Scottish Sanitary Survey Project

Sanitary Survey Report
Gruting Voe: Browland Voe and Gruting Voe: Quilse
SI 081 and SI 083
April 2009

Cefas

FOOD STANDARDS AGENCY
SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Gruting Voe: Browland Voe and Gruting Voe: Quilse

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

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1. General Description

Gruting Voe is located on the eastern coastline of the Shetland Isles. Gruting Voe is sheltered behind Vaila Sound and the island of Linga. The main voe, which is roughly 2.5 km in length and 1 km wide, splits into three smaller channels. In the main part of the voe the depth varies from 0 – 50 m, whilst in the smaller channels the depth ranges from 0 – 20 m.

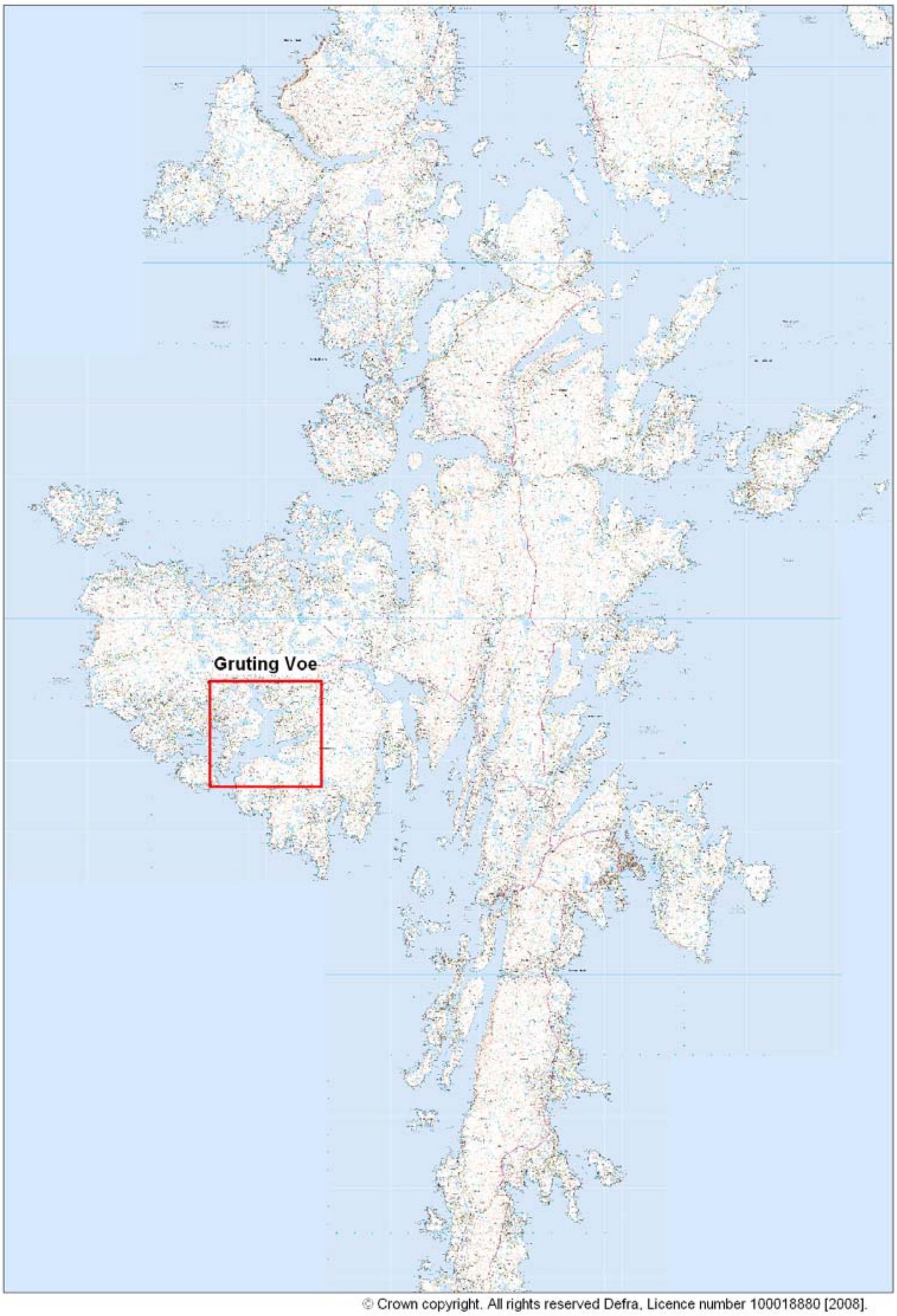


Figure 1.1 Location of Gruting Voe, Shetland

2. Fishery

The fishery at Gruting Voe is composed of two long line mussel (*Mytilus* sp.) farms as listed in Table 1 below:

Table 1. Gruting Voe shellfish farms

Site	SIN	Species
Gruting Voe: Browland Voe	SI 081 425	Common mussels
Gruting Voe: Quilse	SI 083 427	Common mussels

There are two adjacent production areas within the survey area. The Gruting Voe: Browland Voe current production area is bounded by lines drawn between HU 2690 4940 to HU 2750 4940 and HU 2643 5106 to HU 2619 5100. The Gruting Voe: Quilse current production area is bounded by lines drawn between HU 2645 4820 to HU 2747 4820 and HU 2750 4940 to HU 2690 4940.

The nominal Representative Monitoring Point (RMP) grid reference for Gruting Voe: Browland Voe is HU 268 508 and for Gruting Voe: Quilse is HU 267 485. Neither falls within the actual fisheries or Crown Estates lease areas.

The Gruting Voe: Browland Voe site consists of two large blocks of rope grown mussels in close proximity. The larger block, to the south consists of seven 440 m lines with 7 m droppers. The smaller block to the north consists of five 220 m lines with 5 m droppers. Stock of a range of sizes was present at the time of the shoreline survey, including stock of a harvestable size.

The Gruting Voe: Quilse site consists of one block of five 220 m long lines, with 12 m droppers. Stock of a range of sizes was present at the time of the shoreline survey, including stock of a harvestable size.

Both sites are harvested year round, with timing of harvesting depending on demand, biotoxin status, and the status of other sites under the same ownership.

There are some differences in the seabed lease/permit areas reported by the Crown Estate and SIC, so both are included here for reference. There is a further small, unoccupied lease within the Gruting Voe: Browland Voe production area at Scutta Voe and a larger, unoccupied lease area identified by Shetland Islands Council (SIC) in the northern half of the Gruting Voe: Quilse production area.

Figure 2.1 shows the relative positions of the shellfisheries, Food Standard Agency Scotland designated production area, seabed lease areas, and RMPs.

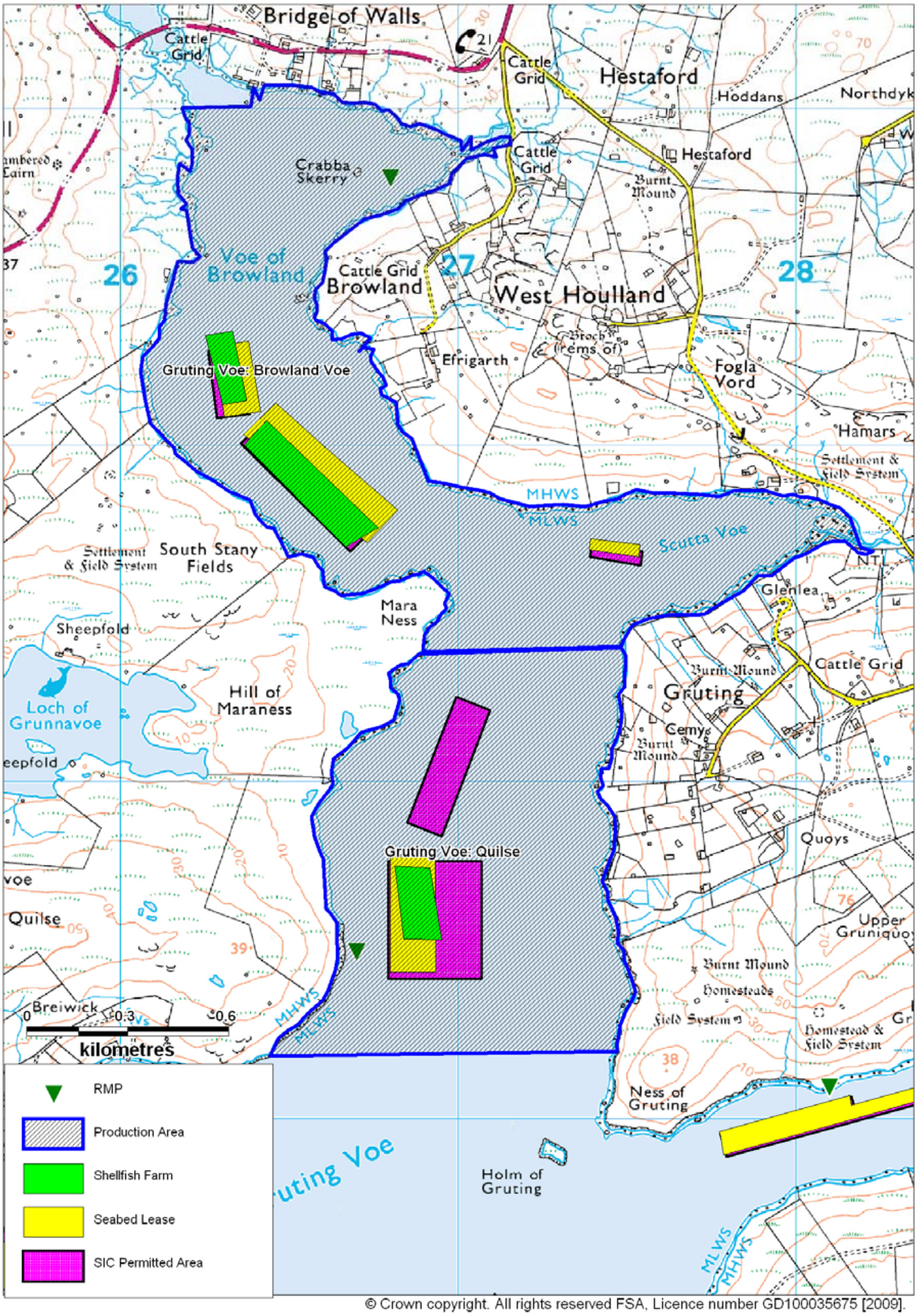


Figure 2.1 Gruting Voe Fishery

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Gruting Voe.

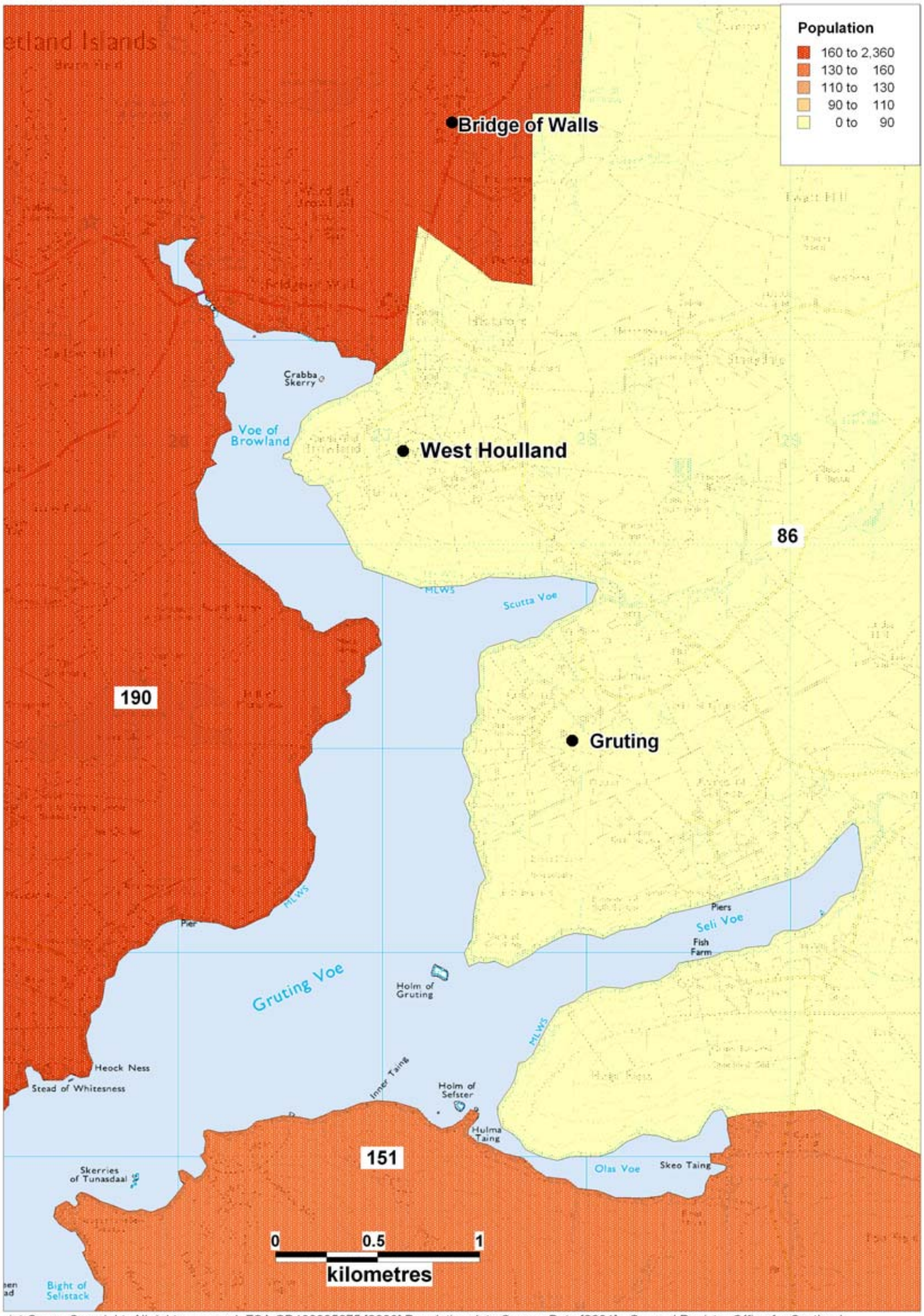


Figure 3.1 Population of Gruting Voe

The population for the three census output areas bordering immediately on Gruting Voe are:

60RD000029	190
60RD000030	86
60RD000031	151
Total	427

The settlements of the Bridge of Walls, West Houlland and Gruting are located on the eastern coastline of Gruting Voe. There are no settlements on the western coastline of Gruting Voe. The majority of the population is therefore concentrated along the eastern coastline and any associated faecal pollution from human sources is also likely to be concentrated in this area.

4. Sewage Discharges

There are no community septic tanks and/or sewage discharges identified by Scottish Water for the area surrounding Gruting Voe. There is no mains sewerage in the area.

A discharge consent was provided by SEPA for the only registered septic tank in the area. It is detailed in Table 4.1 and mapped in Figure 4.1.

Table 4.1 Discharge consent issued by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented/ design PE
CAR/R/1025329	HU 2792 4989	Domestic	Septic tank	-	5

A number of septic tanks and/or outfalls were recorded during the shoreline survey. Their locations have been included in the mapped discharges in Figure 4.1. Observed septic tanks, covers and/or discharge pipes are listed in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline survey

No.	Date	Grid Reference	Observation
1	04-JUN-08	HU 26413 51046	150mm orange plastic sewage pipe to underwater
2	04-JUN-08	HU 26469 51057	Septic tank, no apparent overflow
3	04-JUN-08	HU 26518 51055	110mm metal sewer pipe to underwater
4	04-JUN-08	HU 27920 49858	Concrete casing for sewer pipe to underwater

There is little in the way of sewage input to the production areas. Septic discharges were only noted in two areas where houses were close to the shore. At Bridge of Walls, two small private discharges to Gruting Voe and one septic tank with no apparent overflow were recorded. At the head of Scutta Voe a septic discharge from the village hall was found. This was the same discharge to which SEPA consent CAR/R/1025329 applies. These three discharges are likely to equate to a population equivalent of 15 or less on average, although it is possible that larger numbers of people may be present at the village hall from time to time.

Where buildings are further back from the shoreline, it is likely that any waste water overflows from their septic tanks discharge to soakaway. The impacts of these on water quality in the production area, if any, will be considerably less than for any septic tank overflows discharging directly to the production areas.

A few of the dwellings may be holiday homes, but there are no specific tourist attractions in the area so no large inundations of visitors are expected during the summer months.

No boats were seen during the course of the shoreline survey, and it is likely that boat traffic in the area is very light. A small marina is proposed near the head of Scutta Voe, but this is still at the planning stage.

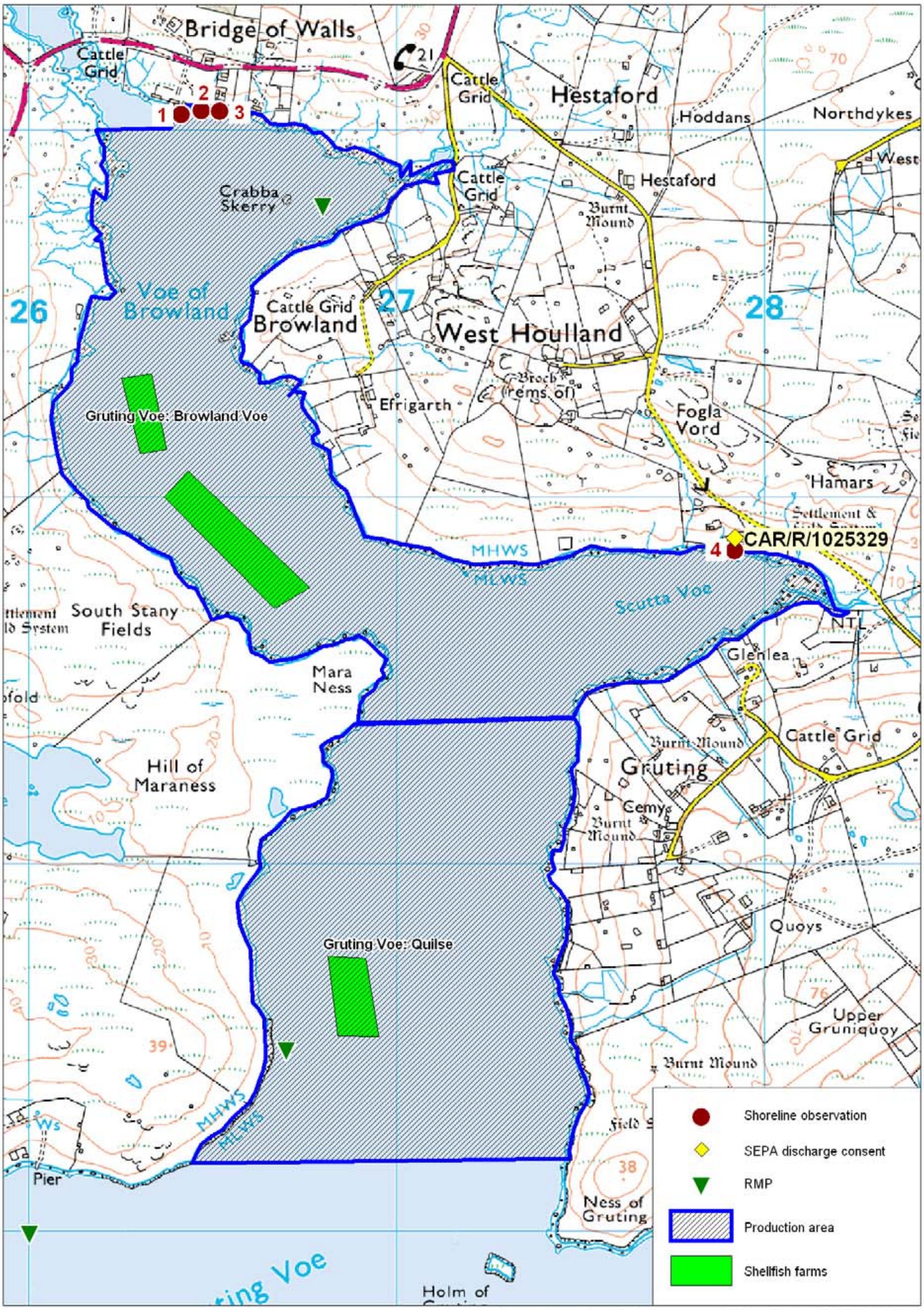


Figure 4.1 Sewage discharges at Gruting Voe

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. 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.

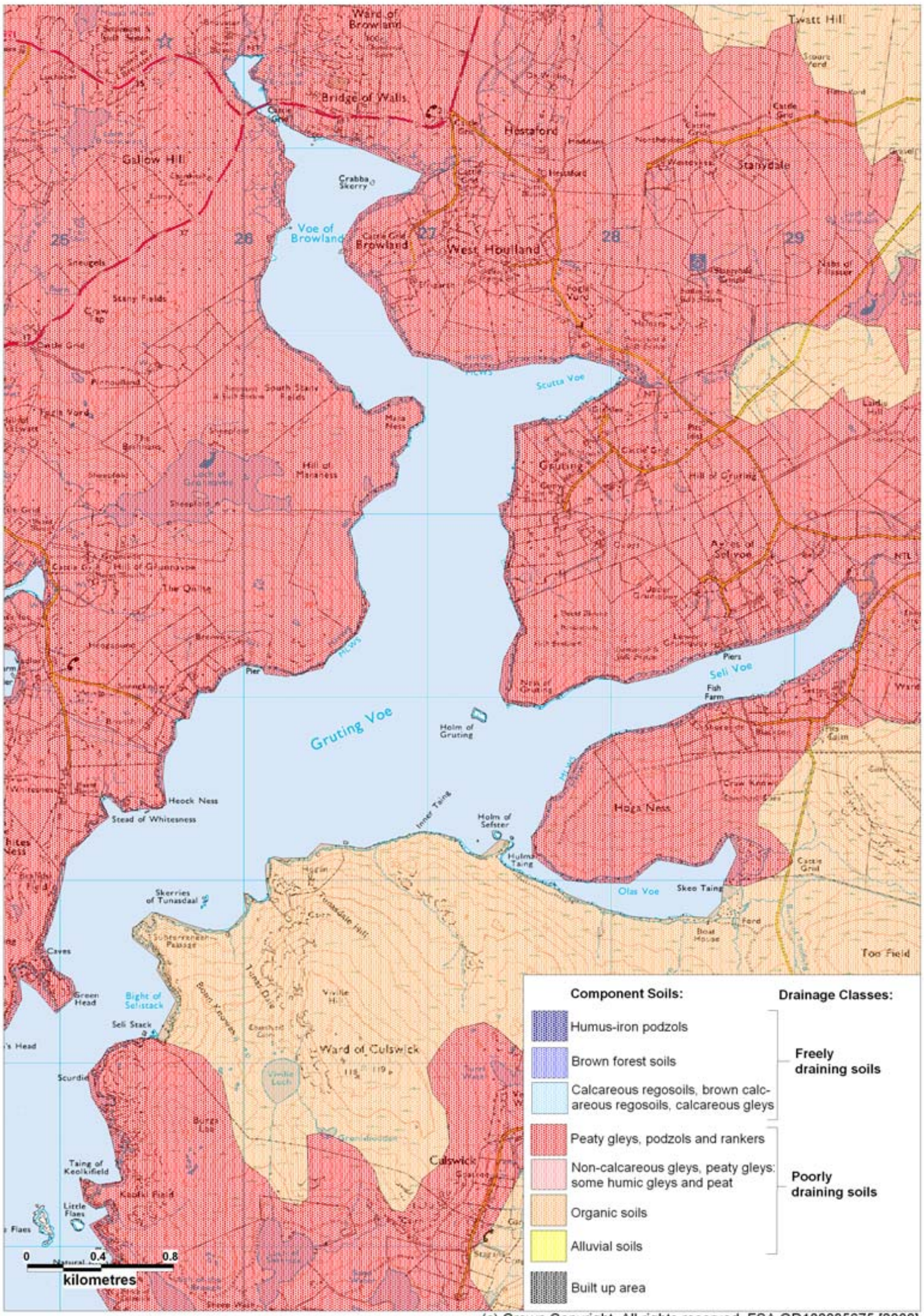


Figure 5.1 Component soils and drainage classes for Gruting Voe

Two types of component soils are predominant in this area. The most dominant is composed primarily of peaty gleys, podzols and rankers. This soil type covers the majority of the coastline of Gruting Voe apart from an area of organis soils along part of the southeastern coastline extending inland. Both soil types are classed as poorly draining, therefore the potential for runoff contaminated with *E. coli* from human and/or animal waste is high along the coastline of Gruting Voe.

