EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Dovey Estuary (Wales)

2010

Cover photo: Mussel bed No 3 at Aberdovey.

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

DISSEMINATION: Food Standards Agency, Gwynedd Council, Environment Agency, North Western and North Wales Sea Fisheries Committee.

CONTENTS

1. INTRODUCTION

LEGISLATIVE REQUIREMENT

Filter feeding, bivalve molluscan shellfish (e.g. cockles, mussels and 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.

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 BMPAs. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This sanitary survey was prompted by three applications for microbiological monitoring and classification of wild mussels (*Mytilus* spp.) at Aberdovey (Dovey Estuary) bivalve mollusc production area (BMPA), in the west coast of Wales. The assessment is supported by published relevant information for the Dovey Estuary area together with new information obtained from a shoreline and a bacteriological survey.

The results of the desk study and shoreline surveys are drawn together in an overall assessment of the potential sources of pollution likely to impact on the levels of microbiological contamination for bivalve mollusc classification zones (CZs).

The sampling plan includes the recommended boundaries of CZs, locations of representative monitoring points (RMPs) and sampling frequency.

SITE DESCRIPTION

DOVEY/DYFI ESTUARY

The Dovey Estuary is located in the coast of western Wales. The estuary is broad, shallow and fringed by exposed rock. Steep slopes dominate along the northern shores, whilst flat land dominates along the southern shores of the estuary. The main channel is 19.6km long, 2.4km wide near Aberdovey and follows the northern side of the estuary tapering in the upper reaches of the estuary to less than 1.6km.

The shoreline forms a funnel-shape, which is restricted at the mouth by a beach-spit exposed to the west (Figure 1.1). The spit extends from the southern side of the estuary for several kilometres and is protected by groynes (Halcrow Group Ltd., 2003). The groyne creates a narrow channel of approximately 0.35km at its widest point (ABPmer and Wallingford, 2007).

Figure 1.1 Aerial view of the Dovey Estuary.
Reproduced under licence Google Earth™ mapping service.

The lower estuary contains extensive intertidal sandflats and mudflats. The upper reaches contain extensive areas of saltmarsh (approximately 431ha) fringing the shores (Boorman, 2003) and extensive areas of reclaimed land.

Saltmarsh contributes significantly to pollution control and water quality through nutrient cycling (e.g. nitrogen and phosphorous release during decomposition of organic matter) and sediment retention (e.g. adsorption of pollutants onto sediment particles) (see Adnitt *et al*., in press).

The morphological characteristics of the Dovey Estuary are summarised in Table 1.1. The Dovey is a medium-length estuary in which the partial closure of its mouth results in shallow depths and high velocities and the development of flood and ebb delta lobes (HR Wallingford *et al*., 2007).

Table 1.1 Morphological characteristics of the Dovey Estuary.

Geomorphological classification	Bar Built (spit enclosed)
Shoreline length (km)	52.2
Core area (ha)	1,954
Intertidal area (ha)	1,524

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

CATCHMENT

Pollution from two river catchments (total area = 471km^2) is drained to the estuary through a complex river network (Figure 1.2).

Figure 1.2 Location of the Dovey/Dyfi Estuary and its river catchments.

These river catchments flow into Cardigan Bay, which is a Special Area of Conservation (SAC), designated under the EC Habitats Directive on the conservation of natural habitats and wild fauna and flora (Council of the

European Communities, 1992). On its northern side, the catchment is bordered by the Snowdonia National Park and contains a wide range of habitats and conservation designations: the Lower Dovey estuary is a designated Site of Special Scientific Interest (SSSI), SAC, RAMSAR site, Special Protection Area (SPA) (Birds Directive) and National Nature Reserve (NNR) (Figure 1.3).

Grassland is the dominant land cover, with significant patches of woodland throughout the lower and upper reaches of the catchment (Figure 1.4). The northwestern area is almost solely dominated by woodland. Small areas of heath and bog occur on the higher grounds of the upper catchment. Areas of grassland supporting livestock production could represent a risk of pollution of diffuse origin to the estuary.

The topography of the catchment is characterised by steep sided valleys around the larger tributaries rising to an elevation of 600–900m in the highest points which are found in the northern sections. Across the catchment, the elevation is, at least, 100–150m gradually increasing towards the edge with the average elevation being around 100–250m throughout the lower to middle reaches (NERC, 2005).

Steep land may generate significant volumes of surface runoff and potentially microbiological contamination of faecal origin, which can be drained into watercourses under heavy and/or prolonged rainfall.

Catchment geology comprises mainly impermeable Silurian formations, which occur south of Aberdovey and Machynlleth, and minor Boulder Clay and alluvium deposits. Marine and estuarine deposits comprise of clays, sands and gravels in the Dovey Estuary (Gwynedd Council, 1998). Grassland on impermeable soils means that surface or sub-surface runoff is the most likely route of pollution across the catchment (Mawdsley *et al.*, 1995).

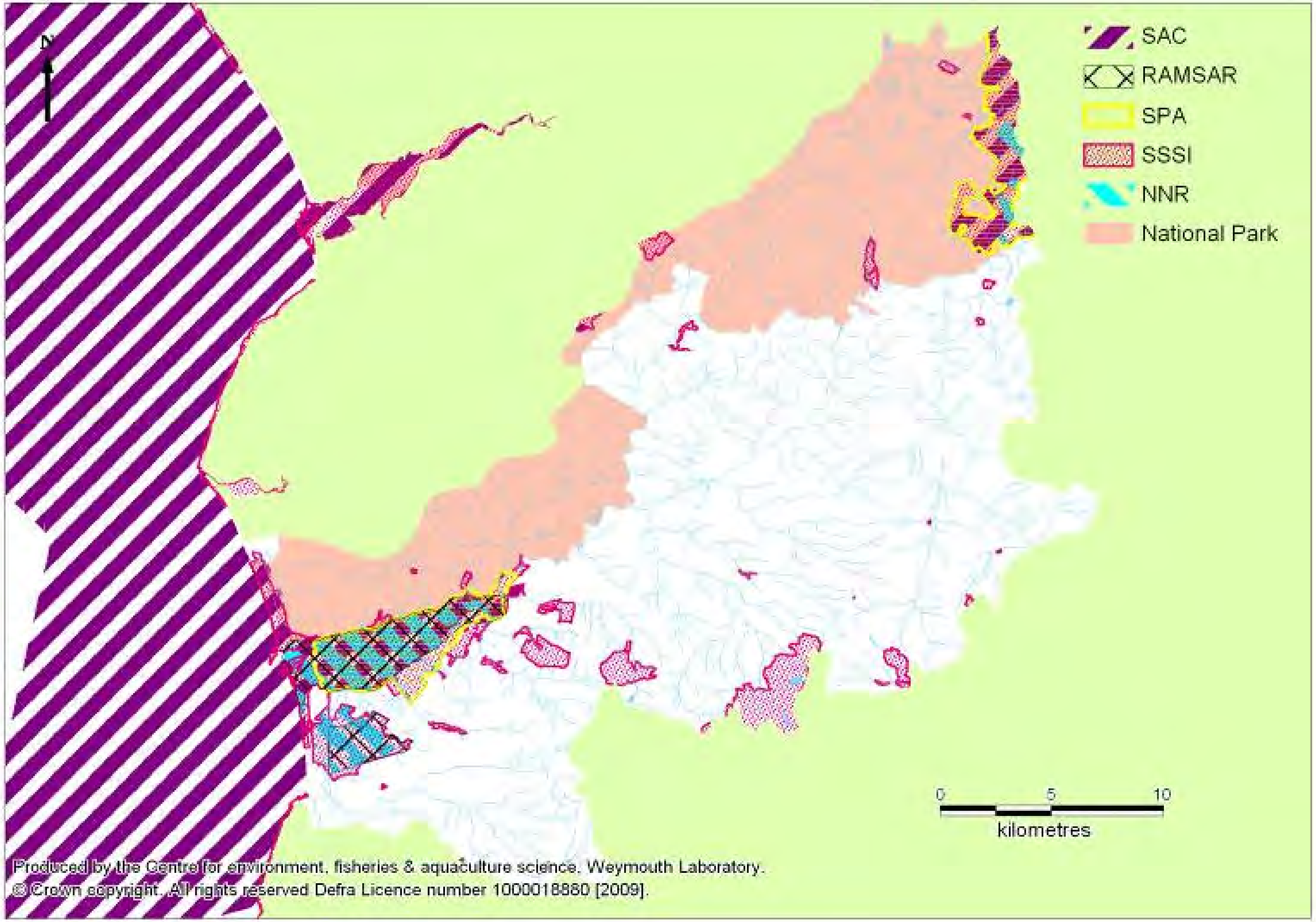

Figure 1.3 Nature conservation designations in catchments draining to the Dovey Estuary.
Boundary data from and regularly updated by Natural England (2008) (http://www.naturalengland.org.uk).

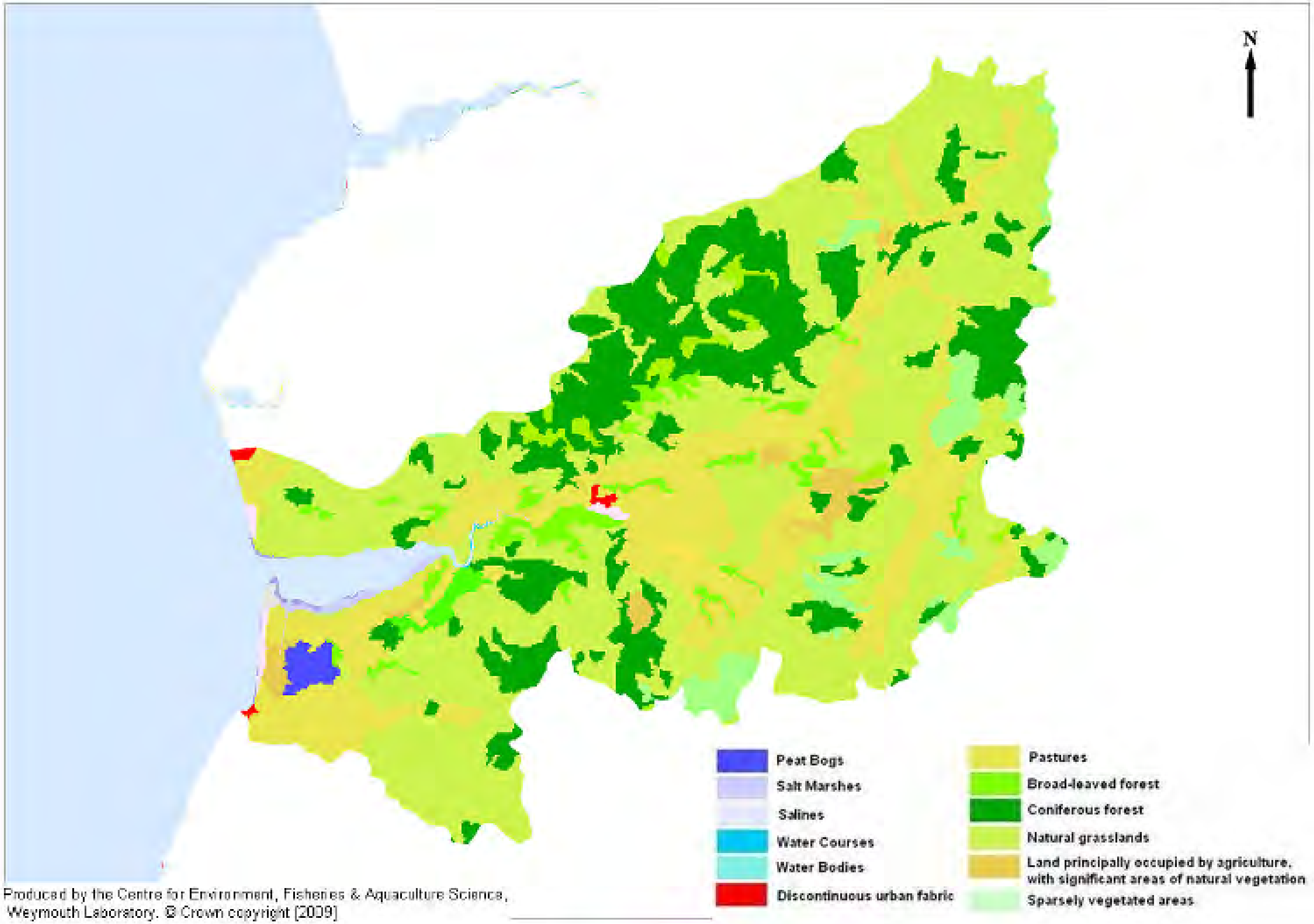

Figure 1.4 Land cover in the Dovey catchment.
Derived from the Corine Land Cover Map 2000.
Reproduced with the permission of the European Environment Agency (2009).

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

The harvesting of cockles (*Cerastoderma edule*) and mussels (*Mytilus* spp.) for human consumption is a traditional activity in the Dovey Estuary. Classifications for mussels and cockles were initially given in 1993 (Table 1.2), following the implementation of statutory controls on the commercial production of bivalve molluscs in England and Wales (Appendix XII). However, the commercial interest for both species was lost in 2005.

Table 1.2 Historical classifications of bivalve mollusc production areas in the Dovey Estuary.

Bed name	Aberdyfi Slipway	Coed y Gofer	Dovey Estuary	Site A	Site C	Picnic Island
Bed ID	B041F	B041F	B041B	B041A	-	-
Species	*Mytilus* spp.	*C. edule*	*C. edule*	*Mytilus* spp.	*Mytilus* spp.	*Mytilus* spp.
Year						
1993	C	C	C	C	B[1]	B[1]
1994	C	C	C	B[1]	B[1]	B[1]
1995	C	C	C	B[1]	B[1]	B[1]
1996	C	B	C	B[1]	B[1]	B[1]
1997	C	B	C	B[1]	B[1]	B[1]
1998	C	B	C	B[1]	B[1]	B
1999	C	B	B	B	B	B
2000	C	B	B	B	B	B
2001	C	B	B	B	B	B
2002	C	B	N/c	N/c	N/c	B
2003	B	B	N/c	N/c	N/c	B
2004	B	B	B	N/c	N/c	N/c
2005	B-LT[1]	D/C	N/c	N/c	N/c	B-LT[1]
2006	N/c	N/c	N/c	N/c	N/c	N/c

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

This sanitary survey was prompted by applications for microbiological monitoring and classification of mussels in three new beds at Aberdovey (Figure 1.4). The location of these beds together with historical beds and Representative Monitoring Points (RMPs) from which monitoring data is analysed for the purposes of this assessment is shown in Figure 1.5.

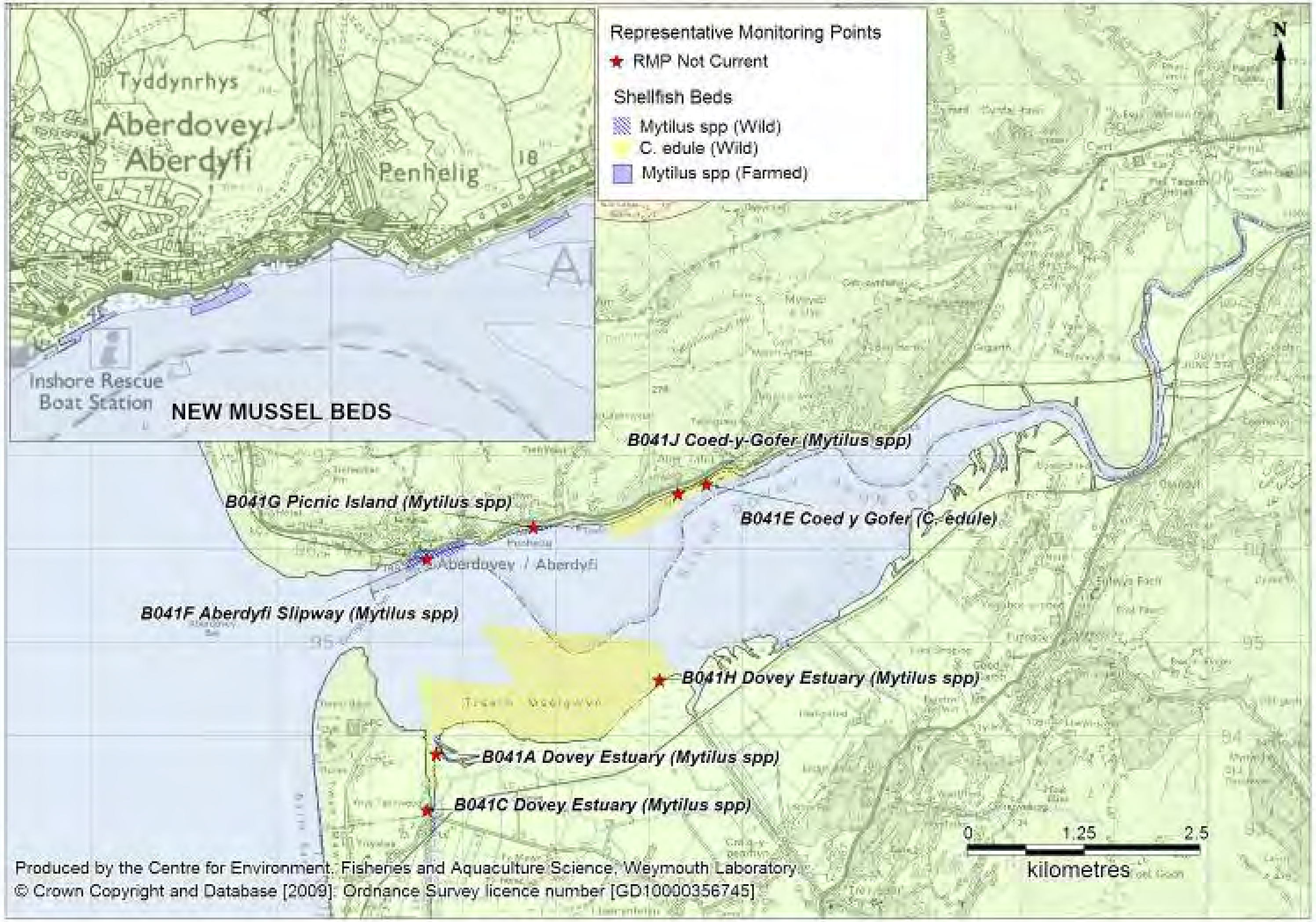

Figure 1.5 Location of existing (inset) and historical bivalve mollusc beds and representative monitoring points in the Dovey Estuary.
Historical beds are indicated for information only as historical monitoring data was reviewed to support the overall assessment.

Both *Mytilus galloprovincialis* and *Mytilus edulis* have been recorded in the Dovey Estuary. Literature indicates that both species present large morphological, physiological and behavioural similarities and are therefore difficult to differentiate for commercial purposes due to adaptations to environmental conditions (see Wijsman and Smaal, 2006 and references therein). Data from molecular analyses have demonstrated high levels of hybridisation[1] and gene introgression[2] between these species along the West coast of Cornwall. Therefore, in the context of the present sanitary survey, taxonomy of mussels is referred at genus level.

Mussels are often found in sheltered estuaries, just below the low water, where a food supply of suspended organic detritus and phytoplankton is available (Tebble, 1976). The optimum salinity range for mussel growth is 20–35psu (Laing and Spencer, 2006).

Table 1.3 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 1.3 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 MPN *E. coli* $100g^{-1}$ FIL	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 4,600 *E. coli* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ FIL	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	>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.

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

Mussels grow naturally on the river-bed (Figure 1.6) and are to be harvested by hand during the low water period of the tidal cycle.

[1] The formation of a hybrid organism, e.g. by a cross between genetically dissimilar organisms.
[2] The incorporation of the genes of one species into the gene pool of another species.

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

The operation will be initiated in 2010. The applicant is considering harvesting on a seasonal basis (September–March).

At the moment, harvesting of bivalves in the Dovey Estuary is not subject to any Several, Regulating or Hybrid Order or other stock conservation controls.

The estimated annual production in each bed is 5 tonnes.

The activity involves one fishermen working full-time.

Figure 1.6 Adult mussels growing on the riverbed in Mussel Bed No1 at Aberdyfi.

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of pollution sources on the microbiological contamination of mussels at Aberdovey (Dovey Estuary) in the west coast of Wales[3], as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of this bivalve mollusc production area (BMPA). The survey was prompted by applications for microbiological monitoring and classification of wild mussels (*Mytilus* spp.) at Mussel Bed No 1, Mussel Bed No 2 and Mussel Bed No 3[4].

SHELLFISHERIES

High densities of commercially sized mussels[5] were observed in the three beds during a shoreline survey undertaken in the estuary on 24 June 2009[6]. These mussel beds occur in muddy (Bed No. 1) and predominantly sandy (Beds Nos 2, 3) intertidal areas.

At the moment, harvesting of bivalves in the Dovey Estuary is not subject to any Several, Regulating or Hybrid Order.

The applicant intends to harvest by hand during low water periods between September and March. The estimated annual production for each bed is 5 tonnes.

