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INTRODUCTION

BACKGROUND

Jersey's mariculture industry occupies around 70ha of intertidal area for the cultivation of oysters and mussels. This is located in the St Clement's and Royal Bay of Grouville areas of Jersey on the south-east corner of the Jersey coastline (Figure 1.1)[1]. All beaches and sub-tidal areas are administered on behalf of the Crown for the public of Jersey, by the States of Jersey (SoJ). Oysters and mussels are filter feeders; they siphon water over their gills, filter out phytoplankton for food, extract oxygen for respiration, and expel the waste water. Their metabolic needs increase with size, as more food, oxygen and energy are required to support a larger animal.

Commercial production in 2011 amounted to 972 tonnes of Pacific Oyster (*Crassostrea gigas*), and 89 tonnes of mussels (*Mytilis edulis)*[1]. Between 2010 and 2011, the value of Jersey's mariculture industry increased by 109%, to around £3.89 million in 2011[2]. The Pacific Oyster harvest is estimated to have contributed £3.72 million to 2011's figures. Much of this increase has purportedly been driven by the continued demand but low local supply of oysters in continental France due to Oyster Herpes Virus. These economic conditions have generated an increased interest in mariculture in Jersey, and subsequently led to greater interest in licences for the remaining intertidal and sub-tidal areas around Jersey's coast. Pacific oyster production at one of the areas (Green Island) has recently been replaced with flat oysters *(Ostrea edulis)*. These would be harvested from September to April inclusive.

Oysters and other bivalve shellfish may accumulate pathogenic bacteria or viruses if the water in which they live and feed becomes contaminated with faecal pollution. Occasionally this can lead to food poisoning incidents in humans (gastroenteritis), particularly if affected shellfish are consumed raw. Bacterial infections are usually caused by strains of *Escherichia coli* (*E. coli)*. Norovirus is becoming an increasingly significant source of viral infection and is recognised as a major human health risk associated with the consumption of contaminated shellfish. Norovirus is not considered manageable through conventional *E. coli* based monitoring and assessment, although recent research offers support for use of *E. coli* as an indicator organism[3]. Bivalve shellfish may also accumulate marine toxins, such as paralytic shellfish poisons (PSP), diarrhetic shellfish poisons (DSP) and lipophilic toxins when toxic phytoplankton blooms occur. These toxins are heat stable and not removed by cooking. If present in high enough concentrations, they can be responsible for

1 States of Jersey (2011) Marine Resources Annual Status Report.
2 States of Jersey (2013) *Tender document.*
3 Food Standards Agency (2011) *Investigation into the prevalence, distribution and levels of norovirus titre in oyster harvesting areas in the UK.* Accessed at http://www.food.gov.uk/science/research/foodborneillness/microriskresearch/p01programme/p01projlist/p01009/#.Ue04Vm1S7ug

incidents of severe poisoning[4].

In the European Union (EU), food hygiene legislation requires that controls are in place to protect the consumer from risks associated with microbiological contamination and algal toxins produced by naturally occurring phytoplankton (algal biotoxin contamination), as described above.

Jersey is home to the largest shellfish producer in the British Isles[5]; the economic significance of the industry to the island is highlighted above. Accordingly, maintenance of high water quality in the waters around the island and particularly at the fisheries is of vital importance. Shellfish beds are classified according to the results of regular testing and analysis of shellfish flesh samples, based on a classification system specified by European legislation. The determination of designated boundaries and identification of potential sources of contamination for ongoing monitoring is informed by a sanitary survey, also specified by European legislation. The States of Jersey undertook a sanitary survey in 2012[6], noting that Jersey sits outside the EU and is not subject to most EU legislation. The classifications determine whether areas can be used for harvesting and what level of post-harvesting treatment is needed to reduce the risk to a level that is regarded as acceptable. Shellfish harvested from beds other than Class A must be subject to depuration[7] prior to consumption, imposing additional production costs. There are also reputational implications in terms of public and market perception. In recent years, classifications for the concessions around South East Jersey have been downgraded. In 2006, half of all oyster concessions were at Class A, and half at Class B - A classifications occurred in Le Hurel Main and Holding Beds (Areas 1 and 6, at Seymour Tower and in Le Hocq Main Bed, Area 8). By 2008, three were Class A and seven were Class B. By 2009, only one area remained at Class A (Area 26, Seymour Tower), with nine areas rated as Class B. The latest classifications (effective from April 1, 2013 to March 31, 2014 [amended June 6, 2013]) show little change from the 2009 situation although certain areas have been merged under single classifications; only one area (Area 20 - Seymour Tower B) remains at Class A[8]. It is noted that the latest classifications for the whole of England and Wales show that two of 377 beds were classified as Class A[9].

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4 Cefas (2012) *Cefas shellfish testing.*

5 States of Jersey (2011) *Protecting* our *Marine Environment.* Environment Scrutiny Panel. Presented on 9 November 2011.

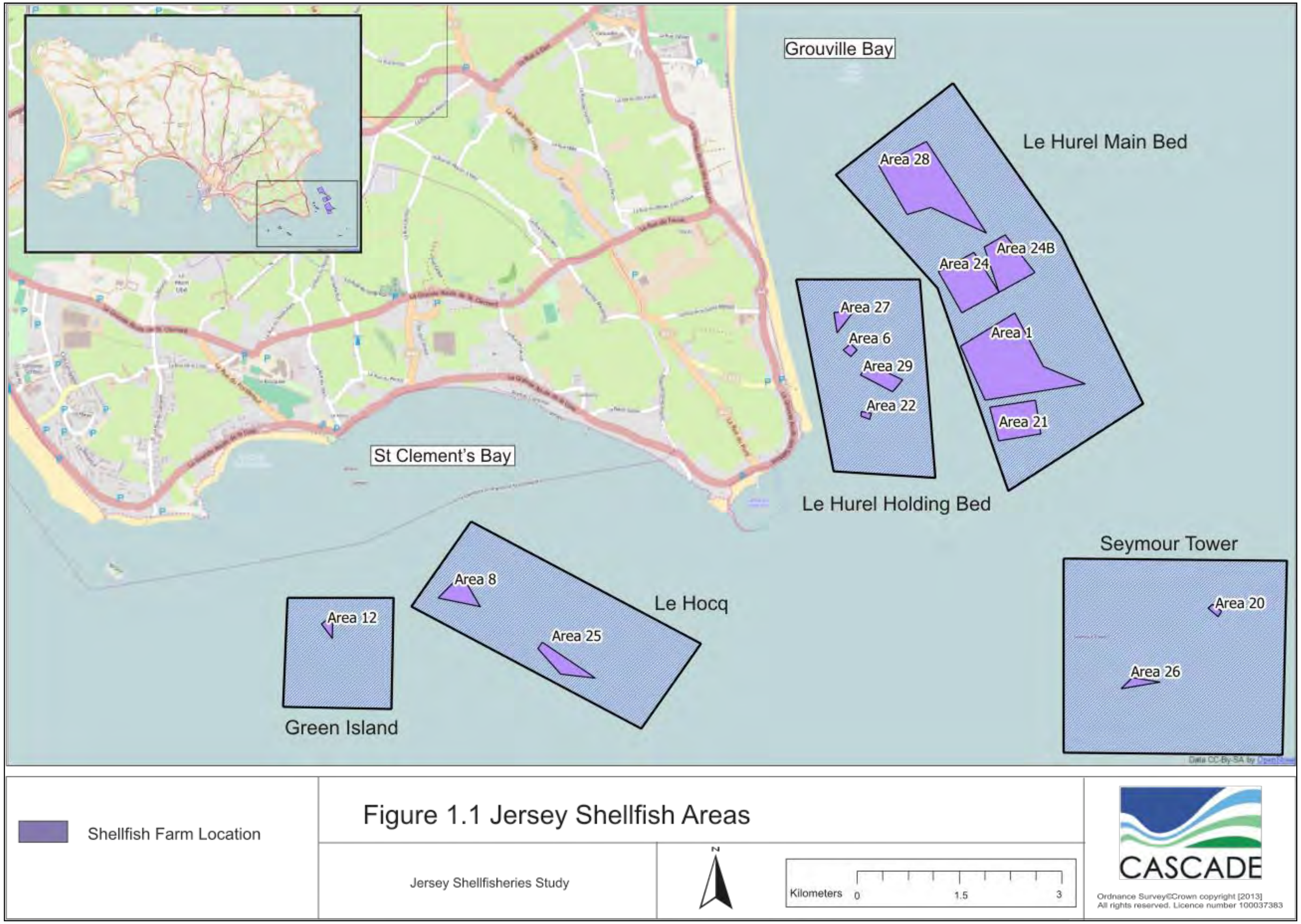
6 States of Jersey (2012) Sanitary Survey Report. Grouville Bay and St Clement Bay

7 Depuration is a process by which shellfish are held in tanks of clean seawater under conditions to maximise the filtering activity which results in expulsion of intestinal contents, and prevents their recontamination.

8 States of Jersey (2013) Classifications of the Bivalve Mollusc Production Areas in Jersey Effective from 1 April 2013 to 31 March 2014 (amended 6 June 2013). June 6, 2013.

9 Food Standards Agency (2013) *Shellfish Harvesting Classifications England and Wales: 2012-2013.*

Figure 1.1 Jersey Shellfish Production Areas



As a result of the reduced classifications and the results of analyses that have informed them, aquaculture industry stakeholders hold a view that water quality around the beds has reduced over recent years. However, there are a number of potential causes for reduced classifications other than an actual reduction in water quality around the concessions and subsequent increase in shellfish flesh *E. coli* concentrations, including the following:

A change in laboratory (and associated protocols) used for analysis of samples, from a Jersey based laboratory (Jersey Hospital) to a UK UKAS accredited laboratory in May 2008, noting the Jersey Hospital laboratory rarely counted *E. coli* exceeding the Class C threshold[10].

Since 2008, a three year rolling mean has been used for classification of the areas, whereas prior to this, classifications were based on sometimes less than a year's worth of data.

The States of Jersey have commissioned or undertaken a number of investigations to determine the driver behind the reduced classifications. To date, none have conclusively supported the hypothesis that reduced water quality is the cause of the reduced classifications.

PURPOSE OF INVESTIGATION AND THIS REPORT

The key objective of the overall investigation is to identify the historic and contemporary baseline in terms of water quality for the key oyster and mussel shellfish areas in the South East of Jersey, and if necessary design and undertake a focused monitoring programme to establish source-pathway-receptor contamination pathways. A sequential four step programme has been proposed:

1) Complete a strategic review of the history and current position regarding faecal contamination of the shellfishery, identifying current knowledge and any significant knowledge gaps, considering any potential for deterioration in water quality around the shellfishery.

2) Develop a monitoring programme specific to addressing the significant knowledge gaps within the constraints of the project budget.

3) Facilitate or undertake the monitoring programme.

4) Analyse the monitoring data, undertake an assessment, and establish conclusions and recommendations regarding the potential for contamination of the shellfisheries.

This report details the outcome of Step 1; the *Strategic Review,* and has been informed by the following tasks:

10 States of Jersey (2013) Personal communication.

Review of existing data and reports

Assessment of the state of current understanding of the quality of the shellfishery, including consideration of concerns and opinions from the mariculture industry.

Identification of data gaps

Recommendations for the next step - monitoring proposals.

The investigation aims to determine the influences on water quality at the shellfish areas, and to identify the cause of reduced classifications. It is fundamentally important that the investigation is objective and comprehensive. With this in mind stakeholders have been asked to review the draft version of this report. This report will be updated following monitoring and subsequent analysis.

As discussed in Section 1.1, norovirus is becoming an increasingly significant source of viral infection and human health risk. This investigation does not consider norovirus in isolation as at present there are limited norovirus data linked to areas available. However, a recent study3 found a significant correlation between *E. coli* or classification status and norovirus levels, providing support for the use of *E. coli* as an indicator organism on a site specific rather than sample specific basis. This investigation will therefore focus on *E coli* counts and establishing linkages between sewage sources of faecal contamination of the shellfish beds. In so doing, consideration of *E coli* will also act as a proxy for norovirus, noting that norovirus levels have also been found to be strongly correlated with environmental temperatures.

POLICY AND REGULATORY CONTEXT

INTRODUCTION

Jersey has a special relationship with the European Union (EU). In simple terms, the Island is treated as part of the European Community for some purposes under Protocol 3 of the1972 UK Treaty of Accession, but otherwise is not a part of the EU. If EU legislation is clearly not related to Protocol 3 and thus obligatory in Jersey, the 'Lead Department' in a particular area of Jersey policy may make a decision to voluntarily introduce the principles of such legislation either wholly or partially. Jersey 'Lead Departments' may also choose to introduce supporting legislation.

Consequently, Jersey has historically chosen limited aspects of EU legislation to implement in relation to water related issues, and has instead chosen to adopt some of the principles of key directives without necessarily legislating for it. However, Jersey Water Pollution Law 2000 requires that a best environmental practice approach is adopted in Jersey. This means the spirit of EU legislation is followed where possible and appropriate for the Island (as such approaches are often considered best environmental practice).

EU directives can therefore be useful in that they provide a ready-made framework which has been designed and tested in the European bio-geographic context. The following sections explain the European and UK transposing legislation on the understanding that there is a will to regulate and monitor accordingly, despite Jersey not being legally bound to do so.

SHELLFISH WATERS DIRECTIVE

The **Shellfish Waters Directive (2006/113/EEC)** was adopted on December 12, 2006, to protect, and where necessary, improve the quality of waters where shellfish grow and reproduce, and to contribute to the high quality of directly edible shellfish products. The Directive codifies and supersedes the original **Shellfish Waters Directive (79/923/EC)**. Under Article 22 of the Water Framework Directive (WFD), the Shellfish Waters Directive is due to be repealed in December 2013. When this happens, the WFD must provide at least the same level of protection to shellfish waters as currently provided by the Shellfish Waters Directive. The Shellfish Waters Directive requires Member States to:

- Set standards for specified parameters that must be achieved in shellfish waters (Articles 2 & 3).
- Designate shellfish waters (Article 4)
- Establish programmes to reduce pollution in designated waters over a 6 year period (2007 to 2013) (Article 5)
- Endeavour to achieve guideline standards (Article 3(2)) including a standard of 300

faecal coliforms (FC) per 100ml in the shellfish flesh and intervalvular fluid. No mandatory standard for FC is specified in the Directive or the Regulations.