6. Land Cover

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

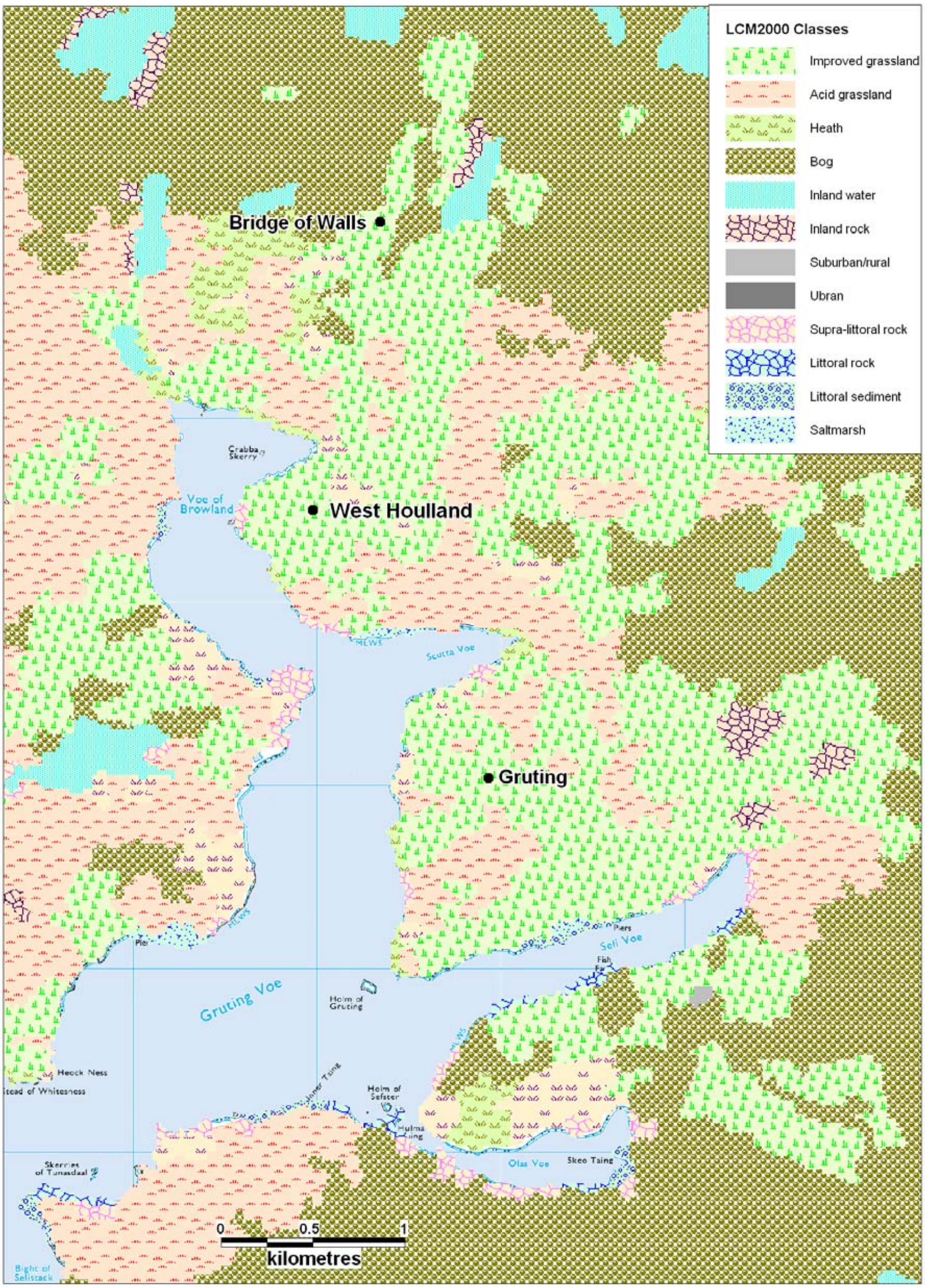


Figure 6.1 LCM2000 class land cover data for Gruting Voe

There are two main types of land cover for the coastline surrounding Gruting Voe, including improved grassland and acid grassland. Improved grassland dominates much of the eastern coastline, whereas acid grassland dominates much of the western coastline. On the eastern coastline further inland there are also large areas of bog and smaller patches of inland and supra-littoral rock. On the western coastline there are also small patches of bog, open heath and supra-littoral rock. Although not identified by the LCM2000 class data, there are three areas of suburban/rural land located at the settlements of Bridge of Walls, West Houlland and Gruting.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^{9} cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^{8} cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^{8} cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

Therefore, the overall potential for contaminated runoff based on land cover types may be slightly higher along the eastern coastline, and would be expected to increase significantly in all areas following heavy rain.

7. Farm Animals

Agricultural census data was received from the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for Sandsting and Walls parishes., which both border on the Gruting Voe production areas. The Sandsting parish covers an area of 73 km^2, and the Walls parish an area of 57 km^2. Recorded livestock populations for the parishes for 2008 are presented in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reported would have made it possible to discern individual farm data.

Table 7.1 Livestock numbers in Sandsting and Walls Parishes, 2008

	Sandsting (73 km^2)		Walls (57 km^2)	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	*	*
Total poultry	19	242	9	149
Total cattle	11	200	10	175
Total sheep	88	18170	62	14418
Horses and ponies	10	56	16	99

*Data withheld on confidentiality basis

Livestock kept within these parishes is predominantly sheep. Due to large area of the parishes, this data does not provide information on the livestock numbers in the area immediately surrounding the production areas. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 17th June 2008. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information should be treated with caution, as it applies only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain)..

The shoreline survey confirmed that agriculture in the area is dominated by sheep grazing. The most significant concentrations of livestock were sheep on the eastern coastline and around Scutta Voe. However, given than sheep are grazed over wide areas, it is unlikely that they would be limited to this area. Given that the local crofts are also located along the eastern coastline, it would be expected that during certain times of the year contamination may be higher along this coastline, where faecal bacteria from livestock will be carried into the production areas principally via land runoff.

Numbers of sheep will approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. Therefore higher impacts from livestock may to be expected during this period.

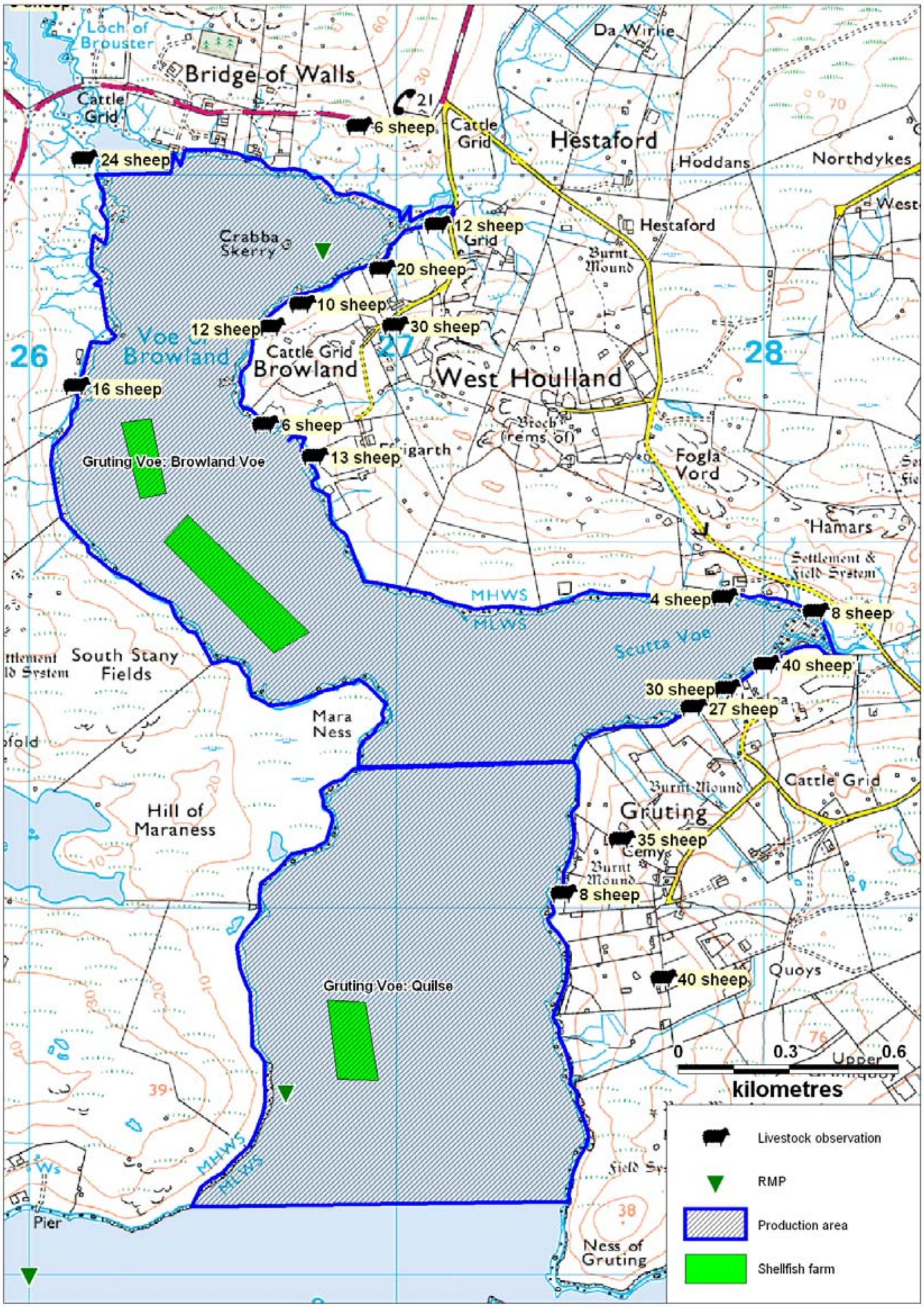


Figure 7.1 Shoreline survey livestock observations

8. Wildlife

Seals

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage. The Shetland-wide count in 2006 was 3021 harbour seals, though this was anticipated to be an underestimation of the total population (Sea Mammal Research Unit 2007). More detailed information from the previous count (2001) identified haulout sites for this species around the head of Gruting Voe.

Minimum grey seal pup production in Shetland was estimated as 943 in 2004. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, personal communication). No breeding colonies were reported for grey seals in Gruting Voe.

A group of seven seals were seen just off Browland during the shoreline survey, confirming that these animals are present in the area. Seals have been observed lying between mussel floats in other parts of Shetland (R. Anderson, personal communication) so it is anticipated that there could be some impact to the fisheries. However, as these animals are highly mobile, any impact to the shellfish farms is likely to be unpredictable in nature.

Whales and Dolphins

A variety of whales and dolphinsare routinely observed near Shetland. It is possible that cetaceans will be found from time to time in the area, although the larger species will not visit this area as it is fairly shallow and enclosed. Any impact of their presence is likely to be fleeting and unpredictable.

Seabirds

A number of seabird species breed in Shetland. These were the subject of a detailed census carried out in sections during the late spring of 1999, 2000, 2001 and 2002. Total counts of all species recorded within 5 km of the mussel lines are presented in Table 8.2. Where counts were of occupied sites/nests/territories, actual numbers of birds breeding in the area will be higher.

The seabird census indicated a high density of breeding seabirds in the general area, but no major aggregations were recorded on the shores of the production areas, with population limited to about 140 gulls spread around the shores and 170 terns, mainly located around the head of the voe. Though breeding occurs during the summer, after which some species disperse though others, such as gulls, remain in the area throughout the year.

Waterfowl

Waterfowl (ducks and geese) are present in Shetland at various times of the year. Eider ducks feed on mussel lines and are present in the Shetlands throughout the year, and a group of around 50 were disturbed from the Quilse site during the shoreline survey. Geese tend to pass through the Shetlands during migrations but do not linger in very large numbers as they do further south. No geese were seen during the shoreline survey.

Table 8.1 Seabird counts within 5 km of the site.

Common name	Species	Count	Qualifier
Northern Fulmar	*Fulmarus glacialis*	2828	Occupied sites
Arctic Tern	*Sterna paradisaea*	850	Individuals on land/Occupied nests
Black Guillemot	*Cepphus grylle*	531	Individuals on land
Common Guillemot	*Uria aalge*	405	Individuals on land
Common Gull	*Larus canus*	363	Individuals on land/Occupied territory/nests
Great Black-backed Gull	*Larus marinus*	220	Individuals on land/Occupied territory/nests
Black-headed Gull	*Larus ridibundus*	196	Individuals on land/Occupied territory
European Shag	*Phalacrocorax aristotelis*	167	Occupied nests
Kittiwake	*Rissa tridactyla*	98	Occupied nests
Herring Gull	*Larus argentatus*	73	Individuals on land/Occupied terrotory/nests
Arctic skua	*Stercorarius parasiticus*	51	Occupied territory
Great Skua	*Stercorarius skua*	48	Occupied territory
Atlantic Puffin	*Fratercula arctica*	44	Individuals on land
Razorbill	*Alca torda*	10	Individuals on land
Common Tern	*Sterna hirundo*	2	Individuals on land
Lesser Black-backed Gull	*Larus fuscus*	1	Occupied territory

Otters

There is a significant population of European Otters (*Lutra lutra*) present in Shetland, but none was seen during the shoreline survey. Overall densities of otters are low relative to livestock and seabirds, so it is unlikely that otter faeces will be a significant source of contamination to the fishery.

Summary

In summary, the main wildlife species potentially impacting on the production areas are seals and seabirds. However, as these animals are highly mobile, the impacts of these on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

9. Meteorological data

The nearest weather station is located at Lerwick, approximately 20 km to the south east of the production areas, for which uninterrupted rainfall data is available for 2003-2007 inclusive. It is likely that the rainfall patterns at Lerwick are similar but not identical to those on Gruting Voe and surrounding land due to their proximity, but it is not certain whether the local topography may result in differing wind patterns (Lerwick is on the east coast, Gruting Voe is on the west coast). This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Gruting Voe.

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 summarise the pattern of rainfall at Lerwick by year and by month respectively.

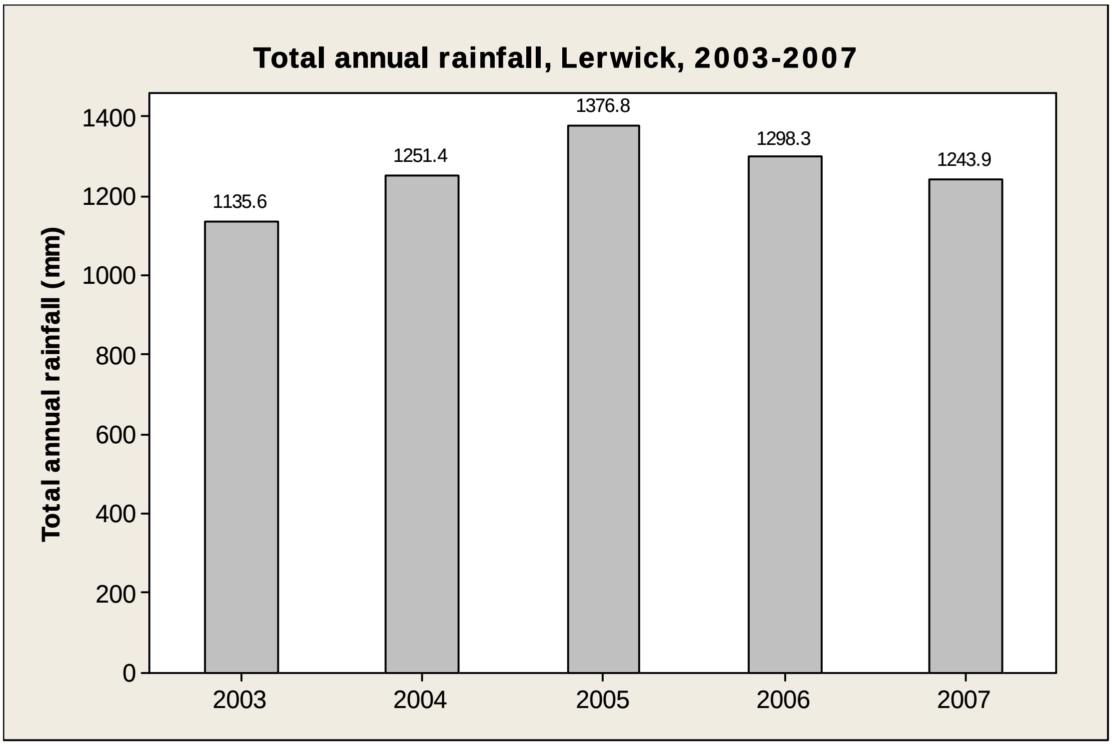


Figure 9.1 Annual rainfall at Lerwick 2003-2007

Figure 9.1 shows that 2005 was the wettest of these years, and 2003 was the driest. Inter-annual variation in rainfall was not nearly as great as monthly variation shown in Figure 9.2.

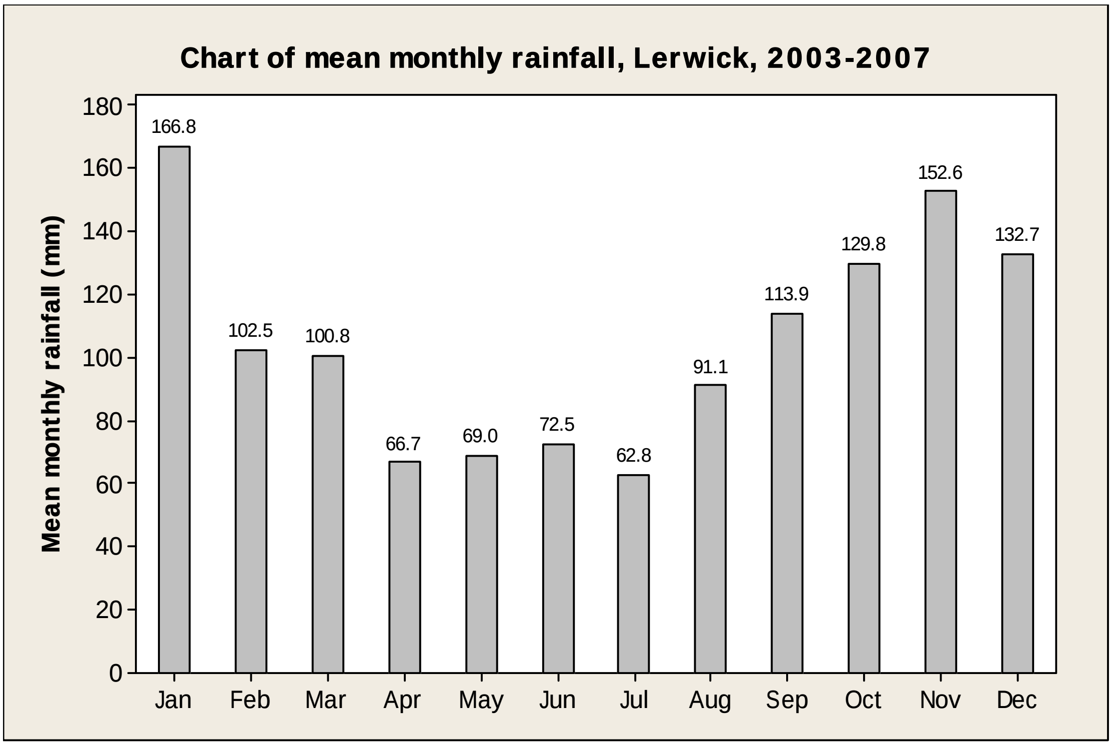


Figure 9.2 Mean monthly rainfall at Lerwick 2003-2007

The wettest months were October, November, December and January. For the period considered here (2003-2007) 44.6% of days experienced rainfall of 1 mm or less, and 9.4% of days experienced rainfall of 10mm or more.

A comparison of Lerwick rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.1 (Data from Met office website © Crown copyright). This indicates that rainfall in Lerwick was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Lerwick during the autumn, winter and spring.

Table 9.1 Comparison of Lerwick mean monthly rainfall with Scottish average 1970-2000.

Month	Scotland rainfall (mm)	Lerwick rainfall (mm)	Scotland - days of rainfall >= 1mm	Lerwick - days of rainfall >= 1mm
Jan	170.5	135.4	18.6	21.3
Feb	123.4	107.8	14.8	17.8
Mar	138.5	122.3	17.3	19
Apr	86.2	74.2	13	14.4
May	79	53.6	12.2	10.1
Jun	85.1	58.6	12.7	11.3
Jul	92.1	58.5	13.3	11
Aug	107.4	78.3	14.1	12.5
Sep	139.7	115.3	15.9	17.4
Oct	162.6	131.9	17.7	19.4
Nov	165.9	152.4	17.9	21.5
Dec	169.6	150	18.2	22.2
Whole year	1520.1	1238.1	185.8	197.9

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher during the autumn and winter months. As there are few dry days, it is likely that a steady flow contaminated of runoff from pastures is to be expected throughout the wetter months. It is possible that there is a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest which could either result in a heavily contaminated 'first flush' of runoff following a summer storm, or higher levels of contamination in runoff in the autumn at the onset of the wetter months.

9.2 Wind

Wind data collected at the Lerwick weather station is summarised by season and presented in figures 9.3 to 9.7.

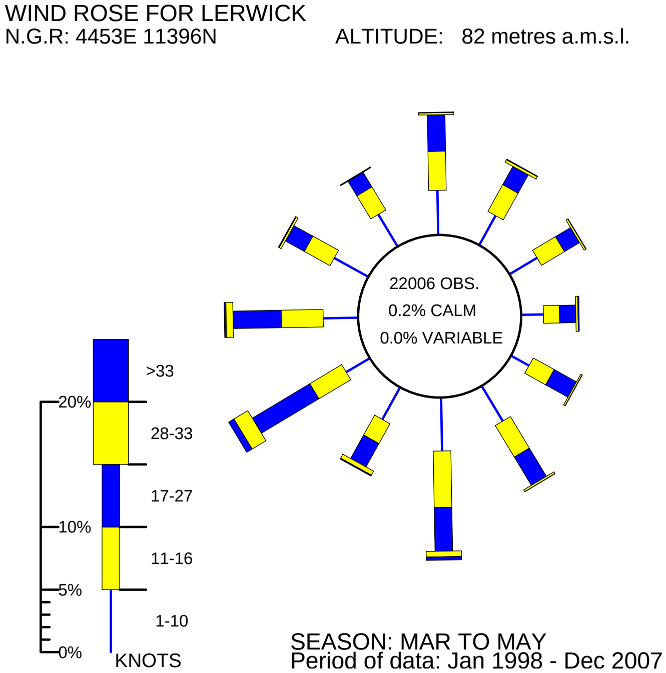


Figure 9.3 Wind rose for Lerwick (March to May)

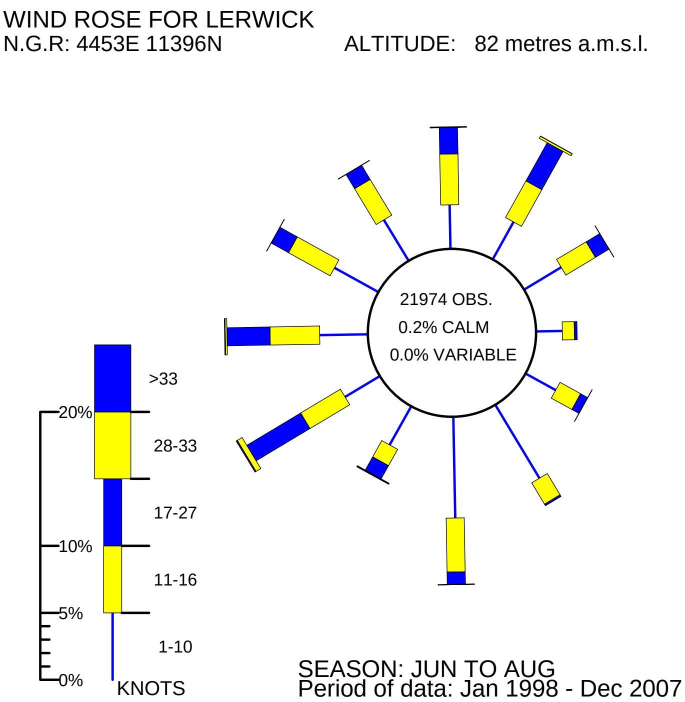


Figure 9.4 Wind rose for Lerwick (June to August)

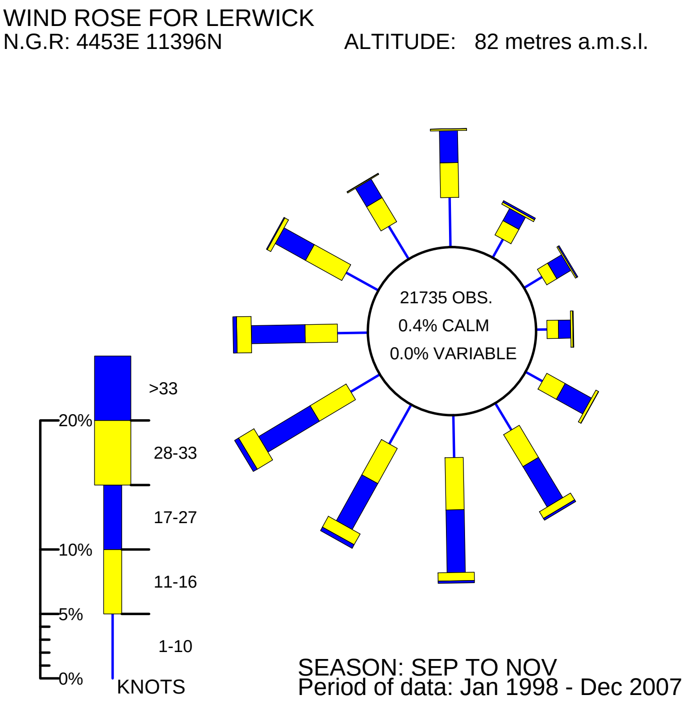


Figure 9.5 Wind rose for Lerwick (September to November)

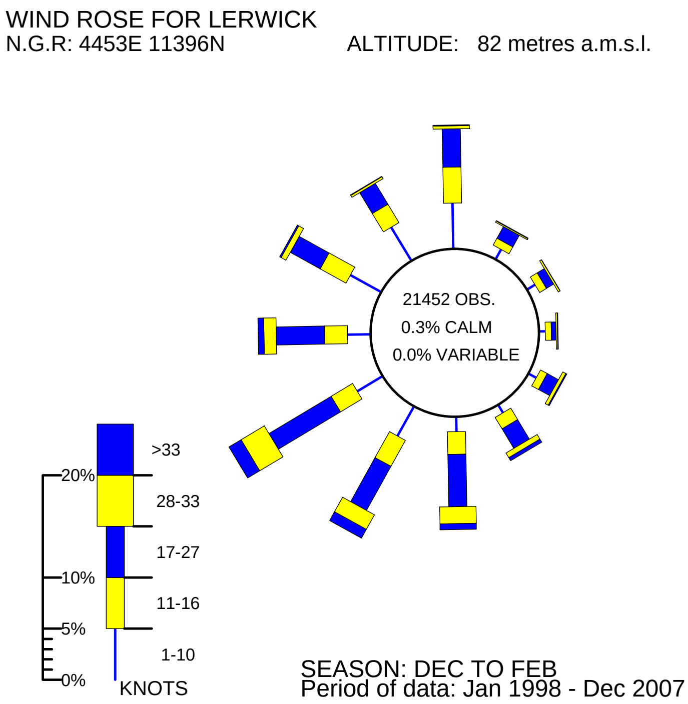


Figure 9.6 Wind rose for Lerwick (December to February)

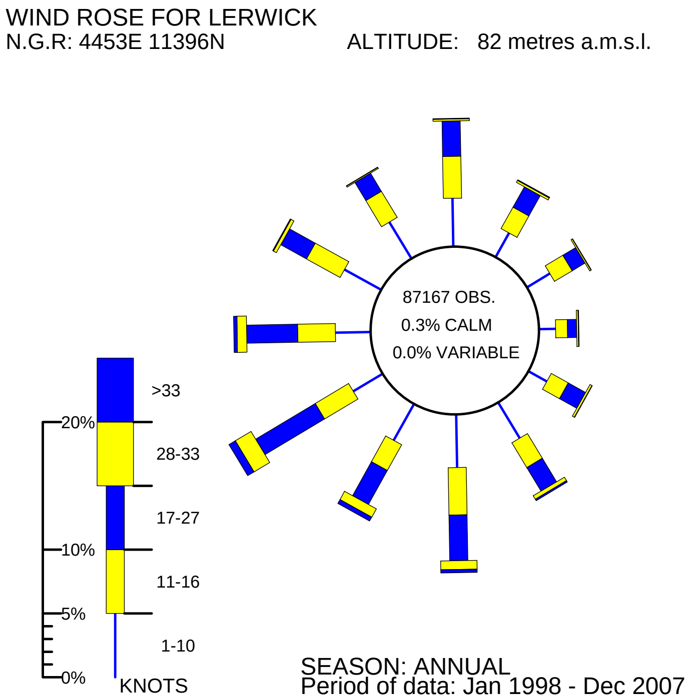


Figure 9.7 Wind rose for Lerwick (Annual)

Shetland is one of the more windy areas of Scotland with a much higher frequency of gales than the country as a whole. The wind roses show that the overall prevailing direction of the wind is from the south and west, and when it is blowing from these directions it is likely to be stronger than when blowing from other directions. Winds are generally lighter during the summer months and strongest in the winter.