POLLUTION SOURCES

The River Dovey drains a catchment area of 471km^2, from its headwaters on Craiglyn Dyfi [altitude = 732m above Ordnance Datum (OD)] to the sea at Cardigan Bay along a distance of approximately 46km[7]. The river follows a steep gradient for approximately 4.5km until a recognisable valley floor begins at Pennant at 169m above OD. The river catchment network includes two main rivers: Cywarch and Cerist that join the River Dovey (mean flow = 23.1m^3 s^{-1} at Dyfi Bridge) and four other tributaries (Dugoed, Twymyn and both the North and South Dulas) which enter the river at Machynlleth[8]. These constitute the most significant routes of contamination of faecal origin from the wider catchment to the estuary.
The catchment is predominantly rural and used for agricultural purposes[9]. The Environment Agency considers that significant pressures are associated with

[3] 1. Introduction - Site Description, Figure 1.5.
[4] 2.1 Species, location and extent.
[5] The statutory minimum size for mussels in force within the jurisdiction area of the North Western and North Wales Sea Fisheries Committee is 45mm (http://www.nwnwsfc.org/page/home.htm).
[6] Appendix XIII.
[7] Introduction – Site Description.
[8] Appendix III.
[9] 1. Introduction, Figure 1.4.

diffuse pollution from land management practices in these rural areas. Livestock production (total number of farmed animals over 895,000), is based on sheep farming[10], predominantly in the uplands and mixed cattle and sheep in areas of natural or improved grassland in the valleys. Cattle and sheep also graze in saltmarsh areas fringing the upper reaches of the estuary. At the time of the shoreline survey (24 July 2009), it was observed that these animals have direct access to estuarine water[11]. High densities of cattle, pigs and goats occur in the lower catchment[12].
Deteriorated microbial water quality is expected to occur from faecal matter deposited in these areas and when farm yard manure and slurries are spread in agricultural fields from the wider catchment shortly before/during rainfall events, in particularly when these are spread near a watercourse. Given the impermeable characteristic of the predominant geological formations and the increase in runoff levels in the autumn[13], it is estimated that the first months of the mussel harvesting season will correspond to the period of higher risk of runoff contamination from the wider catchment.

Human population (human faecal coliform load = 1.9×10^{9} FC day^{-1}) in the river catchments (total resident population = 12,000)[14] compares with a significantly higher number of cattle (over 6,000 animals in the lower catchment; faecal coliform load = 5.4×10^{9} FC day^{-1}) and sheep (over 130,000 animals in the lower catchment; faecal coliform load = 1.8×10^{10} FC day^{-1})[15] suggesting that pollution sources of animal origin have the potential to significantly contribute to microbiological loads to the estuary. However, mussel beds are adjacent to the urban area of Aberdovey (resident people in the Ward=1,136), where a significant proportion of the land is impermeable (car parks, pier, roads, seawalls, slipways). Therefore, runoff contamination from these areas could be locally significant. Furthermore, human presence and activities in and around the estuary increase during the summer due to tourism, particularly beaches at Aberdovey, Borth (designated bathing waters) and Ynislas. Most importantly, a large proportion of sources discharge directly to watercourses.

A number of continuous and intermittent sewage discharges representing a significant or potentially significant impact on the microbial water quality of the estuary occur within 10km of the estuary or its tidal limits[16]. The most significant continuous discharges to mussel beds at Aberdovey are Machynlleth sewage treatment works (STW) (DWF = 1,195 m^3 day^{-1}), which discharges approximately 4km upstream of the tidal limit, and Borth STW (DWF = 818 m^3 day^{-1}), which discharges to the tidal reaches of the Afon Leri. Two private continuous discharges [Ynyslas Beach Borth (DWF = 33m^3 day^{-1}) and Plas Pant Eidal Holliday Village (DWF = 10m^3 day^{-1})] from holiday parks may contribute to pollution loads during the holiday season (July–August). Effluents from these continuous discharges receive secondary treatment. Another eleven intermittent

[10] Appendix IX.
[11] Appendix XIII.
[12] Appendix IX.
[13] Appendix III, Figure III.3.
[14] Appendix I.
[15] Appendix IX.
[16] Appendix VII.

discharges (emergency and storm overflows) discharge to the estuary or to tributaries of the River Dovey. Locally significant to mussel beds are Aberdyfi Wharf (eastern edge of Mussel Bed No.1) and Ynyslas PS (approximately 4km from Mussel Bed No.1).

In 2005, Dwr Cymru Welsh Water improved secondary treatments at Machynlleth STW and maintenance at Aberdyfi Wharf PS, as part of a programme of work to maintain and improve water quality in the Dovey catchment and ensure compliance with mandatory standards of the Shellfish Waters Directive and endeavour to observe the guideline standards drawn up by the Environment Agency (EA)[17].

Three sailing clubs operate from Aberdovey Wharf[18]. There are 102 moorings within Aberdovey Harbour limits. An estimated 80% were occupied at the time of the shoreline survey.
It has long been established that sewage discharged from boats could represent a significant public health risk for bivalve mollusc beds. The contribution of these sources is difficult to quantify due to the intermittent nature of discharges. During the shoreline survey, it was noted that a very low number of people were likely to stay overnight[19] and therefore the risk of contamination of mussel beds from a pollution incident from boats is considered to be low.

The Dovey Estuary provides habitat for high numbers of wintering wild fowl and waders[20]. The intertidal mudflats are also important feeding areas for passage waders during summer. Canada goose (over 2,000 individuals recorded in 2001/02) in the upper reaches of the estuary. Lapwing (over 1,000 individuals recorded in 2001/02) tend to use the south shores of the estuary and Dyfi National Nature Reserve (NNR) at Borth, whereas Golden Plover (1,200 individuals recorded in 2002/03) tend to occur in the sandbanks of the estuary and Dyfi NNR.
Previous studies in the UK have indicated significant concentrations of microbial contaminants in sediment samples from estuaries supporting large communities of birds. Literature also suggests that approximately 10% of the faecal matter could be deposited under a roost. This suggests that birds will contribute to background levels of contamination in the Dovey Estuary, in particular during the autumn-winter period, when mussel harvesting will take place. The most vulnerable areas are intertidal sandflats and mudflats in the mid and upper reaches of the estuary as these are important feeding areas over the low water period. Mussel Bed No 3 is potentially more vulnerable to contamination of faecal origin from birds than the other two beds. The south shores will also contribute to background levels due to various watercourses establishing hydrological connections between roosting areas and the estuary.
A schematic representation of the most significant pollution sources likely to impact on the microbial status of the mussel beds at Aberdovey is shown in Figure 3.1.

[17] Environment Agency (2008).
[18] Appendix VIII.
[19] Appendix XIII.
[20] Appendix X.

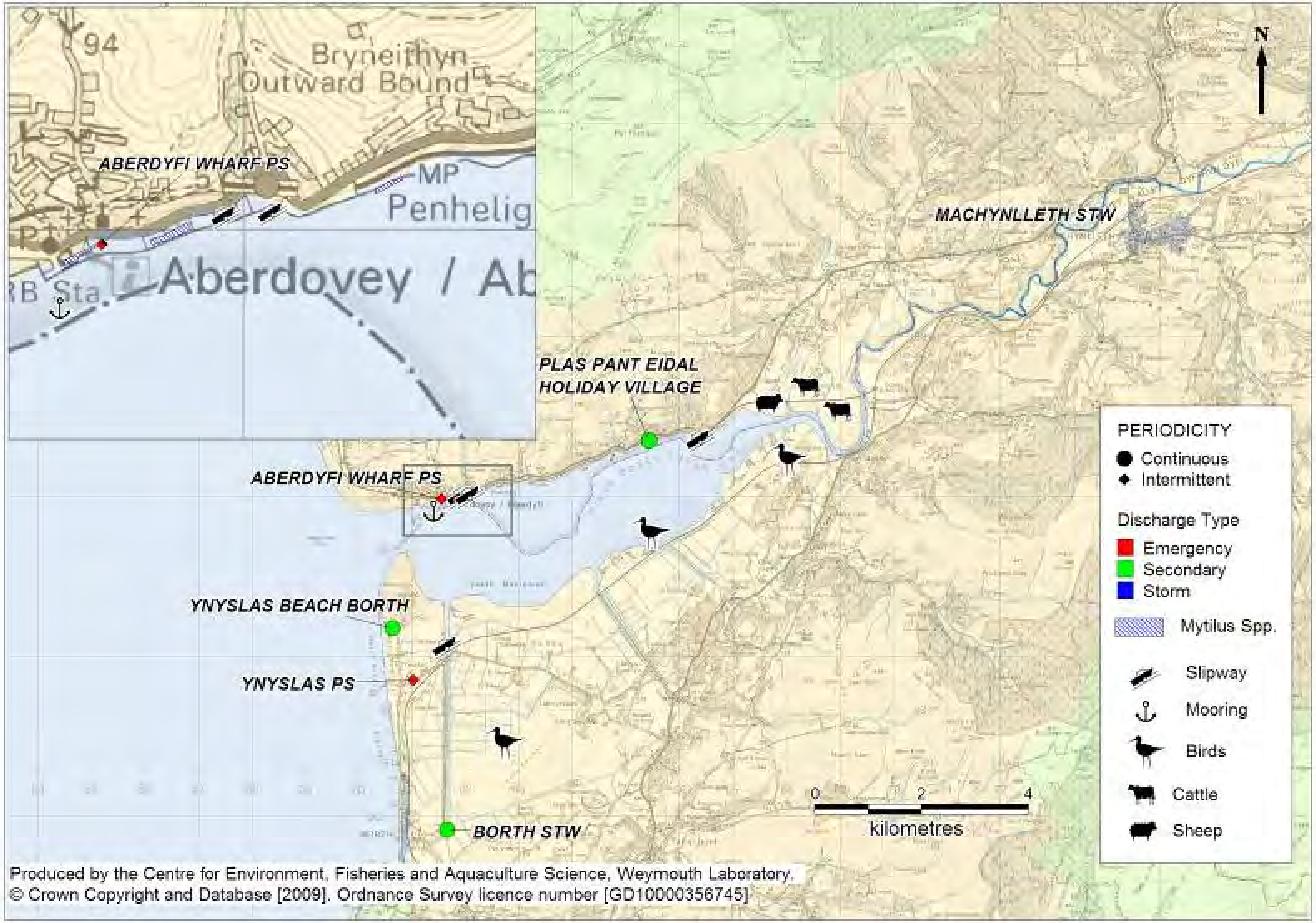

Figure 3.1 Significant pollution sources impacting on the microbial status of the mussel beds at Aberdovey.

HYDRODYNAMICS

The Dovey is a shallow estuary, with most of the areas drying on spring tides[21]. However, there is a scour hole (fixed elliptic feature of approximately 800m long and 150m wide) at the mouth of the estuary which is 12m deep relative to Chart Datum (CD), where peak flows are enhanced due to the funnelling effect of the sides of the estuary[22]. If a pollution event occurs at Aberdovey, this velocity enhancement may help to promote the dilution of contamination with incoming saline water during the flood stage of the tide. However, the estuary as a whole is ebb dominant. This means that the net transport of contamination across the estuary is seawards. Ebb dominance and the long tidal length (20km) means that contamination from the wider catchment may be more significant to the overall water quality within the estuary than that originating from more local sources at the mouth. The micro-tidal regime suggests that tidal currents may play a minor role in dispersion of contaminants. Furthermore, mussels in intertidal drying areas will not retain or accumulate microbial contamination during a significant proportion of the tidal cycle.

At low water, the flows along the estuary occur along one main channel, which meanders from the tidal limit to the mouth[23]. A secondary channel develops just south of Trefri, which intersects the main channel at the mouth of the estuary in Aberdovey in the proximity of mussel beds. This channel will be the main route of transport of contamination across the estuary. Mussel beds will be impacted by contamination from this channel and Afon Leri, the main freshwater input from the southern shores.

On spring tides at Aberdovey, the range of flood currents (0.15–0.61m s^{-1}) is bigger than that of the ebb currents (0.36–0.50m s^{-1}). This suggests that the concentration of microbial contaminants will be lower during the flood stage of the tide on springs, when most of the water at the mouth of the estuary will be fully saline.
The period of maximum dispersion of contamination at the mouth of the estuary is expected to be about 2 hours before and after high water, when maximum tidal currents occur.

At the time of the shoreline survey[24], it was observed that there is significant wave attenuation along the stretch of coastal area were mussel beds are established. However, it is likely that wind-driven currents govern estuarine mixing processes in the area.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

Levels of faecal coliforms for the period 2000–2008 in the water have been considerably higher at Aberdovey (median=56) than those at Borth (median =5)[25]. Furthermore, annual medians of the indicator indicate periods of

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[21] Appendix IV.
[22] Appendix V.
[23] Appendix IV.
[24] Appendix XIII.
[25] Appendix XI.

deteriorated water quality in 2002–2004 and 2005–2007. This is consistent with the lack of appreciable sources of pollution from seaward.

Historical data from the Shellfish Hygiene monitoring programme indicated higher levels of *E. coli* in mussels during summer than those during winter[26]. The bacteriological survey undertaken during the desk study phase of the sanitary survey indicated a decrease in levels of *E. coli* from July to October[27]. These results are not consistent with the increase of rainfall-runoff levels during the autumn-winter period. Further analyses should be carried out to monitoring programme data at the time of the review of the sanitary survey to confirm whether these factors will promote seasonal variation of the microbiological indicator in mussels at Aberdovey.

Rainfall levels across the catchment increase during the period October–December[28]. Hydrographs for River Dovey (Llawr Cae and Dyfi Bridge gauging stations) showed rapid responses of water levels following rainfall events. Levels of runoff coefficient at Dyfi Bridge also increase substantially from summer to autumn–winter periods to peak in December.

Correlation analyses between two hydrometric parameters (rainfall and river flow) and levels of *E. coli* in bivalves showed significant positive relationships (Spearman's *rho* coefficient; 95% confidence level) between levels of the indicator in mussels harvested from Picnic Island and levels of rainfall and river flows on the day of sampling[29]. This suggests that rainfall-dependent discharges and runoff from the wider catchment are significant risk factors to mussels at Aberdovey. However, mussels may not retain high levels of *E. coli* for a longer period of time since significant correlations were not obtained for previous days.

The results from the shoreline survey[30] evidenced the River Dovey as the most significant route of microbial contamination from the wider catchment to the estuary (5.0×10^8 *E. coli* day^{-1}). However, mussel beds are also potentially impacted by contamination from two other streams discharging to the south shores of the estuary (stream at Pen-Y-Graig; 1.9×10^7 *E. coli* day^{-1} and Afon Einion; 3.1×10^7 *E. coli* day^{-1}).

During the shoreline survey, it was observed that cattle graze on the saltmarsh in the upper reaches of the estuary and have direct access to the River Dovey. Grazing animals defecating directly in the water will give rise to increased levels of microbial pollution in the estuary.

[26] Appendix XII.
[27] Appendix XIV.
[28] Appendix II.
[29] Appendix XII.
[30] Appendix XIII.

4. RECOMMENDATIONS

The results from the sanitary survey suggest that two classification zones (CZs) may adequately represent the variation of microbiological contamination across and between mussel beds at Aberdovey:

- one CZ encompassing mussel beds Nos. 1 and 2, defined by enforceable lines 10m from the edge of an area encompassing the western edge of Mussel Bed No 1 to the eastern edge of Mussel Bed No 2 (Aberdyfi - West);
- a second CZ to encompass mussel bed No. 3 be enforced 10m from the edge of Mussel Bed No 3 (Aberdyfi - East).
- The most westerly bacteriological survey monitoring point showed the highest peak *E. coli* concentration during the bacteriological survey and best represents the extent of contamination across the CZ Aberdyfi - West.
- The bacteriological survey monitoring point sited in the middle of Mussel Bed No 3 adequately represents contamination impacting the recommended CZ Aberdyfi - East.
- The recommended maximum tolerance for RMPs is 10 metres. This tolerance minimises the effects of spatial variability in the extent of contamination whilst preserving the fixed geographical location.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Dovey Estuary
Cefas Main Site Reference	M041
Cefas Area Reference	FDR 3038
Ordnance survey 1:25,000 map	Explorer OL23: Cadair Idris & Llyn Tegid
Admiralty Chart	Admiralty 1484: Plans in Cardigan Bay. 1995.

Shellfishery

Species/culture	Mussels (*Mytilus* spp.)	Wild
Seasonality of harvest	September–March	

Local Enforcement Authority

Name of Local Enforcement Authority	Gwynedd Council Regulatory Department Public Protection Service Cae Penarlag, Dolgellau, GWYNEDD, LL40 2YB
Telephone number ☎	01341 422341
Environmental Health Officer	Michael Thomas
Telephone number ☎	01341424372
Fax number	01341424478
E-mail	mikethomas@gwynedd.gov.uk

REQUIREMENT FOR REVIEW

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

Table 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones in the Dovey Estuary.

Classification zone			**Aberdovey - West**	**Aberdovey - East**
RMP			**B041M**	**B041O**
RMP name			**Mussel Bed No 1**	**Mussel Bed No 3**
Geographic grid references (datum) of sampling points	**Eastings** **Northings**		261,420 295,900	262,480 296,149
	NGR		SN61429590	SN62489614
	WGS84	**Latitude** **Longitude**	52°32.59N 04°02.69W	52°32.74N 04°01.76W
Species			*Mytilus* spp.	*Mytilus* spp.
Growing method			Wild	Wild
Harvesting technique			Hand-picking	Hand-picking
Sampling method			Hand-picking	Hand-picking
Depth (m)			Riverbed	Riverbed
Tolerance for sampling points (m)			10	10
Frequency of sampling (PRELIMINARY Classification)			10 samples taken over, at least, 3 months (interval between sampling not less than 1 week).	10 samples taken over, at least, 3 months (interval between sampling not less than 1 week).
Frequency of sampling (FULL Classification)			At least monthly over one year. If seasonal classification is required, 12 samples taken during the active season and the preceding 2 months (interval between sampling not less than 1 week)	At least monthly over one year. If seasonal classification is required, 12 samples taken during the active season and the preceding 2 months (interval between sampling not less than 1 week)

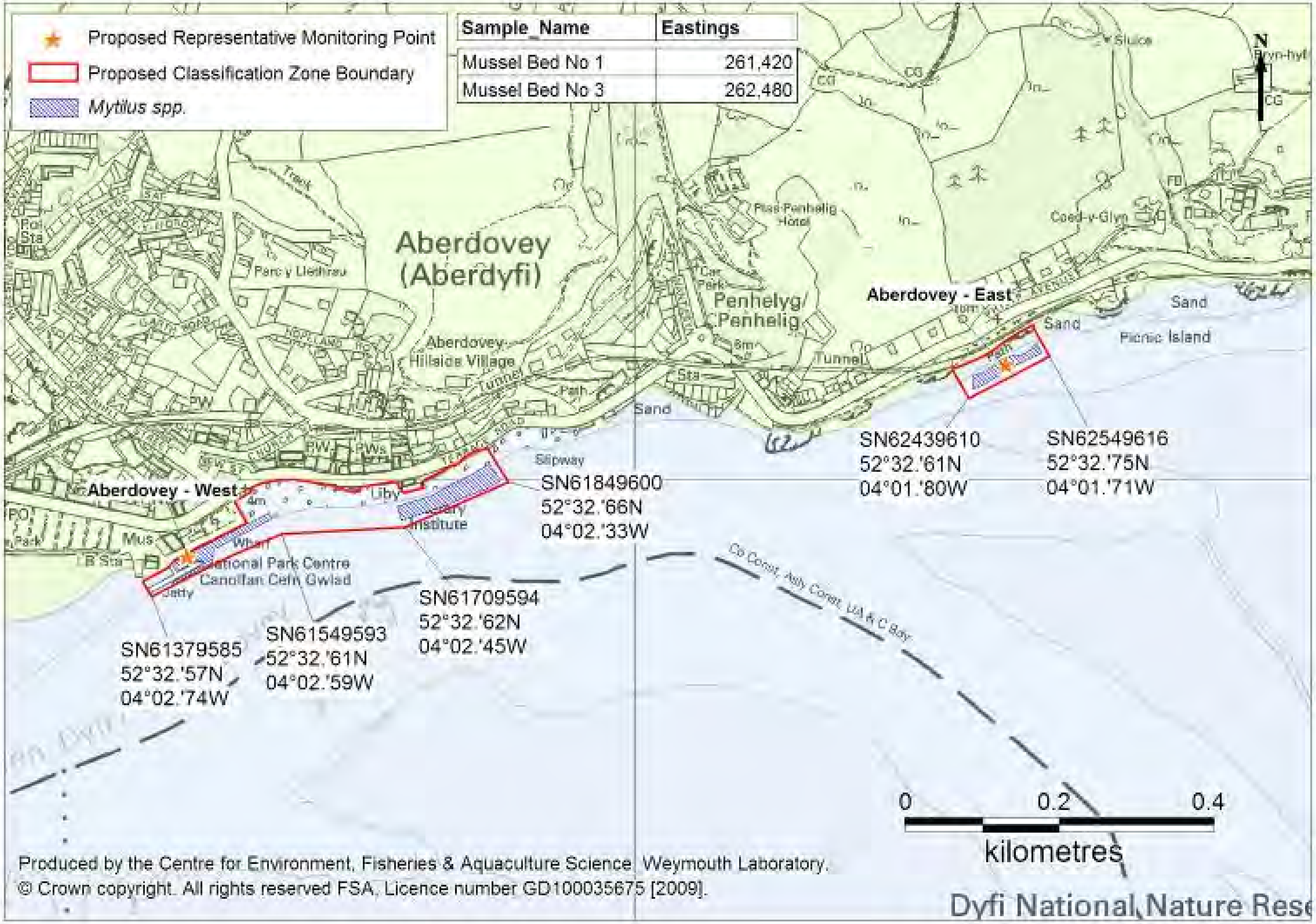

Figure 5.1 Location of recommended representative monitoring points (RMP) and classification zone boundaries for mussels in the Dovey Estuary.

