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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Conwy

October 2014

Food Standards Agency

Cover photo: Conwy Bay

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Statement of use

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

Report prepared by

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal consultation	Fiona Vogt	24/10/2014
2	Draft for client/consultee comment	Simon Kershaw	04/11/2014
3	Final	Simon Kershaw	13/04/2015

Consultation

Consultee	Date of consultation	Date of response
Conwy County BC	04/11/2014	24/12/2014
Natural Resources Wales	04/11/2014	27/11/2014
Welsh Government Fisheries	04/11/2014	-
Welsh Water	04/11/2014	-
Shellfish Association of Great Britain	04/11/2014	-

Dissemination

Food Standards Agency, Conwy County BC. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2014. Sanitary survey of Conwy. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. Infectious disease outbreaks are more likely to occur where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and/or animal origin. In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007).

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

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

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

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

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

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

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

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

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

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.) at Conwy. The area was prioritised for survey in 2014-15 by a risk ranking exercise.

1.2. Area description

Conwy estuary and Conwy Bay are situated along the coast of North Wales (Figure 1.1). The area supports a fishing fleet and some industry and tourism. Agriculture is also important to the local economy. Around two thirds of the catchment falls within Snowdonia National Park.

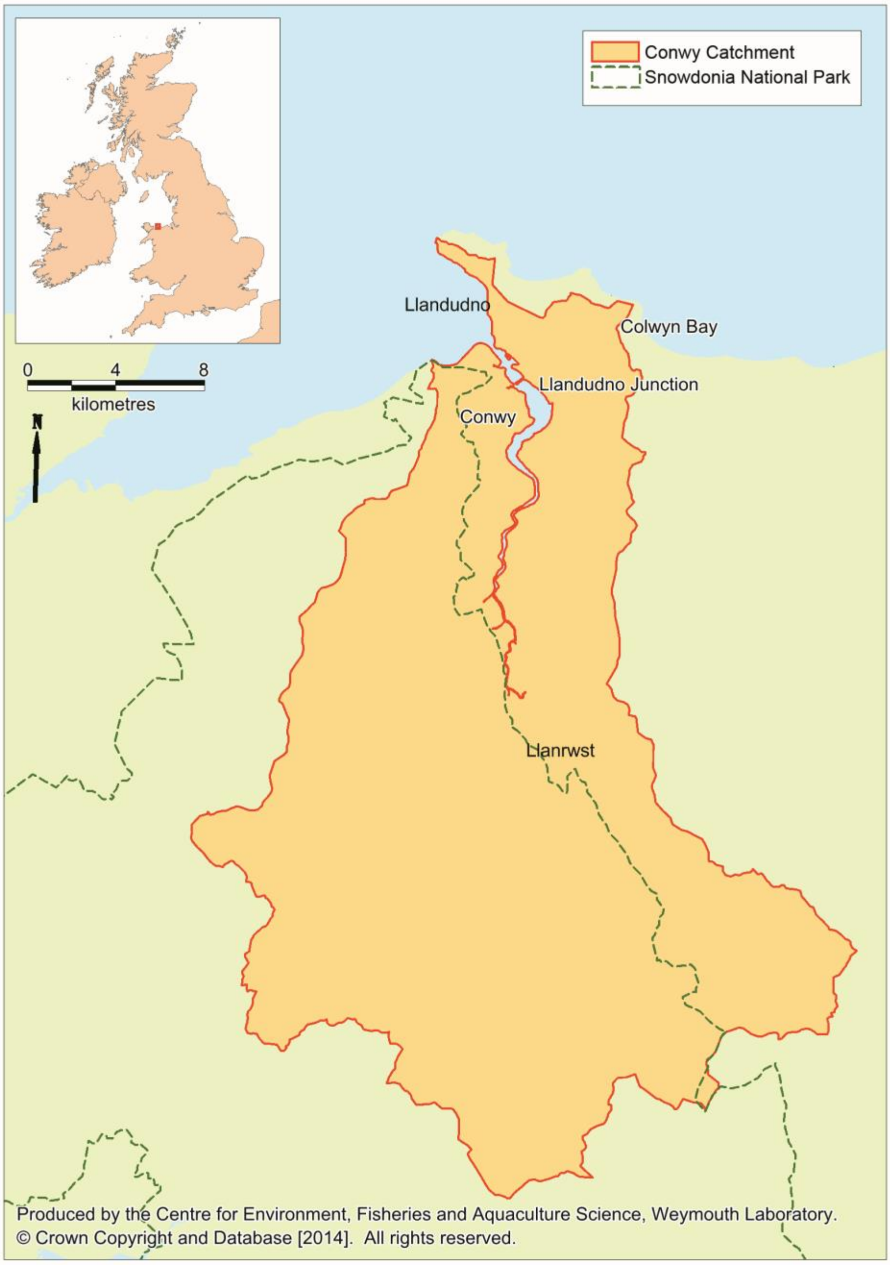


Figure 1.1: Location of Conwy estuary

The Conwy estuary is narrow and about 21 km in length, covering an area of approximately 7.6 km². Conwy Bay, to which the estuary drains, is an open, shallow north west facing embayment. There are two marinas within its outer reaches of the estuary and a significant spate river drains to its head. Mussels have been harvested from Conwy Bay and estuary for over 200 years for human consumption and to this day are still harvested by the traditional method; by small boat using pitch pine hand rakes.

1.3. Landcover

The Conwy estuary has a hydrological catchment of about 590 km^2, almost all of which drains to the head of the estuary via the River Conwy. The estuary lies within a steep valley with a narrow flood plain. The Conwy catchment extends up into the Snowdonia mountainous region, and its' maximum elevation is just over 1,000 m. Figure 1.2 shows land cover within this area.

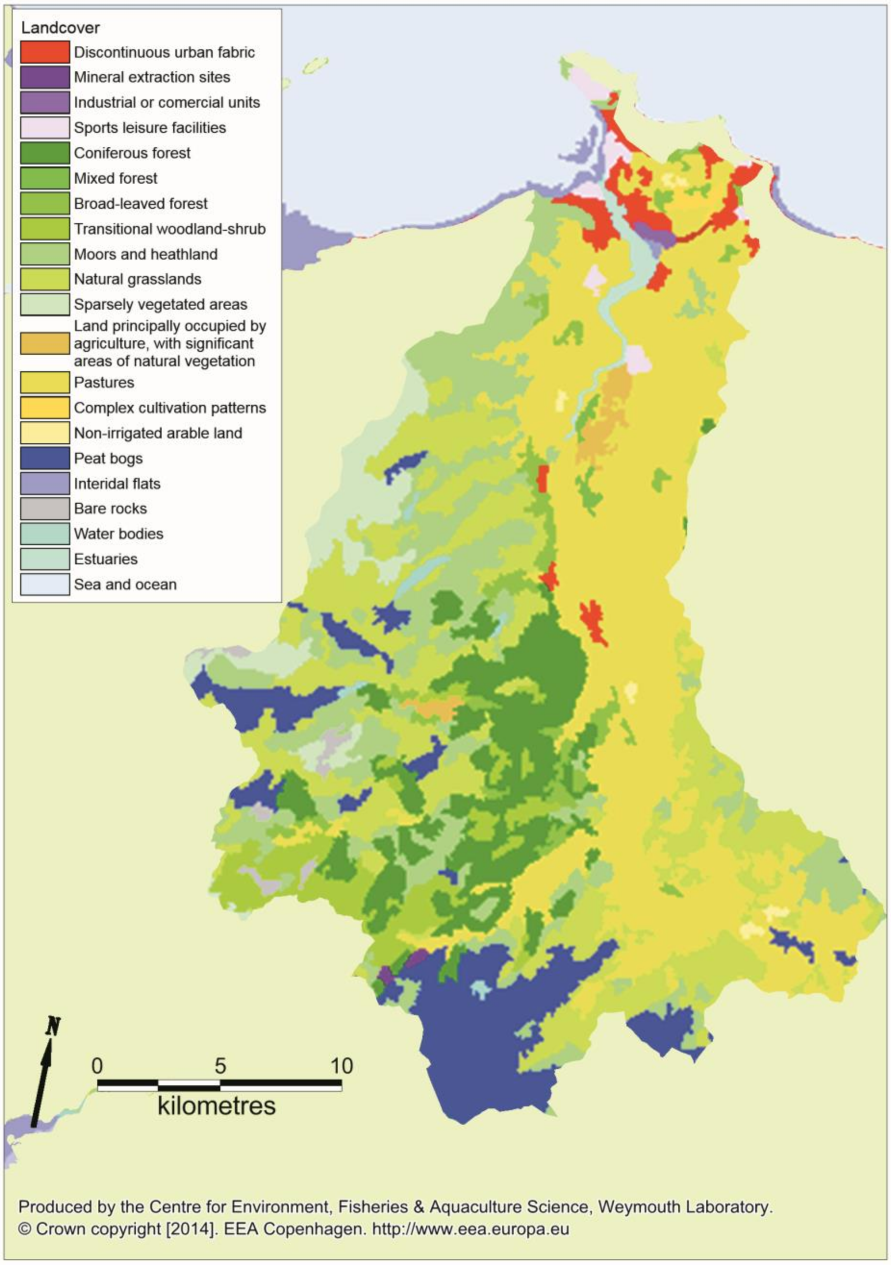


Figure 1.2: Landcover in the Conwy estuary catchment area

The catchment is rural and sparsely populated with few urbanised areas, most of which are located on the coast, including the towns of Conwy, Llandudno, Llandudno Junction and Colwyn Bay. Pasture predominates in the eastern and lower catchment, with pasture and woodlands in the middle reaches. The western and upper reaches are a mix of heathland, peat bog and forest.

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland the contribution from which increases up to 100 fold.

Hydrogeology maps indicate that the catchment geology is of low water permeability throughout (NERC, 2012). This, together with the generally hilly nature of the catchment suggests that watercourses will respond rapidly to rainfall, a high proportion of which will run off.

2. Recommendations

The following four zones are proposed. One RMP is proposed for each, and these are located to best capture peak levels of contamination within the zone. The presence of mussels in the exact recommended RMP locations could not be confirmed at the time of writing, so it is possible that some slight adjustments may be required both on the first sampling run and as distributions shift in future seasons. Any revision of RMP locations should be based on the principles identified within these recommendations, and should be communicated to the FSA and the classification team at Cefas.

Conwy Bridge

This zone will be heavily influenced by upstream catchment sources. There are two watercourses draining to either side of the estuary, just south of the bridge (Gyffin and Wydden) which are likely to cause localised elevations of faecal indicator organisms. Their drainage channels both run through mussel beds. The Gyffin, which is the larger of the two, discharges to the west shore. It receives sewage from two small sewage works, two intermittent discharges, and a few small private discharges. There are six intermittent discharges to the Wydden. Bacteriological sampling indicates that both carry significant concentrations of faecal indicator bacteria, with the Wydden being slightly more contaminated on average. Within this zone there are also two small private discharges to the subtidal by the mouth of the Gyffin, and the outfall from the depuration plant is to the west shore just south of the bridge. The main estuary channel runs under the bridge by the west shore so there will be more scope for dilution on this side, but increased exposure at the lower elevations to the end of the ebb tide when contamination from upstream sources will be most concentrated. On balance, it is recommended that the RMP be located on the lower intertidal immediately adjacent to the drainage channel from the Gyffin.

Estuary Mouth

The main contaminating influence in this zone is the ebb plume from the estuary. Hygiene monitoring results show a slight increase in average results towards the estuary mouth, although the RMPs within this zone returned similar results in terms of the proportion exceeding the class B threshold. It is therefore recommended that the RMP is located at the upstream end of the Green Island Bed.

Outer West

The main contaminating influence in this zone is likely to be the ebb plume from the estuary. The zone may also be influenced by the plume from the Penmaenmawr sewage works during the flood tide. Hygiene monitoring results showed an increase in average results towards the estuary mouth and in the proportion exceeding the class

B threshold. It is therefore recommended that the RMP is located at the upstream end of the Cae Conwy Bed, at the lowest elevation on its southern side, immediately adjacent to the estuary approach channel.

Outer North

This zone includes a significant seed mussel bed, but no harvestable stock, and is not currently classified. It will not require classification unless stocks of a harvestable size develop here, and either the harvesters or Welsh Government Fisheries request a classification. The only identified source direct to this zone is an intermittent discharge to the foreshore at Llandudno. There are two other intermittent discharges further offshore and to the north of the zone. Additionally there are three small private sewage discharges to the foreshore just to the south of Great Orme. In the absence of any major sources locally, the main contaminating influence is likely to be any ebb plume from the estuary that reaches the bed, and spatial variation in levels of contamination across this bed are likely to be minor. The secondary (northern) estuary approach channel runs to the east and then north of the mussel bed but does not pass through it. As it does not lie close to the path of any drainage channels, the estuarine influence is unlikely to be acute. An RMP located at the inshore (eastern) corner of this bed should be suitably protective of public health.

Sampling requirements

Mussels should be sampled using the harvest method (rake) if possible, although hand gathering would also be acceptable if this is more practical at some RMPs. A tolerance of 50 m applies. Sampled stock should be of a harvestable size (50 mm). Whilst monthly sampling on a year round basis is encouraged, it is not strictly necessary to sample the first two months of the closed season (May and June) assuming all other months are successfully sampled at all RMPs, giving a total of 10 samples per year from each.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Conwy
Cefas Main Site Reference	M044
Ordnance survey 1:25,000 map	Explorer OL17
Admiralty Chart	1463

Shellfishery

Species/culture	Mussels	Wild
Seasonality of harvest	September to April	

Local Enforcement Authority

Authority	Environmental Health Department Conwy County Borough Council Civic Centre Colwyn Bay LL29 8AR
Environmental Health Officer	Mark Hughes
Telephone number ☎	01492 575130
Fax number	01492 575204
E-mail	mark.d.hughes@conwy.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2020. The assessment may require review in the interim should any significant changes in sources of contamination come to light or any changes to the shellfishery occur other than those currently planned.

Table 3.1: Location of representative monitoring point (RMP) and frequency of sampling

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Conwy Bridge	B044T	Conwy Bridge	SH 7846 7738	53° 16.765' N 03° 49.460' W	Mussels	Wild	Rake	Rake	50 m	Monthly	New RMP
Morfa, Gamlyws & Green Island	B044U	Conwy East	SH 7743 7943	53° 17.856' N 03° 50.434' W	Mussels	Wild	Rake	Rake	50 m	Monthly	New RMP
Scabs & Cae Conwy	B044V	Conwy West	SH 7604 7992	53° 18.100' N 03° 51.700' W	Mussels	Wild	Rake	Rake	50 m	Monthly	New RMP
Outer North	B044W	Outer Conwy Sands	SH 7601 8144	53° 18.920' N 03° 51.759' W	Mussels	Wild	Rake	Rake	50 m	Monthly, or 10 samples at least 1 week apart if more rapid provisional classification is required	This bed/zone is currently unclassified and only supports seed stocks. It will therefore not require classification until requested by the harvesters or Welsh Government Fisheries

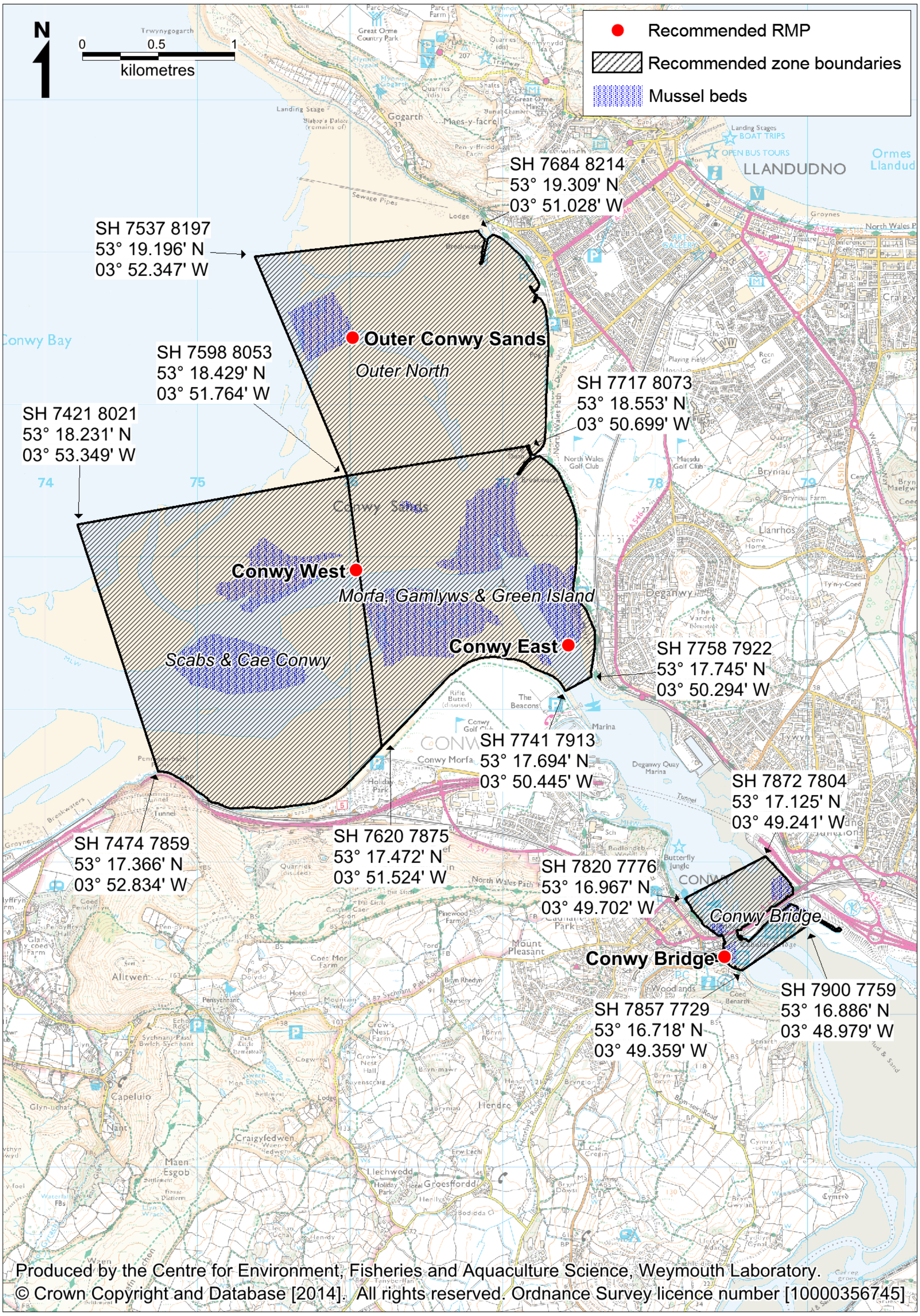


Figure 3.1: Recommended zoning and monitoring arrangements

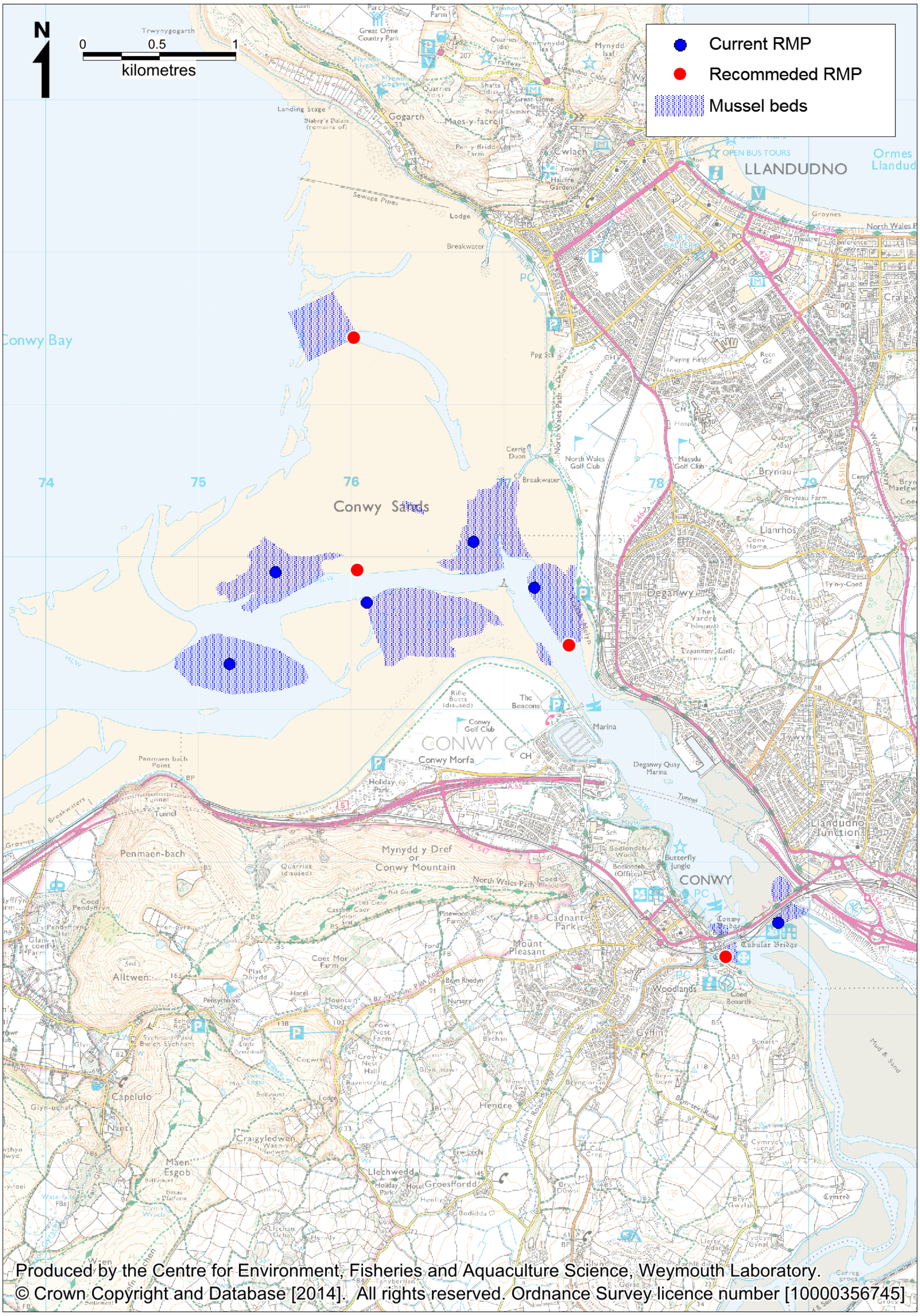


Figure 3.2: Current and recommended RMPs

4. Shellfisheries

4.1. Description of fisheries

The outer reaches of the Conwy Estuary and the adjacent Conwy Bay support a significant and long standing mussel fishery.

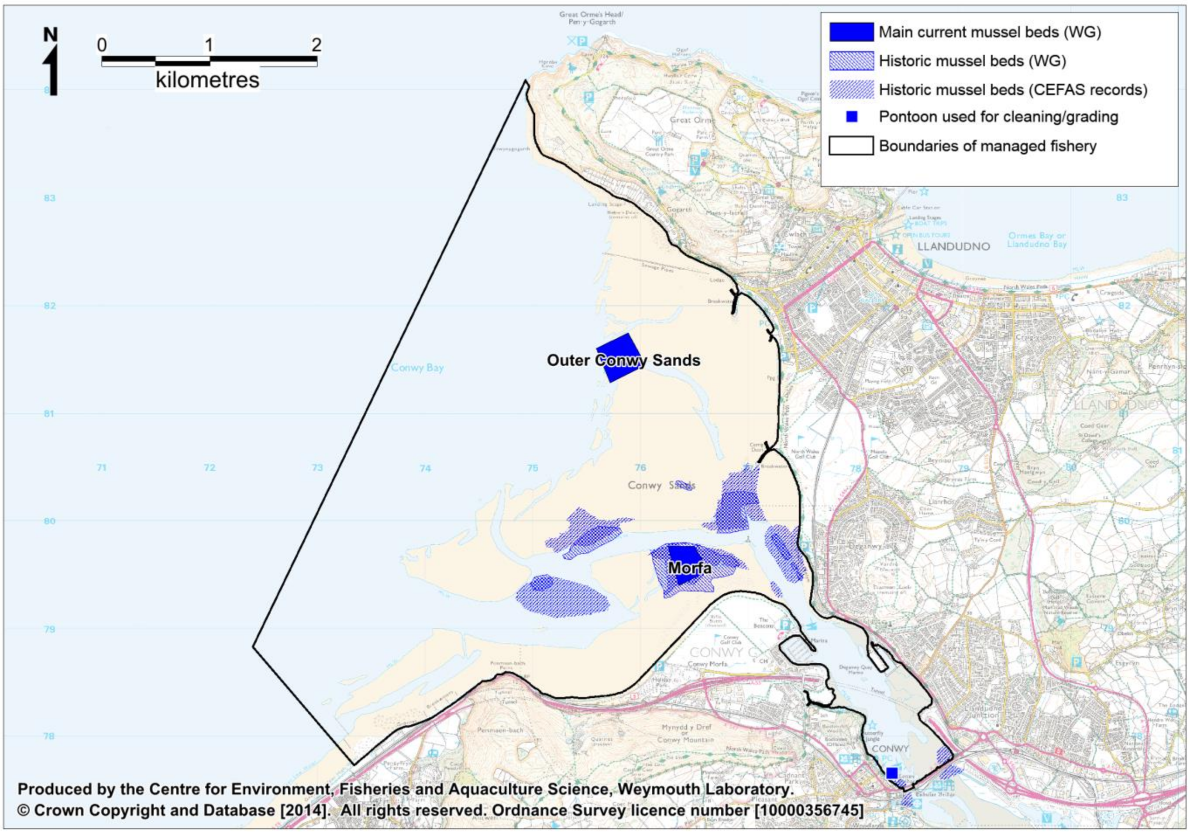


Figure 4.1: Mussel distributions

The Conwy estuary and the adjacent Conwy Sands support naturally occurring mussel beds which are the subject of this fishery. The two main mussel beds (according to Welsh Government Fisheries) are currently located at Morfa and Outer Conwy Sands, but mussels are widespread throughout the fishery area. The Outer Conwy Sands bed only supports seed stocks (Conwy Borough Council, pers. comm.). The exact mussel distribution varies from year to year.

Mussels are harvested by hand from small boats using pitch pine hand rakes over the low water period, when the tide is not running. They are then brought into Conwy to a pontoon adjacent to the depuration plant where they are cleaned, graded, and bagged. Following this they are depurated and marketed live for consumption. Stocks may also be sold unpurified for ongrowing or purification elsewhere. Annual production is in the order of 200-400 tonnes.

The fishery used to be managed under a regulating order, but this expired in 2008. It is now managed by the Welsh Government via former North West and North Wales Sea Fisheries Committee byelaws. Permits to participate in the fishery within a defined area are issued to a maximum of 22 harvesters. Harvesting methods are limited to those described above, and catch returns must be submitted. The fishery is closed during spawning (May to August inclusive) and a minimum harvesting length of 50 mm applies.