The Directive is transposed into UK legislation by:

The Surface Waters (Shellfish) Classifications Regulations 1997, and
The Surface Waters (Shellfish) Directions 2010.

The Classification regulations specify the requirements for a water to be classified as a shellfish water, while the Directions set guideline values and comments which the applicable environmental agency must *'endeavour to observe'*. These include the guideline standard of 300 FC/ 100ml of flesh or intervalvular fluid listed above, as well as parameters relating to physico-chemical conditions (including temperature, salinity and dissolved oxygen), petroleum hydrocarbons, organohalogens and metals.

EUROPEAN FOOD HYGIENE LEGISLATION

The Shellfish Waters Directive sets environmental standards for the quality of the waters where shellfish live, in order to promote healthy shellfish growth. However, it does not ensure the protection of public health. The quality of commercially harvested shellfish intended for human consumption must comply with the EU Food Hygiene Regulations:

Regulation (EC) No 853/2004 of the European Parliament and of the Council laying down specific hygiene rules for food of animal origin; and
Regulation (EC) No 854/2004 of the European Parliament and of the Council laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption).

Harvested shellfish were previously classified under the **Shellfish Hygiene Directive (91/492/EEC)**. This Directive was repealed in January 2006. Under Regulations 853 and 854, member states are required to put in place a programme of monitoring and classification for shellfish harvesting areas.

Shellfish harvesting areas are classified according to the extent of contamination shown by monitoring of *E. coli* in shellfish flesh and intra-valvular fluid. The level of *E. coli* in bivalve shellfish shows how much faecal pollution (human sewage or animal waste) they have been exposed to in the harvesting area. This in turn determines what, if any treatment shellfish require before they are eaten (whether or not the shellfish require further purification before they can be placed on the market).

Treatment processes are stipulated according to the classification status of the area. The classification categories are:

Class A (≤ 230 *E. coli* MPN/100g) - molluscs can be harvested for direct human consumption.

Class B (90% of samples must be ≤ 4,600 *E. coli* MPN/100g; all samples must be less than 46,000 E. coli/100g.) - molluscs can be sold for human consumption:

after purification in an approved plant, or
after re-laying in an approved Class A re-laying area, or
after an EC-approved heat treatment process.

Class C (≤46,000 *E. coli* MPN/100g) - molluscs can be sold for human consumption only after re-laying for at least two months in an approved re-laying area followed, where necessary, by treatment in a purification centre, or after an EC-approved heat treatment process.

Prohibited (>46,000 *E. coli* MPN /100g) - harvesting not permitted

Regulation No. 854/2004 requires the competent authority to conduct a 'sanitary survey' of shellfish production areas. The following information is reviewed and assessed in a sanitary survey:
location and extent of the bivalve mollusc fishery
type of shellfishery (species, method of harvest, seasonality of harvest)
location, type and volume of sewage discharges
location of river inputs and other potentially contaminated water courses (from OS maps / nautical charts)
location of harbours and marinas (from OS maps / nautical charts)
hydrographic and hydrometric data
existing microbiological data from water quality or shellfish monitoring undertaken in the same area or adjacent areas.

In 2011/2012 the Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook a sanitary survey for the intertidal production areas on the south-east coast of Jersey on behalf of SoJ, in compliance with the requirements stated in Regulation No. 854/2004. The sanitary survey made recommendations on the location of representative monitoring points (RMPs), the frequency of monitoring and the boundaries of the production areas deemed to be represented by the RMPs. The sanitary survey was undertaken on the basis recommended in the European Union Reference Laboratory publication '*Microbiological Monitoring of Bivalve Mollusc Harvesting Areas Guide to Good Practice: Technical Application*'. Findings of the sanitary survey are reviewed and referred to throughout this report.

COMPLIANCE WITH EUROPEAN LEGISLATION

The Shellfish Waters Directive guideline microbiological standard of no more than 300 FC per 100 ml of shellfish flesh implies a requirement to achieve Class A status for classification of harvesting areas. However, the current policy in the UK is to aim to improve water quality such that at least Class B classification can be achieved. This is stated as an achievable interim target towards meeting the guideline FC standard for shellfish flesh quality under the Shellfish Waters Directive.

There appears to be no similar policy statement on the level of ambition for shellfish quality in Jersey, and the degree of influence that this will have on infrastructure investment and operational resources. The lack of a clear policy position on the objectives for shellfish quality may contribute to misunderstandings with stakeholders on the level of support and investment they can expect. The recent Jersey Aquaculture Strategy recommends the establishment of shellfish quality objectives for the Jersey Liquid Waste Strategy and Water Framework Directive which should lead to clearer policy in this area. The 2011 States of Jersey Environment Scrutiny Panel (Protecting our Marine Environment) recommended a position statement clearly stating the aims for desired shellfish quality and a strategy for achieving these objectives would be helpful to stakeholders and would deliver confidence in the process.

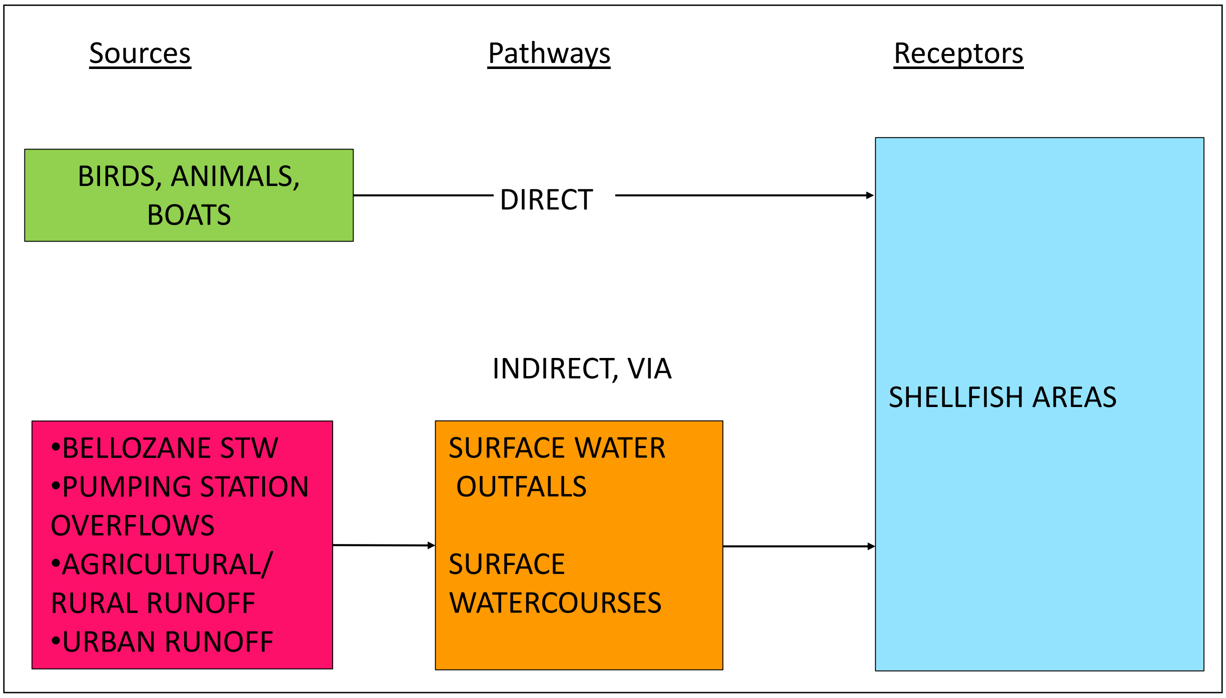
Compliance with the classifications stipulated under Regulation (EC) No 854/2004 is continually monitored. As described in Section 1.1, areas with Class A classification reduced between 2006 and 2009, but since 2009 classifications have remained relatively constant.

APPROACH

CONCEPTUAL MODEL

The aim of the investigation is to identify potential sources and associated pathways for faecal contamination at the shellfish areas. The use of the source-pathway-receptor conceptual model provides a framework to enable a systematic and comprehensive consideration of potential influences. This approach is well-established in the field of environmental investigations and will ensure the validity of the investigation. Figure 3.1 illustrates the main categories for the investigation under each of the three components of the conceptual model.

Figure 3.1 Source-Pathway-Receptor Model as a basis for the investigation



The review examines existing data and reported information under each of the three components of the conceptual model; receptors in Section 4, sources in Section 5, and pathways in Section 6, to establish a current understanding. It will identify uncertainties and gaps which can be resolved with further investigation and monitoring.

REVIEW OF EXISTING DATA AND REPORTS

A significant amount of investigation and analysis has already been undertaken in order to understand the influences on faecal contamination of the shellfish areas. Accordingly there are a number of existing reports and documents which are of direct relevance to the current investigation. Under each of the three components of the conceptual model, existing understanding will be reviewed and the current understanding summarised. All derived information has been clearly referenced.

Reports which are reviewed include, but are not limited to:

- States of Jersey Sanitary Survey Report (including appendices such as the shoreline survey report)
- Drogue Tracking Report, August 2012, v01
- Geophysical Survey Report, August 2012, v0
- Outfall Assessment Study, April 2010, v010
- Bellozanne STW effluent flow and quality data, including operation of the UV disinfection system and measured faecal indicator organism (FIO) data
- All reports and FIO monitoring data from previous sampling of the shellfisheries and any associated sources or stream inputs.
- Meteorological data (rainfall, wind speed and direction) for co-assessment with FIO data
- Wyer, M. D. and Kay, D. (2000). Evaluation of the Fort Regent storm retention scheme in relation to faecal indicator loading and bathing water quality. Report to the States of Jersey Public Services Department.
- Marcon St Aubin's Bay model calibration and validation reports, and Marcon outfall report.

Data and information will be analysed and reviewed in order to determine temporal and spatial patterns in evidence of faecal contamination at the shellfish areas. Review of potential sources will attempt to apportion relative loadings and determine how and when sources become valid. Investigations of pathways will determine the circumstances under which contamination can be conveyed between the sources and receptors.

FAECAL CONTAMINATION AT THE SHELLFISH AREAS

INTRODUCTION

The majority of the shellfish areas in the study area (see Figure 1.1) are used to farm Pacific oyster (*Crassostrea gigas*). However, native oyster *(Ostrea edulis)* and common (or blue) mussel (*Mytilus edulis*) are also farmed on some of the areas. All oysters and mussels are farmed on trestles or poles, and not on the natural substrate. All of these bivalve shellfish are filter feeders. They siphon the water in and over their gills, filter out phytoplankton for food, extract oxygen for respiration, and expel the waste water. Their metabolic needs increase with their size, as more food, oxygen and energy are required to support a larger animal. Metabolic rate is also influenced by water temperature[11].

HISTORIC AND CURRENT CLASSIFICATIONS

Tables 4.1 (oysters) and 4.2 (mussels) describe the historic and current classifications for each of the areas. The tables illustrate how the organisation of the areas has changed over time; areas have been merged, discarded and added since records started in 1996. Classifications are taken from the States of Jersey Department of the Environment notification reports for years 2008 to 2013. Prior to this, classifications were calculated based on geometric means of the data from the preceding year, according to the approach recommended by Cefas[12]. The classifications show that since 2008, the frequency of A Classifications has declined, such that only the Seymour Tower areas (Areas 20 and 26) consistently attain Class A since 2008. Since 2008, B Classifications have been prevalent at all areas other than those at Seymour Tower. Area 12, newly classified in 2009, was originally awarded a provisional Class C for oysters. Since then it has been Class B.

Tables 4.3 (oysters) shows what historic (prior to 2008) classifications may have been where the current CEFAS classification criteria applied. Changes from Table 4.1, each of which is a reduction from Class A to Class B, are indicated in blue shading. This demonstrates a less marked reduction in statuses over time than compared with Table 4.1. This indicates that several of the reductions may be due to a change in the classification process.

Tables 9.1 and 9.2 of the Sanitary Survey report6 also present classifications for oysters and mussels. However the presented classifications span only four years; 2009 to 2012.

11 Lannig, G. Eilers, S. Pörtner, H.O. Sokolova, I.M. Bock, C. (2010) *Impact of Ocean Acidification on Energy Metabolism of Oyster, Crassostrea gigas—Changes in Metabolic Pathways* and Thermal Response. Mar. Drugs 2010, **8**, 2318-2339.

12 Cefas (2010) Microbiological Monitoring of Bivalve Mollusc Harvesting Areas. Guide to Good Practice: Technical Application. Issue 4: August 2010

Table 4.1 Classification for Pacific oysters (*Crassostrea gigas*)[4]

Year	Le Hurel Main Bed						Le Hurel Holding Bed			Seymour Tower		Le Hocq Main Bed		Green Island
	Area 1	Area 21	Area 22	Area 23	Area 24	Area 28	Area 6	Area 27	Area 29	Area 20	Area 26	Area 8	Area 25	Area 12
1996	B[1]						B[1]			< 3 years data		B[1]		B[1]
1997	< 3 years data						< 3 years data			A[1]		B[1]		
1998	A[1]						A[1]			A[1]		B[1]		
1999	A[1]	B[1]			B[1]		B[1]			A[1]	A[1]	B[2]		B[1]
2000	B[1]	B[2]			B[1]		B[2]				< 3 years data	B[2]		
2001	B[2]	B[2]			B[1]		B[2]	< 3 years data			A[2]	B[2]		
2002	A[1]	B[2]			A[1]		B[2]	B[1]			A[2]	B[2]		
2003	B[1]	B[2]			B[1]		B[2]	A[1]			A[2]	B[2]		
2004	B[2]	B[2]			B[1]		B[1]	B[1]			A[2]	A[1]		
2005	B[1]	B[2]			B[1]	B[1]	A[1]	A[1]			A[2]	B[2]		
2006	A[2, 3]	B[1]			B[2]	B[1]	A[1]	B[2]			A[1]	A[2, 3]		
2007	A[2, 3]	B[2]			B[2]	B[1]	A[1]	A[1]			A[2]	B[2]		
2008	B	B	B	A	B	B	B	B			A	A		
2009	B	B	Areas 21 and 22 combined for purposes of testing	B	B	B	B	B			A	B	B[2]	C[2]
2010	B	B		Area 23 amalgamated into Area 28 from 01/04/10	B	B	B	B		< 3 years data	A	B	B	B
2011	B	B			B	B	B	B	< 3 years data	A[2]	A	B	B	B
2012	Seasonal A/B	B			B	B	B	B	B[2]	A[2]	A	Seasonal A/B	Seasonal A/B	B
2013	B	B			B	B	B	B	B	A[1]	B[2]	B	B	Sept. 2012 to Mar. 2013 B

Notes

1 Classifications provided in excel data sheets provided by States of Jersey Department of the Environment

2 Classification derived from data made available by States of Jersey Department of Environment, and according to CEFAS classification criteria12

3 By cross-reference from Regulation (EC) No 854/2004, via Regulation (EC) No 853/2004, to Regulation (EC) 2073/2005. Areas for which the limit of 230 MPN *E. coli* / 100g but less than 1,000MPN *E. coli* / 100g is not exceeded in 90% of samples shall continue to be classified as Class A.

