Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: North Bay

SA 337

December 2011

Cefas

Food Standards Agency
food.gov.uk
Buidheann Inbhe-Bìdhe

Report Distribution – North Bay

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* Distribution of both draft and final reports to relevant agency personnel and harvesters is undertaken by FSAS.

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I. Executive Summary

A sanitary survey at North Bay has been undertaken as the area was first classified after 2006, when the requirement for conduct of sanitary surveys under Regulation (EC) No. 854/2004 came into force. North Bay is located at the southern end of Irvine Bay, adjacent to the town of Troon approximately 35 km southwest of Glasgow. The surrounding area is heavily populated with the towns of Troon, Prestwick, Ayr, Irvine, Stevenston and Saltcoats bordering the shore.

The fishery at North Bay is for razor clams (*Ensis* spp). Natural razor clam beds are found in the subtidal sands and are gathered by divers throughout the year, depending on weather conditions. The exploitable razor clam bed is likely to extend some distance beyond the boundary of the currently classified area.

The principal sources of faecal contamination to the fishery are the continuous discharges from sewage treatment works at Meadowhead, and to a lesser extent at Stevenston, intermittent discharges from a number of CSOs that discharge into the bay and into the River Irvine, diffuse urban and agricultural runoff carried via the River Irvine and a series of smaller burns to the bay. The Meadowhead WWTW outfall discharges to the sea 1.4 km north of the production area boundary, and within the predicted extent of the razor clam bed.

Historical monitoring of waters at the Irvine bathing beach indicates intermittently high levels of faecal contamination. Historical monitoring of *E. coli* in shellfish similarly indicates periodically high levels of contamination and results for the 2010-11 show elevated contamination levels overall compared to previous years.

During a shoreline survey of the area, water samples taken from the main watercourses discharging area showed high loadings of faecal indicator bacteria. The highest loading was attributed to the River Irvine, however loadings from the smaller burns discharging within the production area boundaries were also high and would be more likely to impact on the bacteriological quality of the shellfish harvested there.

Overall the area receives significant input of human sewage as well as urban and agricultural diffuse pollution.

<u>Recommendations</u>

As the likely shellfish bed extends well beyond the boundaries of the current production area, it is recommended that the areas nearest shore be excluded due to the likelihood of higher contamination levels there and that area be extended seaward to include more of the likely shellfish bed.

The recommended production area is the area contained within lines drawn between NS 2800 3450 to NS 3200 3450 and NS 3200 3450 to NS 3200 3200 and NS 3200 3200 to NS 3079 3188 and NS 3079 3188 to NS 2800 3100 and NS 2800 3100 to NS 2800 3450.

Due to the nature of the fishery, it is recommended that a representative monitoring zone be established that will allow sufficient scope for collection of samples within the zone.

The recommended sampling zone is the area contained within lines drawn between NS 3160 3260 to NS 3200 3260 and NS 3200 3260 to NS 3200 3200 and NS 3200 3200 to NS 3160 3196 and NS 3160 3196 to NS 3160 3260. It is situated in the Southeast corner of the production area, near CSO and diffuse pollution sources.

Due to the intermittent nature of some of the significant contamination sources sampling frequency should be at least monthly.

II. Sampling Plan

PRODUCTION AREA	North Bay
SITE NAME	Barrassie
SIN	SA 337 719 16
SPECIES	Razor clam
TYPE OF FISHERY	Wild, subtidal
NGR OF RMZ	NS 3160 3260 to NS 3200 3260 and NS 3200 3260 to NS 3200 3200 and NS 3200 3200 to NS 3160 3196 and NS 3160 3196 to NS 3160 3260
TOLERANCE (M)	0
DEPTH (M)	Not applicable
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	South Ayrshire
AUTHORISED SAMPLER(S)	William Murray Angela Patton
LOCAL AUTHORITY LIAISON OFFICER	Angela Patton

III. Report

1. General Description

North Bay is located at the southern end of Irvine Bay, adjacent to the town of Troon approximately 35 km southwest of Glasgow. The bay is open to the west, with a small peninsula extending into the bay approximately midway along the coast. The area surrounding North Bay is heavily populated with the towns of Troon, Prestwick, Ayr, Irvine, Stevenston and Saltcoats bordering the shore. Troon has a busy port with freight and ferry services and a yacht marina.

The sanitary survey at North Bay is being undertaken as it was first classified after 2006, when the requirement for conduct of sanitary surveys under Regulation (EC) No. 854/2004 came into force. A map of the area of interest is shown in Figure 1.1.

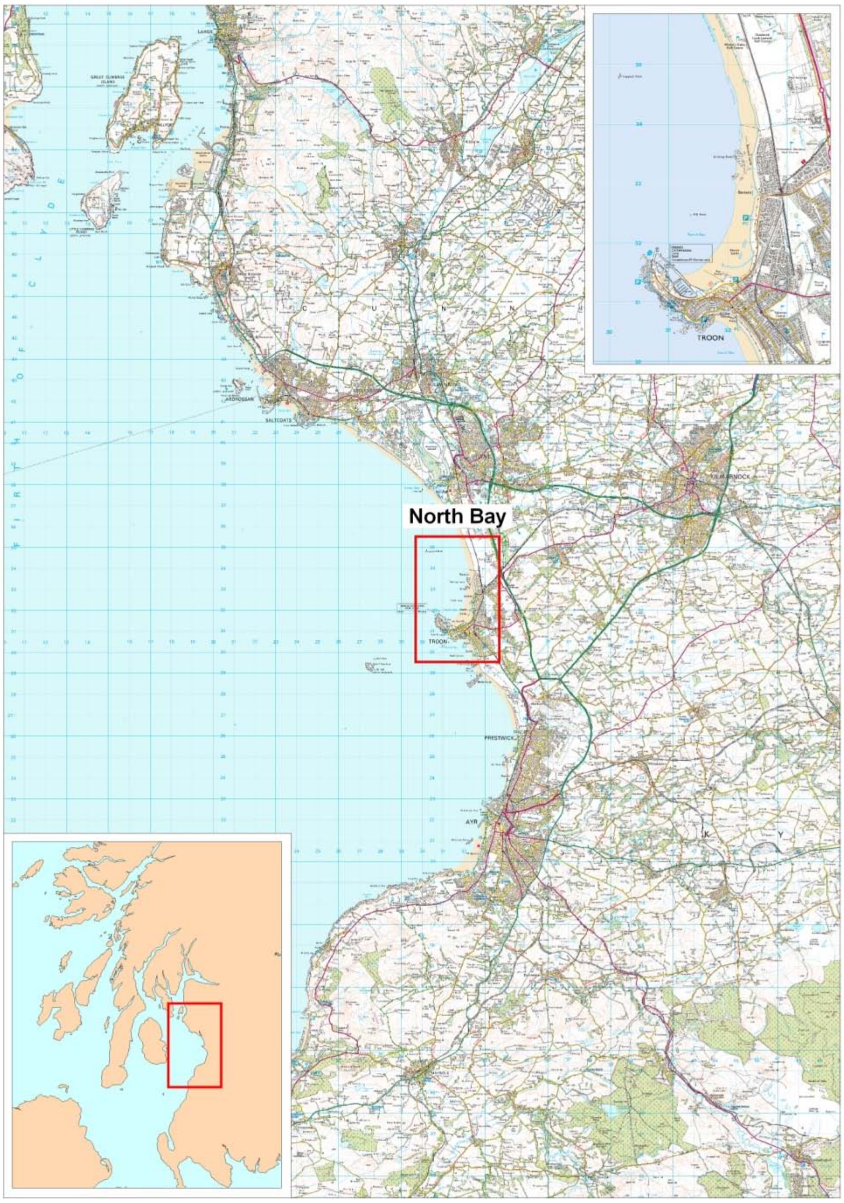

Figure 1.1 Location of North Bay

2. Fishery

The fishery at North Bay is for razor clams (*Ensis* spp). Natural razor clam beds are found in the subtidal sands between the areas of reef. The razor clams are gathered by divers and the area is fished throughout the year, depending on weather conditions. National Biodiversity Network data was used together with depth areas from UKHO charts to establish the potential extent of the exploitable razor clam bed. The bed extent shown has been curtailed at approximately 20m depth, as commercial diving for razor clams is not thought to usually exceed this depth. It has also been curtailed approximately at the mouth of the River Irvine, as there was no information available on the presence of razor clams north of this.

The North Bay production area has been defined as an area bounded by lines drawn between NS 3130 3136 and NS 3130 3450 and between NS 3130 3450 and NS 3236 3450 extending to MHWS. The nominal Representative Monitoring Point (RMP) is identified as NS 319 336. The production area boundaries and razor bed areas are mapped in Figure 2.1 below.

Figure 2.1 North Bay Fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the human population living in the vicinity of the North Bay production area.

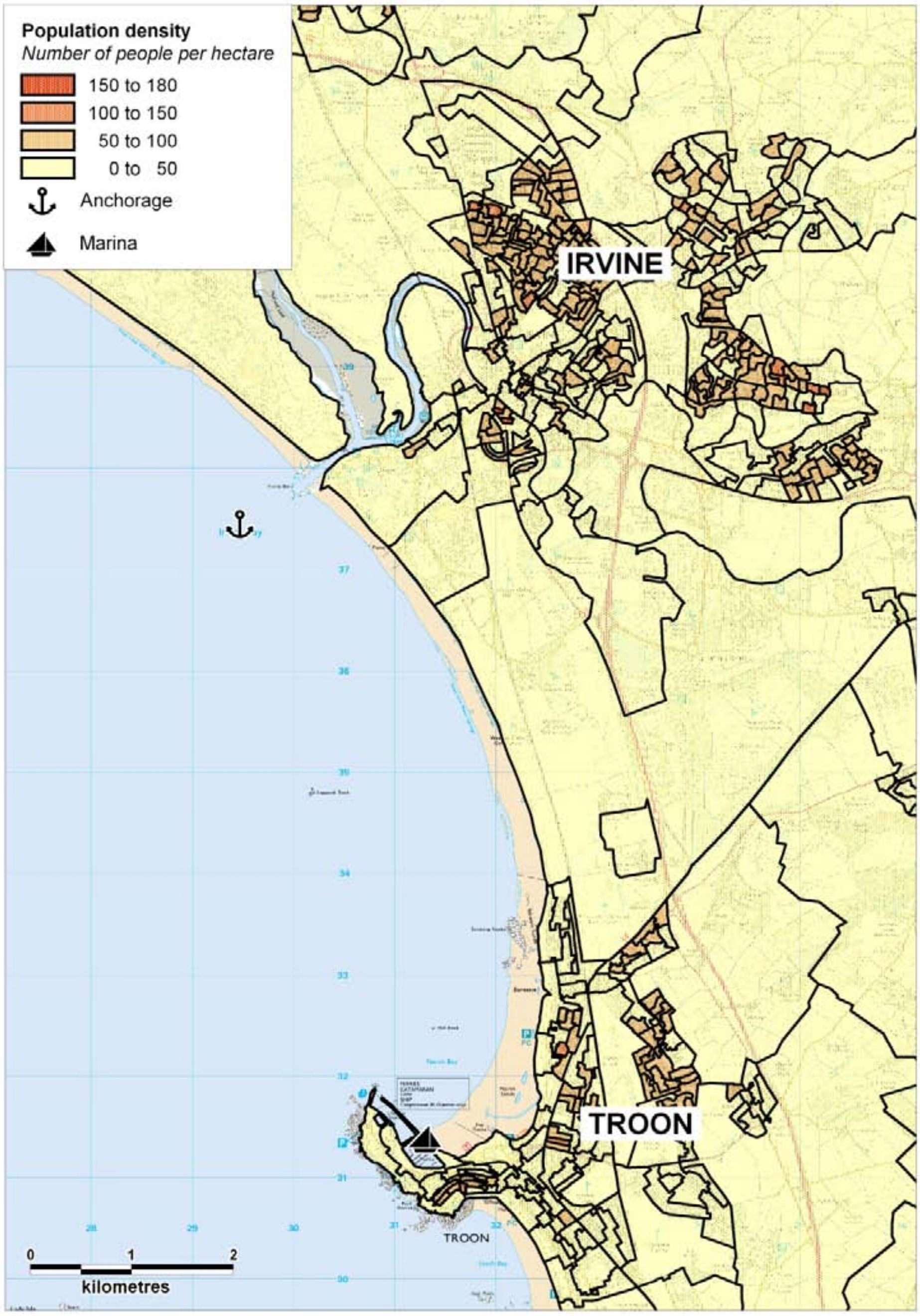

Figure 3.1 Population map of North Bay

The immediate area contains the towns of Irvine and Troon. The production area lies adjacent to the town of Troon which had a population of 14,766 in 2001. Irvine, which is located 3 km north of the current production area had a population of 33,090. The town of Prestwick is located 4 km south of Troon and had a population of 14,934. A number of smaller towns and villages are situated around and between the towns, bringing the total population of the area shown in Figure 3.1 to over 62,000.

A yacht marina is situated at Troon, with 400 berths and facilities including restaurant, toilets and showers. Therefore, yacht traffic is likely to be busy particularly during summer. Troon also has a port with freight and ferry services. From March and September, P&O operate a daily express service to Larne, Northern Ireland. A ferry service between Troon and Campbeltown also operates from April to September three days per week on a demand only basis. Prestwick airport is located 7km southeast of Troon.

The area between Irvine and Prestwick hosts 9 golf courses, 3 bathing beaches, and a large holiday park (approx 150 static pitches). Troon harbour and Barassie beach are popular with windsurfers and kite surfers, who are likely to use the area year-round.

Given the human population and urban development in the area, it is highly likely that contamination from human sewage will affect the waters around the fishery. Tourism is likely to cause a significant seasonal increase in human population during the summer months.

4. Sewage Discharges

Information on public sewerage discharges to the waters in and around the North Bay production area was requested from Scottish Water. The identified community septic tanks and sewage discharges for the area are listed below in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

No.	Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
1	CAR/L/1003301	NS 3213 3390	Barassie SPS CSO	intermittent	6 mm screen	7,791	-
2	CAR/L/1003301	NS 3254 3389	Barassie SPS EO	intermittent	10 mm screen	*	-
3	CAR/L/1033660	NS 3083 3710	Beach Park SPS CSO	intermittent	6 mm screen	240	-
4	*	NS 3111 3825	Irvine Harbour Rd Sports Club	intermittent	*	2539	-
5	*	NS 3000 3764	Irvine Harbour SPS EO (Gottries Cr)	intermittent	*	*	-
6	*	NS 3190 3870	The Forum CSO	intermittent	*		-
7	*	NS 3081 3822	142 Harbour St/Cross Keys CSO	intermittent	*	34.6	-
8	WPC/W/72192	NS 3160 3973	24 Kilwinning Road CSO NO6	intermittent	*	50	-
9	*	NS 3317 3873	47 Sillars Meadow CSO	intermittent	*	777	-
10	*	NS 3170 3919	47 West Road CSO	intermittent	6 mm screen	6,954	-
11	WPC/W/72195	NS 3247 3810	75 Lamont Dr/Rubie Cres CSO	intermittent	*	155	-
12	CD 12888	NS 3301 3848	Annick Road CSO	intermittent	*	1,382	-
13	WPC/W/72731	NS 3612 3765	Garrier Bridge (Dreghorn) CSO	intermittent	*	1,397	-
14	*	NS 3243 3838	Goldfields/East Bank Of River	intermittent	*	1,382	-
15	*	NS 3302 3849	Hospitality Inn SPS CSO	intermittent	*	*	-
16	*	NS 3001 3764	Magnum Car Park/Adj Magnum	intermittent	*	199	-
17	CAR/L/1003265	NS 3034 3546	Meadowhead STW CSO EO	continuous intermittent	secondary 6mm screen 15mm screen	85,782	313,333
18	CAR/L/1003265	NS 3170 3480	Meadowhead Gailes SPS CSO	intermittent	40 mm screen	*	-
19	*	NS 3385 3679	Oldhall West CSO	intermittent	*	*	-
20	*	NS 3175 3899	R/O 25 West Rd/Low Green CSO	intermittent	*	*	-
21	*	NS 3164 3969	R/O 4 Williamfield Grove CSO	intermittent	*	*	-
22	CAR/L/1033598	NS 3372 3735	Shewalton SPS CSO	intermittent	*	11,482	-
23	*	NS 3300 3782	Tarryholme SPS CSO	intermittent	*	86.4	-
24	*	NS 3149 3982	Williamsfield CSO	intermittent	6 mm screen	4,654	-
25	*	NS 3169 3940	Sports Club SPS	intermittent	6 mm screen	6,281	-
26	*	NS 3159 3966	Waterside SPS	intermittent	6 mm screen	15	-
27		NS 3249 3809	Milgarholm SPS	intermittent	6 mm screen	1,402	-

No.	Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
28		NS 3215 3138	Pan Rocks N	Not specified	*	*	*
29	CAR/L/1003264	NS 2665 3924	Stevenston STW and EO	continuous intermittent	secondary 6mm screen	45,961	90,000
30	CD 10277	NS 3065 3122	Troon Harbour SPS CSO	intermittent	6 mm screen	*	-
31	CAR/L/2033565	NS 3268 3194	Maple Grove SPS	intermittent	10 mm screen	231	-
32		NS 3301 3181	Marr College CSO	intermittent	*	1,813	-
33		NS 3215 3138	Pan Rocks SPS EO	intermittent	*	3,024	-

* Data not provided

The area is characterised by a mix of towns and villages, most of which are served by one of two public sewerage networks comprising two wastewater treatment plants (Meadowhead WWTW and Stevenston WWTW) and a large number of intermittent discharges from Combined Sewer Overflows (CSOs) and pumping station Emergency Overflows (EOs). Meadowhead treatment works serves the towns of Ayr, Irvine, Kilmarnock, Prestwick and Troon, as well as a number of smaller villages and has a consented population equivalent of over 300,000. Both treatment works provide secondary waste treatment, though discharges from the overflows receive screening only. No information was provided on spill frequencies.

Data related to chemical parameters and BOD were provided for the period from 31 January 2010 to 3 May 2011 for Meadowhead WWTW and from 5 July 2010 to 13 May 2011 for Stevenston WWTW. Reported results are summarised in Table 4.2. For the limited periods reported, the geometric mean BOD was 6.02 mg/l for Meadowhead and 5.19 mg/l for for Stevenston. These values are within the Urban Waste Water Treatment Directive 95-percentile limit of 25 mg/l. Of the results provided, only one from Meadowhead exceeded the UWWTD upper tier limit of 50 mg/l O_2. No microbiological data were provided for either of the discharges, however for the dates covered by the data it is expected that bacteriological quality of the effluent would also be within the range expected for secondary treated sewage, or approximately 3.3×10^5 cfu/100 ml for faecal coliforms.

The SEPA bathing water report for Irvine Beach identified that CSOs comprised the main risk of sewage contamination to bathing water at the beach, which lies north of the production area. An assessment of the impact of development on the sewerage network was undertaken by Atkins on behalf of Scottish Water and the Ayrshire Joint Structure Plan and Transportation Committee (Atkins, 2005). It identified 126 CSOs within the catchment for Meadowhead WWTW and a further 41 within the catchment for Stevenston WWTW. For the purposes of this survey, only those discharging to sea or to the lower 10km of the River Irvine have been considered. However it is important to recognise that a large part of the complex sewerage infrastructure in the area lies well upstream of the sea.