4.2. Hygiene Classification

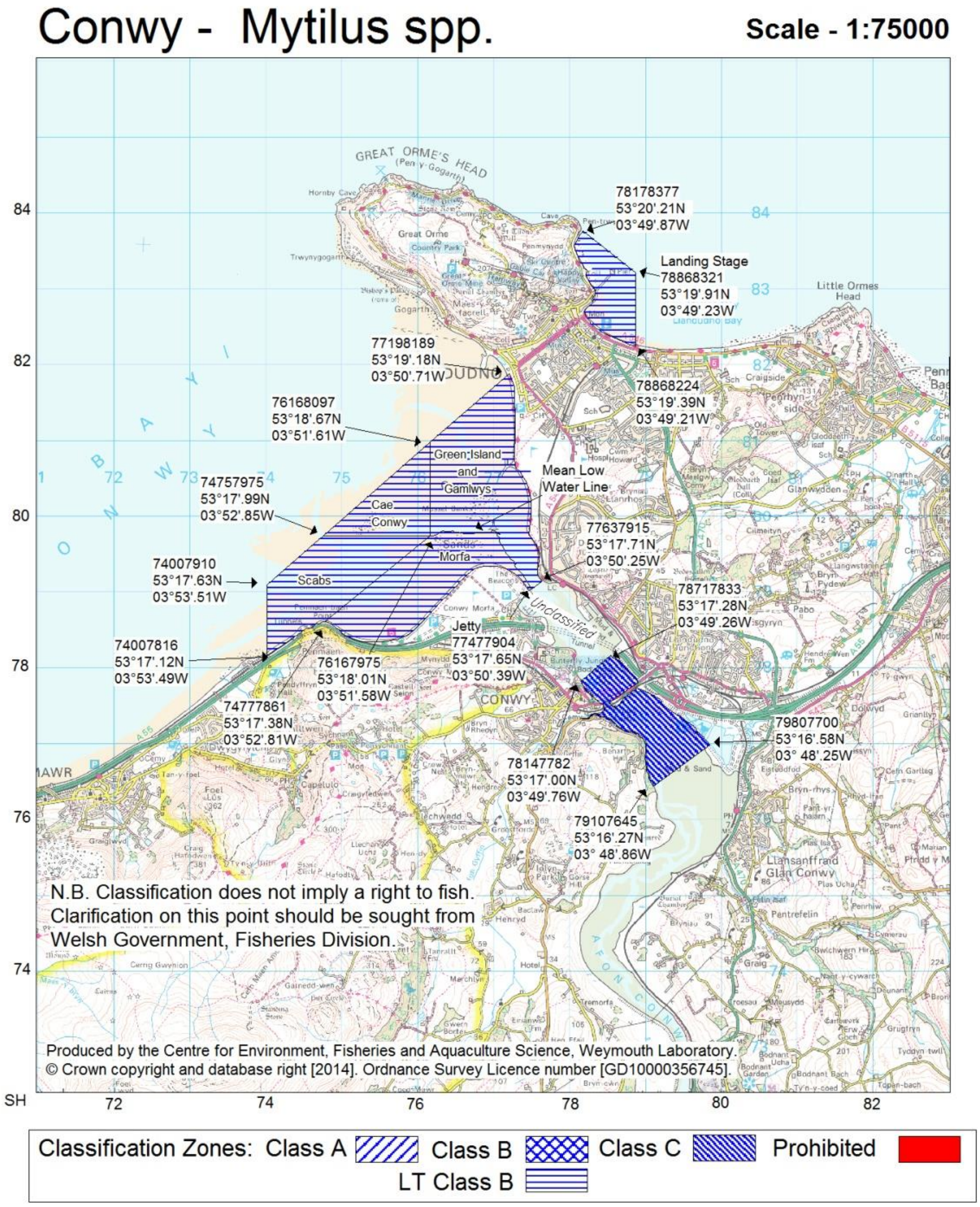
Table 4.1 lists all classifications within the survey area since 2005.

Table 4.1: Classification history for Conwy, 2005 onwards

Area	Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Morfa	Mussels	B	B	B	B	B	B	B	B	B	B
Cae Conwy	Mussels	C	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
Green Island	Mussels	B	B	B	B	B	B	B	B	B	B
Gamlwys	Mussels	B	B	B	B	B	B	B	B	B	B
Benarth	Mussels	B	C	C	C	C	B	B	B	B	B/C
Conwy Bridge	Mussels	B	C	C	C	C	B	B	B	B	B/C
Scabs	Mussels	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT

LT denotes long term classification

The area around Conwy Bridge (Conwy Bridge and Benarth) currently holds seasonal classifications, with a B classification applying from 1 December to 31 March, reverting to a C classification at other times. The areas in the very outer reaches of the estuary and Conwy Bay have been classified B throughout recent years.



Classification of Bivalve Mollusc Production Areas: Effective from 1 May 2014

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

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

N.B. Lat/Longs quoted are WGS84

Food Authority: Conwy County Borough Council

Figure 4.2: Current mussel classifications

The seed mussel bed at Outer Conwy Sands falls outside of the currently classified area, but as it is only used as a source of seed it will not require classification. The classified area at Colwyn Bay is considered in a separate survey.

Table 4.2: Criteria for classification of bivalve mollusc production areas.

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

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

5. Overall Assessment

5.1. Aim

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

5.2. Shellfisheries

The naturally occurring mussel beds in the outer reaches of the Conwy estuary and the adjacent Conwy Bay have supported a significant fishery for many years. Mussels are hand raked from small boats around low water, then transported back to a pontoon by Conwy Bridge where they are graded and bagged before undergoing purification. They may also be sold unpurified, for either ongrowing or purification elsewhere. The fishery is managed by the Welsh Government. Management measures include permits (issued to a maximum of 22 harvesters), a closed season (May to August inclusive) and a minimum size (50 mm).

The current classification zones do not include one the seed mussel bed at Outer Conwy Sands, but as it is used as a source of seed only it will not require classification at present. Should stocks which are directly harvestable develop here in the future, it may require classification, so a sampling plan should be provided for this bed in case of such an eventuality. The classified zone by Conwy Bridge extends about 1 km further up the estuary than is necessary.

5.3. Pollution Sources

Freshwater Inputs

All rivers and streams carry some contamination from land runoff and so will require consideration in this assessment. The hydrological catchment draining into Conwy Bay and estuary is about 592 km². The principle land use is pasture, so some impacts from agriculture are anticipated. There are also some limited built up areas, mainly on the coast, from which there will be some urban runoff. It receives relatively high rainfall, is underlain by impermeable geology, and the topography is steep and hilly. Watercourses draining it therefore have highly variable discharge rates and respond rapidly to rainfall.

The vast majority (>90%) of the catchment drains to the Conwy estuary upstream of the shellfishery, but there are also a few small watercourses draining to the outer reaches of the estuary and the bay. As such, there will be a gradient of decreasing average levels of runoff derived contamination through the outer reaches of the estuary and out into Conwy Bay. There are also likely to be further localised hotspots in the vicinity of the fishery where smaller watercourses drain to the shore.

The principle watercourse is the River Conwy, which drains to the head of the estuary. Records from a flow gauging station on this river about 7 km upstream of the tidal limit were examined. Runoff from about 60% of the catchment drains through this gauge, and the mean flow here was around 20 m^3/sec. Discharge was highly variable, with flood flows (Q_{10}) exceeding base flows (Q_{95}) by a factor of about 30. As well as significant day to day variation in discharge, there was a seasonal pattern of higher average discharge rates in the autumn and winter. Whether there is a corresponding seasonal fluctuation in average bacterial loadings delivered by the river is uncertain.

There are four streams of potential significance draining to the estuary/bay in the vicinity of the fishery. Two of these (the Gyffin and Wydden) discharge opposite one another just south of the Conwy Bridge, and the drainage channels from both cut through areas where small mussel beds have been located historically. Both were found to carry relatively high levels of faecal indicator organisms during the shoreline survey and Natural Resources Wales investigations. A third stream discharges to the west shore just south of the marina (Morfa Drive Conwy Stream). Finally, there is another minor watercourse discharging at the eastern extremity of the managed fishery boundary at Dwygyfylch (the Gyrach), although this lies about 2 km from the nearest mussel bed so is unlikely to be a significant influence on shellfish hygiene.

Human Population

Total resident population within census areas contained within or partially within the catchment area was approximately 78,600 at the time of the last census (2011). The largest settlements in the area are Llandudno (population 20,700), Conwy/Llandudno junction (population 14,200) and Colwyn Bay (population 11,000). The majority of the population is concentrated in the coastal areas adjacent to the shellfisheries. The rest of the catchment is sparsely populated. The seaside towns are popular tourist destinations, so their populations will peak during the main summer holiday period.

Sewage Discharges

There are 24 water company owned sewage works discharging within the survey area. Of these, one discharges to Conwy Bay (Penmaenmawr STW), three discharge to the upper reaches of the Conwy estuary (Tyn Y Groes, Dolgarrog/Talybont and Trefriw STWs), and one discharges to soakaway (Dolwyd Septic Tank). The remainder discharge to watercourses that drain to the Conwy estuary.

The Penmaenmawr STW is the largest, providing secondary treatment for a dry weather flow of 2,329.7 m^3/day, which equates to an estimated bacterial loading of about $8x10^{12}$ faecal coliforms/day. It discharges to the shallow subtidal area just to the west of where the main Conwy estuary approach channel loses its identity. The plume from this outfall is likely to be carried towards the mussel beds around the channel on the flooding tide, the nearest of which is around 2.5 km away.

The three works discharging direct to the estuary are located between 8 and 17 km upstream of the Conwy Bridge. They are consented to discharge a combined dry weather flow of 773.7 m^3/day of secondary treated effluent, and generate an estimated bacterial loading of about $3x10^{12}$ faecal coliforms/day.

Of those discharging to watercourses, there are two small works discharging to the Gyffin, which drains to the estuary immediately to the south of the Conwy Bridge. One is consented to discharge a dry weather flow of 46 m^3/day (Henrhyd STW) but the other (Groesffordd STW) does not have any discharge volumes specified in the permit. These will make a contribution to the bacterial loading delivered by the Gyffin.

The Dolwyd Septic Tank discharges to soakaway, so should be of no impact on coastal waters, assuming that it is functioning correctly. The remaining 17 works discharging to watercourses which drain in turn to the estuary at least 2 km upstream of the Conwy Bridge. They all provide secondary treatment, and their combined consented dry weather flow is 2,526 m^3/day, although this total does not include three small works for which the discharge volumes are not specified in the permit. Die-off of faecal indicator organisms is likely to occur during transit to the estuary, particularly for those that are located further inland. The two largest individual works (Betws Y Coed and Llanrwst STWs) account for about 60% of the effluent volume discharged from the 17 works between them. They are located 7.5 and 2 km upstream of the tidal limit.

There are 49 intermittent discharges in the area. The main cluster of intermittent discharges is around the outer reaches of the Conwy estuary. Additionally, there are three towards the northern end of Conwy Bay, and two to its southern reaches off Dwygyfylchi. There are also a significant number which are located inland, and these will contribute to the bacterial loading delivered to the upper reaches of the estuary at times. No spill records were available for any of these assets at the time of writing and as such it is difficult to assess their impacts aside from noting their locations and their potential to spill storm sewage. Discharges from storm overflows tend to operate following rainfall events which can inundate sewers. Emergency overflows occur following failures (blockages, power cuts etc) and are typically very rare occurrences. Welsh Water plan to install event monitoring to those which are likely to impact on the shellfish waters in the near future.

Although most properties in the area are connected to mains sewers, there are a further 1,269 private sewage discharges either permitted by or registered with Natural Resources Wales. These are generally small, serving one or a small number of properties, providing treatment via septic tank or package plant. The vast majority discharge to soakaway and so should be of no impact on coastal waters. Of those discharging to water, most are to watercourses that drain to the estuary upstream of the fishery. There are a further two small private discharges to the west shore of the estuary just south of the Conwy Bridge, and one just north of it. There are three small private discharges to the Conwy Morfa Drive Stream that drains to the estuary just south of the Conwy Marina. There is also a cluster of private discharges by the shore of Conwy Bay just south of Great Orme, of which three discharge to water but most discharge to soakaway.

It is therefore concluded that significant volumes of sewage are discharged to watercourses draining to the estuary upstream of the fisheries, and monitoring points at the upstream end of shellfish beds would best capture this. There is a significant cluster of intermittent discharges by the outer reaches of the estuary, although it is difficult to assess their impacts without examining spill records from them. The plume from the Penmaenmawr STW will be carried towards the mussel beds by the main estuary approach channel during the flood tide.

Agriculture

The majority of land within the Conwy hydrological catchment is used for agriculture. Most of the agricultural land is grassland and rough grazing although there is a small amount of cropping. A total of 348,766 sheep and 18,567 cattle were recorded within the catchment area in the 2012 agricultural census, so significant and widespread impacts from grazing animals are anticipated. Higher elevations support sheep production on rough grazing. Lower elevations support a mix of sheep and cattle production on more productive land with higher stocking rates and some fertiliser applications. Faecal matter from grazing livestock is either deposited directly on land by grazing animals , or collected from livestock buildings if animals are housed (generally in the winter) and then applied to agricultural lands as a fertilizer. There are also some poultry farmed in the area as well as a small number of pigs. Manure from poultry and pigs is typically stored and then applied to nearby farmland. Sewage sludge is occasionally applied to some fields in the lower catchment.

The primary mechanism for mobilisation of faecal matter from agricultural land is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. All significant watercourses are expected to be affected to some extent. Therefore, RMPs should be located at points where the influence of freshwater inputs are the highest which in this case is towards the up-estuary ends of the shellfish beds. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). During the warmer months, livestock are likely to spend more time accessing watercourses. The seasonal pattern in application of manures and slurries to agricultural land is uncertain. Good practice is for manures and slurries to be applied to land when the crop requirement for its nutrient content is highest which is typically in the spring and summer. Farms with housed stock and limited storage capacity are more likely to spread in the winter months.

Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within the survey area. Boat traffic is limited to recreational craft such as yachts and a few commercial fishing vessels. It is centred around the outer reaches of the estuary, where there are two large marinas providing about 765 berths between them. There are also numerous other mooring and pontoon berths on the estuary downstream from the Conwy Bridge. The two marinas are impounded by flap gates which limit the draining of water and any associated contamination from them to the first half of the ebb tide. The moorings and pontoon berths are mainly located towards the west shore. A small fleet of 10 fishing vessels are registered to Conwy. There are no longer any commercial ports within Conwy Bay or the estuary and this, together with its shallow nature makes it unlikely that merchant shipping will enter the survey area.

It is therefore concluded that boat traffic in the area consists of large numbers of pleasure craft as well as a few fishing vessels, so the impacts from boat traffic may be of potential significance to the fishery. Private vessels such as yachts, motor cruisers and fishing vessels of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the area. Both marinas contain sewage pump out facilities which should help to eliminate overboard discharges in the marinas. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the moorings and the main navigation routes to the estuary are most at risk of contamination from this source. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Wildlife

The Conwy estuary and Bay encompass a wide range of marine habitats including large expanses of intertidal sand and mud flats, sand dunes, a wetland area and salt marsh. Such features attract wildlife aggregations, which may have impacts on shellfish hygiene. Conwy estuary and Conwy Sands attracts a population of overwintering waterbirds (wildfowl and waders). An average count of 3,722 waterbirds (wildfowl and waders) was reported during the winter of 2011/12, which is quite small relative to that observed in other similar areas. Grazers, such as geese and ducks will mainly frequent the grassland and saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Such areas are generally found flanking the upper reaches of the estuary. Waders, such as dunlin and oystercatchers forage upon shellfish and so will forage (and defecate) directly on any shellfish beds on the intertidal so are likely to be of much greater impact. However, their spatial patterns of foraging are uncertain and so their impacts may be considered as diffuse. Therefore, although they may be a significant contaminating influence during the winter months, it is not possible to specify a monitoring point location that will best capture their impacts.

Seabirds (gulls etc) are present in the area throughout the year, and there is a significant breeding colony on Great Orme, where 2,198 individuals were recorded in a survey in 2000. Further minor nesting areas were also recorded in various locations around the outer estuary, where 218 individuals were recorded during the same survey. Seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. As there are no large colonies in the immediate vicinity of the shellfisheries, the presence of seabirds will have no bearing on the sampling plan.

There is a grey seal haul out site on Puffin Island, 10 km to the west of the survey area. Seal numbers are reported to range from around 11 to 130, with the highest numbers recorded in the winter. Seals will forage widely and it is highly likely that they enter Conwy Bay and the estuary from time to time, particularly during the main period of return migration of salmon and sea trout in summer and autumn. However, away from their haul-out sites their impacts may be considered as spatially diffuse and unpredictable, so their presence will have no bearing on the sampling plan. No other wildlife species which may have an influence on the sampling plan have been identified.

Domestic animals

Dog walking takes place on paths adjacent to the shoreline of the survey area and could represent a potential source of diffuse contamination to the near shore zone. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

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

Table 5.1: Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff												
Urban runoff												
Continuous sewage discharges												

Intermittent sewage discharges	?	?	?	?	?	?	?	?	?	?	?	?
Birds												
Boats												

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

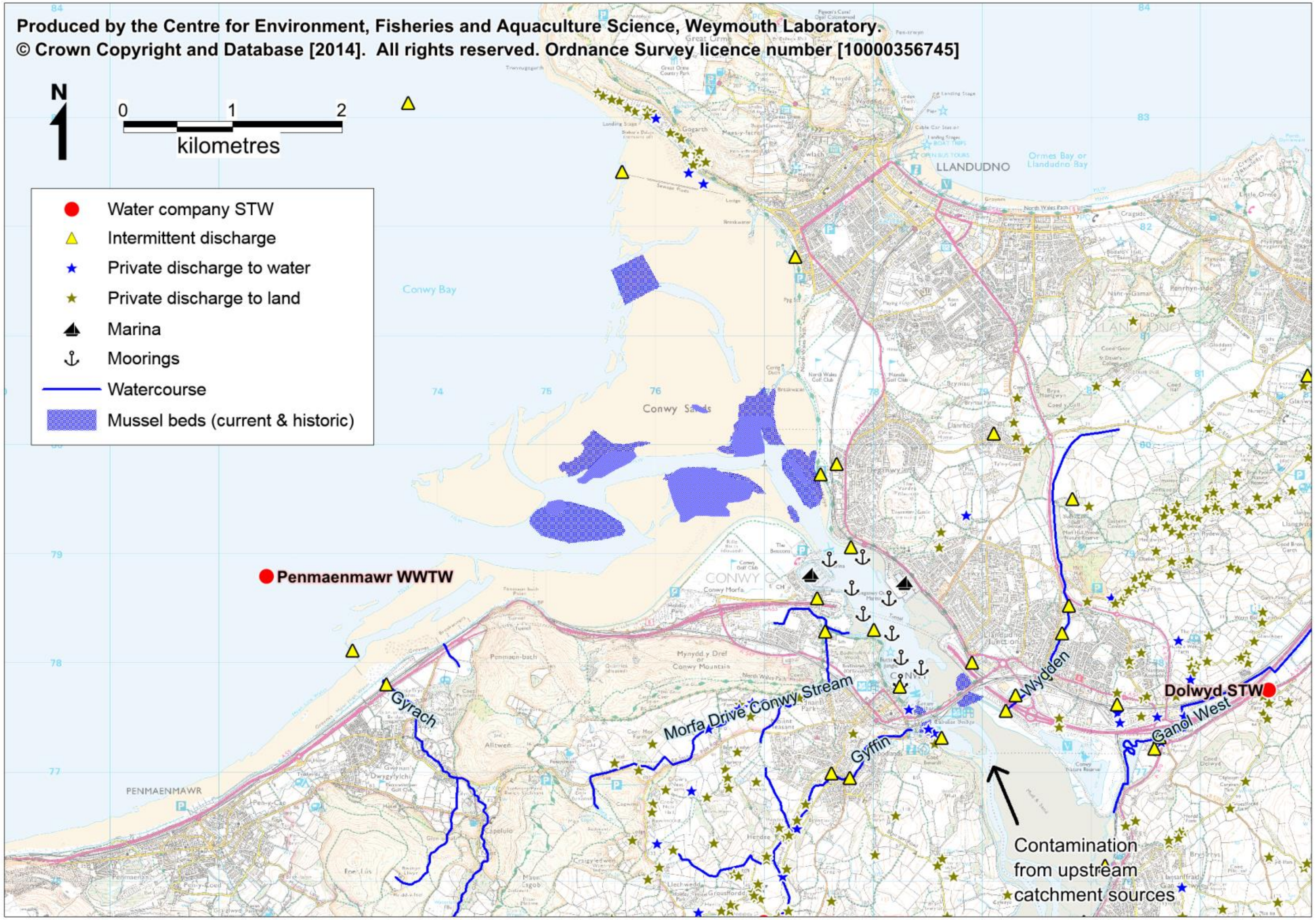


Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

Conwy Bay is an open, north west facing bay with extensive sandy intertidal areas that slope gently into the subtidal. The Conwy estuary adjoins the central part of the bay. The main channel connecting the estuary with the open sea has an east-west orientation across the intertidal area. There is a second shallower channel that runs north, and a third channel emanating from the estuary in a north westerly direction is also apparent on aerial photography, but not on the nautical chart. The estuary is a narrow, steep sided drowned river valley of about 21 km in length. The river channel is flanked by intertidal sand/mudflats, the latter representing 82% of the estuary area. The high proportion of intertidal will promote flushing, but reduce dilution potential. There is a constriction just inside its mouth (Deganwy Narrows) where it narrows to about 210 m, which will reduce wave penetration from Conwy Bay. The width then increases before it passes under the Conwy Bridge, where the channel is constrained to an opening of 120 m adjacent to the west shore. At these constrictions tidal streams are likely to accelerate, promoting turbulent mixing, as evidenced by scoured holes at both. Upstream of the bridge the estuary widens to about 1 km with extensive intertidal areas bisected by a meandering river channel. The width then decreases gradually towards the tidal limit, where the estuary consists of a narrow river channel only. The fishery is only located in the outermost reaches, up to and around Conwy Bridge.

The tidal range is large, at 6.8 m on spring tides and 3.6 m on neap tides, and this is the main driver of water circulation in the area. Tides flood into Conwy Bay from the north-west as an offshoot of the main tidal streams passing around the north coast of Anglesey and into Liverpool Bay. During the early flood tide, streams will progress into the Bay and up the main Conwy estuary approach channel. As the level rises water will spread across the intertidal areas from the channel and offshore subtidal area. Effluent from the Penmaenmawr STW sea outfall is likely to be carried in a westerly direction, towards the shellfisheries, during the flood. Flood streams are also likely to align to some extent with the secondary north approach channel once this has filled. The reverse will occur on the ebb, so whilst the ebb plume will impact all around the mouth of the estuary, the most acute impacts will be felt in the approach channels as low water approaches, when the plume is most concentrated and constrained geographically. The strength of these currents, and hence the distances over which contamination will be carried before the tide reverses are uncertain. A tidal diamond further offshore (~6 km north of Llanfairfechan) indicates tidal excursions of around 9 km on spring tides and 5 km on neap tides.

Tidal streams will move up the estuary on the flood, and back down on the ebb, and the main flows will tend to follow the main channel. Sources discharging to the estuary shoreline will therefore impact up and down estuary, along the bank to which they discharge. Impacts will decrease with distance as the plume becomes less concentrated. At lower states of the tide contamination from some shoreline sources such as watercourses will follow intertidal drainage channels where the dilution potential is low. Tidal streams will accelerate at the constrictions at the estuary mouth and Conwy Bridge where there will be more scope for turbulent mixing of the water column. Between the Deganwy Narrows and Conwy Bridge, and just to the south of the bridge, the shallower intertidal areas towards the east bank are likely to experience weaker currents than the deeper areas by the west shore.

Circulation in coastal waters may be modified by density effects arising from freshwater inputs. River flow is significant in relation to volumes of water exchanged tidally, suggesting that density effects are likely to arise. When such effects occur, they will result in a shear between surface and bottom currents, with less dense freshwater moving in a net seaward direction at the surface, and a net movement of more saline water up-estuary lower in the water column. Observational studies have generally reported little saline stratification within the estuary however. An axial convergence has been described in the upper estuary (i.e. cross channel density driven circulation) which will promote mixing of the water column during flood tides. One density effect of potential relevance is that the plume from Penmaenmawr STW will be buoyant so will rise in the water column. This may reduce its impacts to some extent on the benthic shellfish beds, and also render it susceptible to advection by wind driven surface currents.

As land runoff typically contains higher levels of faecal indicator bacteria than seawater, lower salinities tend to coincide with higher levels of faecal indicator organisms in the water column. A large lateral salinity gradient has been reported through the estuary, the profile of which changed greatly with tidal state. At the outermost station used in this study (2.4 km up-estuary from the mouth) for example, salinity was approaching 35 ppt at high water, but ranged from ~ 5 to ~ 25 ppt at low water. This indicates that on average, the impacts from catchment sources will be higher towards the up-estuary ends of the mussel beds. It also indicates that the outer estuary will be exposed to more concentrated runoff borne contamination at lower states of the tide.

Given that river discharge may greatly exceed that experienced when these salinity measurements were made, it is likely that at times of higher river flow a plume of lower salinity water can extend out into Conwy Bay where the main mussel beds are located. Repeated salinity measurements have been taken in the bay at the shellfish water and bathing water monitoring points (see Figure 5.2 for locations). Average salinities were 32.5 ppt at Conwy and 30.9 ppt at West Shore suggesting the plume from the Conwy does not often extend out as far as the monitoring points, although lower salinities were occasionally recorded. The West Shore monitoring point recorded lower salinities than the Conwy monitoring point. However, it was sampled more frequently at lower states of the tide whereas the vast majority of samples from Conwy were taken around high water. It is apparent from these results that any plume of less saline water is not restricted to the main estuary approach channel, but also impacts on the secondary north channel, and possibly more widely across the bay. A general principle of defining monitoring points within the bay at low elevations on the edge of these channels and towards the estuary mouth would best capture any plume from the estuary.

Strong winds can drive surface currents, which in turn will create return currents which may travel lower in the water column or along sheltered margins. The area is largely sheltered from the prevailing south westerly winds by the adjacent land. Strong winds from the north west will have the greatest effect on the area. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended. Strong north westerly winds will create significant wave action in the bay, but this is unlikely to penetrate far into the estuary given its narrow mouth.

5.5. Summary of Existing Microbiological Data

The survey area has a comprehensive microbiological monitoring history, deriving from the bathing waters and shellfish waters monitoring programmes, as well as hygiene classification monitoring. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Results of samples taken from 2004 onwards are considered in these analyses.