4 Note all Class A classifications in the table were necessarily Class for the whole year with some being regarded during the year

Table 4.2 Classification for mussels (*Mytilus edulis*)

Year	Le Hurel Main Bed			Le Hurel Holding Bed	Le Hocq Main Bed	
	Area 23	Area 24	Area 28	Area 27	Area 8	Area 25
2008		< 3 years data	< 3 years data	< 3 years data	< 3 years data	
2009	B	B	B	B	B	B[1]
2010	Area 23 amalgamated into Area 28 from 01/04/10	B	B	B	Not Classified	B
2011		B	B	B	Not Classified	B
2012		Seasonal A/B	B	B	Not Classified	B
2013		B	B	B	Declassified	Declassified

Notes

1 Provisional classification.

Table 4.3 Application of current standards across the monitoring period for classification for Pacific oysters (*Crassostrea gigas*) based

Year	Le Hurel Main Bed						Le Hurel Holding Bed			Seymour Tower		Le Hocq Main Bed		Green Island
	Area 1	Area 21	Area 22	Area 23	Area 24	Area 28	Area 6	Area 27	Area 29	Area 20	Area 26	Area 8	Area 25	Area 12
1998	B[1]	< 3 years data					B[1]			A[1]		B[1]		B[1]
1999	B[1]	< 3 years data			< 3 years data		B[1]			A[1]	< 3 years data	B[1]		< 3 years data
2000	B[1]	B[1]			< 3 years data		B[1]	< 3 years data		< 3 years data	< 3 years data	B[1]		< 3 years data
2001	B[1]	B[1]			B[1]		B[1]	< 3 years data		< 3 years data	A[1]	B[1]		< 3 years data
2002	B[1]	B[1]			B[1]		B[1]	B[1]			A[1]	B[1]		
2003	B[1]	B[1]			B[1]		B[1]	A[1]			A[1]	B[1]		
2004	B[2]	B[1]			B[1]		B[1]	B[1]			A[1]	B[1]		
2005	B[1]	B[1]			B[1]	< 3 years data	B[1]	A[1]			A[1]	B[1]		
2006	B[1]	B[1]			B[1]	< 3 years data	B[1]	B[1]			A[1]	A[1, 2]		
2007	A[1,2]	B[1]			B[1]	B[1]	B[1]	A[1]			A[1]	B[1]		
2008	B	B	B	A	B	B	B	B			A	B		
2009	B	B	Areas 21 and 22 combined for purposes of testing	B	B	B	B	B			A	B	< 3 years data	C[2]
2010	B	B		Area 23 amalgamated into Area 28 from 01/04/10	B	B	B	B		< 3 years data	A	B	< 3 years data	B
2011	B	B			B	B	B	B	< 3 years data	< 3 years data	A	B	B	B
2012	Seasonal A/B	B			B	B	B	B	< 3 years data	A[1,2]	A	Seasonal A/B	Seasonal A/B	B
2013	B	B			B	B	B	B	B	A[1,2]	B[2]	B	B	Sept. 2012 to Mar. 2013 B

Notes

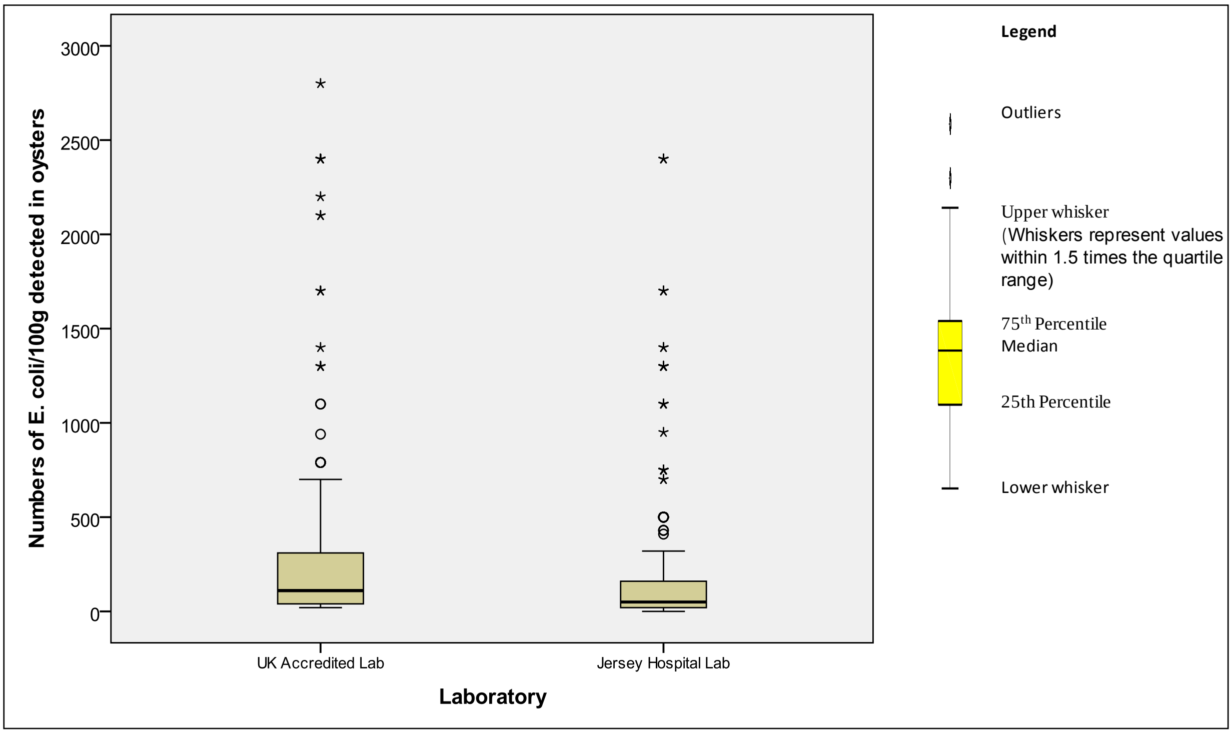
1 Classification derived from data made available by States of Jersey Department of Environment, and based on having data from 3 preceding calendar years (i.e. 1998 reporting year is based on 1996-1998 data) and CEFAS classification criteria12

2 By cross-reference from Regulation (EC) No 854/2004, via Regulation (EC) No 853/2004, to Regulation (EC) 2073/2005. Areas for which the limit of 230 MPN *E. coli* / 100g but less than 1,000MPN *E. coli* / 100g is not exceeded in 90% of samples shall continue to be classified as Class A.

CURRENT UNDERSTANDING FROM EXISTING REPORTS

Data for shellfish flesh *E. coli* counts are held spanning 1996 to the present. This is a relatively substantial dataset. However, it should be used with caution, as over such a period inconsistencies in analysis protocol are likely to have arisen. For example, the laboratory used for analysis of samples was changed in May 2008, from Jersey Hospital laboratory, to a UKAS accredited laboratory in England. Counts from the Jersey Hospital laboratory have been found found to be significantly lower (P<0.01) than those obtained from the accredited laboratory[13]. Figure 4.1, taken from du Feu (2011), shows box plots to illustrate the difference between the data reported from the two laboratories.

Figure 4.1 Variability in *E. coli* data recorded from two different laboratories, Jersey Hospital data obtained 2000 to 2008, UK Accredited lab data obtained 2008 to 2011



Acknowledging that there is a significant difference between the data reported from each laboratory as shown above, this does not necessarily mean that the change in the laboratory is the cause of this difference. There are numerous other variables other than different laboratories that could be responsible for the variance in results, not least of which is the fact that the samples are not 'paired,' i.e. each set of data span different periods, with differing environmental conditions, and potential variations in sample collection protocol. Therefore it cannot be concluded with certainty that the change in laboratory has caused the change in the distribution of reported results.

13 Dr T A du Feu (2011) Long term trends of bacterial contamination in Oysters (*Crassostrea gigas*) cultured in South-East Jersey. States of Jersey Department of the Environment.

However, it is fair to conclude that the change in laboratories is a potential source of variation over the time period. To investigate the influence of the different laboratories on results, it would be necessary to send split samples to each laboratory to compare results of analyses.

Du Feu (2011)[13] also looked at temporal trends in the oyster data limited to that analysed by the accredited laboratory, i.e. between 2008 and 2011. The data showed no evidence of increased counts over the four year period which might correspond to declining water quality. Instead, data showed that counts in 2008 and 2009 were generally higher than those recorded in 2010 and 2011. 2008 and 2009 were stated as 'wet' years. Du Feu (2011) also explored the frequency of exceedence of classification trigger values, and found that the incidence of counts falling below 230 *E. coli* MPN/100g (i.e. Class A) increased from 55% in 2008 to 80% in 2010 and 2011, while the incidence of Class B and C values reduced over the same period.

The Sanitary Survey report[6] presents a comprehensive appraisal of the historical *E. coli* data spanning 2005 to 2011, for oysters in Section 10, and for mussels in Section 11. Data were analysed to determine temporal and spatial patterns, and environmental influences. For oysters, the survey analysis concluded that sampling location has a highly significant effect on *E. coli* concentration, and that counts at Areas 20 and 26 (Seymour Tower) were significantly lower than those at other areas. Scatter plots and fitted lines (LOESS)[14] were used to show temporal changes in the data. This analysis suggested a general increase in counts around the 2008/9 winter period, with no other overall change in results over time. The report notes that '*although laboratory testing transferred from the Jersey Hospital Laboratory to a Health Protection Agency laboratory in May 2008, the time series plots do not show a sustained difference between the results of samples taken either side of that date.*' Area 12 showed the highest mean and highest individual result. Seasonal analysis of the oyster data showed no significant difference at any areas except Area 27, where results for winter were found to be significantly lower than for the other three seasons (p=0.039). A significant correlation with preceding day rainfall and preceding two days rainfall was found at Area 8 and Area 21. Data from Areas 8, 21 and 24 were found to show a significant correlation with preceding seven day rainfall. Incidences of high counts (>4,600 *E. coli* MPN/100g) arose at Areas 8 and 12, in the centre and west of St Clements Bay, after moderate to heavy rainfall. The report noted that Area 8 lies in the Le Hocq gutter, and on a falling tide the sampling point lies in the surface water stream draining from the coast. Area 21 is also located in a surface water stream that drains from La Rocque harbour.

Mussel data also showed a highly significant effect of location. The highest average counts were seen at Area 27, close to the shore at the southern end of Grouville Bay. This area also showed the highest maximum count and the most results >4,600 *E.*

[14] Locally weighted scatterplot smoothing (LOESS) – allows a smooth curve to be fitted to empirical data to depict the 'local' relationship.

coli MPN/100g. Results at Areas 24 (Le Hurel Main Bed) and 25 (Le Hocq Main Bed) tended to be lower than at other areas. No change in results over the time-span of the data (2008-2011) was apparent, nor were any seasonal or cyclical patterns. Areas 24 and 28 showed significant correlation with rainfall, although Area 27, which recorded the highest counts, did not. All results >4,600 *E. coli* MPN/100g occurred after some rainfall, but only 3 of the 6 results occurred after moderate to heavy amounts. Recent results have not shown such high peaks as have occurred in oysters.

The analyses summarised above provide a useful starting point for further investigation, indicating where further analysis may be informative. This review will look at all available data; for oysters this spans 1996 - 2013, and for mussels, 2008 to 2013. Spatial and temporal trends will be re-examined using the entire dataset, as will potential correlations with environmental variables, and incidences of particularly high counts. As identified in the Sanitary Survey report, no correlations with tidal state, salinity or temperature could be analysed due to lack of available data and in the case of tidal variation, the fact that all samples are necessarily collected at low tide.

ANALYSIS OF SHELLFISH FLESH FAECAL COLIFORM COUNTS - OYSTERS

Flesh *E. coli* count data spanning 1996 to 2013 were analysed. Samples have been and are collected and analysed on an approximately monthly basis to inform classification of the fisheries. Samples are not collected according to any specific environmental conditions, other than always at low tide. Therefore any attempt to link environmental conditions to counts is limited by available data. It is noted that the analysing laboratory was changed during May 2008, and that at the same time the classification process was changed such that it is based on a three year rolling mean, whereas prior to this it had been based on sometimes less than a year of data. It is also the case that sampling effort and rigour may have changed over the period. The absence of seasonal A classifications in 2013 is due to reduced sampling effort; the beds were not assessed for seasonal classification in 2012/13.

It is notable from the data shown in Table 4.3 that the geomean of all counts is below the 230 *E. coli* MPN/100g threshold for Class A. The geomeans at Areas 20 and 26 are notably lower than elsewhere, although maximum count recorded at Area 26 of 16,000 was from a sample collected during 2013. The difference between the counts at Areas 20 and 26 elsewhere suggests a background level of contamination at the other areas which is not an influence at these outer areas. Gaps in the sampling summary reflect where areas were taken out of production.