APPENDICES

APPENDIX I
HUMAN POPULATION: DENSITY AND ACTIVITY

The distribution of resident human population totally or partially included within the river catchment areas is shown in Figure I.1. Human population densities are very low, between <0.08–0.21 persons ha^{-1}. Densities by Super Output Area Boundary[31] have maximum values of 5.36 at Tywyn and 4.24 at Machynlleth.

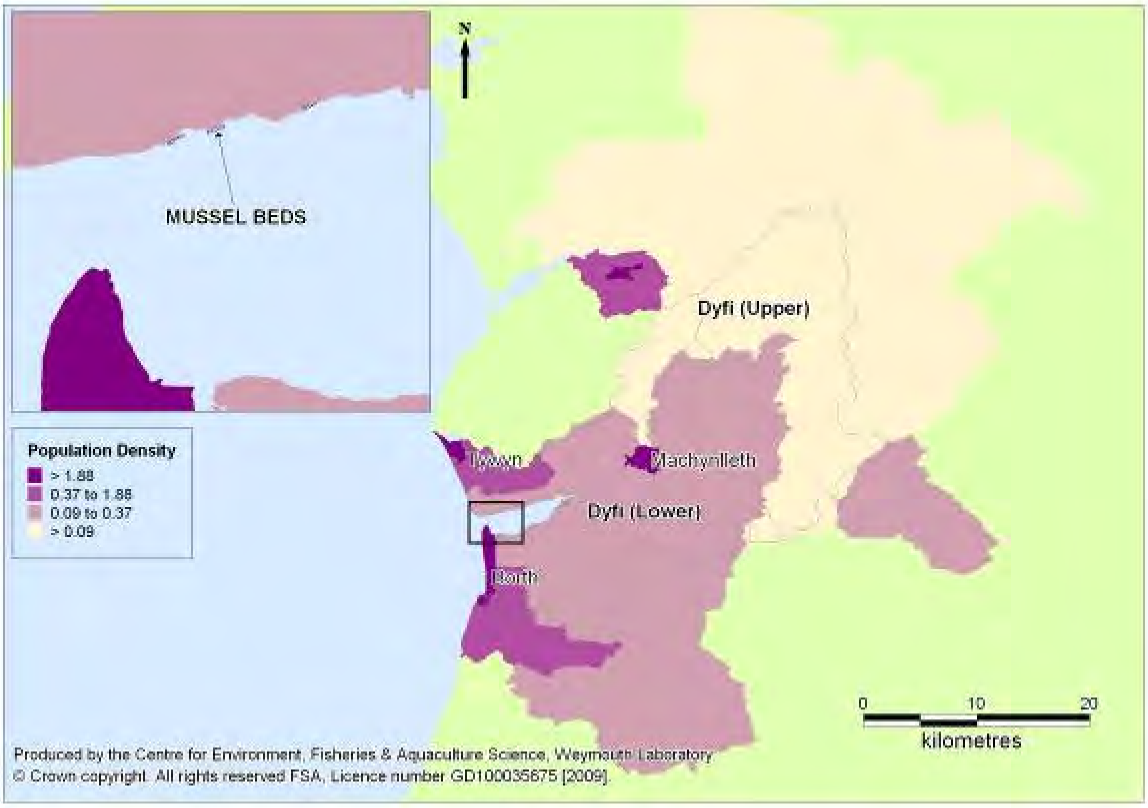

Figure I.1 Human population density in the Dovey/Dyfi river catchments.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Borth has higher population density, with an average of 0.08–0.21 persons ha^{-1}. Other areas of high density are Aberdyfi (total resident population in the Ward = 1136 people) and Machynlleth (total resident population in the Ward = 2,147). However, these densities are very low when compared to the mean values for rural areas in the rest of the country. The total resident population (Table A1.1) is small, considering the relatively high catchment area (471km).

Urbanised areas contain the majority of point-sources of pollution (continuous and intermittent sewage discharges) in these catchments. An inventory of the significant sewage discharges to the estuary is presented in the Appendix VII.

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

Table I.1 Human population in the Dovey/Dyfi river catchments.

River catchment	Resident population
Lower Dyfi	9,668
Upper Dyfi	2,399
Total	12,067

Source: Office for National Statistics, Crown copyright 2007.
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NB. Based on provisional mid-2005 population estimates for river catchment areas within England and Wales.

Urbanised areas also contain the majority of impervious surfaces[32] (e.g. roads, parks, pavements), which are known to contribute with significant loads of microbiological contaminants (Ellis and Mitchell, 2006)[33]. Bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

There is no heavy industry in the catchment. Agriculture and tourism represent the main activities in terms of local economy.

Aberdovey and Borth Sands are popular with sunbathers and swimmers and fishermen. The estuary attracts a wide range of water-based activities (e.g. kite surfers, sail-boarders, sand-yachters and para-sailors). There are two golf courses at Aberdovey and Borth. It is estimated that at least 2M tourists passed through the Dyfi Biosphere Reserve area (UNESCO, 2008). The Countryside Couyncil for Wales estimates that some 250,000 people visit Ynislas per year (UNESCO, 2008). In addition, the camping and caravan sites at Borth can accommodate up to 7,231 people when fully occupied (UNESCO, 2008). Exact numbers of visitors/tourists to Aberdovey are unknown. However, tourists were noted to represent a significant proportion of human population at the time of the shoreline survey.

Human population greatly fluctuates seasonally due to tourism. Increased population represents increased likelihood of pollution in the estuary negatively impacting mussel beds. For example, seasonal changes in human population may result in increased microbiological loads from sewage treatment plants (see Younger *et al.*, 2003)

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

APPENDIX II
HYDROMETRIC DATA: RAINFALL

The rainfall pattern varies greatly across the Dovey catchment. This variation is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall throughout the upper reaches of the catchment. The coastal area at Aberdovey experiences less than 1,000mm of rainfall per annum, whilst the upper reaches of the catchment may receive as much as 2,000mm per annum (Figure II.1). This compares with an average annual rainfall for England and Wales of approximately 1,250 mm (Perry, 2006).

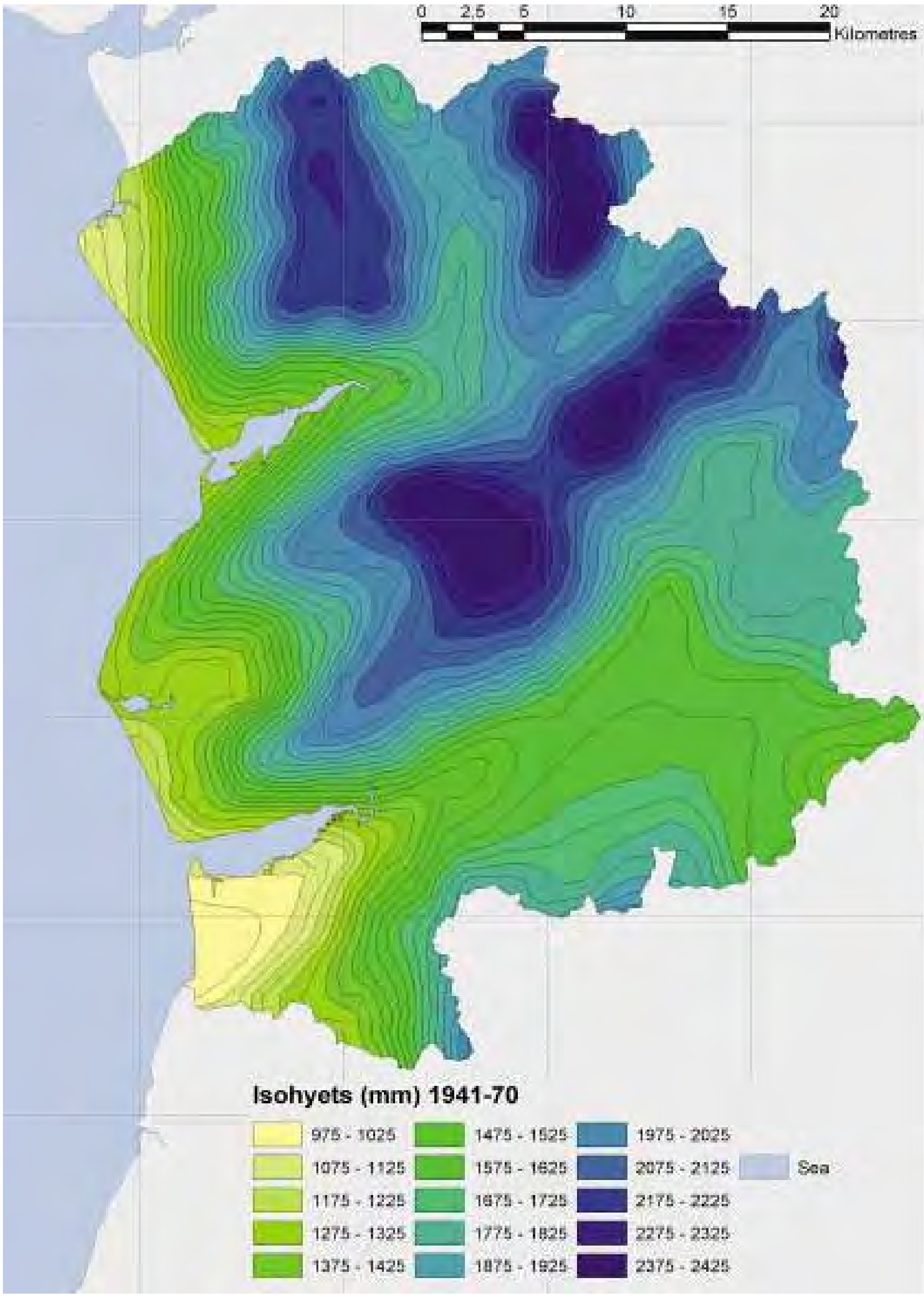

Figure II.1 Isohyets in the wider Meirionnydd catchment area.

Figure II.2 shows monthly averaged and monthly total rainfall monitored daily in tipping bucket gauges operating at Aberdyfi (Eastings/Northings: 260,494/296,053) (representative of the lower catchment) for the period January 2000–December 2008 and Llanymawddwy (288,946/317,121) (representative of the upper catchment) for the same period. On average, a significant increase in rainfall levels occurred between September and February. The wettest month varied between October and December.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). An inventory of the most significant sewage discharges to the Camel Estuary is listed in Appendix VII. Levels of microbiological contamination are expected to increase during autumn-winter months.

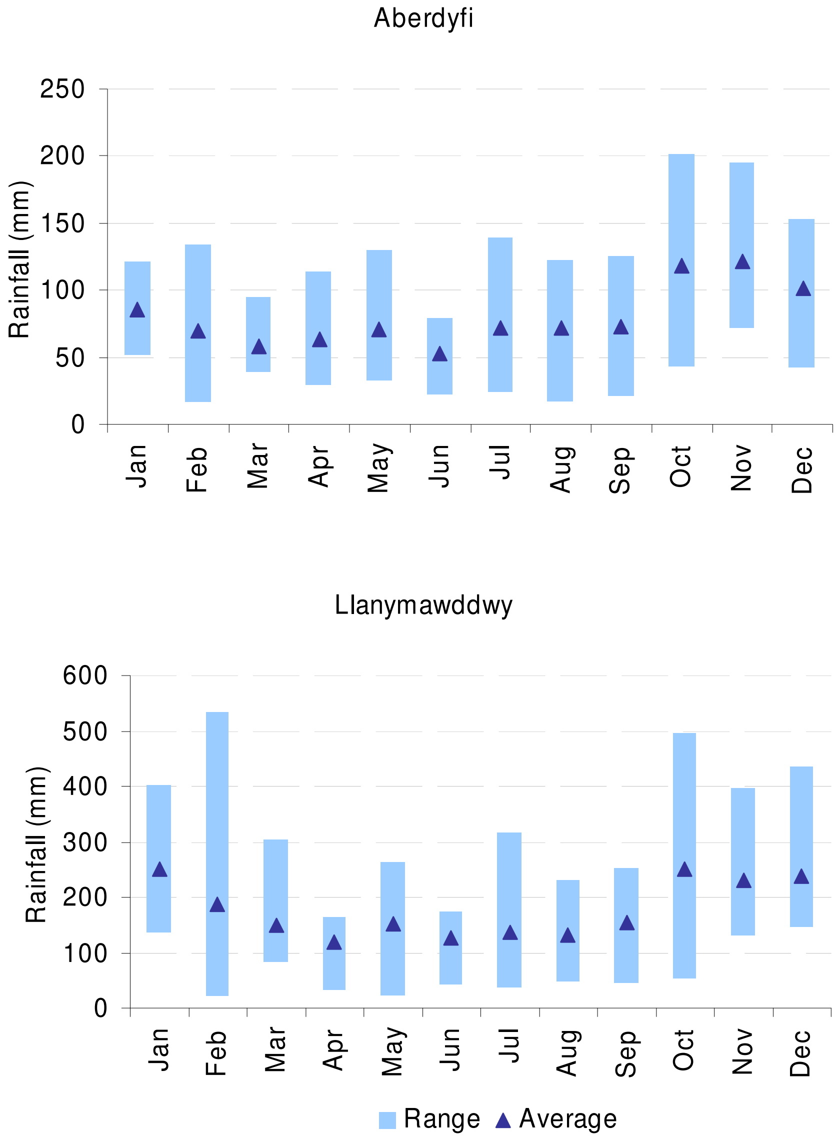

Figure II.2 Monthly variation of rainfall recorded at Aberdyfi (lower catchment) and Llanymawddwy (upper catchment) gauging stations for the period January 2000–December 2008.
Data from the Environment Agency (2009).

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

The River Dovey, from its headwaters on Craiglyn Dyfi [altitude=732m above Ordnance Datum (OD)] to where it enters the sea at Cardigan Bay is approximately 46km (Figure III.1). The river follows a steep gradient for approximately 4.5km until a valley floor begins at Pennant at 169m above OD.

The rivers Cywarch and Cerist join the Dyfi as it begins to meander across the valley floor. Four other tributaries enter the river upstream of Machynlleth: Dugoed, Twymyn and North and South Dulas join just upstream of Machynlleth.

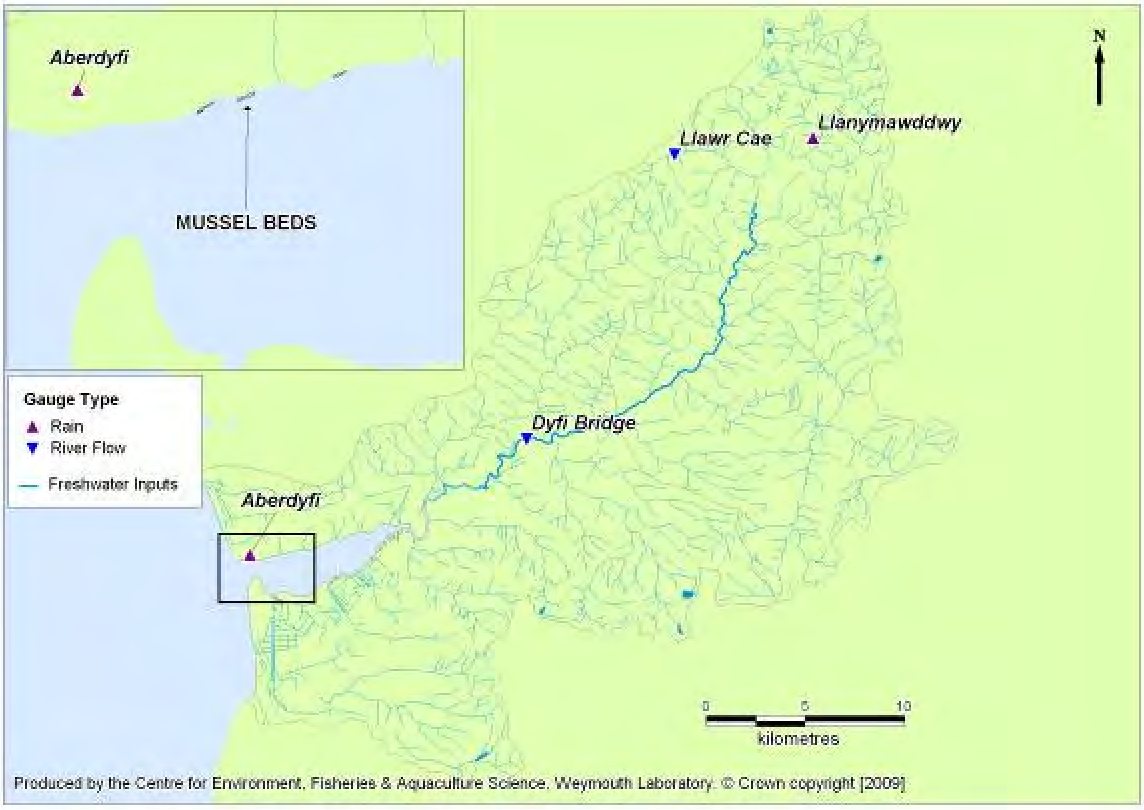

Figure III.1 Rivers and streams in catchments draining to the Dovey Estuary.

Table III.1 summarises the hydrological characteristics of the River Dovey at Dyfi Bridge. Q95 and Q10 represent the averaged flow that is exceeded for 95% and 10% of the time, respectively.

Table III.1 Hydrological characteristics in the River Dovey.

	Gauging station at Dyfi bridge[(a)]
Catchment Area (km^2)	471.3
Level of Station (m OD)	5.9
Maximum altitude (m OD)	907
Mean flow ($m^3 s^{-1}$)	23.15
95% exceedance (Q95) ($m^3 s^{-1}$)	2.2
10% exceedance (Q10) ($m^3 s^{-1}$)	54

[a] data for the period 1960–1990.
Data from the National River Flow Archive (NERC-CEH, 2008).

The combination of steep topography and impermeable rocks is likely to promote rapid changes in water flows on the River Dyfi in response to rainfall events.

The rising and falling limbs of the hydrographs for the River Dovey shown in Figure III.2 indicate that water levels tend to respond quickly to rainfall events.