Gruting Voe faces south, and is surrounded by low hills rising to over 100 m in places. The surrounding land may have the effect of channelling the wind up or down Gruting Voe.

A strong southerly wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, above the normal high water mark, into the production area.

Wind effects are likely to cause significant changes in water circulation within the voe as tidally influenced movements of water are relatively weak. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These surface water currents create return currents which may travel along the bottom or sides of the water body depending on bathymetry. Exact effects will be difficult to predict given the complex shape of the voe. In general, strong winds will increase the circulation of water and hence dilution of contamination from point sources within the voe. A strong northerly wind may have the effect of pushing any contamination originating from the settlement of Bridge of Walls towards the mussel lines in the Browland Voe production area. A strong easterly wind may carry any contamination originating from the point source in Scutta towards both production areas.

10. Current and historical classification status

Gruting Voe: Browland Voe and Gruting Voe: Quilse have both been classified since at least 2001. Prior to 2004, when Gruting Voe was split into its current boundaries, both areas were classified together. The classification histories are presented in Tables 10.1 and 10.2. Both areas have held split A/B seasonal classifications throughout their classification history, although the timing of the B months has differed slightly between the two areas since 2004. Months of B classification only occurred during the second half of the year, implying higher levels of contamination during this period. For Gruting Voe: Browland Voe the RMP lies 650 m away from the nearest mussel line, and for Gruting Voe: Quilse, the RMP lies 150 m away from the nearest mussel line. A map of the current production areas showing locations of the RMPs, mussel lines and Crown Estates leases is presented in Figure 10.1.

Table 10.1. Classification history, Gruting Voe: Browland Voe

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	B	B	B	B	B	B
2002	A	A	A	A	A	A	B	B	B	B	B	B
2003	A	A	A	A	A	A	A	B	B	A	A	A
2004	A	A	A	A	A	A	A	B	A	A	A	A
2005	A	A	A	A	A	A	A	B	A	A	A	A
2006	A	A	A	A	A	A	A	B	B	B	A	A
2007	A	A	A	A	A	A	A	B	B	B	B	A
2008	A	A	A	A	A	A	A	B	B	B	A	A
2009	A	A	A									

Table 10.2. Classification history, Gruting Voe: Quilse

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	B	B	B	B	B	B
2002	A	A	A	A	A	A	B	B	B	B	B	B
2003	A	A	A	A	A	A	A	B	B	A	A	A
2004	A	A	A	A	A	B	B	B	B	A	A	A
2005	A	A	A	A	A	A	B	A	A	A	A	A
2006	A	A	A	A	A	A	B	B	B	B	B	A
2007	A	A	A	A	A	B	B	B	B	B	B	A
2008	A	A	A	A	A	A	B	A	A	A	A	A
2009	A	A	A									

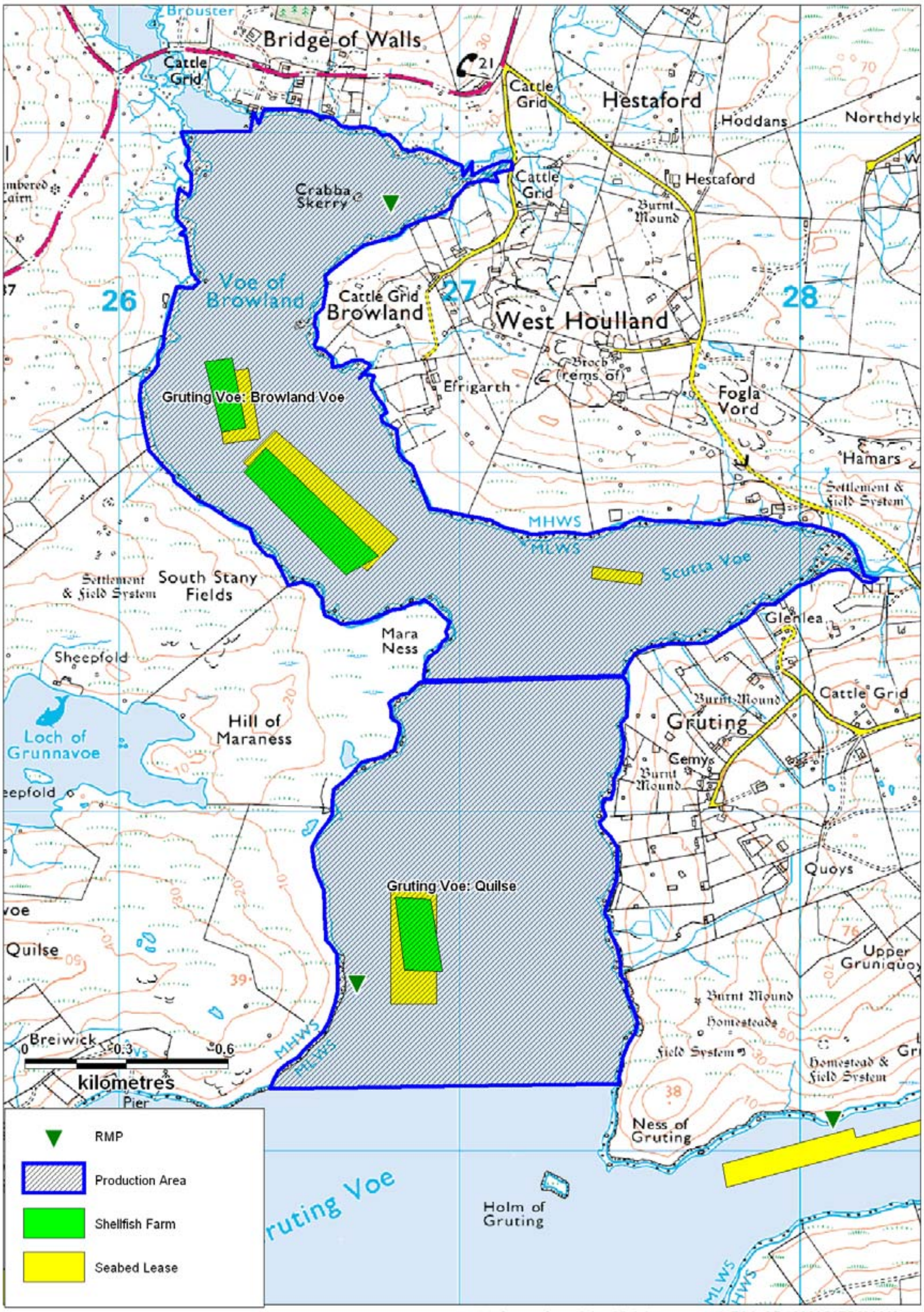


Figure 10.1 Current Gruting Voe production areas

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Gruting Voe: Browland Voe and Gruting Voe: Quilse from the beginning of 2002 up to the end of 2007 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

The reported sampling location of one sample collected from Gruting Voe: Quilse was HU 257476, which falls 950 m outside the production area in an adjacent production area, and as a consequence this sample was excluded from the analysis. 12 samples from Gruting Voe: Quilse were reported as being collected from HU 266485, which falls on land 40 m outside the production area. These 12 samples were included in the analysis, as they were within 100 m of the production area, the level of accuracy which can be expected when estimating a grid reference from an Ordnance Survey map.

18 samples from Gruting Voe: Quilse and 26 from Gruting Voe: Browland Voe 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 100 g of shellfish flesh and intravalvular fluid. All results were log transformed prior to carrying out statistical tests.

11.2 Summary of microbiological results by production area

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

Table 11.1 Summary of results from Gruting Voe: Quilse and Gruting Voe: Browland Voe

Sampling Summary								
Production area	Gruting Voe: Quilse	Gruting Voe: Quilse	Gruting Voe: Quilse	Gruting Voe: Quilse	Gruting Voe: Quilse	Gruting Voe: Browland Voe	Gruting Voe: Browland Voe	Gruting Voe: Browland Voe
Site	Quilse	Quilse	Quilse	Quilse	Quilse	Browland Voe	Browland Voe	Browland Voe
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI-83-427-8	SI-83-427-8	SI-83-427-8	SI-83-427-8	SI-83-427-8	SI-81-425-8	SI-81-425-8	SI-81-425-8
Location	All (4)	HU266483	HU266485	HU267485	HU268486	All (2)	HU263501	HU268508
Total no of samples	69	5	12	48	4	72	6	66
No. 2002	11	0	11	0	0	11	0	11
No. 2003	13	3	1	9	0	12	0	12
No. 2004	14	2	0	12	0	13	0	13
No. 2005	11	0	0	11	0	13	0	13
No. 2006	12	0	0	12	0	12	0	12
No. 2007	8	0	0	4	4	11	6	5
Results Summary								
Minimum	<20	<20	<20	<20	<20	<20	<20	<20
Maximum	2400	2400	1700	2400	160	9100	9100	5400
Median	50	70	60	45	25	20	45	20
Geometric mean	63.4	89.9	67.0	64.5	28.3	41.2	79.6	38.8
90 percentile	540		481	560		725		625
95 percentile	1730		1040	1400		1700		1600
No. exceeding 230/100g	14 (20%)		3 (25%)	10 (21%)		12 (17%)		11 (17%)
No. exceeding 1000/100g	5 (7%)		1 (8%)	3 (6%)		6 (8%)		5 (8%)
No. exceeding 4600/100g	0 (0%)		0 (0%)	0 (0%)		2 (3%)		1 (2%)
No. exceeding 18000/100g	0 (0%)		0 (0%)	0 (0%)		0 (0%)		0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling locations (with OS grid reference, site, number of samples and sampling dates).

Neither RMP coincides with the actual location of the mussel lines. For Gruting Voe: Quilse, the RMP is 140 m from the mussel lines, and for Gruting Voe: Browland Voe the RMP is 650 m from the mussel lines. For both areas, the majority of the samples were reported as collected from the RMP.

A comparison of sampling results from different locations within the production areas indicates no significant difference in result between sampled location within Gruting Voe: Browland Voe (One-way ANOVA, p=0.466, Appendix 6) or within Gruting Voe: Quilse (One-way ANOVA, p=0.745, Appendix 6).

A comparison of all results from the two production areas indicates there is no significant difference between them (T-test, T=-1.53, p=0.129, Appendix 6). On 52 occasions, both sites were sampled on the same day, and hence under the same environmental conditions, permitting a more robust comparison. No significant difference between sites was found when these results were compared (paired T-test, T=-1.74, p=0.089, Appendix 6). The overall geometric mean of results was highest for Gruting Voe: Quilse, but the only two results over 4600 *E. coli* MPN/100g both came from Gruting Voe: Browland Voe.

A total of 26 results of over 230 *E. coli* MPN/100g were reported from the two production areas. Proportions of these higher results occurring by production area are presented in Table 11.2

Table 11.2 Proportion of historic *E. coli* sampling result over 230 MPN/100g by production area

	Gruting Voe: Browland Voe	Gruting Voe: Quilse
No. results > 230 MPN/100g	12 (17%)	14 (20%)
No. results < 230 MPN/100g	60 (83%)	55 (80%)

No significant difference was found in the proportion of results over 230 *E. coli* MPN/100g between the production areas (Chi-Sq = 0.308, DF = 1, P-Value = 0.579, Appendix 6).

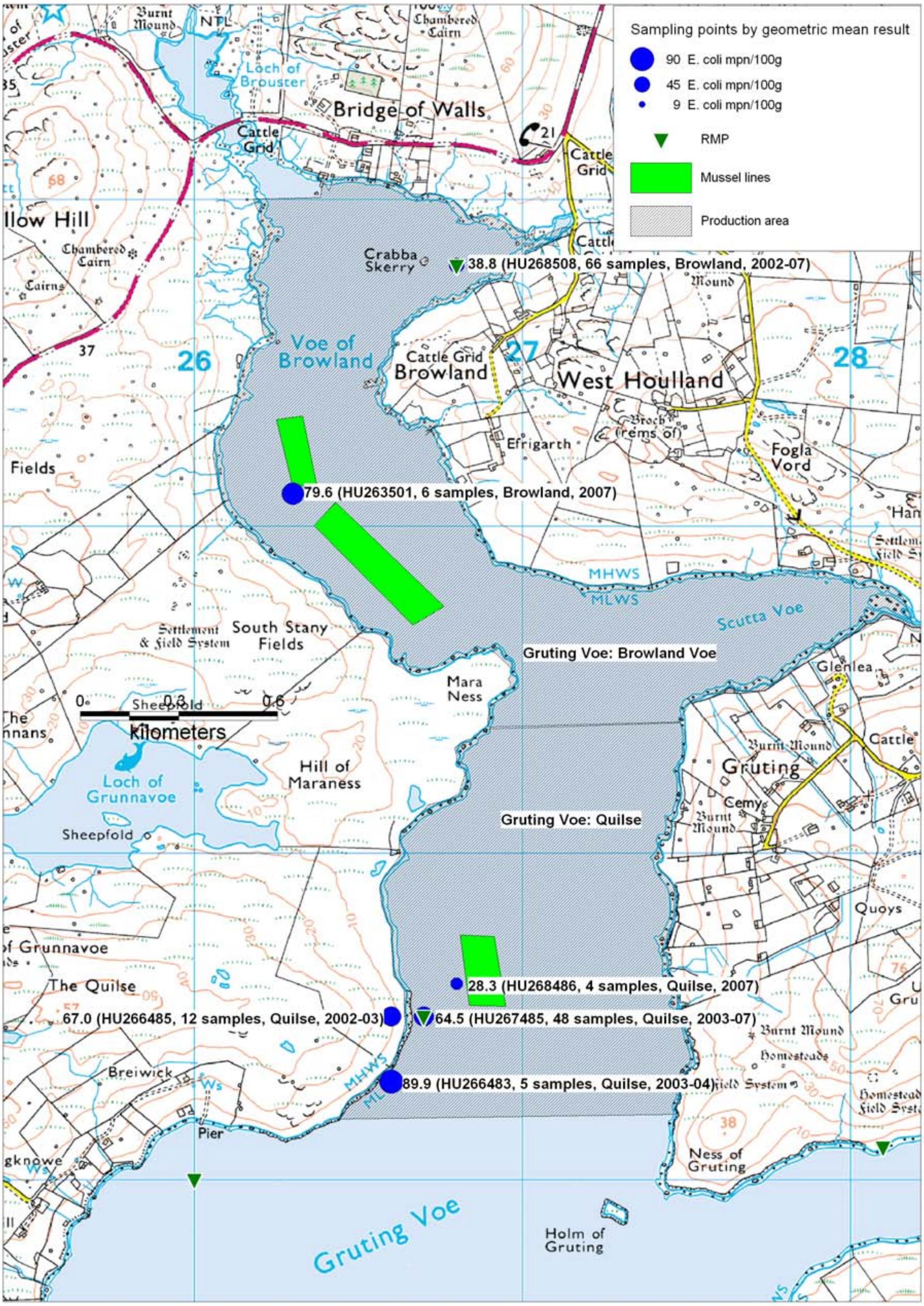


Figure 11.1 Sampling points and geometric mean *E. coli* results

11.4 Overall temporal pattern of results

Figures 11.2 and 11.3 present scatter plots of individual results against date for all mussel samples taken from Gruting Voe: Browland Voe and Gruting Voe: Quilse. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.2 is fitted with lines indicating the geometric mean of the previous 5 samples for each site, the current sample and the following 6 samples. Figure 11.3 is fitted with loess smoothers for each area, a regression based smoother line calculated by the Minitab statistical software.

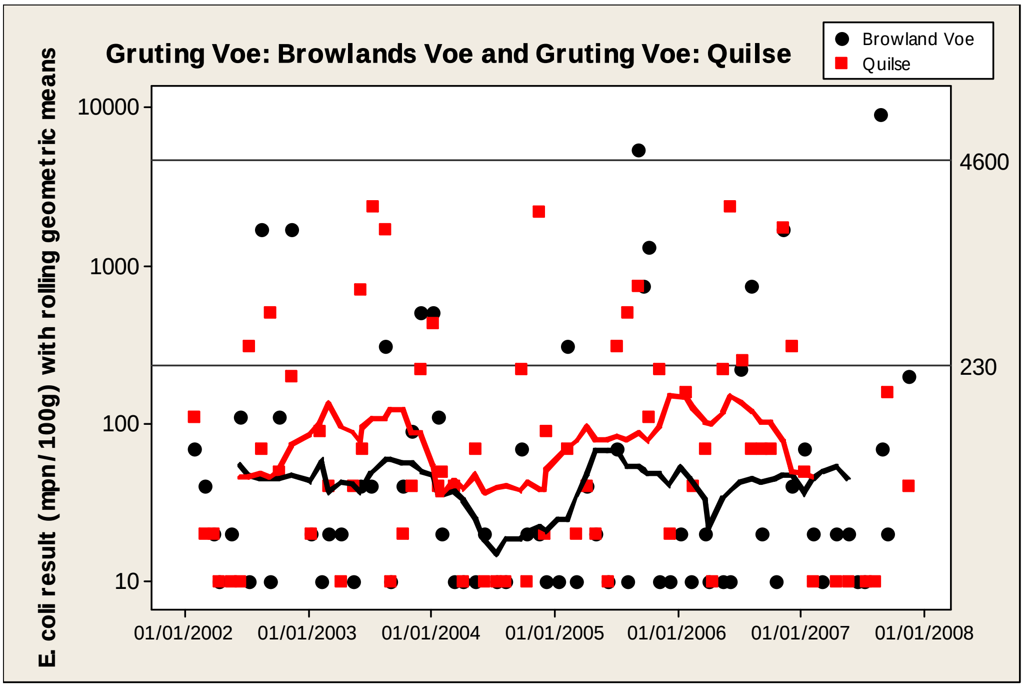


Figure 11.2 *E. coli* results by date with rolling geometric mean

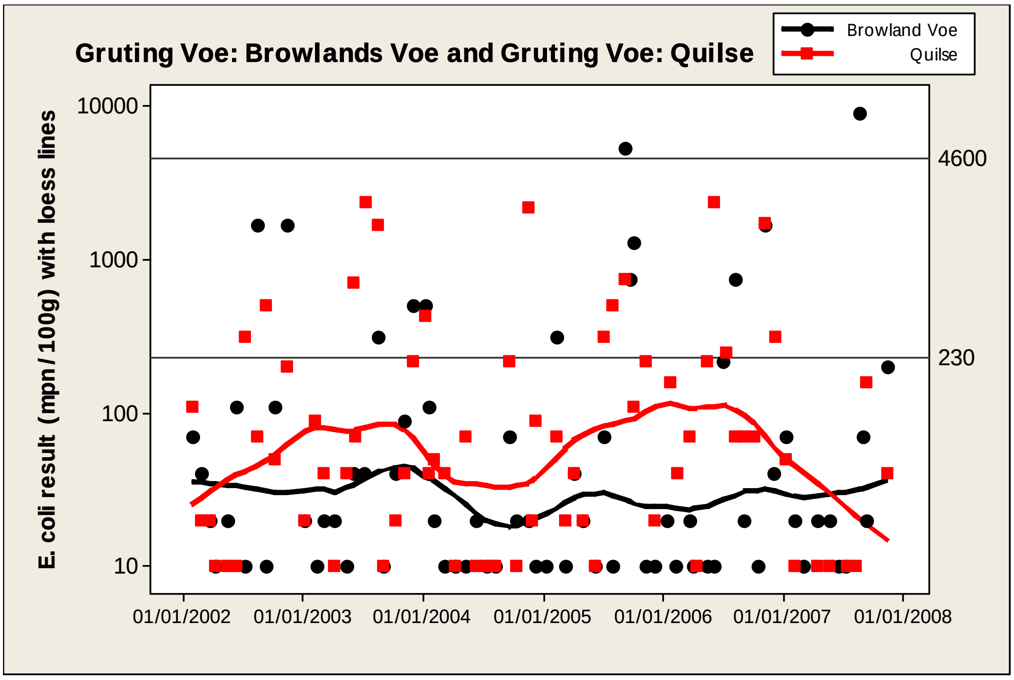


Figure 11.3 *E. coli* results by date with loess smoother

No obvious overall improvement or deterioration, or trends or cycles can be seen for either area in Figures 11.2 or 11.3.

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. Figures 11.4 and 11.5 present the geometric mean *E. coli* result by month (+ 2 times the standard error) for Gruting Voe: Quilse and Gruting Voe: Browland Voe respectively.

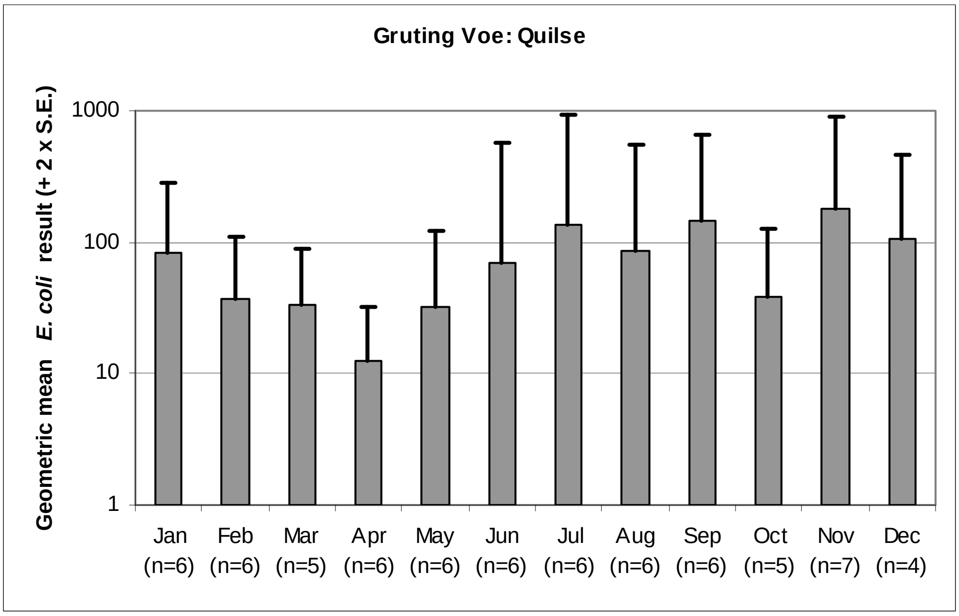


Figure 11.4 Geometric mean *E. coli* result by month (Gruting Voe: Quilse)

Higher mean results generally occurred from July to December, and lowest mean results occurred from February to May.