Annual spill frequencies reported by Atkins for the Meadowhead CSOs ranged from 0 to 193 per year. It was not possible to cross reference all CSOs listed in Table 4.1 with those listed in the Atkins report due to differences in names and the lack of geographic references for data in the Atkins report. For those discharges that were clearly identifiable in both, the spill frequencies ranged from 0 to 157, with the highest frequency of spills at No 10. West Road, No 14. Goldfields, and No 26. Waterside. All three discharge to the River Irvine.

Scottish Water are currently undertaking extensive improvement works to the stormwater provision by upgrading the trunk sewerage line (due to complete in 2012) and increasing the capacity flow capacity to the Meadowhead WWTW (due to complete in 2013). These improvements are expected to reduce the frequency of CSO spills in the area and thereby improve water quality within Irvine Bay.

Information on discharge consents for the Irvine area was sought from the Scottish Environment Protection Agency (SEPA) and a list of the provided consents for discharges located within the vicinity of the fishery is provided in Table 4.2.

Table 4.2 Discharge consents identified by SEPA

No.	Reference	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/L/1003264	NS 2665 3924	Continuous	Secondary	*	*	Firth of Clyde
2	CAR/L/1079790	NS 3002 3761	Intermittent	EO	*	*	Firth of Clyde
3	CAR/L/1033660	NS 3241 3727	Intermittent	EO	*	*	Firth of Clyde
4	CAR/L/1033660	NS 3083 3710	Intermittent	CSO	*	*	Firth of Clyde
5	CAR/L/1008842	NS 2816 3689	Continuous	Trade	*	*	Firth of Clyde
6	CAR/L/1003265	NS 3170 3480	Intermittent	EO	*	*	Firth of Clyde
7	CAR/L/1003265	NS 3034 3546	Continuous	Secondary	*	*	Firth of Clyde
8	CAR/L/1000181	NS 3166 3496	Continuous	Landfill leachate	*	*	Firth of Clyde
9	CAR/L/1003301	NS 3209 3363	Intermittent	CSO	*	*	Firth of Clyde
10	CAR/L/1003301	NS 3256 3389	Intermittent	EO	*	*	Gailes Burn
11	CAR/L/1003301	NS 3213 3390	Intermittent	EO	*	*	Firth of Clyde
12	CAR/L/1033565	NS 3267 3193	Intermittent	CSO	*	*	Darley Burn
13	CAR/L/1033972	NS 3303 3187	Intermittent	CSO	*	*	Darley Burn
14	CAR/L/1024584	NS 3260 3656	Continuous	Sec	*	*	*
15	CAR/L/1000187	NS 3270 3650	Continuous	Sec	*	*	Soakaway
16	CAR/L/1033598	NS 3372 3736	Intermittent	CSO	*	*	River Irvine
17	CAR/L/1036153	NS 3188 3882	Intermittent	CSO	*	*	River Irvine
18	CAR/L/1003393	NS 3168 3919	Intermittent	CSO	*	*	River Irvine
19	CAR/L/1003394	NS 3164 3969	Intermittent	CSO	*	*	River Irvine
20	CAR/L/1003392	NS 3146 3984	Intermittent	CSO	*	*	River Irvine
21	CAR/L/1000770	NS 3442 3444	Continuous	Trade	*	*	Gailes Burn
22	CAR/R/1051252	NS 3271 2949	Continuous	ST	*	*	South Bay
23	CAR/R/1092646	NS 3399 2976	Continuous	ST	*	*	Soakaway
24	CAR/R/1063155	NS 3374 2987	Continuous	ST	*	*	Soakaway
25	CAR/R/1068064	NS 3391 2992	Continuous	ST	*	*	Soakaway
26	CAR/R/1072178	NS 3433 3244	Continuous	ST	*	*	Darley Burn
27	CAR/R/1030575	NS 3421 3270	Continuous	ST	*	*	Soakaway
28	CAR/R/1072504	NS 3416 3263	Continuous	ST	*	*	Soakaway
29	CAR/R/1048008	NS 3413 3350	Continuous	ST	*	*	Land
30	CAR/R/1077457	NS 3323 3392	Continuous	ST	*	*	Gailes Burn
31	CAR/R/1077458	NS 3352 3398	Continuous	ST	*	*	Soakaway
32	CAR/R/1048011	NS 3423 3409	Continuous	ST	*	*	Soakaway
33	CAR/R/1048007	NS 3429 3397	Continuous	ST	*	*	Land
34	CAR/R/1017627	NS 3422 3406	Continuous	ST	*	*	Soakaway
35	CAR/R/1045428	NS 3252 3692	Continuous	ST	*	*	Soakaway
36	CAR/R/1057439	NS 3258 3688	Continuous	ST	*	*	Soakaway
37	CAR/R/1061709	NS 3259 3686	Continuous	ST	*	*	Soakaway

No.	Reference	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
38	CAR/R/1061561	NS 3256 3701	Continuous	ST	*	*	Soakaway
39	CAR/R/1062884	NS 3256 3699	Continuous	ST	*	*	Soakaway
40	CAR/R/1044758	NS 3258 3697	Continuous	ST	*	*	Soakaway
41	CAR/R/1061802	NS 3256 3696	Continuous	ST	*	*	Soakaway
42	CAR/R/1061493	NS 3257 3708	Continuous	ST	*	*	Soakaway
43	CAR/R/1052464	NS 3303 3708	Continuous	ST	*	*	Soakaway

* Data not provided

No information on the volume or consent conditions was provided by SEPA for these discharges. In some cases, it was not possible to cross-refer data provided by Scottish Water with the consent information provided by SEPA. A number of the consent references provided by Scottish Water are of older types that predate the current Water Environment (Controlled Activities) Scotland Regulations 2011. Two of the consents, Table 4.2, Numbers 5 and 21, relate to trade discharges. No information was provided regarding the nature or volume of these discharges and therefore it is only presumed that they may carry an proportion of septic waste. One discharge relates to landfill leachate, which may contain human pathogens and faecal indicator organisms depending on the nature and age of the landfill (Cameron and McDonald, 1977).

Approximately half the consents listed in Table 4.2 relate to small, private septic tanks which are likely to serve only one or two properties each. Only three of these discharge to water, one of which discharges to the sea at South Bay over 4 km away from the production area. One discharges to Gailes Burn (No. 30), which in turn discharges to the bay at the northern end of the production area. The third discharges to Darley Burn, which then discharges to the bay between North Sands and Pan Rocks. The impact of these discharges is likely to be very small compared to the larger, public discharges in the area.

A paper mill is situated south of Shewalton, east of the A78. According to the 2008 environmental statement for the mill, over the year it discharged 2,991,229 m^3 of effluent to water, which included sanitary waste (UPM-Kymmene, 2009). Although paper mill effluent normally contains non-pathogenic faecal indicator bacteria in the absence of a septic waste stream (Archibald, 2000), this mill does note the inclusion of sanitary waste in the effluent. Therefore, it should be considered a potential source of both indicator bacteria and pathogens. No consent information was received from SEPA relating to this discharge, therefore it is not clear whether the effluent is discharged to the Meadowhead WWTW, to a watercourse, or to sea. Clarification has been sought from SEPA, however at the time of writing this had not yet been received.

Sewage-related observations recorded during the shoreline survey is listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	11/07/2011	NS 31643 31301	Sanitary debris - sanitary towel
2	11/07/2011	NS 31923 31376	SW discharge, static water next to outfall
3	11/07/2011	NS 32096 31435	Sanitary debris - 3 x sanitary towels spread over 10 m area
4	11/07/2011	NS 32159 31398	SW discharge pipe, not flowing
5	11/07/2011	NS 32174 31404	SW discharge pipe, pooled water with sewage fungus, foul odour
6	11/07/2011	NS 32228 31410	SW discharge pipe, flowing. Orange growth around outfall.
7	12/07/2011	NS 32252 31394	Disused iron pipe coming out from wall of main road
8	12/07/2011	NS 30689 31290	SW discharge pipe, no flow, mussel spat growing in and around pipe.
9	12/07/2011	NS 32535 33791	SW Barassie SPS. Northern end of Troon Bay, outfall visible at low water
10	12/07/2011	NS 32297 34753	Sanitary debris - cotton bud
11	12/07/2011	NS 30375 37816	Inspection cover for Irvine SW discharge
12	12/07/2011	NS 30219 37741	SW discharge outfall pipe leading into sea

Only a small proportion of the overall area was visited during the shoreline survey. Evidence of sanitary discharges was observed predominantly along the southern shore of the production area. Most of the discharge pipes observed were not found to be flowing at the time of shoreline survey. The discharge pipe for the Magnum car park/Irvine Harbour SPS CSO was also observed, though the end was below water and therefore it was not possible to determine whether it was flowing at the time.

Evidence of recent foul discharge was noted at the Pan Rocks EO/CSO pipe where sewage fungus and foul odour were observed. The weather was dry at the time of survey and therefore it is not known whether this was due to a leakage or an emergency overflow. Observation number 6 was an iron outfall pipe that did not appear to relate to a known sewerage asset. A water sample taken from this discharge was found to contain <1000 *E. coli* cfu/100ml, therefore it was unlikely to have been sewage effluent.

Overall, the area has sewage discharges and associated overflows serving a large population and therefore the risk of contamination to waters of the production area is significant. Highest risk is around the CSO/EOs at Pan Rocks and Barassie and at the northern extent of the production area, where the Meadowhead CSO/EO discharge lies 300m and the continuous effluent discharge lies 1.4 km from the production area boundary.

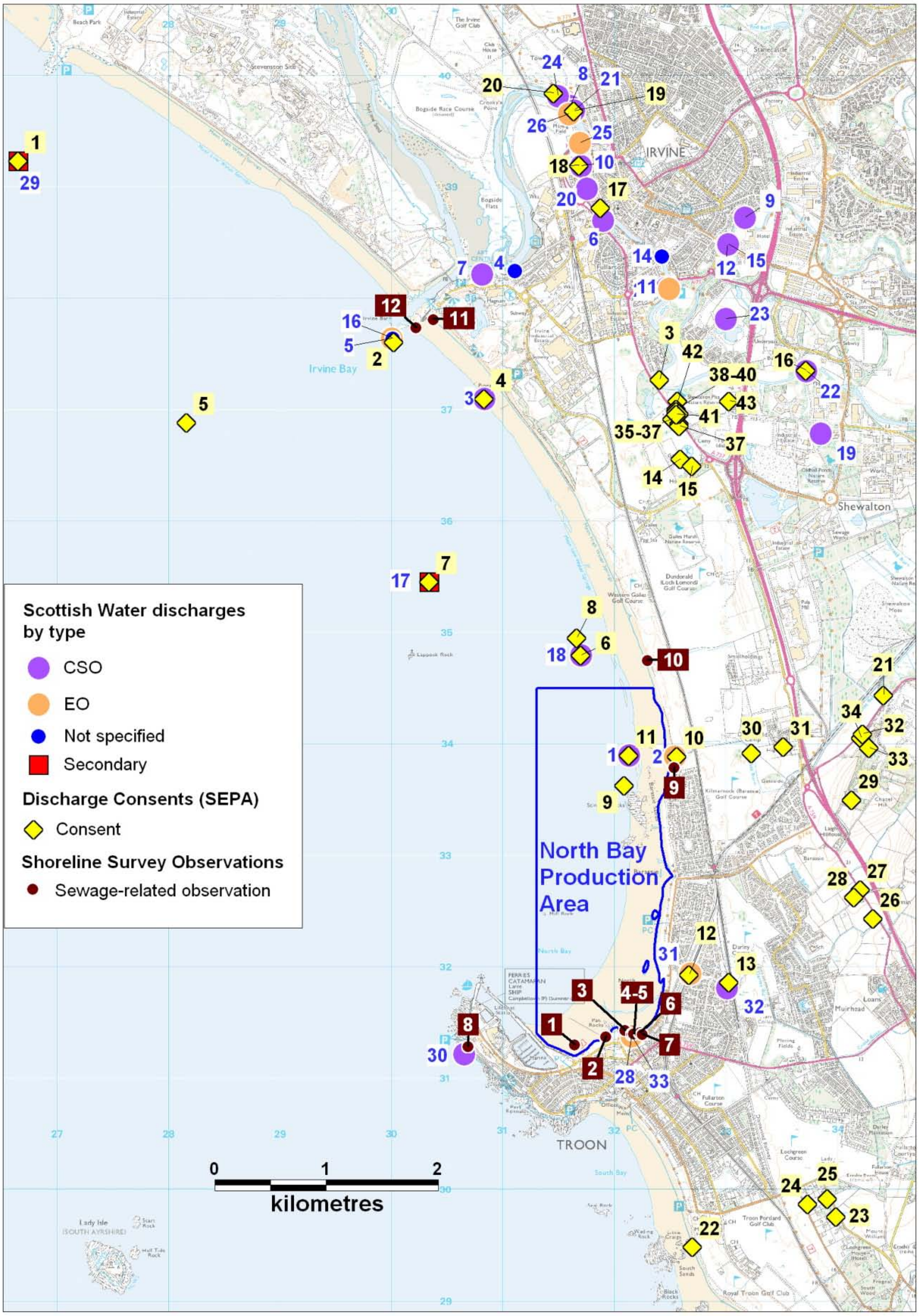

Figure 4.1 Map of discharges for North Bay

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils. Solid grey areas indicate predominantly impermeable surfaces on built-up areas.

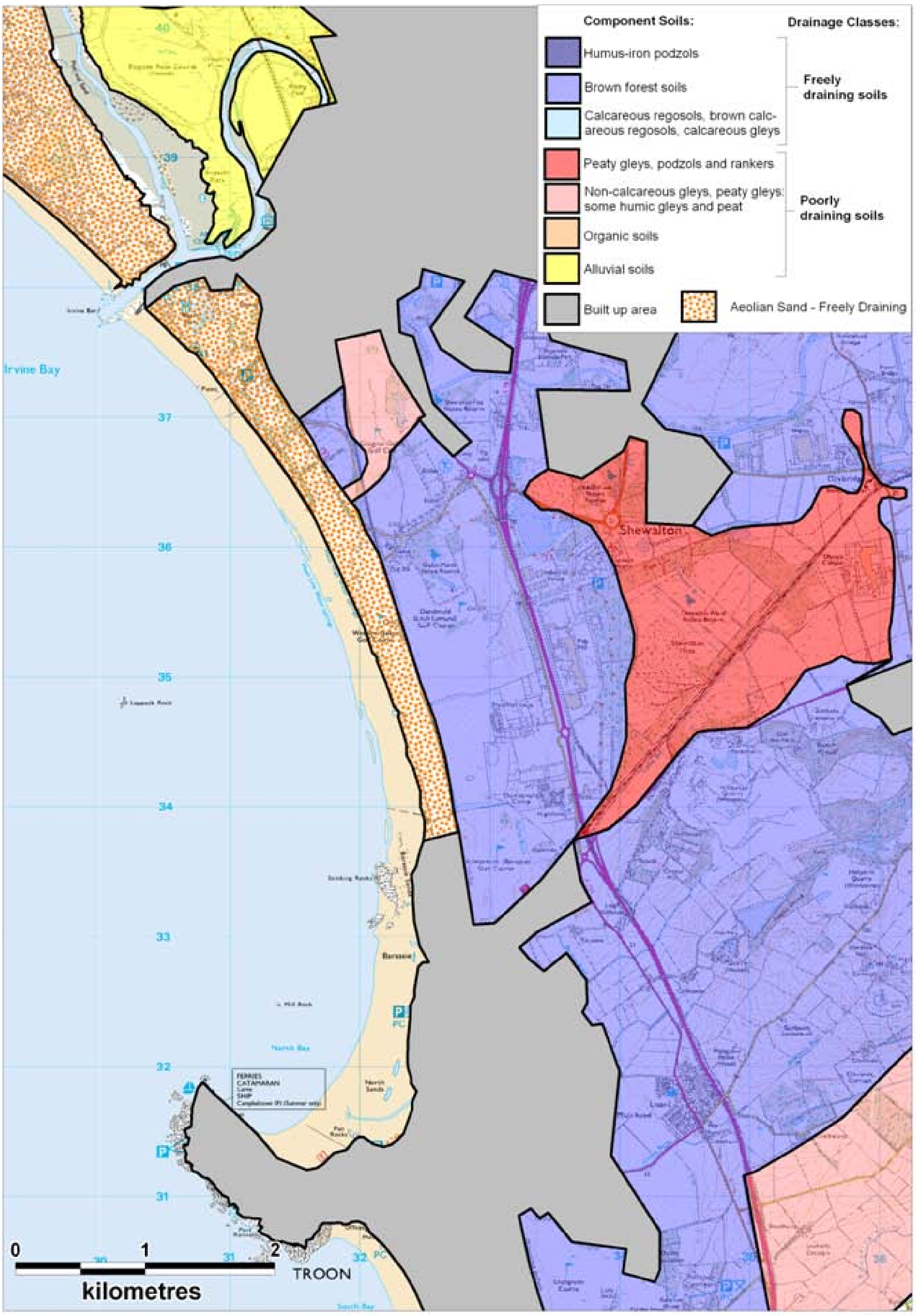

Figure 5.1 Component soils and drainage classes for North Bay

Three main types of component soil are present in this area. Brown forest soils cover most of the inland area between Troon and Irvine. Areas of peaty gleys, podzols and rankers and non-calcareous gleys, peaty gleys, some humic gleys and peat are found amongst the brown forest soils. Aeolian sand is present in a narrow band adjacent to the shoreline. Alluival soils are present near the River Irvine. Impermeable surface covers a significant proportion of the area, particularly along the southern shoreline of the production area and along the River Irvine to the north of the area.