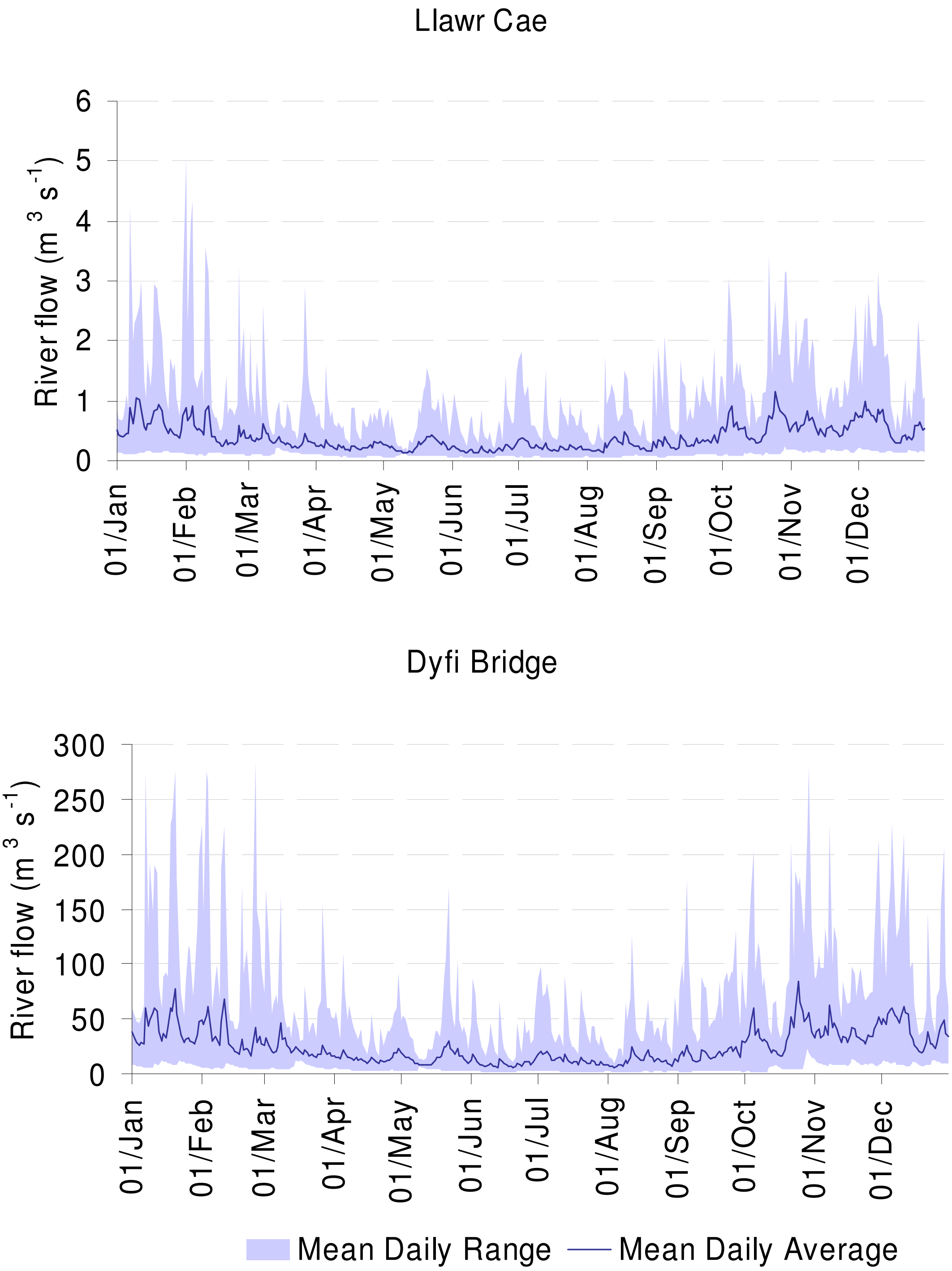

Figure III.2 Hydrographs for River Dovey at Dyfi Bridge and rainfall at Aberdyfi for the period January 2000–December 2008.
Data supplied by the Environment Agency (2008).

Figure III.3 illustrates the seasonal pattern of runoff within the Dovey catchment in response to rainfall.

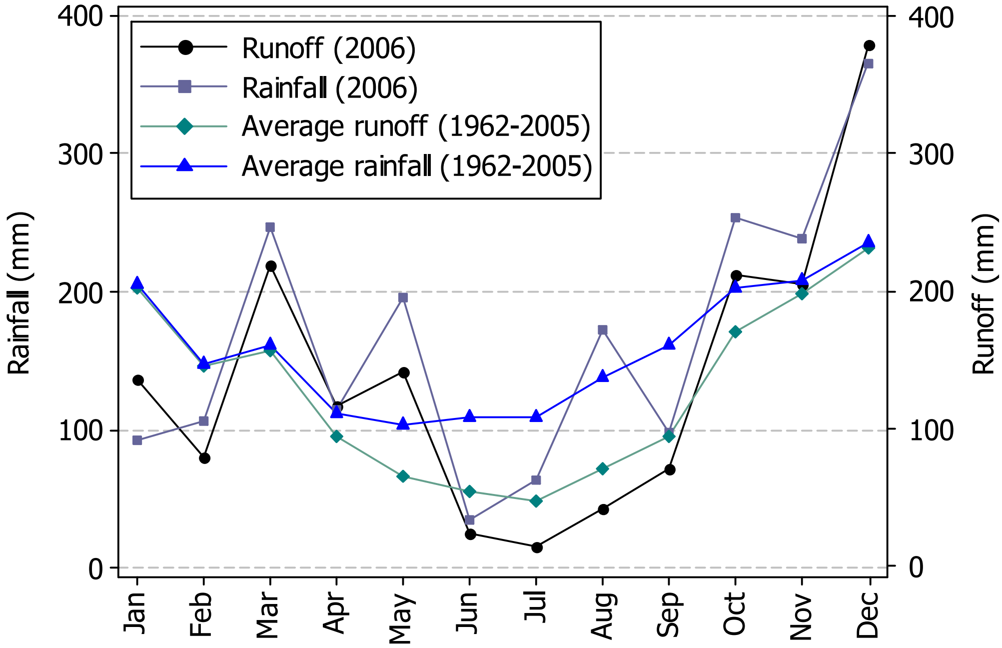

Figure III.3 Monthly variation in rainfall and runoff for River Dovey at Dyfi Bridge.
Data from NERC National River Flow Archive (2008).

Significantly higher geometric means of faecal indicator microorganisms have been found on watercourses during high-flow conditions relative to those during low flow conditions in UK coastal catchments with >50% of improved grassland (Crowther *et al.*, 2002; Stapleton *et al.*, 2006). The percentage of grassland in the upper Dyfi catchment is approximately 64% (CEH, 2005).

Locally significant are a number of springs in the north and south shores of the estuary (Figure A3.1). The later flow on flat land and their water levels tend to have slower responses to rainfall.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

The Dovey estuary is a type 3 Ria with spits (Halcrow Group Ltd., 2003). Its cross-sectional width is approximately 0.8km at Twyni Bach, from where the spit causes reduction in channel width to approximately 0.35km. Further up at Aberdovey/Aberdyfi, the estuary width increases to around 2.2km, decreasing again to approximately 1.9km in the upper estuary at Aber-Tafol and 0.7km at Fron-goch.

Bathymetric contours with upper and lower limits of 10m and -5m relative to Chart Datum (CD), respectively is shown in Figure IV.1. The estuary is very shallow and most of it dries completely at low water springs. Most of the drying areas occur along the south shores and upper reaches of the estuary.

The bathymetric gradient is higher in the mouth of the estuary at Aberdovey, where mussel beds are established (Figure IV.2). Also at the mouth there is a scour hole, a fixed elliptic shaped feature of approximately 800m long and 150m wide, which is 12m deep relative to CD (Davies and Brown, 2007).

Depths on the south western side of Aberdovey Bar at Cardigan Bay reach 15m relative to CD (Robins, 2008a).

Sedimentation of microbiological contaminants and re-suspension of contaminated sediment is a common feature of shallow estuaries such as the Dovey. However, dispersion and dilution of contamination will increase in deeper areas of the estuary mouth

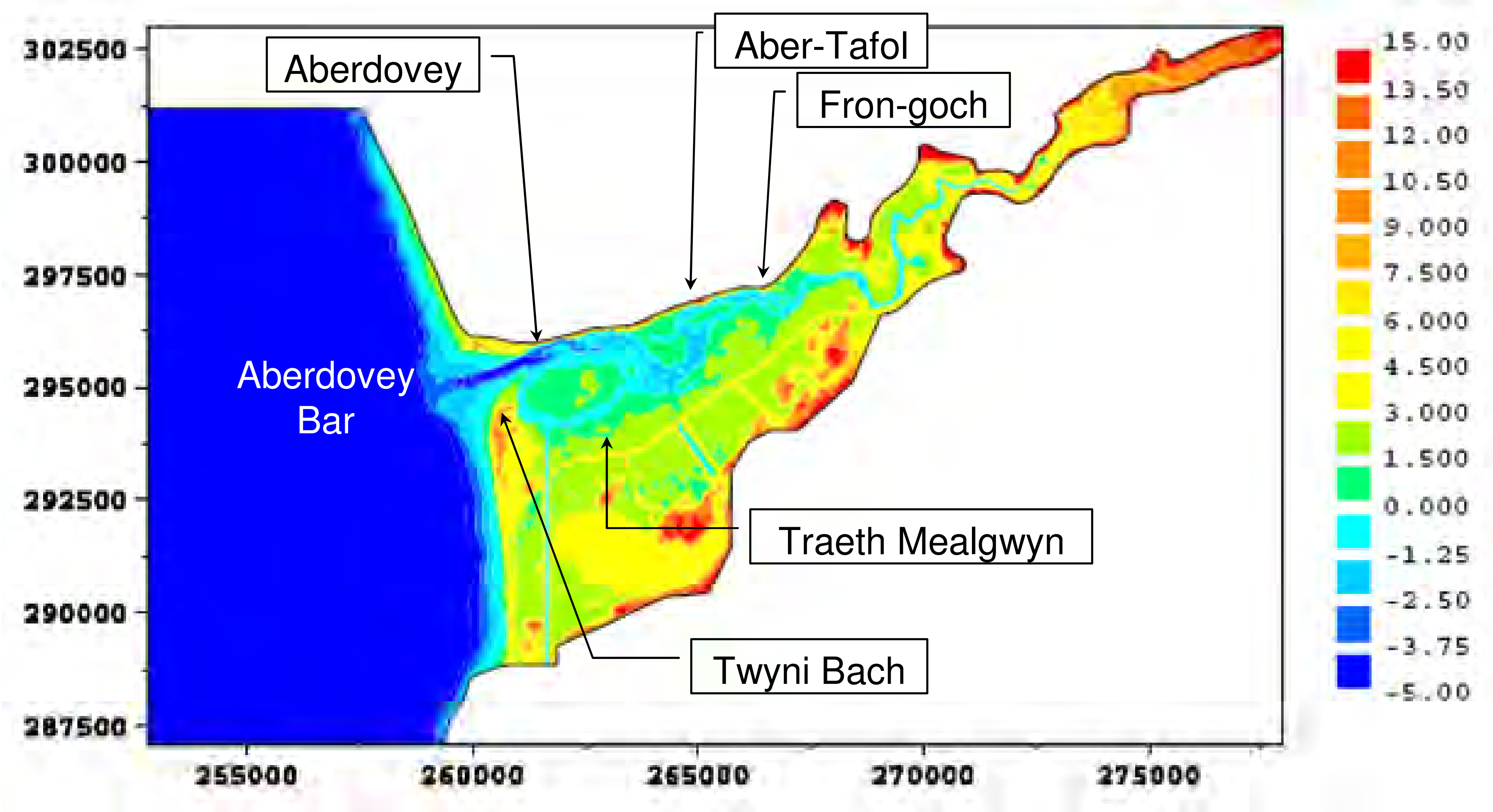

Figure IV.1 Bathymetry of the Dovey Estuary.
Reproduced from Robins (2008) under permission of the author.

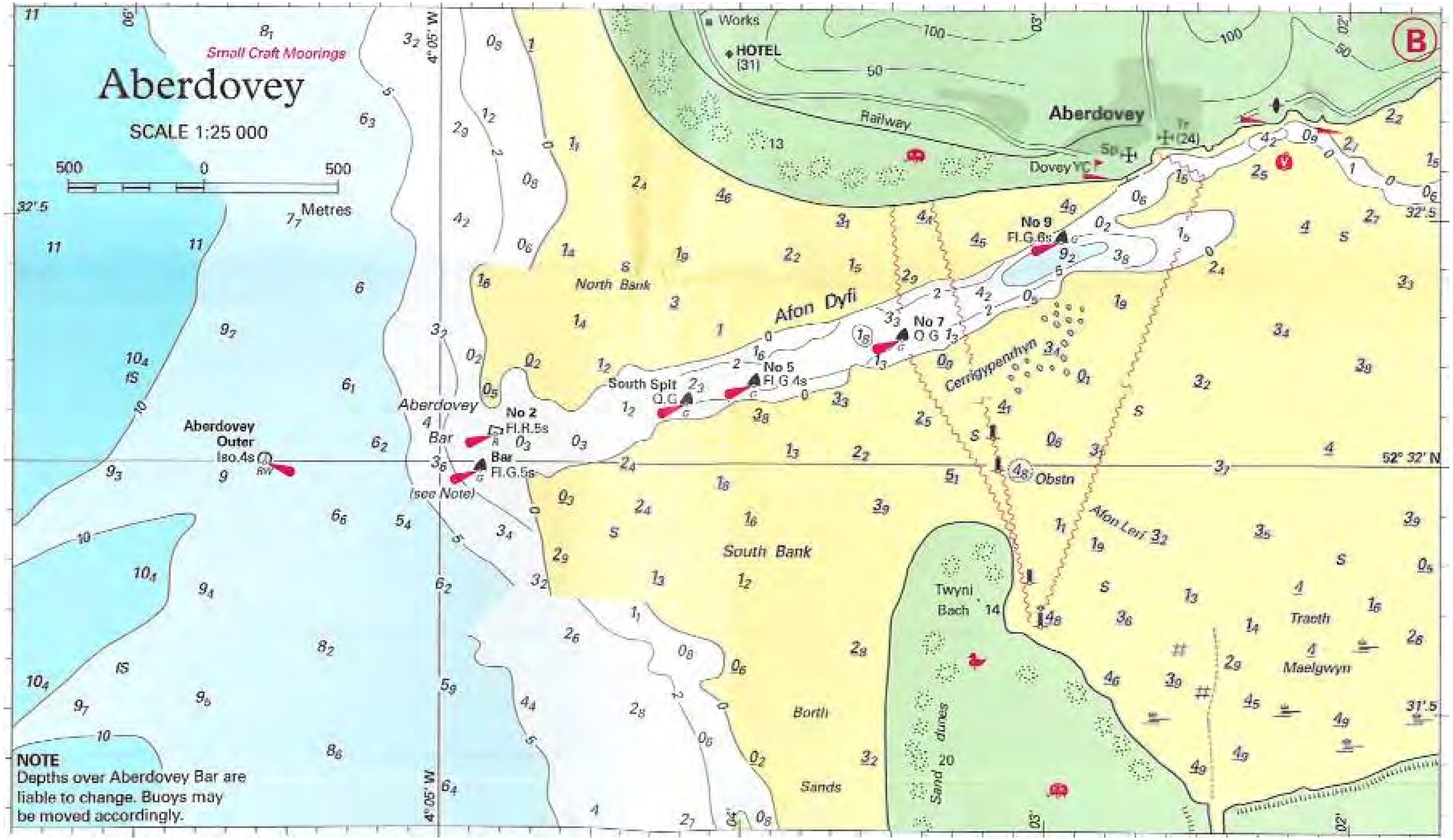

Figure IV.2 Bathymetry of the mouth of the Dovey Estuary.
Reproduced by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk).

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND TIDAL CURRENTS

The estuary has an asymmetrical micro-tidal regime with semi-diurnal tides (i.e. two tidal cycles per day). The entire Dovey Estuary is inundated at the highest spring tides.

At Aberdovey, the mean spring tide range is 2.9m and the mean neap tide range is 1.4m (Table V.1).

Table V.1 Tide levels and ranges at Aberdovey/Aberdyfi.

		Height (m) above Chart Datum				Range (m)	
Port	Mean Sea Level (m)	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Aberdovey	2.6	5	3.5	2.0	0.7	2.5	1.5

Data from UK Admiralty Total Tide. Admiralty © TotalTide (The UK Hydrographic Office).

Around low water, flows in the estuary are restricted to one main channel, which meanders from the tidal limit to the mouth of the estuary. A secondary channel develops just south of Trefri, which intersects the main channel at the mouth of the estuary in Aberdovey.

The estuary is ebb dominant (the flood being of shorter duration than the flood) and there is an ebb delta off the mouth. The tidal length (mouth to limit of reversing tidal currents) is approximately 20km.

The low cross sectional area ratio indicates a sediment-dominated system (Halcrow Group Ltd., 2003). Levels of suspended particulate matter would be expected therefore to be high with the turbidity maximum located not too far up the estuary. This seems to be confirmed by the extent of the saltmarsh and estimated sediment accretion rates (Shi, 1993).

The funnelling convergence of the estuary sides and the friction of the bed on the tidal currents can produce significant modifications on the tide. The convergence causes a partial reflection of the tidal wave, as well as squeezing it into a small cross section, thereby increasing the height of the tidal wave (Dyer, 1995).

The intertidal area ratio is high at 0.89. The mouth width to channel length is about average. The volume of the tidal prism consistently exceeds discharge from the rivers entering the estuary by several orders of magnitude (Jarvis, 1970).

Flood currents range between 0.15 and 0.61 m s^{-1} and ebb currents range between 0.36 and 0.50 m s^{-1} during spring tides. Maximum velocities tend to occur about 2 hours before and after high water, with highest speeds recorded on the flood (Haynes and Dobson, 1969).

Peak flood and ebb velocity vectors in the estuary mouth are shown in Figure V.1. Maxima peak flood currents occur in the area of the scour hole, diminishing considerably further east along the main channel and also along the drying areas of the south shores (Robins, 2008). A reverse pattern is observed in the channel during the ebb tide. A jet-like plume directed to the west into Cardigan Bay is formed at the scour hole.

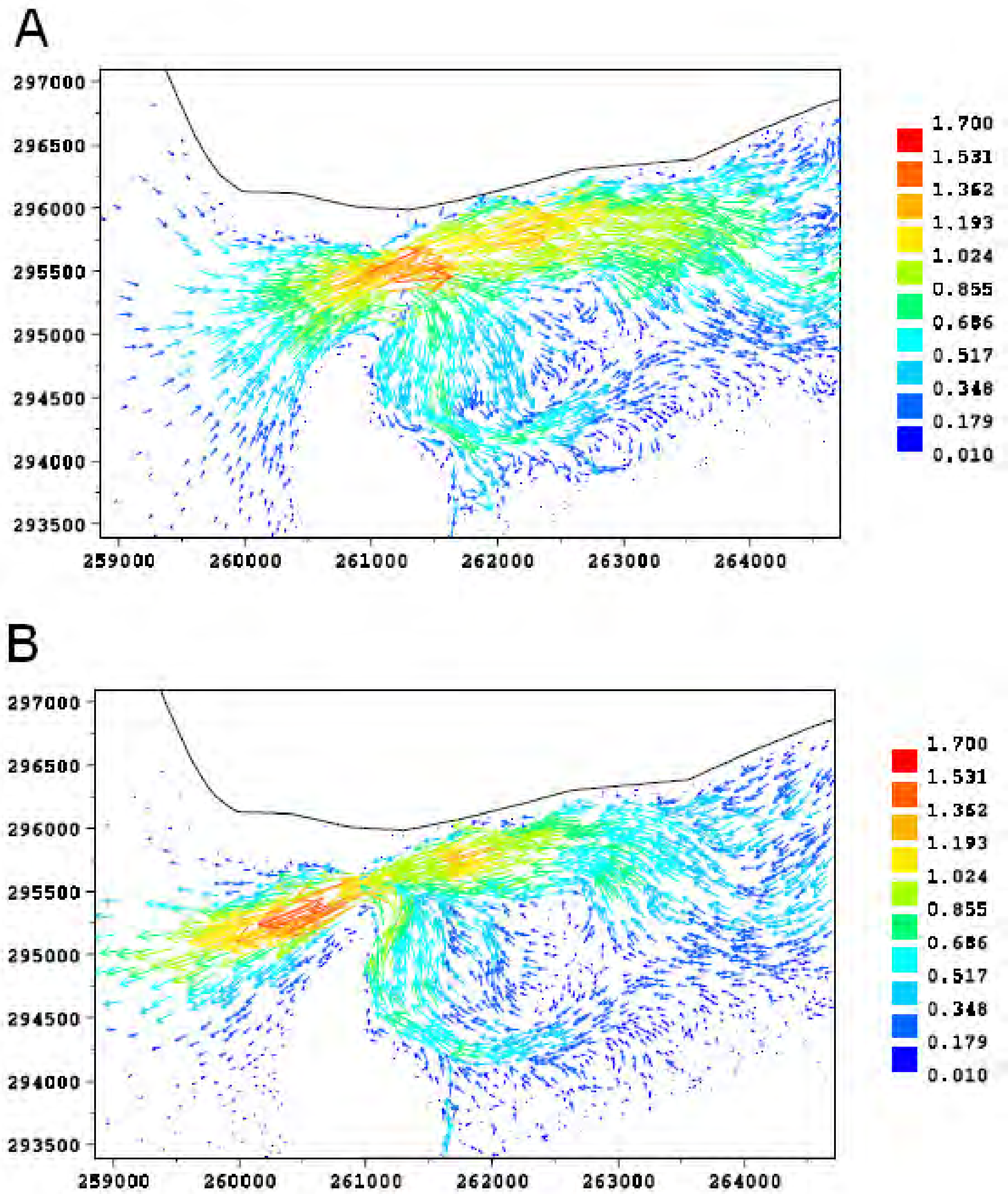

Figure V.1 Peak flood and ebb tidal currents at the mouth of the estuary.
Reproduced under permission of Peter Robbins, Centre for Applied Marine Sciences, Bangor University.

APPENDIX VI
METEOROLOGICAL DATA: WIND PATTERN

Wales is one of the windier parts of the United Kingdom. The windiest areas are over the highest grounds and along the coasts. The range of directions between south and north-west accounts for the majority of occasions and the strongest winds nearly always blow from these directions. However, there is a high frequency of north to north-east (N-NE) winds in spring (Met Office, 2009).

The relationship between wind speed and levels of faecal coliforms quantified at Aberdyfi bathing water for the period May 1995–September 2008 is illustrated in Figure VI.1. Wind blew from N-NE during 99.3% of the sampling occasions. The LOcally WEighted Scatterplot Smoothing (LOWESS) highlights the non-linearity of the relationship. The highest range of concentrations of faecal indicator bacteria was detected under conditions of light breeze.