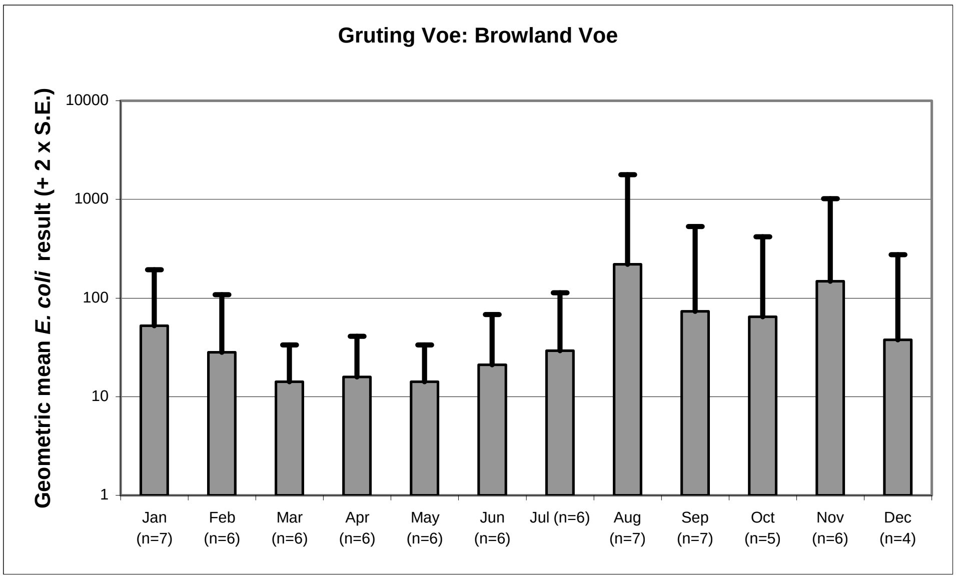


Figure 11.5 Geometric mean result *E. coli* by month (Gruting Voe: Browland Voe)

Higher mean results generally occurred from August to November, and lowest mean results occurred from March to May.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

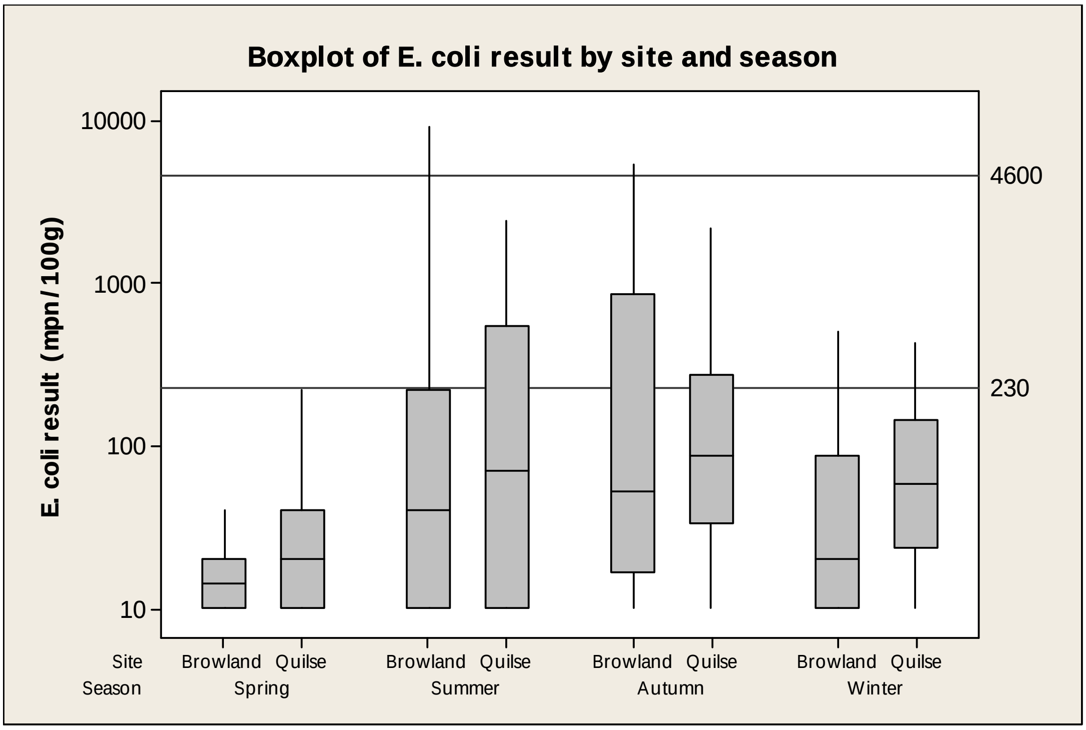


Figure 11.6 *E. coli* result by season

For Gruting Voe: Quilse, a significant difference was found between results by season (One-way ANOVA, p=0.020, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results for the summer and autumn were significantly higher than those in the spring. For Gruting Voe:

Browland Voe, a significant difference was also found between results by season (One-way ANOVA, p=0.012, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results for the autumn were significantly higher than those in the spring. The seasonal pattern of results was therefore similar for both production areas, although results were significantly higher in both the summer and autumn compared to the spring at Gruting Voe: Quilse, whereas results were significantly higher in the summer only compared to the spring at Gruting Voe: Browland Voe.

Table 11.3 Proportion of historic *E. coli* sampling result over 230 MPN/100g by season

	Spring	Summer	Autumn	Winter
No. results > 230 MPN/100g	0 (0%)	12 (32%)	9 (25%)	5 (17%)
No. results < 230 MPN/100g	35 (100%)	25 (68%)	27 (75%)	25 (83%)

A significant difference was found between the seasons in the proportion of results over 230 *E. coli* MPN/100g (Chi-Sq = 13.581, DF = 3, P-Value = 0.004, Appendix 6). More results over 230 occurred than expected in the summer and autumn, and less occurred than expected in spring and winter.

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 is Lerwick, approximately 20 km to the south east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). The coefficient of determination was calculated for *E. coli* results and rainfall in the previous 2 days at Lerwick. Figure 11.7 presents a scatterplot of *E. coli* results against rainfall for both production areas. Figure 11.8 presents a boxplot of results by previous 2 days rainfall quartile for both production areas (quartile 1 = 0 to 0.9 mm, quartile 2 = 0.9 to 4.2 mm, quartile 3 = 4.2 to 10.4 mm, quartile 4 = more than 10.4 mm).

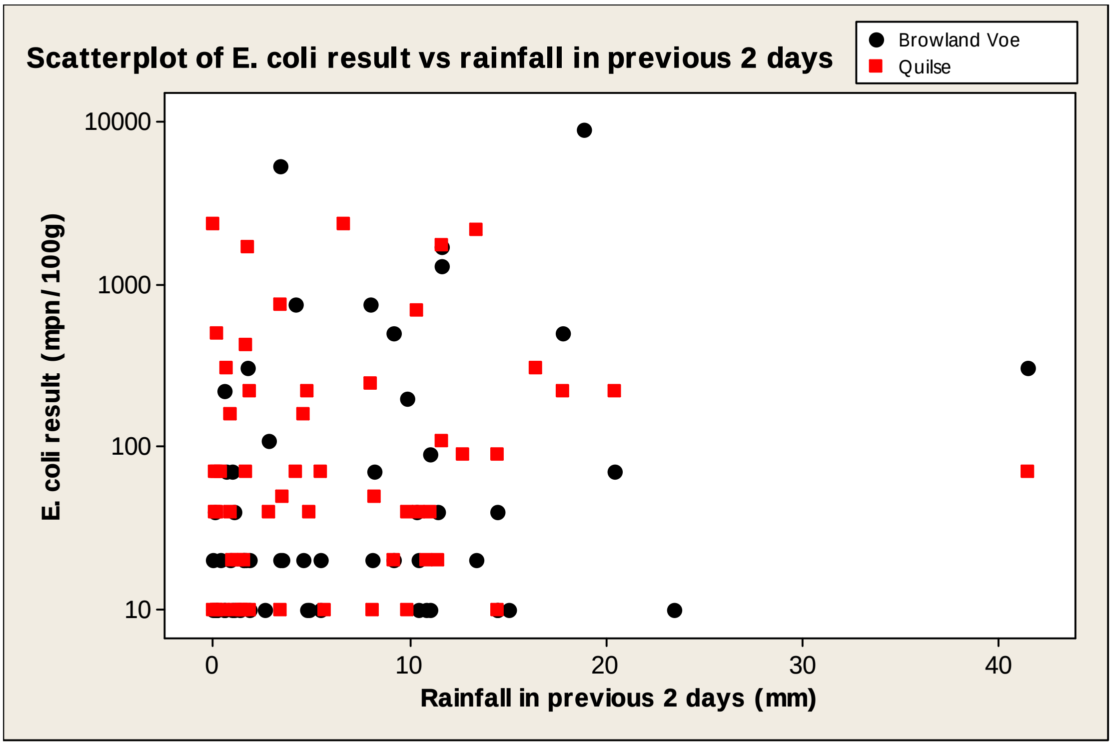


Figure 11.7 *E. coli* result against rainfall in previous 2 days

The coefficient of determination indicated that there was no relationship between the *E. coli* result and the rainfall in the previous two days for Gruting Voe: Quilse (Adjusted R-sq=0.6%, p=0.247, Appendix 6). For Gruting Voe: Browland Voe, the coefficient of determination indicates that there was an extremely weak positive relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=7.9%, p=0.016, Appendix 6).

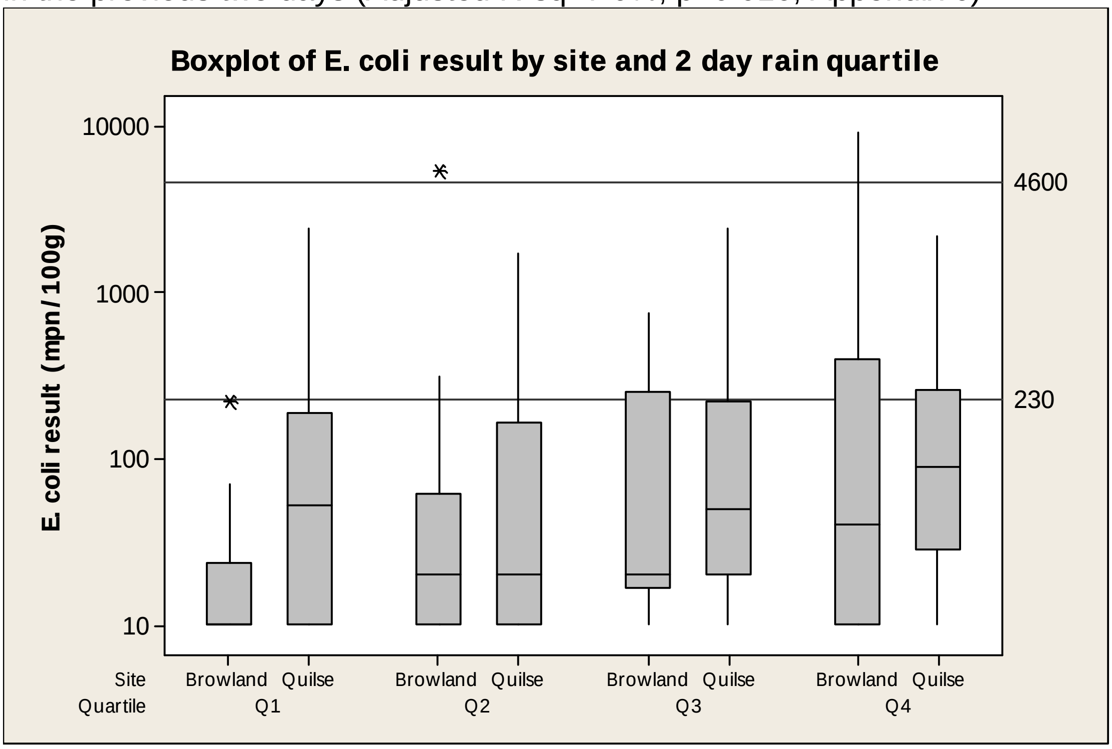


Figure 11.8 *E. coli* result by rainfall in previous 2 days quartile

No significant difference was found between the results for each 2-day rain quartile for either Gruting Voe: Quilse (One way ANOVA, p=0.469, Appendix 6) or for Gruting Voe: Browland Voe (One way ANOVA, p=0.212, Appendix 6).

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 for Gruting Voe was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 10.2 mm; quartile 2 = 10.2 to 20.4 mm; quartile 3 = 20.4 to 35.075 mm; quartile 4 = more than 35.075 mm.

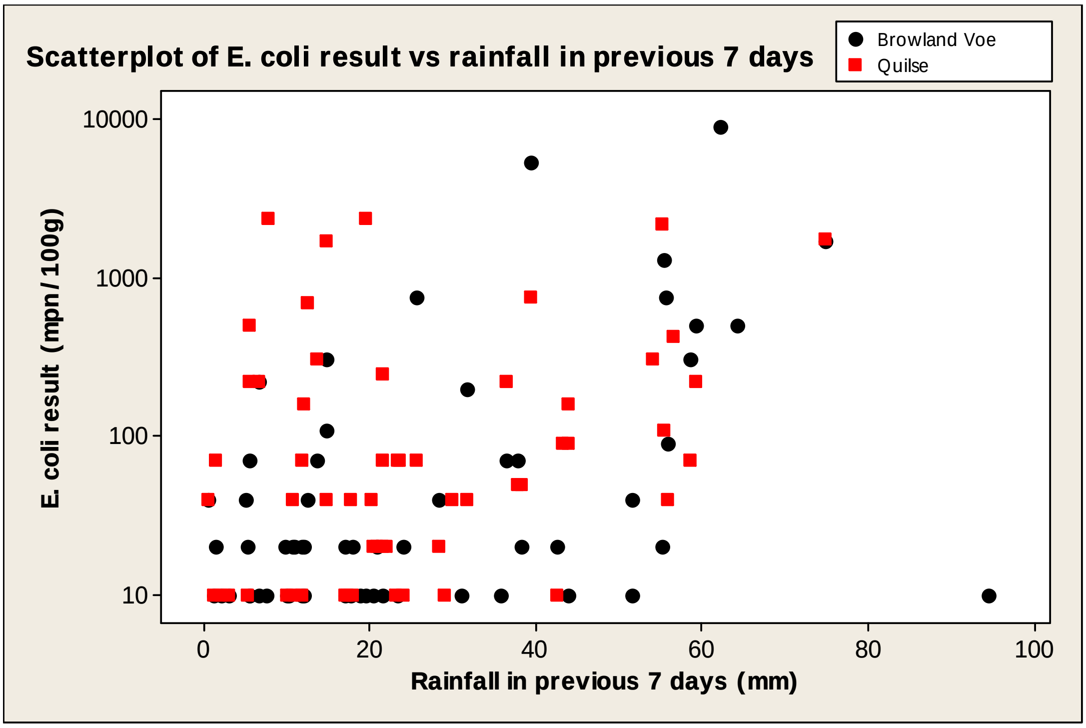


Figure 11.9 *E. coli* result against rainfall in previous 7 days

The coefficient of determination indicated that there was an extremely weak positive relationship between the *E. coli* result and the rainfall in the previous 7 days for Gruting Voe: Quilse (Adjusted R-sq=7.9%, p=0.019, Appendix 6). For Gruting Voe: Browland Voe, the coefficient of determination indicated that there was a stronger, but still fairly weak positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=22.5%, p=0.000, Appendix 6).

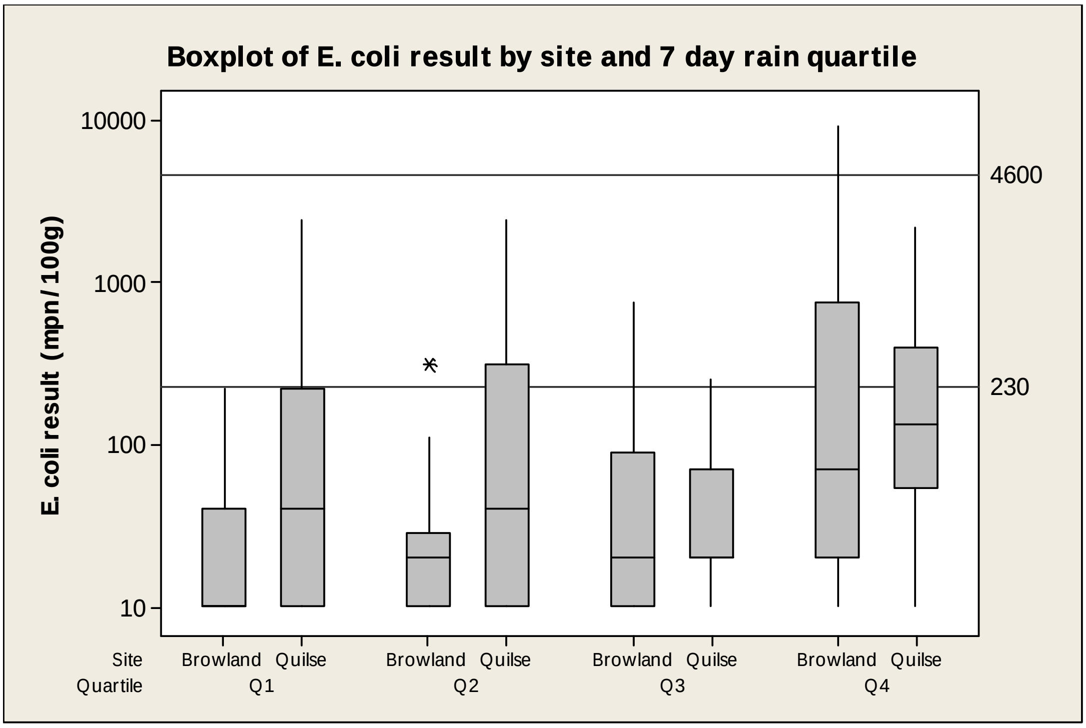


Figure 11.10 *E. coli* result by rainfall in previous 7 days quartile

A significant difference was found between the results for each 7-day rain quartile for Gruting Voe: Quilse (One way ANOVA, p=0.047, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results were significantly higher for quartile 4 compared to quartile 3.

A significant difference was found between the results for each 7-day rain quartile for Gruting Voe: Browland Voe (One way ANOVA, p=0.002, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results were significantly higher for quartile 4 compared to quartiles 1 and 2.

Overall, there was an extremely weak relationship between rainfall in the previous 2 days and *E. coli* results for Gruting Voe: Browland Voe only. This relationship was not apparent when results were compared by rainfall quartile. When rainfall in the previous 7 days was considered a very weak positive relationship was found with results from Gruting Voe: Quilse, and a stronger positive relationship was found with results from Gruting Voe: Browland Voe.

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 voe. Figure 11.11 presents a scatterplot of *E. coli* results by height of the previous high water at Scalloway (predictions from Totaltide tidal prediction software). It should be noted that local meteorological conditions such as atmospheric pressure and wind strength and direction can influence the height of tides and this is not taken into account.

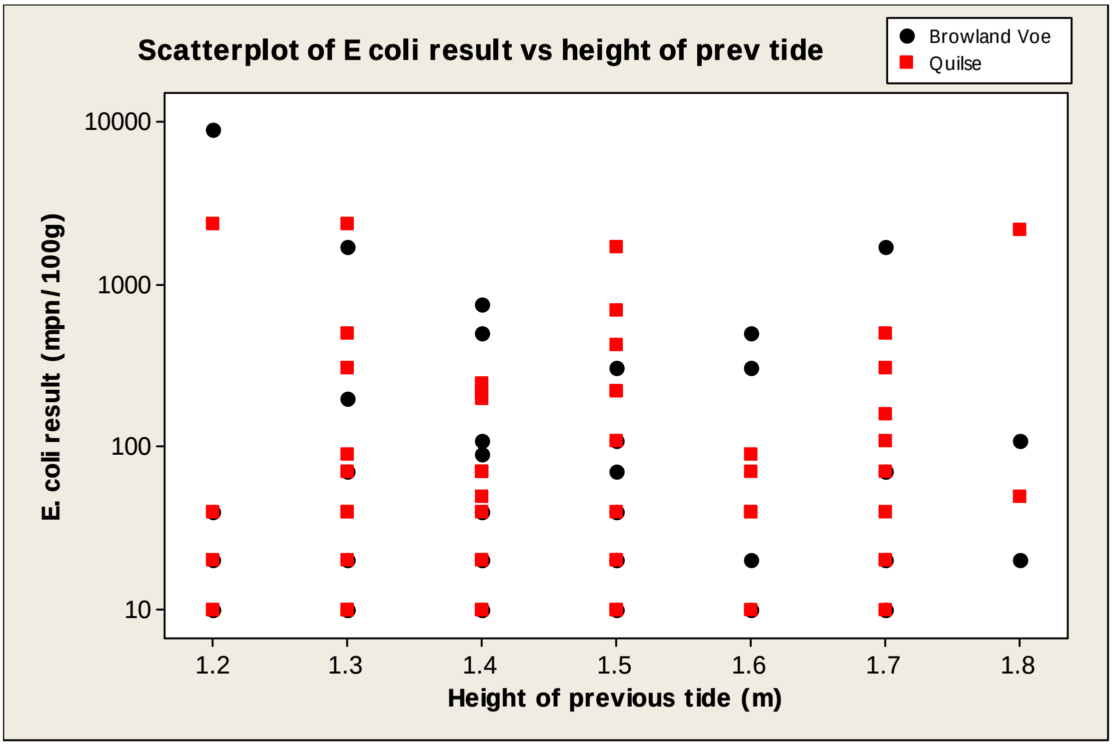


Figure 11.11 *E. coli* result by tide height

The coefficient of determination indicated that there was no relationship between the *E. coli* result and predicted height of the previous tide for Gruting Voe: Quilse (Adjusted R-sq=1.0%, p=0.209, Appendix 6) or for Gruting Voe: Browland Voe (Adjusted R-sq=0.0%, p=0.906, Appendix 6).

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 mussels 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.

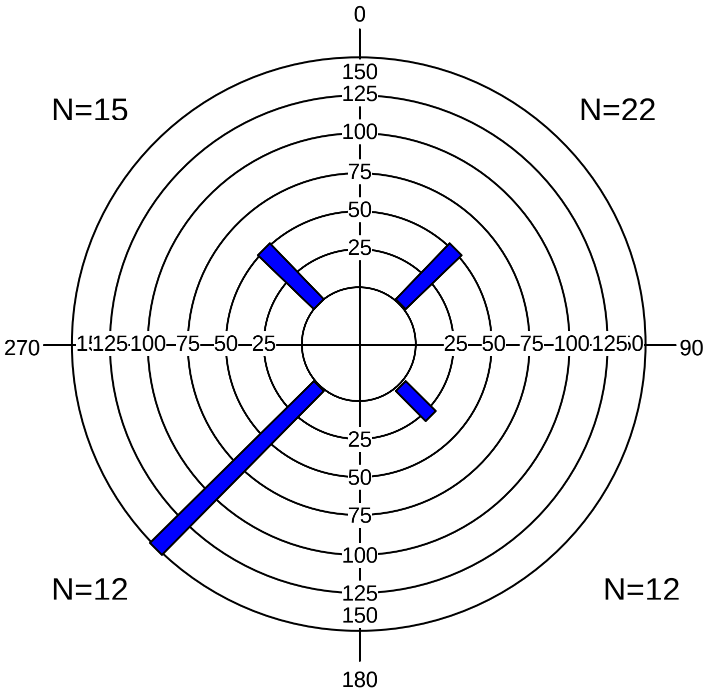


Figure 11.12 Circular histogram of geometric mean *E. coli* result tidal state (Gruting Voe: Quilse). High water is at 0 degrees, low water is at 180 degrees.

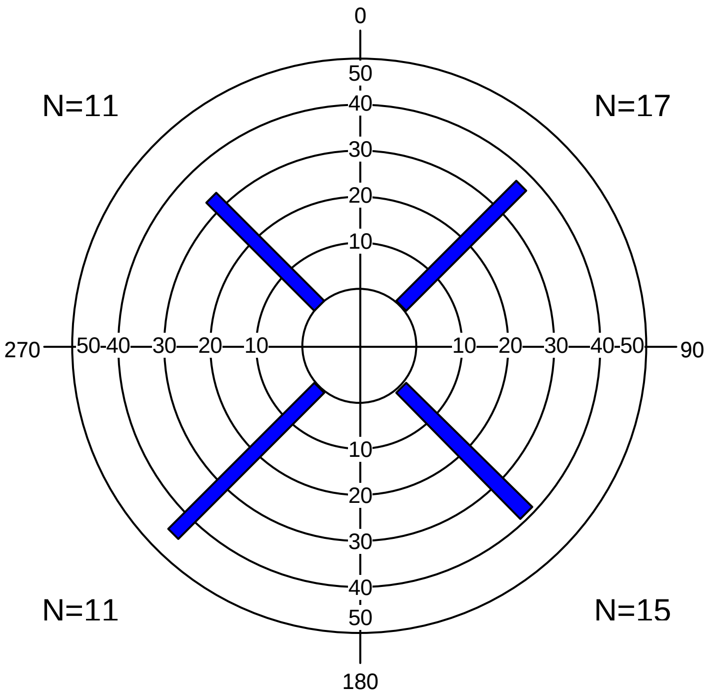


Figure 11.13 Circular histogram of geometric mean *E. coli* result by tidal state (Gruting Voe: Browland Voe) High water is at 0 degrees, low water is at 180 degrees.

No significant correlation was found between tidal state and *E. coli* result at either Gruting Voe: Quilse (circular-linear correlation, r=0.187, p=0.131, Appendix 6) or Gruting Voe: Browland Voe (circular-linear correlation, r=0.061, p=0.825, Appendix 6). For both sites mean results were highest in the first half of the flood tide.

Overall, tide size does not appear to have an influence on result. Tidal currents in the area are relatively weak, but larger tides will result in increased particle transport distances so the shellfish will be exposed to contamination originating from sources which are further afield.

No significant correlation between tidal state at time of sampling was found for either site, but mean results were highest in the first half of the flood tide at both sites.

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.

Records of water temperature at time of sampling were only available for a total of four samples from each site, so no investigation of the relationship between water temperature and *E. coli* result could be carried out.

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production areas. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Lerwick weather station, and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.14 for Gruting Voe: Quilse, and 11.15 for Gruting Voe: Browland Voe.

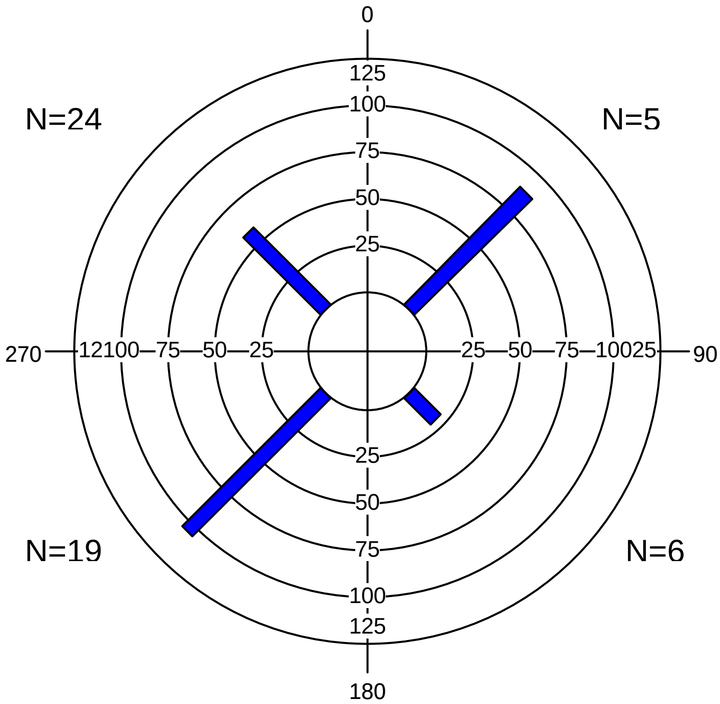


Figure 11.14 Circular histogram of geometric mean *E. coli* result by wind direction (Gruting Voe: Quilse)

No significant correlation was found between wind direction and *E. coli* result for Gruting Voe: Quilse (circular-linear correlation, r=0.114, p=0.513, Appendix 6).