The varied soil types create a patchy permeability throughout the area, with zones of permeable soils found sandwiched between built up area and less permeable soils.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is high along the areas of the fishery immediately adjacent to the impermeable built-up areas of Troon and Irvine and along parts of the lower River Irvine.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

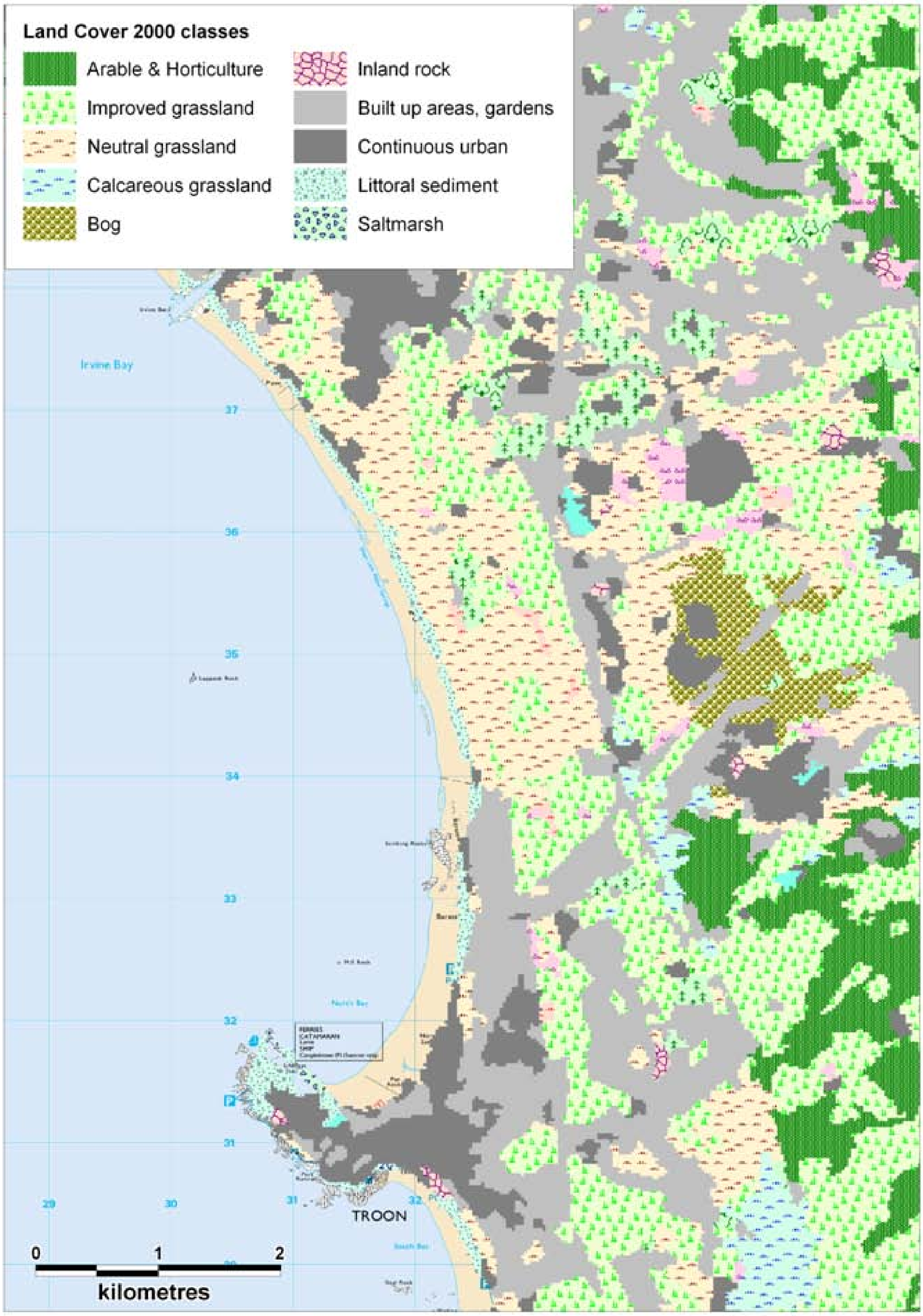

Figure 6.1 LCM2000 class land cover data for North Bay

A variety of land cover types are found in the North Bay area. Urban and built up areas shown along the south eastern shoreline roughly correspond with those identified in the soil profile map and the towns of Irvine and Troon. Improved grassland is interspersed amongst the other land cover types and is also found along the northern shore of the bay, to the south of Irvine. It constitutes a significant proportion of the non-urban land area. There are small areas of littoral sediment and saltmarsh along the shoreline.

Studies undertaken by Kay et al (2008) found that faecal indicator organism export coefficients for faecal coliform bacteria were highest for urban catchment areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and rough grazing (approximately 2.5×10^8 cfu km^{-2} hr^{-1}) areas. Lowest contributions would be expected from areas of woodland (approximately 2.0×10^7 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

Therefore, the overall predicted contribution of contaminated runoff from the area around North Bay would be relatively high and would be expected to increase significantly following rainfall events.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for Dundonald, Irvine and Stevenston parishes for 2009 and 2010. Of these, only Dundonald had significant agricultural activity as the other two parishes covered mainly urban or suburban areas. A further parish, Dreghorn, lies to the east of Dundonald and Irvine, however at its boundary nearest the fishery covers urban area and so data was not sought for this parish. The parish areas are illustrated in Figure 7.1 overleaf.

Reported livestock populations for Dundonald parish are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk. The data for horses and ponies presented below does not include the category 'Horses used in Agriculture' as no data were provided for this category.

Table 7.1 Livestock numbers in Dundonald parish 2009 - 2010

	Dundonald 49.17 km^2			
	2009		2010	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	0	0
Poultry	9	194	10	177
Cattle	21	3259	22	3280
Sheep	17	3411	18	3697
Horses and ponies	19	96	18	96
Other	*	*	*	*

There was little change in either the number of farms reporting or the reported number of animals between 2009 and 2010. Cattle and sheep are kept in comparable numbers and the reported populations of both are relatively low. The majority of these are likely to be kept in the eastern part of the parish as urban areas and golf courses predominate the western parts. The Irvine bathing water profile (http://www.sepa.org.uk/water/bathing_waters/bathing_water_profiles.aspx; accessed 06/12/11) identifies that the upland areas of the River Irvine catchment are used for extensive beef and sheep production while areas further down the catchment are used for intensive dairy production.

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area.

No livestock were seen during the shoreline survey. The majority of diffuse agricultural-source pollution is likely to impact the upper parts of the river catchments in the area.

Wyer *et al* looked at agricultural source pollution within the River Irvine catchment, and studies indicated that relatively little of the faecal indicator bacteria loadings found during base flow conditions were attributable to agricultural sources. This proportion increases, however, after heavy rainfall (Wyer *et al*. 1999). Therefore the risk to water quality at the fishery from agricultural-source faecal contamination is moderate, though less significant than the human sources at this time.

Figure 7.1 Scottish agricultural parishes at North Bay

8. Wildlife

Wildlife may also contribute to faecal contamination observed at fisheries. General information on the impacts of wildlife species can be found in Appendix 2. Bogside Flats Site of Special Scientific Interest (SSSI) is located adjacent to the lower River Irvine and is important for migratory wading birds and waterfowl.

Birds

Seabirds

Seabird 2000 data has been provided for a 5 km radius of the North Bay production area and is shown in Table 8.1 below.

Table 8.1 Seabird counts within 5km of the site.

Common name	Species	Count	Method
Herring Gull	*Larus argentatus*	1504	Occupied territory/occupied nests
Black Guillemot	*Cepphus grylle*	22	Individuals on sea
Great Black-backed Gull	*Larus marinus*	200	Occupied territory
Lesser Black-backed Gull	*Larus fuscus*	1059	Occupied territory/occupied nests
European Shag	*Phalacrocorax aristotelis*	178	Occupied nests
Cormorant	*Phalacrocorax carbo*	198	Occupied nests

The majority of seabirds were recorded on Lady Isle, a small island that lies approximately 4 km southwest of Troon. The remainder were recorded along the bay and their locations are shown in Figure 8.1. Breeding seabirds are likely to have a localised affect near their nests, where accumulated droppings may be washed into the sea with rainfall or birds directly deposit dropping on their way to and from the nest.

Gulls are likely to be present in the area throughout the year, and some species may also be nesting on rooftops in the area. Approximately 300 gulls were observed on the beach during the shoreline survey, all toward the southern end of the production area.

Waders and Wildfowl

Bogside Flats SSSI is home to a Royal Society for the Protection of Birds reserve and is known as an important stop for both migrating and overwintering wading birds and ducks (Bogside RSPB reserve http://clydeserver.com/narspb/node/43). No specific information was available on likely populations, however. These birds are unlikely to pose a significant threat of contamination to the fishery when compared to other sources of faecal indicator bacteria to the River Irvine.

Seals

Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in the Clyde, though not in large numbers. These animals are likely to be present in and around the fishery from time to time and could potentially leave faeces behind, though any effect would be very minor in comparison to other sources.

Deer

Deer are likely to be present within the catchment area, though no information was available on numbers of animals. Faecal indicator bacteria arising from deer droppings are likely to be carried via rainfall runoff to rivers and streams.

Produced by Cefas Weymouth Laboratory.
Ordnance Survey licence number [GD100035675]

Figure 8.1 Map of seabird distributions in North Bay

9. Meteorological data

Both rainfall and wind data was available for RNAS Gannet located at Prestwick, approximately 6km to the south-east of North Bay. Rainfall data was available for 2003-2010 inclusive: data was missing for only four days in 2008Data for the stations was purchased from the Meteorological Office. Due to the extensive missing rainfall data, summaries for both rain stations are presented below. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at North Bay.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Figures 9.1 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

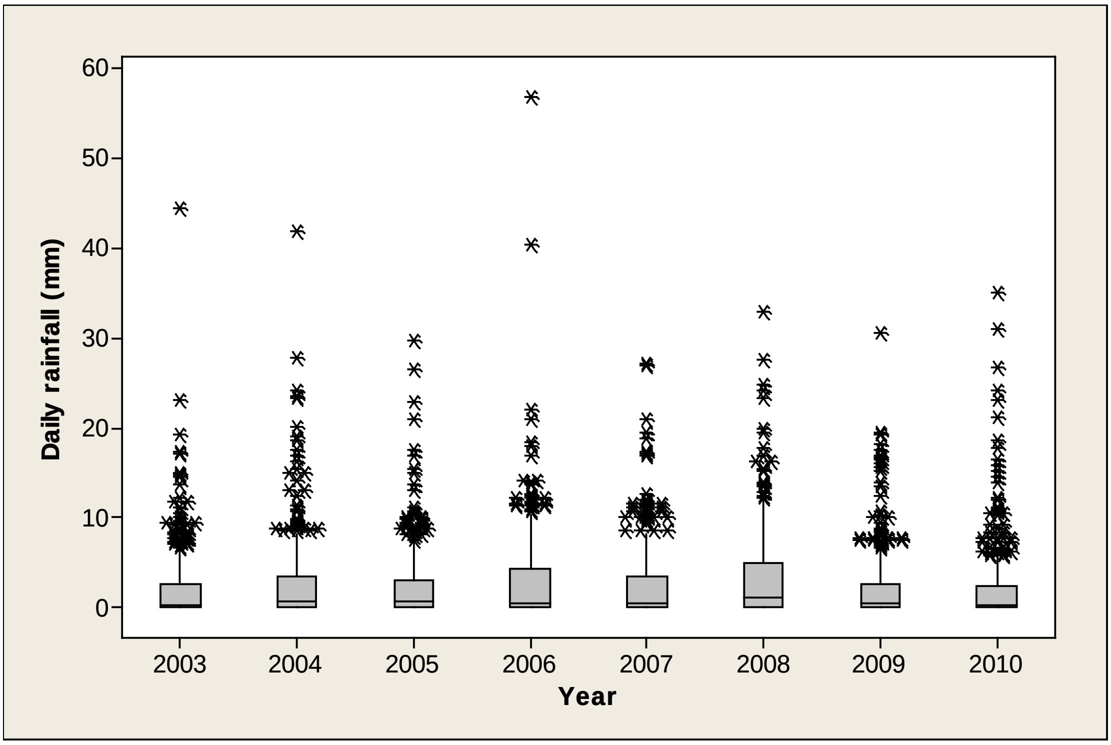

Figure 9.1 Box plot of daily rainfall values by year at Prestwick: Gannet, 2003-2010

Figure 9.1 shows that rainfall patterns varied markedly between the years with 2003 being the driest and 2008 the wettest.

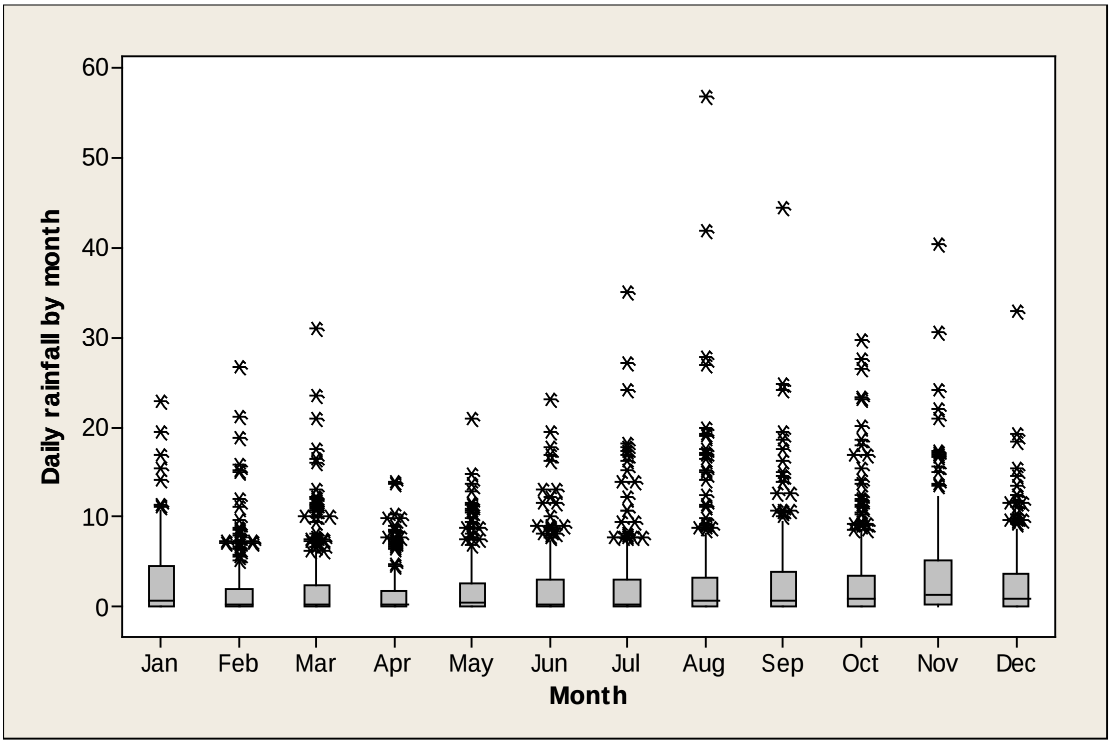

Figure 9.2 Box plot of daily rainfall values by month at Prestwick: Gannet, 2003-2010

Weather was wettest in the period from September to January. More extreme rainfall events (in which over 30mm fell in a day) tended to occur in the second half of the year. For the period considered here (2003-2010), 57% of days experienced rainfall less than 1 mm, and 6% of days experienced rainfall of 10 mm or more.

The potential for increased run-off is therefore highest in autumn and winter. However, the amount of contamination in any run-off will depend on the higher rainfall levels occurring when faecal contamination is present on the land. This is most likely in the late summer and early autumn periods.

9.2 Wind

Wind data collected at the Prestwick: Gannet weather station is summarised by season and presented in Figures 9.3 and 9.4, as provided by the Meteorological Office. The prevailing wind direction at Prestwick is from the south-west. There is a higher occurrence of north-easterly winds during the winter and spring. Winds are generally lightest in the summer and strongest in the autumn and winter.

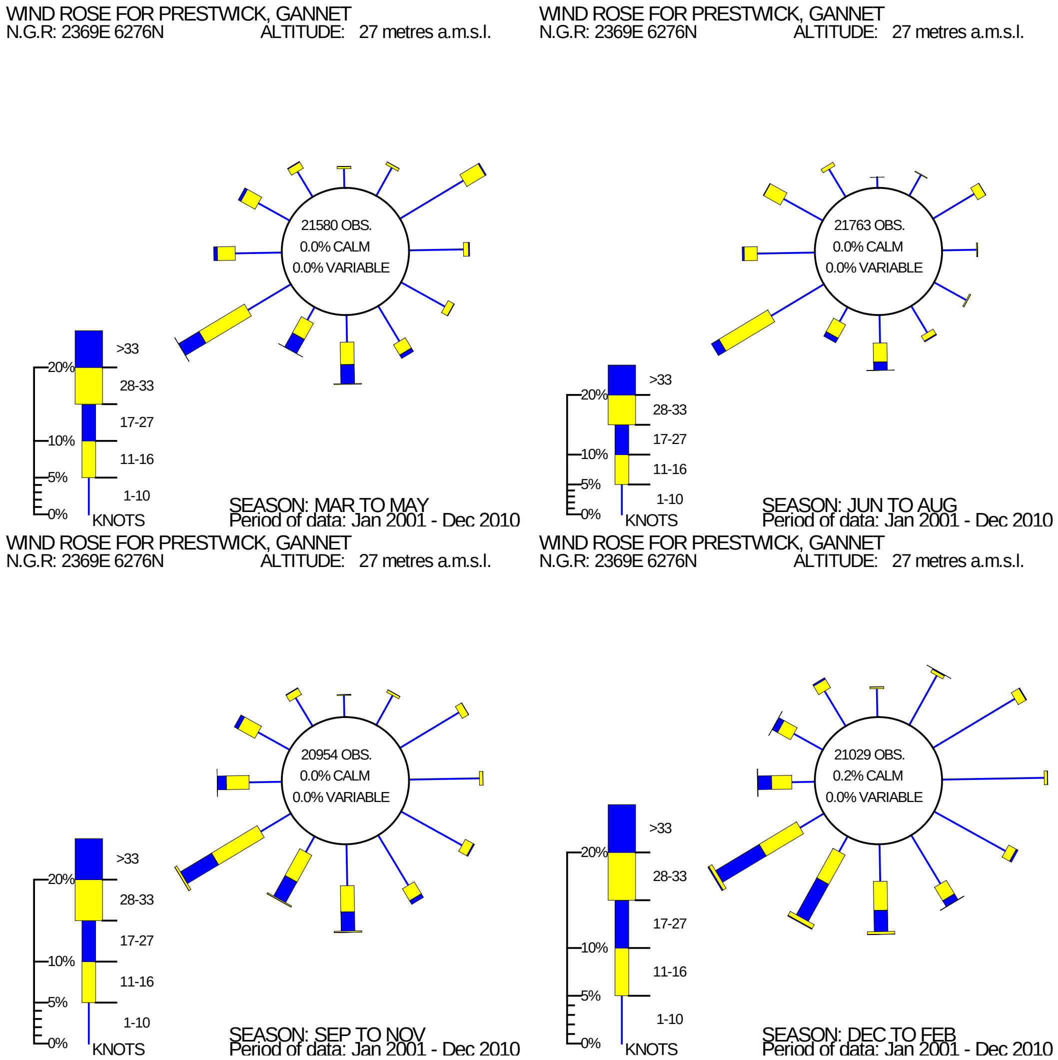

Figure 9.3 Seasonal wind roses for Prestwick: Gannet

Irvine Bay is aligned in an approximately south-east to north-west direction. Prevailing winds will therefore tend to blow on shore but, given the curve of the bay, might be expected to drive near-shore currents towards the northern end. 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 be expected to drive a surface water current of about 1 knot or 0.5 m/s. However, there was no evidence for this in the analysis of current meter versus wind data (see Section 14). Strong winds may also affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area.

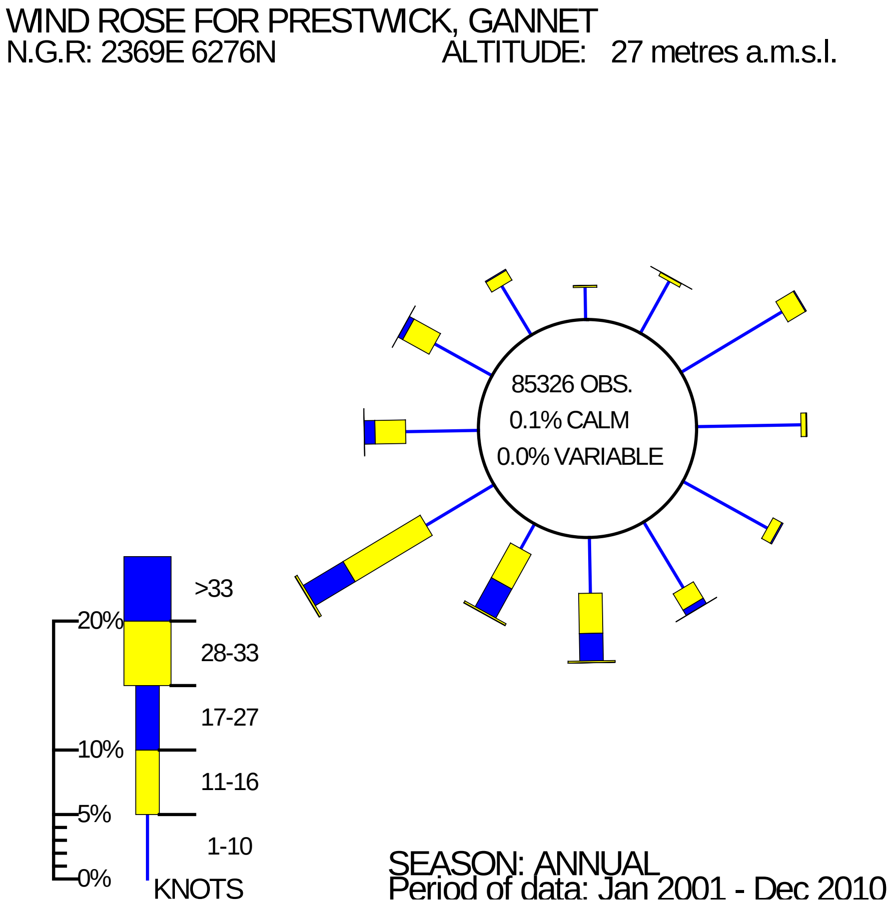

Figure 9.4 Annual wind rose for Prestwick: Gannet

10. Current and historical classification status

North Bay was first given a classification for razor clams (*Ensis* spp) in 2006. The historical and current classifications for the area are shown below in Table 10.1.