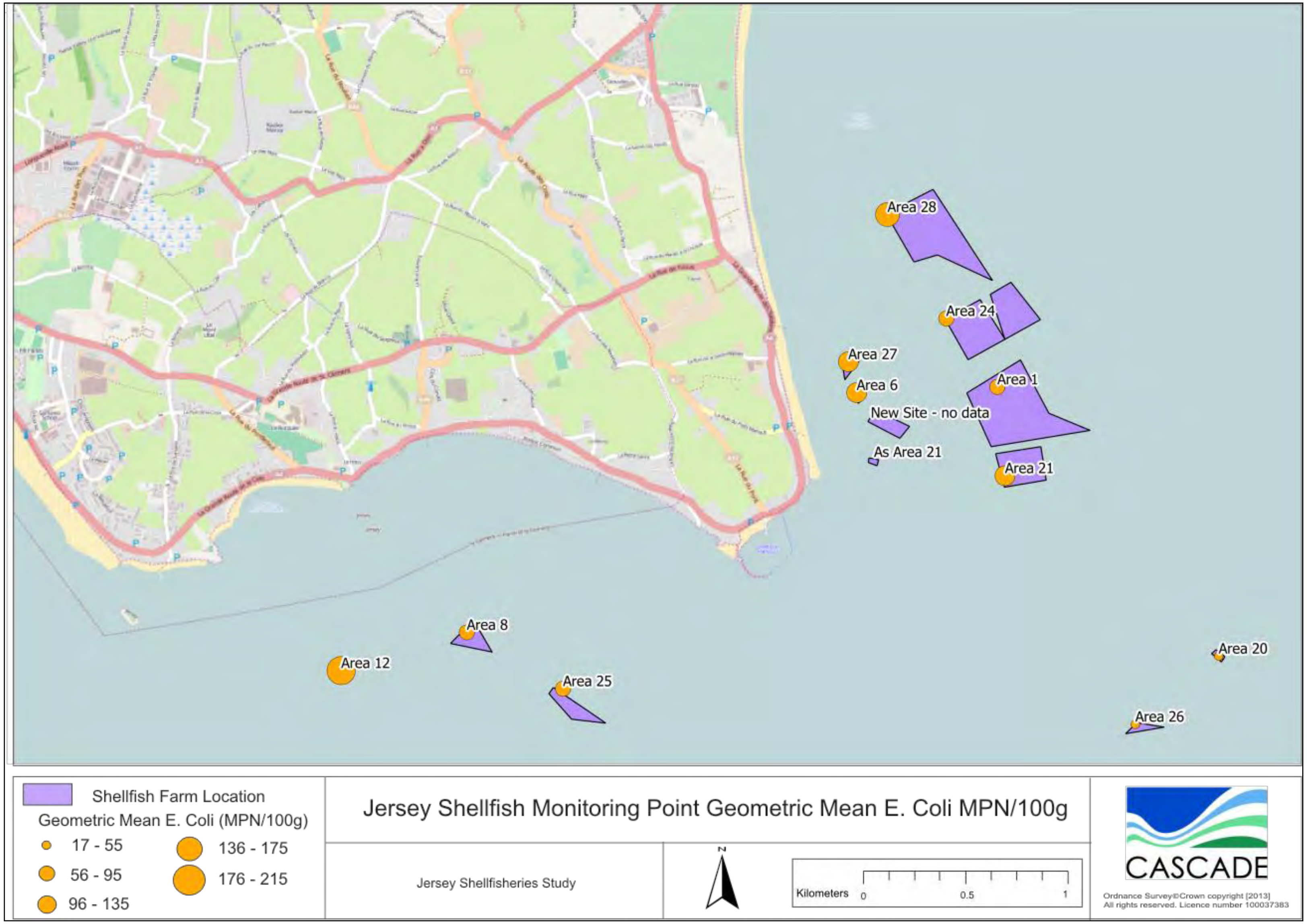
Table 4.3 Summary of historical sampling and results for oysters

	Le Hurel Main Areas				Le Hurel Holding Areas		Le Hocq		Green Island Area	Seymour Tower Area	
Concession	**1**	**21**	**24**	**28**	**6**	**27**	**8**	**25**	**12**	**20**	**26**
Sampling Summary											
Total number of samples	198	180	164	88	204	145	201	52	96	73	150
1996	10				10		10		8	10	
1997	12				12		12		11	11	
1998	12	11			12		12		12	12	
1999	11	11	6		11		11		2	8	2
2000	12	11	11		12	3	10				11
2001	12	12	12		12	12	10				12
2002	11	11	11		11	11	10				10
2003	11	11	11		11	11	11				11
2004	11	11	11		11	11	11				11
2005	12	12	13	2	12	12	12				12
2006	12	12	12	12	12	12	12				11
2007	12	13	12	12	13	12	12				12
2008	12	12	12	13	12	12	13		7		12
2009	12	12	12	13	12	13	13	13	14		12
2010	12	12	12	12	12	12	12	14	12	11	12
2011	12	12	12	12	12	12	12	12	12	12	12
2012	12	12	12	12	12	12	12	13	14	6	6
2013 (January to May)		5	5		5		6		4	3	4
Results Summary											
Min (*E. coli* MPN/100g)	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Max (*E. coli* MPN/100g)	5,400	9,200	5,400	3,500	5,400	3,500	9,200	3,500	16,000	490	16,000
Median (*E. coli* MPN/100g)	70	85	90	130	110	90	70	110	225	20	10
Geometric Mean (*E. coli* MPN/100g)	85	104	91	140	108	100	76	95	214	21	17
90 percentile (*E. coli* MPN/100g)	500	821	500	762	500	496	310	490	1,100	78	56
95 percentile (*E. coli* MPN/100g)	756	1,305	790	1,920	1,054	918	500	790	1,825	202	130
No. at Limit of Detection (<20 MPN/100g)	5	10	9	3	4	4	9	4	1	12	45
No. Exceeding 230 MPN/100g	45	48	41	26	45	36	30	12	42	4	5
No. Exceeding 1,000 MPN/100g	6	18	8	8	11	7	7	2	11	0	1
No. Exceeding 4,600 MPN/100g	1	1	2	0	1	0	2	0	3	0	2
No. Exceeding 18,000 MPN/100g	0	0	0	0	0	0	0	0	0	0	0

Spatial Analysis

Appendix A of this report contains details of statistical analyses which have been undertaken to explore the available *E. coli* count data. Analyses suited to non-parametric data have been used as appropriate to coliform data which generally show a non-normal distribution. One way analysis of variance (ANOVA) using the longer term dataset (1996-2013) showed a highly significant effect of sampling location ($p<0.0001$) (details of statistical analysis are shown in Appendix A), i.e. counts were significantly different between sites. This corroborates the findings of the Sanitary Survey report which uses a shorter dataset. Further comparison analysis using all data (Tukey-Kramer method) showed counts at Areas 26 and 20 (Seymour Tower) to be highly significantly different ($p<0.0001$) from those at all other areas, and that there was no significant difference between counts at Areas 20 and 26. Analysis also showed that counts at Area 12 were significantly different to those at Areas 1, 24, 27, 21 and 6 in Le Hurel, and nearby 25 and 8. Analysis of paired data (70) at Areas 1, 21, 24, 28, 6, 27, 8 and 26 using two-way ANOVA supported the Sanitary Survey conclusion that Area 26 counts are highly significantly lower than those at other areas ($p<0.0001$). No paired data were available for Areas 12, 25 and 20. It is therefore apparent that the areas which are furthest from the shore, Areas 20 and 26 at Seymour Tower, show significantly lower *E. coli* counts. This suggests that these areas are not affected to the same extent by the influence or influences on counts at the other areas. Figure 4.2 shows the oyster sampling locations with geomeans of all data indicated by the size of the data point; the highest geomean occurs at Area 12 - 214 *E. coli* MPN/100g.

Figure 4.2 Map of geometric mean *E. coli* MPN/100g in oysters



Temporal Analysis

The graphs in Figure 4.3 show all oyster data plotted against time, with LOESS lines fitted in order to help detect any trends or patterns in the data. This technique was used in the Sanitary Survey report and is a tool for depicting relationships between variables in non-parametric data, and is therefore suitable for looking at temporal patterns in these long-term, non-parametric datasets[15]. Data are available over varying time spans for each area. Similar analysis was undertaken and reported in the Sanitary Survey Report, though for a shorter data set. Water quality data are conventionally presented as $\log_{10}$ transformed data as they do not generally conform to a normal distribution, and transformation helps visualisation and analysis of data.

Areas 1, 21, 24, 28, 6 and 27 comprise the main and holding bed areas in Grouville Bay. The count data at Areas 1, 21, 24, 6 and 27 suggest no change or perhaps a very gradual falling trend between 1996 and 2005. Between 2005 and 2013 there appears to be an increase in the counts recorded at these areas, which is also suggested in the shorter data set for Area 28. This increase is not evident in the Sanitary Survey report analyses based on data to 2011, which at Areas 1, 21, 24 suggest counts are reducing between late 2008/9 and late 2011. Counts since 2011 have therefore been higher. The Sanitary Survey report does note the peak in winter of 2008/9, at Areas 1, 21, 24, 6 and 27.

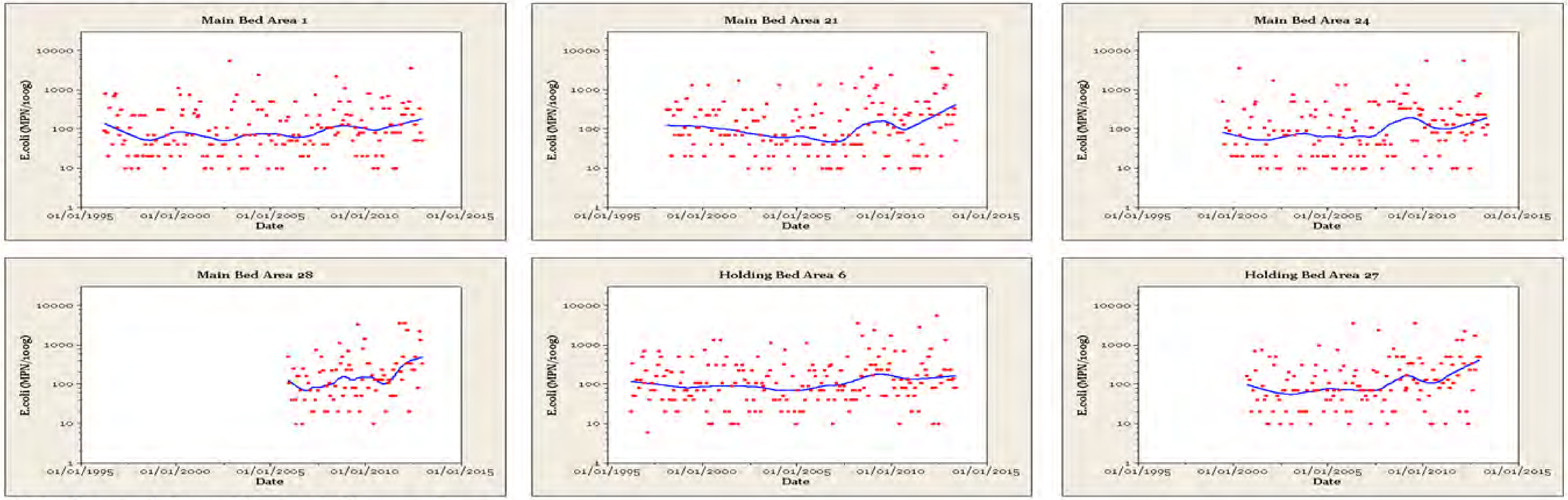
Areas 12, 25 and 8 comprise the Green Island and Le Hocq beds in St Clements Bay. Data for Area 8 suggest a similar pattern as that seen for Areas 1, 21, 24, 6 and 27, with a falling trend up to 2005, then a rising trend between 2008 and 2013. The datasets for Areas 12 and 25 are not long enough for meaningful interpretation of trends, but the data do suggest comparable counts to those seen at the other St Clement's and Grouville Bay sites.

Areas 20 and 26 (Seymour Tower) comprise a distinct group and are the furthest away from the shore. As reported in the Sanitary Survey report, the data shown in the charts reflect markedly lower flesh concentration values reported for these sites. The shorter data sets do not show temporal trends at these areas, although there does appear to be increased scatter in the data at Area 26 after 2008.

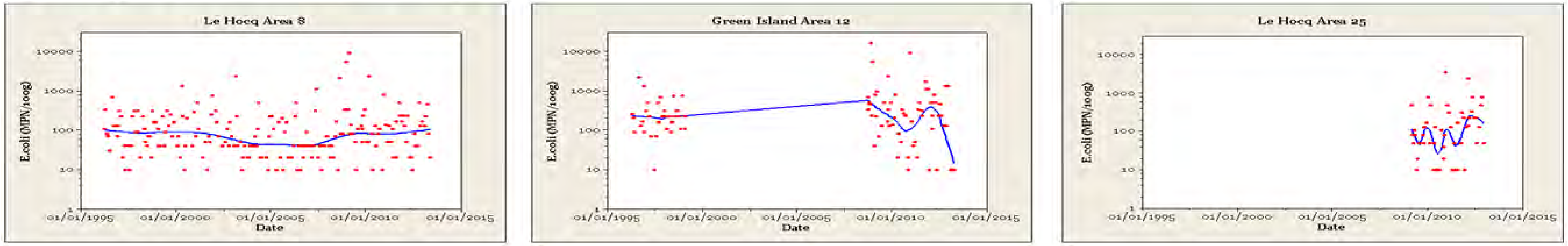
[15] Locally weighted scatterplot smoothing (LOESS) – allows a smooth curve to be fitted to empirical data to depict the 'local' relationship.