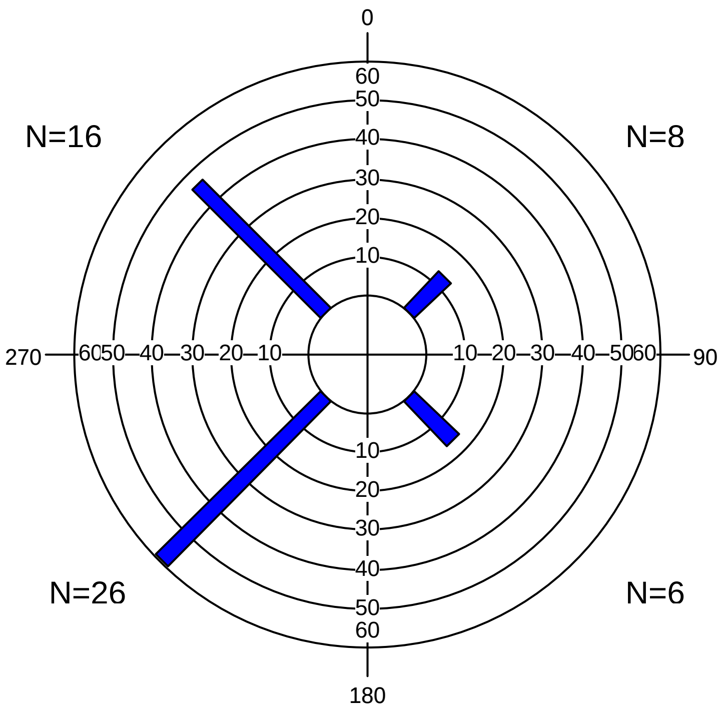


Figure 11.15 Circular histogram of geometric mean *E. coli* result by wind direction (Gruting Voe: Browland Voe)

A significant correlation was found between wind direction and *E. coli* result for Gruting Voe: Browland Voe (circular-linear correlation, r=0.332, p=0.003, Appendix 6). Higher mean results occurred when the wind was in a westerly direction. It must also be noted that the majority of samples were collected during periods of westerly winds, and wind speeds are not taken into consideration.

11.7 Evaluation of results over 4600 *E. coli* MPN/100g

Two results over 4600 *E. coli* MPN/100g were reported. Both of these came from Gruting Voe: Browland Voe, one from each of the two reported sampling locations within Browland Voe. Both arose during the late summer/early autumn and followed a relatively wet week with westerly winds.

Table 11.4 Historic *E. coli* sampling results over 4600 MPN/100g

Collection date	*E. coli* result (MPN/100g)	Location sampled	Area	2 day rain quartile	7 day rain quartile	7 day wind direction	Previous tide height	Time since high water
5/9/2005	5400	HU268508	Browland	Q2	Q4	213^{o}	1.5 m	*
22/8/2007	9100	HU263501	Browland	Q2	Q4	341^{o}	1.2 m	5h39min

* Time of collection not recorded

11.8 Summary and conclusions

No statistically significant difference in results between the two production areas was detected. Geometric mean result was higher at Gruting Voe: Quilse, but the two highest individual results came from Gruting Voe: Browland Voe.

A seasonal effect was found for both production areas, with mean results for both areas highest in the autumn, next highest in the summer, lower in the winter and lowest in the spring. This suggests that either inputs are higher in summer and autumn and/or the uptake of bacteria by the shellfish is higher in warmer water.

An extremely weak positive relationship was found between rainfall in the previous 2 days and results at Gruting Voe: Browland Voe only. An extremely weak positive relationship was found between rainfall in the previous 7 days and results at Gruting Voe: Quilse, with a stronger positive relationship found for Gruting Voe: Browland Voe. This may be expected, as Gruting Voe: Browland Voe is closer to the head of the voe where the main freshwater inputs are located, and as a consequence is likely to be more heavily influenced by land runoff.

No significant influence of either tide size (i.e. spring or neap) or tidal state (i.e. high/low/ebb/flood) was found. This may be expected as tidal currents in the area are relatively weak, and there are no major point sources of contamination in the area.

A correlation was found between wind direction and magnitude of *E. coli* results for Gruting Voe: Browland Voe only.

The two highest individual results occurred in the late summer/early autumn following a wet week with westerly winds, which is consistent with the overall pattern of results in relation to these variables.

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 has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for either production area as they have both held seasonal classifications for the last three years.

12. Designated Shellfish Growing Waters Data

The area considered in this report is also a SEPA shellfish growing water which was designated in 2002. The growing water encompasses a larger area than the two production areas covered by this report. The extent of the growing water is shown on Figure 12.1.

The monitoring requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Twice yearly for metals in water
- Annually for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

There are 3 designated monitoring points within the growing water indicated on the map. The most easterly of these, located at the head of Seil Voe is the routine mussel sampling point, and this falls outside of both FSAS production areas considered in this report. The other two locations are sampled for water. Monitoring results for faecal coliforms in shore mussels from 2002 to the end of 2007 have been provided by SEPA. These results are presented in Table 12.1. The first two samples were reported from the same location as the RMP for the Gruting Voe: Browland Voe production area, so may have been rope grown mussels rather than shore mussels and were not used in the calculation of the geometric mean due to this uncertainty.

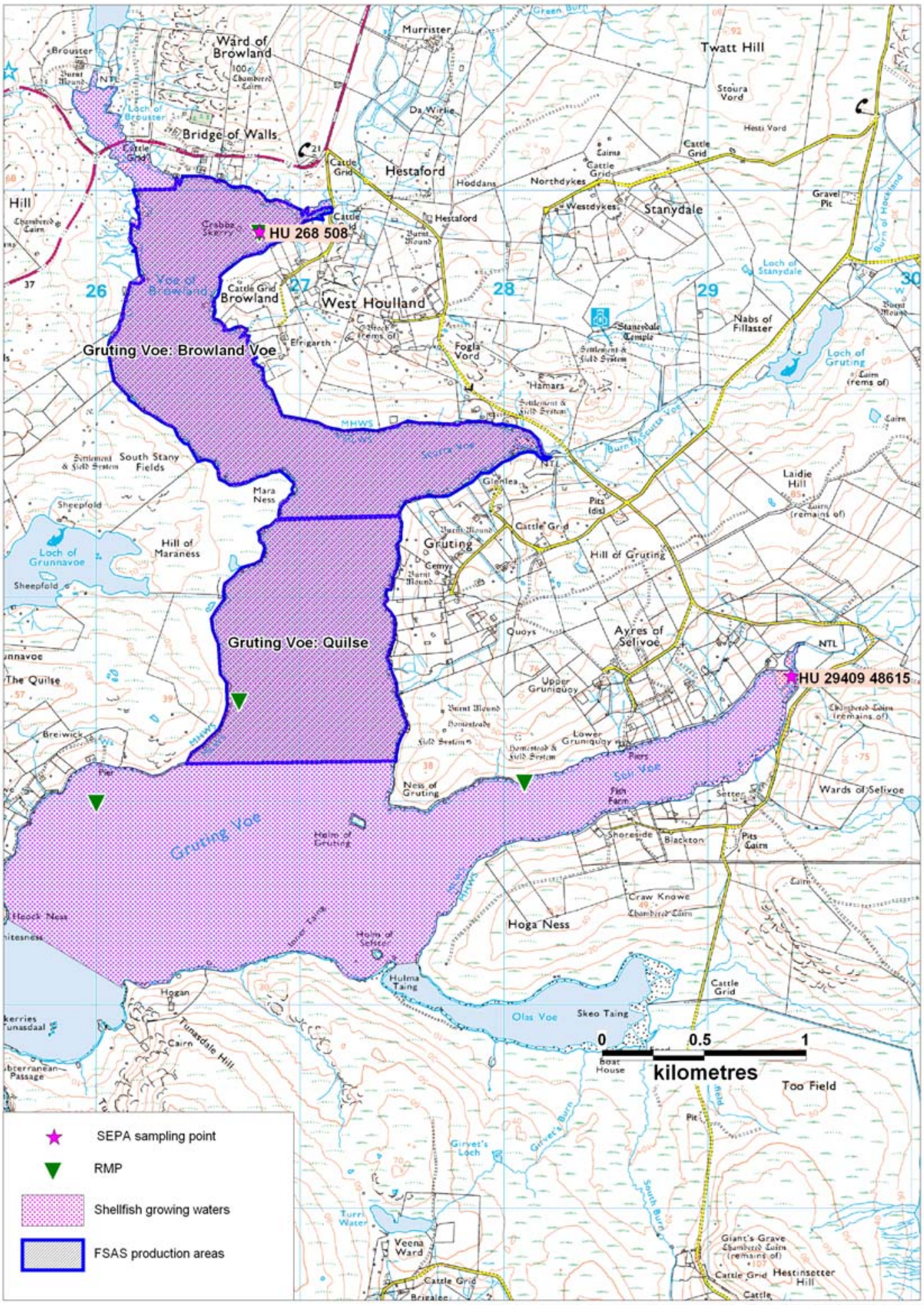


Figure 12.1 Shellfish growing waters and monitoring points

Table 12.1. SEPA Faecal coliform results (faecal coliforms/100g) for shore mussels gathered from Gruting Voe.

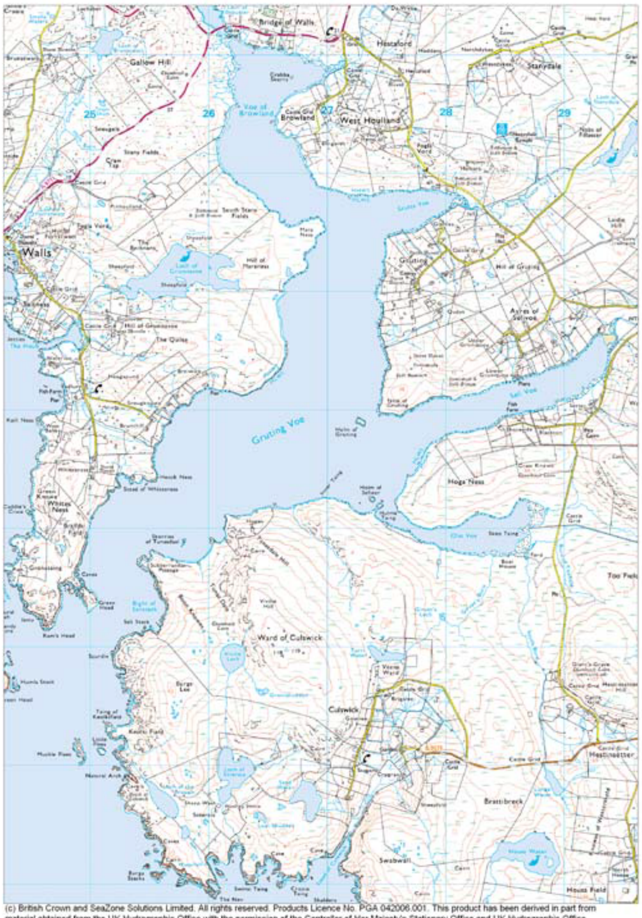
	Site	Gruting Voe	Gruting Voe
	OS Grid Ref.	HU 268 508	HU 29409 48615
2002	Q1		
	Q2		
	Q3		
	Q4	40	
2003	Q1	<20	
	Q2		
	Q3		5400
	Q4		500
2004	Q1		160
	Q2		9100
	Q3		310
	Q4		50
2005	Q1		40
	Q2		750
	Q3		>18000*
	Q4		515
2006	Q1		40
	Q2		320
	Q3		1300
	Q4		9100
2007	Q1		130
	Q2		
	Q3		
	Q4		

* Assigned a nominal value of 36000 for the calculation of the geometric mean.

The geometric mean result of all SEPA shore mussel samples from HU 29409 48615 was 614 faecal coliforms / 100g. Results ranged from 40 to >18000 faecal coliforms/100g. Results were highest for quarter 3, and lowest for quarter 1, but differences between results by quarter were not significant (One-way ANOVA, p=0.068, Appendix 6). This is a similar seasonal pattern to that observed for the classification samples.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. The geometric mean level of faecal coliforms in shore mussels taken as part of the SEPA monitoring programme is approximately an order of magnitude higher than the overall geometric mean of all rope mussel samples tested for *E. coli* from Gruting Voe: Browland Voe (41.2 MPN/100g) and Gruting Voe: Quilse (63.4 MPN/100g) as part of the classification monitoring. This is likely due to geographical differences in levels of contamination – the shore mussel samples are taken from the intertidal zone where a watercourse enters the voe.

13. Bathymetry and Hydrodynamics



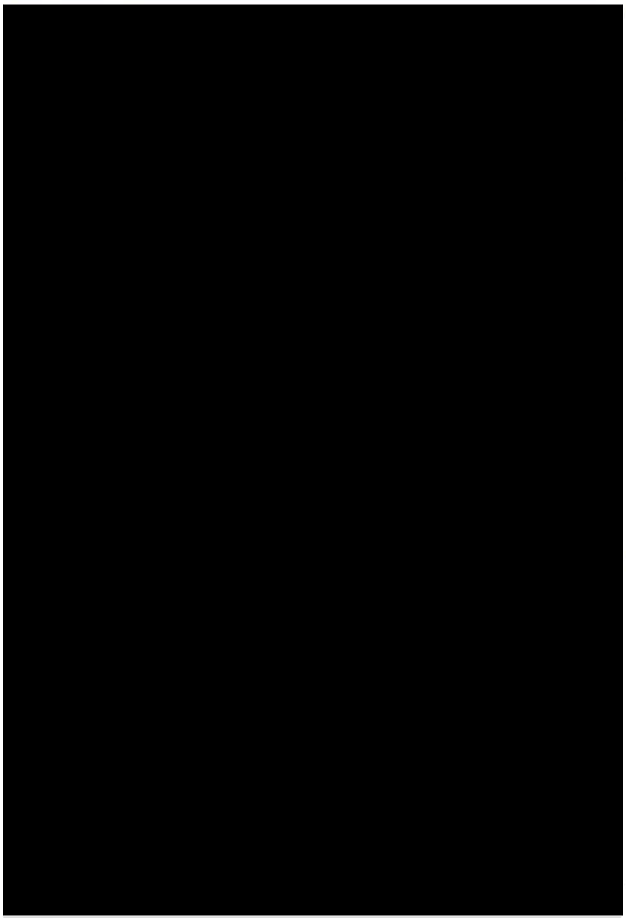


Figure 13.1 OS map of Gruting Voe

Figure 13.2 Bathymetry of Gruting Voe

Figure 13.2 above shows that both production areas are in relatively shallow water, with a sill at the south end of the Gruting Voe: Browland Voe production area between Mara Ness and West Houlland. Maximum depth in the Gruting Voe: Browland Voe production area is 15 m, and maximum depth in the Gruting Voe: Quilse production area is less than 40 m. There is also another sill close to the mouth of the voe. It faces the Atlantic Ocean to the south.

13.1 Tidal Curve and Description

The two tidal curves below are for Scalloway, the closest port for which tidal predictions are available. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 29/05/08 and the second is for seven days beginning 00.00 GMT on 05/06/08. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

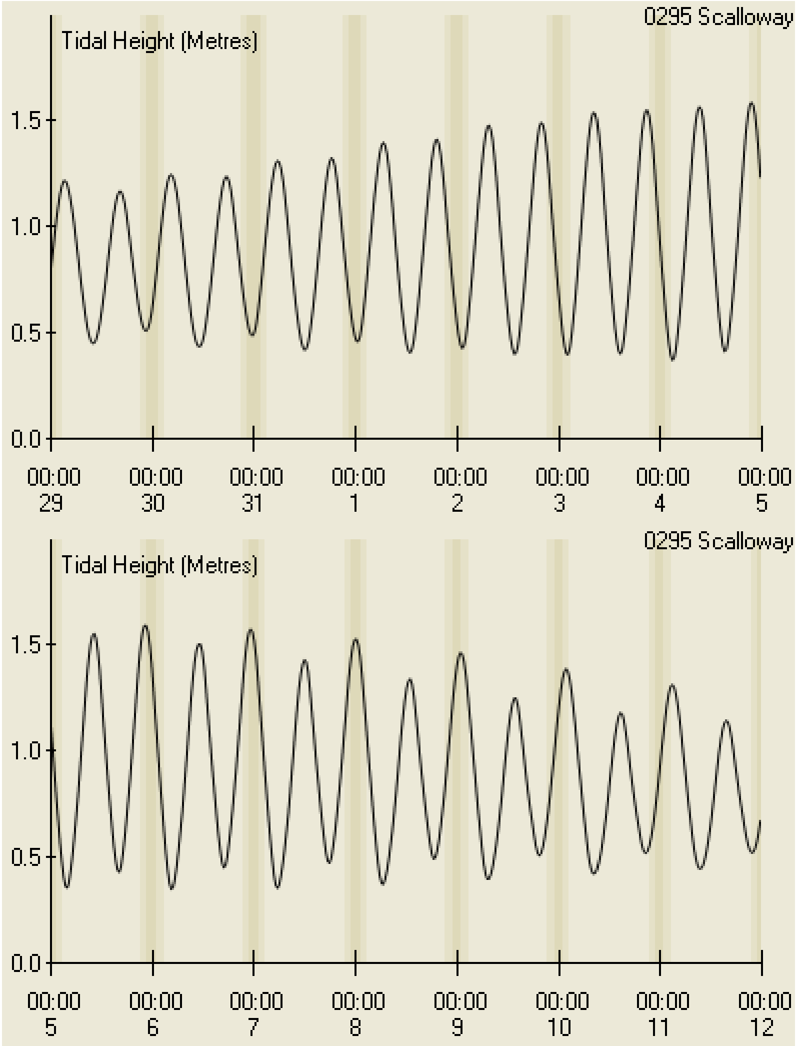


Figure 13.3 Tidal curves for Scalloway

The following is the summary description for Scalloway from TotalTide:

The tide type is Semi-Diurnal.

HAT	1.9 m
MHWS	1.6 m
MHWN	1.3 m
MLWN	0.6 m
MLWS	0.5 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 1.1 m and at neap tide 0.7 m, so tidal ranges here are small.

13.2 Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The tidal range here is small, so tidally driven exhange of water is likely to be weak. This is reflected in the relatively lengthy calculated flushing time of 9 days for the whole voe (Edwards and Sharples, 1986). Each basin will have its own local flushing characteristics, with some deep waters exchanging more slowly than this. Tidally driven currents within the voe would be expected to move in a northerly direction on the flood tide, and a southerly direction on the ebb tide. Contamination from sources along the shore would tend to hug the shoreline. Currents will be faster over the sills than in areas of deeper water, and greater mixing will occur in these areas. Tidally driven currents will be faster on the larger spring tides and the distance of transport of contaminants will be expected to be greater.

The land surrounding the production areas is low lying, and the voe has a north south aspect, so will be fairly exposed to winds from all directions, particularly southerly winds, which would be funnelled up the voe, and to a lesser extent northerly winds which would be funnelled in the other direction. Given the relatively weak tidal currents, wind driven currents have the potential to significantly alter flows around the production areas.

The catchment area of Gruting Voe is about 52 km^2, which is large for Shetland. An average salinity reduction of 0.5 ppt was calculated on the basis of tidal and freshwater inflows (Edwards and Sharples, 1986) although this is likely to fluctuate greatly depending on rainfall. The main freshwater inputs measured during the shoreline survey were the Burn of Scutta Voe, which discharges to the head of Scutta Voe, and the two watercourses discharging to the head of Gruting Voe. Salinity profiles taken at the mussel lines during the course of the shoreline survey indicated very low freshwater influence. Surface salinities ranged from 34.6 to 34.8 ppt, and all readings taken at 10 m depth were 34.8 ppt. The harvester indicated that turbidity within the voe often increases during periods of high rainfall in the winter months, suggesting that significant amounts of freshwater do enter the voe at times. Freshwater (density) driven currents may be of significance following heavy rainfall. It will create a net seaward flow of fresh water at the surface of the voe, possibly with return currents of more saline water at depth.

The best available source of real data on the movement of water around the area was from a series of five studies carried out by the North Atlantic Fisheries College, Scalloway (NAFC) to assess movement of water around potential salmon cage farm sites withing Gruting Voe. These were carried out on separate occasions, therefore under differing environmental conditions. The studies involved the deployment of a fixed current meter for periods of around 2 weeks, recording average speed and direction of the current at various depths at 10-minute intervals. A weather station was deployed simultaneously which recorded wind speed and direction hourly. Locations of these five current meter stations are shown in Figure 13.4. Polar plots of current velocity and direction readings near the surface and near the bottom and wind data for each of the five locations are presented in Figure 13.5.

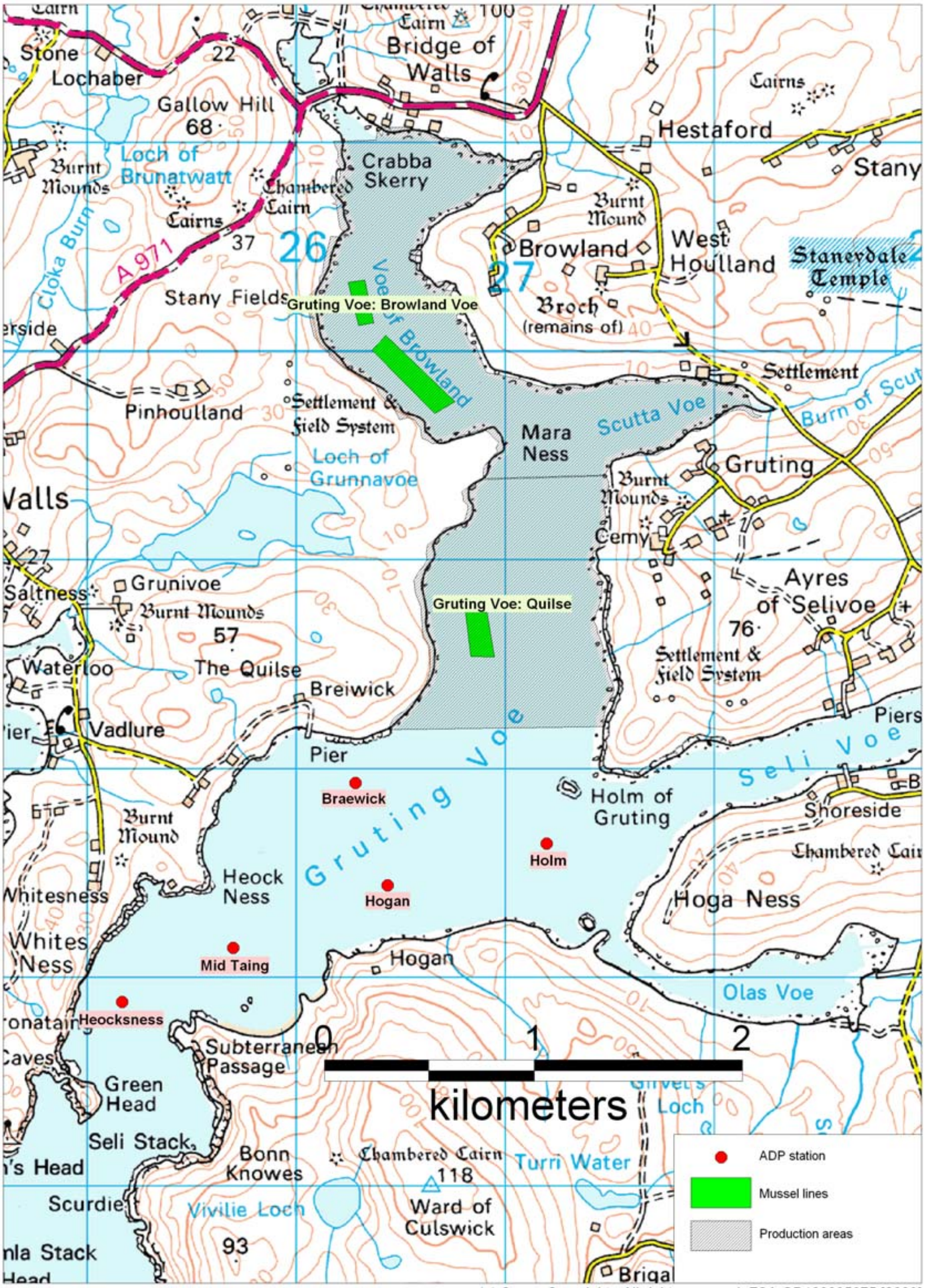


Figure 13.4 Location of the fish farm study sites

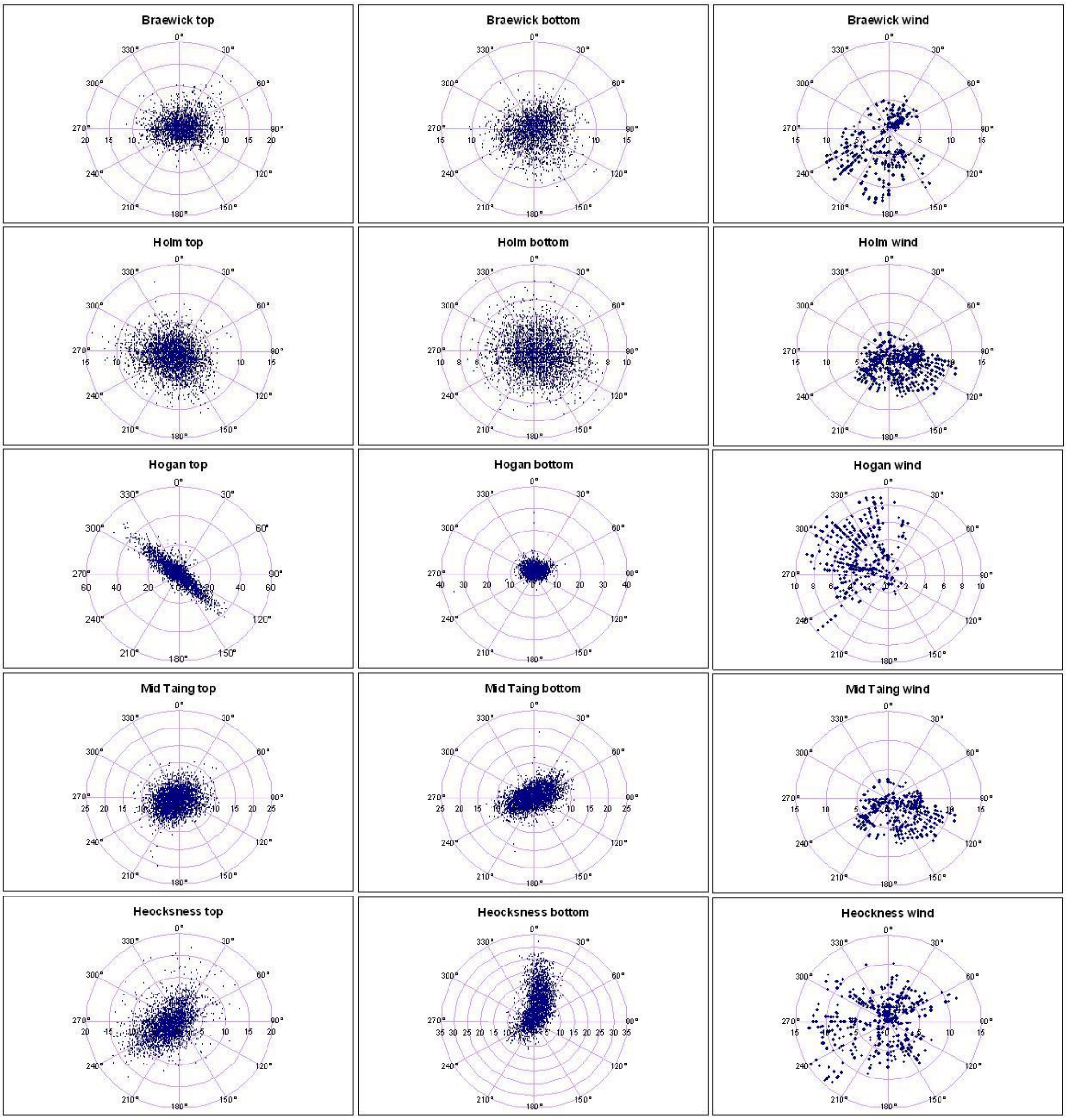


Figure 13.5 Polar plots of tidal direction and velocity readings near the top (surface) and bottom for the fish farm study sites, with polar plots of simultaneous wind recordings. Current velocity is in cm/s, and wind speed is in m/s.