Table 10.1 North Bay, razor clams

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	B	B	B	B	A	A	A	A	A	A	A	A
2007	B	B	B	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A									

The razor clams have therefore held a year-round A classification, except in 2006 and 2007 where they were B during the first part of each year.

11. Historical *E. coli* data

11.1 Validation of historical data

All results for razor clam samples taken from North Bay since 1 January 2006 up to the 15th August 2011 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

All samples were received by the testing laboratory within two days of collection. The reported coolbox temperatures were all <8°C. Two samples were removed from the analysis. One, dated 23/10/2007, had been rejected by FSAS during initial result validation. The other, dated 15/08/2011, did not have an *E. coli* result on the data base due to an import problem. One sample, dated 13/10/2010, had an NGR that had been entered incorrectly: the format was incorrect but the numerical values appeared consistent with other samples from the production area. The NGR was therefore corrected. After this action, all reported sample locations fell within the classified production area.

Twenty samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results is presented in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	North Bay
Site	Barassie
Species	Razor clams
SIN	SA-337-719-16
Location	9 locations
Total no of samples	45
No. 2006	7
No. 2007	13
No. 2008	8
No. 2009	10
No. 2010	2
No. 2011	13
Results Summary	
Minimum	<20
Maximum	5400
Median	20
Geometric mean	40
90 percentile	278
95 percentile	2200
No. exceeding 230/100g	5
No. exceeding 1000/100g	4
No. exceeding 4600/100g	1
No. exceeding 18000/100g	0

11.3 Overall geographic pattern of results

Of the 45 samples included in the analyses, 13, taken up to September 2007, were reported to 100 m accuracy and against 5 different locations. Seven samples were reported to have been taken from one location, three from another location, and single samples from the other three. Of the 32 samples taken since September 2007, and reported to at least 10 m accuracy, 26 were reported as being taken at NS 31545 33572 (this is to an accuracy of 1 m). It would be unusual for sufficient animals to be available at a single location in a wild fishery and it is assumed that this represented a nominal sampling location (not coincident with the RMP (NS 319 334). Figure 11.1 is a map showing reported sampling locations with the number of samples given against each. All except one sample was reported to have been taken in the northern part of the production area to the north of Stinking Rocks. The exception was reported to have been taken in the south of the production area between Pan Rocks and the marina.

Due to the uncertainty in the actual sampling locations, a spatial analysis of the magnitude of the *E. coli* result by location was not undertaken.

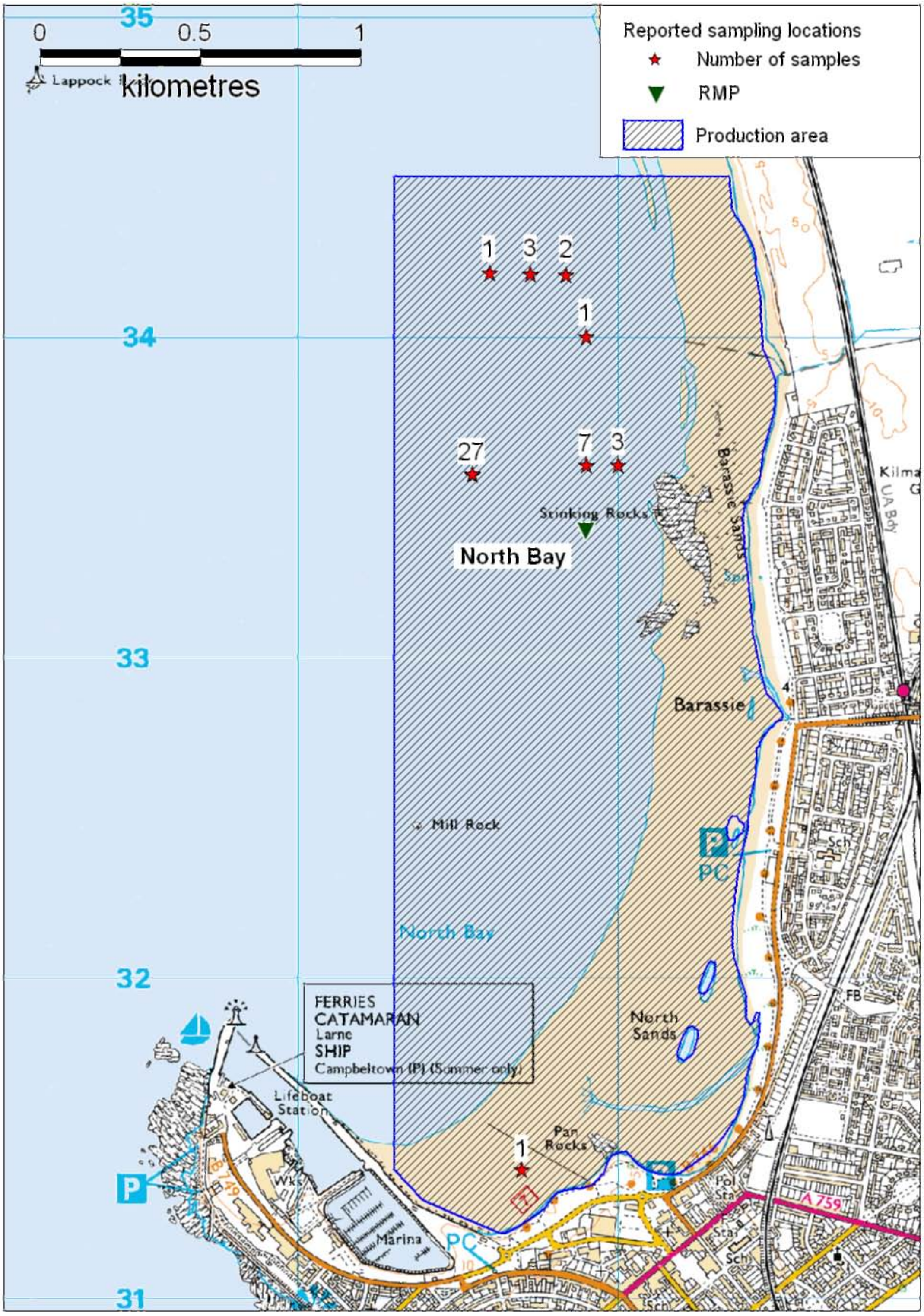

Figure 11.1 Map of reported sampling locations

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual razor results against date, fitted with a loess trend line. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

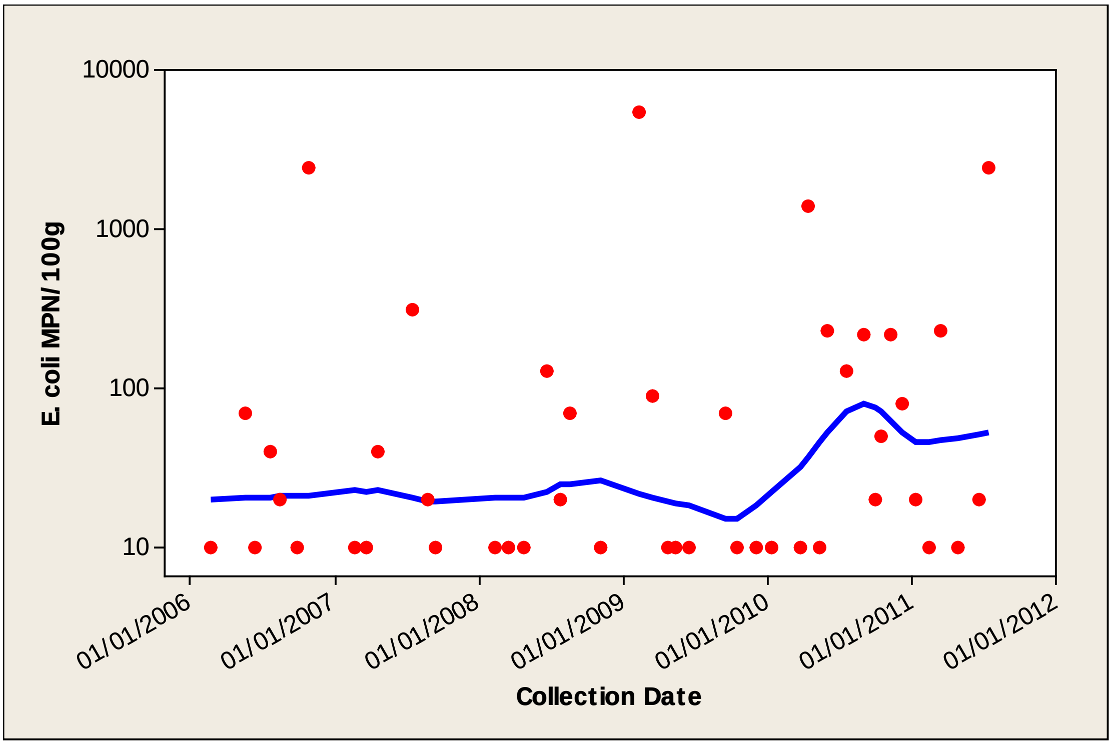

Figure 11.2 Scatterplot of E. coli results by date with loess line

The general level of contamination of the razors is low with intermittent, but ongoing, results greater than 1,000 *E. coli* MPN/100 g. There was an apparent increase in the general level of contamination in mid-2010 and this has largely been sustained.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 presents a scatterplot of *E. coli* result by month, overlaid with a loess line to highlight any trends.

No strong seasonal pattern is apparent in Figure 11.3, although results do appear to be slightly higher on average from June to December. However, results over 1,000 *E. coli* MPN/100 g occurred across the year.

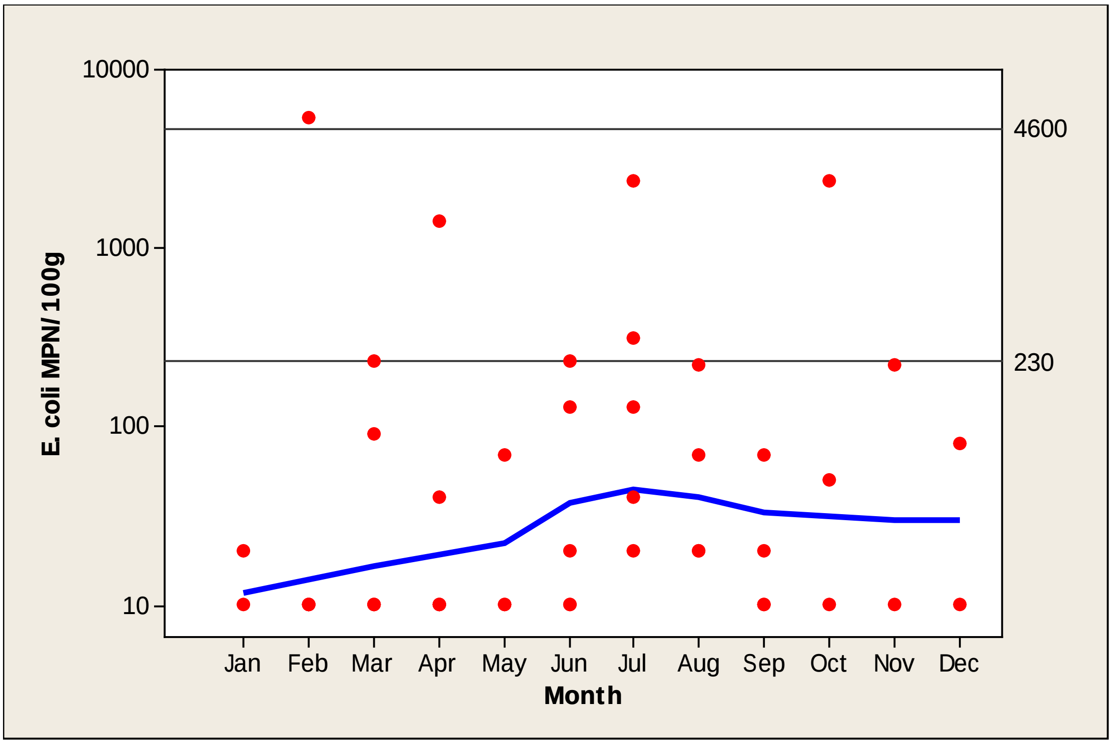

Figure 11.3 Scatterplot of results by month

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of results by season are shown in Figure 11.4.

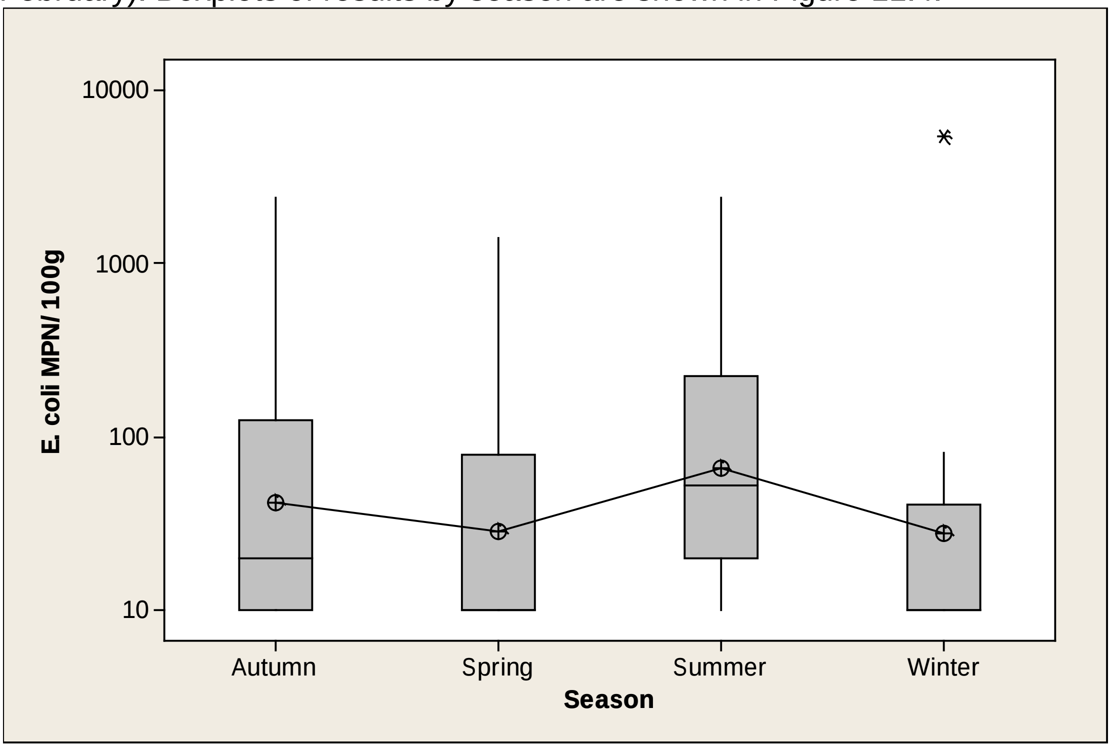

Figure 11.4 Boxplot of result by season

No significant difference was found between results by season (One-way ANOVA, p=0.570, Appendix 4).

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station for which most rainfall was available for most days during the period is at Prestwick: Gannet, to the south-east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2002 to 31/12/2010 (total daily rainfall in mm). Data was extracted from this for the period 1/1/2006 to 31/12/2010.

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling. A Spearman's Rank correlation was carried out between the results and the two day rainfall.

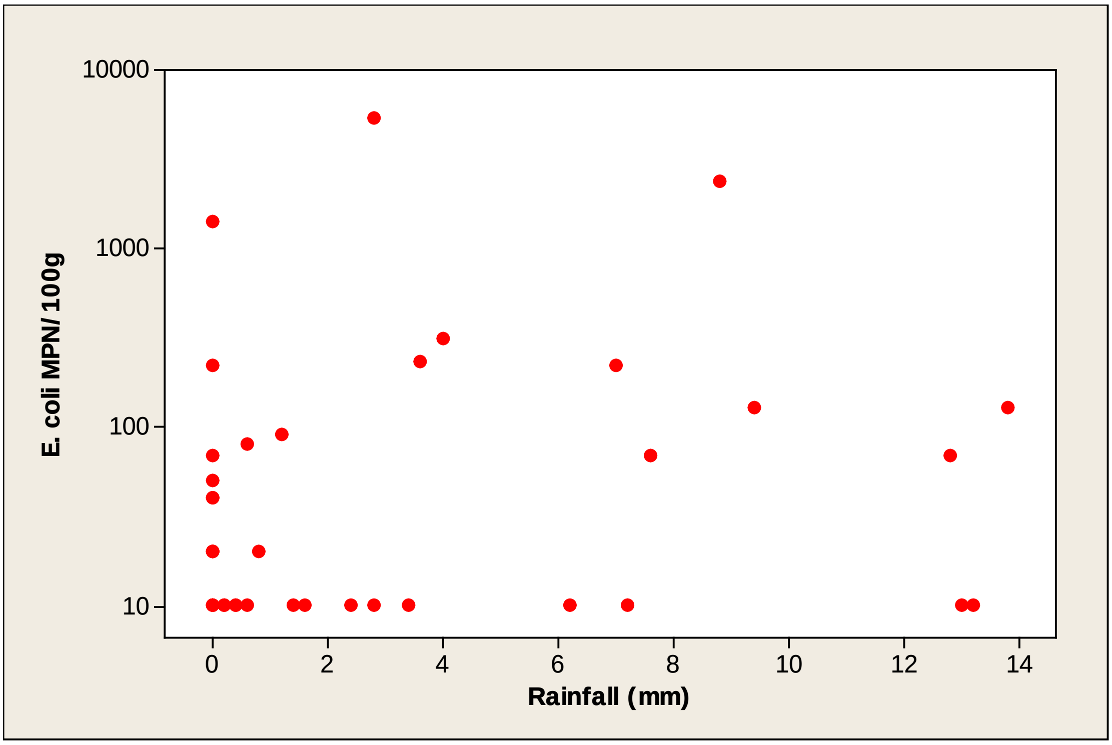

Figure 11.5 Scatterplot of result against rainfall in previous 2 days

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.134, p=0.42).

Seven-day antecedent rainfall

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. Figure 11.6 presents a scatterplot of E. coli results against total rainfall recorded on the two days prior to sampling.