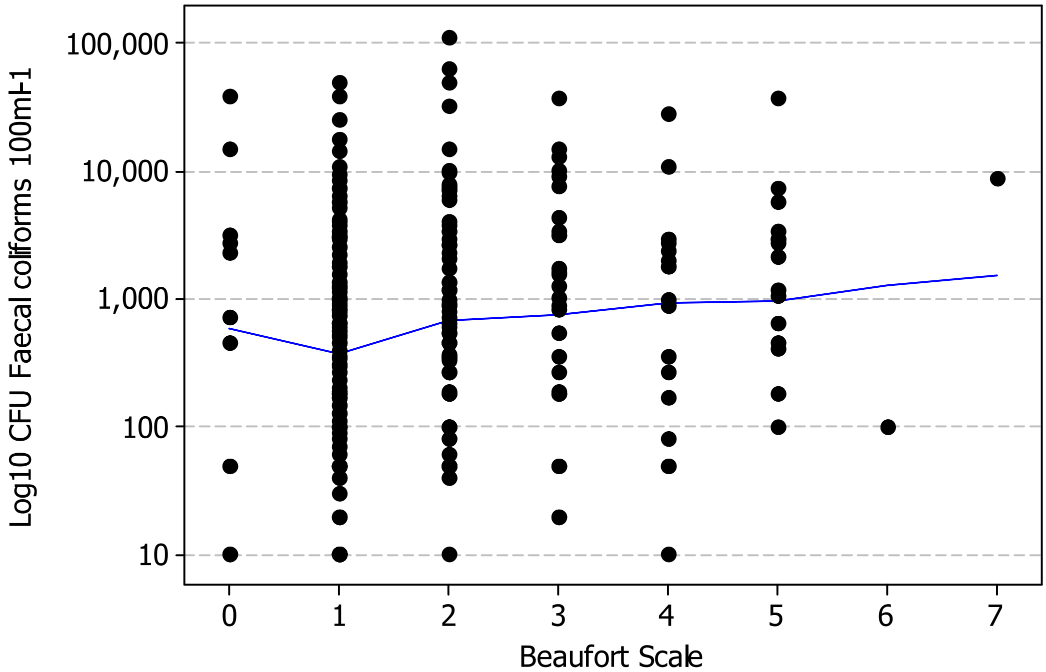

Figure VI.1 Scatterplot with superimposed LOWESS line for wind speed and levels of faecal coliforms in seawater at Aberdyfi Beach for the period May 1995–September 2008.
Beaufort 0=calm; 0–0.2m s^{-1}. Beaufort 1=light air; 0.3–1.5m s^{-1}.
Beaufort 2=light breeze; 1.6–3.3m s^{-1}. Beaufort 3=gentle breeze; 3.4–5.4m s^{-1}.
Beaufort 4=moderate breeze; 5.5–7.9m s^{-1}. Beaufort 5=fresh breeze; 8–10.7m s^{-1}.
Beaufort 6=strong breeze; 10.8–13.8m s^{-1}. Beaufort 7=near gale; 13.9–17.1m s^{-1}.

The LOWESS line suggests that the relationship between the concentration of faecal coliforms in water and wind speed is non-linear. Although the dataset is not representative of the full range of wind directions that may occur at Aberdyfi throughout the year, it is likely that other factors are influencing the magnitude of microbiological contamination in seawater when wind speed is less than 3.4m s^{-1} (Beaufort scale 3).

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION
SEWAGE DISCHARGES

The locations of sewage discharges that are potential sources of microbiological contamination of shellfisheries in the Dovey Estuary production area are shown in the map in Figure VII.1.

Sewage treatment facilities for the area are provided by Dŵr Cymru Welsh Water (DCWW). Continuous DCWW sewage discharges that are potential sources of contamination are listed in Table VII.1. The most significant sewage discharges are Machynlleth sewage treatment works (STW), which discharges approximately 4km upstream of the tidal limit of the River Dovey, and Borth STW, which discharges to the tidal reaches of the Afon Leri. Both STWs have secondary treatment.

Table VII.1. Continuous water company sewage discharges to the Dovey Estuary.

Name	Population equivalent	Treatment	Flow (m^3 day^{-1})	NGR of the outfall	Receiving water
Pennal STW	822	Secondary	148[a]	SN 70220 99650	River Dovey
Borth STW	4,544	Secondary	818[a]	SN 61640 89750	Afon Leri
Talybont STW	767	Secondary	138[a]	SN 65770 89060	Afon Leri
Derwenlas STW	119	Secondary	21.5[a]	SN 72110 99261	River Dovey
Machynlleth STW	6,639	Secondary	1,195[a]	SH 73885 01230	River Dovey
Penegoes STW	139	Secondary	25	SH 77580 00870	Tributary of R. Dovey
Pant Perthog STW	28	Secondary	5[b]	SH 74880 04270	Tributary of R. Dovey
Pont ar Dyfi septic tank	22	Primary	4[b]	SH 74350 01940	River Dovey

STW - sewage treatment works.
[a] Consented DWF
[b] Consented maximum flow. Data source DCWW.
Only discharges within 10km of the tidal limit are listed.

Intermittent sewage discharges (emergency and storm overflows) that are potential sources of contamination to the production area are listed in Table VII.2.

Table VII.2 Intermittent water company sewage discharges to the Dovey Estuary.

Name	Type	NGR of the outfall	Receiving water
Aberdyfi Wharf PS	Emergency/Storm	SN 61530 95950	Dovey Estuary
Ynyslas PS	Emergency	SN 61010 92550	Tributary of Afon Leri
Derwenlas STW PS	Emergency	SN 72110 99260	River Dovey
Poplar Road CSO Machynlleth	Storm	SH 74394 00750	Tributary of River Dovey
Doll Street CSO Machynlleth	Storm	SH 74400 01110	Tributary of River Dovey
Heol Penrallt CSO Machynlleth	Storm	SH 74407 00922	Tributary of River Dovey
Garsiwn Ditch CSO Machynlleth	Storm	SH 74230 00900	Tributary of River Dovey
Machynlleth STW	Storm	SH 73885 01230	River Dovey
Machynlleth STW	Emergency	SH 74230 00920	Tributary of River Dovey
Penegoes PS	Storm	SH 77580 00870	Tributary of River Dovey
Llanwrin PS Machynlleth	Emergency	SH 78900 03370	Tributary of River Dovey

STW - sewage treatment works, PS - pumping station, CSO - combined sewer overflow.
Trib. - tributary.
Only significant discharges within 10km of the tidal limit are listed.

Figure VII.1. Significant sewage discharges to the Dovey Estuary.

Aberdyfi Wharf pumping station (PS) discharges in very close proximity to the proposed mussel harvesting area at Aberdovey and therefore has the potential to significantly affect levels of contamination in the event of a storm or emergency discharge.

There are several storm overflows in Machynlleth that discharge to the River Dovey or its tributaries.

In addition to the water company discharges listed above, there are two private discharges to the Dovey Estuary that are potential sources of contamination of the production area (Table VII.3). Both are from holiday parks and the polluting load is anticipated to be highest during the holiday season (July–August).

Table VII.3 Continuous private sewage discharges to the Dovey Estuary.

Name	Population equivalent	Treatment	Flow ($m^3\ day^{-1}$)	NGR of the outfall	Receiving water
Plas Pant Eidal Holiday Village (new permit 1997)	556	Secondary	100 (max.)	SN 65420 97040	Dovey Estuary
Ynyslas Beach Borth (Riverside Caravan Park)	183	Secondary	33	SN 60620 93530	Dovey Estuary

Data source: Cefas discharges database.
Only direct discharges to estuary are listed.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION
BOATS

The Dovey Estuary supports a variety of boating activities, most operating from Aberdovey. Watersports such as sailing, canoeing and windsurfing are very popular during the holiday season.

In the south shores of the estuary, Ynyslas boatyard (see Figures VIII.1–2) provides mooring and boat launching, storage and repair. Borth Rowing Club also operates from this area. The sandy beaches at Borth and Ynislas also attract those with an interest in kite-surfing, land-yachting and sail-boarding (UNESCO, 2008).

Marinas and ports have historically been identified as major sources of faecal contamination (Sobsey *et al.*, 2003). This is based on the assumption that some boat owners will, at some time, illegally discharge their head (onboard toilet) into harbour waters. Discharges from moored boats are intermittent in nature, making their impact difficult to quantify (Garreis, 1994).

There are 102 swinging moorings in the Aberdovey Harbour (Aberdyfi Harbour Consultative Committee, 2008). An estimated 80% were occupied at the time of the shoreline survey; it was noted that a very low number of people are likely to stay overnight.

In a Google Earth image, nearly 70 sailing boats can be identified between Aberdify and Trefri. Three sailing clubs operate from Aberdovey Wharf (see Figure VIII.1): Dyfi Yacht Club, which has boat storage facilities and develops a programme of activities for both dinghy and cruiser sailors, Aberdyfi Rowing Club and the Aberdyfi Boat Club, which provide facilities for Jetski and Powerboat enthusiasts. Launching facilities are available.

An assessment of the potential impact of sewage discharges from boats on the microbiological status of mussel beds would require detailed quantitative information on boat movements, occupancy rates and seasonality and accurate knowledge on dilution of contaminants in receiving waters. The information collated during the desk study and shoreline survey suggests that, during most of the time, boats are not significant sources of contamination in the estuary. However, Mussel Beds Nos 1, 2 would be more impacted than Mussel Bed No 3 in case of a pollution incident from boats occurring at Aberdovey.

Figure VIII.1 Moorings and slipways in the Dovey Estuary.

Figure VIII.2 Downstream view of Afon Leri at Ynislas Boatyard.

APPENDIX IX
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION
AGRICULTURE

Livestock production is the dominant agricultural activity in the Dovey Upper and Lower river catchments. A high number of farms exist in the lower catchment (Figure IX.1). The main source of income for most farmers is from beef and sheep; dairy farming is an activity with a low number of farms (Gwynedd Council, 1999).

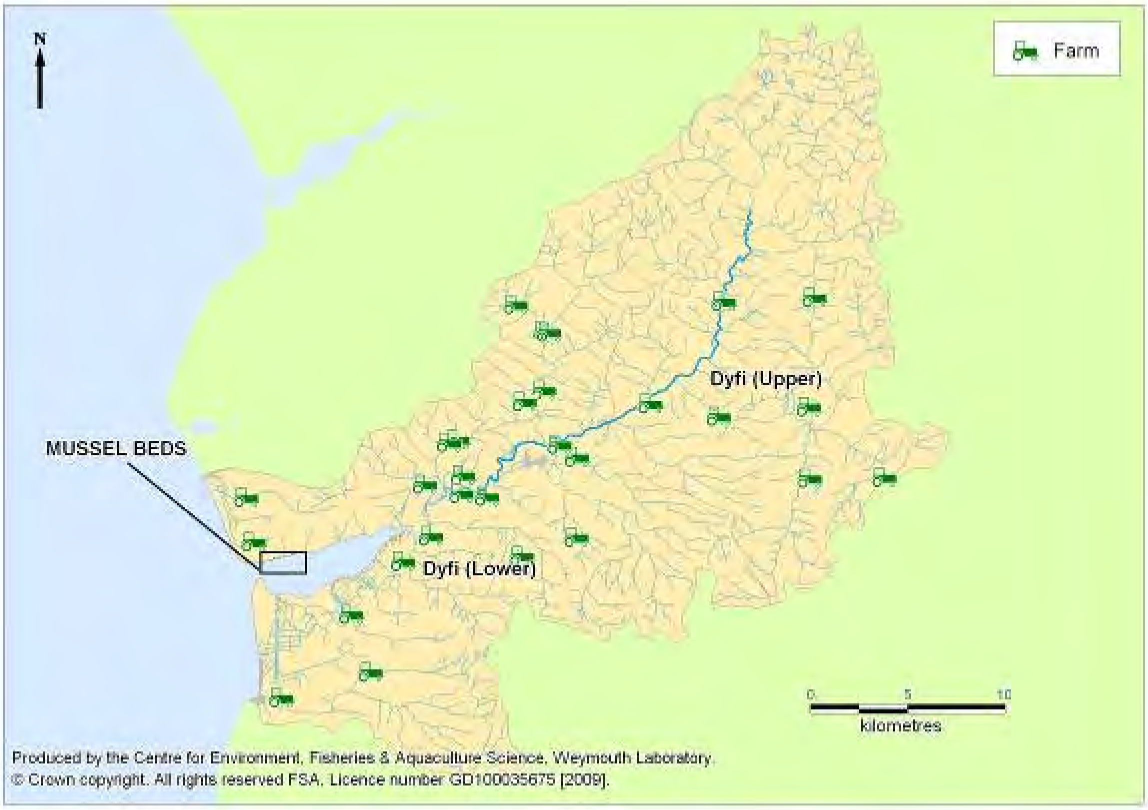

Figure IX.1 Location of farms in the Dyfi catchments.

In rural areas of Western Wales, there are significant issues associated with diffuse pollution from land management practices. Pathogenic microorganisms from pollution sources of animal origin were identified by the Environment Agency as significant pressures on the water quality of Western Wales River Basin District (Environment Agency, 2009).

Farmyards can significantly contribute to loads of faecal indicator microorganisms to watercourses or coastal waters when they have a ready and renewable source of faecal material, a direct hydrological connection with open water channels exists and a sufficient proportion of livestock farms are present in the catchment (Edwards *et al.*, 2008).

There are approximately 895,000[34] farmed animals in these catchments. Numbers of cattle and sheep in the lower catchment exceed 6,000 and 130,000, respectively (Figure IX.2).

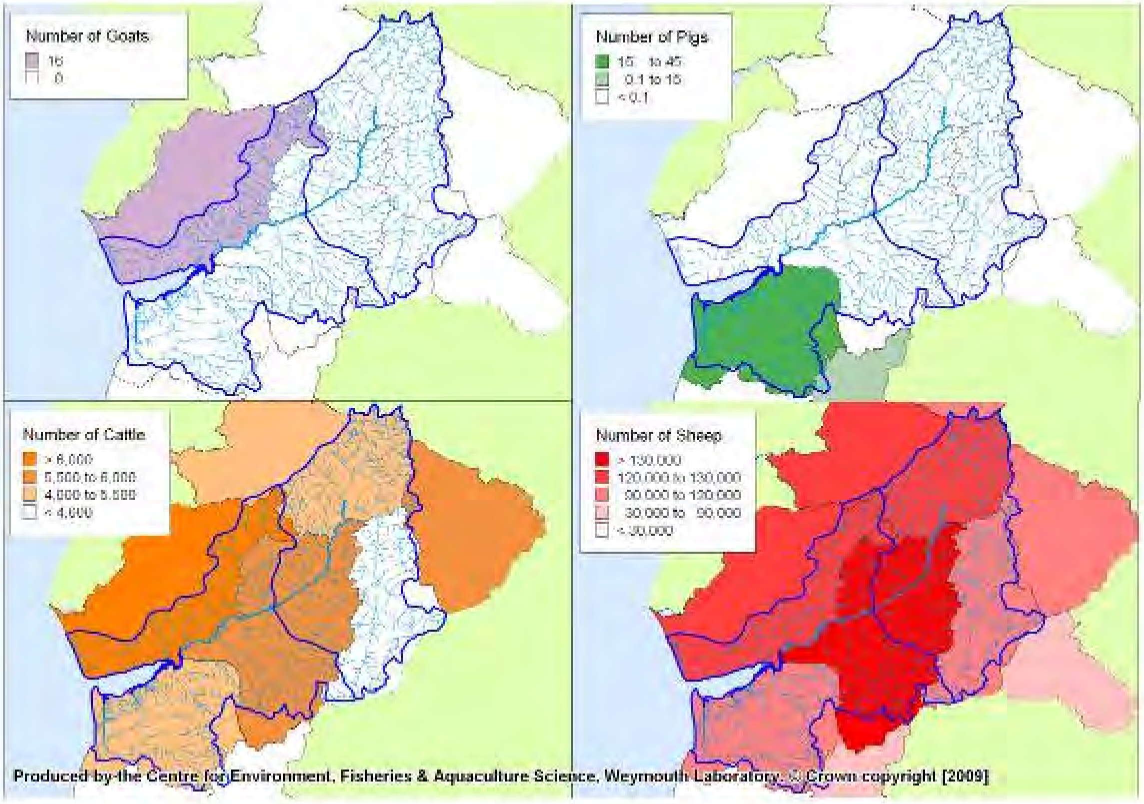

Figure IX.2 Numbers of farmed animals in the Dyfi catchments.

The concentration of faecal coliforms excreted in the faeces of animal and humans and corresponding loads per day are summarised in Table IX.1.

Table IX.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})
Pig	3 300 000	84 000 000	8.9×10^{8}
Human	13 000 000	3 000 000	1.9×10^{9}
Cow	230 000	23 600	5.4×10^{9}
Sheep	16 000 000	38 000 000	1.8×10^{10}

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

A research project was initiated in 2006 to apply the faecal indicator organism-source apportionment model (FIO-SA) to estimate the source apportionment of faecal indicator microorganism (FIO) loads from agricultural and urban sources to a number of bathing and shellfish waters in selected UK catchments (Defra, 2007). Results from this study also highlighted the important potential contribution of beef cattle and sheep to FIO loads and indicated that inputs from all types of livestock farms should be considered when assessing contributions of FIO loads and also that the most important driver is stocking density.

[34] The figure does not include poultry or horses.

The River Dyfi and four other watercourses to the estuary were sampled at the time of the shoreline survey on 24 June 2009. The results indicate that the River Dovey constitutes the main route of faecal contamination to the estuary, although streams in the south shores also contribute significantly to microbial loads. The potential impact of these watercourses should be considered in relation to the siting of RMPs for the microbiological monitoring programme.

In June 2009, there was speculation that livestock grazing on the saltmarsh of the Dovey Estuary could be causing deterioration of the microbiological quality of the water at Aberdyfi beach, when the guideline value failed (Environment Agency, pers. comm.). Direct access of livestock to the estuarine water was observed at the time of the shoreline survey (see Appendix XIII).

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION
WILDLIFE

The Dovey Estuary provides habitat for a variety of wintering wild fowl and waders. In spring, breeding waders such as Teal (*Anas crecca*) are attracted to the shores of the estuary. Intertidal mudflats are also important feeding areas for passage waders during summer. Through the autumn and winter, wintering wildfowl such as the Canada goose (*Branta canadensis*) and White-fronded goose (*Anser albifrons*) arrive in large numbers, tending to occupy the sandflats of the inner estuary. Figure X.1 shows the distribution of some of the most common bird species in the estuary.

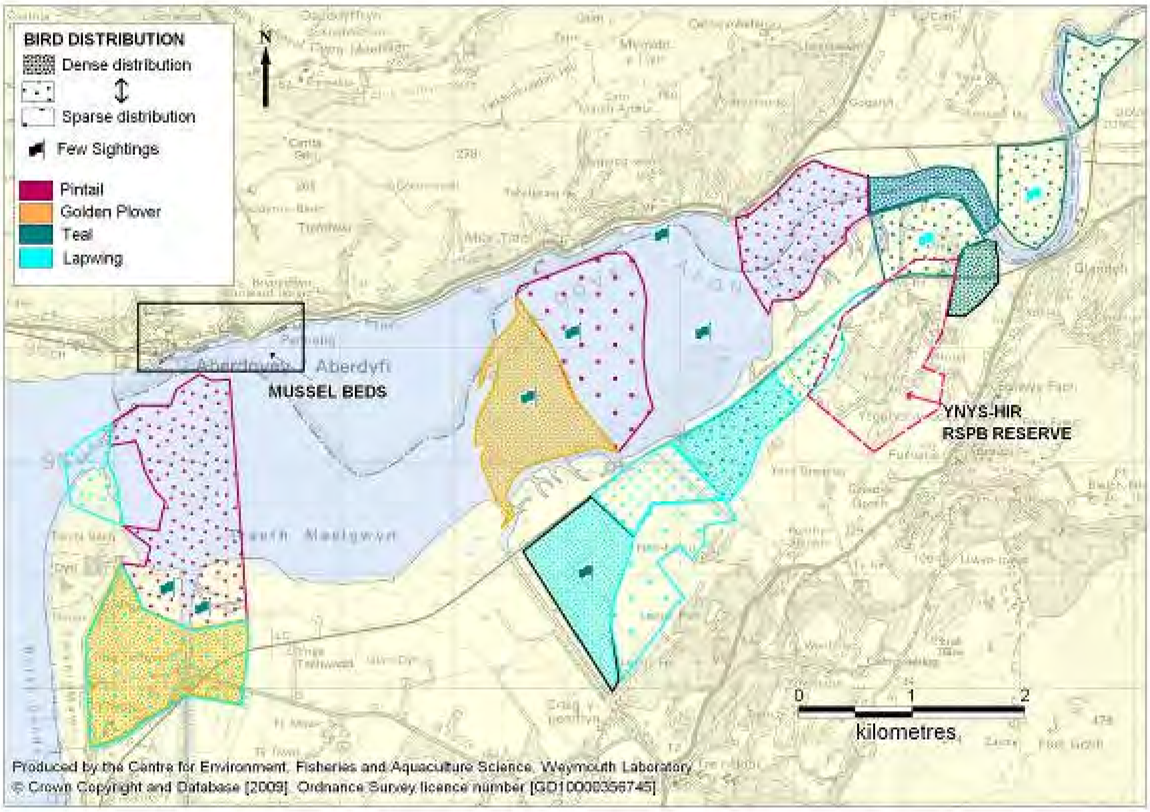

Figure X.1 Distribution of birds in the Dovey estuary.
Data from Wetland Bird Survey 2001–2003.