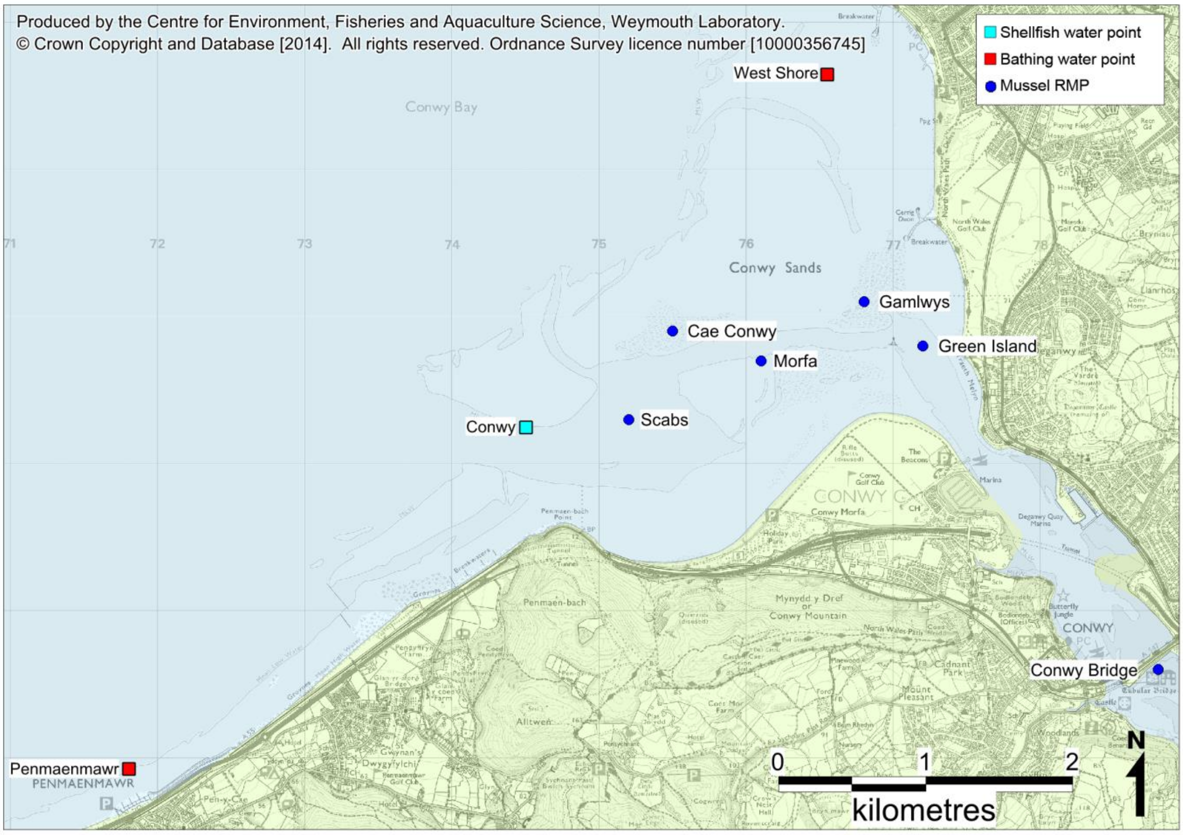


Figure 5.2: Microbiological sampling locations

Shellfish Waters monitoring

The shellfish water monitoring point is located in the outer reaches of the estuary approach channel. Water samples were taken from here on a quarterly basis and enumerated for faecal coliforms. Levels of bacterial contamination were low, with a geometric mean result of 3.9 faecal coliforms/100ml and a maximum result of 251 faecal coliforms/100ml. Faecal coliform concentrations remained fairly stable on average through the period considered. A statistically significant seasonal effect was detected, with faecal coliform levels significantly higher in winter than in spring and summer. Statistically significant influences of both the high/low and spring/neap tidal cycles were detected. Across the high/low cycle, higher results tended to occur in samples collected during the second half of the ebb tide suggesting the ebb plume from the estuary may be an influence. This also suggests that estuarine sources are of more importance here than any plume from Penmaenmawr STW. Across the spring/neap cycle, higher results tended to occur during the smaller tides, perhaps as a consequence of reduced tidal transport distances. Higher results were correlated with higher rainfall, but not until four days after a rainfall event. A strong negative correlation between faecal coliform concentration and salinity was found, suggesting that the estuary plume is a significant influence.

Bathing water monitoring

There are two bathing waters in Conwy Bay, where water samples were taken every two weeks throughout the bathing season (May to September) and enumerated for faecal coliforms up to 2011, then *E. coli* from 2011 onwards. Statistical analyses were undertaken using the faecal coliform results as the dataset was larger. Geometric mean results were 16.0 and 12.7 faecal coliforms/100ml at West Shore and Penmaenmawr respectively. The highest individual result (22,500 faecal coliforms/100ml) was recorded at West Shore. There was no statistically significant difference in average result between the two. Results were strongly correlated on a sample by sample basis suggesting they are subject to similar sources of contamination.

Faecal coliform levels have remained fairly stable on average from 2004 to 2011. Average bacterial concentrations increased following the implementation of *E. coli* monitoring. This suggests a recent decline in water quality, as *E. coli* are a subset of the faecal coliforms. Statistically significant influences of both the high/low and spring/neap tidal cycles were found at both monitoring points. Plots of results against the high/low cycle suggested that results were lower on average around high and low water, but were higher while the tide was either ebbing or flooding. Across the spring/neap cycle, no strong patterns are apparent in the plot for West Shore, whereas at Penmaenmawr results were lower on average as tide size increased from neap to spring. The reasons for these patterns are unclear. A strong influence of antecedent rainfall was observed at both locations. This influence was more prolonged at West Shore, possibly as it is more in the influence of the larger Conwy catchment area, whereas watercourses near Penmaenmawr are smaller. Strong negative correlations were found between faecal coliforms and salinity at both locations, confirming the importance of contamination delivered by land runoff.

Shellfish Hygiene classification monitoring

A total of six mussel RMPs in Conwy Bay and estuary have been sampled on a more or less monthly basis since 2004. *E. coli* levels exceeded 4,600 MPN/100 g in over 10% of samples at all sites except Scabs, the outermost RMP. This indicates that compliance with class B requirements is generally borderline. There were statistically significant differences in average *E. coli* levels between the RMPs. Conwy Bridge, the only RMP in the estuary, had significantly higher *E. coli* levels than all the other RMPs, which are located out in Conwy Bay. Across the remaining RMPs, results were significantly higher at Green Island (the innermost of those outside the estuary) than at Scabs (the outermost RMP). Overall, the results clearly show a gradient of decreasing contamination from Conwy Bridge out through the estuary and bay. *E. coli* levels at all RMPs correlated very strongly with each other, indicating that they share similar contamination sources. The geographic analyses therefore strongly suggest that the main contaminating influences to the fishery originate from the estuary.

E. coli levels have remained stable on average at all monitoring points through the period considered. There was a general tendency for higher average results during the summer and autumn at most RMPs, but the seasonal variation was not found to be statistically significant at any. Significant correlations between *E. coli* results and tidal state across the high/low tidal cycle were found at several RMPs, but sampling was strongly targeted towards low water and no patterns were apparent when the data was plotted. Significant correlations were found between the spring/neap tidal cycle and *E. coli* results at Conwy Bridge, Green Island, Gamlwys and Cae Conwy. However, when the results were plotted none showed any obvious patterns with relation to tidal state. At all RMPs, antecedent rainfall had a significant effect on *E. coli* levels. This was strongest two days after a rainfall event in all cases.

Bacteriological survey

Due to the comprehensive classification monitoring history whereby six RMPs were usually all sampled on each monthly sampling run, there was little to be gained by undertaking a bacteriological survey.

A published bacteriological survey of levels of *E. coli* in the water column across the outer estuary was found during the literature search (Quilliam *et al*, 2011). Four transects were each sampled four times on the same day in October 2010. Across the three outermost transects, at Glan Conwy, Conwy Bridge and Conwy Marina, results were significantly higher towards the east bank. These variations were not accompanied by corresponding variations in salinity or turbidity. Levels of *E. coli* were broadly similar at these three transects, despite their differing distance from the estuary mouth. Surprisingly, the fourth transect, which was furthest upstream and did not show any cross channel variation, returned the lowest results. The tidal state at the time of sampling was not specified. The authors suggested that localised re-suspension of sediment entrained contamination rather than a specific point source was possibly the reason for the observed spatial variation, even though there were no accompanying differences in turbidity. As the sample numbers were not particularly large, and they were all taken on the same day it cannot be concluded that such an effect is consistently observed here.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within or partially within the Conwy catchment area, derived from data collected from the 2011 census.

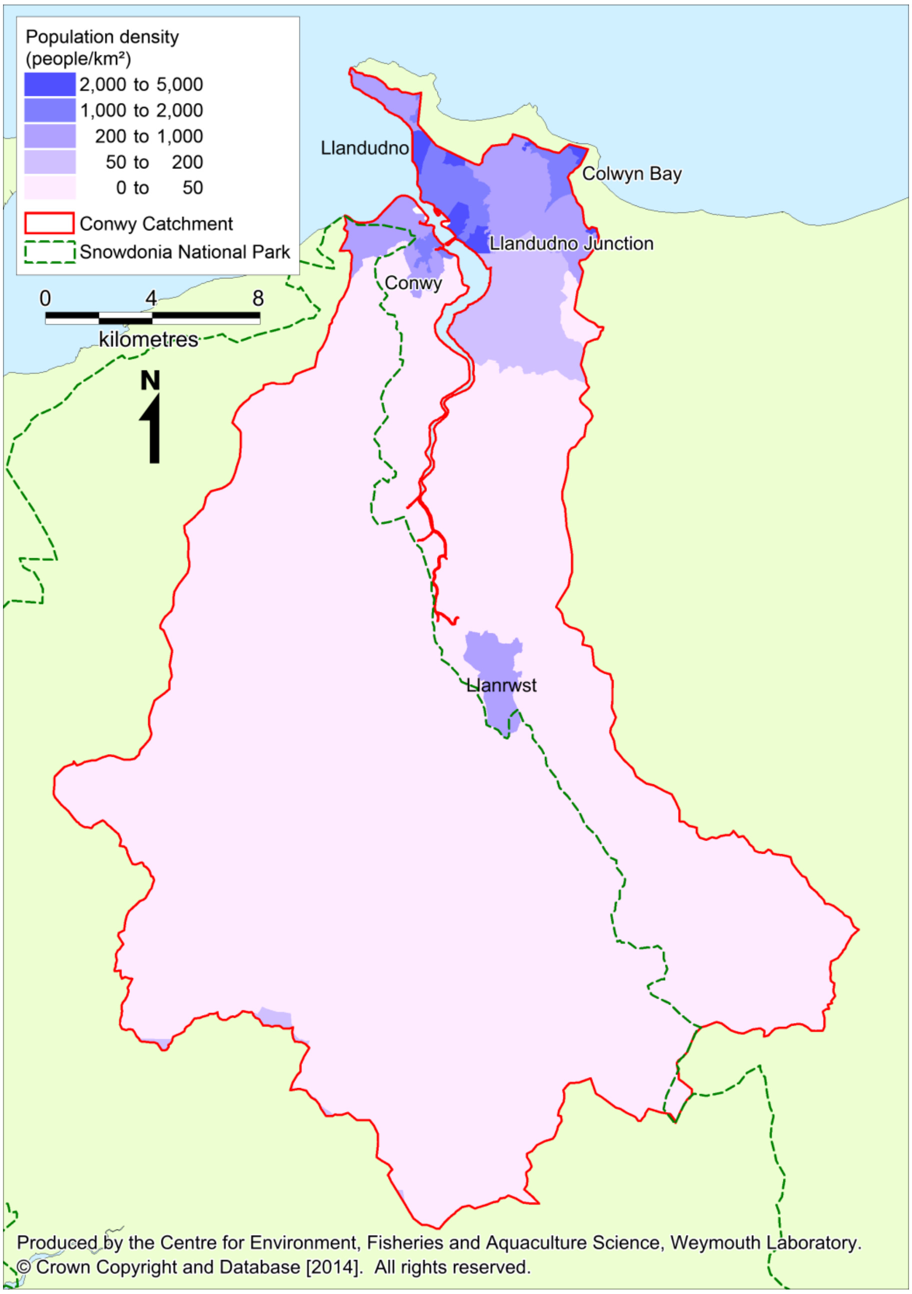


Figure I.1: Human population density in census areas in the Conwy catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 78,600 at the time of the last census. The largest settlements in the area are Llandudno (population 20,700), Conwy/Llandudno junction (population 14,200) and Colwyn Bay (population 11,000). The majority of the population is concentrated towards the lower catchment, in the areas directly adjacent to the shellfisheries. Outside of these areas, the majority of the catchment has a population density of less than 50 people/km².

The towns of Conwy and Llandudno are popular tourist destinations. Additionally, 66% of the Conwy catchment area lies within the Snowdonia national park. The population of the catchment is therefore likely to fluctuate throughout the year, with higher numbers of tourists visiting the area in the summer.

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

Details of all consented sewage discharges within the Conwy hydrological catchment were taken from the March 2014 update of the Environment Agency national permit database. These are mapped in Figure II.1. A second map (Figure II.2) shows sewage discharges local to the fishery.

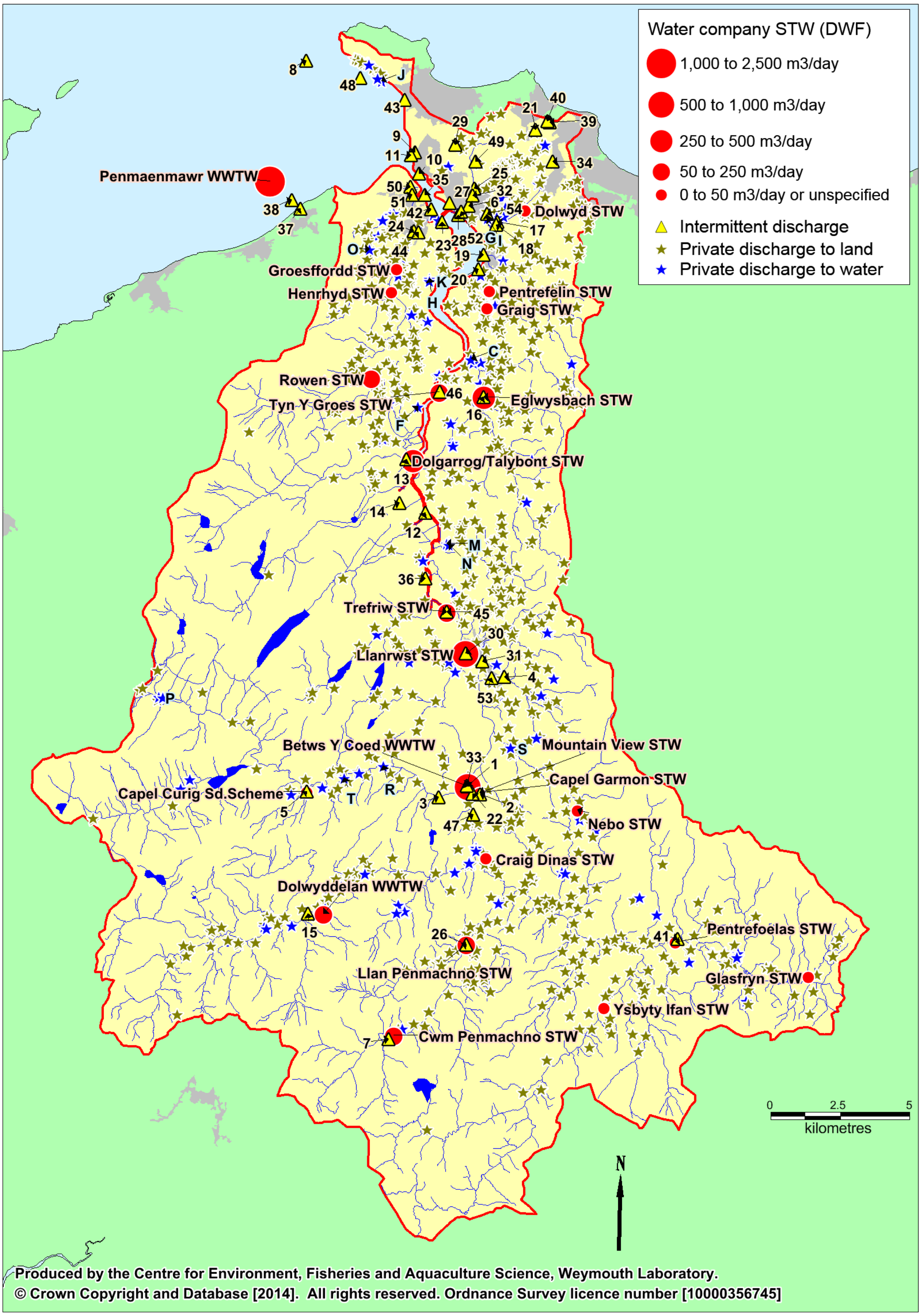


Figure II.1: All permitted sewage discharges to the Conwy catchment

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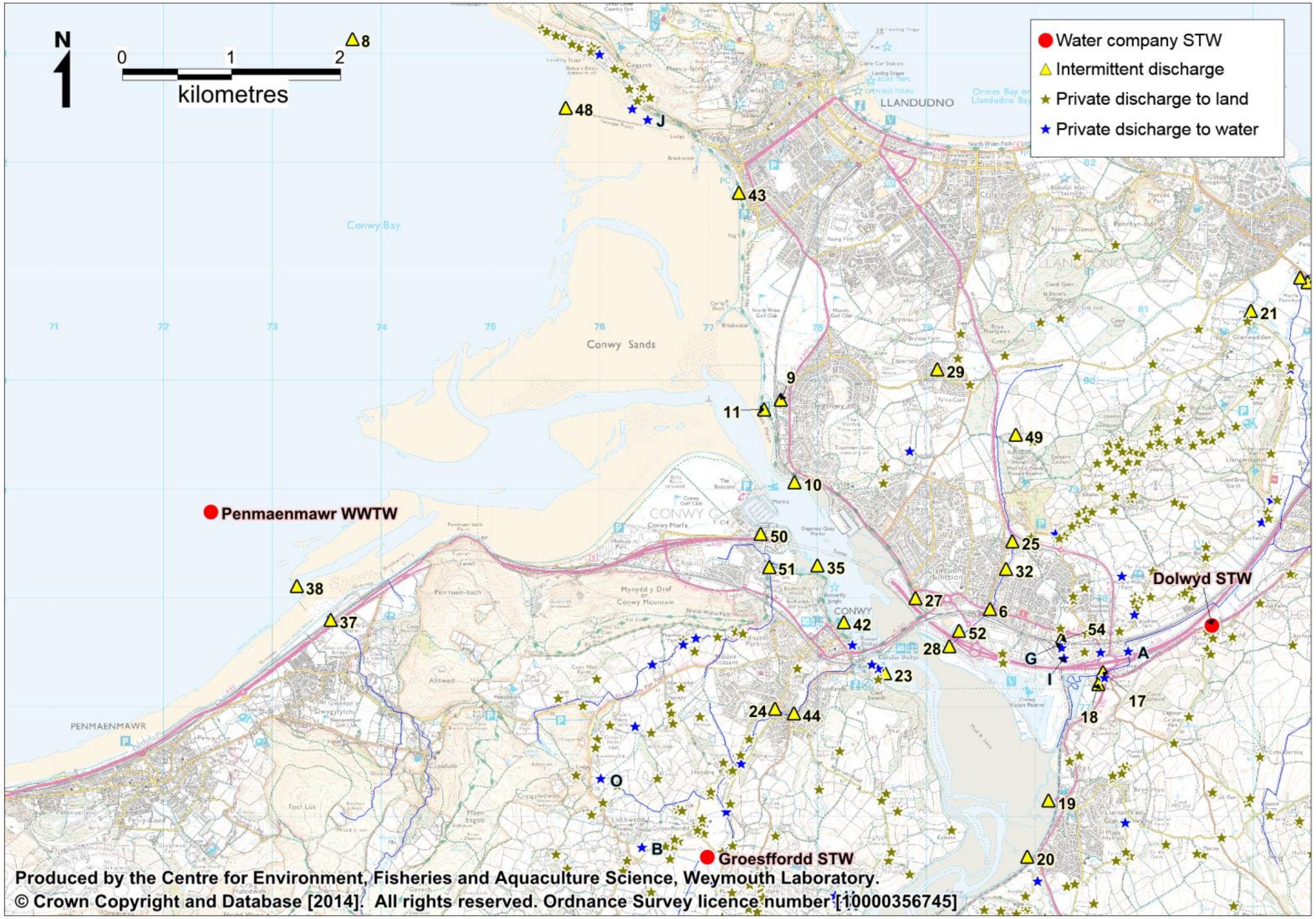

Figure II.2: Sewage discharges local to the fishery

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There are 24 continuous water company sewage works discharging within the survey area, details of which are presented in Table II.1.

Table II.1: Details of continuous water company sewage works to the Conwy catchment

Name	**NGR**	**Treatment**	**DWF (m^3/day)**	**Estimated bacterial loading (cfu/day)***	**Receiving environment**
Betws Y Coed WWTW	SH7954757003	Biological Filtration	592.2	1.95 x10^{12}	River Llugwy
Capel Curig SD.Scheme	SH7376056820	Biological Filtration	Unspecified	Unknown	Llugwy
Capel Garmon STW	SH7997056770	Biological Filtration	Unspecified	Unknown	Conwy
Craig Dinas STW	SH8021054430	Biological Filtration	3.4	1.12 x 10^{10}	Conwy
Cwm Penmachno STW	SH7688048040	Biological Filtration	61	2.01 x 10^{11}	Trib. Of Afon Machno
Dolgarrog/Talybont STW	SH7756068740	Biological Filtration	477	1.57 x 10^{12}	Conwy
Dolwyd STW	SH8162077760	Septic Tank	Unspecified	Unknown	To Land
Dolwyddelan WWTW	SH7436052421	Biological Filtration	246	8.12 x 10^{11}	The Afon Lledr
Eglwysbach STW	SH8012071020	Biological Filtration	250	8.25 x 10^{11}	Afon Hiraethlyn
Glasfryn STW	SH9181050160	Biological Filtration	13.6	4.49 x 10^{10}	Trib Of Afon Merddwr
Graig STW	SH8024074220	Package Treatment Plant	10.08	3.33 x 10^{10}	Trib Of Nant Garreg Ddu
Groesffordd STW	SH7699075630	Biological Filtration	Unspecified	Unknown	Gyffin
Henrhyd STW	SH7680074800	Biological Filtration	46	1.52 x 10^{11}	Henrhyd
Llan Penmachno STW	SH7950051320	Biological Filtration	174.9	5.77 x 10^{11}	Afon Machno
Llanrwst STW	SH7945761794	Biological Filtration	955	3.15 x 10^{12}	The Afon Conwy
Mountain View STW	SH7997056770	Biological Filtration	Unspecified	Unknown	Conwy
Nebo STW	SH8349156144	Biological Filtration	19.6	6.47 x 10^{10}	Trib. Of Afon Iwrch
Penmaenmawr WWTW	SH7243078800	Biological Filtration	2329.7	7.69 x 10^{12}	Coastal Waters Of Conwy Bay

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
Pentrefelin STW	SH8032074860	Biological Filtration	16.2	5.35×10^{10}	Nant-Y-Garreg Ddu
Pentrefoelas STW	SH8703051390	Biological Filtration	41	1.35×10^{11}	Merddwr
Rowen STW	SH7608071700	Biological Filtration	95.5	3.15×10^{11}	Roe
Trefriw STW	SH7879063280	Biological Filtration	234.6	7.74×10^{11}	Conwy Estuary
Tyn Y Groes STW	SH7852071210	Biological Filtration	62.1	2.05×10^{11}	Conwy Estuary
Ysbyty Ifan STW	SH8445049040	Biological Filtration	47.3	1.56×10^{11}	Conwy

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

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

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

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

The largest and most significant continuous water company discharge is Penmaenmawr WWTW, with a consented dry weather flow of 2,329.7 m^3/day of secondary treated effluent. This discharge is made offshore to Conwy Bay, approximately 1.6 km west of the classified area. Given the large volume of the discharge it is likely to be a significant local influence on water quality in the bay. Its geographic pattern of impacts will depend on water circulation patterns.

There are three water company continuous discharges direct to the middle/upper reaches of the estuary (Tyn Y Groes, Dolgarrog/Talybont and Trefriw STWs). The effluents all undergo biological filtration and together are consented to discharge a dry weather flow of 773.7 m^3/day. There are several discharges located inland discharging to smaller watercourses draining directly to the estuary. Most of these discharge to watercourses draining to the upper reaches of the estuary, so their impacts will be best captured by monitoring points at the upstream end of the shellfish beds. Two small works discharge to the Gyffin/Henrhyd (Groesffordd and Henrhyd STWs), which drains to the west shore of the estuary by the Conwy Bridge. For those discharges located further inland some natural die-off of micro-organisms is likely to occur between the point of discharge and the shellfisheries, depending on river transit times.

In addition to the continuous sewage discharges, there are several intermittent water company discharges associated with the sewerage networks also shown on Figure II.1. Details of these are shown in Table II.3.