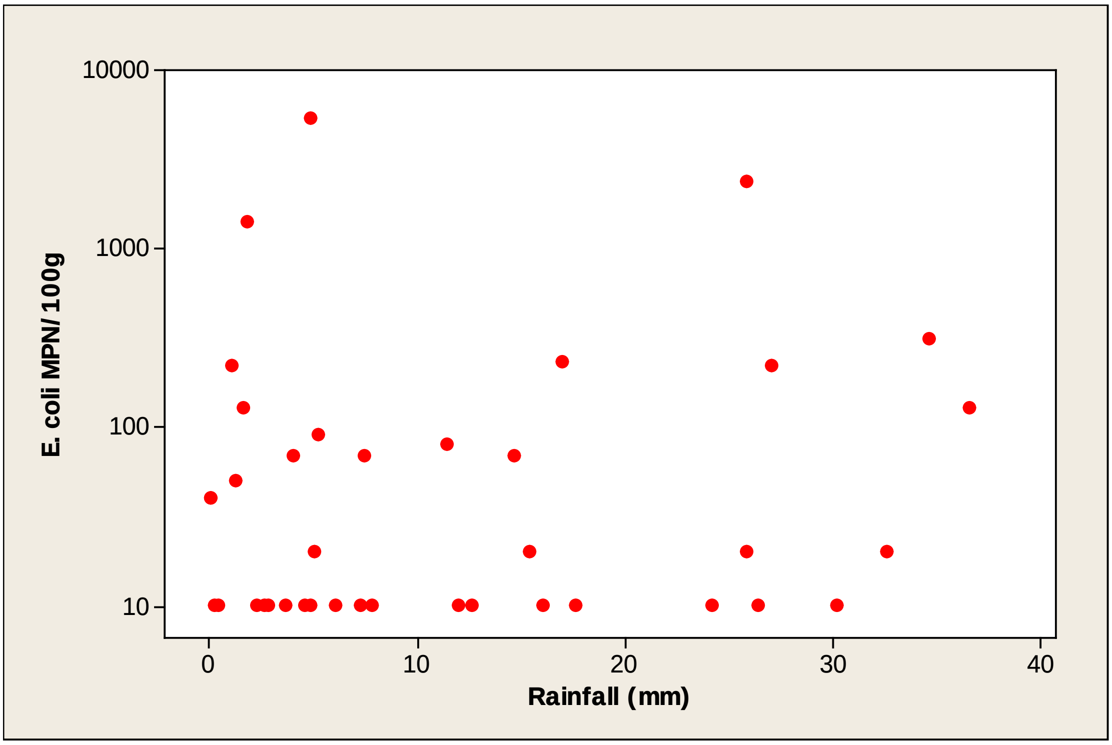

Figure 11.6 Scatterplot of result against rainfall in previous 7 days

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.083, p=0.62).

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

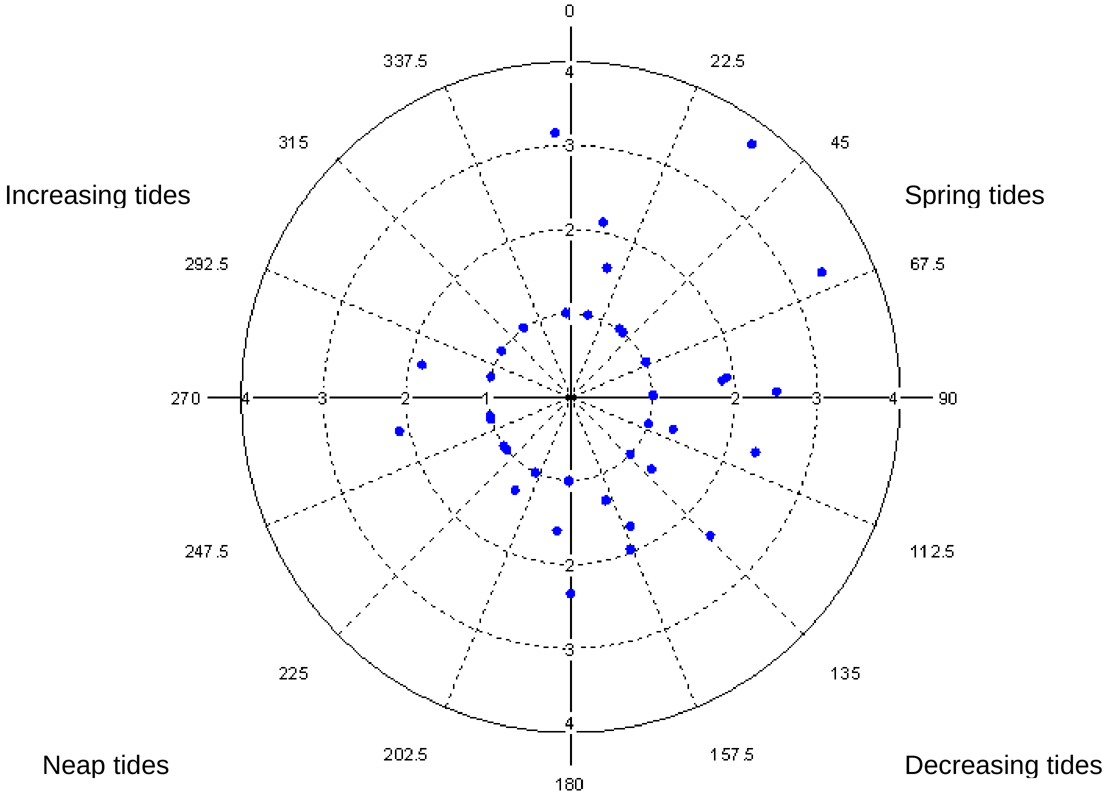

Figure 11.7 Polar plot of log10 E. coli results on the spring/neap tidal cycle

A weak correlation was found between $\log_{10}$ *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.298, p=0.04) suggesting that the results were not entirely random with respect to this tidal cycle. In Figure 11.7, it can be seen that higher results occurred around the time of spring tide.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle. High water occurs at 0º, and low water at 180º.

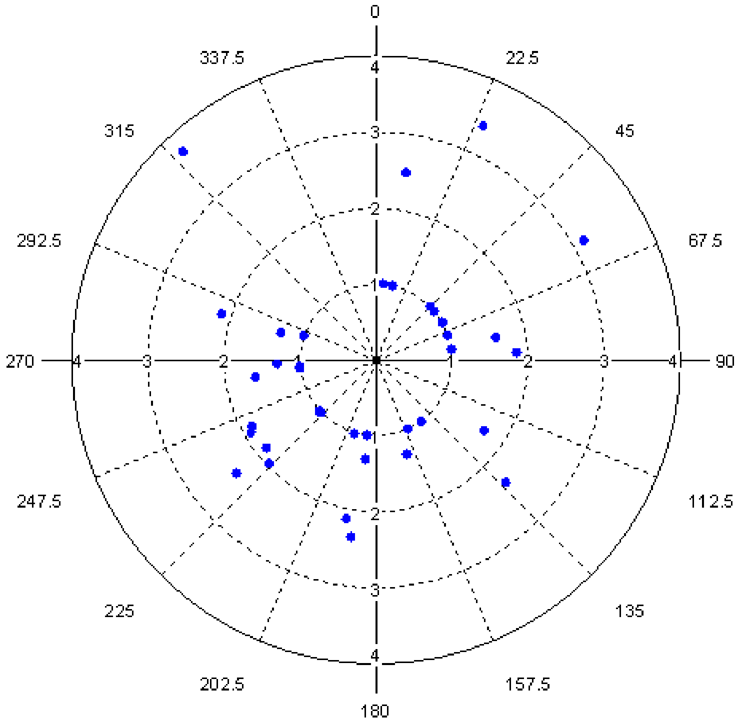

Figure 11.8 Polar plot of log10 E. coli results on the high/low tidal cycle

Although the higher *E. coli* values appear to occur around the time of high water, no significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.33, p=0.175).

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Water temperature was recorded against only 16 of the razor sampling occasions. No significant correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.378, p=0.148).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Salinity was only recorded for 5 of the razor sampling occasions for the data analysed, so a comparison with *E. coli* results was not possible for this area.

11.7 Evaluation of results over 230 *E. coli* MPN/100g

Of the razor samples, five gave results of over 230 *E. coli* MPN/100g. Details of these samples are presented in Table 11.2.

Table 11.2 Historic E. coli sampling results over 230 E. coli MPN/100g

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
24/10/2006	2400	NS319336	8.8	25.8	13	-	High	Spring
17/07/2007	310	NS319340	4	34.6	-	-	High	Spring
10/02/2009	5400	NS 31545 33572	2.8	4.8	-	-	High	Spring
13/04/2010	1400	NS 31545 33572	0	1.8	-	-	Ebb (just after high)	Spring
13/07/2011	2400	NS 31727 34197	-	-	-	34	Flood (just before high)	Spring

Samples were collected over a wide range of months through the year. Three of the 5 samples were taken after some rainfall, no rainfall data was available for the most recent sample. All of the samples giving these high results were taken around high water springs.

11.8 Summary and conclusions

Due to the uncertainty of many of the sampling locations, no spatial assessment could be made of the data. There were no significant effects of season, water temperature or rainfall. A weak correlation was found between the *E. coli* results and the spring/neap tidal cycle but not the high/low cycle. However, all of the samples yield results greater than 230 *E. coli* MPN/100 g were taken around high water springs.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area holds a non-seasonal classification and the geometric mean of the results falls within a certain range, the EURL Good Practice Guide (GPG) recommends that consideration be given to the sampling frequency being decreased from monthly to bimonthly. The production area has held a year-round A classification since 2008. However, the geometric mean of the 26 results obtained between 1/01/2008 and 31/12/2010 is 26 *E. coli* MPN/100g. This is higher than the upper limit of 13 *E. coli*/100 g given in the GPG for class A stability assessment.

12. Designated Waters Data

12.1 Shellfish Growing Waters

The North Bay production area does not fall within or adjacent to any designated shellfish growing waters. The nearest SGW (Ayrshire Coast SGW) is located over 14km northwest of the northern production area boundary. Conditions at Ayrshire Coast are unlikely to be representative of those to be found at North Bay, and therefore the Ayrshire Coast SGW monitoring results are not considered further.

12.2 Bathing Waters

Two designated bathing waters lie adjacent to the production area. The Irvine bathing water is located along the shore north of the production area, south of the River Irvine mouth. The Troon (South Beach) bathing water lies along the shore of South Bay, south of the peninsula at Troon. Bathing waters are monitored for total and faecal coliforms, as well as for other parameters, between 1 June and 15 September. An additional sample is taken during the last two weeks of May, prior to the start of the bathing season. Normally at least 20 samples are taken each season.

Faecal coliform results from the two identified bathing waters for the 2011 bathing season are listed in Table 12.1 below. Only those samples collected during the bathing season, including the May samples, were considered. For the purposes of calculating a geometric mean, all samples reported as <10 were assigned a value of 5. One sample had a recorded result of >1600 and this was assigned a value of 2500. One sample had a recorded result of <16000 and this was assigned a value of 8000.

Table 12.1 Bathing Water results for 2011

Year	Site	No of samples	Geometric mean	Min	Max	>100	>2000
2009	Troon	22	31	<10	1900	5	0
2009	Irvine	22	180	<10	<16000	15	3
2010	Troon	21	24	<10	600	5	0
2010	Irvine	23	54	<10	12400	9	3
2011	Troon	20	21	<10	5600	5	1
2011	Irvine	20	108	<10	4900	9	2

Higher results were regularly recorded at Irvine, though on some occasions results from the same date were higher at Troon, most notably during 2011. Overall, geometric mean results were higher at Irvine. This suggests that the waters at Irvine are subject to higher levels of contamination of a regular basis than are the waters at Troon. Although these results are for faecal coliforms and cannot be directly compared with *E. coli* results reported elsewhere in this report, in general the ratio of *E. coli* to faecal coliforms is likely to be close to 1:1.

No comparison of these results with recorded rainfall was undertaken, however bathing waters reports prepared by SEPA for Irvine and Troon have suggested a link between rainfall and faecal contamination of the bathing waters (http://www.sepa.org.uk/water/bathing_waters/bathing_water_profiles.aspx; accessed 06/12/11).

13. River Flow

The Garnock and Irvine rivers combine and discharge to the sea in Irvine Bay, to the north of North Bay. These are the most significant watercourses in the area. There are a number of other watercourses that enter these two rivers above their confluence and there are a number of gauging stations on the system. The gauging stations for which historical flow summaries were available are shown in Figure 13.1 and summary data for them is given in Table 13.1. During the shoreline survey, the River Irvine was sampled just below the weir at Irvine and returned a result of 600 *E. coli* cfu/100 ml.

Table 13.1 Gauging stations in the Garnock and Irvine catchments for which flow summary data was available

Catchment	Watercourse	Catchment Area	Station Name	NGR	Q_{50} (m^3/s)	Q_{10} (m^3/s)
River Garnock	Lugton Water	55 km^2	Eglinton Castle	NS 31579 42059	0.745	4.691
	River Garnock	184 km^2	Kilwinning	NS 30699 42416	2.597	16.313
River Irvine	Annick Water	91 km^2	Dreghorn	NS 35114 38426	1.588	9.186
	River Irvine	73 km^2	Newmilns	NS 53252 37188	1.073	6.239
	River Irvine	381 km^2	Shewalton	NS 34525 36895	4.135	25.33

Source: SEPA/CEH National River Flow Archive

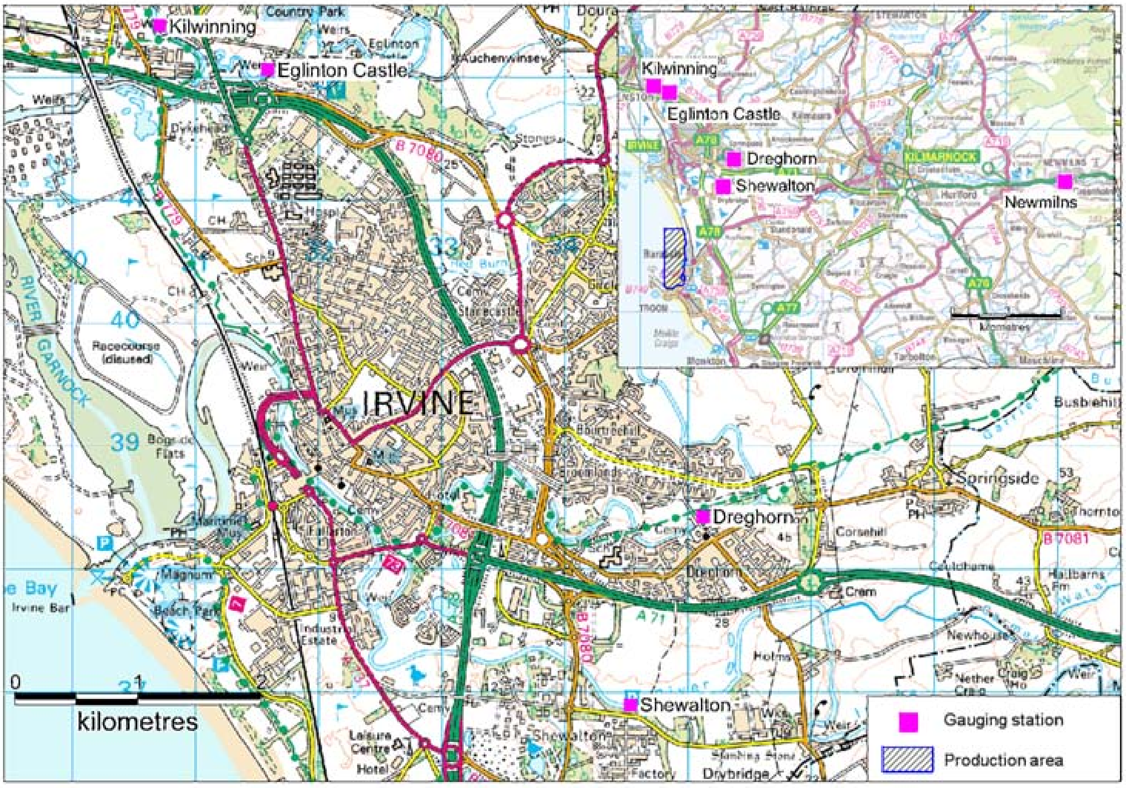

Figure 13.1 Location of River Garnock/River Irvine gauging stations

The Newmilns station is much farther up the River Irvine than is the Shewalton station and so the latter was preferred for estimation of flows impacting at the coast. The confluence for Annick Water and the River Irvine is below the two gauging stations and the same applies to Lugton Water and River Garnock. The median flow for the system was therefore calculated by combining the Q_{50} values for the four gauging stations. This yielded a total of 9.1 m^3/s. This is significantly less than the value which results from combining the average flows for the Garnock and Irvine quoted by the Ayrshire Rivers Trust (ART) in their Fishery Management Plan (http://www.ayrshireriverstrust.org/uploads/docs/3%20Catchment%20description.pdf): this gives a value of 21.2 m^3/s. The combined estimate for the River Irvine was 5.7 m^3/s: again, this was markedly less than the average value of 13.1 m^3/s quoted by the ART. The differences are likely to be due to the effect of skewed data sets on the mean values quoted as averages. Using a value of 5.7 m^3/s, combined with the E. coli result of 600 cfu/100 ml, yields an estimated loading of 3×10^{12} *E. coli*/day being discharged at the coast by the Irvine River. Wyer et al (1999a) showed that the faecal coliform contributions to coastal waters from the Rivers Irvine and Garnock, over an eight week period, were 4.23×10^{16} and 1.02×10^{16} respectively. This equals a combined average daily loading of approximately 9.5×10^{14}. However, improvements to a number of faecal sources within the catchment have been undertaken since then and this will have reduced the total loading from these two catchments. Both Kashepifour and co-workers (2006) and Wyer and co-workers (1999b) showed that the faecal coliform loading of the River Irvine increased many fold during high flow conditions.

The watercourses listed in Table 13.2 were observed during the shoreline survey. Where possible, these were measured and sampled. The locations, together with the calculated loadings, are shown in Figure 13.2 (the location and estimated loading for the River Irvine is also shown). The weather was dry at the time of the survey. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

Table 13.2 Watercourse loadings for North Bay

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NS 3239 3195	Darley Burn	2.36	0.12	0.119	2910	31000	9.0×10^{11}
2	NS 3250 3284	Stream	2.0	0.06	0.128	1330	4100	5.4×10^{10}
3	NS 3252 3388	Stream	1.78	0.20	0.220	6770	200	1.4×10^{10}
4	NS 3232 3473	Stream running through culvert	1.0	0.15	0.002	26	<100	$<2.6 \times 10^{7}$
5	NS 3217 3514	Stream running through culvert	1.01	0.05	0.015	65	50000	3.3×10^{10}
6	NS 3157 3976	River Irvine	Not measured				600	3.0×10^{12}

Figure 13.2 Map of watercourse loadings at North Bay

The watercourses shown in Figure 13.2 will provide significant local sources of contamination to the shellfishery. The loadings will be expected to be significantly higher after moderate to heavy rainfall. The loading associated with the Irvine and Garnock Rivers will be much higher than the more local watercourses and will provide a significant source of contamination to the north of the shellfishery.