The Pintail can be found in the inner estuary, while waders such as the Lapwing favour saltmarshes and wet farmland. Teal prefer the freshwater flows of the River Dovey and are frequently found by the inner estuary. Table X.1 shows peak bird counts for some of the most significant species in the Dovey over the period 2000–2003.

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

Table X.1 Peak bird counts for species commonly found in the Dovey Estuary.

Common name	Species name	2001–2002	2002–2003
Canada Goose	*Branta canadensis*	2,100	1,900
Feral Barnacle Goose	*Branta leucopsis*	158	90
Greenland White-fronded Goose	*Anser albifrons*	168	212
Wigeon	*Anas penelope*	1,900	*
Pintail	*Anas acuta*	300	196
Golden Plover	*Pluvialis apricaria*	800	1,250
Lapwing	*Vanellus vanellus*	1,106	*
Grey Plover	*Pluvialis squatorola*	26	*
Bar-tailed Godwit	*Limosa lapponica*	20	*
Curlew	*Numenius arquata*	615	825
Redshank	*Tringa totanus*	142	52
Black-headed Gull	*Lorus ridibundus*	6	*
Greylag Goose	*Anser anser*	17	*
Dark-Bellied Brent Goose	*Branta bernicla*	1	*

Data from Wetland Bird Survey.

Birds will contribute to the background levels of contamination in the estuary. Autumn-winter would be the period of higher impact from this source. The most vulnerable areas are the sandflats in the mid and lower estuary, in close proximity to mussel beds at Aberdoveyi as these are feeding areas for wildfowl during the low water period.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

There are two bathing waters (BWs) in the Dovey lower catchment designated under Directive 76/160/EEC (European Communities, 2006)[35]: Borth and Aberdyfi. Borth is outside the estuary, 6km from the mussel bed at Aberdovey; the eastern part of Aberdyfi is in close proximity to that mussel bed (approximately 50m) (Figure XI.1).

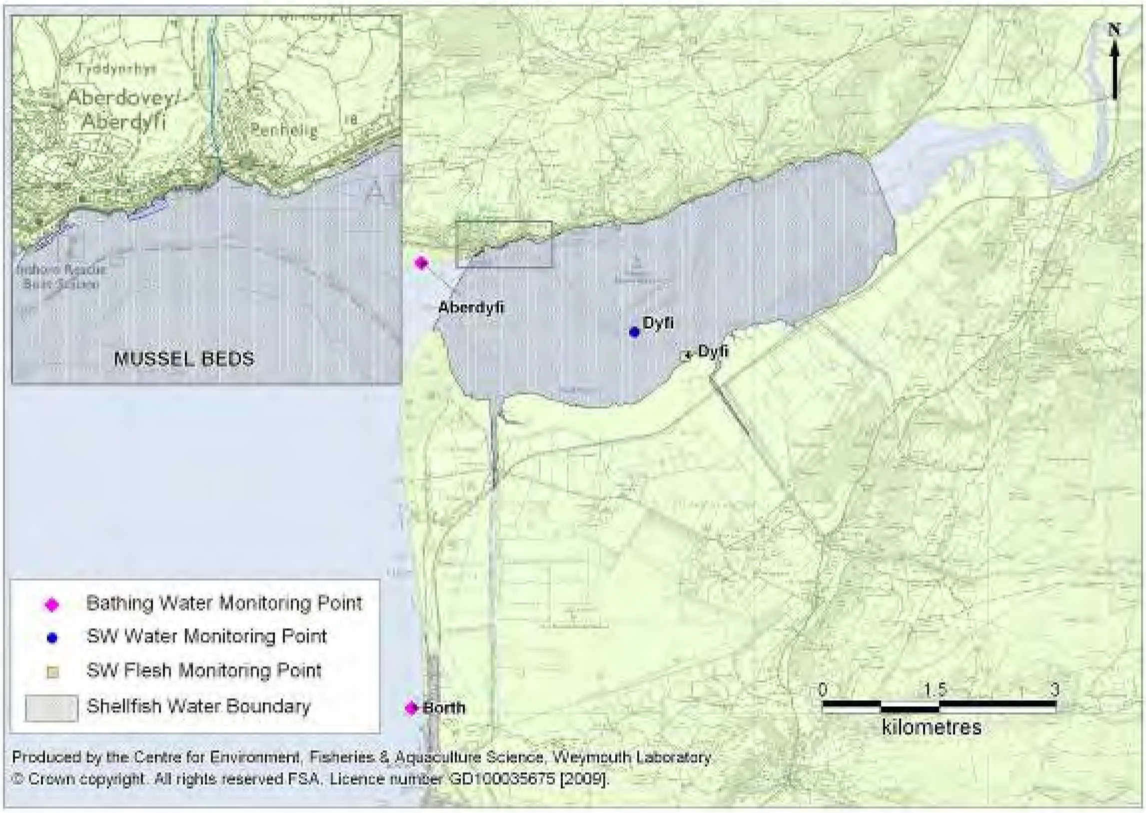

Figure XI.1 Location of bathing waters, designated shellfish water and associated monitoring points in the Dovey Estuary.

The overall quality of these (BWs) for the period 2000–2008 is summarised in Table XI.1. In Aberdyfi, the quality of the bathing water has varied between "excellent" and "poor" since 2005.

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

Table XI.1 Quality of designated Bathing Waters in the vicinity of the Dovey Estuary for the period 2000–2008.

	Bathing Water	
Year	Aberdyfi	Borth
2000	Good	Good
2001	Good	Excellent
2002	Good	Good
2003	Good	Excellent
2004	Good	Excellent
2005	Excellent	Excellent
2006	Excellent	Excellent
2007	Poor	Excellent
2008	Good	Excellent

Information from Environment Agency (2009).

The bathing water monitoring results are summarised in box-and-whisker plots (Figure XI.2)[36].

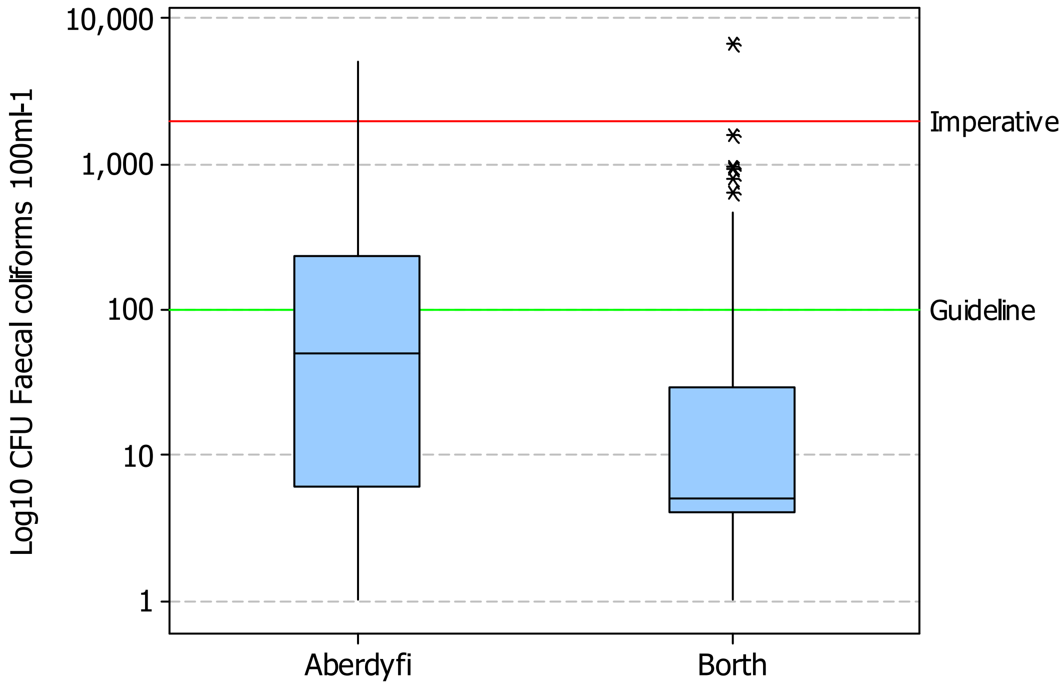

Figure XI.2 Box-and-whisker plots of levels of faecal coliforms in designated bathing waters in the vicinity of the Dovey Estuary for the period 2000–2008.

Table XI.2 summarises the annual range, geometric mean and median of levels of faecal coliforms in water at these bathing waters. Maximum concentrations of faecal coliforms above the "Imperative" value at Aberdyfi indicate periodic deterioration of the microbiological water quality at the mouth of the estuary. Median values suggest two periods of deterioration during the period: 2002–2004 and 2005–2007.

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

The low geometric means of faecal coliforms at Borth reflect better water quality along the open coast outside the estuary.

Table XI.2 Summary statistics of levels of faecal coliforms in two designated Bathing Waters in the vicinity of the Dovey Estuary for the period 2000–2008.

	Bathing Water					
	Aberdyfi			Borth		
	CFU Faecal coliforms 100ml^{-1}					
Year	Min.–Max.	Geometric mean	Median	Min.–Max.	Geometric mean	Median
2000	18–2,600	210	310	5–973	39	41
2001	5–1,820	107	132	5–6,800	23	8
2002	5–580	42	46	5–440	18	12
2003	2–5,120	49	40	4–280	11	6
2004	<2–1,440	54	88	<2–936	10	6
2005	<2–3,962	16	11	<2–800	6	7
2006	<2–792	20	19	<2–96	4	4
2007	<2–3,808	51	68	<2–1,600	4	1
2008	<2–1,010	25	37	<2–308	7	4
2000–2008	<2–5,120	46	56	<2–6,800	10	5

N.B. Number of samples per year=20.
Data from Environment Agency (2009).

The mid and low estuarine areas from Pant Eidal-Ynis Edwin have been designated under Directive 2006/113/EC as Dyfi Shellfish Water (European Communities 2006) since 1999 (Figure XI.1).

Figure XI.3 shows the relationship between salinity and levels of faecal coliforms in water sampled during the period January 2000–February 2009. Samples taken under conditions of lower salinity (<1.0ppt) corresponded to higher concentrations of the indicator indicating the impact of microbial contamination from upstream.

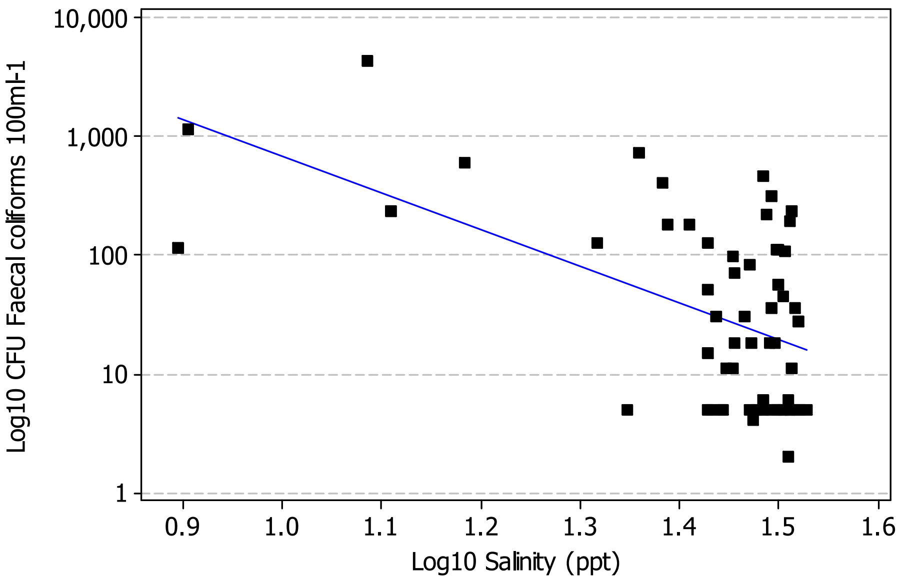

Figure XI.3 Scatterplot for salinity and levels of faecal coliforms in the Shellfish Water of the Dovey Estuary for the period January 2000–February 2009.
Data from the Environment Agency (2009).

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Variation of *Escherichia coli* according to rainfall

Rainfall data from Aberdyfi and Llanymawddwy gauging stations (Figure III.1) were correlated with *E. coli* levels in bivalve molluscs from five non-current representative monitoring points (RMPs) in the Dovey Estuary (Figure 1.5) for the period January 2000–April 2009. Statistically significant positive correlations were obtained between rainfall and the levels of the microbiological indicator in mussels from Picnic Island (north shore, approximately 950m upstream of Mussel Bed No 3 at Aberdovey) in the day of sampling (Table XII.1).

Table XII.1 Spearman's rho coefficients between rainfall recorded at two gauging stations and MPNs of* E. coli *$100g^{-1}$ FIL in bivalves from five monitoring points in the Dovey Estuary for the period January 2000–November 2007.

		MPN *E. coli* $100g^{-1}$ FIL				
Rainfall		Dovey Estuary (B041A) *Mytilus* spp	Dovey Estuary (B041 B) *Cerastoderma edule*	Coed y Gofer (B041D) *Cerastoderma edule*	Aberdyfi Slipway (B041F) *Mytilus* spp	Picnic Island (B041G) *Mytilus* spp
Aberdyfi	Time	(n=16)	(n=19)	(n=11)	(n=11)	(n=52)
Daily	Day of sampling	-0.134	-0.101	0.375	0.088	0.412*
	-1 day	-0.011	0.157	0.207	-0.271	0.092
	-2 days	0.216	0.445	0.298	0.132	0.225
	-3 days	0.271	0.381	0.195	0.310	0.137
	-4 days	0.257	0.164	0.512	0.535	0.192
	-5 days	0.371	0.076	0.495	0.432	0.007
	-6 days	0.150	0.256	-0.027	-0.002	0.037
	-7 days	0.179	0.245	0.361	0.260	0.054
Cumulative	-2 days	-0.089	-0.021	0.223	0.198	0.287*
	-3 days	-0.013	0.116	0.154	0.228	0.291*
	-4 days	0.033	0.258	0.142	0.181	0.314*
	-5 days	0.042	0.225	0.350	0.355	0.304*
	-6 days	0.172	0.240	0.438	0.392	0.288*
	-7 days	0.211	0.280	0.460	0.442	0.318*
Llanymawddwy		(n= 12)	(n=14)	(n=10)	(n=9)	(n=47)
Daily	Day of sampling	0.107	-0.012	0.738*	0.221	0.362*
	-1 day	0.141	0.332	0.300	0.169	0.173
	-2 days	0.481	0.639*	0.664*	0.807*	0.135
	-3 days	0.582	0.715*	0.901*	0.261	0.208
	-4 days	0.579	0.594*	0.833*	0.564	0.315*
	-5 days	0.494	0.247	0.506	0.615	0.091
	-6 days	0.561	0.458	-0.227	0.217	0.123
	-7 days	0.417	0.531	0.234	0.237	-0.016
Cumulative	-2 days	0.200	0.212	0.791*	0.352	0.371*
	-3 days	0.274	0.411	0.824*	0.477	0.341*
	-4 days	0.327	0.542*	0.847*	0.448	0.305*
	-5 days	0.406	0.582*	0.891*	0.546	0.328*
	-6 days	0.460	0.590*	0.883*	0.670	0.312*
	-7 days	0.554	0.669*	0.905*	0.657	0.372*

*n=number of samples. * Statistically significant (p<0.05).*
Less-than and greater than E. coli results were assigned half and double the numerical values, respectively.

Positive association was also found between cumulative levels of rainfall recorded at both gauging stations and levels of *E. coli* in mussels from Picnic Island between the first and seventh days before sampling.

A two dimensional scatterplot showing levels of *E. coli* in mussels from Picnic Island and rainfall on the day of sampling is shown in Figure XII.1. A LOcally WEighted Scatterplot Smoothing (LOWESS) line was superimposed to help identify any trend in the relationship between variables.

The scatterplot appears to show at least two different groups of data points. The spread of *E. coli* levels appears to be less variable when rainfall exceeds 5mm though less number of samples fall into that category.

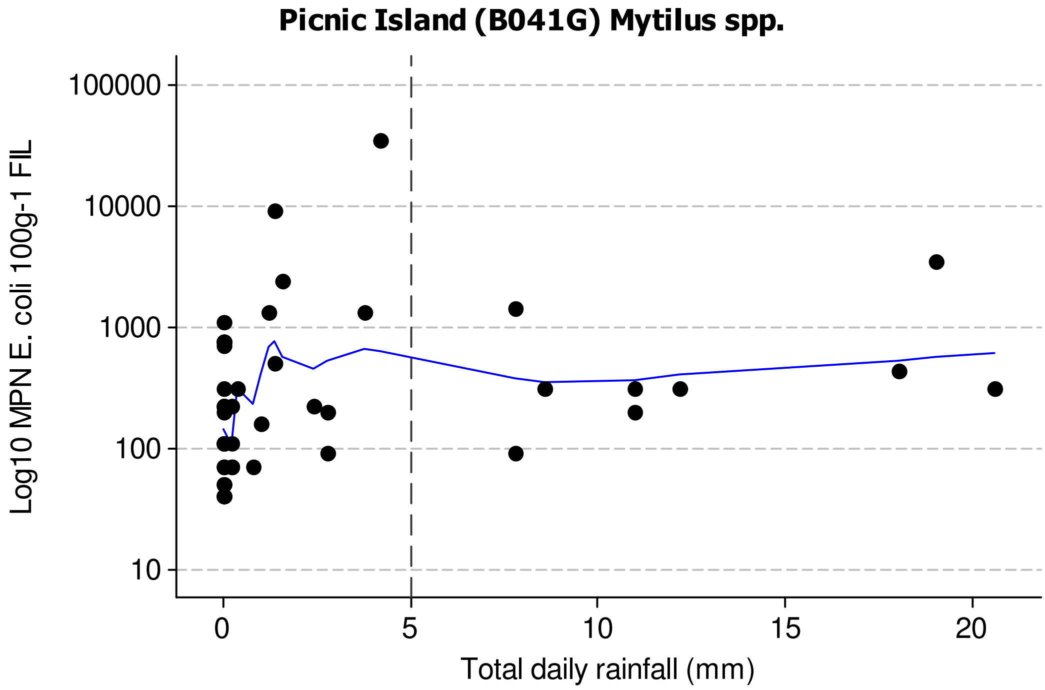

Figure XII.1 Scatterplot of rainfall recorded at Aberdyfi versus levels of* E. coli *at Picnic Island on the day of sampling.

Levels of *E. coli* in cockles were also found to be positively associated with rainfall from Llanymawddwy. However, results were not consistent with those for rainfall representative of the lower catchment, possibly due to the low number of samples considered.

Variation of *Escherichia coli* according to river flows

River flow data for River Cerist at Llawr Cae and River Dyfi at Dyfi Bridge (Figure III.1) were correlated with *E. coli* levels in bivalve molluscs from five non-current RMPs (Figure 1.5) in the Dovey Estuary for the period January 2000–November 2007.

Statistically significant positive correlations were obtained between levels of the microbiological indicator in cockles from Coed Y Gofer (B041D) and daily and cumulative river flows between the second and fourth day before sampling.

Statistically significant positive correlations were also obtained between levels of *E. coli* in mussels from Picnic Island and daily river flow on the day of sampling/cumulative river flow on the fourth day before sampling.

Table A7.2. Spearman's rho coefficients between river flows recorded at two gauging stations and MPNs of* E. coli *100g^{-1} FIL in bivalves from five monitoring points in the Dovey Estuary for the period January 2000–April 2009.