Table II.3: Intermittent discharges to the Conwy catchment

No.	Name	Grid reference	Receiving water	Type
1	Betws Y Coed WWTW	SH7954757003	Afon Llugwy	Storm Overflow / Storm Tank
2	Betws Y Coed Muriau PS	SH8000056700	Conwy	Pumping Station
3	Betws Y Coed- Pentre Ddu-SSO	SH7850056600	Llugwy	Storm Overflow
4	Bryn Afon CSO	SH8086660927	Afon Nant-Y-Goron	Storm Overflow
5	Capel Curig Sd.Scheme	SH7376056820	Llugwy	Storm Overflow
6	Conwy Road Storm PS	SH7958077900	Afon Wydden	Emergency
7	Cwm Penmachno – SSO	SH7670047900	Ditch	Storm Overflow

No.	Name	Grid reference	Receiving water	Type
8	Dale Road Storm PS	SH7373083130	Coastal Waters Of Conwy Bay	Pumping Station
9	Deganwy Beach SPS	SH7766079820	Unnamed Ditch	Pumping Station
10	Deganwy PS	SH7779079060	Afon Conwy (Estuarial)	Emergency
11	Deganwy Road	SH7751079730	Conwy Estuary	Storm Overflow
12	Dolgarrog SSO	SH7803066850	Conwy	Storm Overflow
13	Dolgarrog SSO No. 2	SH7735068780	Dulyn	Storm Overflow
14	Dolgarrog Tan Y Ffordd PS	SH7710067200	Conwy	Pumping Station
15	Dolwyddelan WWTW	SH7380052420	Afon Lledr	Emergency and Storm Overflow
16	Eglwysbach STW	SH8012071020	Afon Hiraethlyn	Storm Overflow / Storm Tank
17	Ganol Stw PS	SH8062077320	Afon Ganol	Storm Overflow
18	Ganol WWTW	SH8057577210	Coastal Waters Of Penrhyn Bay	Storm Overflow / Storm Tank
19	Glan Conwy SPS	SH8012076140	Conwy Estuary	Pumping Station
20	Glan Y Mor Pumping Station	SH7992675625	Nant Garreg Ddu	Pumping Station
21	Glanwyddan Pumping Station	SH8197780634	Afon Wydden	Emergency
22	Golf Club House PS B	SH7973056730	Conwy	Storm Overflow
23	Gyffin PS	SH7862077310	Afon Conwy (Estuarial)	Storm Overflow
24	Hendre Road SSO	SH7761076985	Gyffin	Storm Overflow
25	Ind Estate Llandudno Junction	SH7979078520	Unnamed Watercourse	Pumping Station
26	Llan Penmachno STW	SH7950051300	Machno	Storm Overflow / Storm Tank
27	Llandudno Junction Glan Y Mor Road	SH7890078000	Culvert	Storm Overflow
28	Llandudno Junction PS	SH7921077560	Afon Conwy (Estuary)	Emergency
29	Llandudno Llanrhos SPS	SH7910080100	Unnamed Ditch	Pumping Station
30	Llanrwst STW	SH7947761781	The Afon Conwy	Storm Overflow / Storm Tank
31	Llanwrst Old Nursery CSO	SH8007361495	A Trib Of The Afon Conwy	Storm Overflow
32	Marl Drive CSO	SH7973078270	Afon Wydden	Storm Overflow
33	Mill Road SPS	SH7952757016	Afon Llugwy	Emergency
34	Mochdre PS	SH8260079500	Stream	Pumping Station
35	Morfa PS	SH7800078300	Conwy Estuary	Emergency
36	Near PS No 2	SH7802064490	Afon Conwy	Storm Overflow
37	Penmaenmawr WWTW	SH7353077800	Gyrach	Pumping Station
38	Penmaenmawr WWTW	SH7322078110	Coastal Waters Of Conwy Bay	Storm Overflow / Storm Tank
39	Penrhyn Bay Llandudno Road -	SH8250080900	Ganol	Storm Overflow
40	Penrhyn Bay Llandudno Road -	SH8243080940	Un-Named Stream	Storm Overflow
41	Pentrefoelas – SSO	SH8710051500	Merddwr	Storm Overflow
42	Quay PS	SH7824077780	Afon Conwy	Emergency
43	Rhoslan PS	SH7728081720	Coastal Waters Of Conwy Bay	Storm Overflow

No.	Name	Grid reference	Receiving water	Type
44	St. Agnes Road CSO	SH7778176942	Gyffin	Storm Overflow
45	Trefriw STW	SH7879063280	Grafnant	Storm Overflow / Storm Tank
46	Tyn Y Groes STW	SH7854071210	Conwy	Storm Overflow / Storm Tank
47	Waterloo Pumping Station	SH7974955979	Afon Conwy	Pumping Station
48	West Shore PS	SH7569082500	Conwy Bay	Emergency
49	Woodlands PS	SH7982079500	Afon Wydden	Storm Overflow
50	Ellis Way Ps Conwy Marina Village	SH7748078590	Afon Conwy via surf wtr sewer	Pumping Station
51	Morfa Drive Ps (Emergency) Conwy ,	SH7755578286	Conwy	Pumping Station
52	Mud Flats Site Junction A546 & A55	SH7930077700	Afon Wydden	Storm Overflow
53	Ps At Ty Gwyn Ind Estate Llanrwst	SH8040060900	Nant y Goron	Storm Overflow
54	Sps Serving Former Hotpoint Site	SH8023577615	Jacksons Stream	Pumping Station

There are 54 intermittent discharges in the area. No spill records were available for any of these assets at the time of writing and as such it is difficult to assess their impacts aside from noting their locations and their potential to spill storm sewage. Discharges from storm overflows tend to operate following rainfall events which can inundate sewers. Emergency overflows occur following failures (blockages, power cuts etc) and are rare occurrences if the asset is working correctly.

Many discharge to the River Conwy and tributaries, so any effluent spilled will be delivered to the estuary upstream of the fishery. There is a more concentrated cluster of 24 intermittent discharges around the mouth of the estuary around Conwy, Llandudno Junction and Deganwy, and five which are coastal or offshore in Conwy Bay. Those discharges located around the outer estuary are of most potential significance by virtue of their location. Ganol WWTW storm overflow receives UV disinfection which should result in a significant reduction in the bacterial content of any spills from this asset.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also a number of private discharges. Where specified, these are generally treated by small package treatment works such as package plants, and the majority of these are small, serving one or two properties. All permitted private sewage discharges are mapped in Figure II.1, and Table II.4 presents details of those consented to discharge more than 5 m^3/day to water.

Table II.4: Details of private sewage discharges >5 m³/day to the Conwy catchment

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Advance Factories STW	SH8085077520	Package Treatment Plant	12	Afon Ganol West
B	Berthlwyd Hall Holiday Park	SH7639075720	Unspecified	21	Unnamed Trib. Of Afon Henrhy
C	Bodnant Garden – NT	SH7967472388	Membrane Filtration	26	Afon Hiraethlyn
D	Bodnant Garden – NT	SH7974172252	Package Treatment Plant	13.4	Afon Hiraethlyn
E	Bodnant Welsh Food Centre	SH7967272385	Package Treatment Plant	17.3	Afon Hiraethlyn
F	Caer Rhun Hall	SH7775070680	Package Treatment Plant	17.1	Unnamed Trib Of River Conwy
G	Conway Road Llandudno Junction	SH8023077580	Unspecified	5	Jackson's Stream
H	Conwy Touring Park	SH7816075280	Unspecified	100	Unnamed Trib Of A.Conwy
I	Ffordd Maelgwyn Llandudno Junction	SH8026077460	Unspecified	1	Jackson Stream Llandudno Junct
J	Fron Dawel & Cartrefle Marine Drive	SH7644082400	Unspecified	5	Conwy Estuary
K	Gorse Hill Caravan Park Trefriw Roa	SH7818075210	Unspecified	60	Unnamed Trib.Of A.Conwy
L	Lledr Hall Outdoor Education Centre	SH7584653856	Package Treatment Plant	7	River Lledr
M	Maenan Abbey Caravan Park	SH7880065740	Septic Tank	17.5	Abbey Stream
N	Maenan Abbey Hotel	SH7888165704	Package Treatment Plant	11	Abbey Stream
O	Oakwodd View Nursing Home	SH7601076350	Package Treatment Plant	6	Unnamed Trib. Of Afon Gyffin
P	Septic Tank At Caseg Fraith	SH6843260225	Septic Tank With Conversion Unit	5	Afon Llugwy
Q	ST & Reedbed Serving Gwern Gof Isaf	SH6856460215	Reedbed	5	Afon Llugwy
R	Swallow Falls Hotel	SH7651057740	Package Treatment Plant	9.9	Afon Llugwy
S	The Oaklands Centre	SH8110058400	Package Treatment Plant	8.1	Afon Gallt Y Gwg
T	Training Camp Capel Curig	SH7510057300	Package Treatment Plant	90	Afon Llugwy

Altogether there are 1,269 private discharges within the Conwy catchment, including some that have recently been registered by NRW but are not yet recorded on the discharge permits database. The vast majority of these are to soakaway and, provided systems are working correctly, these should be of no impact on coastal waters. Of those discharging to water, most are to watercourses that drain to the estuary upstream of the fishery. This includes two relatively large private discharges from caravan parks to the middle reaches of the estuary (H and K). The treatment method is unspecified on the permit database and as such the effluent quality is uncertain. There are a further two small private discharges to the estuary just south of the Conwy Bridge, and one just north of it. There are three small private discharges to the Conwy Morfa Drive Stream that drains to the estuary just south of the Conwy Marina. There is also a cluster of private discharges on the shore of Conwy Bay just south of Great Orme. Most of these discharge to soakaway, although three discharge directly to the sea, including one consented to discharge up to 5 m^3/day (J).

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

The majority of agricultural land within the catchment is grassland with rough grazing for sheep in the upper reaches and more productive land supporting a mix of sheep and cattle in the lower lying areas. There is also a small amount of cropping (Figure 1.2). Numbers and overall densities of livestock as recorded in the 2012 agricultural census are presented in Table III.1. This data attributes each farm to a single point, whereas in reality farms may span the catchment boundary. It should nevertheless give a reasonable indication of numbers and types of livestock in the survey area.

Table III.1: Summary statistics from 2012 livestock census within the survey catchment

Cattle		**Sheep**		**Pigs**		**Poultry**	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
18,567	31.4	348,766	589.4	156	0.3	41,668	70.4

Data from Welsh Government.

Sheep farming is ubiquitous, with almost 350,000 animals. There are also significant numbers of cattle and some poultry farmed within the catchment. The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table III.2.

Table III.2: Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

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

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

Faeces from grazing animals will be deposited directly onto farmland, and Slurry and manure from housed livestock will be spread on agricultural land as a fertiliser. Sewage sludge is also occasionally applied as a fertilizer within the lower reaches of the catchment, with 21 individual applications recorded by Natural Resources Wales from January 2009 to May 2013. There may therefore be some impacts arising from the periodic application of organic fertilizers to grassland and crops as well as from deposition by grazing animals.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the survey will be highly variable and depend on rainfall. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Most, if not all significant watercourses are expected to be impacted to some extent by agriculture. The largest and most consistent fluxes of indicator bacteria into coastal waters are anticipated to arise from fields where grazing animals have access to watercourses, particularly if this is in close proximity to the coast.

As well as significant day to day variation driven by rainfall there is likely to be some seasonal differences in the fluxes of faecal indicator bacteria of agricultural origin into the survey area depending on seasonal fluctuations in livestock numbers and the timing of manure and slurry applications. In warmer weather, grazing animals are more likely to access watercourses to drink. It is likely that a significant number of sheep are moved from higher ground to lower ground during the winter. During winter cattle may be housed and during this time slurry and manure will be stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are more likely to spread during the winter. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application.

Appendix IV. Sources and variation of microbiological pollution: Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within the survey area. Boat traffic is limited to recreational craft such as yachts and cabin cruisers, as well as a few fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

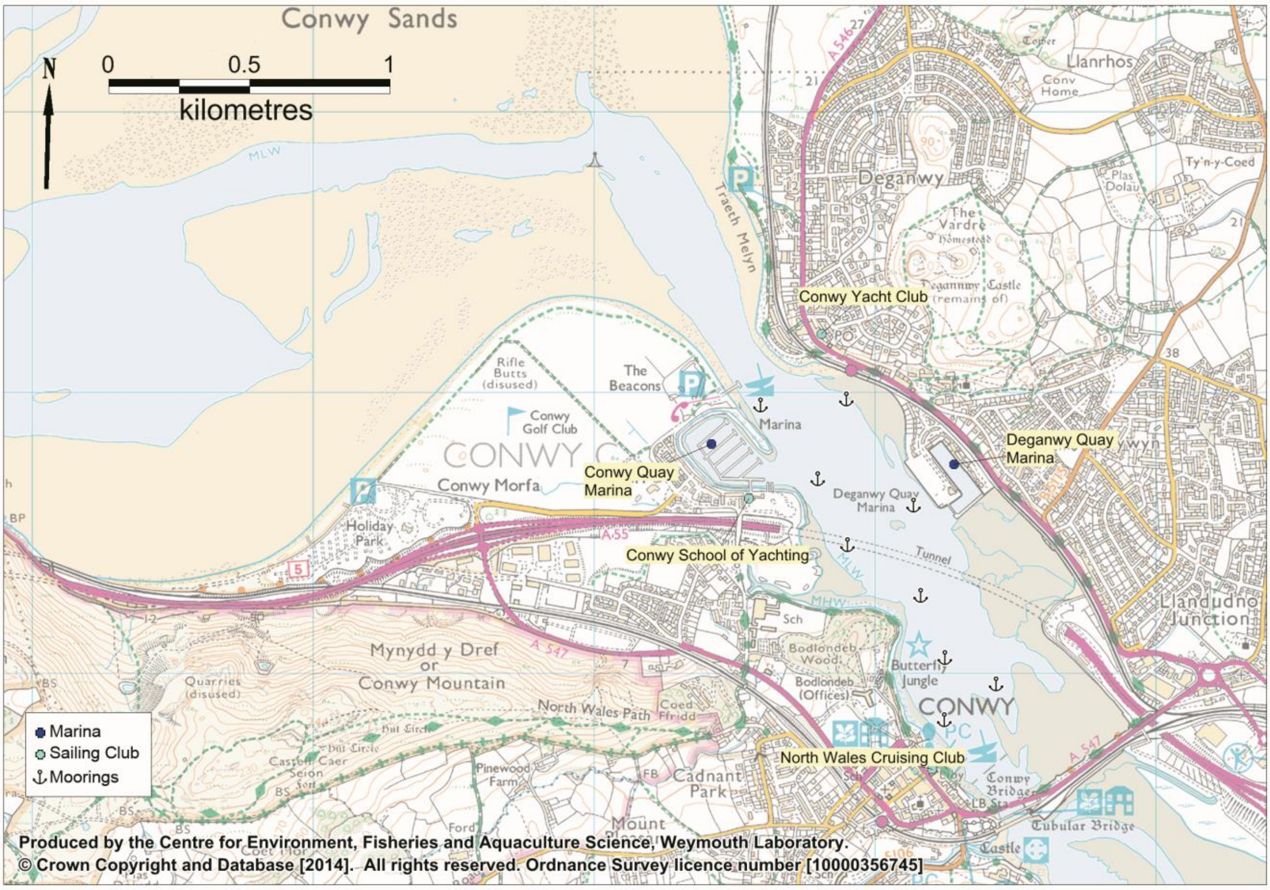

Figure IV.1: Boating activity in the Conwy survey area

There are two marinas within the survey area, the Deganwy Quay which holds 500 pontoon berths and Conwy Quay which holds 165 berths for recreational vessels (Quay Marinas, 2010). They are impounded by flap gates to maintain water levels at low tide, so exchange of water within them is limited to higher states of the tide. Both have sewage pump out facilities. In addition to this there are numerous swinging and pontoon moorings located in the sheltered waters of the Conwy downstream of the Conwy Bridge and predominantly along the west shore.

There are three yacht clubs which offer racing and cruising for both yachts and the smaller sailing dinghies. Other water sports such as kayaking, windsurfing and jet skiing are more popular around the headland in Colwyn Bay. However, water sports of this nature are taken place on vessels which are too small to contain onboard toilet facilities so should not make overboard discharges.

There are no commercial ports within Conwy Bay or the estuary and therefore it is unlikely that commercial vessels will enter the survey area. In addition to this merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land[1].

There is a small fishing fleet in the area, of which 9 fishing vessels under 10 metres and 1 vessel over 10 metres are listed as having Conwy as their home port (MMO, 2014). Their fishing patterns are uncertain but they will navigate through the outer estuary and the approach channel on a regular basis.

It is therefore concluded that boat traffic in the area consists of large numbers of pleasure craft and a handful of fishing vessels, so the impacts from boat traffic may be of potential significance to the fishery. Private vessels such as yachts, motor cruisers and fishing vessels of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the area. Both marinas contain sewage pump out facilities which should help to eliminate overboard discharges in the marina. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the moorings and the main navigation routes to the estuary are most at risk of contamination from this source. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

[1] The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The Conwy estuary encompasses a wide range of marine habitats including large expanses of intertidal sand and mud flats, sand banks sand dunes, a wetland area and salt marsh. Consequently it is protected by several international and national environmental legislations including part of the Menai Strait and Conwy Special Area of Conservation (SAC), Sites of Special Scientific Interest (SSSI), and several Local Nature Reserves. Snowdonia National Park forms over half of Conwy's hydrological catchment.

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). An average monthly count of 3,722 waterbirds (wildfowl and waders) was reported during the winter of 2011/12 for the Conwy estuary and Conwy Sands (Austin et. al, 2014). Overwintering species include oystercatchers, redshank, teal, lapwing, curlew and dunlin.

Grazers, such as geese and ducks will mainly frequent the grassland and saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas or watercourses draining pastures will be best located to capture contamination from this source. Waders, such as dunlin and oystercatchers forage upon shellfish and so will forage (and defecate) directly on any shellfish beds on the intertidal. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but this will probably vary from year to year. Contamination via direct deposition may be patchy, with some shellfish containing high levels of *E. coli* while others a short distance away are unaffected. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence particularly during the winter months.

In addition to overwintering waterbirds, seabirds such as gulls and terns are also present in the area. The main breeding colony is at Great Orme, where a total of 2,198 individuals were recorded during a survey during the late spring/early summer of 2000 (Mitchell *et al*, 2004). Additionally, a further 218 breeding individuals were recorded in various locations around the outer estuary (Conwy, Conwy Mountain and Deganwy). Seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal. As there are no large colonies in the immediate vicinity of the shellfisheries, the presence of seabirds will have no bearing on the sampling plan.

It has been estimated that there are around 365 grey seals in North Wales (Westcott & Stringell, 2004). No formal counts or haul out locations have been identified within the Conwy estuary or Conwy Bay. The closest recorded haul out site is 10 km west on Puffin Island where seal numbers range from around 11 to 130, with the highest numbers recorded in the winter. Seals will forage widely and it is highly likely that they enter the bay/estuary from time to time, particularly during the main period of return migration of salmon and sea trout in summer and autumn. However, away from their haul-out sites their impacts may be considered as spatially diffuse and unpredictable, so their presence will have no bearing on the sampling plan. No other wildlife species which may have an influence on the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

The locations of the Capel Curig (upper catchment) and Maes Du Logger (lower catchment) weather stations are shown in Figure VI.1. The monthly rainfall data for these stations are shown in Figure VI.2 and Figure VI.3.

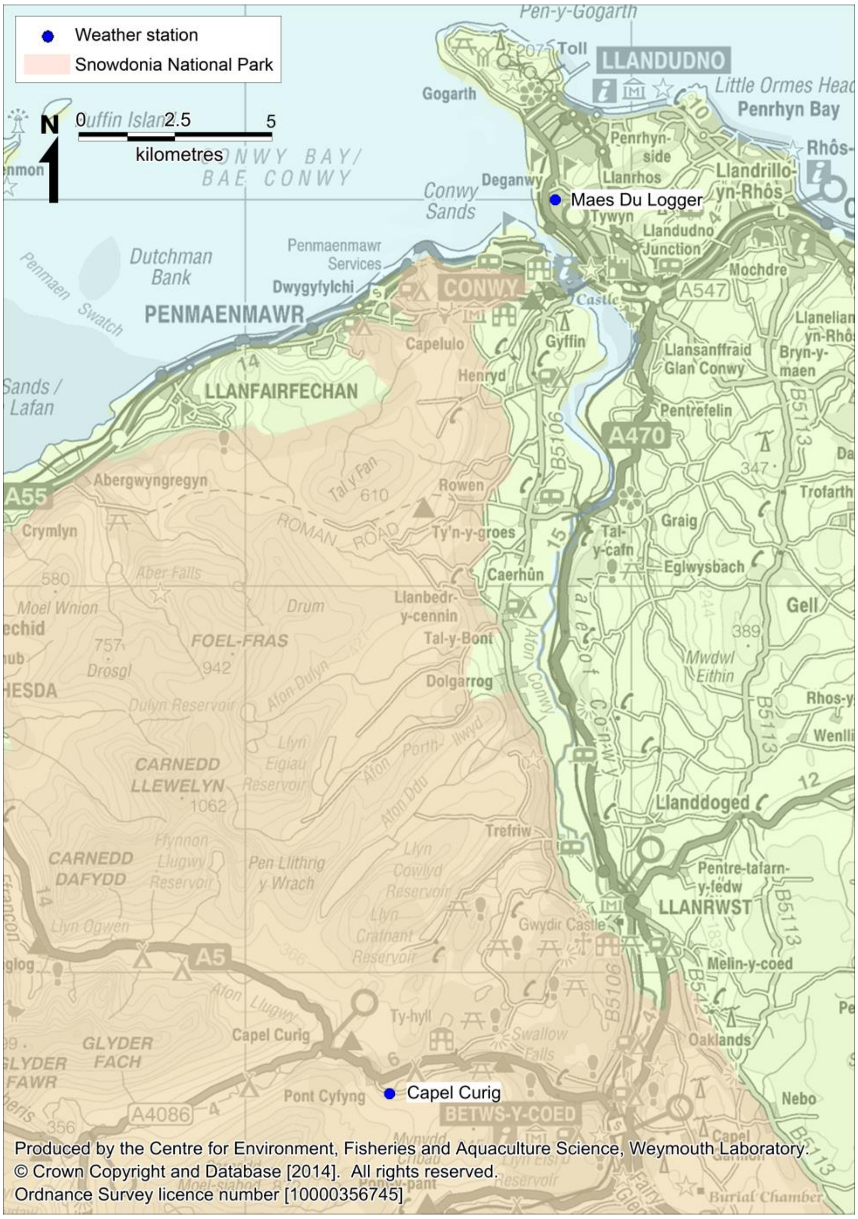

Figure VI.1: Locations of the Capel Curig and Maes Du Logger weather stations

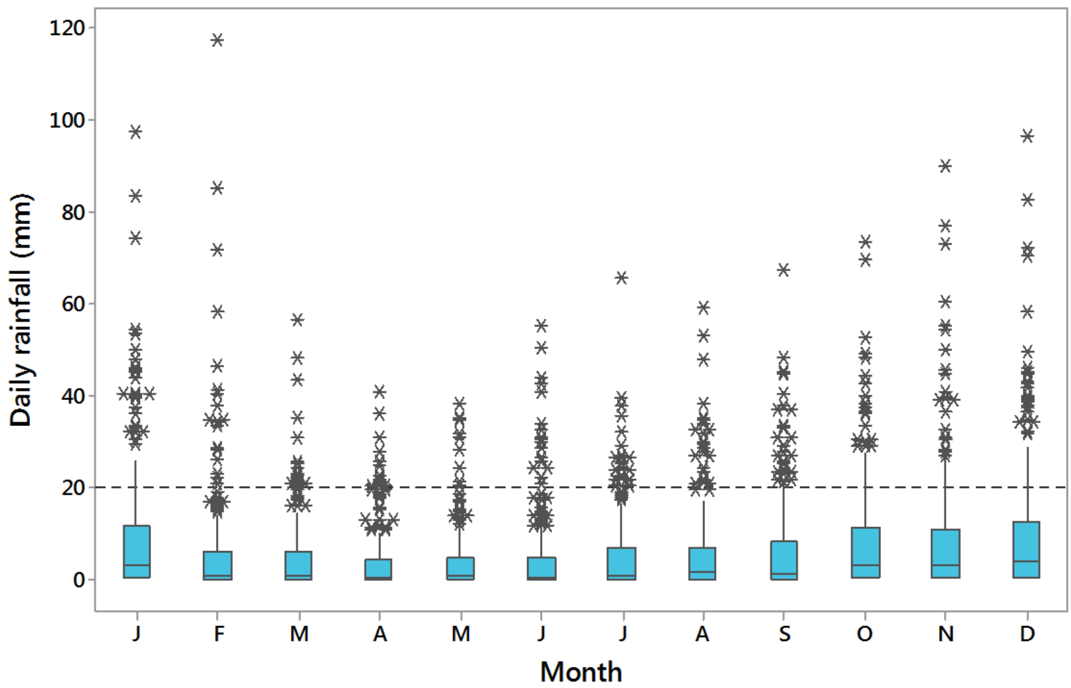

Figure VI.2: Boxplot of daily rainfall totals at Capel Curig, January 2004 to December 2013.
Contains Natural Resources Wales information © Natural Resources Wales and database right

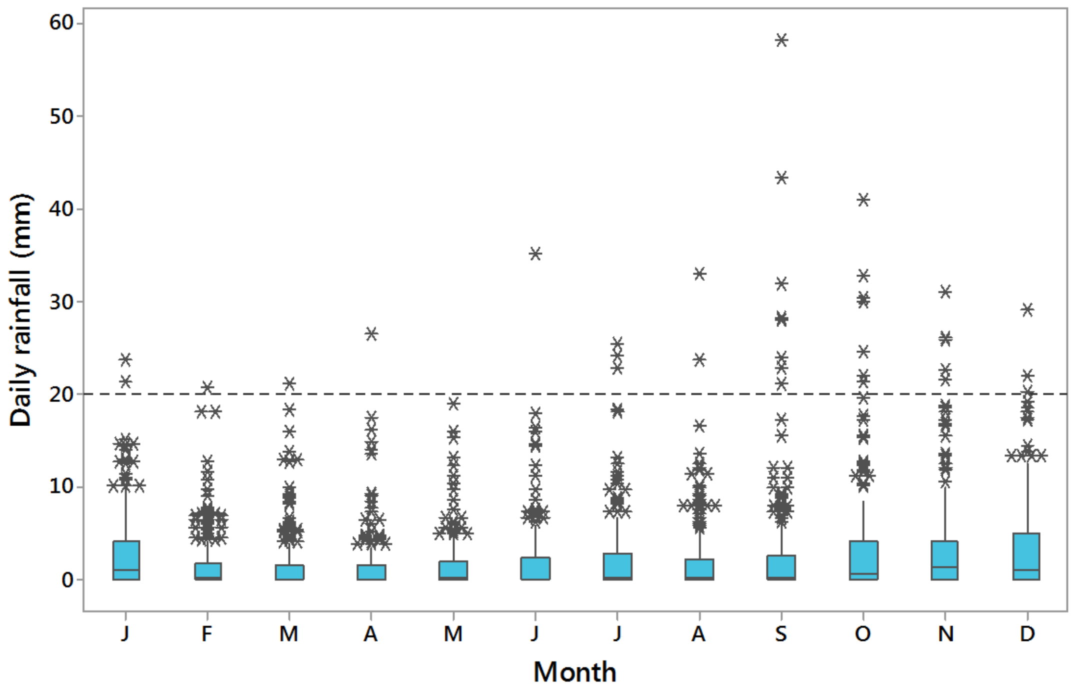

Figure VI.3: Boxplot of daily rainfall totals at Maes Du Logger, January 2004 to December 2013.
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The Capel Curig and Maes Du Logger weather stations received an average of 2441 mm and 979 mm per year respectively between 2004 and 2014. Rainfall data from both stations indicate some seasonal variation with heavier average rainfall in winter at Capel Curiog and autumn and winter at Maes Du Logger. At both Capel Curig and

Maes Du Logger, December had the highest average rainfall. Daily totals of over 20 mm were recorded on 9.1% of days at Capel Curig and 1.2% of days at Maes Du Logger. No rainfall was recorded on 32% and 41% of days between 2004 and 2014 at Capel Curig and Maes Du Logger respectively.