14. Bathymetry and Hydrodynamics

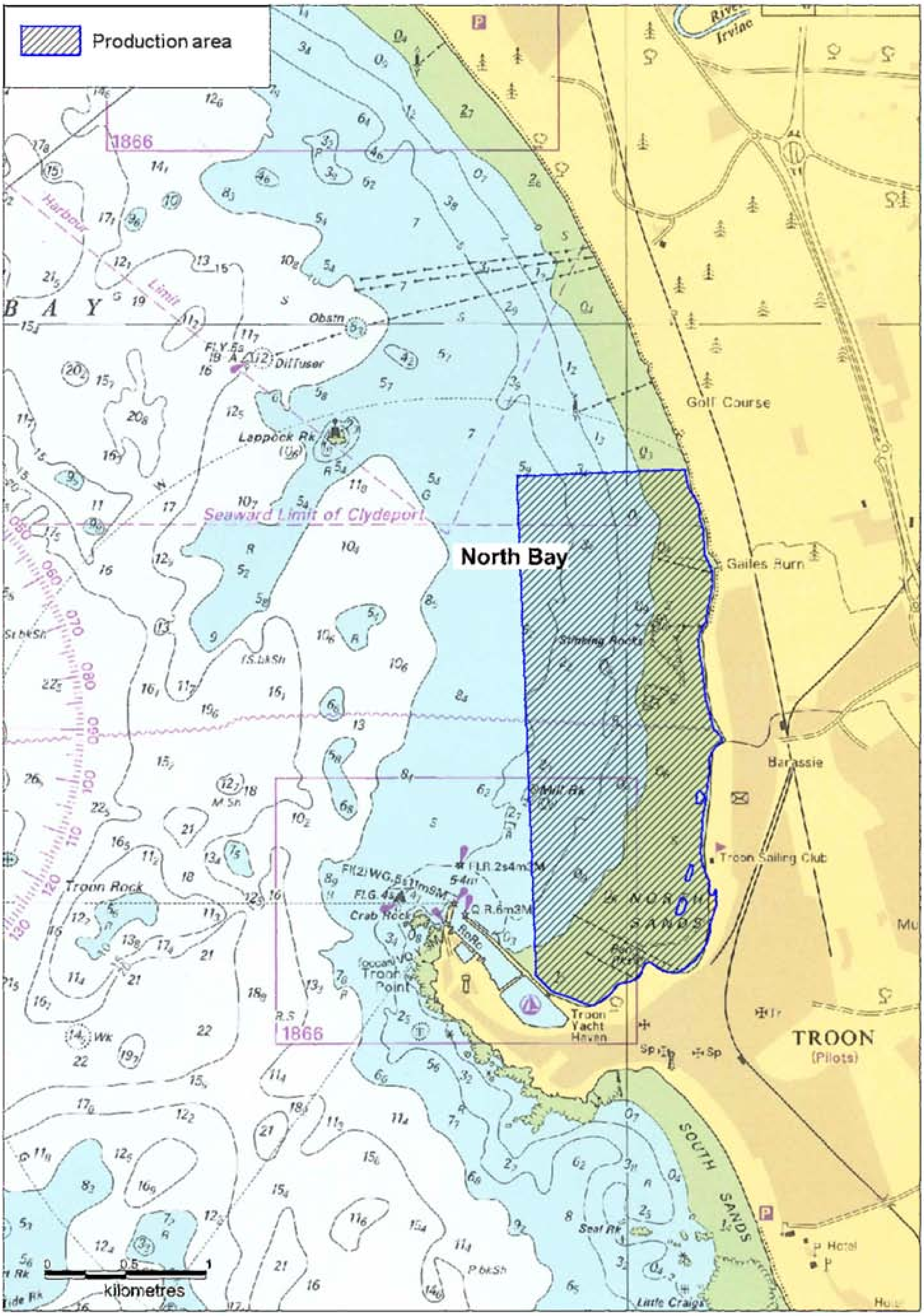

Figure 14.1 Bathymetry at North Bay

North Bay is situated on the eastern side of the Firth of Clyde. The island of Arran lies on the western side of the firth at that point. The bay lies in a generally north-south direction. There is a promontory at the southern end, Troon Point, with Troon

Yacht Haven located on the northern side of the promontory. A drying area approximately 300 m wide occurs along much of the bay but there is a more extensive drying area located at North Sands to the north of Troon Point. Towards the southern end of North Bay there are some rocky outcrops located within the drying area. Below the drying area the seabed slopes to more than 10 m in depth at the edge of the bay. However, depths only reach about 6 m at the western edge of the present production area. The seaward limit of Clydeport cuts across North Bay.

North Bay is contiguous with Irvine Bay which lies to the north. The rivers Garnock and Irvine, which join and discharge into Irvine Bay, have estuarine stretches at their lower ends.

14.1 Tidal Curve and Description

The two tidal curves below are for Troon, located at the south end of the North Bay production area. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 12/07/11 and the second is for seven days beginning 00.00 BST on 19/07/11. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle and cover the period during which the shoreline survey was undertaken.

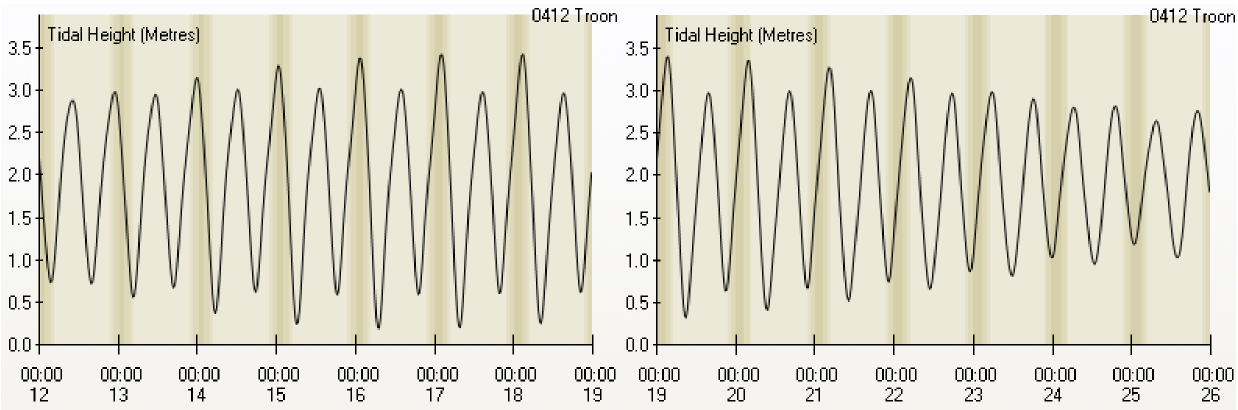

Figure 14.2 Tidal curves for Troon

The following is the summary description for Troon from TotalTide:
0412 Troon is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	3.7 m
MHWS	3.2 m
MHWN	2.6 m
MSL	1.92 m
MLWN	1.0 m
MLWS	0.3 m
LAT	-0.3 m

Predicted heights are in metres above chart datum. The average tidal range at spring tide is 2.9 m and at neap tide 1.6 and so tidal ranges at this location are moderate (mesotidal).

14.2 Currents

Tidal stream information was available for a station in the middle of the Firth of Clyde, between Troon and Arran. The location of the station, together with the tidal streams for peak flood and ebb tide, are presented in Figures 14.3 and 14.4. The tidal diamond for the station is presented in Table 14.1. A second tidal stream station is visible in Figures 14.3 and 14.4, located immediately off the coast of Arran, south of Holy Island.

Figure 14.3 Spring flood tide in the Firth of Clyde

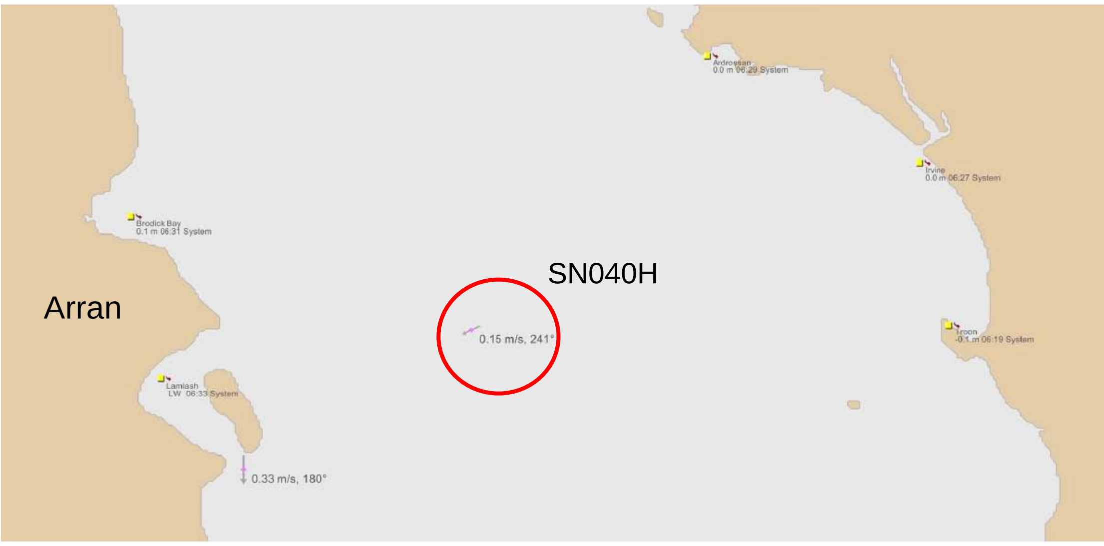

Figure 14.4 Spring ebb tide in the Firth of Forth

Table 14.1 Tidal streams for station SN040H (55°32.90'N 4°56.77'W) (taken from Totaltide)

Time	Direction	Spring rate (m/s)	Neap rate (m/s)
-06h	048°	0.15	0.10
-05h	059°	0.15	0.10
-04h	055°	0.10	0.05
-03h	083°	0.10	0.05
-02h	106°	0.15	0.10
-01h		0.00	0.00
HW	215°	0.15	0.10
+01h	253°	0.15	0.10
+02h	277°	0.10	0.05
+03h	238°	0.15	0.10
+04h	246°	0.10	0.05
+05h		0.00	0.00
+06h	064°	0.10	0.05

At this location in the middle of the Firth of Clyde, the tidal streams are very weak, peaking at 0.15 m/s on spring tides (15 cm/s; 0.3 knots). In addition, while there is a general tendency for the current direction to be approximately east-north-east on the flood tide, and west-south-west on the ebb tide, it can be seen from Table 14.1 that the direction oscillates significantly.

Additional current data was provided by the British Oceanographic Data Centre (BODC). Location and time period details for the data are listed in Table 14.2. All data was defined as “Currents -subsurface Eulerian”. The studies presented here in relation to Series Reference 12191, 12209, 12351, 12560, 12885 and 12916 use data from The Marine Scotland Marine Laboratory Aberdeen, provided by the British Oceanographic Data Centre and funded by the UK Government. The studies presented here in relation to Series Reference 60605 and 60617 use data from The Clyde River Purification Board, provided by the British Oceanographic Data Centre and funded by the UK Government. Locations of current data stations are shown in Figure 14.5.

Table 14.2 Details of the current data provided by BODC

Series Ref	Data Type	Latitude (Deg Min)	Longitude (Deg Min)	Start Date	End date	Sea Floor Depth (m)	Min. Sensor Depth (m)	Max. Sensor Depth (m)
12191	LA	055°34.4'N	004°47.6'W	1971-07-14	1971-07-19	46	24	24
12209	LA	055°34.4'N	004°47.6'W	1971-07-14	1971-08-02	46	41	41
12351	LA	055°35.2'N	004°46.1'W	1972-03-19	1972-04-06	34	30	30
12560	LA	055°36.9'N	004°54.0'W	1972-03-03	1972-04-10	70	65	65
12885	LA	055°36.8'N	004°54.4'W	1973-11-05	1973-11-18	72	27	27
12916	LA	055°37.6'N	004°53.3'W	1974-01-14	1974-03-18	65	55	55
60605	LA	055°35.1'N	004°41.4'W	1986-08-05	1986-09-04	10	8.5	8.5
60617	LA	055°35.1'N	004°41.4'W	1986-08-05	1986-09-04	10	3.5	3.5

Figure 14.5 Current meter locations

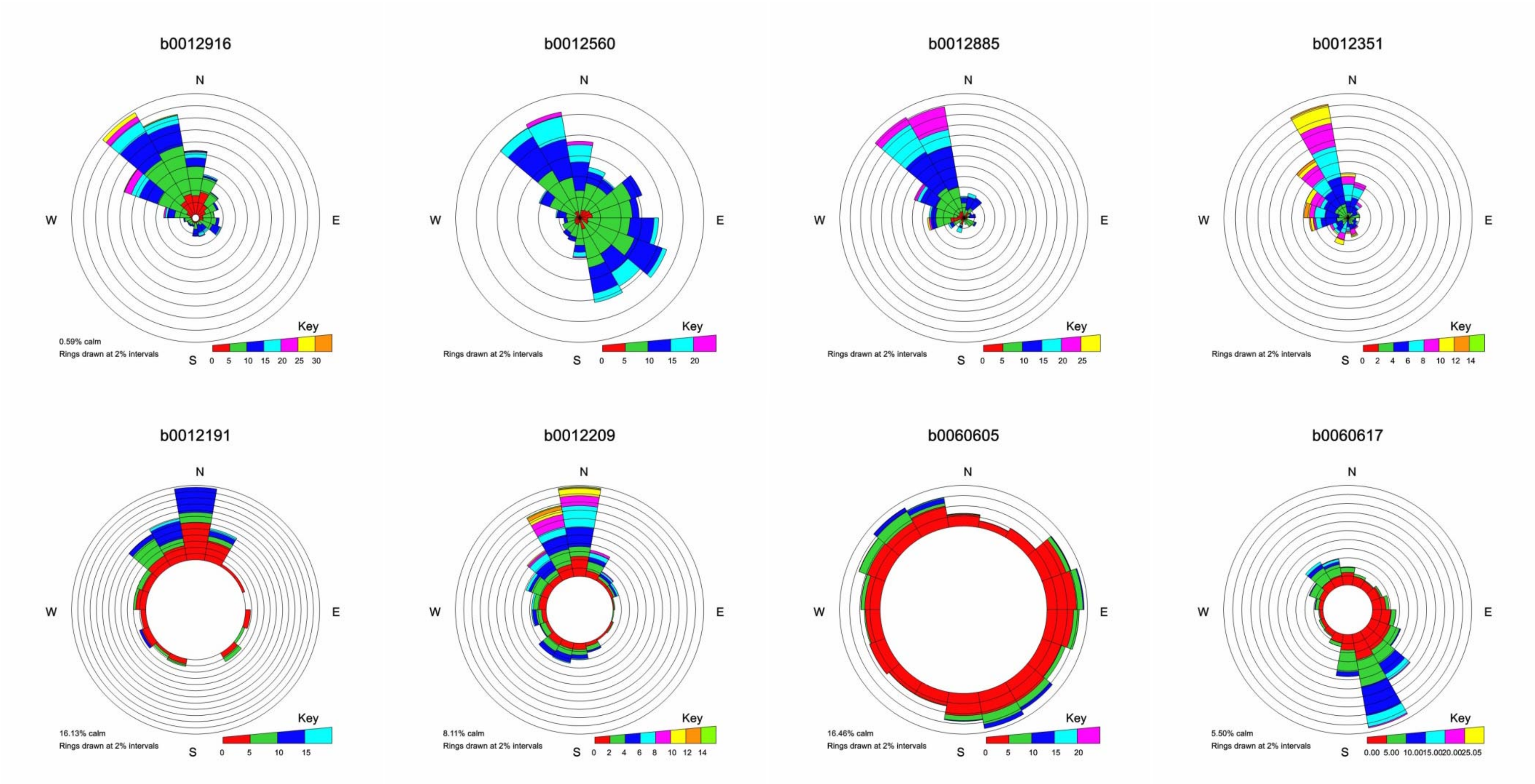

Figure 14.6 Current plots for North Bay

Currents measured in cm/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range. Clear areas at the centre of each plot are proportional to the amount of data showing no, or negligible, current. Directions are in degrees True.

The current meter deployments took place at a number of locations around Irvine Bay. Some of the meter deployments differed in depth. In general, those located at the same, or nearby, locations gave similar plots (as shown in Figure 14.6) except for the two located to the north of North Bay (b0060605 and b0060617). The former showed a large proportion of essentially quiescent results, with no predominating directional flow at others times, whereas the latter showed a predominating current to the south-south-east. B0060605 was located near the seabed whereas b0060617 was located near the surface. Both data sets covered the same period of one month in 1986 and so environmental factors (such as wind direction and speed) would have been the same for both. Meteorological data for the area for that period was not available and so it cannot be determined whether the predominating current at b0060617 was due to wind effects. The August wind rose for Prestwick: Gannet, located approximately 7 km south-east of the Troon, is shown in Figure 14.7.

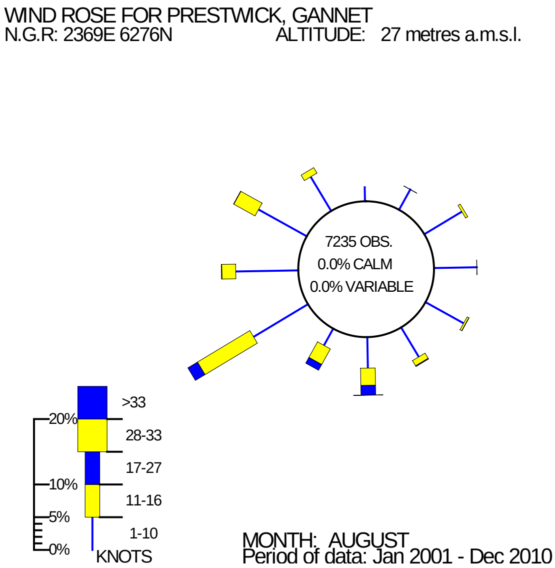

Figure 14.7 August wind rose for Prestwick

This wind rose represents average winds for the month of August over the period 2001 to 2010 inclusive and so it doesn't cover the period of the current data sets in question. However, it shows that winds during August are predominantly from the south-west and it is unlikely that the surface currents at b0060617 were solely due to wind effects. If that is correct, then the data indicates that subsurface currents at the north end of North Bay flow principally in a south-south-easterly direction.

At the other meter deployment locations, either northerly or north-westerly currents tend to predominate. However, at b0012560, there were also currents flowing in a south-easterly direction for a significant proportion of time.

In general, peak current speeds at the outer locations of Irvine Bay were between 15 and 30 cm/s (0.15 to 0.3 m/s; 0.3 to 0.6 knots). The subsurface current at the north end of North Bay showed a median of 4.8 cm/s and a maximum of 25.1 cm/s. Currents in the area are therefore generally low. At a maximum current speed of 25 cm/s, contaminants will be expected to be carried a maximum distance of less than 4 km over an ebb or flood tide, ignoring any effects of dilution or dispersion.

Currents will be more complex in the vicinity of Troon Point and it is expected that there will be eddies around the point and to the north of Troon harbour.

14.3 Salinity effects

No salinity profiles were measured during the shoreline survey. Spot subsurface seawater samples taken during the survey returned results of between 33.1 and 33.9 ppt. This indicates little freshwater impact at those locations. The two lowest results of 33.1 ppt derived from the two seawater samples taken from the boat during the gathering of razor samples: these samples were therefore taken further from shore than the others.

14.4 Conclusions

Currents within the Irvine Bay area are generally weak and flows to the north and north-east predominate over much of the tidal cycle. Within North Bay itself, the available information indicates that the predominant current direction will be southward. Contamination from sources to the north of North Bay, including from the Irvine/Garnock estuary, may therefore be transported down to the shellfishery. Contamination from sources within the production area will tend to flow south along the coast. In the vicinity of Troon Point, this will impact across the southern part of the production area.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 11th and 12th July 2011 under dry and calm weather conditions.

The harvester indicated that razor clams are believed to occur across much of the bay, apart from where there are areas of reef. The razor clams are hand dived and fished year-round depending on weather conditions.