None of these sites fell within either of the production areas considered in this report. All fell to the south of the production areas, in slightly deeper water closer to the mouth of the voe so do not actually represent conditions experienced at the mussel lines, but should provide a broad indication of current speeds and directions which may be expected here. All stations were in similar depth of water (20-30 m) in a fairly uniform area. The NAFC classed current speeds of greater than 10 cm/s as strongly flushed, between 5 and 10 cm/s as moderately flushed, between 3 cm/s and less than 5 cm/s as weakly flushed and less than 3 cm/s are classed as quiescent.

At Braewick, flows were weak on average, with a mean current speed near the surface of 3.5 cm/s, and 3.4 cm/s at the bottom. Flows were quite evenly spread in terms of direction at both the top and the bottom, with slightly more records indicating a northeasterly flow at the top. Wind was predominantly from the southwest, and quite strong at times, and this would account for the flow directions recorded at the surface. Rainfall data was unavailable for the survey dates (late March 2002).

At Holm, flows were again weak on average, with a mean current speed near the surface of 3.5 cm/s, and 2.7 cm/s at the bottom. Flows were evenly spread in terms of direction at both the top and the bottom. Wind was light to moderate in strength, and mainly from the southeast or southwest. A total of 69.7 mm of rain fell during the 25 day survey period.

At Hogan, flows were on average strong at the top, and weak at the bottom, with a mean current speed near the surface of 11.2 cm/s, and 3.2 cm/s at the bottom. Flows at the surface appeared to be strongly bidirectional, a feature generally associated with tidally driven flows. Closer examination of the data indicated that the changes in current directions did not align with the tidal cycle, but were characterised by rapid shifts from one direction to the other. The pattern emerged within 10 m of the bottom and strengthened towards the surface. Generally bidirectional tidally driven currents would be expected to flow along the shore, which would be along the northeast-southwest axis, rather than along the northwest-southeast axis as seen in Figure 13.5. Wind records show that the wind was persistently blowing from the northeast at light to moderate strengths, and it is likely that this will have influenced flows at the surface. A total of 41.9 mm of rain fell during the 18 day survey period.

At Mid Taing, flows were weak on average, with a mean current speed near the surface of 4.1 cm/s, and 3.9 cm/s at the bottom. A vague bidirectional tendency along the southwest-northeast axis was apparent, and this pattern was stronger near the bottom, where tidally driven currents are less disrupted by wind effects. Wind was light to moderate in strength, and mainly from the southeast. A total of 69.7 mm of rain fell during the 25 day survey period.

At Heocksness, flows were on average weak at the surface, and moderate at the bottom, with a mean current speed near the surface of 4.7 cm/s, and 8.7 cm/s at the bottom. As this station was located in a slight constriction, and close to a sill, higher current speeds were not unexpected. At the surface a vague bidirectional tendency was seen along the southwest-northeast axis at the surface, although there was more of a tendency for the current to move in a southwesterly direction. At the bottom, there was a strong tendency for northerly flows. These may represent return flows created by seaward moving surface waters, which could either be wind or density (freshwater) driven. Wind blew from a wide spread of directions, but was strongest when blowing from the southwest, approaching gale force at times. It is therefore quite possible that density (freshwater) effects were influencing flow patterns observed here, but rainfall data was unavailable for the survey dates (early March 2002).

In summary, the fish farm study data confirms that tidally driven currents are weak within the voe, and can be heavily influenced by wind, and possibly freshwater inputs at times. It is likely that currents around the mussel lines would be weaker still, and more susceptible to influence by freshwater driven flows as they are nearer to the head of the voe.

13.3 Conclusions

Circulation around the voe will be driven by tide, winds, and, at times, freshwater inputs. Tidal currents are weak, and vaguely bidirectional. Superimposed on this, wind driven currents are likely to significantly alter circulation within the voe, depending of course on wind strength and direction. Also, following heavy rainfall, density driven surface currents of fresher water will flow slowly in a seaward direction.

Sources of contaminants identified in the area include land runoff contaminated by livestock, and three small private septic tanks. These sources mainly enter at the head of Gruting Voe and the head of Scutta Voe. Therefore, northerly or north easterly winds, and freshwater driven currents may be expected to transport contamination towards the shellfisheries.

14. River Flow

There are no river gauging stations on rivers or burns surrounding Gruting Voe. The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into Gruting Voe.

Table 14.1 River loadings for Gruting Voe

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	HU 26005 51538	Stream	1.55	0.15	0.211	4239	110	$4.7x10^9$
2	HU 27161 50948	Stream	1.80	0.01	0.272	423	140	$5.9x10^8$
3	HU 26607 50340	Stream	0.20	0.01	0.155	26.8	600	$1.6x10^8$
4	HU 28221 49693	Stream	1.35	0.22	0.061	1565	500	$7.8x10^9$
5	HU 27455 48644	Stream	0.10	0.05	0.204	88.1	20	$1.8x10^7$
6	HU 26181 50678	Stream	0.30	0.025	0.037	24.0	300	$7.2x10^7$

The shoreline survey followed a prolonged dry period, and discharge from the streams was relatively low, with some dry stream beds seen while some other streams were wetted in places but had negligible flow, even on the second day following rain on the first day. All these streams drain areas of pasture, and had low to moderate levels of *E. coli* (20-600 cfu/100ml) at the time of survey. The highest overall *E. coli* loadings were for streams 1 and 2 (draining to the head of Gruting Voe) and 3 (draining to the head of Scutta Voe). The total loading contributed by these streams at the time of survey $1.33x10^{10}$ *E. coli* per day, roughly equivalent to a discharge of septic tank treated wastewater from a population of 2. Following heavy rain, the loadings contributed by these streams would be expected to increase significantly. They may be the principal pathways by which diffuse contamination from livestock will be carried into the production areas.

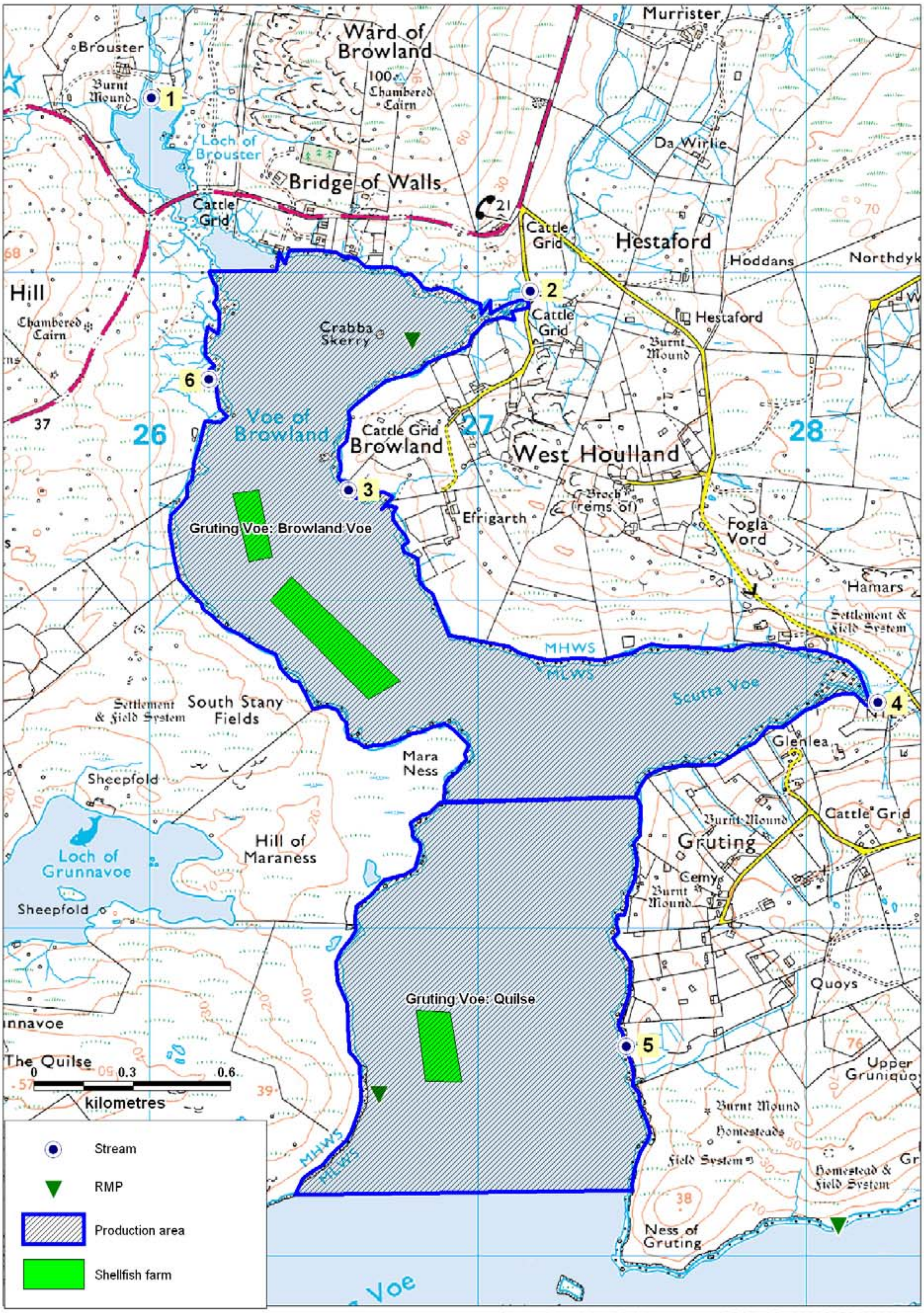


Figure 14.1 Streams at Gruting Voe

15. Shoreline Survey Overview

The shoreline survey was conducted on the 4th to 5th of June 2008 following a period of dry weather.

The fishery at Gruting Voe: Browland Voe consisted of two adjacent blocks of mussel longlines owned by North Atlantic Shellfish. The fishery at Gruting Voe: Quilse consisted of one block of mussel lines owned by Peter Tait. Both sites had stock of a range of sizes, including that of a harvestable size. Both sites can be harvested year round, with the timing of harvest depending on demand, biotoxin status and the status of other sites under the same ownership.

Human population in the area was low, and confined to scattered settlements on the east shore. Small private wastewater discharges to Gruting Voe were only seen in two areas; one outfall at the head of Scutta Voe, and two outfalls at the Bridge of Walls. It is believed that the majority of dwellings in the area have septic tanks, which are either the pumpout variety or discharge to soakaway, as most dwellings are some distance back from the shore. A few of the dwellings may be holiday homes, but there are no specific tourist attractions in the area so no large inundations of visitors are expected during the summer months. No boats were seen during the course of the shoreline survey. A small marina is proposed near the head of Scutta Voe, but this is still at the planning stage.

The land surrounding the production areas is pasture, some of which appeared to be improved, but the majority appeared unimproved. Almost 400 sheep were counted grazing on these pastures, with the highest concentrations around the settlements on the east shore. Sheep were free to access the shoreline in most areas. Rabbits were also present on these pastures but not in great numbers. A group of seven seals were seen just off Browland. A group of about 50 ducks were disturbed from the Quilse site, and a few gulls were seen.

A few streams discharge into the voe, which drain areas of pasture. Water samples were taken, and discharge estimated for these. Water levels were very low, as rainfall in the weeks prior to the survey was very low. A number of dry streambeds were encountered, and some other streambeds were still wetted in places but had negligible flow, even on the second day of the survey following rain on the first day. Stream inputs had low to moderate levels of *E. coli* (20-600 cfu/100ml).

The highest result *E. coli* result for a seawater sample (1000 cfu/100ml) came from Scutta Voe, next to the sewage discharge from the village hall. High *E. coli* results were also found in seawater samples taken around the head of the voe (two samples giving a result of 100 cfu/100ml). Seawater samples taken from the shore in other areas had lower levels of *E. coli* (maximum of 13 cfu/100ml). Seawater samples taken offshore in the vicinity of the mussel farms had very low levels of *E. coli* (<1 cfu/100 ml in all cases).

Rope mussel samples gave results ranging from 50 to 16000 *E. coli* MPN/100g. Five of the 12 samples exceeded 230 *E. coli* MPN/100g, and two exceeded 1000 *E. coli* MPN/100g. The highest result (16000 *E. coli* MPN/100g) was obtained from a sample taken near the surface at Gruting Voe: Browland Voe, and this result was considerably higher than any of the historic *E. coli* monitoring results. All samples apart from the very high result fell within the 95 percentiles for historic *E. coli* monitoring results presented in Table 11.1.

Salinity profiles taken from around the mussel lines indicated very low freshwater influence at all sites at the time of survey. The grower advised that turbidity in the voe often increases during the winter months due to inputs of fresh water.

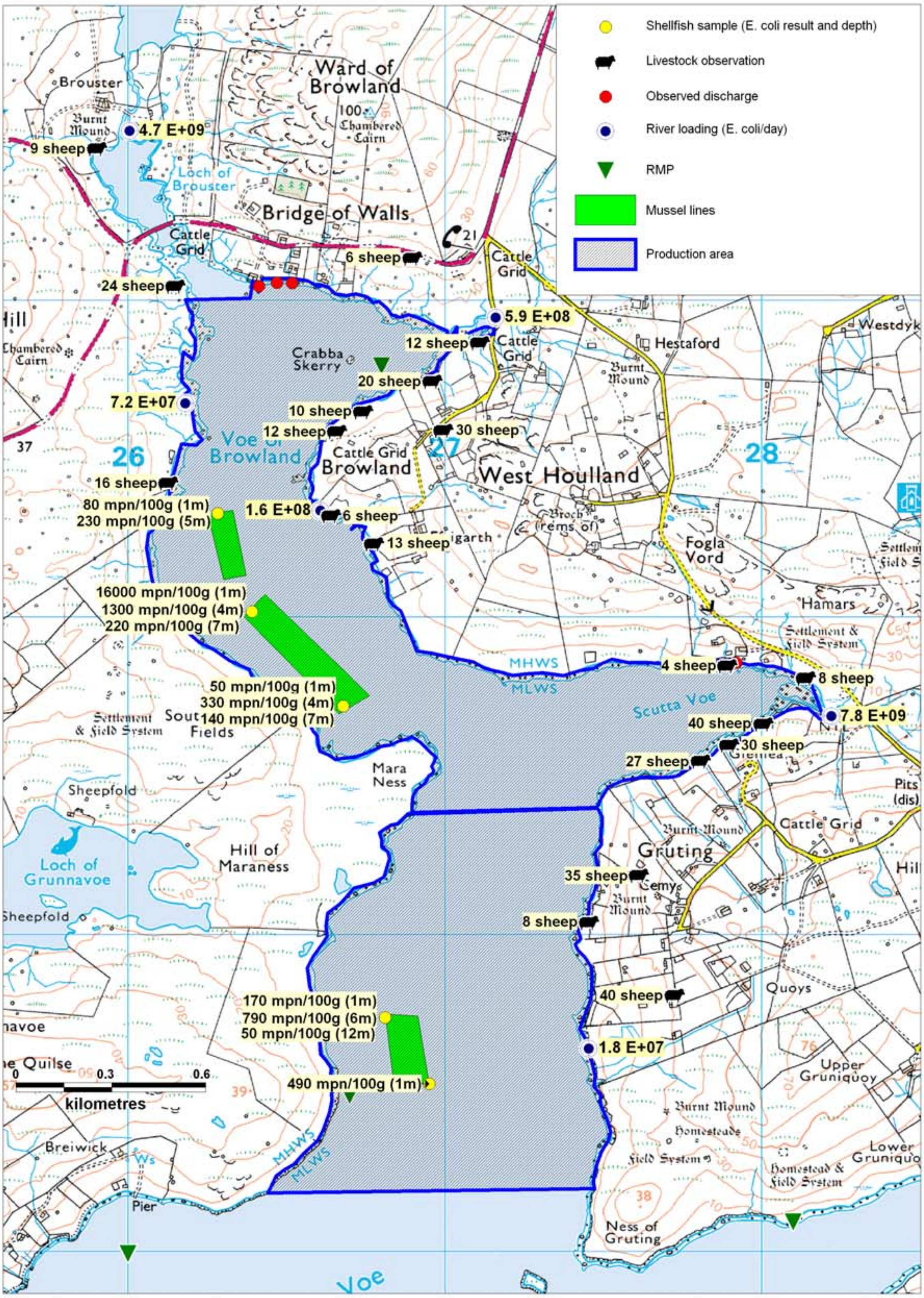


Figure 15.1 Summary of shoreline survey findings for Gruting Voe

16. Overall Assessment

Human sewage impacts

There is little in the way of sewage input direct to the production areas. Septic discharges were only noted in two areas where houses were close to the shore. At Bridge of Walls, two small private discharges to Gruting Voe and one septic tank with no apparent overflow were recorded. At the head of Scutta Voe a septic discharge from the village hall was found. These three discharges are likely to equate to a population equivalent of 15 or less. All discharges were over 700m from the mussel lines, so their impact would be small. Their location suggests that their impact may be slightly greater at the northern ends of the fisheries. Where buildings are further back from the shoreline, it is likely that any waste water overflows from their septic tanks discharge to soakaway.

No boats were seen during the course of the shoreline survey, and it is likely that boat traffic in the area is very light. A small marina is proposed near the head of Scutta Voe, but this is still at the planning stage.

Agricultural impacts

Agricultural census data for 2008 identified that agriculture within the surrounding parishes is predominantly sheep production, at a high density of 250.7 animals / km^2. The shoreline survey confirmed the presence of extensive sheep grazing in the area at roughly this density. The most significant concentrations of livestock were sheep on the eastern coastline and around Scutta Voe. The geographical spread of contamination at the shores of the voe is therefore likely to be concentrated along the eastern coastline. Shoreline survey observations must be treated with caution however, as they only apply to the date of survey, and it is likely that all pastures in the area are grazed by sheep at some point.

Numbers of sheep will approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. Therefore higher impacts from livestock may to be expected during this period.

Wildlife impacts

The main wildlife species potentially impacting on the production areas are seals and seabirds, including eider ducks. Seven seals were seen just off Browland, and there are reported seal haulout sites near the head of Gruting Voe. 50 ducks were seen at the Quilse site during the shoreline survey. These animals are highly mobile, so their impacts on the fishery will be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area and so cannot be considered when deciding the location of the RMP.

They may however cause significant and highly localised inputs by direct deposition in the immediate vicinity of the mussel lines which may be detected in any sampling. It is suspected that wildlife inputs may have been the cause of the particularly high levels of *E. coli* found in one of the mussel samples taken during the shoreline survey.

Seasonal variation

A few of the dwellings may be holiday homes, but there are no specific tourist attractions in the area so no large inundations of visitors are expected during the summer months.

Livestock numbers will be higher in the summer, so contamination from livestock sources is likely to be higher during the summer.

Weather is wetter and windier during the winter months, so higher overall levels of rainfall dependent contamination, such as runoff from pasture may be expected during these times. Summer storms during the drier months when contamination from livestock has built up on pastures may result in a 'first flush' of more contaminated runoff.

A seasonal effect was found in historic *E. coli* monitoring results, with mean results for both areas highest in the autumn, next highest in the summer, lower in the winter and lowest in the spring. This suggests that either inputs are higher in summer and autumn and/or the uptake of bacteria by the shellfish is higher in warmer water.

Seasonal variation in livestock numbers and weather are expected, and the historical *E. coli* monitoring data confirms a seasonal pattern in contamination levels, so monthly monitoring should be continued for these areas.

Rivers and streams

Streams are the principal pathways by which diffuse contamination from livestock will be carried into the production areas. Gruting Voe has a catchment area of 52 km^2, which is large for Shetland.

Significant streams were sampled for *E. coli* and discharge was measured during the shoreline survey. The survey followed a prolonged dry period, so their typical contribution may have been underestimated. All drained areas of pasture, and had low to moderate levels of *E. coli* (20-600 cfu/100ml) at the time of survey. The highest overall *E. coli* loadings were two streams draining to the head of Gruting Voe and one stream draining to the head of Scutta Voe. The total loading contributed by these streams at the time of survey 1.33×10^{10} *E. coli* per day, roughly equivalent to a discharge of septic tank treated wastewater from a population of two. Following heavy rain, the loadings contributed by these streams may increase significantly.

None of these streams discharge particularly close to the mussel lines, but tentatively RMPs could be set as close to the head of the voe as possible to best capture contamination from these sources.

Meteorology, hydrology, and movement of contaminants

The weather is wetter and windier during the autumn and winter months, and the prevailing wind direction is from the south west.

No significant influence was found on historic *E. coli* monitoring results of either tide size (i.e. spring or neap) or tidal state (i.e. high/low/ebb/flood). This may be expected as tidal currents in the area are relatively weak, and there are no major point sources of contamination in the area.

A correlation was found between wind direction and magnitude of *E. coli* results for Gruting Voe: Browland Voe only. Higher mean results occurred when the wind was in a westerly direction. The reasons for this are unclear.

Overall, historic *E. coli* monitoring results from Gruting Voe: Browland Voe were more influenced by recent rainfall than those at Gruting Voe: Quilse, although relationships with recent rainfall at both sites were quite weak. This may be expected, as Gruting Voe: Browland Voe is closer to the head of the voe where the main freshwater inputs are located, and as a consequence is likely to be more heavily influenced by land runoff.

The two highest individual results occurred in the late summer/early autumn following a wet week with westerly winds, which is consistent with the overall pattern of results in relation to these variables.

Circulation around the voe will be driven by tide, winds, and, at times, freshwater inputs. Tidal currents are weak, and vaguely bidirectional. Superimposed on this, wind driven currents are likely to significantly alter circulation within the voe, depending of course on wind strength and direction. Also, following heavy rainfall, density driven surface currents of fresher water will flow slowly in a seaward direction. Under these conditions, contamination is likely to be higher in the surface layer carrying land runoff. Sources of contaminantion (land runoff and small private septic tanks) mainly enter at the head of Gruting Voe and the head of Scutta Voe. Therefore, northerly or north easterly winds, and freshwater driven currents may be expected to transport contamination towards the shellfisheries.

Temporal and geographical patterns of sampling results

No overall improvement or deterioration was apparent in historic *E. coli* sampling results from 2002 to 2007. A seasonal pattern was seen as described earlier in this section.

No statistically significant difference was detected in historic *E. coli* monitoring results between the two production areas. Highest geometric mean result came from Gruting Voe: Quilse, but the two highest individual results came from Gruting Voe: Browland Voe. There was no significant difference in the proportion of results over 230 *E. coli* MPN/100g between production areas. This suggests that differences in levels and patterns of contamination in the production area are subtle. Small differences in responses in historic *E. coli* results to environmental variables and in seasonal patterns were found between the two production areas. Since 2004, when Gruting Voe was split into its current boundaries, both areas have held split A/B seasonal classifications, although the timing of the B months has differed slightly between the two areas. These small differences tentatively support the continued separate classification of the two areas.

No significant difference was found in historic *E. coli* monitoring results from different reported sampling locations within each individual production area, so provide no firm basis for advising the location of the RMPs.

Seawater samples taken from the shore during the shoreline survey found highest levels of contamination at the head of Scutta Voe, and the head of Browland Voe. Seawater samples taken offshore in the vicinity of the mussel farms had very low levels of *E. coli* (<1 cfu/100 ml in all cases).

Rope mussel samples taken during the shoreline survey gave results ranging from 50 to 16000 *E. coli* MPN/100g. Five of the 12 samples exceeded 230 *E. coli* MPN/100g, and two exceeded 1000 *E. coli* MPN/100g. The highest result (16000 *E. coli* MPN/100g) was considerably higher than any reported from the historic monitoring programme, and was obtained from a sample taken near the surface at Gruting Voe: Browland Voe. It was not expected, and could not be attributed to any of the point sources identified. The most likely explanation for this may be direct deposition by wildlife, such as seals or birds, in very close proximity to the mussel lines. If this is the case, then this result does not provide a basis for setting the RMP at the point sampled, as wildlife impacts are likely to be spatially unpredictable. No clear spatial pattern was apparent in the results of samples taken during the shoreline survey, either horizontally or vertically.

17. Recommendations

Small differences in historic E. coli monitoring results tentatively support the continued separate classification of the two areas.

The Gruting Voe: Quilse current production area is bounded by lines drawn between HU 2645 4820 to HU 2747 4820 and HU 2750 4940 to HU 2690 4940. The Gruting Voe: Browland Voe current production area is bounded by lines drawn between HU 2690 4940 to HU 2747 4940 and HU 2643 5106 to HU 2619 5100. There is no reason to recommend alteration of the boundaries for Gruting Voe: Quilse, but it is recommended that the Gruting Voe: Browland Voe production area is decreased to exclude possible hotspots of contamination at the head of Gruting Voe and the head of Scutta Voe. Therefore it is recommended that boundaries for Gruting Voe: Browland Voe be revised to lines drawn between HU 2619 5070 and HU 2682 5070 and between HU 2764 4986 and HU 2764 4950 and between HU 2690 4939 and HU 2748 4940 extending to MHWS.