Figure 4.3 Scatterplots of *E. coli* oyster flesh count data, with LOESS lines to show temporal trends and patterns

a) Main and Holding Beds – Grouville Bay



b) Le Hocq and Green Island – St Clements Bay



c) Seymour Tower Areas

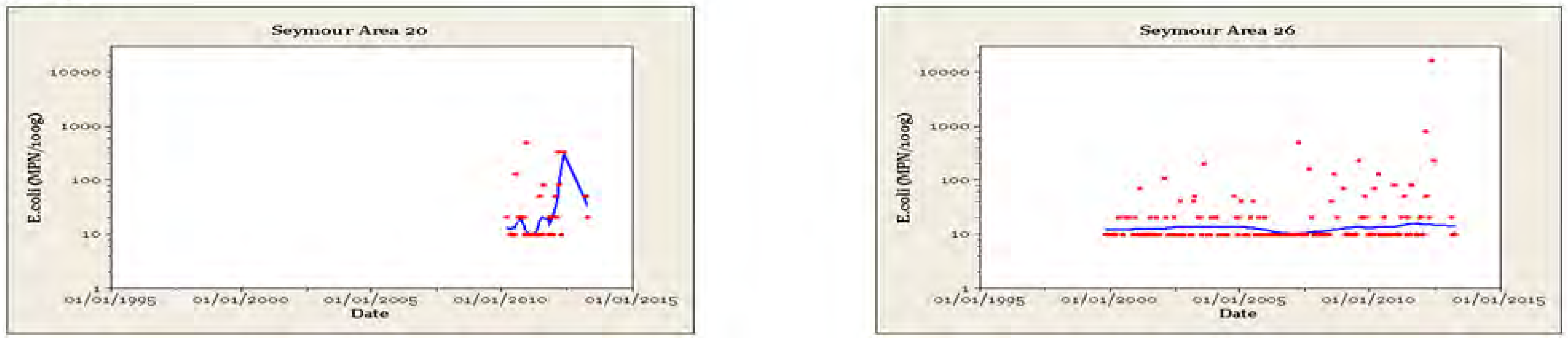
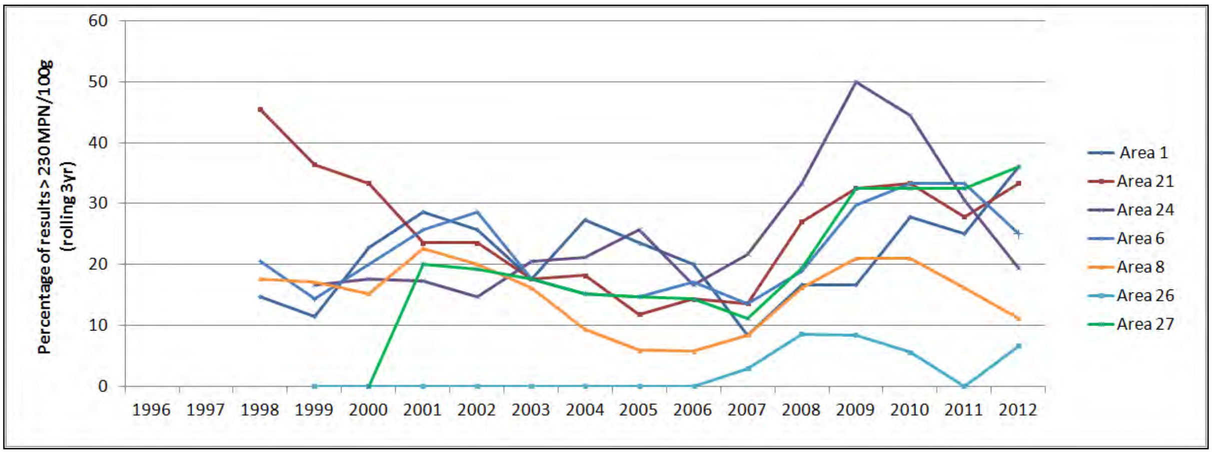


Figure 4.4 shows the percentage of results over a preceding three year period which exceeds the 230 *E. coli* MPN/100g threshold, for those areas with the longest and most complete datasets. The peak in counts during 2008 and 2009, discussed in Section 4.4.2 is clear and appears to be evident at all areas shown, noting that data for Areas 28, 12, 25 and 20 are not shown. It is noted that the change in analysing laboratory occurred in May 2008. The chart shows that although the frequency of counts exceeding the threshold rose at all sites in 2008, since 2010 the data show a reduction in the frequency which continued through 2011 and 2012. It is noted that for any area to remain at Class A, the percentage of results exceeding 230 *E. coli* MPN/100g must not exceed 10%. The graph therefore provides an indication of the required effort to attain Class A at each of the areas.

Figure 4.4 Frequency of exceedance of 230 *E. coli* MPN/100g (% of results using rolling 3 year totals)



Seasonal trends in the data

The Sanitary Survey reported no significant seasonal influence on counts other than at Area 27. Analysis of the longer term dataset (one-way ANOVA) showed no significant difference between seasons at Area 27, nor at Areas 6, 12, 20, 21, 24, 26 and 28. However, significant differences between seasons were found at Areas 1 ($p<0.01$), 8 and 25. Subsequent comparison analysis (Tukey Kramer) showed results at Area 1 were lower during summer than winter ($p<0.01$) and lower during summer than spring ($p<0.01$), at Area 8 they were lower in summer than in winter ($p<0.01$), and at Area 25 they were lower in summer than in winter ($p<0.01$).

The results for Areas 1, 8 and 25 could be explained by their moderate distances off shore and the greater opportunity for dilution and *E. coli* die-off anticipated in the sunnier, warmer conditions expected in the summer months. Areas 20 and 26 (the Areas furthest off shore) have already been identified as having low results throughout the year and therefore the suggested die-off signal for Areas 1, 8 and 25 is not evident.

Environmental Influences

The Sanitary Survey explored effects of recent rainfall on counts at the fisheries. As reported in the Sanitary Survey report, data were not available to investigate other influences such as tides, winds, sunshine (i.e. effects of irradiance on coliform viability), temperature and salinity, although the report acknowledged that these factors are potential influences. It is arguable that rainfall is the primary environmental influence on transfer of faecal organisms from the terrestrial to the marine environment. The influences of rainfall (gauged at Maison St Louis), and hours of sunshine (recorded at Fort Regent, St Helier), are reviewed below.

Correlation analysis (Spearman's rank - see Appendix A for detailed results) using the long term dataset available for this investigation showed that counts at Areas 1, 8, 6, 21, 24 and 28 are positively correlated with 7 antecedent day cumulative rainfall at a highly significant level ($p<0.01$). No significant correlations were found for counts at Areas 12, 25, 27, 20 and 26. It is notable that it is those areas that are closest to the shore which show a significant correlation with rainfall, with the exception of Area 27.

Correlation analysis showed that counts at Areas 1, 8, 24, 21 and 25 showed a significant negative correlation with antecedent seven day sunshine hours. No significant negative or positive correlation was found at Areas 6, 12, 20, 26, 27 and 28.

Incidences of high counts

The Sanitary Survey report listed oyster samples which had given results exceeding 4,600 *E. coli* MPN/100g. Two incidences of such high counts arose from separate areas on the same date, and all samples arose after moderate to heavy rainfall. Five of the six samples came from Areas 8 and 12 in St Clement's Bay, the other sample from Grouville Bay (Area 24).

Analysis of data collected since publication of the Sanitary Survey showed that there were two additional occasions where results exceeding 4,600 *E. coli* MPN/100g were recorded. In both instances two samples with high counts arose from separate areas on the same date (Areas 21 and 24 on February 7, 2012, and Areas 6 and 26 on May 8, 2012). Incidences of high counts and occurrence of PS spills is discussed further in Section 5.5.

SHELLFISH FLESH FAECAL COLIFORM COUNTS - MUSSELS

Flesh *E. coli* count data spanning a period from 2008 to 2013 were made available for analysis. Samples had been collected and analysed on an approximately monthly basis to support classification of the fisheries. The 2008-2013 dataset extends that analysed in the Sanitary Survey Report (2008 to 2011). The data have been analysed to determine temporal and spatial trends and patterns. Effects of potential influences on counts have also been explored, noting the temporal extent of the mussel dataset is much shorter than that for oysters. The data are summarised in Table 4.7. It is notable that the geometric *E.coli* mean for Area 27 mussels is the only mean, for either mussels or oysters, to exceed the 230 *E. coli* MPN/100g threshold (that applies for both mussels and oysters).

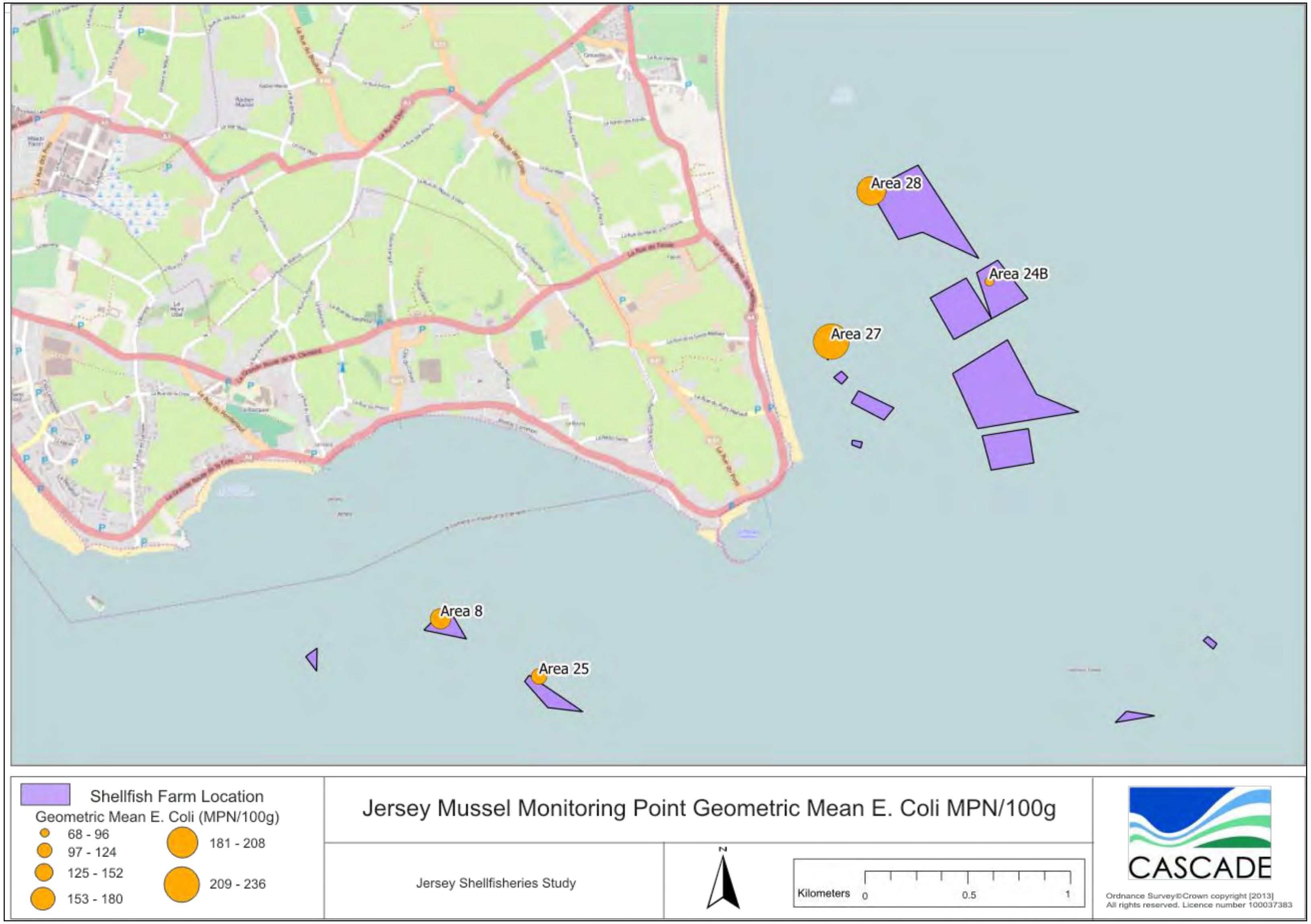
Table 4.7 Summary of historical sampling and results for mussels

Production Area	**Le Hurel Main Beds**		**Le Hurel Holding Bed**	**Le Hocq Main Bed**	
Concession	**24B**	**28**	**27**	**8**	**25**
Sampling Summary					
Total number of samples	74	65	69	36	51
2008	13	13	13	13	
2009	15	15	15	15	12
2010	13	12	12	5	14
2011	13	13	12		12
2012	15	12	12		13
2013	5		5	3	
Results Summary					
Min (*E. coli* MPN/100g)	<20	<20	<20	<20	<20
Max (*E. coli* MPN/100g)	5,400	16,000	24,000	3,500	4,910
Median (*E. coli* MPN/100g)	80	170	230	120	80
Geometric Mean (*E. coli* MPN/100g)	68	195	236	130	100
90 percentile (*E. coli* MPN/100g)	700	976	790	1,427	330
95 percentile (*E. coli* MPN/100g)	968	1,380	1,220	2,400	490
No. at Limit of Detection (<20 MPN/100g)	25	3	3	5	5
No. Exceeding 230 MPN/100g	14	26	34	12	14
No. Exceeding 1,000 MPN/100g	4	7	6	6	1
No. Exceeding 4,600 MPN/100g	1	1	3	0	0
No. Exceeding 18,000 MPN/100g	0	0	1	2	0

Spatial analysis

One way analysis of variance (ANOVA) using the extended dataset (2008-2013) showed general agreements with the results reported in the Sanitary Survey Report. The analysis showed a highly significant effect of sampling location ($p<0.0001$) (details of statistical analysis shown in Appendix A). Further comparison analysis (Tukey-Kramer method) using all data showed that the counts at Areas 24 and 25 were significantly lower from those at Area 27. The test also showed counts at Area 24 to be significantly lower than those at Area 28 (not previously identified).

Figure 4.5 Map of geometric mean *E. coli* value by sampling location



Areas 24, 27 and 28 have been sampled on the same date on 63 occasions (an additional 15 since the Sanitary Survey report). A two-way ANOVA supported the Sanitary Survey conclusion that there is a significant difference between Areas ($p<0.0001$, Appendix A) and that Areas 24 and Area 25 counts were significantly lower than those at Area 27 ($p<0.0001$, Appendix A). It is noted that, as was the case for oysters, the areas which are furthest from the shore, in this case Areas 24 and Area 25 (rather than Areas 20 and 26), show significantly lower *E. coli* counts. The highest geomean was recorded for Area 27; 236 *E. coli* MPN/100g. Figure 4.5 shows the oyster sampling locations with geomeans of all data indicated by the size of the data point.