		MPN *E. coli* 100g^{-1} FIL				
River Flow		Dovey Estuary (B041A) *Mytilus* spp	Dovey Estuary (B041 B) *Cerastoderma edule*	Coed y Gofer (B041D) *Cerastoderma edule*	Aberdyfi Slipway (B041F) *Mytilus* spp	Picnic Island (B041G) *Mytilus* spp
Dyfi Bridge	Time	(n=16)	(n=19)	(n=11)	(n=11)	(n=52)
Daily	Day of sampling	0.148	0.336	0.821*	0.311	0.235
	-1 day	0.236	0.460*	0.788*	0.276	0.167
	-2 days	0.209	0.444	0.807*	0.315	0.176
	-3 days	0.306	0.393	0.776*	0.326	0.159
	-4 days	0.357	0.252	0.691*	0.358	0.135
	-5 days	0.363	0.388	0.275	0.083	-0.007
	-6 days	0.312	0.363	0.271	-0.216	-0.031
	-7 days	0.248	0.286	0.423	-0.239	0.025
Cumulative	-2 days	0.204	0.411	0.815*	0.280	0.210
	-3 days	0.202	0.421	0.821*	0.325	0.203
	-4 days	0.232	0.437	0.825*	0.337	0.209
	-5 days	0.254	0.419	0.808*	0.367	0.196
	-6 days	0.253	0.424	0.782*	0.371	0.166
	-7 days	0.283	0.449	0.725*	0.354	0.138
Llaw Cae		(n= 16)	(n=19)	(n=11)	(n=11)	(n=52)
Daily	Day of sampling	0.144	0.328	0.881*	0.352	0.308*
	-1 day	0.211	0.440	0.842*	0.305	0.214
	-2 days	0.210	0.465*	0.864*	0.351	0.196
	-3 days	0.292	0.453	0.824*	0.271	0.224
	-4 days	0.384	0.270	0.732*	0.289	0.124
	-5 days	0.347	0.337	0.295	-0.045	0.025
	-6 days	0.282	0.322	0.278	-0.236	-0.006
	-7 days	0.319	0.323	0.403	-0.385	0.020
Cumulative	-2 days	0.179	0.396	0.861*	0.346	0.270
	-3 days	0.182	0.411	0.880*	0.377	0.269
	-4 days	0.203	0.432	0.888*	0.342	0.274*
	-5 days	0.241	0.438	0.861*	0.368	0.245
	-6 days	0.259	0.436	0.832*	0.371	0.210
	-7 days	0.279	0.440	0.794*	0.324	0.180

*n=number of samples. * Statistically significant ($p<0.05$).*
Less-than and greater than E. coli results were assigned half and double the numerical values, respectively.

A scatterplot with LOWESS line showing levels of *E. coli* in mussels from Picnic Island and river flow at Llaw Cae on the day of sampling shows a consistent increase in *E. coli* levels when river flows are below 1m s^{-1} (Figure XII.2).

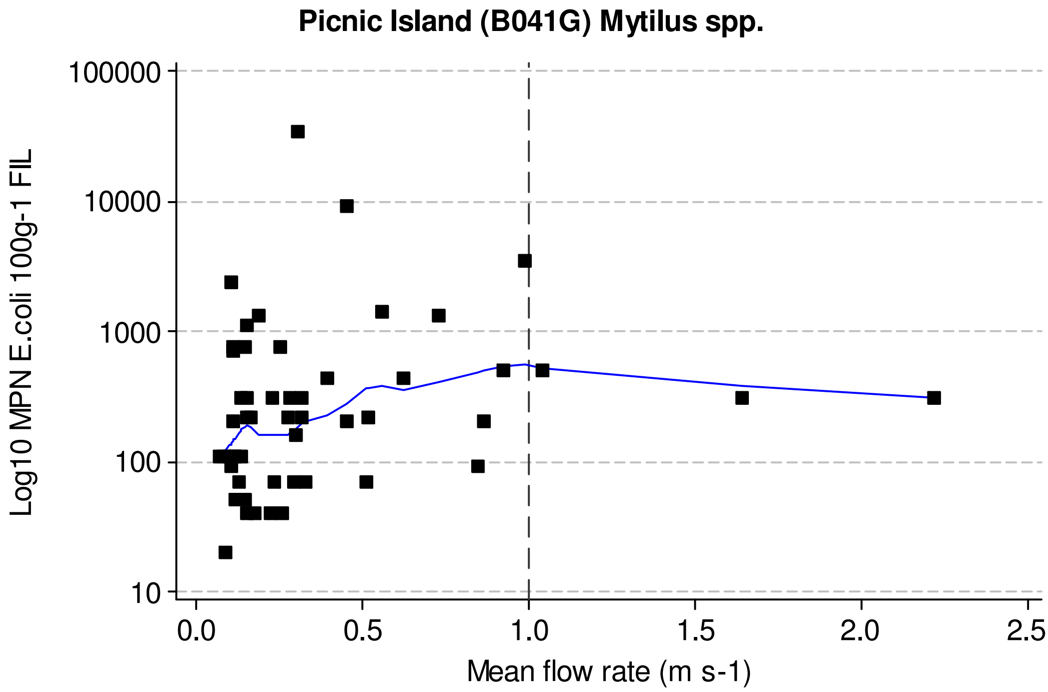

Figure XII.2 Scatterplot of river flow recorded at Law Cae versus levels of* E. coli *at Picnic Island on the day of sampling.

Seasonal variation of *Escherichia coli*

The effect of season on the levels of microbiological contamination in bivalve molluscs could be due to biological activity of these animals, variation in microbiological loading due to factors such as tourism or seasonality in rainfall patterns (Younger *et al.*, 2003).

Historical levels (January 1992–November 2007) of *E. coli* in mussels from three non-current beds (Aberdyfi Slipway, Picnic Island, Dovey Estuary) was used to investigate the existence of seasonal variation of levels of *E. coli* in bivalves from the Dovey Estuary. This period was selected to ensure that sufficient number of results (>50) from each bed was used for the analysis. The initial study consisted of the analysis of seasonal variation of *E. coli* levels. For this purpose, data was amalgamated by season, considering spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). One-way analysis of variance (ANOVA) was used to test differences between months and between seasons followed by a Tukey HSD test using the 95% confidence level. This parametric test was used because levels of *E. coli* in mussels from all beds were found to follow a lognormal distribution (Anderson-Darling; $p>0.05$). Analysis of monthly geometric means of *E. coli* and monthly number of *E. coli* results >4,600 MPN $100g^{-1}$ FIL was also undertaken to identify the months in which elevated concentrations of the microbiological indicator have occurred in mussels.

Figure XII.3 shows box-and-whisker plots of seasonal variation of *E. coli* levels in mussels. ANOVA revealed statistically significant ($F_{(3,130)}=5.51$; $p<0.005$ for

Aberdyfi Slipway; $F_{(3,155)}=13.51$; $p=0.000$ for Dovey Estuary; $F_{(3,119)}=5.48$; $p<0.005$ for Picnic Island) differences between the levels of the microbiological indicator during summer and those levels during the winter.

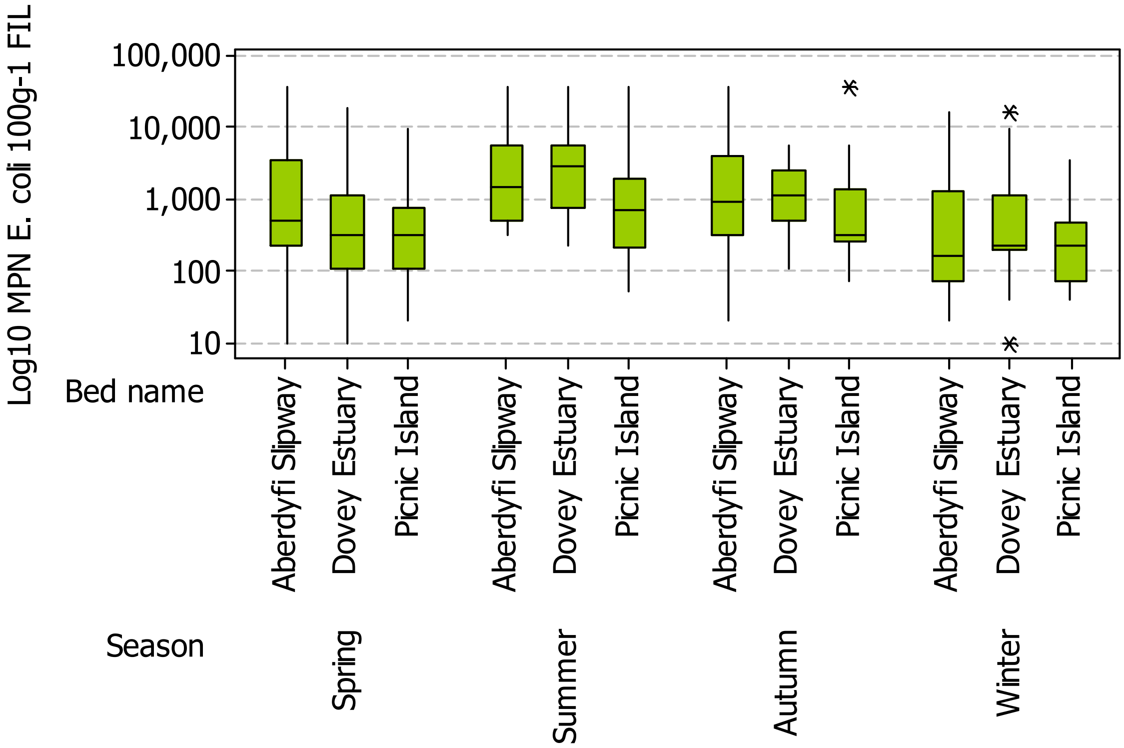

Figure XII.3 Box-and-whisker plots of seasonal variation of E. coli levels in mussels from three RMPs in the Dovey Estuary for the period January 1992–November 2007.

Figure XII.4 shows that June and August are the months when higher geometric means of *E. coli* were detected in mussels; this is also true for the first month of autumn. The highest numbers of *E. coli* results >4,600 MPN $100g^{-1}$ FIL were also detected in these months (not shown). The geometric means of *E. coli* shown in Figure XII.4 indicate the following tendency: Aberdyfi Slipway>Dovey Estuary>Picnic Island. This suggests that the new Mussel Bed No 3 is potentially less impacted by contaminating sources than Mussel Bed No 1. A bacteriological survey was recommended following the desk study in order to confirm this hypothesis and the results of this survey are summarised in the Appendix XIV.

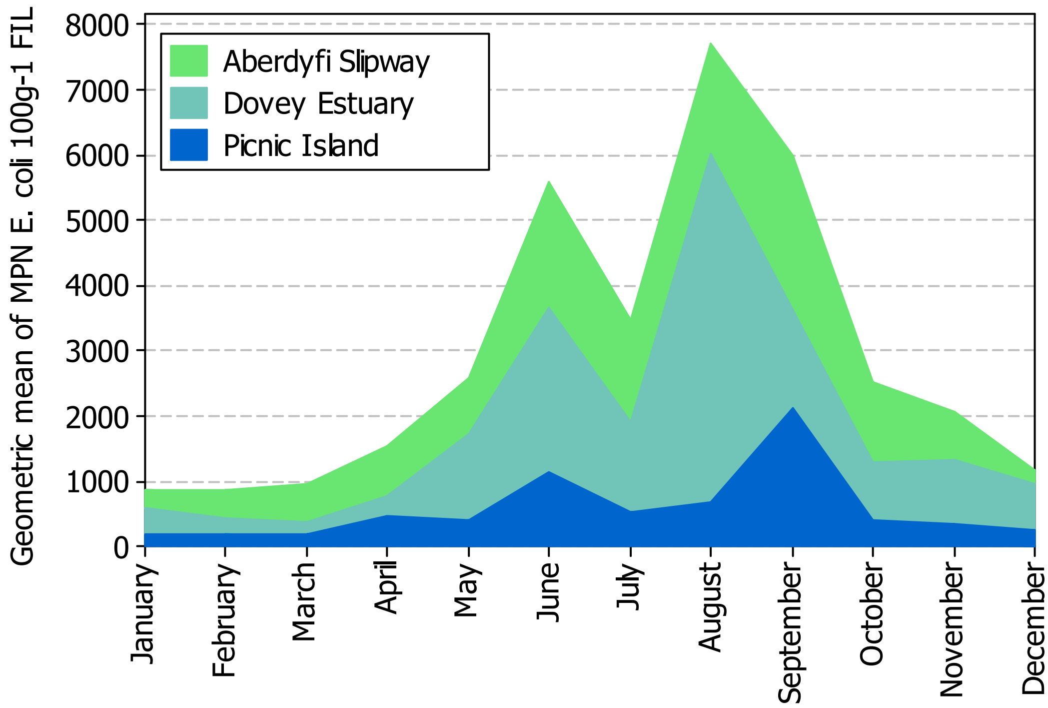

Figure XII.4 Area graph for monthly geometric means of E. coli in mussels from three RMPs in the Dovey Estuary for the period January 1992–November 2007.

It is considered that a routine monthly regime would adequately reflect the levels of contamination detected between October and March. However, the applicant proposes to harvest mussels at Aberdyfi from September to March. Cefas may request an increased monitoring frequency (e.g. fortnightly) for mussels at Aberdovey in September since historical data has shown that mussels tend to accumulate high levels of E. coli during the period May–September. This will assist whether the underlying level of contamination changes during the first months of the harvesting season.

If mussel beds at Aberdovey will become commercially inactive between April and August, Cefas protocol determines that it may be possible to agree a reduced frequency of monitoring. The LEA should discuss these details with Cefas. Full monthly monitoring must be resumed prior to any recommencement of commercial activity (see Cefas, 2009).

APPENDIX XIII
SHORELINE SURVEY

Date (time): 24 July 2009 (09:24–17:00 BST)
Applicant: David Hughes (Dyfi Seafoods)
Cefas Officer: Carlos Campos
Local Enforcement Authority Officer: Michael Thomas (Gwynedd Council).

Area surveyed: shoreline walks over the tidal cycle were conducted in the north and south shores of the Dovey Estuary, between Borth and Aberdyfi, including the area requiring classification for mussels at Aberdyfi (Figure XIII.2–3).

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

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

Table XIII.1 Predicted high and low water times and heights for Aberdydi (52°32'N, 4°03'W) on 24 July 2009.

	Time (height)
Low Water	04:48 (0.4m)
High Water	10:01 (4.9m)
Low Water	17:05 (0.7m)
High Water	22:19 (5.2m)

Predicted heights are in metres above Chart Datum. Republished with permission from Admiralty Total Tide (UK Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office. © Crown copyright.

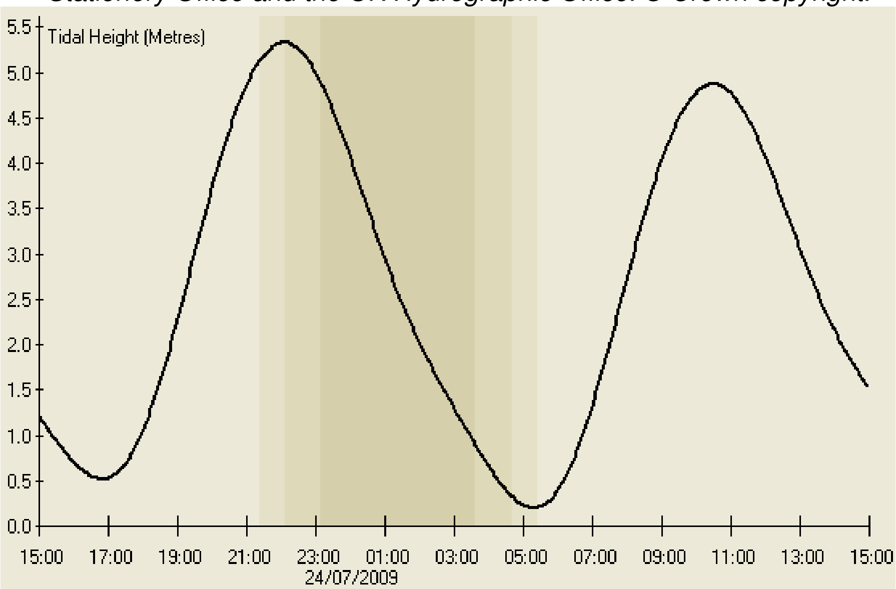

Figure XIII.1 Tidal curve at Aberdyfi on 24 July 2009.
Wadebridge is a Secondary Harmonic port.
Predicted heights are in metres above Chart Datum Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office.
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Figure XIII.2 Locations of sites sampled in the Dovey Estuary on 24 July 2009.
Red lines indicate areas where shoreline walks were carried out.

Figure XIII.3 Locations of sites sampled in Aberdyfi on 24 July 2009.
Red lines indicate areas where shoreline walks were carried out.

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

Table XIII.2 Observations and results made during the shoreline survey.

Classification zone and ID/species	Classification zones: Aberdovey – West and Aberdovey - East Bed name: Mussel beds Nos 1, 2, 3 Species: Mussels (*Mytilus* spp.)	
Location of beds /Coordinates OSGB36 (Easting, Northing)	Mussel Bed No. 1: Aberdovey Pier (western edge), 261529/295955 Mussel Bed No. 3: 262437/296146-262518/296187	Mussel Bed No. 2: 261707/295976-261833/296021
Production area	Dovey Estuary	
Area of beds	Mussel bed N1 = 0.001792km^2 (Figure XIII.10H) Mussel bed N2 = 0.002892km^2 (Figure XIII.10I) Mussel bed N3 = 0.001299km^2 (Figure XIII.10J)	
SWD Flesh Point	264100/294600 (Dyfi)	
SWD Water Point	263450/294900 (Dyfi)	
BWD Sampling point(s)	Aberdyfi (260700/295800) Borth (260600/290100)	
Applicant's details	David Hughes Dyfi Seafoods 6 Evans Terrace, Aberdyfi LL35 0HB ☎ 01654 707678	
Cefas officer	Carlos Campos	
Local Enforcement Authority Officer	Michael Thomas Gwynedd Council, Resources Directorate Cae Penarlag, Dolgellau, Gwynedd LL40 2YB ☎ 0134 1424372	
Date/time of survey	24 June 2009 (09:24–17:00)	
Extent of survey area	Borth–Aberdyfi (Figures XIII.2–3)	
Map/Chart references	UKHO Admiralty Chart 1484: Aberdovey OS Explorer OL23: Cadair Idris & Llyn Tegid	

Weather forecast	Met Office (24 July 2009): Wind Variable 3 or less becoming mainly east 3 or 4. Sea state Smooth or slight Weather Fog patches at first Visibility Moderate or good, occasionally very poor at first
Air temperature	72.5°F at 09:30
Wind	15.6km h^{-1} (maximum recorded)
Precipitation	None during the survey
Streams/springs	Afon Leri (261650/293146) sampled (Figure XIII.10A) Stream at Pen-Y-Graig (265643/292592) sampled (Figure XIII.10C) Afon Ddu (265530/294950) not sampled Springs at Furnace (268495/295201) sampled (Figure XIII.10D) Springs at Caerhedyn (270840/297580) not sampled Stream at Pennal (269905/200399) sampled (Figure XIII.10F) Springs at Pont Pant-Eidal (266065/97228) (Figure XIII.10G) Springs at Aber-Tafol (264800/296870) not sampled Springs at Coed Y Gofer (264060/296540) not sampled Springs at Trefri (263180/296310) not sampled Springs at Penhelig (262020/296120) not sampled
River flows (gauged)	River Dovey/Afon Dyfi (274355/201907) sampled at Dyfi Bridge (Figure XIII.10E)
Significant sewage discharges (Cefas database)	Borth STW storm overflow (261640/289750) (Figure XIII.10B) Swansea Dry Docks Ltd (266000/294000) Aberdyfi Wharf PS EO (261530/295950) Aberdyfi sea outfall (261300/295780) Pennal Plas Pant Eidal (265420/297040) Pennal STW (270220/299650) Borth Ynyslas Beach (261630/293520) Machynlleth STW (300920/274230) Talybont STW (289060/265770) Derwenlas STW (299261/272110) Esgairgeirigog STW (306300/275950) Aber Llefni STW (309480/277000) Aberhosan STW (279380/280960) Lower Corris (307410/275560) Garneddwen STW (308740/276450) Pont Ar Doyfi (301940/274350) Pant Perthog STW (304270/274880) Corris Uchaf STW (308564/274896)
Discharges (observed)	Borth STW (Figure XIII.4) Aberdyfi Wharf (Figure XIII.5) Pennal STW (Figure XIII.6) Borth Ynyslas Beach? (Figure XIII.7)
Boats/port	Approximately 80 moorings at Aberdyfi Harbour (Figure XIII.8) Approximately 50 moored boats (sailing and fishing) at Aberdyfi Two slipways at Aberdyfi
Dogs	(dog faeces) 261579/293538, 261567/293575, 261556/293578

Other animals	Rabit? faeces: 261581/293537 Horse faeces (261585/293536, 260800/291670) Birds: 261507/293654 Sheep: undetermined numbers at Ty Mawr, Llancynfelyn and Plas Talgarth Cattle: Dovey valley. High numbers in saltmarsh areas in the upper reaches of the estuary, direct access to River Dovey (Figure XIII.9) Bird flocks in fields at Ynys Tachwedd Manure storage site near Plas Talgarth (no watercourse identified in the vicinity) (Figure XIII.10)
Strand line SRD	Plastics, cans at Borth Ynyslas Beach
Samples taken	See Table XIII.2
Bivalve harvesting activity	Hand-picked mussels
Sewage related debris	None
Water appearance	Seawater: clear in mussel beds See table below for freshwaters
Human population	Significant proportion of tourists in Aberdyfi Recreational activities observed: sailing at Aberdyfi; walking at Pont ar Ddyfi
Topography	Steep-sided valleys in north catchment Flat land in south catchment
Land Use	Urban and suburban at Aberdovey; grassland (improved and natural) and forests across the Dovey Valley; grassland and arable land bordering the south shores of the estuary at Borth

Figure XIII.4 Borth sewage treatment works.