Sources of contamination were identified at the northern and eastern extremities of the voe and overall densities of livestock and human settlement were higher along the eastern side of the voe. Therefore, it is recommended that the RMP for Gruting Voe: Browland Voe be set at HU 2633 5033, and the RMP for Gruting Voe: Quilse be set at HU 2690 4874.

Only stock of a harvestable size should be sampled. Samples should be taken from within 1m of the surface to capture any contamination in the surface layer following heavy rainfall. A sampling tolerance of 20 m is recommended to allow for movement of the mussel lines.

As seasonal fluctuations in historic *E. coli* monitoring results have been found, the sampling frequency should remain monthly.

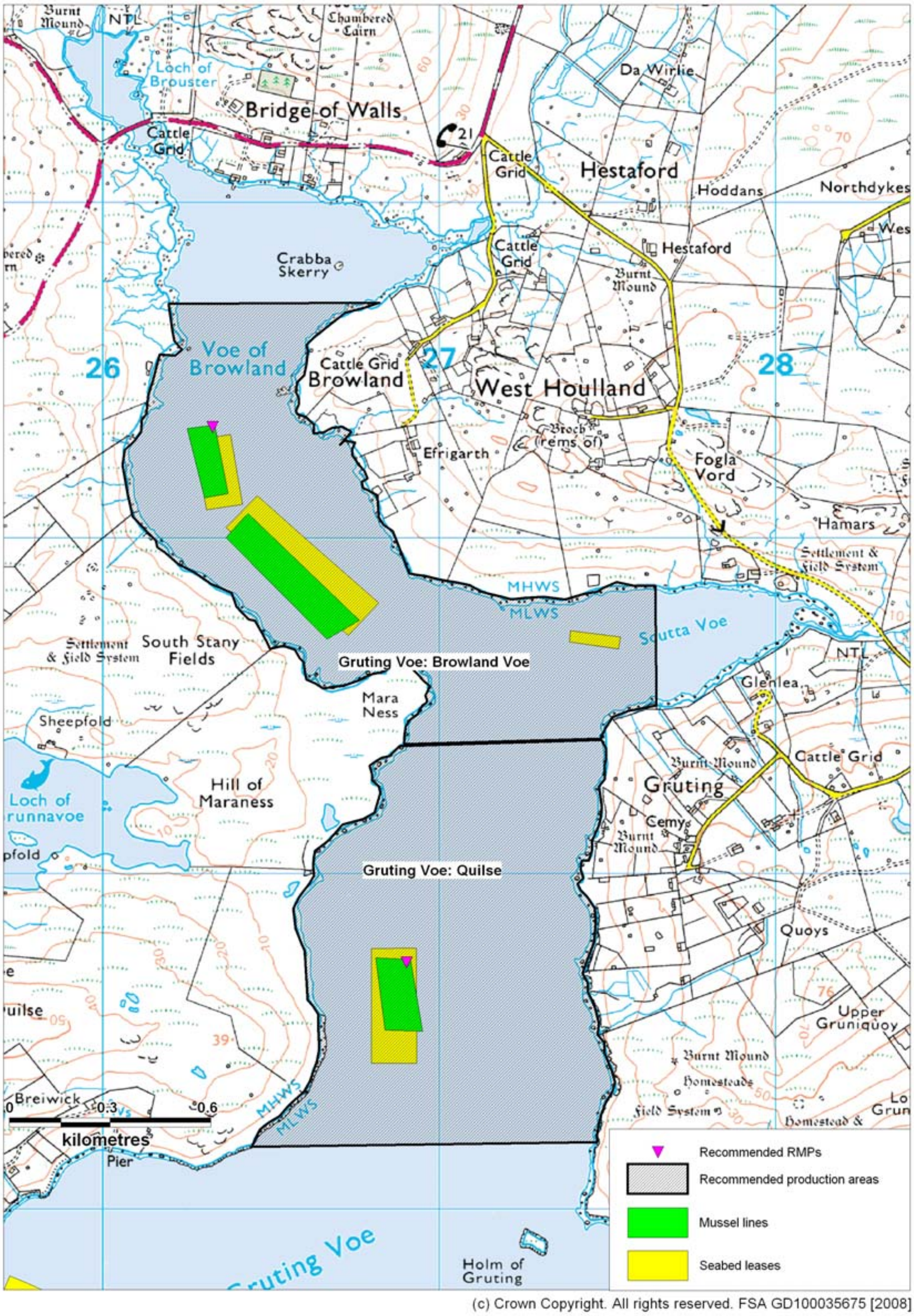


Figure 17.1 Recommended production area boundaries and RMPs

18. References

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

Burkhardt, W., Calci, K.R., Watkins, W.D., Rippey, S.R., Chirtel, S.J. 2000. Inactivation of indicator microorganisms in estuarine waters. Water Research, Volume 34(8), 2207-2214.

Edwards, A. and F. Sharples. (1986) Scottish sea lochs: a catalogue. Scottish Marine Biological Association, Oban. 250pp.

Kay, D, Crowther, J., Stapleton, C.M., Wyler, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research 42, 442-454.

Lee, R.J., Morgan, O.C. (2003). Environmental factors influencing the microbial contamination of commercially harvested shellfish. Water Science and Technology 47, 65-70.

Macaulay Institute. http://www.macaulay.ac.uk/explorescotland. Accessed September 2007.

Mallin, M.A., Ensign, S.H., McIver, M.R., Shank, G.C., Fowler, P.K. (2001). Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. Hydrobiologia 460, 185-193.

Sea Mammal Research Unit (2002). Surveys of harbour (common) seals in Shetland and Orkney, August 2001. Scottish Natural Heritage Commissioned Report F01AA417 .

Sea Mammal Research Unit (2007). The status of British common seal populations. Special Committee on Seals Briefing paper 07/3.

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Appendix 1

Sampling Plan for Gruting Voe: Browland Voe and Gruting Voe: Quilse

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Gruting Voe: Browland Voe	Browland Voe	SI 081 425 13	Mussel	Rope	HU 2633 5033	426330	1150330	20	1m	Hand	Monthly	Sheltand Islands	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Gruting Voe: Quilse	Quilse	SI 083 427 13	Mussel	Rope	HU 2690 4874	426900	1148740	20	1m	Hand	Monthly	Sheltand Islands	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson

Comparative Table of Boundaries and RMPs – Gruting Voe Browland Voe and Quilse

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Gruting Voe: Browland Voe	Common mussel	SI 081 425 13	Area within lines drawn between HU 2690 4940 to HU 2750 4940 and HU 2643 5106 to HU 2619 5100	HU268508	**Area bounded by lines drawn** between HU 2619 5070 and HU 2682 5070 and between HU 2764 4986 and HU 2764 4950 and between HU 2690 4939 and HU 2748 4940 extending to MHWS.	HU 2633 5033	Production area revised to exclude head of Gruting Voe and Scutta Voe. RMP moved to far northeastern corner of mussel farms
Gruting Voe: Quilse	Common mussel	SI 083 427 13	Area within lines drawn between HU 2645 4820 to HU 2747 4820 and HU 2750 4940 to HU 2690 4940	HU267485	Retain as currently described.	HU 2690 4874	RMP moved to northeastern corner of farm, no change to production area boundaries

Geology and Soils Assessment

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 it's 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.

Wildlife

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

A variety of cetacean species are routinely observed around the west coast of Scotland.

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

Common name	Scientific name	No. sighted*
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

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 5km 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 per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). 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 and birds are known to carry *Salmonella*.

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.

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

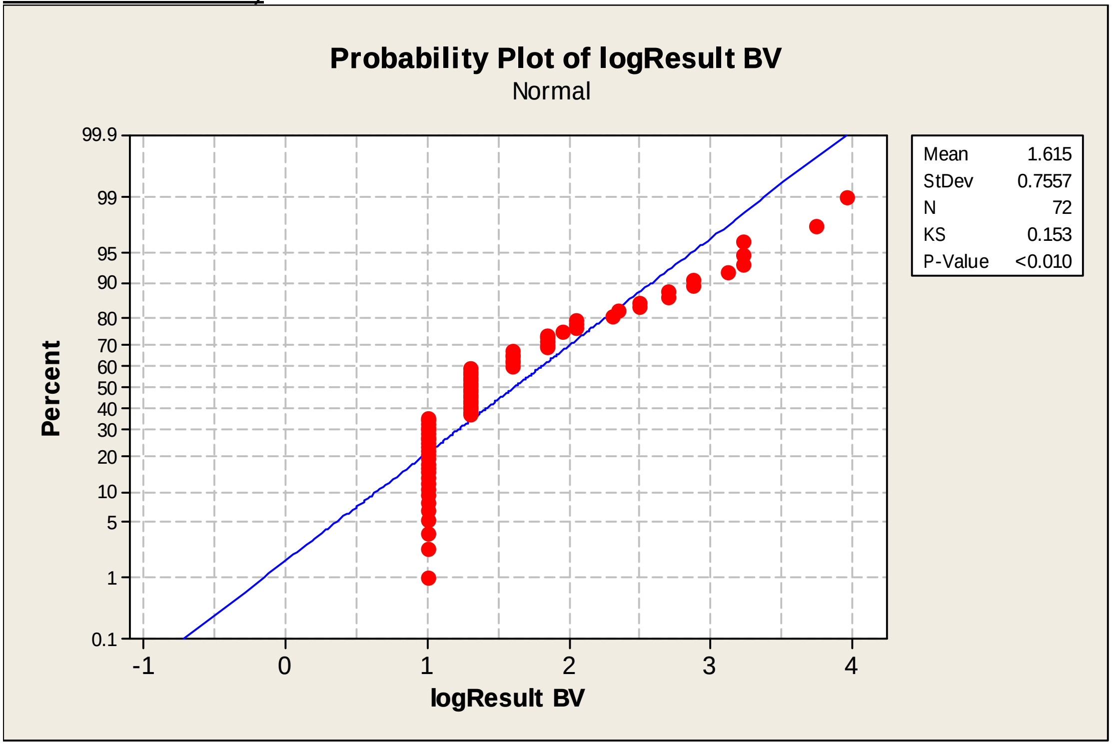
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000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

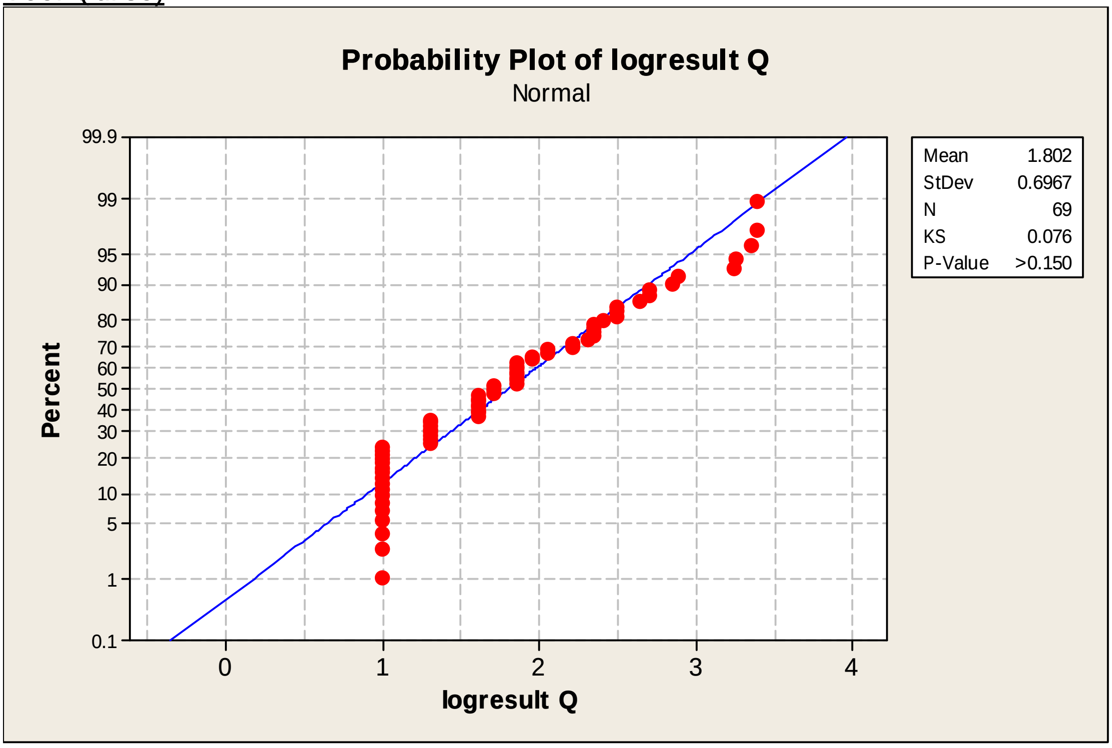
Statistical Data

All analyses were undertaken using log transformed results as this gives a more normal distribution.

Distribution on log scale with Kolmogorov-Smirnov normality test results (Gruting Voe: Browland Voe)



Distribution on log scale with Kolmogorov-Smirnov normality test results (Gruting Voe: Quilse)



Section 11.3 ANOVA comparison of results by sample location within Gruting Voe: Browland Voe

```
Source    DF      SS     MS     F      P
NGR brow   2   0.887  0.443  0.77  0.466
Error     69  39.664  0.575
Total     71  40.551

S = 0.7582   R-Sq = 2.19%   R-Sq(adj) = 0.00%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N    Mean   StDev  ------+---------+---------+---------+---
HU263501   6  1.9010  1.1298                      (-------*------)
hu268508   1  1.0000       *  (------------------*-----------------)
HU268508  65  1.5984  0.7211                        (-*-)
                              ------+---------+---------+---------+---
                                  0.00      0.80      1.60      2.40

Pooled StDev = 0.7582
```

Section 11.3 ANOVA comparison of results by sample location within Gruting Voe: Quilse

```
Source      DF      SS     MS     F      P
NGR quilse   3   0.616  0.205  0.41  0.745
Error       65  32.386  0.498
Total       68  33.003

S = 0.7059   R-Sq = 1.87%   R-Sq(adj) = 0.00%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N    Mean   StDev  -----+---------+---------+---------+----
HU266483   5  1.9539  0.8708           (------------*-----------)
HU266485  12  1.8258  0.7425             (--------*-------)
HU267485  48  1.8097  0.6887                 (---*---)
HU268486   4  1.4515  0.5764  (-------------*-------------)
                              -----+---------+---------+---------+----
                                 1.00      1.50      2.00      2.50

Pooled StDev = 0.7059
```

Section 11.3 T-test comparison of all results from Gruting Voe: Browland Voe with Gruting Voe: Quilse

```
Two-sample T for logResult

Site           N   Mean  StDev  SE Mean
Browland Voe  72  1.615  0.756    0.089
Quilse        69  1.802  0.697    0.084


Difference = mu (Browland Voe) - mu (Quilse)
Estimate for difference:  -0.187
95% CI for difference:  (-0.429, 0.055)
T-Test of difference = 0 (vs not =): T-Value = -1.53  P-Value = 0.129  DF =
138
```

Section 11.3 Paired T-test comparison of results from Gruting Voe: Browland Voe with Gruting Voe: Quilse when both sites were sampled on the same day

```
Paired T for brow for paired - quilse for paired
```

```
                   N    Mean   StDev  SE Mean
brow for paired    52  1.6009  0.7056   0.0978
quilse for paired  52  1.7980  0.7057   0.0979
Difference         52  -0.197   0.819    0.114


95% CI for mean difference: (-0.425, 0.031)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.74  P-Value = 0.089
```

Section 11.3 Chi-square for proportion of results over 230mpn/100g by production area

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Quilse   Brow  Total
    1      14     12     26
        12.72  13.28
        0.128  0.123

    2      55     60    115
        56.28  58.72
        0.029  0.028

Total      69     72    141

Chi-Sq = 0.308, DF = 1, P-Value = 0.579
```

Section 11.5 ANOVA comparison of results by season (Gruting Voe: Quilse) with Tukeys comparison

```
Source    DF      SS     MS     F      P
Season Q   3   4.589  1.530  3.50  0.020
Error     65  28.413  0.437
Total     68  33.003

S = 0.6612   R-Sq = 13.91%   R-Sq(adj) = 9.93%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      17  1.3732  0.4019    (--------*--------)
2      18  1.9695  0.9147                     (--------*--------)
3      18  2.0326  0.7022                       (--------*--------)
4      16  1.8107  0.4635                (---------*--------)
                             +---------+---------+---------+---------
                           1.05      1.40      1.75      2.10

Pooled StDev = 0.6612


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season Q

Individual confidence level = 98.96%


Season Q = 1 subtracted from:

Season Q    Lower  Center   Upper  ----+---------+---------+---------+-----
2          0.0066  0.5963  1.1861               (---------*---------)
3          0.0696  0.6594  1.2491                (---------*---------)
4         -0.1698  0.4375  1.0449           (---------*---------)
                                   ----+---------+---------+---------+-----
                                    -0.60      0.00      0.60      1.20


Season Q = 2 subtracted from:
```

```
Season Q    Lower   Center   Upper  ----+---------+---------+---------+-----
3         -0.5182   0.0631  0.6443      (---------*---------)
4         -0.7579  -0.1588  0.4404   (---------*---------)
                                    ----+---------+---------+---------+-----
                                     -0.60      0.00      0.60      1.20


Season Q = 3 subtracted from:

Season Q    Lower   Center   Upper  ----+---------+---------+---------+-----
4         -0.8210  -0.2218  0.3773  (---------*---------)
                                    ----+---------+---------+---------+-----
                                     -0.60      0.00      0.60      1.20
```

Section 11.5 ANOVA comparison of results by season (Gruting Voe: Browland Voe) with Tukeys comparison

```
Source     DF      SS     MS     F      P
Season BV   3   5.976  1.992  3.92  0.012
Error      68  34.575  0.508
Total      71  40.551

S = 0.7131   R-Sq = 14.74%   R-Sq(adj) = 10.97%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
1      18  1.1672  0.1853  (-------*--------)
2      19  1.7440  0.8846               (--------*-------)
3      18  1.9517  0.9147                    (--------*-------)
4      17  1.5899  0.5959           (--------*-------)
                           ---------+---------+---------+---------+
                                  1.20      1.60      2.00      2.40

Pooled StDev = 0.7131


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season BV

Individual confidence level = 98.95%


Season BV = 1 subtracted from:

Season
BV        Lower  Center   Upper  ----+---------+---------+---------+-----
2       -0.0402  0.5767  1.1937            (--------*--------)
3        0.1592  0.7844  1.4097               (--------*--------)
4       -0.2116  0.4227  1.0571          (--------*--------)
                                 ----+---------+---------+---------+-----
                                  -0.70      0.00      0.70      1.40


Season BV = 2 subtracted from:

Season
BV        Lower   Center   Upper  ----+---------+---------+---------+-----
3       -0.4092   0.2077  0.8247        (--------*--------)
4       -0.7802  -0.1540  0.4722   (--------*--------)
                                  ----+---------+---------+---------+-----
                                   -0.70      0.00      0.70      1.40


Season BV = 3 subtracted from:

Season
BV        Lower   Center   Upper  ----+---------+---------+---------+-----
```

```
4       -0.9961  -0.3617  0.2726  (--------*--------)
                                  ----+---------+---------+---------+-----
                                   -0.70      0.00      0.70      1.40
```

Section 11.3 Chi-square for proportion of results over 230mpn/100g by season

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Spring  Summer  Autumn  Winter  Total
    1       0      12       9       5     26
         6.59    6.97    6.78    5.65
        6.594   3.628   0.725   0.075

    2      35      25      27      25    112
        28.41   30.03   29.22   24.35
        1.531   0.842   0.168   0.017

Total      35      37      36      30    138

Chi-Sq = 13.581, DF = 3, P-Value = 0.004
```

Section 11.6.1 Regression analysis - log Result versus rain in previous 2 days (Gruting Voe: Browland Voe)

```
The regression equation is
logres prev 2 brow = 1.38 + 0.0305 rain prev 2 brow


Predictor            Coef  SE Coef      T      P
Constant           1.3813   0.1235  11.19  0.000
rain prev 2 brow  0.03047  0.01231   2.47  0.016


S = 0.717537   R-Sq = 9.4%   R-Sq(adj) = 7.9%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   3.1530  3.1530  6.12  0.016
Residual Error  59  30.3767  0.5149
Total           60  33.5297


Unusual Observations

       rain  logres
     prev 2  prev 2
Obs    brow    brow     Fit  SE Fit  Residual  St Resid
 26    23.4  1.0000  2.0943  0.2252   -1.0943     -1.61 X
 27    41.4  2.4914  2.6427  0.4370   -0.1513     -0.27 X
 34     3.4  3.7324  1.4849  0.1005    2.2475      3.16R
 49    11.6  3.2304  1.7347  0.1099    1.4957      2.11R
 58    18.8  3.9590  1.9541  0.1750    2.0049      2.88R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.1 Regression analysis - log Result versus rain in previous 2 days (Gruting Voe: Quilse)

```
The regression equation is
logres prev 2 quilse = 1.73 + 0.0154 rain prev 2 quilse
```

```
Predictor              Coef  SE Coef      T      P
Constant             1.7287   0.1227  14.09  0.000
rain prev 2 quilse  0.01536  0.01314   1.17  0.247


S = 0.710384   R-Sq = 2.4%   R-Sq(adj) = 0.6%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.6892  0.6892  1.37  0.247
Residual Error  56  28.2601  0.5046
Total           57  28.9494


Unusual Observations

       rain  logres
     prev 2  prev 2
Obs  quilse  quilse     Fit  SE Fit  Residual  St Resid
  8     6.6  3.3802  1.8301  0.0935    1.5501      2.20R
  9     1.7  3.2304  1.7549  0.1095    1.4756      2.10R
 25    13.4  3.3424  1.9346  0.1341    1.4079      2.02R
 28    41.4  1.8451  2.3646  0.4736   -0.5195     -0.98 X
 44     0.0  3.3802  1.7287  0.1227    1.6515      2.36R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 2 days (Gruting Voe: Browland Voe)

```
Source     DF      SS     MS     F      P
rq2d brow   3   2.526  0.842  1.55  0.212
Error      57  31.004  0.544
Total      60  33.530

S = 0.7375   R-Sq = 7.53%   R-Sq(adj) = 2.67%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
Q1     14  1.2638  0.4092  (----------*----------)
Q2     16  1.5324  0.7239          (----------*---------)
Q3     14  1.6930  0.7026              (----------*-----------)
Q4     17  1.8117  0.9536                   (---------*---------)
                           -----+---------+---------+---------+----
                              1.05      1.40      1.75      2.10

Pooled StDev = 0.7375
```

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 2 days (Gruting Voe: Quilse)

```
Source       DF      SS     MS     F      P
rq2d quilse   3   1.316  0.439  0.86  0.469
Error        54  27.633  0.512
Total        57  28.949

S = 0.7153   R-Sq = 4.55%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
Q1     14  1.7940  0.7141       (------------*------------)
```

```
Q2     16  1.6332  0.7476  (-----------*-----------)
Q3     15  1.8444  0.6905         (-----------*------------)
Q4     13  2.0585  0.7038               (-------------*-----------)
                           --------+---------+---------+---------+-
                                1.50      1.80      2.10      2.40

Pooled StDev = 0.7153
```

Section 11.6.1 Regression analysis - log Result versus rain in previous 7 days (Gruting Voe: Browland Voe)

```
The regression equation is
logres prev 7 brow = 1.15 + 0.0171 rain prev 7 brow


Predictor             Coef   SE Coef     T      P
Constant            1.1475    0.1345  8.53  0.000
rain prev 7 brow  0.017065  0.004003  4.26  0.000


S = 0.662640   R-Sq = 23.9%   R-Sq(adj) = 22.5%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   7.9802  7.9802  18.17  0.000
Residual Error  58  25.4673  0.4391
Total           59  33.4475


Unusual Observations

       rain  logres
     prev 7  prev 7
Obs    brow    brow     Fit  SE Fit  Residual  St Resid
 25    94.4  1.0000  2.7584  0.2871   -1.7584    -2.94RX
 33    39.3  3.7324  1.8181  0.1009    1.9143      2.92R
 48    74.8  3.2304  2.4239  0.2135    0.8065      1.29 X
 57    62.2  3.9590  2.2089  0.1685    1.7502      2.73R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.1 Regression analysis - log Result versus rain in previous 7 days (Gruting Voe: Quilse)

```
The regression equation is
logres prev 7 quilse = 1.52 + 0.0123 rain prev 7 quilse


Predictor               Coef   SE Coef     T      P
Constant              1.5214    0.1573  9.67  0.000
rain prev 7 quilse  0.012336  0.005113  2.41  0.019


S = 0.686609   R-Sq = 9.6%   R-Sq(adj) = 7.9%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.7445  2.7445  5.82  0.019
Residual Error  55  25.9287  0.4714
Total           56  28.6732