Temporal Analysis

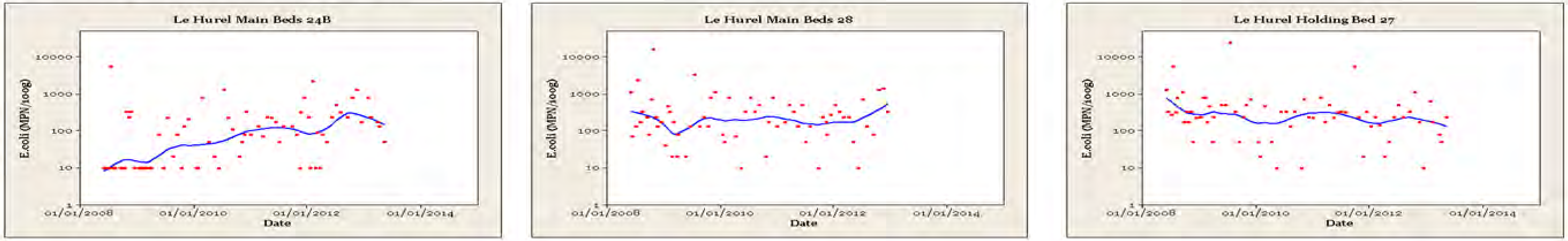
The graphs in Figure 4.6 show all mussel data plotted against time, with LOESS lines fitted in order to help detect any trends or patterns in the data (as were used for oyster data). Data are available over varying time spans for each area. Similar analysis was undertaken and reported in the Sanitary Survey Report, though for a slightly shorter data set.

Areas 24, 28, and 27 comprise the main and holding bed areas in Grouville Bay. The extended dataset has not changed the general pattern identified by the Sanitary Survey report for Areas 25, 27 and 28; the LOESS lines are relatively flat with small deviations which do not appear to relate to each other. Area 8 has very few samples post 2011 on which any analysis further to that in the Sanitary Survey can be based. As noted by the Sanitary Survey report there is an apparent sequence of lower results in 2009. The data at Area 24 show an increasing trend. It is noted that data used in this assessment for Area 24 were from samples taken from poches only, and did not include data from pole grown mussel samples from the outer part of Area 24. This may explain differences between the results reported here and those reported in the Sanitary Survey report.

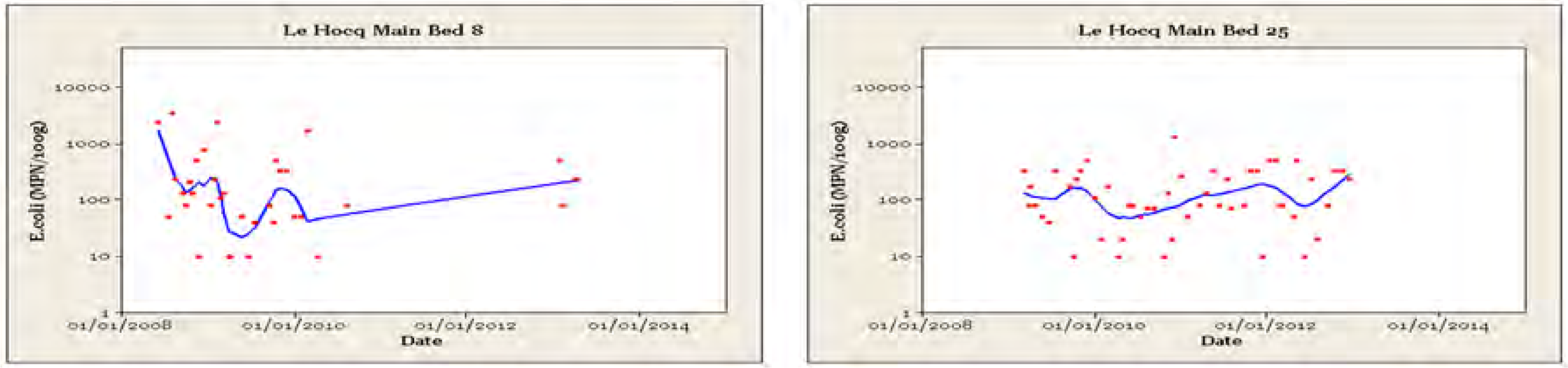
The Sanitary Survey reported no significant seasonal influence on counts. Repeating the analysis with the more recent data (2011 to 2013) concluded similar findings with the exception of Area 27. Area 27 showed a significant difference between results by season (One-way ANOVA, $p = 0.0155$). Further comparison analysis (Tukey-Kramer multiple comparisons test) showed results in the spring were significantly lower than summer ($p = 0.0088$).

Figure 4.6 Scatterplots of *E. coli* mussel flesh count data, with LOESS lines to show temporal trends and patterns

a) Main and Holding Beds – Grouville Bay



b) Le Hocq and Green Island – St Clements Bay



Environmental Influences

As stated in Section 4.4.4 the Sanitary Survey explored effects of recent rainfall on counts at the fisheries. The influences of rainfall (gauged at Maison St Louis), and hours of sunshine (recorded at Fort Regent, St Helier), are reviewed below.

Analysis (Spearman's rank correlation – Appendix A) using the extended dataset available for this investigation showed that counts at Areas 24, 28 and 8 are significantly correlated with 7 antecedent day cumulative rainfall ($p<0.05$). Correlations at Areas 27 ($p=0.086$) and 25 ($p=0.29$) were found not be statistically significant. These results mirror that for oysters from the same Areas.

Analysis (Spearman's rank correlation – Appendix A) showed that counts at Areas 8 and 25 showed a significant negative correlation with antecedent seven day sunshine hours. At Areas 24, 28 and 27 no significant correlation with sunshine hours was found. This corresponds with the results from analysis of oyster counts for those beds which hold both oysters and mussels, with the exception of Area 24, for which oyster counts showed a negative correlation with sunshine.

Incidences of High Counts

The Sanitary Survey report identified six samples for which counts were recorded over 4,600 *E. coli* MPN/100g. All samples were collected between July to October. High results were recorded on the same dates in two separate areas on two occasions; on July 21, 2008 at Areas 24 and 27; and on July 22, 2009 at Areas 23 and 27. No counts exceeding the threshold have been recorded since publication of the report.

Frequency of PS spills in relation to occurrence of high counts and rainfall is discussed further in Section 5.5.

SOURCES OF FAECAL CONTAMINATION

INTRODUCTION

As illustrated by the conceptual model (Figure 3.1), water quality around the shellfish areas may be influenced by a number of sources, through direct transmission to the water column around the areas, or via indirect pathways such as conveyance by watercourses, tides and currents and influenced by environmental conditions such as irradiance by the sun and turbidity. Pathways, including effects such as irradiance and decay rates, are discussed in Section 6.

This section reviews potential sources as identified by the conceptual model. For the purposes of this review, the sources to be considered are:

birds, animals and boats - for which there are direct pathways to the areas

Bellozanne Sewage Treatment Works (STW), agricultural and urban runoff, pumping station (PS) and emergency overflows – for which there are indirect pathways to the areas.

A number of the outfalls are known to convey small streams, while PS overflows are known to spill to both streams and surface water drains. Rural and urban runoff will mainly be conveyed to the sea via streams and surface water drainage outfalls. Acknowledging this inter-connectivity, sources that are conveyed by streams and outfalls are considered in turn, and represented collectively for each catchment at the point of entry of the watercourse to the coastal system. Influences on the activation of each source, for example timing of slurry spreading to land and occurrence of PS spills are also considered. It is noted that slurry application to land is prohibited during October to December inclusive, but that application to potato growing land is likely to occur prior to ploughing during January to March.

In terms of population, there are five parishes close to St Clement's Bay and Grouville Bay, with population densities of up to 3,000 persons/km^2. Three settlements are in close vicinity to the fisheries; St Helier, St Clement which runs the length of St Clement's Bay, and Gorey, located at the northern end of Grouville Bay. There is also a group of dwellings (Grouville) on the central shoreline of Grouville Bay. The peak tourism season runs from May to September. In 2011, approximately 13,000 tourists visited the island per week, amounting to a population increase of 13%. There is a significant amount of boating activity in and around the area surrounding the shellfish areas. Understanding gleaned from the Sanitary Survey is summarised under each of the following sections relating to individual sources, supplemented by further analysis.

BELLOZANNE SEWAGE TREATMENT WORKS

Current Understanding

The only continuously discharging STW on Jersey is Bellozanne STW, which serves the entire island with around 85% of dwellings connected to the works. Sewage is transported via a network of 111 PS and arrives at the works through the First Tower PS. A small package treatment plant at Bonne Nuit provides the only other sewage treatment on the island. However, this discharges on the northern side of the island and is not considered likely to influence water quality at the shellfish areas. Bellozanne STW discharges treated effluent to the sea at the First Tower outfall in St Aubin's Bay, via the culverted Bellozanne Stream (which also discharges via the First Tower outfall). This discharge is 7km northwest of the most western shellfish site (Area 12).

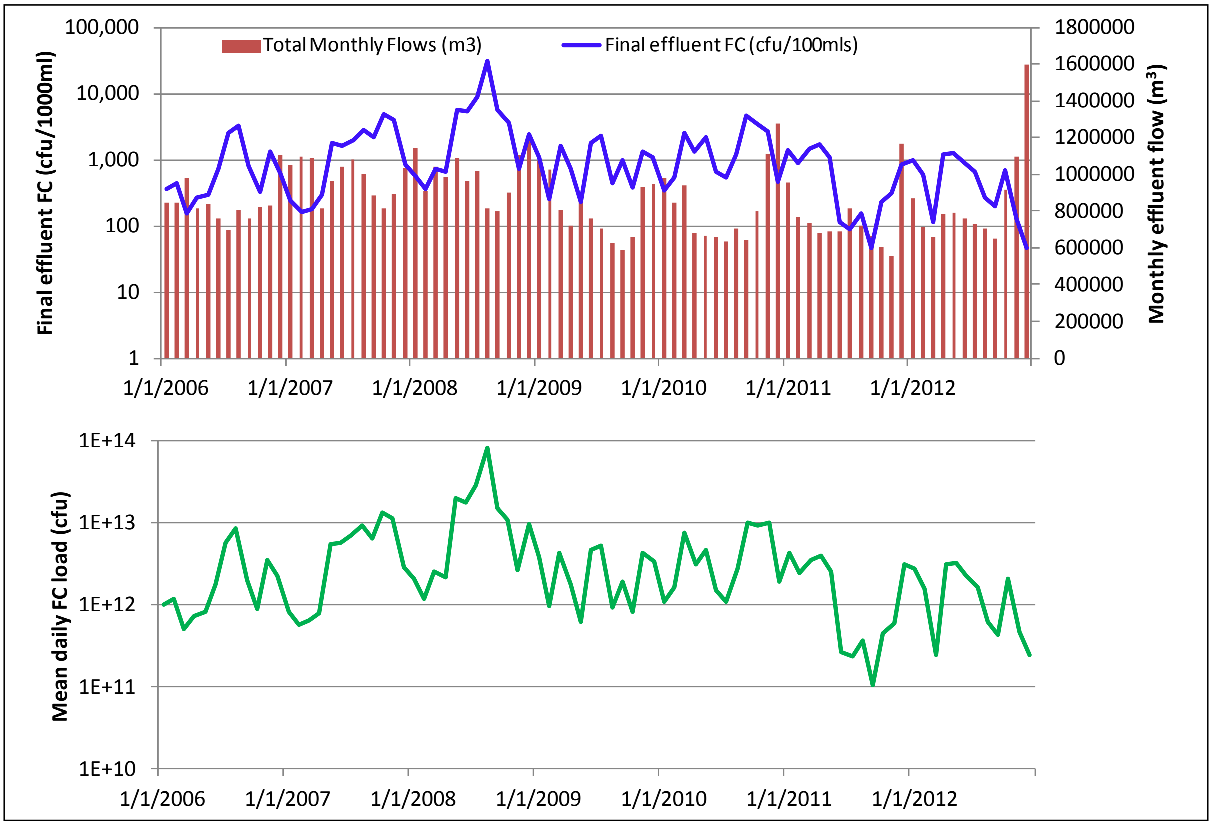
The STW provides tertiary treatment with ultra-violet (UV) disinfection for flows up to 600l/s. During high flow events more UV lamps and treatment lanes can come online such that the plant can treat up to 1,000l/s. However, only 600l/s can undergo full tertiary treatment with UV disinfection. The remaining 400l/s receive primary and UV treatment, but do not undergo secondary treatment - UV treatment of this effluent would be expected to be less effective due to its higher turbidity. Storm overflows are collected at the Fort Regent Cavern, which can store up to 25,000m^3 for treatment as capacity allows. The Cavern infrequently overflows via the West of Albert/Weighbridge outfall and spills untreated sewage (approximately two times per year).

The Sanitary Survey reviews a limited number of 2009 FC data to assess the bacterial quality of storm overflows from the works. Effectiveness of UV treatment was observed to vary, with some outflows during dry weather containing FC concentrations two orders of magnitude greater than that expected for UV treated wastewater. Effluent arriving at the works during storm conditions had FC concentrations an order of magnitude greater than for other days; this is consistent with expected concentrations for storm overflows. It would also be expected that microbial reductions would be reduced at higher flows (above 600l/s), due to the reduced level of secondary treatment. The Sanitary Survey report used a geomean of final effluent concentrations of 330cfu/100ml (May to December 2011) and reported flows, to determine a daily loading of 8.37E+12 cfu/day at mean flows, and 1.16E+13 at 90th %ile flows. The report concluded that these loadings are relatively high and constitute a potentially significant source, subject to effects of dilution, dispersion, irradiance.

Review of Data

For this review, final effluent FC data were available for 2006 to 2012 in the form of monthly geomeans. In combination with daily effluent flow data, these data were analysed to determine any trends over time in the faecal coliform loads from Bellozanne STW. Effluent flows, faecal coliform concentrations and loads are shown by the charts in Figure 5.1.

Figure 5.1 Bellozanne STW effluent flows, faecal coliform concentrations and faecal coliform loads, 2006 to 2012



The data show that final effluent concentrations reduced in 2011 and 2012 compared to the five previous years, resulting in reduced loads as shown on the lower graph and Table 5.1. Loads are primarily driven by concentrations as shown by the very similar shape on the graphs for concentration and load. There is no significant correlation between flows and concentrations observed in the data at the resolution available (monthly mean concentrations). The reduced loads through 2011 and 2012 may reflect a reported improvement in consistency of the treatment stream at the STW. The peak in load during 2008 is influenced by high concentrations between May and September, with a peak of 30,000 cfu/100mls in August of that year.