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

Appendix VII. Meteorological Data: Wind

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

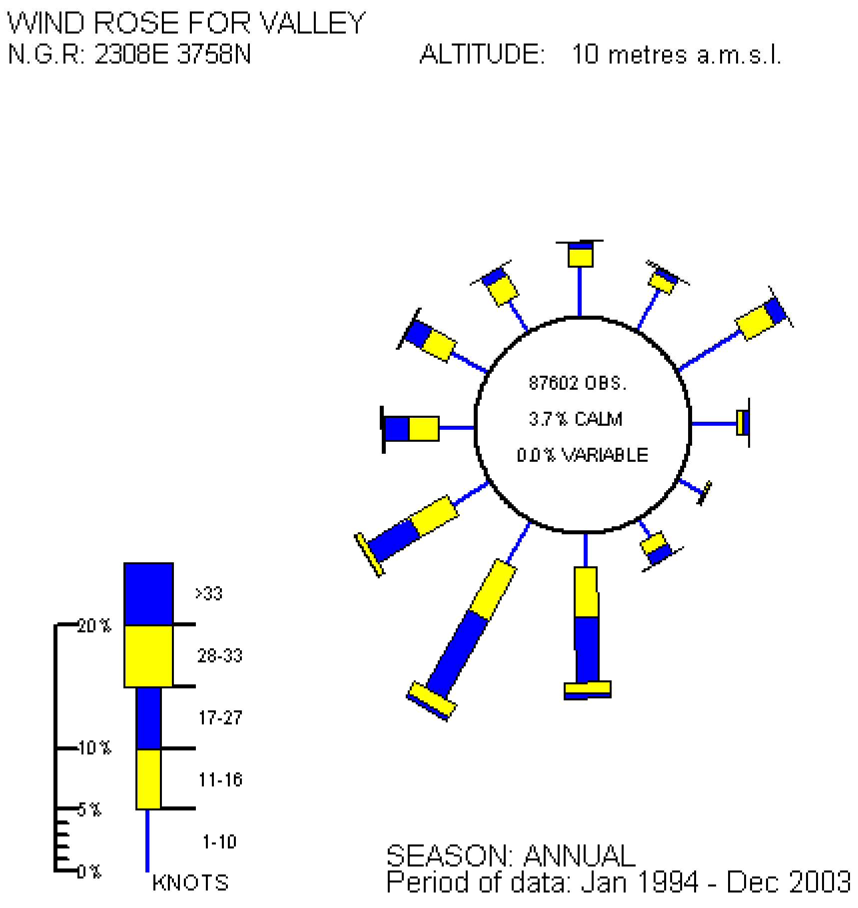

Figure VII.1: Windrose for Valley

Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The annual wind rose for Valley is typical of coastal locations in Wales. The prevailing wind is from the south west throughout the year but there is also a high frequency of winds from the north east in the spring. Conwy Bay faces north west and is afforded some shelter from the prevailing winds by Anglesey and the mainland. The estuary has a narrow north west facing mouth so will be more sheltered than the Bay. It lies in a steep sided valley which will tend to funnel winds up and down it.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The hydrological catchment draining into Conwy Bay and estuary is about 592 km² (Figure VIII.1). The vast majority (>90%) of this area drains to the Conwy estuary upstream of the shellfishery.

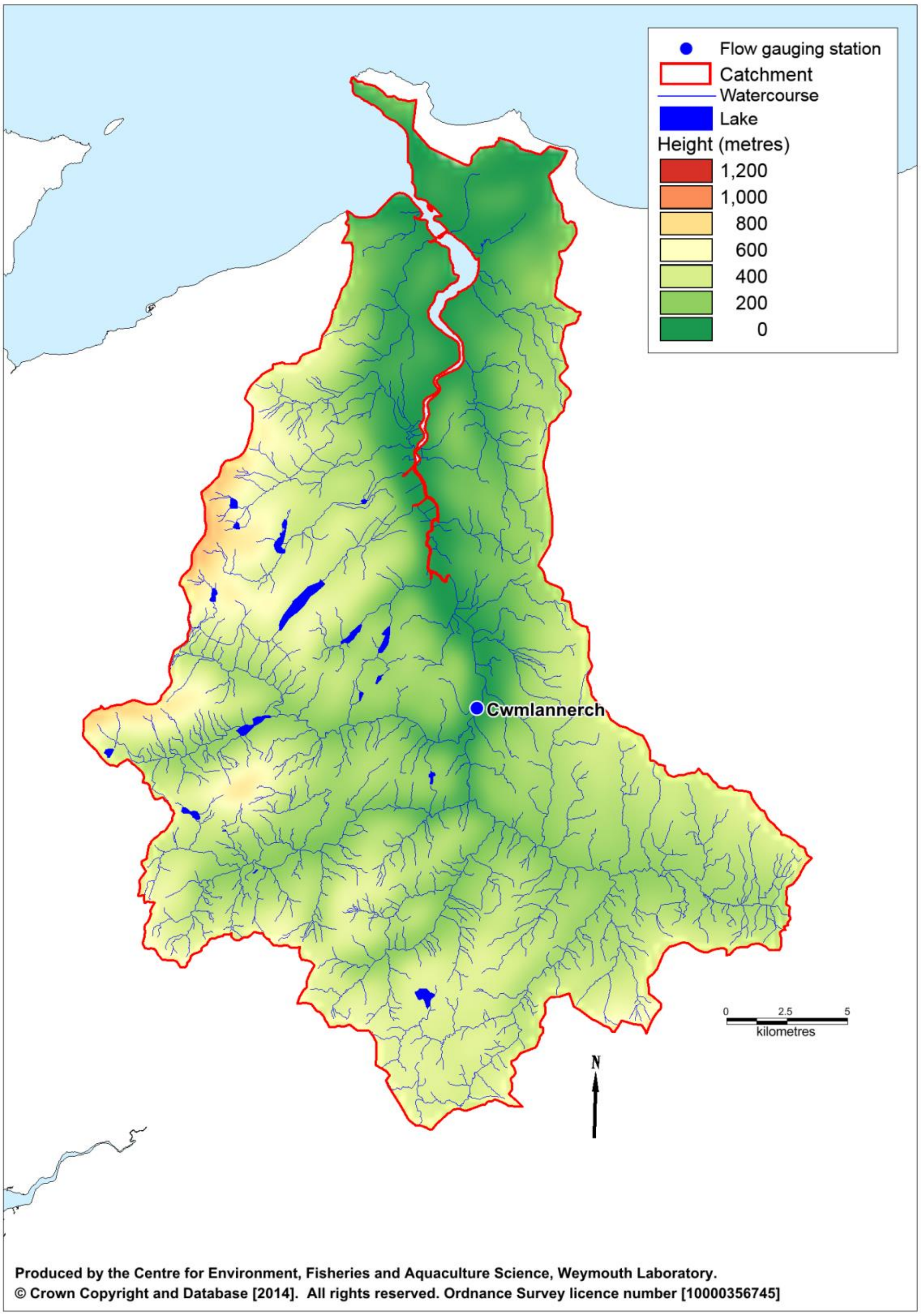

Figure VIII.1: Main watercourses in the Conwy catchment

The principle watercourse is the River Conwy, which drains to the head of the estuary. There are also several smaller watercourses draining to the estuary at intervals, but little in the way of freshwater inputs direct to Conwy Bay in the vicinity of the fishery. Pasture is the principle land cover type. The catchment is underlain with impermeable geology, and is steep and hilly, rising to a maximum elevation of just over 1,000 m. As such, a high proportion of rainfall is likely to run off, and watercourses will have very variable flows and respond rapidly to rainfall. In some of the upland tributaries in the west of the catchment there are reservoirs which are likely to buffer flows to some extent.

The flow gauging station furthest downstream on the River Conwy is located at Cwmlannerch, about 7 km upstream of the tidal limit. About 60% of the catchment area drains through this point, including the upland areas where rainfall is highest. Summary statistics for this station are presented in Table VIII.1 where data for mean flow, Q_{95} and Q_{10} cover the period from 2004-2014.

Table VIII.1: Summary flow statistics for the Cwmlannerch gauging station (2004-2014)

Watercourse	Station Name	Catchment Area (Km²)	Mean Annual Rainfall 1961-1990 (mm)	Mean Flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Conwy	Cwmlannerch	344.5	2,055	20.2	1.53	49.1

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow).

Data from NERC, 2012 and Natural Resources Wales.

Flow is highly variable, with the Q_{10} exceeding the Q_{95} by a factor of about 30.

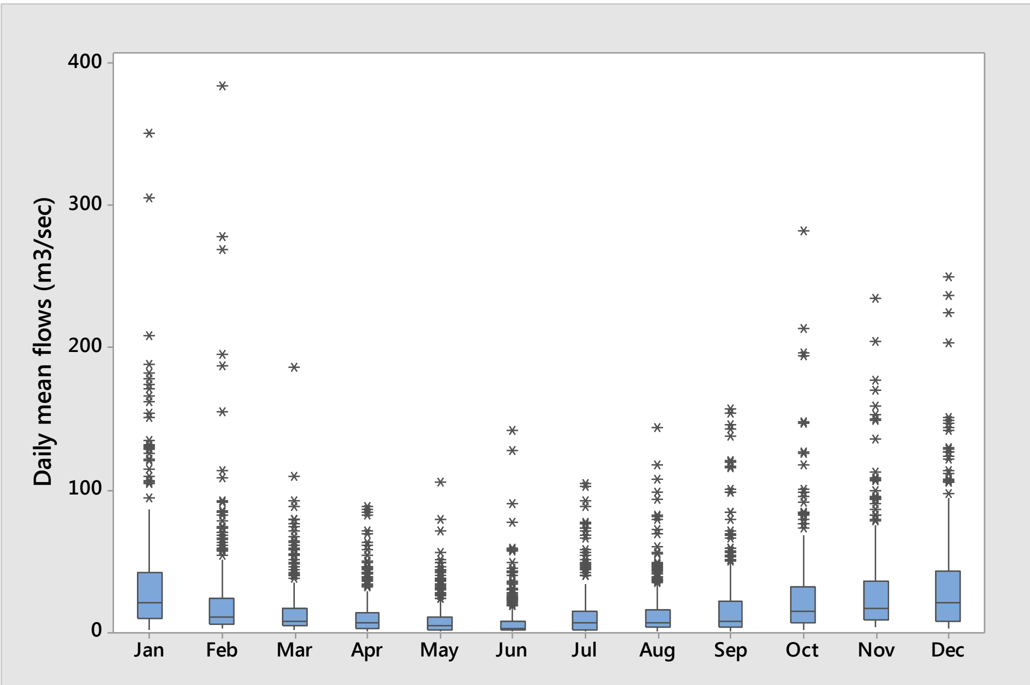

Figure VIII.2: Boxplots of mean daily flow records from the Cwmlannerch gauging station (2004 – 2014)

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As well as significant day to day variation in response to rainfall, a seasonal pattern of higher discharge rates in the autumn and winter is apparent in Figure VIII.2. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

Whilst runoff delivered to the upper estuary via the River Conwy and other watercourses is a highly significant contaminating influence throughout the survey area, there are several smaller freshwater inputs more local to the fishery. These may create localised 'hotspots' of contamination and so require consideration in the sampling plan. Some bacteriological testing results were available for some of these watercourses, deriving from Natural Resources Wales investigative sampling, and samples and spot flow measurements taken during the shoreline survey.

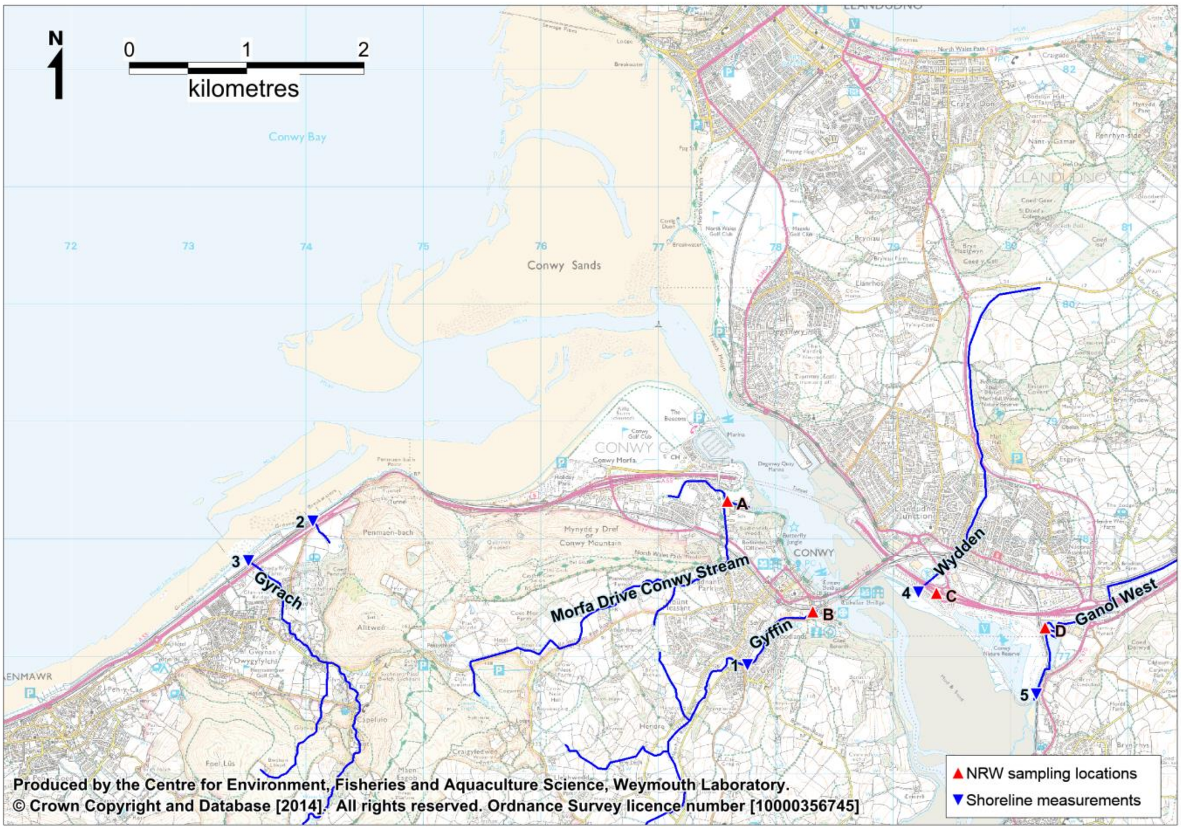

Figure VIII.3: Streams local to the fishery and bacteriological sampling locations.

Table VIII.2: Water sample results from the shoreline survey, measured discharge flow rates and calculated *E. coli* loadings

Ref	Description	Discharge (m³/sec)	*E. coli* (cfu/100 ml)	*E. coli* loading (cfu/day)
1	Gyffin	0.0245	3,500	$7.4x10^{10}$
2	Unnamed outfall	0.0001	6,100	$5.3x10^{8}$
3	Gyrach	0.0191	1,100	$1.8x10^{10}$
4	Wydden	Not measured	940	-
5	Ganol West	Not measured	15,000	-

The Gyffin and Gyrach were delivering bacterial loadings of potentially local significance at the time of shoreline survey. The Wydden and Ganol West outfalls were sampled but not measured, although photographs taken by the surveyor suggest that flow was quite low at both. The Ganol West was carrying a high concentration of *E. coli*. Morfa Drive Conwy Stream was neither sampled nor measured.

The Natural Resources Wales investigations took place between July 2008 and March 2009. Results from samples taken from the lowest site on each watercourse discharging to the outer reaches of the estuary are presented in Table VIII.3.

Table VIII.3: Results of investigative samples from selected sampling points

Site	No.	Faecal coliforms presumptive (cfu/100 ml) Mean	Minimum	Maximum	Average salinity (ppt)
A (Morfa Drive Conwy Stream)	14	675	<10	3,4000	12.8
B (Gyffin at Castle Bridge)	30	7,535	1,000	>100,000	1.1
C (Wydden d/s British Rail)	28	11,298	132	>100,000	7.7
D (Ganol West)	29	2,339	99	>100,000	2.3

Salinities indicate that some of these monitoring points are in the tidal reaches of their respective watercourses, and there are no accompanying discharge measurements. The results demonstrate the variable nature of faecal indicator organism concentrations in watercourses and show high average concentrations in the Gyffin and Wydden, both of which enter the estuary immediately to the south of the Conwy Bridge.

Appendix IX. Hydrography

IX.1. Bathymetry

The survey area includes the inner reaches of Conwy Bay, and the adjacent estuary of the River Conwy. The two may be regarded as hydrographically distinct from one another, although water is of course exchanged between them. Conwy Bay is an open, north west facing bay with extensive sandy intertidal areas that slope gently into the subtidal. The estuary adjoins the central part of the bay. The main channel connecting the estuary with the open sea has an east-west orientation across the intertidal area, with depths ranging from +0.5 to -4.5 m relative to chart datum. There is a second shallower channel that runs north which is intertidal throughout. Aerial photography (Google) shows a third channel emanating from the estuary in a north westerly direction, although this is not apparent on the chart (Figure IX.1). The main channel and adjacent areas are likely to be most impacted by any plume of more contaminated water draining from the estuary, particularly towards the end of the ebb tide when the plume is likely to be most concentrated.

The Conwy estuary is a narrow, steep sided drowned river valley of about 21 km in length, of which only the outermost reaches are shown on the nautical chart. It covers an area totalling 764 Ha of which around 82% is intertidal (Futurecoast, 2002). The high proportion which is intertidal will promote flushing, but reduce dilution potential. There is a constriction just inside its mouth (Deganwy Narrows) where it narrows to about 210 m, which will reduce wave penetration from Conwy Bay. The width then increases to around 600 m, before it passes under the Conwy Bridge, where the channel is constrained to an opening of 120 m adjacent to the west shore. At these constrictions tidal streams are likely to accelerate, promoting turbulent mixing. The channel has been scoured to over 10 m deep relative to chart datum at both. Upstream of the bridge the estuary widens to about 1 km with extensive intertidal areas bisected by a meandering river channel. The width then decreases gradually towards the tidal limit, where the estuary consists of a narrow river channel only.

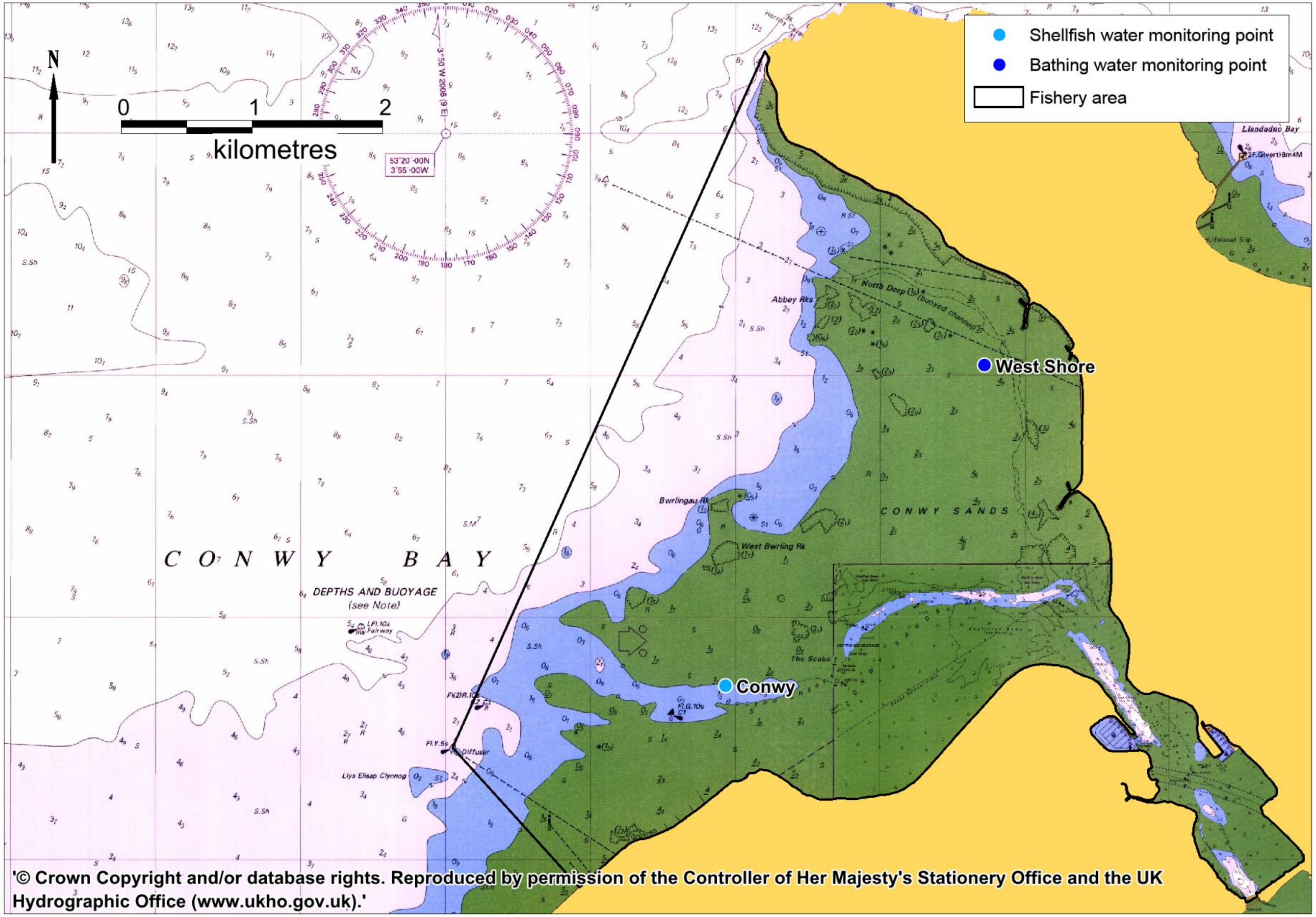

Figure IX.1: Bathymetry of Conwy Bay and the outer Conwy estuary

IX.2. Tides and Currents

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

Table IX.1: Tidal levels and ranges at Conwy

Port	Height above chart datum (m)				Range (m)	
	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Conwy	7.9	6.2	2.6	1.1	6.8	3.6

Data from Admiralty TotalTide©

The tidal range is large, and this will drive extensive water movements through the area. There are no tidal diamonds within either Conwy Bay or the estuary. Despite numerous published hydrographic studies in the general area, no detailed description of tidal streams within Conwy Bay could be found during the literature search. Tidal atlases indicate that tides flood into Conwy Bay from the north west as an offshoot of the main tidal streams passing around the north coast of Anglesey and into Liverpool Bay. During the early flood tide, streams will progress into the Bay and up the main Conwy estuary approach channel. As the level rises water will spread across the intertidal areas from the channel and offshore subtidal area. Effluent from the Penmaenmawr STW sea outfall is likely to be carried in an easterly direction, towards the shellfisheries, during the flood. Flood streams are also likely to align to some extent with the secondary north approach channel once this has filled. The reverse will occur on the ebb, so whilst the ebb plume will impact all around the mouth of the estuary, the most acute impacts will be felt in the main approach channel as low water approaches, when the plume is most concentrated and constrained geographically. The strength of these currents, and hence the distances over which contamination will be carried before the tide reverses are uncertain. A tidal diamond further offshore (~6 km north of Llanfairfechan) indicates tidal excursions of around 9 km on spring tides and 5 km on neap tides.

Tidal streams will move up the estuary on the flood, and back down on the ebb, as confirmed by a dye dispersion study undertaken in the outer estuary (Blackdown Consultants Ltd, 1999). The main flows will tend to follow the main channel. Sources discharging to the estuary shoreline will therefore impact up and down estuary, along the bank to which they discharge. Impacts will decrease with distance as the plume becomes less concentrated. At lower states of the tide contamination from some shoreline sources such as watercourses will follow intertidal drainage channels where the dilution potential is low. There are constrictions at the estuary mouth and the Conwy Bridge where tides will accelerate and there is more scope for turbulent mixing of the water column. During spring tides peak current velocities are 1.85 m/s on flood tides and 1.5m/s on ebb tides whilst on neap tides they are 0.8 m/s on both flood and ebb tides (ABP Marine Environmental Research, 2010). Between the Deganwy Narrows and Conwy Bridge, and just to the south of the bridge, the shallower intertidal areas towards the east bank are likely to experience weaker currents than the deeper areas by the west shore.

Circulation in coastal waters may be modified by density effects arising from freshwater inputs. The mean and maximum flow ratios (river flow:tidal exchange) for the estuary as a whole are high at 0.057 and 1.163 (Futurecoast, 2002). This suggests that some density effects are likely to arise, particularly in the upper estuary and at higher river discharge rates. Neap tides may also accentuate density effects as both tidal current velocities (and hence the extent of turbulent mixing) and the volume of tidal exchange will be lower. When such effects occur, they will result in a shear between surface and bottom currents, with less dense freshwater moving in a net seaward direction at the surface, and a net movement of more saline water up-estuary lower in the water column. Observational studies have generally reported little saline stratification within the estuary however (e.g. Bowers and Al-Barakati, 1997, Simpson *et al*, 2001). An axial convergence has been described in the upper estuary, formed by the higher flood speeds along the centre line of the estuary producing a density maximum and sinking in mid-channel (Nunes and Simpson, 1985). This will promote mixing of the water column during flood tides.

One density effect of potential relevance is that the plume from Penmaenmawr STW will be buoyant so will rise in the water column. This may reduce its impacts to some extent on the benthic shellfish beds, and also render it susceptible to advection by wind driven surface currents.

As land runoff typically contains higher levels of faecal indicator bacteria than seawater, salinity may be a useful indicator of levels of freshwater borne contamination. An overall gradient of decreasing average salinity towards the head is typical within estuaries, and the associated geographic variation in levels of *E. coli* is often a key consideration when developing shellfish hygiene sampling plans. Turrell *et al* (1996) recorded salinity at various stations in the estuary over a 25 day period in September 1986, during which river discharge was relatively low. A large lateral salinity gradient was observed through the estuary, the profile of which changed greatly with tidal state. At the outermost station (2.4 km up-estuary from the mouth) for example, salinity was approaching 35 ppt at high water, but ranged from ~ 5 to ~ 25 ppt at low water. This indicates that mussel beds in the outer estuary will be will be exposed to more contaminated water at lower states of the tide. Given that river discharge may greatly exceed that experienced by Turrell *et al* (1996) it is likely that at times of higher river flow a plume of lower salinity water will extend out into Conwy Bay where the main mussel beds are located.

Repeated salinity measurements made in the bay as part of shellfish water and bathing water monitoring are presented in Figure IX.2. Shellfish waters (Conwy) are monitored throughout the year, whereas bathing waters (West Shore) are only monitored from May to September, so the two datasets are not directly comparable.

