. Investigations into the frequency and rates of flow from the Mumbles Head pumping station outfall are needed to gain a fuller understanding of the microbiological inputs into the sea of this potentially significant source, discharging approximately 0.8 km to the east of Bracelet Bay. Large numbers of dead shells were evident at the western end of the survey area, but not at the eastern end.

Figure XII.3

Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

Figure 3

Figure 4

Figure XII.12

Figure XII.14

Figure XII.14


Figure XII.15


Figure XII.16

Figure XII.17

Figure XII.18

Figure XII.19

Figure XII.20

Figure 5

Figure XII.22

Figure XII.23

Figure XII.24

Figure XII.25

Figure XII.26

References

ASHBOLT, J. N., GRABOW, O. K., SNOZZI, M., 2001. Indicators of microbial water quality. *In* Fewtrell, L. and Bartram, J. (Eds). Water quality: guidelines, standards and health. IWA Publishing, London. pp. 289−315.

BAINES, M.E. AND EVANS, P.G.H. (2012). Atlas of the Marine Mammals of Wales. CCW Monitoring Report No. 68. 2nd edition. 139pp.

BRIDGES, E.M., 1967. The soils of Gower. Gower Journal of the Gower Society, 18, 67-72.

BRITISH GEOLOGICAL SOCIETY, 2012. Geological sketch map of Gower. Available at http://www.geolsoc.org.uk/en/Education%20and%20Careers/Resources/Field%20Work%20Resources/Gower%20Field%20Guide/I%20Gower%20-%20A%20part%20of%20Earth%20History. Accessed November 2012.

BROWN J., 1991. The final voyage of the Rapaiti. A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin* 22: 37-40.

CEFAS, 2011. Sanitary survey of Swansea 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 of EC Regulation No. 854/2004.

CEFAS, 2012. Sanitary survey of Burry Inlet. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of EC Regulation No. 854/2004.

CITY AND COUNCIL OF SWANSEA, 2011. Tourism Research and Statistics. Available at: http://www.swansea.gov.uk/index.cfm?articleid=22846. Accessed October 2012

COUNCIL OF THE EUROPEAN COMMUNITIES, 1975. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. *Official Journal* L031: 0001-0007.

DUNHILL, I., 2003. A preliminary study into the change in faecal indicator concentration of estuarine water attributable to tidal inundation of saltmarsh. Bruen, M. (editor) (2003) In Diffuse Pollution and Basin Management. Proceedings of the 7th International Specialised IWA Conference, Dublin, Ireland.

EC, 1998. Council Regulation (EC) No 850/98 of 30 March 1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. *Official Journal L 125 , 27/04/1998 P. 0001 - 0036*

ENVIRONMENT AGENCY, 2012A. Bathing water profile: Caswell Bay. http://www.environment-agency.gov.uk/static/documents/bwprofiles/BW_37300_Caswell_Bay.pdf

ENVIRONMENT AGENCY, 2012B. Bathing water profile: Limeslade Bay. http://www.environment-agency.gov.uk/static/documents/bwprofiles/BW_37100_Limeslade_Bay.pdf

EUROPEAN COMMUNITIES, 2004. EC Regulation No 854/2004 of the European Parliment and of the Council of 29 April 2004 laying down specific hygiene rules on products of animal origin intended for human consumption. *Official Journal of the European Communities* L226: 83-127.

EUROPEAN COMMUNITIES, 2006. Directive 2006/113/EC of the European parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). Official Journal of the European Communities L376: 14-20.

EU WORKING GROUP ON THE MICROBIOLOGICAL MONITORING OF BIVALVE HARVEST AREAS (2010). Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 4, August 2010.

EUPHORIA SAILING, 2012. Watersports for all. Available at: http://www.euphoriasailing.com. Accessed September 2012

FAHY, E., 2006. Razor Clams on Mainly East Coast. *Fisheries Science Services Advice*. Marine Institute. Available from: https://marine.ie/NR/rdonlyres/352EF90E-8DB6-4B43-8F41-FA55EBD57CFA/0/RazorClamsonEastCoast06.pdf

FUTURECOAST, 2002. Department of Environment, Food and Rural Affairs (Defra), Halcrow Group Ltd 3 CD set.