Table 5.1 Total faecal coliform concentrations and loads, Bellozanne STW final effluent

Year	Geomean FC concentration (cfu/100mls)	Daily load (cfu)
2006	920	2.42E+12
2007	1,740	5.34E+12
2008	5,400	1.60E+13
2009	1,020	2.68E+12
2010	1,700	4.47E+12
2011	690	1.80E+12
2012	580	1.53E+12

The daily loads for all years except 2008 reported in Table 5.1 are lower than the predicted load for mean flows calculated in the Sanitary Survey report (8.37E+12 cfu). As reported in the Sanitary Survey report, typical concentrations for effluent subjected to UV disinfection vary between 280 and 360 cfu/100mls depending on flows. Were the STW to consistently achieve this level of reduction, loads would be reduced by an order of magnitude, for example to 7.9E+11 and 9.0E+11 cfu/day based on 2011 and 2012 flows respectively. Continued recording of flows and concentrations, with further analysis of concentration data at higher than monthly resolution, will allow confirmation of typical loads and effects of improvements to the treatment stream. If continuous data for UV implementation were available it may be possible to investigate a correlation with counts at those areas nearest to the STW (12, 8 and 25). The only currently available UV data is intermittent.

Efficacy of disinfection is also affected by the flows to the STW. Flows in excess of 600l/s are only subject to primary settlement prior to UV treatment. Efficacy is likely to be reduced as the primary effluent would be more turbid. Flow data show that since 2006, most overflow days occurred during 2007 and 2008, and fewest during 2006 and 2011, reflecting the flow data and loads shown in Figure 5.1. Data were analysed to determine any correlation between oyster counts at Area 12, nearest the STW, and volume of 2 day and 3 day antecedent spill; but no significant correlation could be determined. Such analysis is limited by the availability of *E. coli* data.

SURFACE WATER OUTFALLS

Current Understanding

As indicated by the Sanitary Survey, outfalls may discharge permanent or ephemeral streamflow, runoff from urban and rural environments, and PS spills. The Sanitary Survey report reviews permanent watercourses and drainage outfalls together. However the report does not attempt to characterise loadings from the main watercourse catchments, presumably because flow and concentration data were not available.

Spot gauged and sampled flow and concentration data for a number of surface water discharges around the St Clement's Bay and Grouville Bay areas are presented (Table

4.7 of the report). The flows were gauged and samples taken during a shoreline survey on 28 and 29 November 2011, which was preceded by light rainfall (0.8mm over the two days preceding the survey). It was unclear whether flows were derived from piped/culverted watercourses or from septic sources, though it was confirmed that no PS spilled during the survey. Loadings were generally low (in the order of 1E+8 cfu per day) and were stated as probably representing base freshwater flows at most of the locations, noting that antecedent conditions had been dry for a long period. At two sites, in the middle and at the northern end of Grouville Bay, higher loads (up to 6E+10) were recorded - the report stated these have potential for contamination of the Grouville Bay shellfish areas. The Sanitary Survey report also referred to a previous survey (Langley et al, 1997), in which samples collected from outfalls around the same section of coast were analysed for faecal coliforms (rather than *E. coli)*. This survey found higher concentrations and loads. However, it is difficult to draw a meaningful comparison because the antecedent weather conditions of the 1997 survey are unknown, and the analysed parameters, faecal coliforms and *E. coli,* are not directly comparable. Differences in results could also arise due to improvements in management of the sewerage network and to agricultural practices implemented since the 1997 survey. It is noted that consideration of effects of outfalls and streamflows at the point at which they enter the marine environment, will incorporate consideration of up-catchment influences, including all agricultural and urban runoff.

Review of Data

There are around 35 surface water outfalls around the island all of which have the potential to convey septic material to the sea. Of these, 18 discharge at locations such that they are considered worthy of further investigation as to their potential influence on water quality at the shellfish areas. Figure 5.2 shows the locations of these outfalls, which with the exception of Weighbridge, Le Dicq and Dicq Slipway are all within 2km of the shellfish areas. Weighbridge discharges overflows from the Cavern PS which has spilt in recent years according to data provided by Transport and Technical Services (TTS). It is therefore considered important to retain this outfall for consideration. Le Dicq has also spilled, and Dicq Slipway discharges the Baudrette Brook. The First Tower outfall is considered separately as this discharges effluent from the STW (as well as the Bellozanne Stream). Stream watercourses are considered in Section 5.4 below, noting that certain streams discharge via outfalls.

Figure 5.2 Surface water outfalls within 2km of the shellfish areas

Table 5.2 lists the outfalls shown on Figure 5.2 and provides further information as to the sources which feed into them, including PS overflows. The corresponding site reference from Table 4.7 in the Sanitary Survey report is also listed where this can be deduced with some level of certainty. Sites 5 and 6 from the Sanitary Survey did not correspond with routinely monitored outfalls and are not included in the table.

Table 5.2 Outfalls considered to be of relevance to the investigation

Outfall	Location x	Location y	Source	Associated Pumping Station	Sanitary Report Reference
Weighbridge	41135	64935	Rural, urban and road run-off and potential foul storm overflow from St Helier CSOs, including Cavern	Cavern overflow CSO	n/a
Dicq Slipway	42794	64592	Rural, urban and road run-off and stream flow from Baudrette Brook	n/a	n/a
Le Dicq	42616	64267	Foul storm overflow from Le Dicq PS	Le Dicq	n/a
Beach Hotel Slip	47788	66918	Urban and road run-off and potential foul storm overflow	Le Rivage	10
Fauvic	47472	64873	Fauvic marsh and road run-off	n/a	8
Fort Henry	47422	65626	Grouville marsh area, urban and road run-off	n/a	9
La Greve d'Azette	43790	63396	Rural, urban and road run-off and potential foul storm overflow	Maupertuis	n/a
La Rocque	47550	63378	Rural and road run-off	n/a	n/a
Le Bourg 1	46594	63595	Rural, urban and road run-off and potential foul storm overflow	Le Bourg	n/a
Le Bourg 2	46321	63728	Rural, urban and road run-off	n/a	4
Le Hocq	45376	63531	Rural, urban and road run-off and potential foul storm overflow	Le Hocq	1
Le Hurel	47600	64399	Rural, urban and road run-off and potential foul storm overflow, although Le Hurel PS has not spilled since 2006	Le Hurel	n/a
Longbeach outfall	47567	66495	Queen's Valley discharge, urban and road run-off	n/a	n/a
Outfall between Le Hurel & Seymour	47640	64111	Rural and road run-off with discharge from shellfish processing plant	n/a	7
Outfall between Fort Henry & Fauvic	47463	65126	Fauvic marsh, road run-off and foul storm overflow	n/a	n/a
Pontac 1	45801	63805	Rural, urban and road run-off and potential foul storm overflow	Pontac	3
Pontac 2	45773	63799	Rural, urban and road run-off	n/a	2
Seymour Slipway	47702	63837	Rural, urban and road run-off	n/a	n/a

A low flow study conducted in 2010 recorded dry period and wet period measurements for four of the outfalls, summarised in Table 5.3.

Table 5.3 Outfall flow data

Outfall	Sample 1 date (Dry period)	Sample 1 flow (m^3/d)	Sample 2 date (Wet period)	Sample 2 flow (m^3/d)
Beach Hotel Slip	29/07/2010	639	21/12/2010	2,134
Le Hocq	05/08/2010	Seepage only	n/a	n/a
Longbeach	05/08/2010	Dry	22/12/2010	9,141
Dicq Slipway	11/08/2010	1,177	21/12/2010	9,223

The Department of the Environment routinely undertake water quality sampling for outfalls. Table 5.4 shows geomean FC concentrations using available data, with mean flows, and using these approximations provides an estimate of the loads which might be carried by the outfalls. It is noted that this approach only provides an approximate estimate of conveyed loads; as faecal coliform[16] concentration may vary with flow. Loads should ideally be calculated using paired water quality and flow data, preferably covering rising and falling flows across the full flow envelope. For comparison, the loads derived from the shoreline survey reported in the Sanitary Survey report are also included where applicable.

Table 5.4 Outfall concentrations and estimated load

Outfall	Geomean Presumptive FC (cfu/100ml)	n	Mean flow (m^3/d)	Derived Load (cfu/day)	Shoreline Survey load (cfu/day)
Weighbridge	3,047	3	no data	-	-
Dicq Slipway	3,596	41	5,200	1.87E+11	-
Le Dicq	no data	-	no data	-	-
Beach Hotel Slip	5,428	48	1,611	8.75E+10	5.60E+10
Fauvic	966	44	3.5	3.38E+07	5.70E+08
Fort Henry	1,525	20	75	1.14E+09	1.17E+09
La Greve d'Azette	1,875	22	no data	-	-
La Rocque	no data	-	no data	-	-
Le Bourg 1	1,262	19	no data	-	-
Le Bourg 2	1,387	3	232	3.22E+09	2.60E+08
Le Hocq	3,443	21	0.3	1.03E+07	1.80E+06
Le Hurel	1,635	46	no data	-	-
Longbeach outfall	2,109	17	4,571	9.64E+10	-
Outfall between Le Hurel & Seymour	1,505	4	9.9	1.49E+08	9.90E+05
Outfall between Fort Henry & Fauvic	1,335	24	no data	-	-
Pontac 1	2,212	26	513	1.13E+10	4.50E+08
Pontac 2	1,239	4	5.2	6.44E+07	1.30E+07
Seymour Slipway	2,400	1	no data	-	-

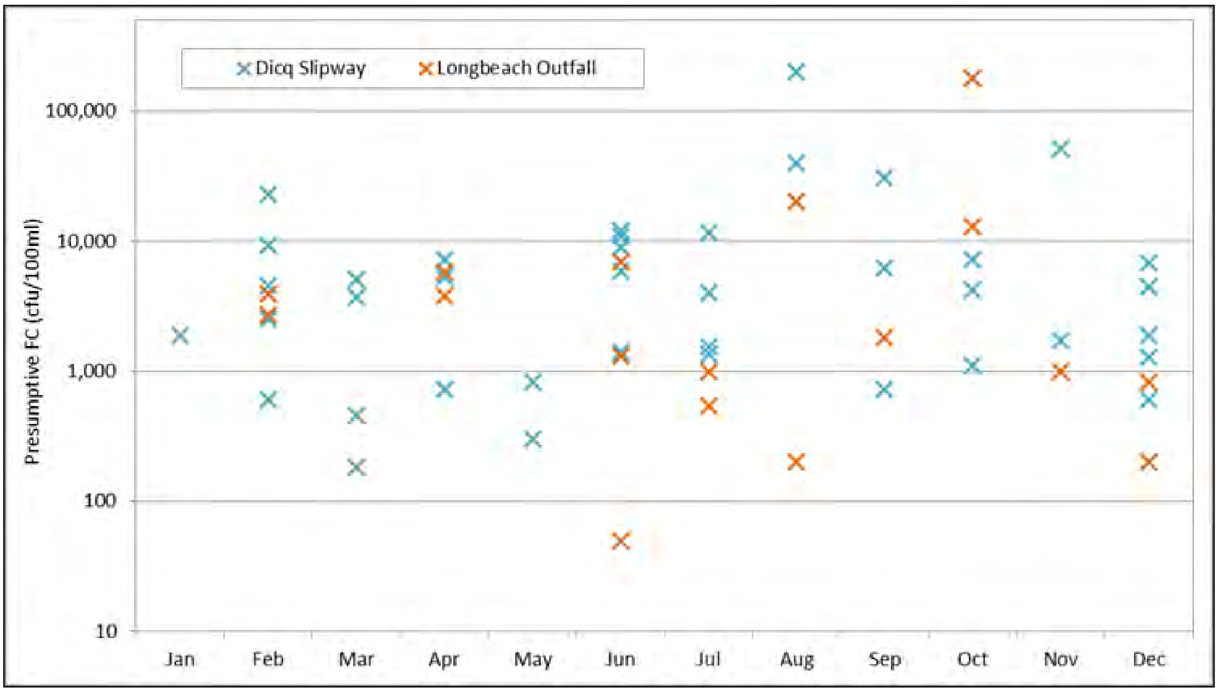
Loads calculated from mean flows and concentrations appear to be aligned with loads derived from the shoreline survey, in that loads at the northern end and centre of

[16] *E. coli* are a sub-set of faecal coliforms.

Grouville Bay are high (Beach Hotel Slip and Fort Henry) in both cases. Derived load is also high at Longbeach outfall, and at Le Bourg 2 and Pontac 1 on St Clement's Bay. The highest estimated load in Table 5.4 for outfalls is a magnitude lower than the lowest estimated for the STW of 1.5E+12 cfu/day. In most cases, the outfalls loads are several magnitudes lower.

Figure 5.3 shows the seasonal variation in FC concentrations in discharges at the Dicq Slipway and Longbeach outfalls. The former discharges streamflow from the Baudreette Brook, and the latter from the Queen's Valley Stream, and as such there is potential for a seasonal signature in FC concentrations due to the effects of slurry spreading to land to December. The data hint at an elevation of concentrations during autumn. The closed season for slurry spreading is October to December inclusive - no effect from this is evident in the data shown. Counts from the Longbeach outfall showed a significant positive correlation with two day antecedent rainfall ($\tau=0.4$, $p<0.05$), but no significant correlation was found in the Dicq Slipway data.

Figure 5.3 Seasonal variation of FC concentrations at Dicq Slipway and Longbeach outfall



Analysis of the paired FC concentration data available for Beach Hotel Slip, Fauvic, Le Hurel and Dicq Slipway outfalls (those outfalls for which more than 40 concentrations are available for analysis - Table 5.4), showed the following significant correlations:

Beach Hotel Slip vs Fauvic ($\tau=0.4$, $p<0.01$) - both in Grouville Bay and both potentially receive storm overflows, although there have been no coincident spillages on record

Beach Hotel Slip vs Le Hurel ($\tau=0.5$, $p<0.01$) - both in Grouville Bay

Fauvic vs Le Hurel ($\tau=3.5$, $p<0.01$) - both in Grouville Bay

Dicq Slipway vs Le Hurel ($\tau=0.3$, $p<0.05$) - Dicq Slipway is in St Clements Bay and receives streamflow from the Baudrette Brook

This suggests that for these outfalls there is a common influence on concentrations. However concentrations at none of the outfalls were correlated with 2 day rainfall. No significant correlation was found between data for Dicq Slipway and Beach Hotel Slip, or Dicq Slipway with Fauvic.