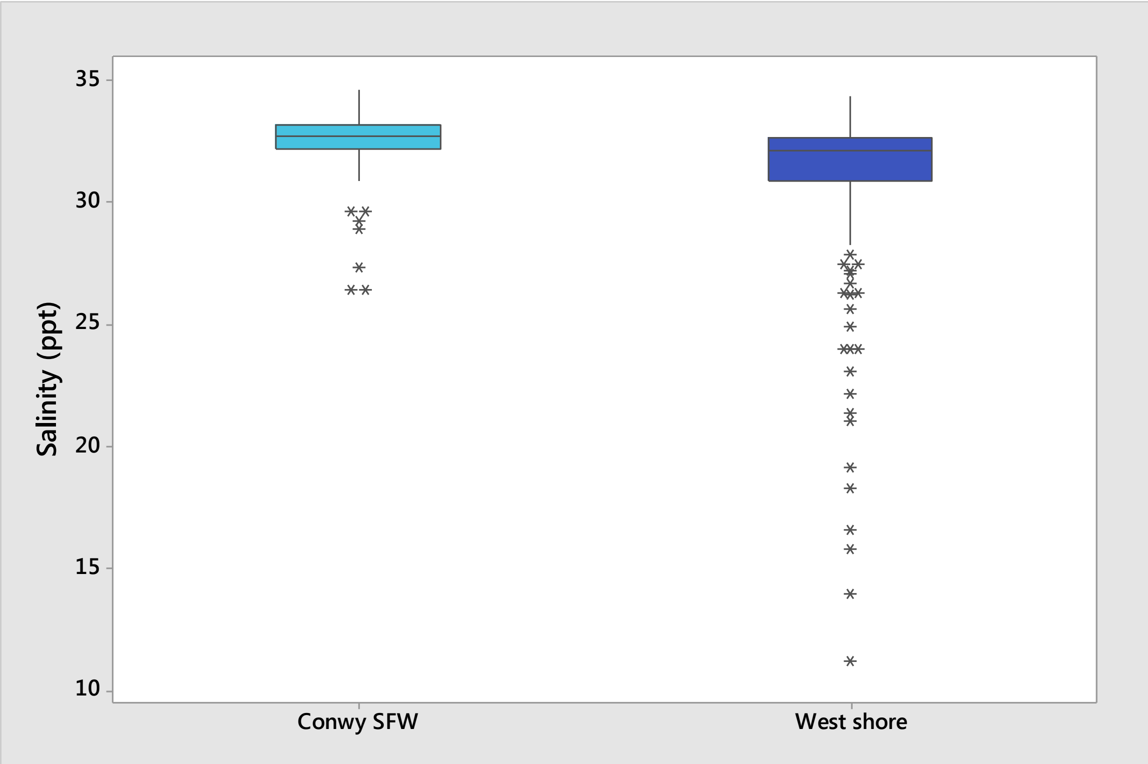

Figure IX.2: Boxplot of salinity measurements at the shellfish and bathing water monitoring points
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Average salinities were 32.5 ppt at Conwy and 30.9 ppt at West Shore suggesting the plume from the Conwy does not often extend out as far as the monitoring points, although lower salinities were recorded occasionally recorded. The West Shore monitoring point recorded lower salinities than the Conwy monitoring point. However, it was sampled more frequently at lower states of the tide whereas the vast majority of samples from Conwy were taken around high water. It is apparent from these results that any plume of less saline water is not restricted to the main estuary approach channel, but also impacts on the secondary north channel, and possibly more widely across the bay.

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive surface water currents of about 0.5 m/s. These create return currents which may travel lower in the water column or along sheltered margins. The area is largely sheltered from the prevailing south westerly winds by the adjacent land. Strong winds from the north west will have the greatest effect on the area. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended. Strong north westerly winds will create significant wave action in the bay, but this is unlikely to penetrate far into the estuary given its narrow mouth.

Appendix X. Microbiological data: Water

X.1. Shellfish Waters

Summary statistics and geographical variation

There is one shellfish waters monitoring site designated under Directive 2006/113/EC (European Communities, 2006) relevant to the Conwy production area. Figure X.1 shows the location of this site. Table X.1 presents summary statistics for bacteriological monitoring results and Figure X.2 presents a boxplot of faecal coliform levels from the monitoring point.

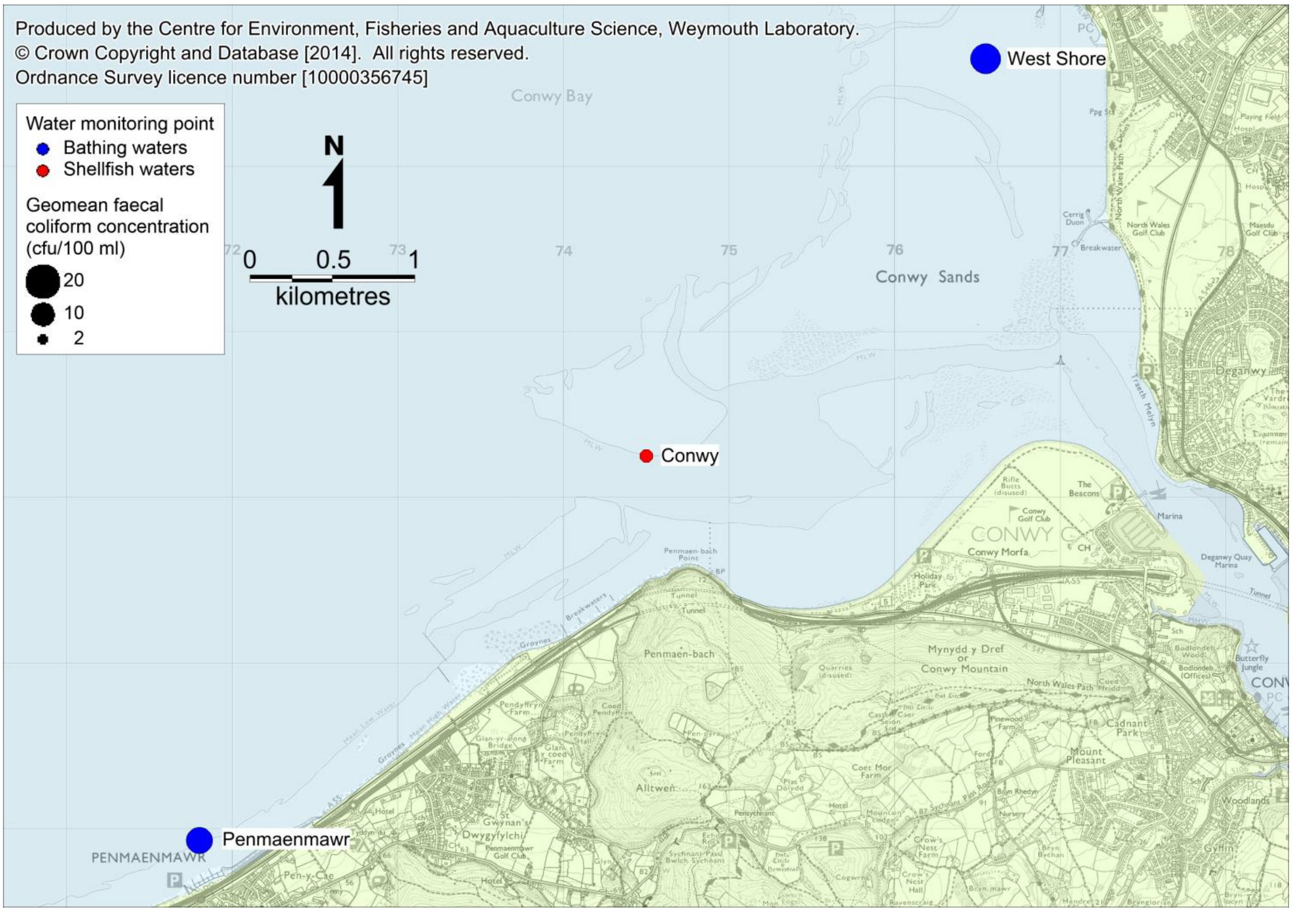

Figure X.1: Water sampling points

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Table X.1: Summary statistics for shellfish waters faecal coliform results, 2004 to 2013 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Conwy	56	05/02/2004	18/11/2013	3.9	<2	251	3.6	0.0

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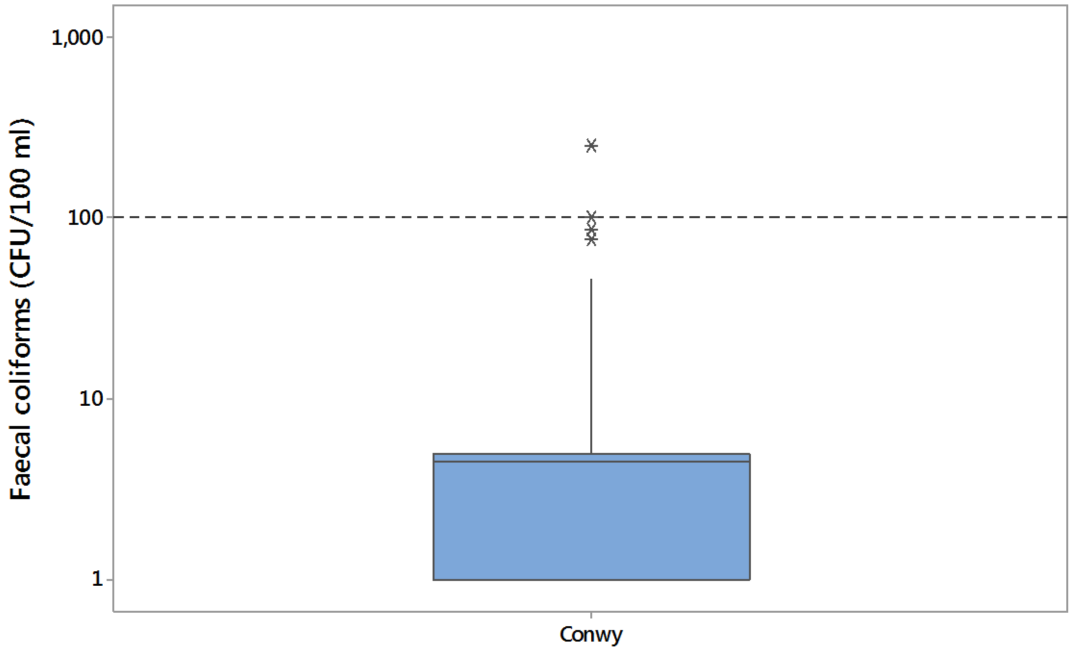

Figure X.2: Box-and-whisker plots of all faecal coliforms results
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Levels of faecal coliforms in the water column were generally very low, although the occasional higher result exceeding 100 cfu/100 ml was recorded.

Overall temporal pattern in results

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

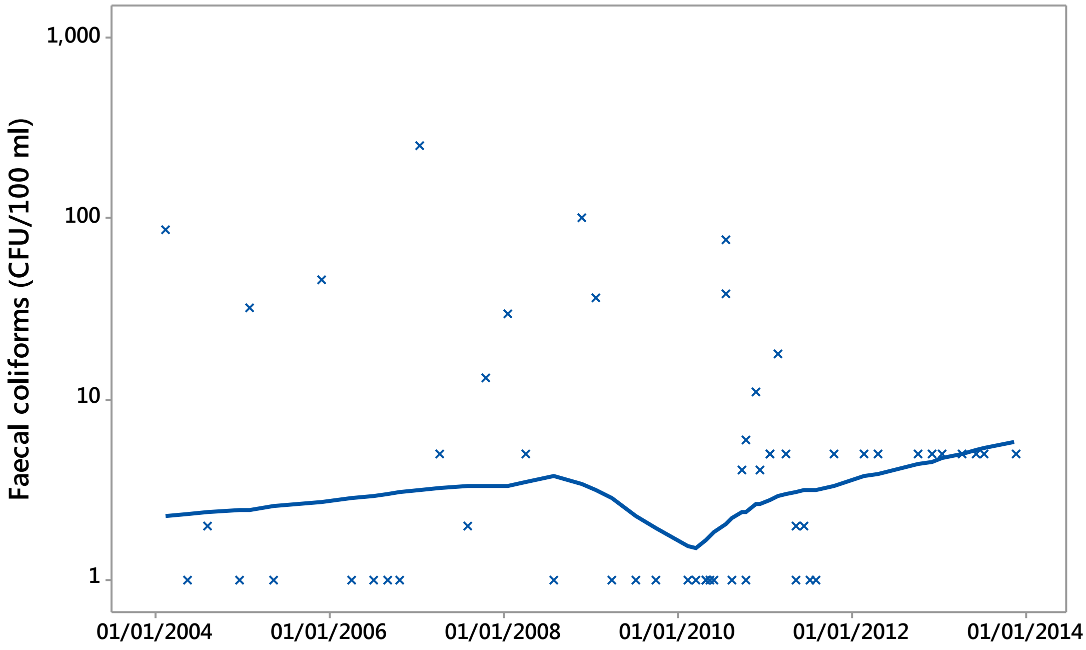

Figure X.3: Scatterplot of faecal coliform results by date, overlaid with loess line
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Faecal coliform concentrations have remained fairly stable on average since 2004. The lower limit of quantification increased from 2 to 10 faecal coliforms/100ml in 2011.

Seasonal patterns of results

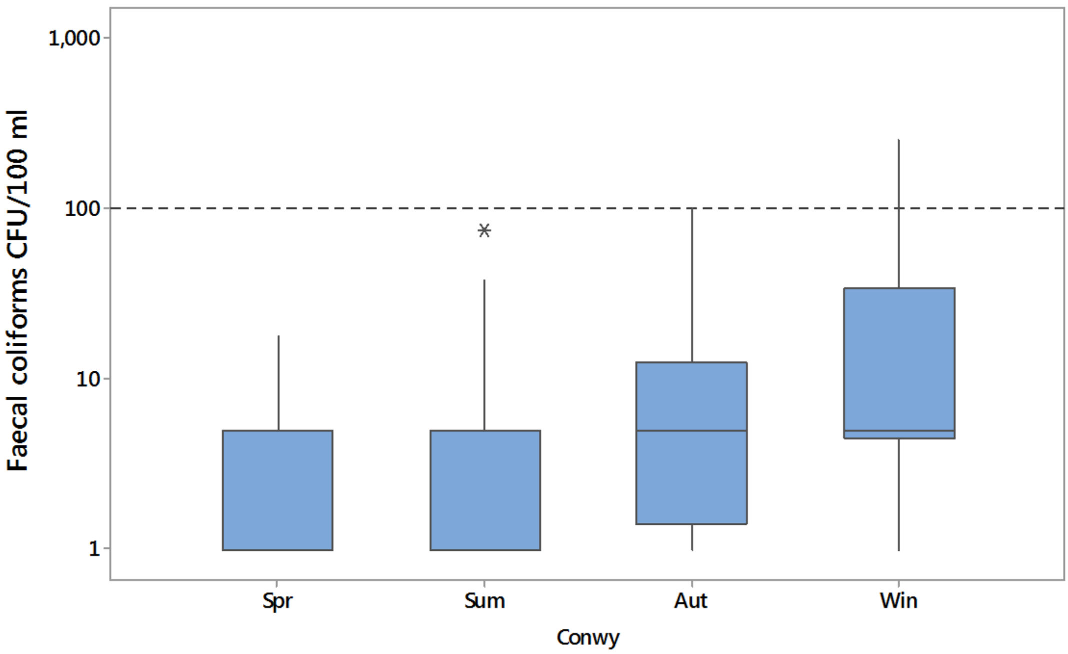

Figure X.4: Boxplot of faecal coliform results by site and season
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One-way ANOVA tests showed that there were significant variations in faecal coliform concentrations between seasons (p=0.010). Post-hoc Tukey tests showed that faecal coliform levels were significantly higher in winter than in spring and summer.

Influence of tide

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

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Conwy	0.511	<0.001	0.449	<0.001

Figure X.5 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle. High water at Conwy is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

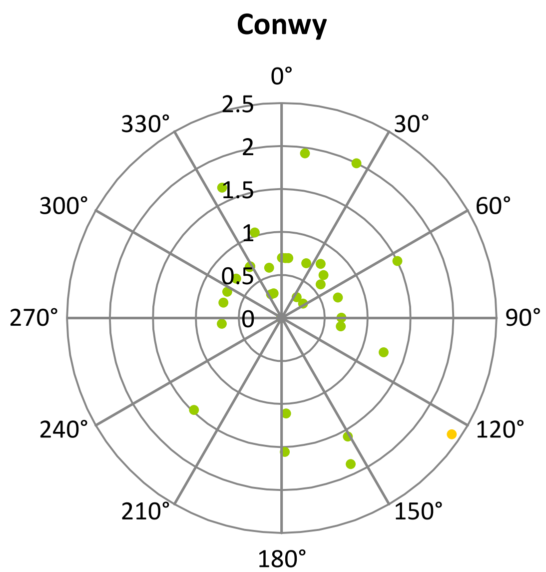

Figure X.5: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for Conwy shellfish waters monitoring point

Higher results tended to occur in samples collected during the second half of the ebb tide indicating that the main contamination sources are located inland.

Figure X.6 presents polar plots of faecal coliform results against the lunar spring/neap cycle, where a statistically significant correlation was found. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

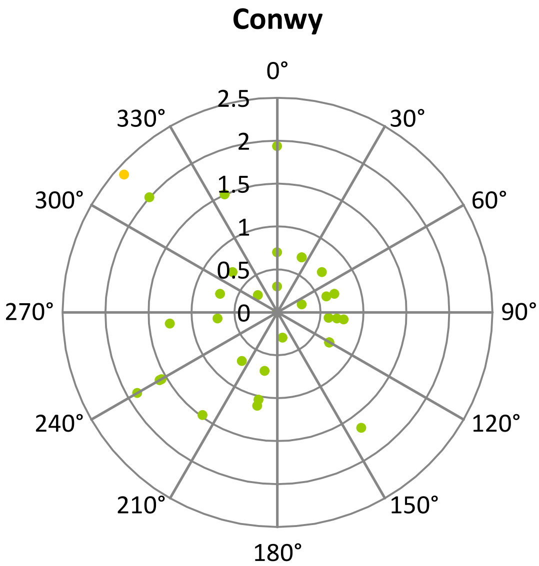

Figure X.6: Polar plot of $\log_{10}$ faecal coliforms against tidal state on the spring/neap tidal cycle for Conwy shellfish waters monitoring point

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Higher results tended to occur during the smaller tides. During the larger tides it is likely that there is a larger degree of mixing and dilution, leading to lower results around spring tides.

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Capel Curig and Maes Du Logger weather stations (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.3: Spearman's Rank correlation coefficients for faecal coliform results against recent rainfall

		Capel Curig	Maes Du Logger
	Site		
	n	51	51
24 hour periods prior to sampling	1 day	0.191	0.021
	2 days	0.158	0.078
	3 days	0.056	0.031
	4 days	0.393	0.405
	5 days	0.324	0.225
	6 days	0.270	0.196
	7 days	0.280	0.226
Total prior to sampling over	2 days	0.183	0.133
	3 days	0.139	0.105
	4 days	0.174	0.146
	5 days	0.250	0.160
	6 days	0.288	0.123
	7 days	0.325	0.128

A significant but delayed influence of rainfall at the inland station (Capel Curig) is apparent. No significant association with rainfall at Maes Du was detected. A large amount of the rainfall records from this station were in the form of monthly rather than daily totals, so a reduced number of samples were included in the Maes Du correlations.

Influence of salinity

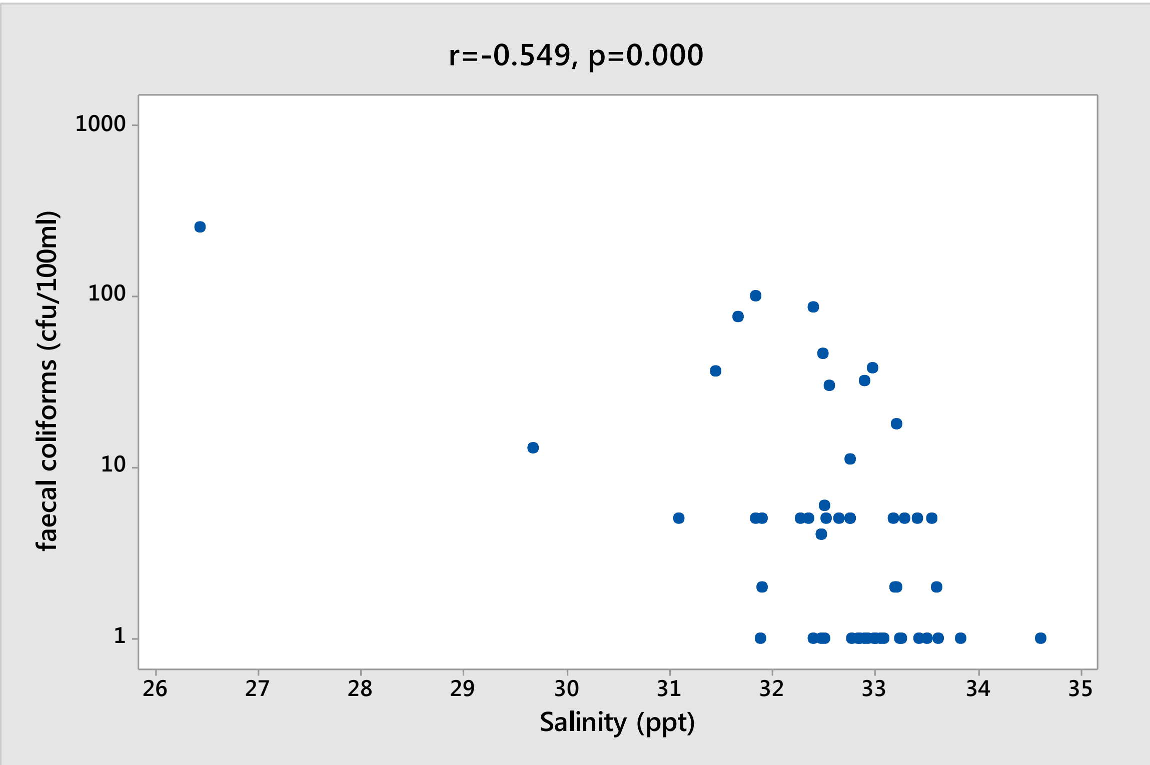

Figure X.1: Scatterplot of salinity against faecal coliforms

A highly significant negative correlation was found between salinity and faecal coliform concentrations. This suggests that land runoff is a significant contaminating factor at the shellfish waters monitoring point.

X.2. Bathing Waters

There are two bathing waters around Conwy designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the locations of which are shown in Figure X.1. Due to changes in the analyses of bathing water quality by Natural Resources Wales from 2012, summary statistics of results by bathing water before and after 2012 are presented separately in Table X.1 and Table X.2 below.

Table X.1: Summary statistics for bathing waters faecal coliforms results, 2004-2011 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
West Shore	164	07/05/2004	23/09/2011	16.0	<2	22,500	18.3	3.0	0.6
Penmaenmawr	162	07/05/2004	18/09/2011	12.7	<2	3,654	14.2	2.5	0.0

Table X.2: Summary statistics for bathing waters *E. coli* results, 2012-2014 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
West Shore	42	08/05/2012	01/05/2014	41.1	<10	>10,000	26.2	11.9	2.4
Penmaenmawr	41	08/05/2012	01/05/2014	26.8	<10	1,000	24.4	2.4	0.0

Average bacterial concentrations increased following the implementation of *E. coli* monitoring. This suggests a decline in water quality as *E. coli* are a subset of the faecal coliforms. It must be noted that the limit of quantification increased from 2 to 10 cfu/100 ml following the change, and this would have an influence on the averages. Due to the relatively restricted number of results available post 2012, only the extended 2004-2011 data are used in the further analyses below. Figure X.2 presents box plots of these data.

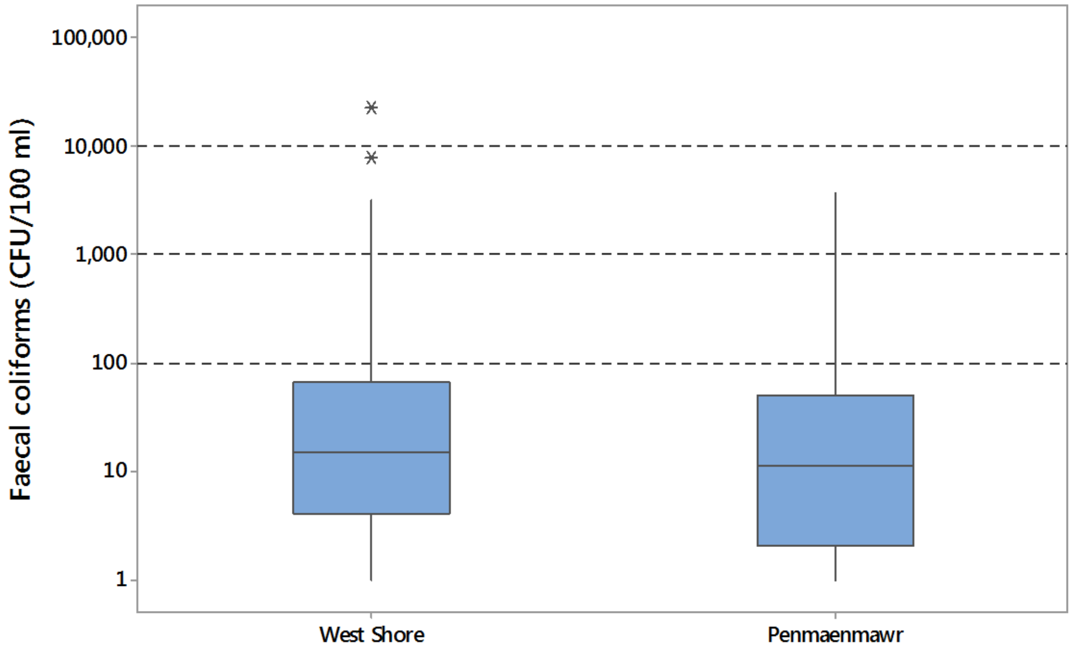

Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
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Both sites had results exceeding 1,000 faecal coliforms/100 ml, but only West Shore had any samples exceeding 10,000 faecal coliforms/100 ml. A two sample T-test showed that there were no significant differences in average faecal coliform concentrations between them (p=0.312).

Correlations (Pearson's) were run between samples that shared sampling dates, and therefore environmental conditions. There were significant correlations between the sites (r=0.442, p<0.001) indicating that the sites are affected by similar sources.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at bathing water sites is shown in Figure X.3.