The area surrounding North Bay is largely urbanised with the towns of Troon and Irvine adjacent to the bay. Several outfall pipes were observed during the shoreline survey. On the west side of Troon a Scottish Water outfall pipe was observed leading down to the shoreline. The outfall pipe had spat growing inside and around the edges and was not flowing on the day of the survey. A further four large outfall pipes were observed at the southern end of North Bay, one of which was flowing. The Barassie SPS Scottish Water treatment works and an outfall pipe leading into the sea were observed at the northern end of North Bay. Sanitary debris was found at the southern and northern end of North Bay, close to the sewage discharge outfalls.

Due to the urban nature of the land surrounding North Bay, no livestock or signs of livestock farming were observed during the shoreline survey. A large number of gulls (approximately 300 in total) were observed on the sands of North Bay. Other seabirds including oyster catchers and mallard ducks were observed in smaller numbers.

A total of seven sea water samples were taken in the vicinity of the fishery, four of which contained <1 *E. coli* (cfu/100 ml). Two sea water samples taken near the shoreline towards the middle of the bay contained 12 and 18 *E. coli* (cfu/100 ml) and another sample taken at the northern end of the bay near Irvine contained 10 *E. coli* (cfu/100 ml).

Freshwater samples and discharge measurements were taken at five of the streams draining into the survey area. The streams were of moderate size and drained urban areas or grassland. Fresh water samples taken the streams all contained significant concentrations of *E. coli* except one. A fresh water sample taken from a stream at the southern end of the bay contained 31000 *E. coli* (cfu/100 ml). A water sample taken from a stream near the Western Gailes golf course had the highest result and contained 50000 *E. coli* (cfu/100 ml). The Barassie stream fresh water sample contained 4100 *E. coli* (cfu/100 ml) and the Irvine River fresh water sample contained 600 *E. coli* (cfu/100 ml).

Razor clam samples were collected from three areas within the bay and contained varying results. A razor sample collected at the southern end of the bay had the highest result and contained 230 *E. coli* (MPN/100 g). The razor sample taken at the middle of the bay contained 130 *E. coli* (MPN/100 g) and the sample taken towards the northern end of the bay contained 50 *E. coli* (MPN/100 g).

Figure 15.1 shows a summary map of the most significant findings from the shoreline survey.

Figure 15.1 Summary of shoreline survey findings for North Bay

16. Overall Assessment

Human sewage impacts

The waters within and adjacent to the North Bay production area are subject to significant input of human sewage effluent. Although the continuous discharge from the Meadowhead WWTW receives secondary treatment, it discharges 1.4km north of the production area. The continuous discharge from the Stevenston WWTW discharges 6.6km northwest of the current production area boundary. The shellfish bed is presumed to extend at least as far as the River Irvine, and though the seabed north of the river is likely to be suitable for the species, it was not possible to ascertain whether and how far north of the river the shellfish bed might extend. Therefore, the Meadowhead discharge impacts directly on the bed and the Stevenston discharge may impact directly on the bed if it extends that far. Given the predicted current movements in the area, contamination arising from the Stevenston discharge is less likely to impact the area of the bed south of the river than either the Meadowhead continuous discharge or its overflow discharges.

Combined sewage overflows have been implicated in several studies into the failures of bathing water standards at Irvine Beach. Although the sewerage system is being improved in order to reduce the number and size of spills, studies have shown that this may not be sufficient to ensure compliance.

Agricultural impacts

Although agricultural impacts have been overshadowed by human sewage inputs to the area, there is some evidence to suggest that diffuse pollution from intensively farmed areas in the lower part of the River Irvine catchment are likely to contribute to the overall loadings during heavy rainfall and would continue to do so after some of the human sewage impact has been reduced. These would be most acute where the river reaches the bay, however hydrodynamic studies have shown wind-driven advection to be a significant driver of contaminant movement and impacts would be spread throughout the bay.

Some of the smaller streams may also carry agricultural-source diffuse pollution from their upper catchments, though these drain far more limited areas than does the River Irvine. Barrassie Burn in particular drains an area with significant open land and if used for grazing or application of slurry this could potentially be a source of rainfall-dependent diffuse runoff.

Wildlife impacts

Species most likely to contribute to the overall faecal contamination of the area are birds, deer and seals. However, the impact from wildlife on water quality at the fishery is expected to be very minor by comparison to other sources of faecal contamination.

Seasonal variation

No statistically significant seasonal variation was observed in historical monitoring results for North Bay. Although the number of people present is likely to be higher during the summer months when tourists utilise the beaches, heavy rainfall events have tended to occur more during the autumn and winter, and therefore sewage spills would also be more likely to occur during this period.

Rivers and streams

All but one of the streams measured and sampled during the shoreline survey were found to carry high loadings of *E. coli*, indicating that watercourses are significant pathways for faecal contamination reaching the fishery. The largest source of faecal indicator bacteria was the River Irvine, which discharges to the north of the North Bay production area. However, watercourses discharging to the bay within the bounds of the production area also constitute significant sources of contamination particularly to the southern end of the fishery.

Movement of contaminants

Analysis of current data suggests that water movement at depth within the fishery is likely to be low to moderate, whilst wind-driven movement at the surface is likely to be more active. It is likely that contamination arising north of the production area, both from the River Irvine and from sewage discharges to Irvine Bay, will affect water quality throughout the bay. A supplementary investigation into the failure of the Irvine bathing beach identified that wind-driven circulation with surface currents balanced by return flows at depth was the main mechanism of particle transport within the bay (Vinten, 2003). Transport of faecal pollution from both the Irvine estuary and the sewage discharge were found to reach the bathing beaches within hours.

Movement of contaminants in the southern end of the bay is likely to be complicated by eddies created by the point at Troon Harbour.

Most, if not all, of the shellfish bed is likely to be subject to significant levels of faecal pollution from both human and agricultural sources on an ongoing basis.

Temporal and geographical patterns of sampling results

Analysis of historical monitoring results from the area suggests intermittently high levels of faecal contamination in razor clams, and that the incidence of lower levels of contamination has increased during the past year. No significant correlation was found between results and season or rainfall during the 2 or 7 days prior to sampling. It was not possible to assess geographic patterns in sampling results due to questions regarding the reported sampling locations. The razor clam bed in the bay is likely to extend well beyond the boundaries of the production area, and it is also likely that a greater extent of this bed is exploited.

Extensive analysis of faecal coliforms in bathing waters and the River Irvine undertaken by SEPA and others have suggested a clear link between faecal coliform concentrations in both bathing waters and the River Irvine and rainfall events.

Once sampling is reported in a manner that allows for some confidence in the sampling locations, a better picture of geographic variation around the area may be obtained.

Conclusions

The North Bay production area is unlikely to represent the true extent of the exploitable razor clam fishery within Irvine Bay. The entire bay is subject to significant human sewage contamination, as well as diffuse urban and agricultural pollution carried via the River Irvine and other watercourses. The nearby bathing beach is known to be significantly affected by sewage contamination. The final effluent discharge from the Meadowhead WWTW discharges to within 2km of the existing production area, and two CSOs discharge within the production area boundaries. Various studies have suggested that sewerage spills into the River Irvine are a significant source of contamination to the beaches of the bay. Although works are underway to reduce the frequency of spills to the river, it has been suggested that this alone will not significantly improve water quality during high flow conditions.

Despite the year-round A classification given to the production area, there are serious concerns regarding the locations from which samples have actually been taken. Little is known about the transport of contamination at the seabed and consequent uptake by the razor clams. In the absence of other information, it is important that sampling at this production area be validated by the official control sampling officer to improve the accuracy and confidence in the sampling locations.

17. Recommendations

Production area

Given the wider extent of the likely razor clam bed and the continuous discharge in the northern end of the bed, it is recommended that the northern production area boundary be retained and the western boundary extended further offshore to incorporate the fuller area that can be exploited by divers.

It is recommended that areas nearest shore, where contamination levels due to diffuse runoff may be higher, be excluded from the production area boundaries.

The recommended production area is the area contained within lines drawn between NS 2800 3450 to NS 3200 3450 and NS 3200 3450 to NS 3200 3200 and NS 3200 3200 to NS 3079 3188 and NS 3079 3188 to NS 2800 3100 and NS 2800 3100 to NS 2800 3450.

Representative Monitoring Zone

Due to the nature of the fishery, it is recommended that a representative monitoring zone be established that will allow sufficient scope for collection of samples within the zone.

The recommended sampling zone is the area contained within lines drawn between NS 3160 3260 to NS 3200 3260 and NS 3200 3260 to NS 3200 3200 and NS 3200 3200 to NS 3160 3196 and NS 3160 3196 to NS 3160 3260. It is situated in the Southeast corner of the production area, near CSO and diffuse pollution sources.

The midpoint of the area from which a sample is gathered should be recorded to 10m accuracy and this location should be reported on the sample submission form.

Frequency

Due to the intermittent nature of some of the significant contamination sources sampling frequency should be at least monthly.

Depth of sampling

Sampling depth is not applicable in this case.

Tolerance

As a representative monitoring zone is recommended, no sampling tolerance is recommended. All samples should come from within the RMZ.

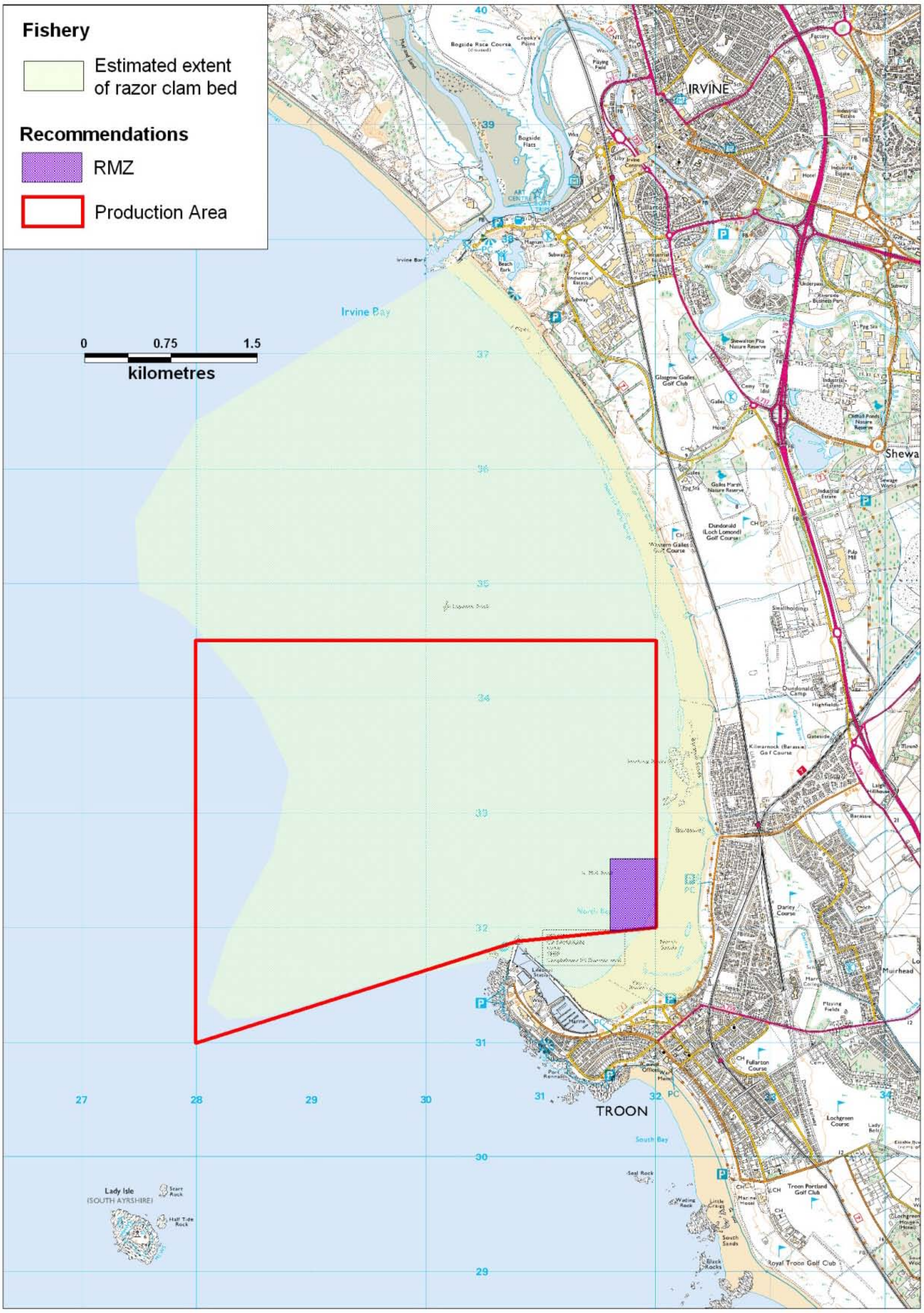

Figure 17.1 Map of recommendations at North Bay

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2. **General Information on Wildlife Impacts**
3. **Tables of Typical Faecal Bacteria Concentrations**
4. **Statistical Data**
5. **Hydrographic Methods**
6. **Shoreline Survey Report**

Geology and Soils Assessment Method

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and its potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

Both bacterial and viral pathogens affecting humans and livestock have been found in wild and captive seals. *Salmonella* and *Campylobacter* spp., some of which were antibiotic-resistant, were isolated from juvenile Northern elephant seals (*Mirounga angustirostris*) with *Salmonella* found in 36.9% of animals stranded on the California coast (Stoddard et al 2005). *Salmonella* and *Campylobacter* are both enteric pathogens that can cause acute illness in humans and it is postulated that the elephant seals were picking up resistant bacteria from exposure to human sewage waste.

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales. Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

References:

Alderisio, K.A. and N. DeLuca (1999). Seasonal enumeration of fecal coliform bacteria from the feces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

Bedard, J. and Gauthier, G. (1986) Assessment of faecal output in geese. *Journal of Applied Ecology*, 23:77-90.

Lisle, J.T., Smith, J.J., Edwards, D.D., andd McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal feces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	150	1.9×10^9

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical Data

One-way ANOVA: Log_EC versus Season

Source	DF	SS	MS	F	P
Season	3	1.182	0.394	0.68	0.570
Error	41	23.823	0.581		
Total	44	25.005			

S = 0.7623   R-Sq = 4.73%   R-Sq(adj) = 0.00%

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

<u>Background processes</u>
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

In sea lochs, mechanisms such as "wind rows" can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

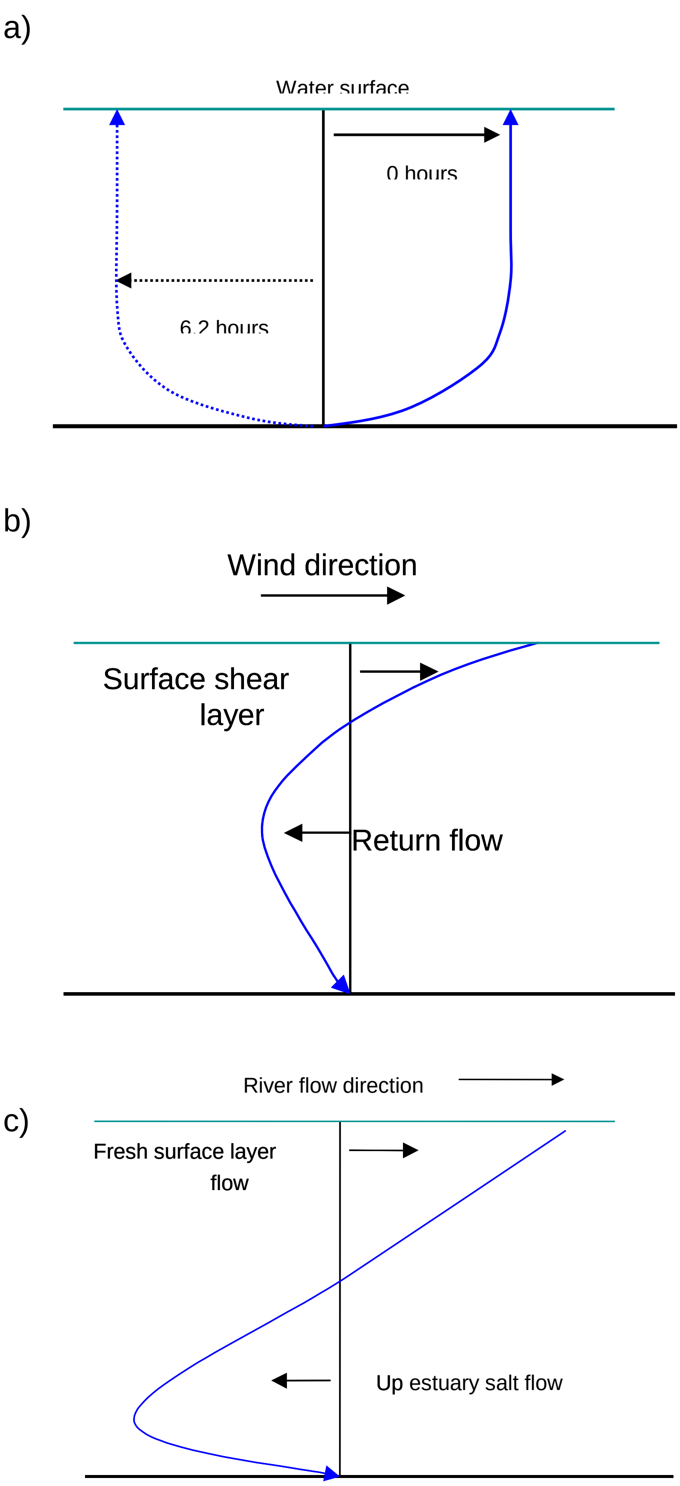

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

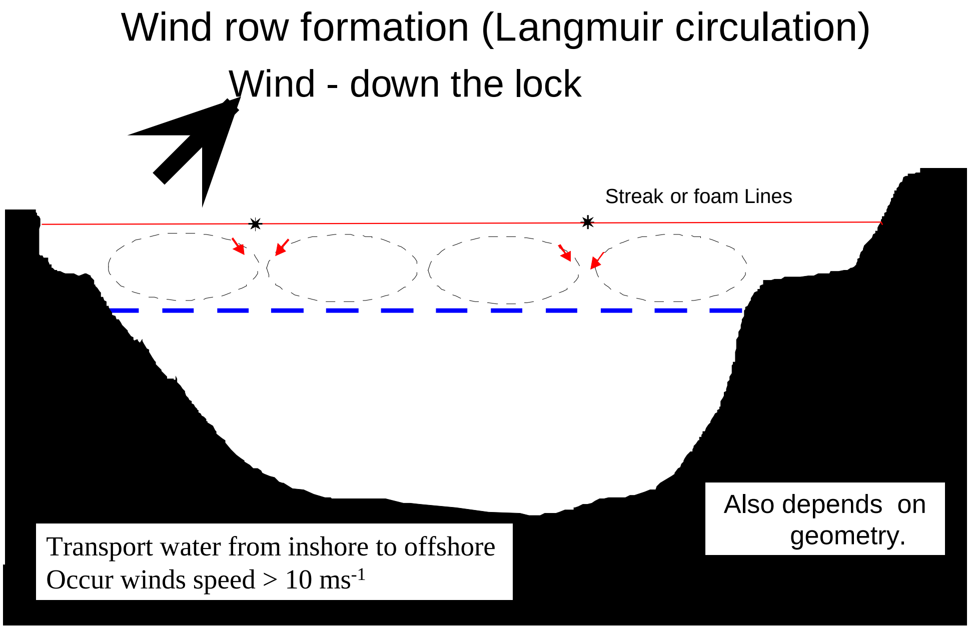

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

References

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

Glossary

The following technical terms may appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.

Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.

Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

Shoreline Survey Report

Production area:	North Bay
Site name:	Barassie
SIN:	SA 337 719 16
Species:	Razor clams
Harvester:	Alan Forbes & Jon Moore (Cumbrae Oysters Ltd)
Local Authority:	North Ayrshire Council and South Ayrshire Council
Status:	Existing site
Date Surveyed:	11/07/2011 & 12/07/2011
Surveyed by:	Jessica Larkham – Cefas William Murray – North Ayrshire Council Angela Patton – South Ayrshire Council
Existing RMP:	NS 319 334
Area Surveyed:	See Figure 1.

Weather observations

12/07/2011 – Dry, Sunny, 21˚C, 8 mph breeze
13/07/2011 – Dry, Sunny, 20˚C, 12 mph breeze

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 4 – 24.

Fishery

North Bay is currently fished for Razor clams (*Ensis* sp.). Natural razor clam beds are found in the sub tidal sandy beds between the areas of reef. The razors are hand dived and fished all year round.

Sewage/Faecal Sources

Human

The town of Troon is adjacent to North Bay and the town of Irvine is approximately 3 km north of the production area. The town of Prestwick is approximately 4 km south of Troon. Several outfall pipes were observed during the shoreline survey. On the west side of Troon a Scottish Water outfall pipe was observed leading down to the shoreline. The outfall pipe had mussel spat growing inside and around the edges and was not flowing on the day of the survey. A further four large outfall pipes were observed at the southern end of North Bay, one of which was flowing. The Barassie Sewage Pumping Station (SPS) Scottish Water treatment works and an outfall pipe leading into the sea were observed at the northern end of North Bay. Sanitary debris was found at the southern and northern end of North Bay, close to the sewage discharge outfalls. A Scottish Water outfall pipe and inspection cover was observed on the beach at Irvine to the north of North Bay. There are several golf courses adjacent to the bay and a caravan park south of Troon.

Livestock
No livestock were observed during the shoreline survey.

Seasonal Population
There are numerous hotels or B&B's in the area. The main attractions are camping, caravanning and sports and leisure, including golf. Tourists are attracted to the area all year round, but it is during the summer months that the caravan parks, hotels and B&B's are likely to reach full capacity.

Boats/Shipping
There is a yacht marina at Troon with 400 berths and facilities including restaurant, toilets and showers. Troon has a port with freight and ferry services including a P&O daily express service to Larne, Northern Ireland. There is also a ferry service from Troon to Campbeltown from April to September on selected days on a demand only basis.

Land Use
The majority of the land adjacent to North Bay is urban and developed with any land in-between being used for leisure purposes, such as golfing.

Wildlife/Birds
During the shoreline survey approximately 300 gulls, 8 oyster catchers and 2 mallard ducks were observed on the shoreline or in the water in close vicinity to the fishery.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the sound.

Figure 1. Shoreline Observations

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	11/07/2011	13:05	NS 31156 31167	231156	631167	Figure 4		Troon Marina with restaurant WC/Shower facilities. Est. 300 boats moored in marina.
2	11/07/2011	13:11	NS 31411 31047	231411	631047			Troon Cruising Club
3	11/07/2011	13:15	NS 31627 31166	231627	631166			P&O ferry terminal
4	11/07/2011	13:24	NS 31406 31309	231406	631309	Figure 5		Approx. 100 gulls, large number of live cockles and empty shells on the beach
5	11/07/2011	13:29	NS 31643 31301	231643	631301			Sanitary debris - sanitary towel
6	11/07/2011	13:31	NS 31790 31416	231790	631416			8 oyster catchers
7	11/07/2011	13:33	NS 31923 31376	231923	631376	Figure 6		Large outfall pipe, static water next to outfall
8	11/07/2011	13:39	NS 32096 31435	232096	631435			Sanitary debris - 3 x sanitary towels spread over 10 m^2 area
9	11/07/2011	13:40	NS 32159 31398	232159	631398	Figure 7		Large outfall pipe, closed end
10	11/07/2011	13:42	NS 32174 31404	232174	631404	Figures 8 & 9		Large outfall pipe, closed end, pool of still water with sewage fungus in it, bad odour
11	11/07/2011	13:45	NS 32228 31410	232228	631410	Figures 10 & 11		Large outfall pipe, flowing. Large quantity of orange fungus around outfall. Took sample following day
12	12/07/2011	13:48	NS 32252 31394	232252	631394	Figure 12		Disused iron pipe coming out from wall of main road
13	12/07/2011	13:59	NS 32393 31947	232393	631947	Figure 13		Stream with a dog in, flowing down from car park. Took sample following day
14	12/07/2011	14:14	NS 32542 32802	232542	632802	Figure 14		Barassie stream flowing under road, with a bridge. Took sample following day
15	12/07/2011	15:38	NS 30689 31290	230689	631290	Figure 15		Scottish Water discharge outfall pipe, no flow and spat growing inside and around pipe. Sea water sample taken off this point the following day
16	12/07/2011	09:26	NS 31461 32189	231461	632189		NBSW1, NBRazor1	Location of sea water sample NBSW1 and razor clam sample NBRazor1 (5 m depth) from southern end of the bay
17	12/07/2011	09:56	NS 31842 32806	231842	632806		NBSW2, NBRazor2	Location of sea water sample NBSW2 and razor clam sample NBRazor2 (4.5 m depth) from middle of the bay
18	12/07/2011	10:33	NS 31650 34424	231650	634424			2 mallard ducks

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
19	12/07/2011	10:41	NS 31712 34398	231712	634398		NBSW3, NBRazor3	Location of sea water sample NBSW3 and razor clam sample NBRazor3 (6 m depth) from northern end of the bay
20	12/07/2011	12:17	NS 30684 31243	230684	631243	Figure 15	NBSW4	Location of sea water sample NBSW4, taken from end of SW discharge outfall pipe, identified yesterday in observation no. 15
21	12/07/2011	12:38	NS 32228 31403	232228	631403	Figures 10 & 11	NBFW1	Location of contaminated fresh water sample NBFW1, taken from flowing SW discharge outfall pipe, identified yesterday in observation no. 11
22	12/07/2011	13:02	NS 32392 31950	232392	631950	Figure 13	NBFW2	Stream, W 2.36 m, D 0.12 m, F 0.119 m/s, S.D 0.002, Location of fresh water sample NBFW2. Approx 200 gulls on beach. Observation no. 13.
23	12/07/2011	13:59	NS 32535 33791	232535	633791	Figures 16 & 17		Scottish Water Barassie Sewage Pumping Station. Northern end of Troon Bay, outfall visible at low water (sea water sample collected on way back)
24	12/07/2011	14:03	NS 32524 33882	232524	633882	Figure 18	NBFW3	Stream, W 1.78 m, D 0.20 m, F 0.220 m/s, S.D 0.000, Location of fresh water sample NBFW3
25	12/07/2011	14:21	NS 32318 34730	232318	634730	Figure 19	NBFW4	Stream running through culvert, W 1.0 m, D 0.15 m, F 0.002 m/s, S.D 0.000, Location of fresh water sample NBFW4. Orange algae settled in water.
26	12/07/2011	14:29	NS 32297 34753	232297	634753			Sanitary debris - cotton bud
27	12/07/2011	14:36	NS 32173 35135	232173	635135	Figure 20	NBFW5	Stream running through culvert, W 1.01 m, D 0.05 m, F 0.203 m/s, S.D 0.015, Location of fresh water sample NBFW5
28	12/07/2011	14:51	NS 32032 34996	232032	634996		NBSW5	Location of sea water sample NBSW5, taken from the northern end of the bay
29	12/07/2011	15:12	NS 32290 33853	232290	633853	Figure 21	NBSW6	Location of sea water sample NBSW6, taken next to Scottish Water outfall pipe, leading from Barassie SPS treatment works identified in observation no. 23
30	12/07/2011	15:31	NS 32504 32836	232504	632836	Figure 14	NBFW6	Stream, W 2.0 m, D 0.06 m, F 0.128 m/s, S.D 0.000, Location of fresh water sample NBFW6. Observation no. 14
31	12/07/2011	16:13	NS 31569 39760	231569	639760	Figure 22	NBFW7	Irvine River, too large to measure flow, location of fresh water sample NBFW7

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
32	12/07/2011	16:31	NS 30375 37816	230375	637816	Figure 23		Inspection cover for Irvine Scottish Water discharge
33	12/07/2011	16:34	NS 30219 37741	230219	637741	Figure 24	NBSW7	Scottish Water discharge outfall pipe leading into sea, location of sea water sample NBSW7

Photographs referenced in the table can be found attached as Figures 4 – 24.

Sampling

Water and shellfish samples were collected at sites marked on the maps in Figures 2 and 3 respectively. Bacteriology results follow in Tables 2 and 3. Samples were transferred to a fridge over night and then collected and packed by the Glasgow Scientific Services courier service on the 12th & 13th July for *E. coli* analysis. Samples were received by the laboratory on the same day as shipping. The box temperatures on arrival varied 8.4˚C, which was outside the recommended temperature range of 2-8˚C. The National Reference Laboratory (NRL) undertook a study on the effect of temperature and time of storage on levels of *E. coli* in shellfish and found no significant effect with up to 48 hours' storage at temperatures ≤10˚C.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. Note that this is equivalent to ppt.

Table 2. Water sample *E. coli* results

No.	Sample Ref.	Date	Position	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
1	NBFW1	12/07/2011	NS 32228 31403	Freshwater	<1000	
2	NBFW2	12/07/2011	NS 32392 31950	Freshwater	31000	
3	NBFW3	12/07/2011	NS 32524 33882	Freshwater	200	
4	NBFW4	12/07/2011	NS 32318 34730	Freshwater	<100	
5	NBFW5	12/07/2011	NS 32173 35135	Freshwater	50000	
6	NBFW6	12/07/2011	NS 32504 32836	Freshwater	4100	
7	NBFW7	12/07/2011	NS 31569 39760	Freshwater	600	
8	NBSW1	12/07/2011	NS 31461 32189	Seawater	0	33.1
9	NBSW2	12/07/2011	NS 31842 32806	Seawater	1	33.1
10	NBSW3	12/07/2011	NS 31712 34398	Seawater	18	33.2
11	NBSW4	12/07/2011	NS 30684 31243	Seawater	0	32.9
12	NBSW5	12/07/2011	NS 32032 34996	Seawater	0	33.2
13	NBSW6	12/07/2011	NS 32290 33853	Seawater	12	33.2
14	NBSW7	12/07/2011	NS 30219 37741	Seawater	10	32.9

Table 3. Shellfish sample *E. coli* results

No.	Sample Ref.	Date	Position	Site	Species	Depth (m)	*E. coli* MPN/100 g
1	NBRazor 1	12/07/2011	NS 31461 32189	North Bay	Razor clam	5	230
2	NBRazor 2	12/07/2011	NS 31842 32806	North Bay	Razor clam	4.5	130
3	NBRazor 3	12/07/2011	NS 31712 34398	North Bay	Razor clam	6	50

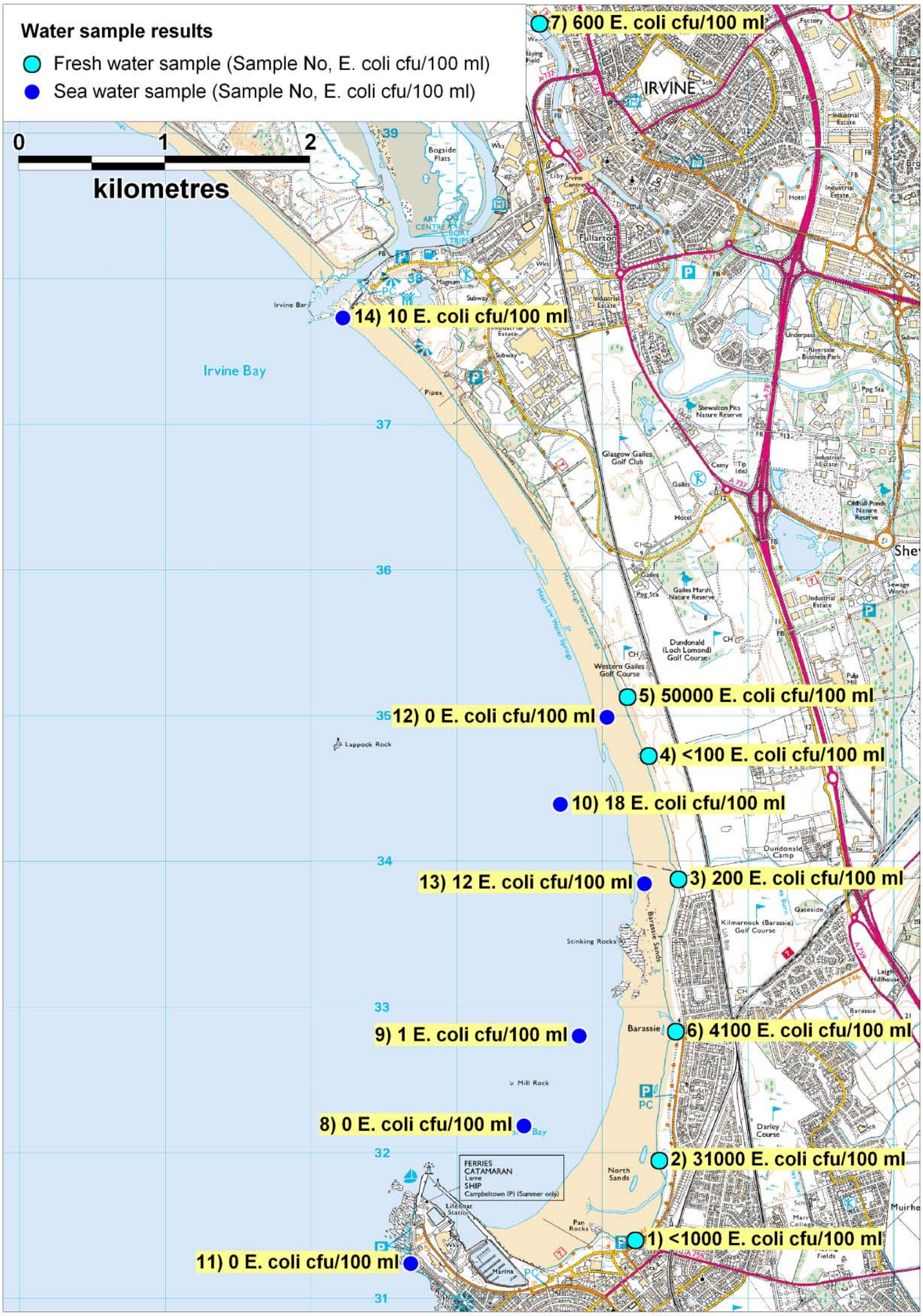

Figure 2. Water sample results

Figure 3. Shellfish sample results

Photographs

Figure 4. Troon Marina

Figure 5. Live cockles and empty shells on North Bay beach

Figure 6. Large outfall pipe, static water next to outfall

Figure 7. Large outfall pipe

Figure 8. Large outfall pipe pool of still water with sewage fungus in next to it

Figure 9. Pool of still water with sewage fungus next to a SW outfall

Figure 10. Large outfall pipe, flowing. Orange growth around the outfall, location of fresh water sample NBFW1

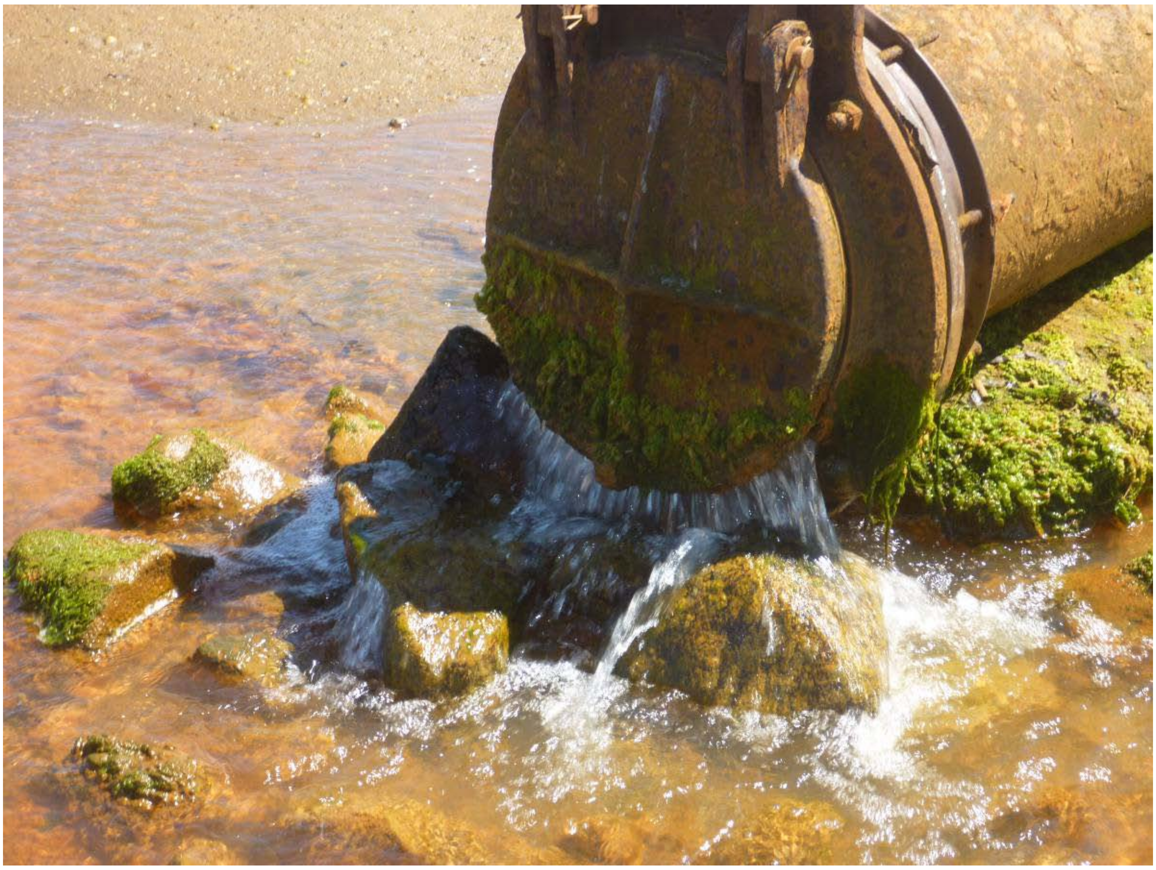

Figure 11. Large outfall pipe, flowing, location of fresh water sample NBFW1 (close up view of pipe in Figure 10).

Figure 12. Disused iron pipe coming out of the wall of the main road

Figure 13. Stream, location of fresh water sample NBFW2

Figure 14. Barassie stream, location of fresh water sample NBFW6

Figure 15. Scottish Water discharge outfall pipe, with spat growing in end of pipe, location of sea water sample NBSW4

Figure 16. Scottish Water Barassie Sewage Pumping Station


Figure 17. Scottish Water Barassie Sewage Pumping Station

Figure 18. Stream, location of fresh water sample NBFW3

Figure 19. Stream running through culvert, location of fresh water sample NBFW4

Figure 20. Stream running through culvert, location of fresh water sample NBFW5

Figure 21. Scottish Water outfall pipe, location of sea water sample NBSW6

Figure 22. Irvine River, location of fresh water sample NBFW7

Figure 23. Inspection cover of Scottish Water discharge

Figure 24. Scottish Water outfall pipe, location of sea water sample NBSW7