Further investigation should seek to ensure all outfalls of potential influence are monitored under base and high flow conditions, and that influences of PS spills and upstream runoff are captured. Antecedent conditions should also be considered to capture any effects of wash-off of material after a prolonged dry period.

SURFACE WATERCOURSES

Current Understanding

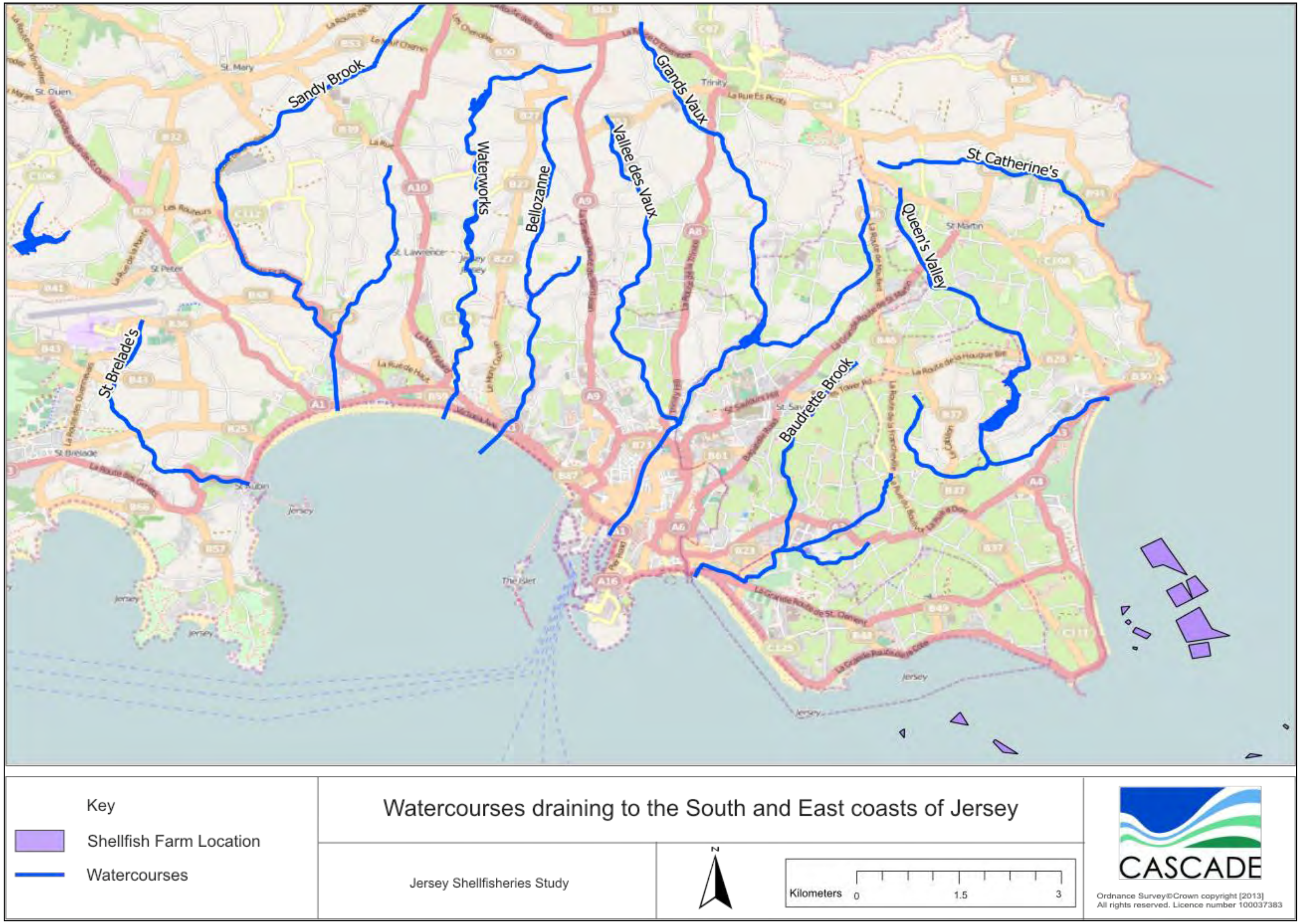
The Sanitary Survey report includes a catchment map taken from another study (Langley et al, 1997), but includes no analysis of contributions attributable to the watercourses separate from that for surface water outfalls. It is noted that consideration of effects of outfalls and streamflows at the point at which they enter the marine environment, will incorporate consideration of up-catchment influences, including all agricultural and urban runoff.

Review of Data

The following watercourses with catchments greater than $2km^2$ discharge to the south and east of the island (shown in Figure 5.3):

St Brelade's Stream
Sandy Brook
Bellozanne Valley Stream (spills with Bellozanne final effluent from the First Tower outfall)
Waterworks Valley Stream
Vallée des Vaux Stream
Grands Vaux Stream
Baudrette Brook (spills at the Dicq Slipway outfall, considered in Section 5.3)
Queen's Valley Stream (spills at the Longbeach outfall, considered in Section 5.3)
St. Catherine's Stream.

Figure 5.3 Watercourses discharging to the south and east of Jersey



Catchment areas are small, with the largest catchment being that of the Grands Vaux/Vallée des Vaux Streams; 18km^2 at the coast. Flows for four of the streams which discharge into St Aubin's Bay (St Brelade's, Sandy Brook, Vallée des Vaux, Grands Vaux) have been described previously[17], based on a derived stage/discharge relationship and stages recorded during 2009, 2010 and 2013. Flows and potential loads at Dicq Slipway outfall, through which the Baudrette Brook discharges, are described in Table 5.4. Table 5.5 summarises flows in the gauged streams and uses geomeans of presumptive faecal coliforms for samples collected over the same period to give a high level estimation of loadings from each watercourse. It should be noted that presumptive faecal coliforms may give an over-indication of counts of *E. coli*.

Table 5.5 Indicative loadings from gauged watercourses

Watercourse	Mean discharge (m^3/s)	Catchment features	Presumptive FC (cfu/100mls)	Daily loading (cfu/day)
St Brelade's Stream	0.053	PWS abstraction, pumping stations	1,643	7.52E+10
Sandy Brook	0.116	PWS abstraction, pumping stations	2,328	2.33E+11
Vallée des Vaux	0.053	PWS abstraction, pumping stations	3,070	1.41E+11
Grands Vaux	0.218	Impounding reservoir, pumping stations	611	1.15E+11

It is noted that all four watercourses listed in Table 5.5 receive PS overflows. Calculated daily loads are not insignificant, but as for all sources, their influence on water quality and flesh counts at the shellfish areas is dependent on dilution, dispersion and decay in the marine environment. Only very limited flow data were available for the Waterworks Valley and St Catherine's streams, considered insufficient to estimate even indicative loadings of coliforms (flows from the Bellozanne Valley, Baudrette Brook and Queen's Valley Stream are considered in Section 5.3 under outfalls). The loads estimated in Table 5.5 are a magnitude lower than the loads estimated for the STW (Table 5.1).

As for surface water outfalls, further investigation would be required to clarify the loads which are delivered to the marine environment by surface watercourses, taking into account effects of PS spills, runoff from agricultural and urban environments and antecedent conditions. The identified outfalls (Section 5.3) and watercourses are understood to comprise all potential significant sources of terrestrial sourced faecal contamination to the shellfish areas, other than the STW. Consideration at the point of which they discharge to the marine environment may provide further evidence for up-catchment investigation and management, for example of agricultural inputs.

Slurry is applied to fields in potato cropping areas. A detailed management plan for slurry application on the island has been developed. Each field is classified according to the risk of water pollution, based on slope, proximity to watercourses, boreholes

[17] Cascade Consulting (2013) *Review of available historic and freshwater and marine data from St Aubin's Bay and surrounding areas.*

and wells. Slurry cannot be spread on high risk fields at any time of the year. The fields in the southeast are primarily classified moderate risk, so slurry cannot be spread from October to December on these fields. Poultry farms represent an additional potential source. Rainfall reactive monitoring may enable targeted source apportionment at field scale. However for the purposes of this investigation, emphasis will be on identifying the inputs which convey high concentrations of faecal contaminants.

PUMPING STATION OVERFLOWS

Current Understanding

Some of the 111 PS which convey sewage to Bellozanne STW spill raw sewage to the sea when their carrying capacity is exceeded. Others spill to watercourses which discharge to the south and east coasts of the island. Spills are crude and there is no screening in place. Spill duration data are available from 2006, but there are no data on volume or *E. coli* concentrations. The Sanitary Survey reports that most spills followed heavy rainfall and tended to occur at multiple locations. West of Albert/Weighbridge PS spilled in all years, and Le Hocq PS in three of the five years 2006-2010. Many more spills were recorded during 2010 than in the previous nine years, attributed to high rainfall and high groundwater levels causing ingress to the system. Work has been and is being undertaken to reduce this ingress in the future.

The Sanitary Survey report examined spills during 2010 for the 16 PS which spill either directly (to the sea via outfalls) or indirectly (to inland watercourses) to the south and east of the island. Of those PS which spilled the most hours (Petit Ponterrin, Paul Mill and Archirondel), the report suggests that spills at Archirondel are most likely to affect water quality at the shellfish areas, although it is not clear from which outfall this PS overflow discharges.

Further Review of Data

The locations of the 16 PS which spill directly or indirectly to the south and east of the island are shown in Figure 5.4. Locations of outfalls and watercourses provide some context. Table 5.6 identifies spill destinations (i.e. sea, manhole, stream). Further investigation is required to clarify ultimate fate of spills from most of the PS; Le Dicq and West of Albert/Weighbridge are known to spill to the sea via Le Dicq and Weighbridge outfalls. Recent discussions have indicated there may be additional overflows which require consideration. Data on their location and connectivity will be reviewed as available for potential implications on contamination at the shellfish areas.

Figure 5.4 Locations of pumping stations which may discharge to the south and east of the island, directly to the sea or via watercourses/outfalls

Table 5.6 Pumping stations and initial understanding of spill destinations

Pumping Station	Destination of Spill
Archirondel	Manhole 57a, close to sea
Bashfords	Covers at station
Beaumont	Foul water sewer at manhole 25A
Becquet Vincent	Manhole 21 in road, close to stream
Fauvic	Manhole C116A in coast road, close to sea – suspected to sea via Fauvic outfall
Le Rivage	Manhole CR1A Gory Old Road, then to sea via Beach Hotel Slip outfall
Le Dicq	Overflows to sea via Le Dicq outfall (distinct from Dicq Slipway outfall)
Le Hocq	Manhole 55 close to sea – suspected to sea via Le Hocq outfall
Le Hocq Lane	covers at station
Maufant	Manhole 29B - inland
Maupertuis	Manhole 24, then to sea via Greve d'Azette outfall
Paul Mill	Manhole PM1 - inland
Petit Ponterin	Covers at station
Pontac	To sea via Pontac outfall
St Martin	Manhole PS1
West of Albert/Weighbridge	Overflows to sea via Weighbridge outfall

Table 4.4 of the Sanitary Survey report identified the spill duration for each of the 16 PS identified on Figure 5.4. Figure 5.5 represents graphically the total spill durations for 2010, 2011 and 2012 for the same PS, noting that 2010 and 2012 were wet years in the hydrological record, and 2011 a dry year.

Figure 5.5 2010, 2011 and 2012 pumping station spill durations

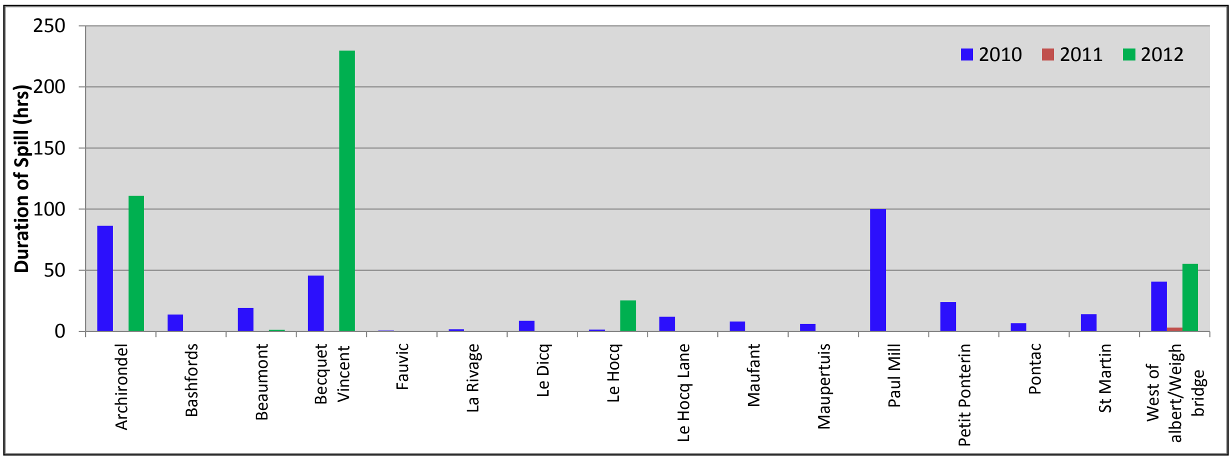


Figure 5.5 shows that Archirondel, Becquet Vincent, Paul Mill and West of Albert/Weighbridge spilled for the greatest durations during the three years. Only Le Dicq and West of Albert/Weighbridge spilled to any extent during 2011, and only five of the PS spilled during 2012 (Archirondel, Beaumont, Becquet Vincent, Le Dicq, Le Hocq and West of Albert/Weighbridge). Of these, Archirondel in St Catherine's Bay is closest to the shellfish areas. Oyster counts recorded at all areas during each of the three years did not suggest a relationship with spill duration; counts in 2011 were