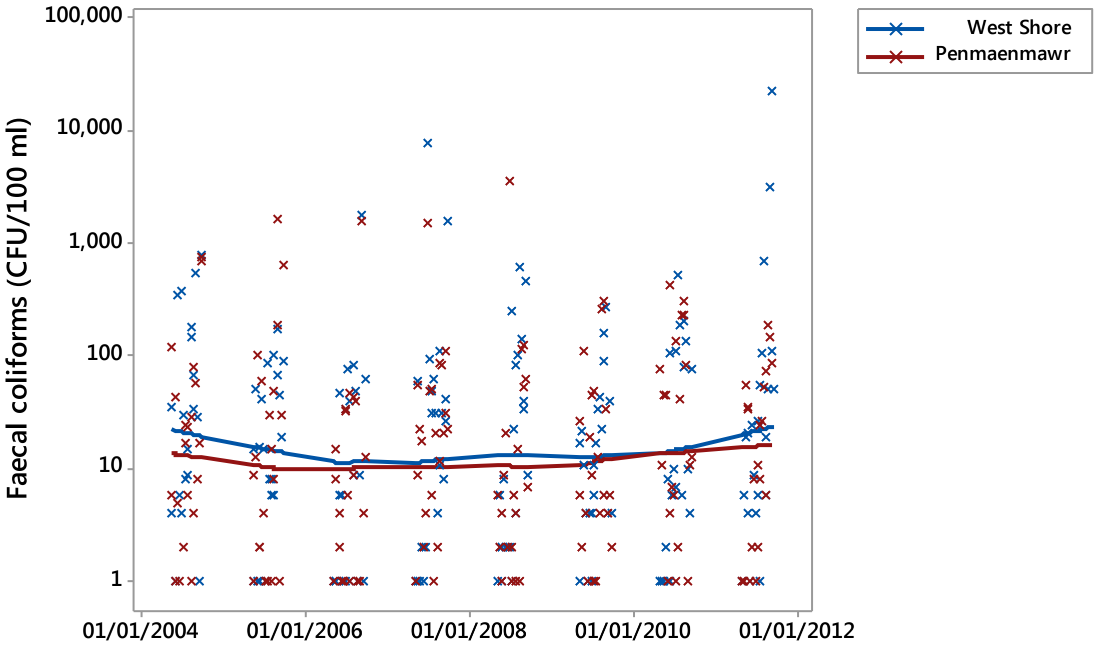

Figure X.3: Scatterplot of faecal coliform results for bathing waters overlaid with loess lines.
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Faecal coliform levels have remained fairly stable on average since 2004 for both sites.

Influence of tides

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of these bathing waters sampling points. Correlation coefficients are presented in Table X.3.

Table X.3: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
West Shore	0.160	0.016	0.188	0.003
Penmaenmawr	0.266	<0.001	0.140	0.045

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Significant correlation between both the high/low and spring/neap tidal cycles and faecal coliform levels were found at both sites.

Figure X.4 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle. High water at Conwy is at 0° and low water is at 180°. Results of 100 faecal coliform cfu/100 ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

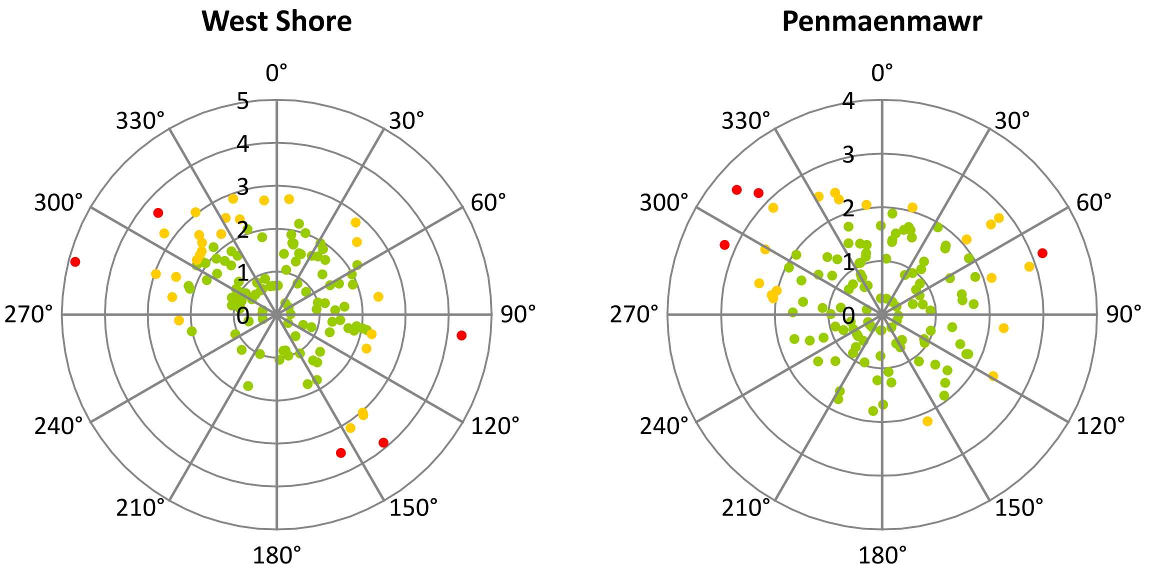

Figure X.4: Polar plots of log_{10} faecal coliform results (cfu/100 ml) against high/low tidal state.
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Lower faecal coliform results tended to occur just after both the high and low tides at both sites, but were higher during the ebb and flood.

Figure X.5 presents polar plots of log_{10} faecal coliform results against the spring neap tidal cycle for each RMP. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliform cfu/100 ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

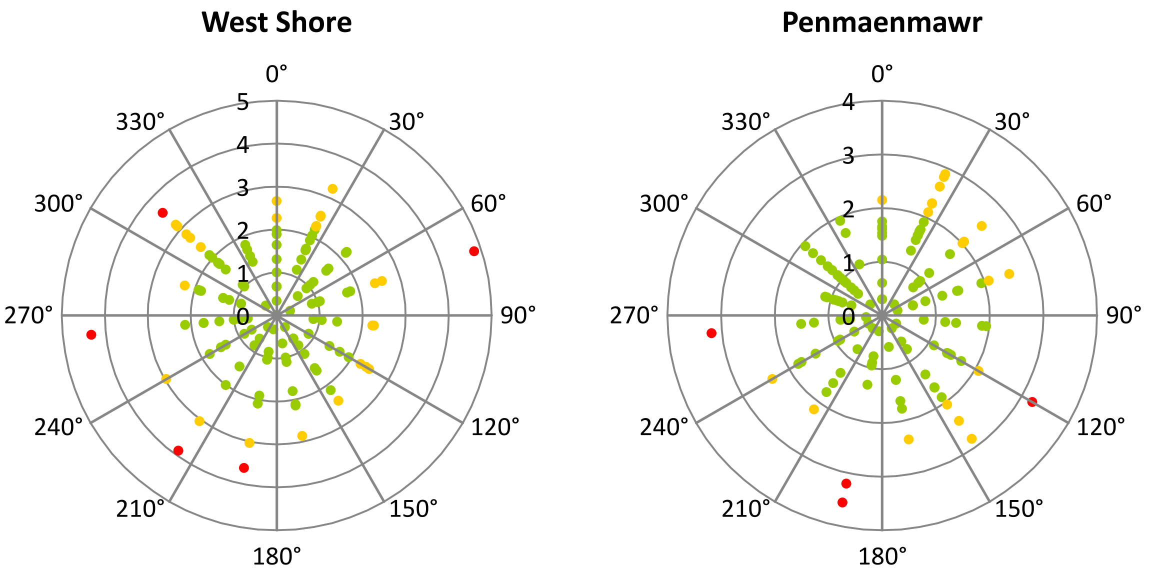

Figure X.5: Polar plots of log_{10} faecal coliform results (cfu/100 ml) against spring/neap tidal state.
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No strong patterns are apparent at West Shore. At Penmaenmawr, results were lower on average as tide size increased from neap to spring.

Influence of Rainfall

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

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

Site		West Shore	Penmaenmawr	West Shore	Penmaenmawr
Weather station		Capel Curig		Maes Du Logger	
n		164	162	164	162
24 hour periods prior to sampling	1 day	0.303	0.141	0.364	0.211
	2 days	0.486	0.385	0.444	0.338
	3 days	0.278	0.171	0.067	0.169
	4 days	0.331	0.098	0.333	0.115
	5 days	0.281	0.056	0.215	0.032
	6 days	0.200	0.100	0.259	0.174
	7 days	0.246	0.145	0.175	0.171
Total prior to sampling over	2 days	0.449	0.275	0.467	0.311
	3 days	0.440	0.265	0.389	0.335
	4 days	0.485	0.270	0.433	0.295
	5 days	0.495	0.253	0.446	0.242
	6 days	0.466	0.219	0.456	0.218
	7 days	0.495	0.255	0.478	0.262

A strong influence of antecedent rainfall was observed at both locations. This influence was more prolonged at West Shore, possibly as it is more in the influence of watercourses from the larger Conwy catchment area, whereas watercourses near Penmaenmawr are smaller.

Salinity

Salinity was recorded on most sampling occasions. Figure X.6 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the bathing waters site.

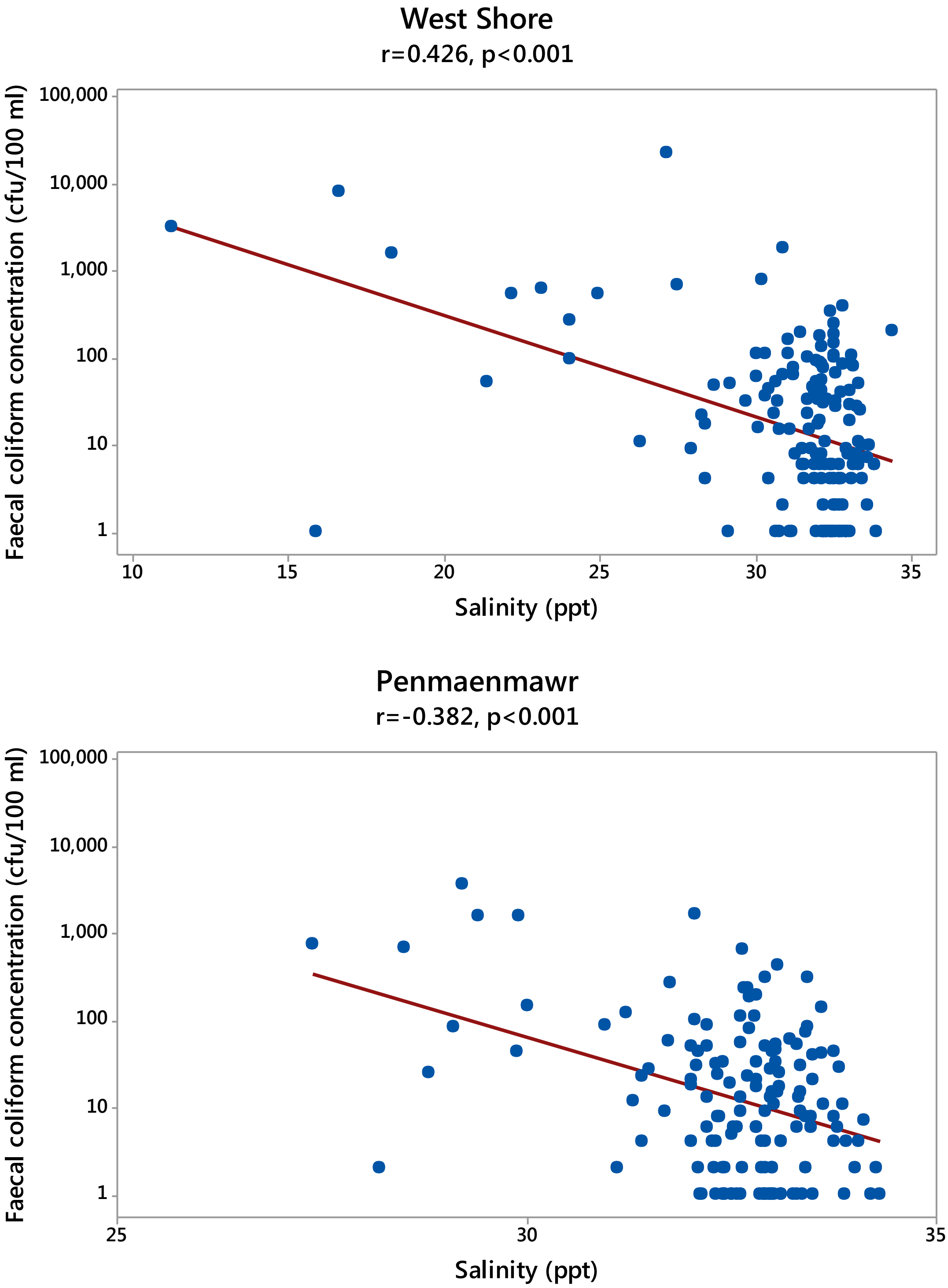

Figure X.6: Scatter-plots of salinity against faecal coliform concentration.
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Faecal coliform levels at both West Shore and Penmaenmawr correlated significantly with salinity. This indicates that land runoff has a significant effect on contamination levels at both sites.

Appendix XI. Microbiological Data: Shellfish Flesh Hygiene

XI.1. Summary statistics and geographical variation

There are a total of eight RMPs in the Conwy production area that have been sampled between 2004 and 2014, all of which are for mussels. However, two of these RMPs located to the west of the Great Orme (Llandudno Pier East and West) lie in a separate hydrological catchment and are addressed in the sanitary survey for Colwyn Bay. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2004 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites are show in Figure XI.2.

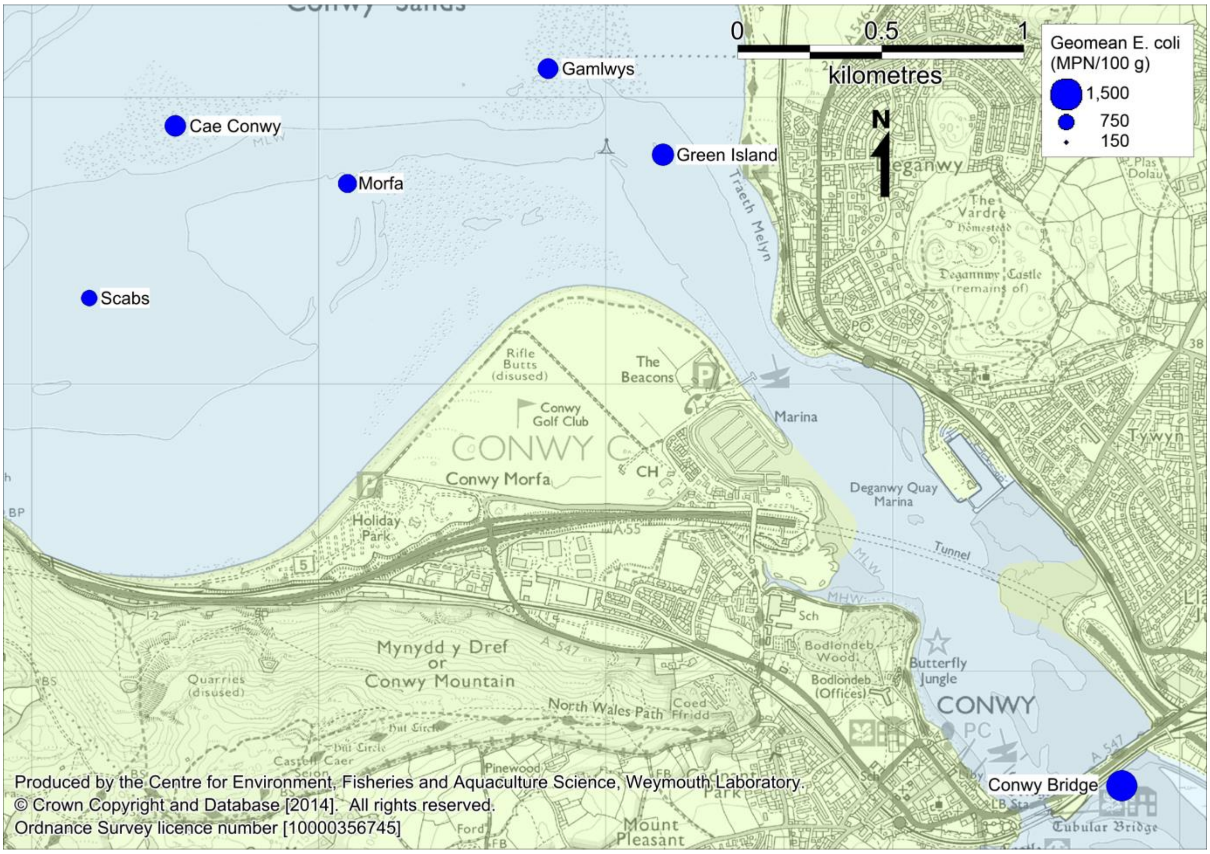

Figure XI.1: Bivalve RMPs active since 2004.

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from RMPs sampled from 2004 onwards.

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Conwy Bridge	Mussel	121	28/01/2004	25/02/2014	1,454.9	40	>18,000	93.4	19.8
Green Island	Mussel	121	28/01/2004	25/02/2014	1,044.3	80	16,000	92.6	10.7
Gamlwys	Mussel	121	28/01/2004	25/02/2014	978.4	20	>18,000	92.6	11.6
Morfa	Mussel	149	28/01/2004	25/02/2014	870.3	20	>18,000	91.3	10.1
Cae Conwy	Mussel	120	28/01/2004	25/02/2014	1,012.7	50	>18,000	93.3	12.5
Scabs	Mussel	120	28/01/2004	25/02/2014	764.6	50	16,000	90.0	5.8

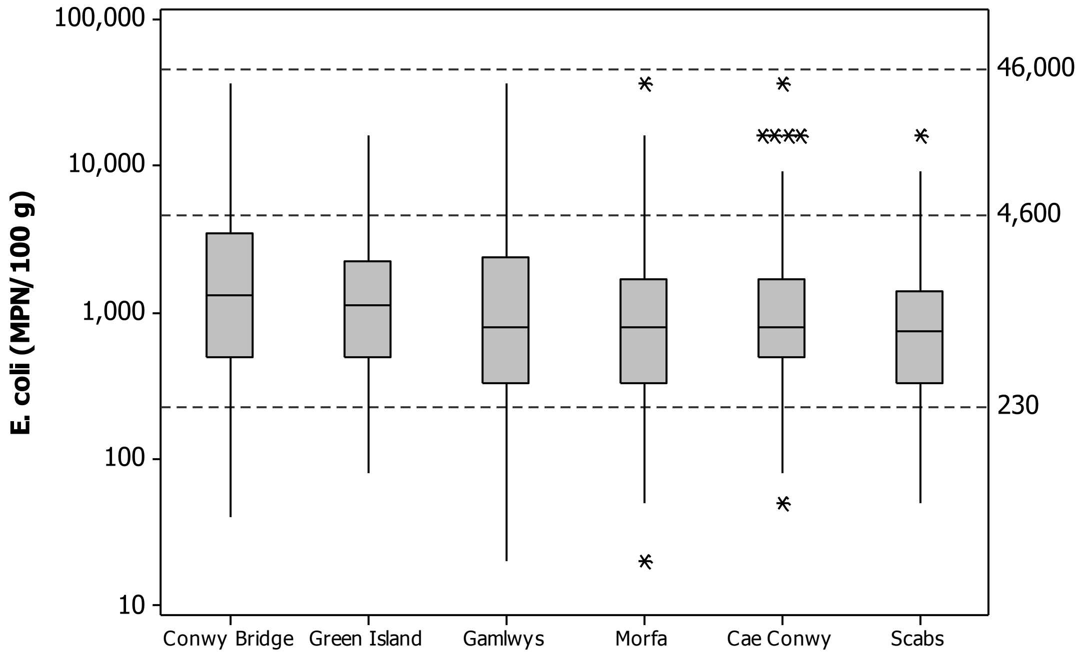

Figure XI.2: Boxplots of *E. coli* results from mussel RMPs from 2004 onwards.

E. coli levels exceeded 230 MPN/100 g in 90% or more samples at all sites and exceeded 4,600 MPN/100 g in over 10% of samples at all sites except Scabs. This indicates that compliance with class B requirements is generally borderline. No samples had more than 46,000 *E. coli* MPN/100 g. A two-way ANOVA test on results from the 112 occasions when all five sites were sampled on the same day showed that there were significant differences in *E. coli* levels between sites (p<0.001). Post ANOVA Tukey tests showed that Conwy Bridge had significantly higher *E. coli* levels than all other RMPs. Across the remaining RMPs, results were significantly higher at Green Island (the innermost of those outside the estuary) than at Scabs (the outermost RMP). Overall, the results clearly show a gradient of decreasing contamination from Conwy Bridge out through the estuary and bay.

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions. *E. coli* levels at all RMPs correlated very strongly (p<0.001 in all cases), indicating that they share similar contamination sources.

XI.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in mussels is shown in Figure XI.3.

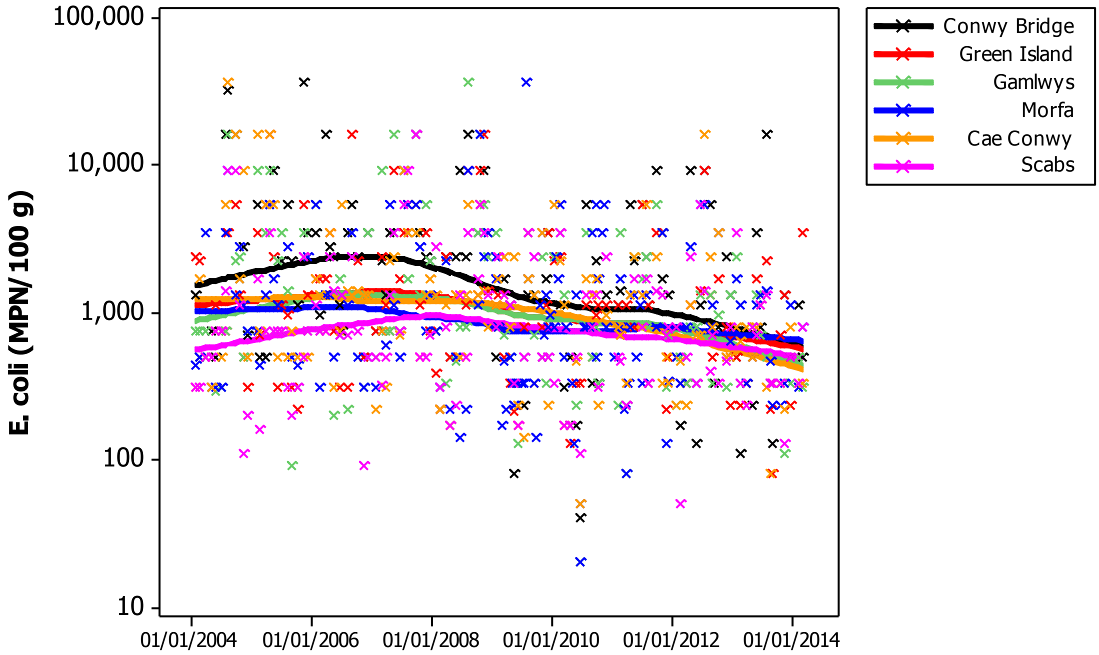

Figure XI.3: Scatterplot of *E. coli* results for mussels overlaid with loess line.

E. coli levels have remained stable on average at all monitoring points through the period considered.

XI.3. Seasonal patterns of results

The seasonal patterns of results from 2004 to 2014 were investigated by RMP. Figure XI.4 shows box plots of *E. coli* levels at each RMP by season.

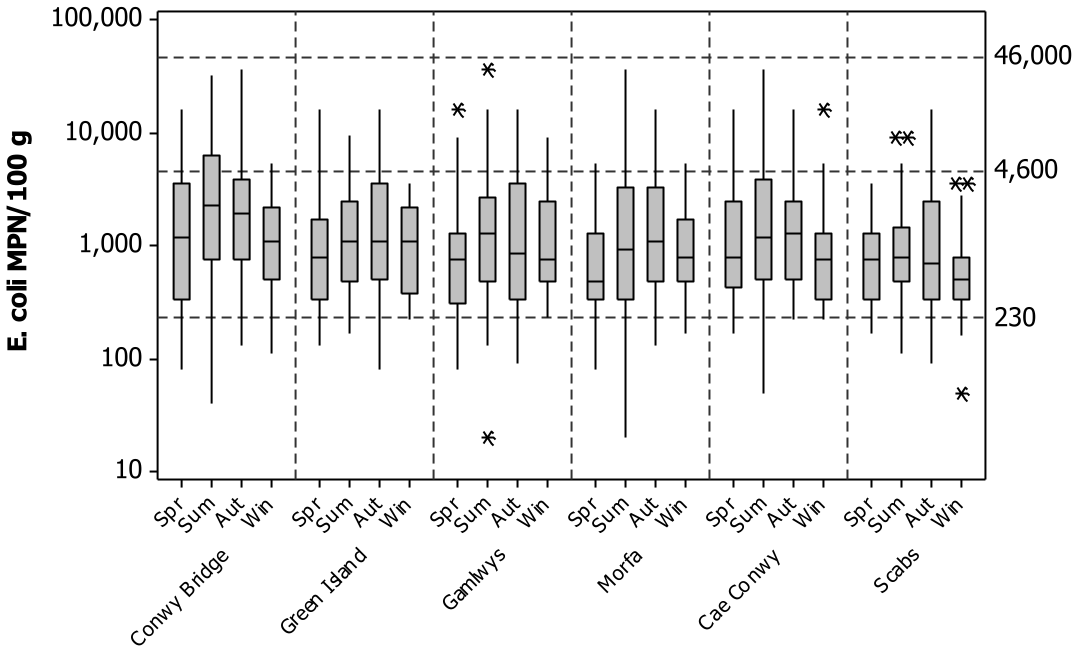

Figure XI.4: Boxplot of *E. coli* results for mussels by RMP and season

Whilst there was a general tendency for higher average results during the summer and autumn, one-way ANOVAs showed that there were no significant variations in average *E. coli* levels between seasons (p=0.073 to 0.473).

XI.4. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low tides at Conwy and spring/neap tidal cycles for each RMP where more than 30 samples had been taken. Results of these correlations are summarised in Table XI.2, and significant results are highlighted in yellow.