Figure XIII.5 Aberdify Wharf emergency overflow.

Figure XIII.6 Pennal sewage treatment works.

Figure XIII.7 Borth Ynyslas Beach.

Figure XIII.8 Sailing boats moored at Aberdovey.

Figure XIII.9 Cattle in saltmarsh North of Glandyfi.

Figure XIII.9 Manure storage site at Plas Talgarth.

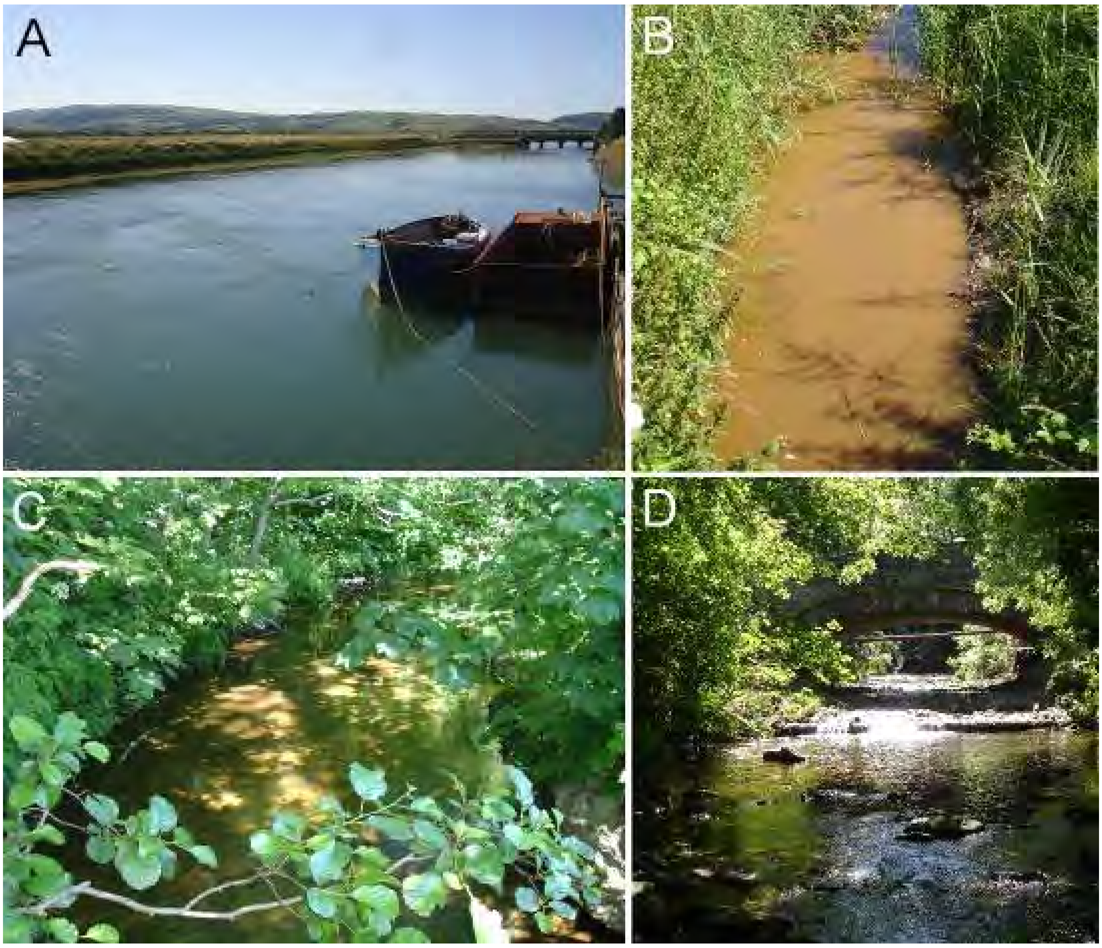

Figure XIII.10 Sites sampled during the shoreline survey.

Figure XIII.10 Sites sampled during the shoreline survey (cont.).

Figure XIII.10 Sites sampled during the shoreline survey (cont.).

Table XIII.2 Results of samples collected during the shoreline survey on 24 July 2009.

Sample ID	Matrix	Collection time	Easting	Northing	E. coli		Salinity (ppt)	Temperature (°C)	Water appearance	Loading (*E. coli* day^{-1})
A	Freshwater	10:10	61650	93146	200	CFU $100ml^{-1}$	33.1	16.8	Clear	(a)
B	Freshwater	10:57	60881	89186	3,700	CFU $100ml^{-1}$	0	19	Turbid (brown)	(b)
C	Freshwater	11:29	65643	92592	610	CFU $100ml^{-1}$	0	15.6	Clear	1.9×10^7
D	Freshwater	12:10	68495	95201	260	CFU $100ml^{-1}$	0	14.4	Clear	3.1×10^7
E	Freshwater	12:57	74355	01907	140	CFU $100ml^{-1}$	0	20.6	Clear	5.0×10^8
F	Freshwater	13:34	69905	00399	200	CFU $100ml^{-1}$	0	17.6	Clear	8.5×10^6
G	Freshwater	14:06	66065	97228	100	CFU $100ml^{-1}$	0.6	20.8	Turbid (yellow/brown)	(b)[1]
H	Seawater	15:21	61421	95918	70	CFU $100ml^{-1}$	31.6	20.2	Clear	n/a
H	Mussels	15:21	61421	95918	1,300	CFU $100g^{-1}$	-	-	-	n/a
I	Seawater	15:40	61718	95975	140	CFU $100ml^{-1}$	30.1	19.8	Clear	n/a
I	Mussels	15:40	61718	95975	220	CFU $100g^{-1}$	-	-	-	n/a
J	Seawater	16:02	62444	96144	20	CFU $100ml^{-1}$	32.1	19.1	Clear	n/a
J	Mussels	16:02	62444	96144	490	CFU $100g^{-1}$	-	-	-	n/a

Please refer to Tables XIII.1–2 for locations where these samples where collected.
(a) Not gauged due to access restrictions.
(b) Stagnant water.
(c) n/a - not applicable.
1 - sampled from intertidal pool, possibly with mixed seawater.

CONCLUSIONS

The following conclusions can be drawn from the shoreline survey:

1. The three mussel beds requiring classification at Aberdovey had appreciable densities of adult stock. All mussel beds can be easily accessed from the public footpath.

2. Water in the main river channel at Aberdovey appeared to be clear and no sewage related debris was observed along the stretch of shoreline between mussel beds.

3. The locations of three significant sewage discharges to mussel beds at Aberdovey (Pennal STW, Borth STW and Aberdyfi Wharf PS) were verified. The close proximity of Aberdyfi Wharf to mussel beds Nos. 1, 2 cause concern from the hygiene point of view.

4. It was noted that visitors/tourists constituted a significant proportion of human population at Borth and Aberdovey. The recreational use of the estuary at Twyni Bach and Aberdovey beach were particularly evident.

5. Despite the high number of moored boats in Aberdovey Harbour, it was noted that very few people were likely to stay onboard overnight since many of those are drying moorings and many boats had no berths.

6. The results from water samples collected and flow measurements made during the survey allowed confirming that the River Dovey constitutes the most important route of faecal contamination from the wider catchment to the estuary. However, *E. coli* loadings from two streams (Stream at Pen-Y-Graig, Afon Einion) discharging to the south shores of the estuary are significant to the overall microbial loading to the estuary. Although it was not possible to take flow measurements in Afon Leri due to access restrictions, literature suggests that this stream is potentially one of the most significant sources of contamination to the estuary.

7. Turbulence caused by wave action decreases upstream of Aberdovey. This suggests that tidal currents will govern the transport of contamination across mussel beds.

8. It was observed that high numbers of cattle graze on the saltmarsh and have direct access to the River Dovey. Grazing animals defecating directly in the water will give rise to very high quantities of microbial pollution in the estuary.

APPENDIX XIV
BACTERIOLOGICAL SURVEY

OBJECTIVES ANS SAMPLING SITES

Cefas initiated a sanitary survey following applications for microbiological monitoring and classification of three mussel beds at Aberdovey (Dovey Estuary) in February 2009.

In July 2009, following a desk-based study of the potential sources of faecal contamination in the catchment and a shoreline survey along the north and south shores of the estuary a bacteriological survey was recommended. This was felt necessary to ensure appropriate position(s) for representative monitoring points (RMPs) for monitoring and classification purposes.

Ten samples of mussels were collected from each of the three mussel beds at intervals not closer than fortnightly and quantified for *Escherichia coli*. All samples were hand picked during the low water periods. These samples were processed by the National Public Health Service for Wales (Bangor). The bacteriological survey period covered part of the bathing season[37] and some wet weather events (see Appendix II).

SAMPLING SITES

Figure XIV.1 shows the location of mussel beds and sampling points used for the purposes of the bacteriological survey.

The location of the sampling point for Mussel Bed No 1 was selected on the basis of presence of adult stock, proximity of a designated bathing water and existence of impervious areas (dock and pier). The location of sampling points for mussel beds Nos 2, 3 were selected on the basis of presence of adult stock and the restricted area of those beds.

The eastern part of Mussel Bed No 1 is muddy. The substrate at mussel beds Nos 2, 3 and western part of mussel bed No. 1 is predominantly sandy.

The bacteriological survey was undertaken during the period July–October 2009. Results for these samples are summarised in Table I.1. Side-by-side box-and-whisker plots summarise the distribution of these datasets (Figure XIV.2). Time series plots of individual *E. coli* results are shown in Figure XIV.3.

[37] The bathing season runs from 15 May to 30 September.

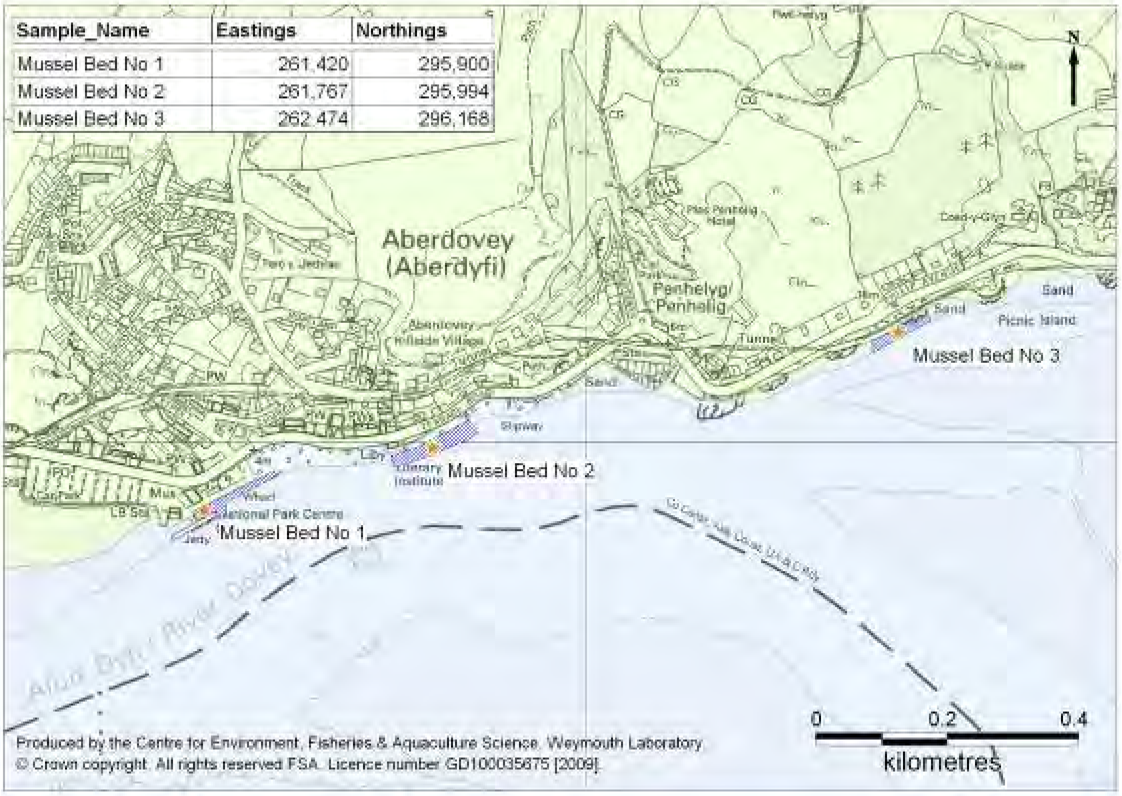

Figure XIV.1 Location of mussel beds at Aberdovey.
The locations of sampling points used for the bacteriological surve are marked by stars.

Three samples from Bed No 3 returned *E. coli* levels below class A threshold (MPN=230 *E. coli* 100g^{-1} FIL). Mussel samples from beds Nos 1 and 2 returned 4 results above the class B threshold (MPN=4,600 *E. coli* 100g^{-1} FIL), whereas mussels from Bed No 3 only returned 2 results above this threshold.

Table I.1 suggests the following gradient of contamination: Mussel Bed No 1>Mussel Bed No 2> Mussel Bed No 3.

Table XIV.1 Summary statistics of levels of* E. coli *in mussels from three beds at Aberdyfi.

	MPN *E. coli* 100g^{-1} FIL			
Bed name	Minimum	Maximum	Geometric mean	No. samples >4,600
Mussel Bed No 1	490	>18,000	2,996	4
Mussel Bed No 2	330	16,000	1,787	4
Mussel Bed No 3	70	9,200	978	3

Date of first sample: 13 July 2009.
Date of last sample: 19 October 2009.
Number of samples per bed=10.

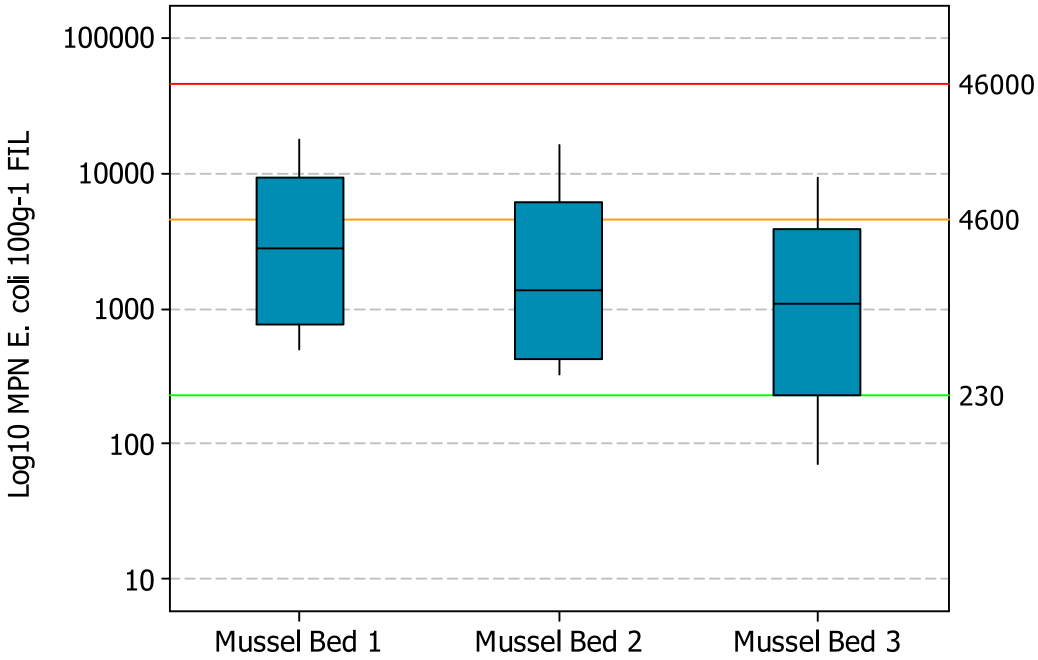

Figure XIV.2 Box-and-whisker plots of levels of* E. coli *in mussels from three beds in Aberdovey with reference lines showing classification thresholds.

The similar sizes of top and bottom box halves and similar lengths of whiskers indicate a symmetric distribution of *E. coli* levels below and above the median value. This and the fact that no outliers (results considerable higher or lower than most of the data) were detected during the sampling period suggest that there is an underlying level of contamination in mussels, particularly at beds Nos. 1, 2.

Levels of *E. coli* in mussels decreased during the monitoring period (Figure I.2). Levels of the indicator of faecal contamination were higher during dry months (July–September) (see Appendix II). This is the most popular period for water-based recreational activities in the lower Dovey Estuary (see Appendix I).

The last sample was collected in the first month of the wettest period in the Dovey catchment (October–December). Although the limited period of sampling does not allow a thorough assessment of the contribution of rainfall on the microbiological status of mussel beds, it should be noted that the three samples that returned maximum *E. coli* levels shown in Table XIV.1 were collected immediately after/during rainfall events.

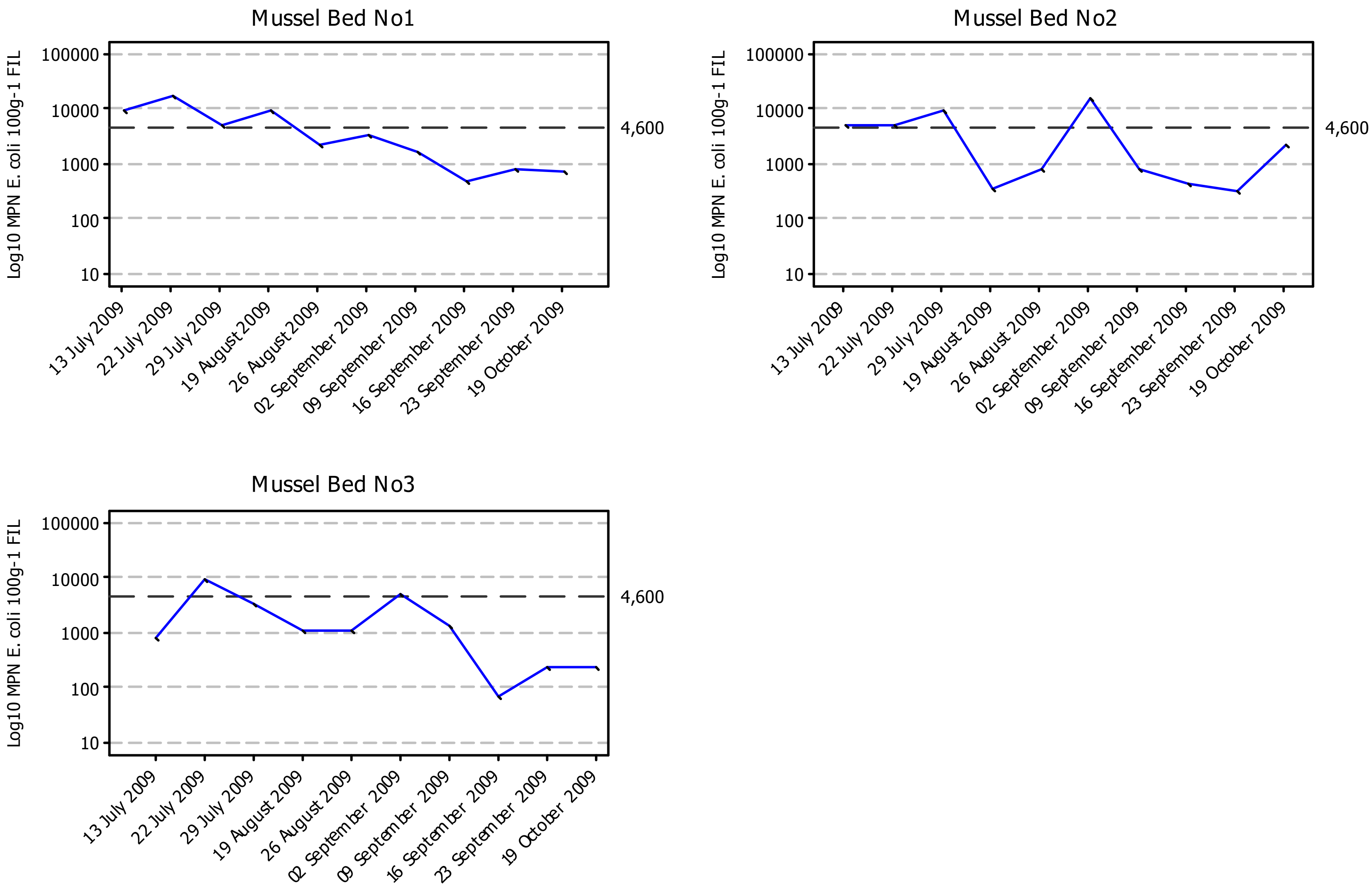

Figure XIV.3 Time series plots of levels of* E. coli *in mussels from three beds in Aberdovey.

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List of Abbreviations

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

Glossary

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

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

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