GRAY, M., 2008. Developing a New Fishery: Guidelines for Environmental Good Practice Based on a Case Study: Feasibility study of a new Razorfish (Ensis spp.) fishery off the Duddon Estuary and Cumbrian Coast, Lancashire. Seafish report, December 2008.

GELDREICH, E.E. 1978. Bacterial and indicator concepts in feces, sewage, stormwater and solid wastes. *In* Berg, G. (ed.). *Indicators of Viruses in Water and Food.* MI: Ann Arbor.

HOLT, C., AUSTIN, G., CALBRADE, N., MELLAN, H., MITCHELL, C., STROUD, D., WOTTON, S., MUSGROVE, A., 2011. Waterbirds in the UK 2009/10. The Wetland Bird Survey.

HUGHES, C., GILLESPIE, I.A., O'BRIEN, S.J., 2007. Foodborne transmission of infectious intestinal disease in England and Wales 1992-2003. *Food Control* 18: 766−772.

KAY, D, CROWTHER, J., STAPLETON, C.M., WYLER, M.D., FEWTRELL, L., ANTHONY, S.G., BRADFORD, M., EDWARDS, A., FRANCIS, C.A., HOPKINS, M. KAY, C., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research 42, 442-454.

KAY, D., CROWTHER, J., STAPLETON, C.M., WYER, M.D., FEWTRELL, L., EDWARDS, A., FRANCIS, C.A., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008b. Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42: 442-454.

KIELY, O., LIGARD, D., MCKIBBEN, M., CONNOLLY, N., BAINES, M. (2000). Grey Seals : Status and Monitoring in the Irish and Celtic Seas. Maritime Ireland / Wales INTERREG Report No. 3

LEE, R.J., YOUNGER, A.D., 2002. Developing microbiological risk assessment for shellfish purification. *International Biodeterioration and Biodegradation* 50: 177−183.

MARINE SCOTLAND, 2011. A report on electrical fishing for razor clams (*Ensis* sp.) and its likely effects on the marine environment. Marine Scotland Science Report 03/11

MET OFFICE, 2012. Regional Climates. Available at: http://www.metoffice.gov.uk/climate/uk/regional/ Accessed October 2012.

MITCHELL, P. IAN, S. F. NEWTON, N. RATCLIFFE & T. E. DUNN, 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

OBIRI-DANSO, K., JONES, K., 2000. Intertidal sediments as reservoirs for hippurate negative campylobacters, salmonellae, and faecal indicators in three EU recognised bathing waters in North-West England. *Water Research* 34 (2): 519−527.

REEDS, 2011. Reeds Nautical Almanac 2012.

THIS IS SOUTH WALES, September 2011. Cockle pickers 'not commercial' says landowner. http://www.thisissouthwales.co.uk/Cockle-pickers-commercial-says-landowner/story-13280926-detail/story.html accessed November 2012.

TYLER, P.A., BANNER, F.T., 1976. The effect of coastal hydrodynamics on echinderm distribution in the Sublittoral of Oxwich Bay, Bristol Channel. *Estuarine and Coastal Marine Science* 5: 293-308.

WALLACE EVANS LTD, 1994. Swansea Bay Bathing Waters improvement scheme. Water quality model performance application studies. Supporting Information for Consent Application.

WOOLMER, A. P., 2011. Drop down video of native oyster (*Ostrea edulis)* habitat in Swansea Bay, South Wales. CCW Contract Science Report No. 958

WOOLMER, A.P., MAXWELL, E., LART, W., 2011. SIPF C0083 - Effects of electrofishing for *Ensis* spp. on benthic macrofauna, epifauna and fish species. Seafish Report SR652. ISBN – 978-1-906634-58-2

YOUNGER, A.D., LEE, R.J., LEES, D.N. 2003. Microbiological monitoring of bivalve mollusc harvesting areas in England and Wales: rationale and approach. In: Villalba, A., Reguera, B., Romalde, J. L., Beiras, R. (eds). Molluscan Shellfish Safety. Consellería de Pesca e Asuntos Marítimos de Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, Santiago de Compostela, Spain. pp. 265−277.

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
NM	Nautical Miles
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
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.
Benthic	The sediment or sub surface layer within a body of water
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”.

Summary of consultations on draft report

Consultee	Comment	CEFAS response
Environment Agency		
Welsh Water		
Swansea Council		
Welsh Government Fisheries		

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