Table XI.2: Circular linear correlation coefficients (r) and associated p values for *E. coli* results against the high/low and spring/neap tidal cycles

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Conwy Bridge	Mussel	0.196	0.011	0.196	0.011
Green Island	Mussel	0.253	0.001	0.253	0.001
Gamlwys	Mussel	0.218	0.004	0.218	0.004
Morfa	Mussel	0.101	0.224	0.101	0.224
Cae Conwy	Mussel	0.220	0.003	0.220	0.003
Scabs	Mussel	0.037	0.853	0.037	0.853

Figure XI.5 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Conwy is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

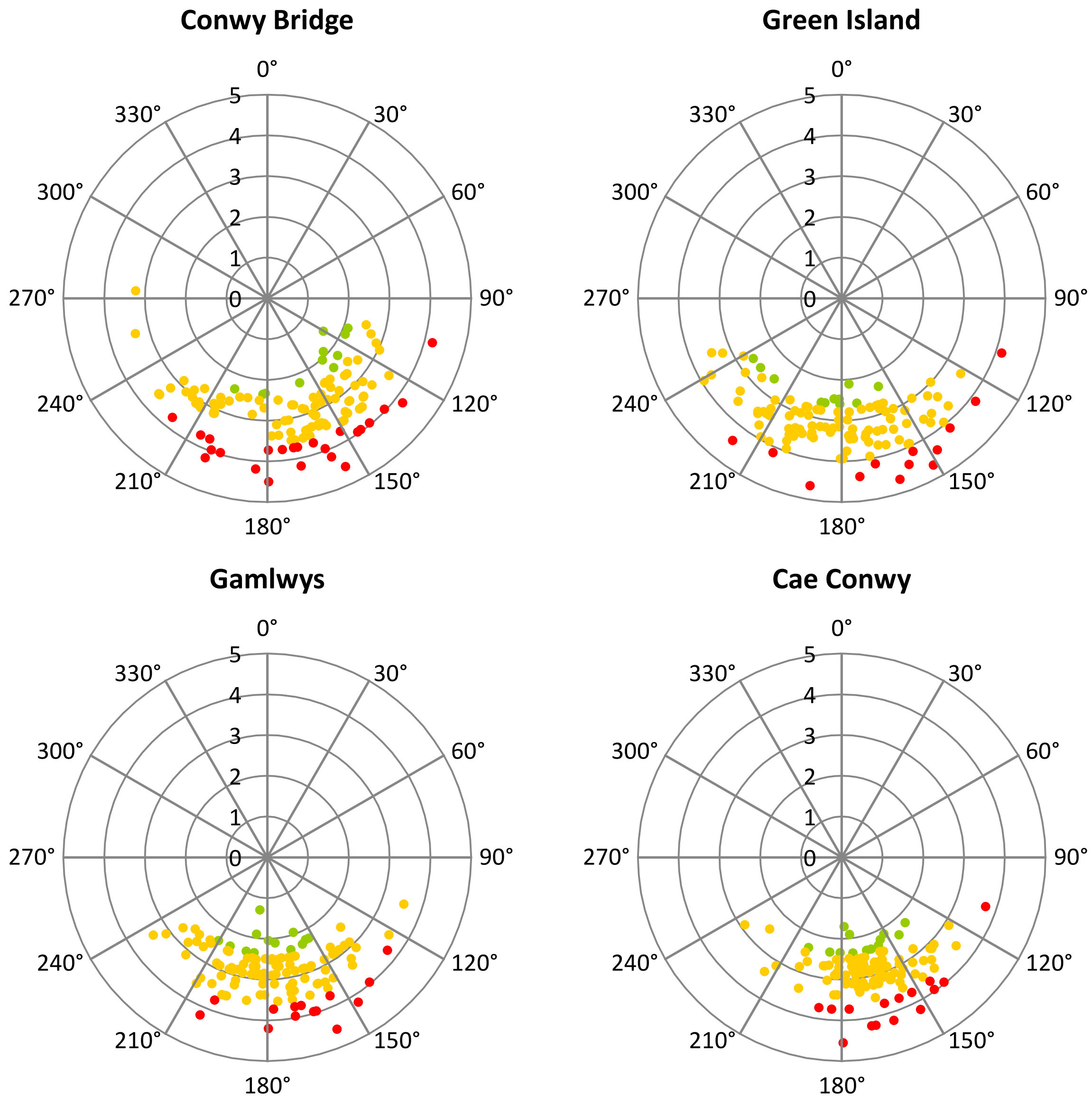

Figure XI.5: Polar plot of log$_{10}$ *E. coli* results (MPN/100 g) at mussel RMPs against high/low tidal state

Sampling of mussels took place around low tide, so only this part of the tidal cycle is represented. While circular correlations showed significant effects of the high/low tidal cycle on *E. coli* levels, none was apparent in the polar plots.

Figure XI.6 presents polar plots of log$_{10}$ *E. coli* results against the spring/neap tidal cycle for each RMP. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

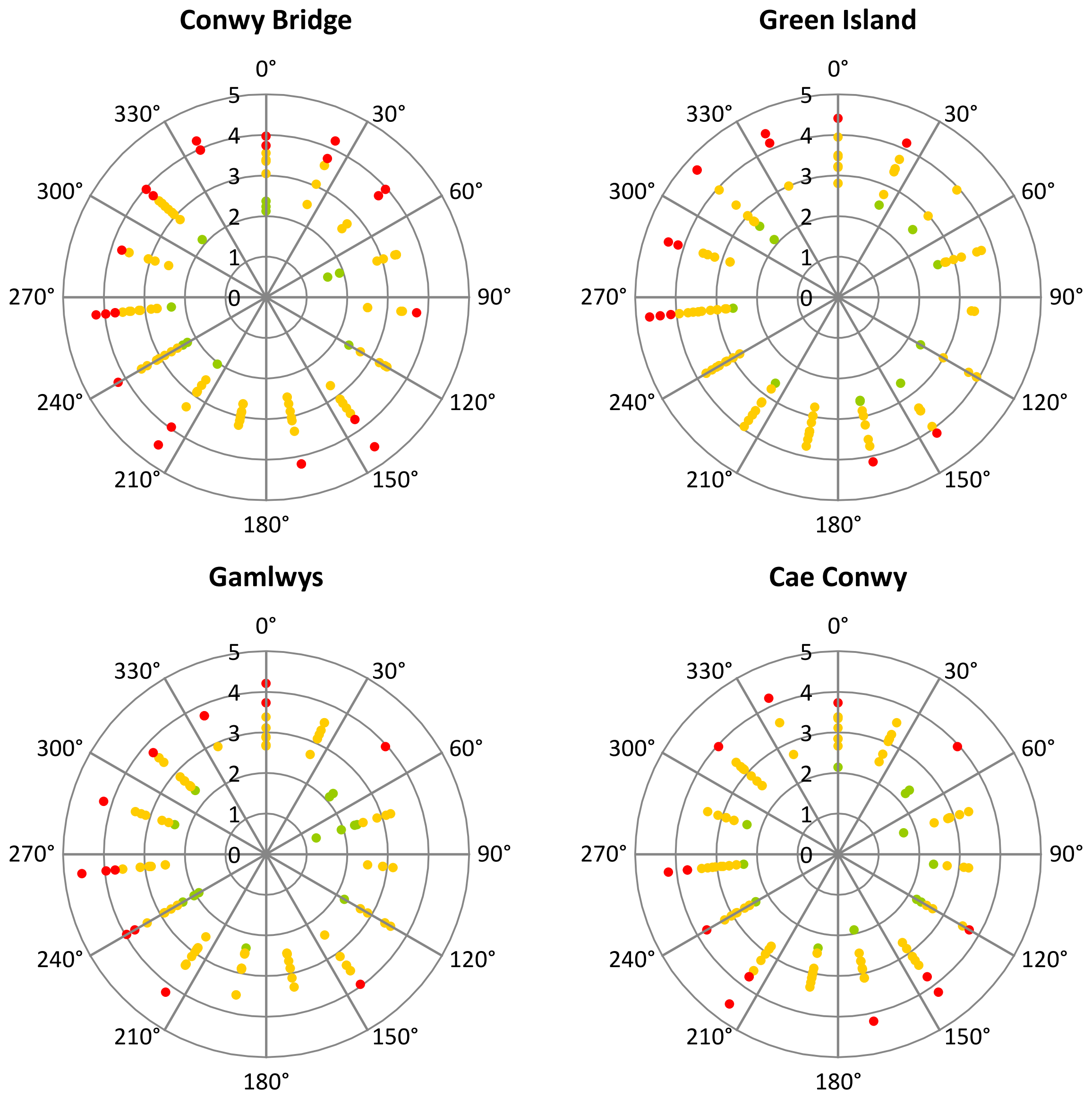

Figure XI.6: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) at mussel RMPs against spring/neap tidal state

While circular correlations showed significant effects of the spring/neap tidal cycle on *E. coli* levels, none was apparent in the polar plots.

XI.5. Influence of rainfall

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Maes Du Logger weather station (Appendix VI for details) over various periods running up to sample collection. These are presented in Table XI.3 and statistically significant positive correlations ($p<0.05$) are highlighted in yellow.

Table XI.3: Spearman's Rank correlations between rainfall recorded at the Maes Du Logger weather station and shellfish hygiene results

Site		Conwy Bridge	Green Island	Gamlwys	Morfa	Cae Conwy	Scabs
n		120	120	120	147	119	118
24 hour periods prior to sampling	1 day	0.417	0.418	0.335	0.150	0.228	0.327
	2 days	0.479	0.519	0.579	0.373	0.419	0.319
	3 days	0.242	0.274	0.257	0.225	0.192	0.107
	4 days	0.098	0.125	0.145	0.153	0.153	0.000
	5 days	0.185	0.216	0.235	0.133	0.304	0.176
	6 days	0.149	0.125	0.264	0.216	0.176	0.043
	7 days	-0.117	0.141	0.029	0.037	-0.026	-0.030
Total prior to sampling over	2 days	0.553	0.515	0.567	0.284	0.373	0.403
	3 days	0.534	0.520	0.546	0.345	0.388	0.422
	4 days	0.514	0.520	0.527	0.359	0.405	0.386
	5 days	0.497	0.494	0.508	0.330	0.424	0.401
	6 days	0.500	0.480	0.514	0.365	0.435	0.376
	7 days	0.428	0.472	0.479	0.372	0.407	0.325

At all RMPs, rainfall had a significant effect on *E. coli* levels within 48 hours. Additionally, all RMPs had significantly higher *E. coli* levels within 24 hours of rainfall except Morfa. At all RMPs the cumulative effect of rainfall significantly increased *E. coli* levels for at least 7 days.

Appendix XII. Shoreline Survey Report

Date (time):
18/08/2014, 09:00 – 12:30
19/08/2014, 08:30 – 15:00
20/08/2014, 08:30 – 15:00

Cefas Officers:
David Walker
Rachel Parks

Survey Partners:
Mark Hughes, Conwy Council (18/08/2014 only)

Area surveyed:
South of Conwy railway bridge to Penmaenmawr. West Shore (base of Great Orme) to Conwy RSPB reserve. Additional spot samples further upstream.

Weather:
18/08/2014 – Partial cloud, 17°C, wind bearing 315° at 14 km/h.
19/08/2014 – Partial cloud, 17°C, wind bearing 315° at 12 km/h.
20/08/2014 – Partial cloud, 17°C, wind bearing 307° at 9 km/h.

Tides:
Admiralty TotalTide© predictions for Conwy 53°17'N 3°50'W. All times in this report are BST.

18/08/2014		
High	05:16	6.8 m
Low	12:10	2.3 m
High	17:57	6.5 m

19/08/2014		
Low	00:48	2.5m
High	06:33	6.4 m
Low	13:22	2.6 m
High	19:20	6.4 m

20/08/2014		
Low	02:09	2.6 m
High	08:00	6.3 m
Low	14:41	2.7 m
High	20:38	6.5 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are shown in Figure XII.1.

XII.1. Fishery

It was not possible to meet with the harvesters on this survey. No additional shellfishery information was obtained.

XII.2. Sources of contamination

Sewage discharges

During this survey, several water company owned overflows and pumping stations were observed (observations 8, 18, 24, 27 and 32). Samples were taken from two of these. The Deganwy Road pumping station (observation 24) had and *E. coli* concentration of 56,000 cfu/100 ml, but had very low flow (<0.001 m^3/s). The Llandudno Junction pumping station (observation 32) had an *E. coli* concentration of 940 cfu/100 ml, but was not accessible to measure the flow rate (which was seen to be very low).

Observation 2 was close to the recorded location for the St Agnes Road CSO. A sample here had an *E coli* concentration of 7,700 cfu/100 ml and just downstream, the *E. coli* concentration dropped to 3,500 cfu/100 ml.

A package treatment plant was seen at observation 5. The effluent of this probably discharged to the stream which it was in close proximity. A downstream sample of this stream (observation 3) had an *E .coli* concentration of 220 cfu/100 ml.

Freshwater inputs

The Gyffin Stream was sampled where it joined the estuary (observation 1). This stream had an *E. coli* concentration of 230 cfu/100 ml, compared with the upstream concentration of 3,500 cfu/100 ml (observation 3).

Other streams were sampled at observations 6, 7 and 17. Flow readings were taken from the streams at observation 7 and 17 and both had calculated daily *E. coli* loads in the region of 10^{10} cfu/day.

A sluice from the Conwy Bird Reserve (observation 34) had an *E. coli* concentration of 15,000 cfu/100 ml.

A sample of the tidal Conwy was taken at observation 4 and an *E. coli* concentration of 1,800 cfu/100 ml was recorded. While the river was too wide to determine the flow rate, it is likely that with these concentrations of *E. coli* and the volume of water, the River Conwy represents one of the largest sources of contamination to the shellfisheries.

Livestock

No livestock was observed during this survey

Wildlife

Very little wildlife was observed during this survey except for flocks of birds at observations 20 and 22.

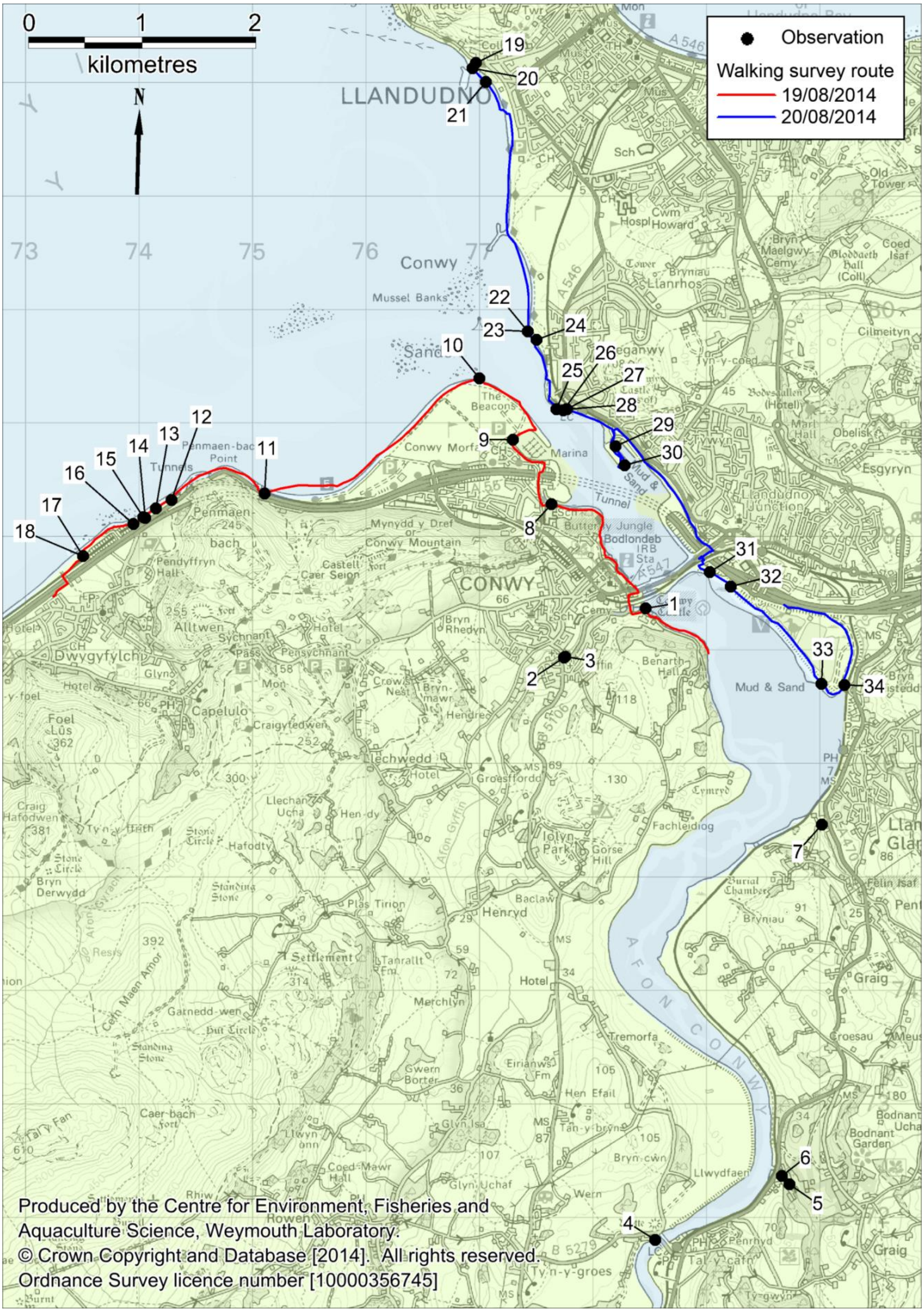

Figure XII.1: Locations of shoreline observations (Table XII.1 and for details).

Table XII.1: Details of Shoreline Observations

Observation no.	NGR	Date	Time	Description	Photo
1	SH7846677369	18/08/2014	08:24	Gyffin Stream mouth (tidal) (Sample LL01).	Figure XII.4
2	SH7774576935	18/08/2014	08:44	Pipe under building upstream of observation 1. Possibly St Agnes Road CSO (0.25m flow width x 0.6m pipe diameter x 0.051m/s) (Sample LL02).	Figure XII.5
3	SH7775476943	18/08/2014	09:17	Stream after confluence with observation 2 (2m x 0.05m x 0.245m/s) (Sample LL03).	
4	SH7854871803	18/08/2014	10:20	River upstream of road bridge (too big to measure flow) (Sample LL04).	Figure XII.6
5	SH7973372294	18/08/2014	10:20	Package treatment plant for toilet block.	Figure XII.7 & Figure XII.8
6	SH7966672367	18/08/2014	10:48	Stream from Bodnant Estate (downstream of observation 5). Not accessible for flow (Sample LL05).	Figure XII.9
7	SH8001775461	18/08/2014	11:17	Stream (1.2m x 0.05m x 0.431m/s) (Sample LL06).	Figure XII.10
8	SH7763678287	19/08/2014	09:29	Morfa Drive pumping station. Two inspection covers in concrete.	Figure XII.11
9	SH7729678854	19/08/2014	09:43	Grated pipe (~2.5m diameter). Not flowing.	Figure XII.12
10	SH7700079396	19/08/2014	09:58	High concentrations of mussel shells.	Figure XII.13
11	SH7510578382	19/08/2014	10:35	Concrete pipe under road (0.02m flow depth x 0.95m diameter x 0.700m/s) (Sample LL08).	Figure XII.14
12	SH7428778322	19/08/2014	10:57	Valved galvanised steel pipe (1m diameter), very low flow (Sample LL09).	Figure XII.15
13	SH7414978248	19/08/2014	11:05	Rusty iron pipe, 0.1m diameter. Not flowing.	Figure XII.16
14	SH7405478167	19/08/2014	11:11	Valved steel pipe under road (0.25m diameter). 2s to fill pot (Sample LL10).	Figure XII.17
15	SH7403878173	19/08/2014	11:14	Rusty iron pipe, 0.1m diameter. Not flowing.	
16	SH7394978110	19/08/2014	11:18	Valved pipe under road. 1.2m diameter. Very low flow.	Figure XII.18
17	SH7350877829	19/08/2014	11:32	Stream flowing under road/rail and over beach (0.55m width x 0.06m average depth x 0.578m/s average flow) (Sample LL12).	Figure XII.19
18	SH7350877829	19/08/2014	11:32	Penmaenmawr WwTW. Two valved pipes upstream of observation 20 (not flowing).	Figure XII.20
19	SH7697082175	20/08/2014	08:53	Series of inspection covers next to boating pond. No outfall visible.	Figure XII.21

20	SH7693882130	20/08/2014	08:55	100 gulls on intertidal.	
21	SH7705782008	20/08/2014	08:57	Iron pipe in beach (0.4m diameter). Not flowing.	Figure XII.22
22	SH7742579809	20/08/2014	09:34	30 oyster catchers, 30 gulls on intertidal.	
23	SH7742579809	20/08/2014	09:34	Mussels on rocks.	
24	SH7750479735	20/08/2014	09:36	Deganwy Road CSO. Concrete pipe with bent grate and a stale smell (0.75m diameter x 0.13m flow width x 0.369m/s) (Sample LL13).	Figure XII.23
25	SH7767779123	20/08/2014	09:54	Grated pipe surrounded with concrete. Not flowing.	Figure XII.24
26	SH7773979113	20/08/2014	09:57	Inspection cover and concrete structure. No outfall visible.	Figure XII.25
27	SH7776679122	20/08/2014	09:59	Deganwy pumping station. Inspection covers at ground level.	Figure XII.26
28	SH7777479123	20/08/2014	09:59	Toilet block.	Figure XII.27
29	SH7820078798	20/08/2014	10:08	Outfall in marina wall (not accessible), not flowing.	Figure XII.28
30	SH7828078628	20/08/2014	10:14	Outfall in marina wall (not accessible), not flowing.	Figure XII.29
31	SH7903177689	20/08/2014	10:55	Possible drainage channel, not flowing.	Figure XII.30
32	SH7921377561	20/08/2014	11:03	Llandudno Junction pumping station. Two 2m diameter pipes not accessible for flow (low) (Sample LL14).	Figure XII.31
33	SH8001476702	20/08/2014	11:34	Three iron pipes (0.8m diameter), not flowing.	Figure XII.32
34	SH8021576692	20/08/2014	11:43	Sluice from bird reserve (two 1.5m diameter pipes) not accessible for flow (low) (Sample LL15).	

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

Figure XII.3: *E. coli* stream loadings (Table XII.2 for details).

Table XII.2: Water sample *E. coli* results, spot flow gauging results and estimated loadings.

Sample ID	Observation number	Date and time	Description	Flow (m^3/s)	*E. coli* concentration (cfu/100 ml)	*E. coli* loading (cfu/day)	NGR
LL01	1	18/08/2014 08:24	Seawater		230		SH7846677369
LL02	2	18/08/2014 08:44	Pipe	<0.001	7,700	$1.56x10^{9}$	SH7774576935
LL03	3	18/08/2014 09:17	Stream	0.025	3,500	$7.41x10^{10}$	SH7775476943
LL04	4	18/08/2014 10:20	Seawater		1,800		SH7854871803
LL05	6	18/08/2014 10:48	Stream		220		SH7966672367
LL06	7	18/08/2014 11:17	Stream	0.026	1,100	$2.46x10^{10}$	SH8001775461
LL08	11	19/08/2014 10:35	Pipe	0.003	15,000	$3.31x10^{10}$	SH7510578382
LL09	12	19/08/2014 10:57	Pipe		26,000		SH7428778322
LL10	14	19/08/2014 11:11	Pipe	<0.001	6,100	$5.27x10^{8}$	SH7405478167
LL12	17	19/08/2014 11:32	Stream	0.019	1,100	$1.81x10^{10}$	SH7350877829
LL13	24	20/08/2014 09:36	Pipe	<0.001	56,000	$8.80x10^{9}$	SH7750479735
LL14	32	20/08/2014 11:03	Pipe		940		SH7921377561
LL15	34	20/08/2014 11:43	Sluice		15,000		SH8021576692

Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

Figure XII.10

Figure XII.11

Figure XII.12

Figure XII.13


Figure XII.14


Figure XII.15


Figure XII.16


Figure XII.17

Figure XII.18

Figure XII.19

Figure XII.20

Figure XII.21


Figure XII.22


Figure XII.23

Figure XII.24

Figure XII.25

Figure XII.26

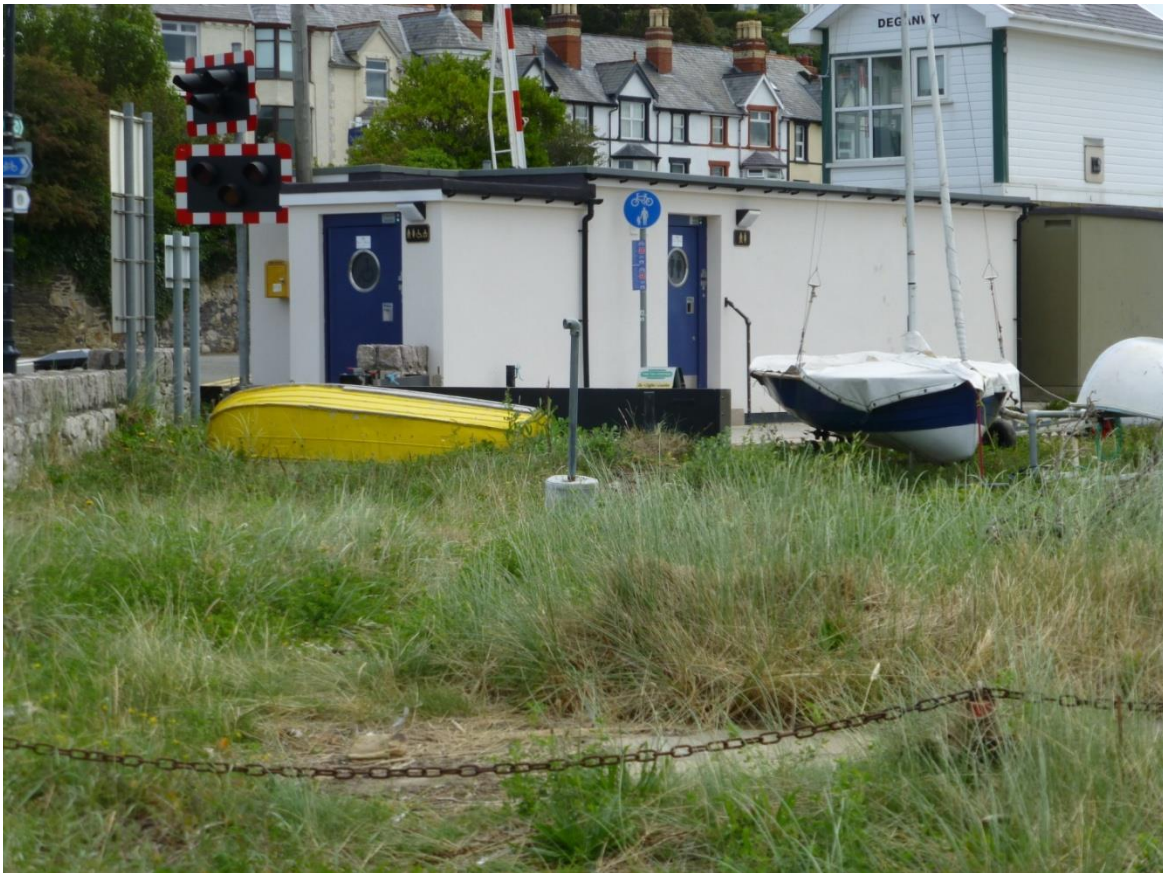

Figure XII.27

Figure XII.28

Figure XII.29


Figure XII.30


Figure XII.31

Figure XII.32

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List of Abbreviations

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

Glossary

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

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

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