Unusual Observations
```

```
       rain  logres
     prev 7  prev 7
Obs  quilse  quilse     Fit  SE Fit  Residual  St Resid
  7     7.8  3.3802  1.6176  0.1269    1.7626     2.61R
  8    14.8  3.2304  1.7040  0.1051    1.5265     2.25R
 43    19.4  3.3802  1.7607  0.0955    1.6195     2.38R
 48    74.8  3.2430  2.4441  0.2698    0.7989     1.27 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 7 days (Gruting Voe: Browland Voe)

```
Source     DF      SS     MS     F      P
rq7d brow   3   7.532  2.511  5.42  0.002
Error      56  25.916  0.463
Total      59  33.447

S = 0.6803   R-Sq = 22.52%   R-Sq(adj) = 18.37%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
Q1     15  1.2863  0.4039  (--------*--------)
Q2     17  1.3404  0.4301    (--------*-------)
Q3      9  1.4867  0.6727     (----------*-----------)
Q4     19  2.1026  0.9733                      (-------*------)
                           -------+---------+---------+---------+--
                                1.20      1.60      2.00      2.40

Pooled StDev = 0.6803


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of rq7d brow

Individual confidence level = 98.94%


rq7d brow = Q1 subtracted from:

rq7d
brow    Lower  Center   Upper  -------+---------+---------+---------+--
Q2    -0.5833  0.0540  0.6914            (-------*-------)
Q3    -0.5582  0.2004  0.9589            (---------*--------)
Q4     0.1949  0.8163  1.4377                     (-------*-------)
                               -------+---------+---------+---------+--
                                   -0.80      0.00      0.80      1.60


rq7d brow = Q2 subtracted from:

rq7d
brow    Lower  Center   Upper  -------+---------+---------+---------+--
Q3    -0.5953  0.1463  0.8880            (--------*--------)
Q4     0.1616  0.7623  1.3629                     (-------*------)
                               -------+---------+---------+---------+--
                                   -0.80      0.00      0.80      1.60


rq7d brow = Q3 subtracted from:

rq7d
brow    Lower  Center   Upper  -------+---------+---------+---------+--
Q4    -0.1121  0.6159  1.3439                  (--------*--------)
                               -------+---------+---------+---------+--
                                   -0.80      0.00      0.80      1.60
```

Section 11.6.1 ANOVA comparison of log Result versus rainfall quartile in previous 7 days (Gruting Voe: Quilse)

```
Source       DF      SS     MS     F      P
rq7d quilse   3   3.960  1.320  2.83  0.047
Error        53  24.713  0.466
Total        56  28.673

S = 0.6828   R-Sq = 13.81%   R-Sq(adj) = 8.93%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
Q1     11  1.7465  0.8428       (----------*---------)
Q2     15  1.8270  0.8291           (--------*--------)
Q3     15  1.4992  0.4010   (-------*--------)
Q4     16  2.2043  0.6182                     (-------*--------)
                            -+---------+---------+---------+--------
                           1.20      1.60      2.00      2.40

Pooled StDev = 0.6828


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of rq7d quilse

Individual confidence level = 98.95%


rq7d quilse = Q1 subtracted from:

rq7d
quilse    Lower   Center   Upper  ---------+---------+---------+---------+
Q2      -0.6383   0.0805  0.7993            (---------*---------)
Q3      -0.9661  -0.2473  0.4715       (---------*----------)
Q4      -0.2513   0.4579  1.1671                 (----------*---------)
                                  ---------+---------+---------+---------+
                                        -0.70      0.00      0.70      1.40


rq7d quilse = Q2 subtracted from:

rq7d
quilse    Lower   Center   Upper  ---------+---------+---------+---------+
Q3      -0.9890  -0.3278  0.3334       (--------*---------)
Q4      -0.2734   0.3774  1.0281                 (--------*---------)
                                  ---------+---------+---------+---------+
                                        -0.70      0.00      0.70      1.40


rq7d quilse = Q3 subtracted from:

rq7d
quilse   Lower  Center   Upper  ---------+---------+---------+---------+
Q4      0.0544  0.7052  1.3559                      (--------*--------)
                                ---------+---------+---------+---------+
                                      -0.70      0.00      0.70      1.40
```

Section 11.6.2 Regression analysis - log Result versus tide height (Gruting Voe: Browland Voe)

```
The regression equation is
logresult brow = 1.68 - 0.067 Height Brow


Predictor       Coef  SE Coef      T      P
Constant      1.6793   0.8364   2.01  0.050
Height Brow  -0.0674   0.5679  -0.12  0.906
```

```
S = 0.706137   R-Sq = 0.0%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0070  0.0070  0.01  0.906
Residual Error  52  25.9287  0.4986
Total           53  25.9358


Unusual Observations

     Height  logresult
Obs    Brow       brow     Fit  SE Fit  Residual  St Resid
  8    1.70     3.2304  1.5647  0.1654    1.6657      2.43R
 11    1.30     3.2304  1.5917  0.1334    1.6387      2.36R
 51    1.20     3.9590  1.5985  0.1776    2.3606      3.45R

R denotes an observation with a large standardized residual.
```

Section 11.6.2 Regression analysis - log Result versus tide height (Gruting Voe: Quilse)

```
The regression equation is
Logresult quilse = 0.767 + 0.676 Height Quilse


Predictor        Coef  SE Coef     T      P
Constant       0.7667   0.7778  0.99  0.328
Height Quilse  0.6759   0.5321  1.27  0.209


S = 0.679844   R-Sq = 2.7%   R-Sq(adj) = 1.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.7456  0.7456  1.61  0.209
Residual Error  59  27.2691  0.4622
Total           60  28.0147


Unusual Observations

     Height  Logresult
Obs  Quilse     quilse     Fit  SE Fit  Residual  St Resid
 19    1.30     3.3802  1.6454  0.1190    1.7349      2.59R
 20    1.50     3.2304  1.7805  0.0906    1.4499      2.15R
 36    1.80     3.3424  1.9833  0.2044    1.3591      2.10R
 51    1.20     3.3802  1.5778  0.1601    1.8024      2.73R

R denotes an observation with a large standardized residual.
```

Section 11.6.2 Circular-linear correlation of tidal state and log result (Gruting Voe: Browland Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 18 July 2008 12:16:58

Variables (& observations)	r	p
Angles & Linear (54)	0.061	0.825

Section 11.6.2 Circular-linear correlation of tidal state and log result (Gruting Voe: Quilse)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 18 July 2008 12:21:22

Variables (& observations)	r	p
Angles & Linear (61)	0.187	0.131

Section 11.6.4 Circular-linear correlation of wind direction and log result (Gruting Voe: Browland Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 07 July 2008 09:06:02

Variables (& observations)	r	p
Angles & Linear (56)	0.332	0.003

Section 11.6.4 Circular-linear correlation of wind direction and log result (Gruting Voe: Quilse)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 07 July 2008 09:10:00

Variables (& observations)	r	p
Angles & Linear (54)	0.114	0.513

Section 12 ANOVA comparison of SEPA monitoring results by quarter

```
Source  DF      SS     MS     F      P
C1       3   5.492  1.831  3.17  0.068
Error   11   6.359  0.578
Total   14  11.851

S = 0.7603   R-Sq = 46.34%   R-Sq(adj) = 31.71%


                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev    +---------+---------+---------+---------
Q1     4  1.8805  0.3237    (--------*-------)
Q2     3  3.1131  0.7556               (---------*---------)
Q3     4  3.4735  0.8819                    (--------*-------)
Q4     4  2.7672  0.9254             (--------*-------)
                            +---------+---------+---------+---------
                          1.0       2.0       3.0       4.0

Pooled StDev = 0.7603
```

Hydrographic Methods

Introduction

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. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. 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 focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

Background processes

This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. 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.

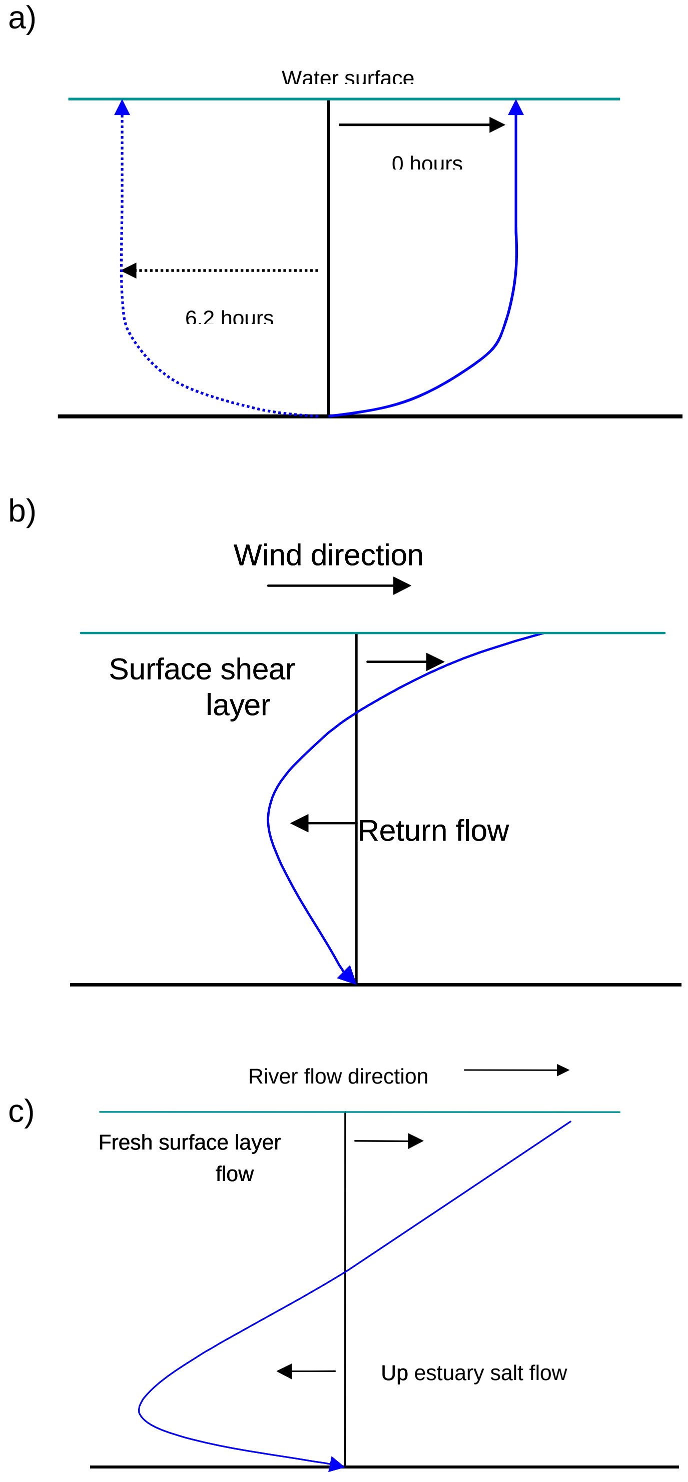


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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.

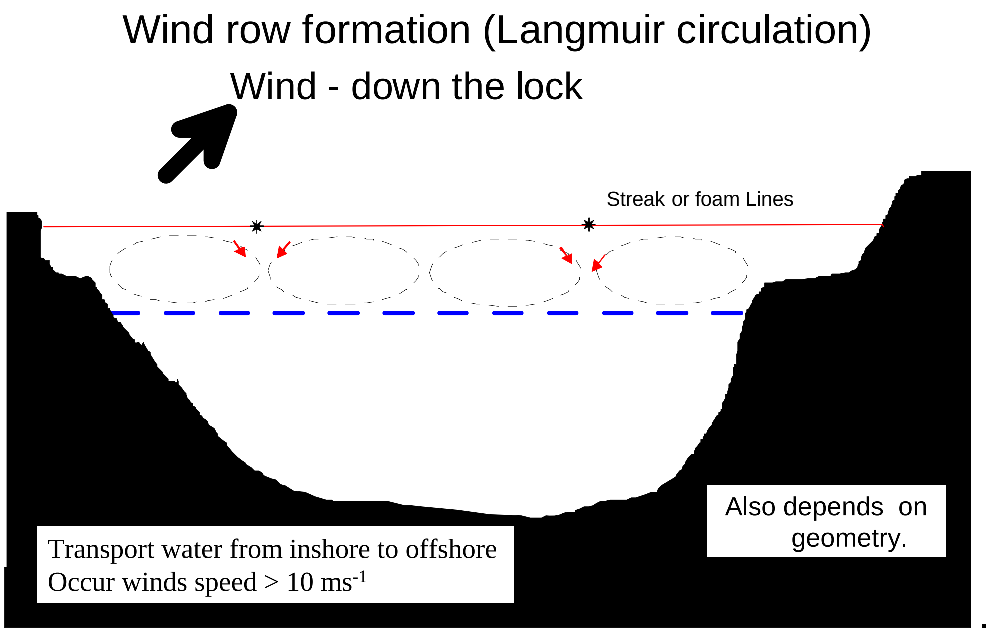


Figure 2: Schematic of wind driven ‘wind row’ currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Survey Area: Gruting Voe: Browland Voe (SI 081) and Quilse (SI 083)

Scottish Sanitary Survey Project

Shoreline Survey Report

Production Areas:

Production Area	Site	SIN	Species
Gruting Voe: Browland Voe	Browland Voe	SI 081 425 08	Common mussels
Gruting Voe: Quilse	Quilse	SI 083 427 08	Common mussels

Harvester: Browland Voe – Richard/Michael Tait, North Atlantic Shellfish
Quilse – Peter Tait
Status: Both production areas are currently classified for harvest.
Date Surveyed: 4/6/08 and 5/6/08
Surveyed by: Sean Williamson, Alastair Cook
Existing RMPs: NR 748202, NR 752198
Area Surveyed: See Figure 1.

Weather observations

4/6/08 – 29 km/h easterly wind, 12 ºC, rain.
5/6/08 – 17 km/h easterly wind, 13 ºC, dry.
Recent rainfall had been low.

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. Salinity profiles are presented in Table 4. Photographs are presented in Figures 5-12.

Fishery

Gruting Voe: Browland Voe (SI 081 425 08). This site consisted of two large blocks of rope grown mussels in close proximity. The larger block, to the south consisted of seven 440 m lines with 7 m droppers. The smaller block to the south consisted of five 220 m lines with 5 m droppers. Stock of a range of sizes was present, including stock of a harvestable size. There is a third smaller crown estates lease to the east of the existing sites that is unoccupied at present.

Gruting Voe: Quilse (SI 083 427 08). This site consisted of one block of five 220 m long lines, with 12 m droppers. Stock of a range of sizes was present, including stock of a harvestable size.

Both sites are harvested year round, with timing of harvesting depending on demand, biotoxin status, and the status of other sites under the same ownership.

Sewage/Faecal Sources

Human – Population on the shores of the voe is low and is confined to the eastern shore. Wastewater discharges direct to the voe were only found in two areas (Bridge of Walls and at the head of Scutta Voe) where the buildings were close to the shoreline. Where buildings were further back from the shoreline it is likely that any wastewater overflows from septic tanks discharge to soakaway. No sewage related debris was seen in the tideline anywhere around the voe.

Livestock – The entire area surrounding the voe is pasture that is grazed by sheep, which are likely to be the primary impact on the microbiological quality of the voe. A total of almost 400 sheep were recorded during the survey, with highest concentrations around the settlements on the east shore. Droppings were present in all areas. Sheep had access the shoreline around most of the voe.

A few streams discharge into the voe, which has a relatively large catchment area for Shetland. These drain areas of pasture. Water samples were taken, and discharge estimated for these. It must be noted that water levels were very low, as rainfall in the weeks prior to the survey was very low. A number of dry streambeds were encountered, and some other streambeds were still wetted in places but had negligible flow, even on the second day of the survey following rain on the first day. Stream inputs had low to moderate levels of *E. coli* (20-600 cfu/100ml).

The highest result *E. coli* result for a seawater sample (1000 cfu/100ml) came from Scutta Voe, next to the sewage discharge from the village hall. High *E. coli* results were also found in seawater samples taken around the head of the voe (two samples giving a result of 100 cfu/100ml). Seawater samples taken from the shore in other areas had lower levels of *E. coli* (<20 cfu/100ml). Seawater samples taken offshore in the vicinity of the mussel farms had very low levels of *E. coli* (<1 cfu/100 ml in all cases).

Rope mussel samples gave results ranging from 50 to 16000 *E. coli* mpn/100g. Five of the 12 samples exceeded 230 *E. coli* mpn/100g, and two exceeded 1000 *E. coli* mpn/100g. The highest result (16000 *E. coli* mpn/100g) was obtained from a sample taken near the surface.

Salinity profiles taken from around the mussel lines indicated very low freshwater influence at all sites at the time of survey. It must be noted that the survey was undertaken following a prolonged dry spell. The grower advised that turbidity in the voe often increases during the winter months due to high inputs of fresh water.

<u>Seasonal Population</u>

A small number of the dwellings seen on the shoreline survey are believed to be holiday homes. However, there is nothing in the way of attractions in the area so it is unlikely that there are significant inundations of visitors during the summer season.

Boats/Shipping

No boats were seen during the course of the shoreline survey. A small marina is proposed near the village hall at the head of Scutta Voe, but this is still at the planning stage and construction has not yet started.

Land Use

The entire area surrounding the voe is pasture, some of which appeared to be improved, with the majority unimproved. All pasture in the area is grazed by sheep. One field that had recently been ploughed was seen (Figure 9).

Wildlife/Birds

Rabbits are present on all pastureland, but not in great numbers. Seven seals were seen just off Browland. A group of approximately 50 ducks was disturbed from the Quilse site. Aside from these, and a few seabirds, no other aggregations of wildlife were seen.

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 voe.

Figure 1. Map of Shoreline Observations

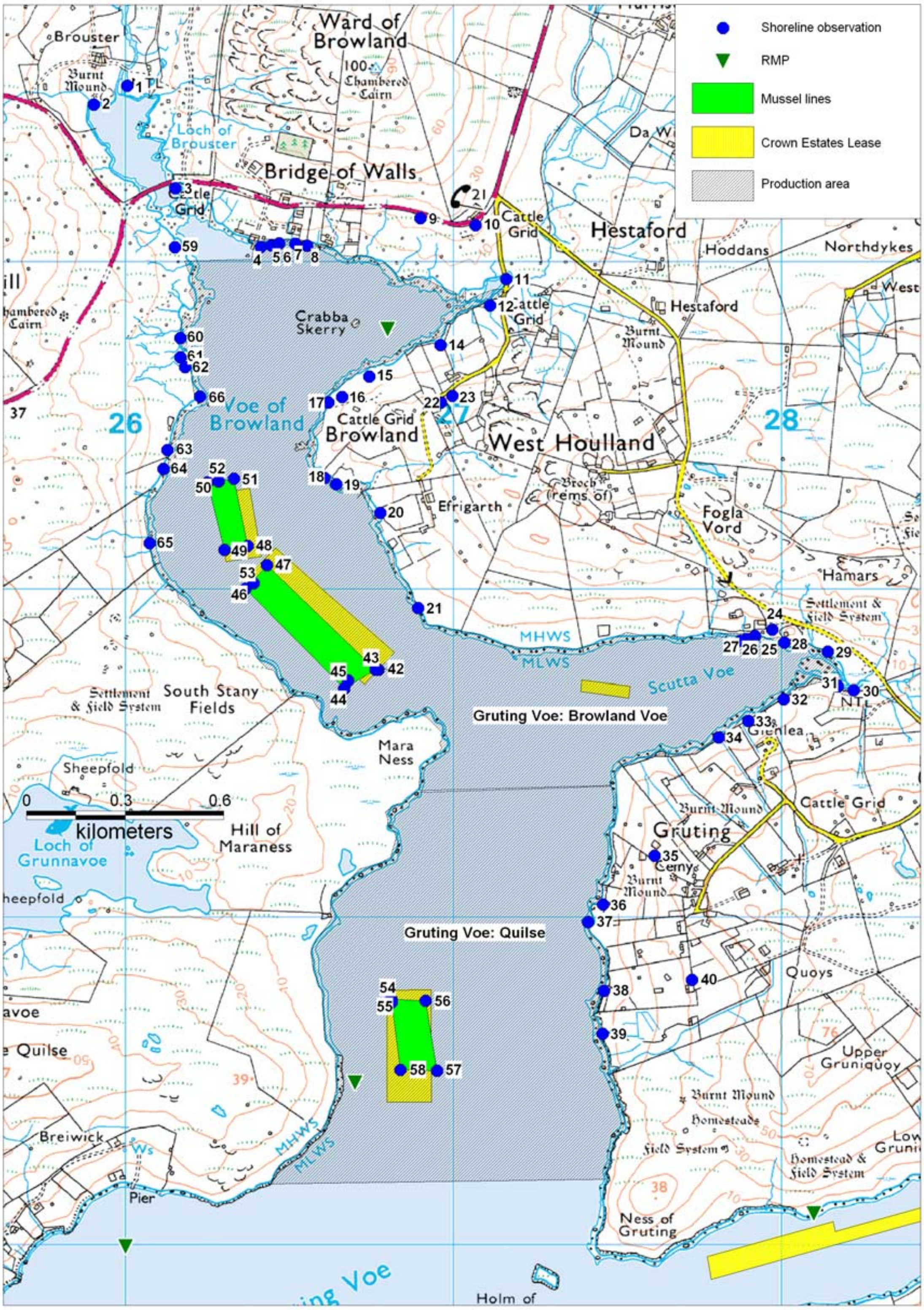


Table 1. Shoreline Observations

No.	Date and time	Grid reference	Photo	Description
1	04-JUN-08 11:22:09AM	HU 26005 51538		Stream 155cmx15cmx0.211m/s. Water sample 1 (fresh)
2	04-JUN-08 11:28:03AM	HU 25903 51480		9 sheep and 1 new house ~100m back
3	04-JUN-08 11:35:51AM	HU 26152 51225		Water sample 2 (seawater)
4	04-JUN-08 11:44:44AM	HU 26413 51046	Figure 5	Terrace of 3 houses on shore. 150mm orange plastic sewage pipe to underwater. Water sample 3 (seawater) taken alongside pipe
5	04-JUN-08 11:47:18AM	HU 26444 51051		Bungalow on shoreline, 3 houses further back.
6	04-JUN-08 11:48:42AM	HU 26469 51057	Figure 6	Septic tank, no apparent overflow
7	04-JUN-08 11:49:47AM	HU 26518 51055	Figure 7	110mm metal sewer pipe to underwater, 2 houses further back
8	04-JUN-08 11:59:44AM	HU 26554 51050		Holiday house with jetty
9	04-JUN-08 12:11:54PM	HU 26899 51134		6 sheep
10	04-JUN-08 12:13:13PM	HU 27067 51112		House
11	04-JUN-08 12:32:35PM	HU 27161 50948		Stream 180cmx1cmx0.272m/s. Water sample 4 (fresh)
12	04-JUN-08 12:37:32PM	HU 27112 50867		Field of 12 sheep
13	04-JUN-08 12:41:55PM	HU 26961 50746		Field of 45 sheep
14	04-JUN-08 12:42:01PM	HU 26961 50746	Figure 8	Field of 20 sheep. 4 houses further back. Rabbits seen everywhere around the loch so far. 7 seals just offshore.
15	04-JUN-08 12:49:14PM	HU 26743 50650		Field of 10 sheep
16	04-JUN-08 12:50:47PM	HU 26660 50587		Field of 12 sheep
17	04-JUN-08 12:55:53PM	HU 26618 50571		Water sample 5 (seawater)
18	04-JUN-08 1:02:02PM	HU 26607 50340		Stream 20cmx1cmx0.155m/s. Water sample 6 (freshwater)
19	04-JUN-08 1:05:06PM	HU 26642 50321		6 sheep. 4 ducks
20	04-JUN-08 1:08:25PM	HU 26777 50233		13 sheep
21	04-JUN-08 1:13:17PM	HU 26892 49943		Water sample 7 (seawater)
22	04-JUN-08 1:26:56PM	HU 26962 50570	Figure 9	Ploughed field
23	04-JUN-08 1:28:02PM	HU 26996 50591		30 sheep
24	04-JUN-08 1:42:36PM	HU 27972 49877		Village hall, jetty. (Sean advises a marina may be built here in the near future).
25	04-JUN-08 1:44:40PM	HU 27920 49858	Figure 10	Concrete casing for sewer pipe to underwater.
26	04-JUN-08 1:45:37PM	HU 27893 49848		4 sheep
27	04-JUN-08 1:46:16PM	HU 27876 49843		Water sample 8 (seawater)
28	04-JUN-08 1:50:42PM	HU 28010 49837		Wooden chalet, 1 holiday house
29	04-JUN-08 1:53:02PM	HU 28141 49810		8 sheep
30	04-JUN-08 2:00:51PM	HU 28221 49693		Stream 135cmx22cmx0.061m/s. Water sample 9 (freshwater).
31	04-JUN-08 2:03:47PM	HU 28172 49705	Figure 11	Sheep droppings on beach. Sheep have access to the shore around most of the voe.
32	04-JUN-08 2:08:01PM	HU 28007 49666		40 sheep
33	04-JUN-08 2:10:25PM	HU 27899 49599		30 sheep and 2 houses back from the shore

34	04-JUN-08 2:12:54PM	HU 27809 49549		27 sheep and 2 houses back from here
35	04-JUN-08 2:35:26PM	HU 27613 49188		35 sheep
36	04-JUN-08 2:40:39PM	HU 27456 49039		8 sheep
37	04-JUN-08 2:42:09PM	HU 27411 48985		Water sample 10 (seawater)
38	04-JUN-08 2:48:53PM	HU 27459 48775		Very small stream impossible to measure
39	04-JUN-08 2:52:13PM	HU 27455 48644		Stream 10cmx5cmx0.204m/s. Water sample 11 (freshwater)
40	04-JUN-08 3:05:09PM	HU 27727 48809		40 sheep
41	04-JUN-08 3:19:59PM	HU 27807 52573		No observation
42	05-JUN-08 9:24:42AM	HU 26771 49754		No observation
43	05-JUN-08 9:24:54AM	HU 26762 49755		Corner 1 of lines (7 lines wide, 440m long, 7m droppers)
44	05-JUN-08 9:26:05AM	HU 26666 49698		Corner 2 of lines
45	05-JUN-08 9:27:17AM	HU 26678 49722		Water sample 12 (seawater), mussel samples 1 (7m depth), 2 (4m depth) and 3 (1m depth). Salinity profile 1.
46	05-JUN-08 9:46:05AM	HU 26365 50002		Corner 3 of lines
47	05-JUN-08 9:46:42AM	HU 26431 50074		Corner 4 of lines
48	05-JUN-08 9:47:38AM	HU 26372 50133		Corner 1 of lines (6 lines wide, 220m long, 5m droppers)
49	05-JUN-08 9:48:11AM	HU 26301 50120		Corner 2 of lines
50	05-JUN-08 9:50:30AM	HU 26250 50327		Corner 3 of lines
51	05-JUN-08 9:51:11AM	HU 26331 50338		Corner 4 of lines
52	05-JUN-08 9:52:11AM	HU 26283 50329		Water sample 13(seawater), mussel samples 4 (5m depth) and 5 (1m depth). Salinity profile 2. Depth here only 8m so no reading at 10m.
53	05-JUN-08 10:21:47AM	HU 26391 50018		Water sample 14 (seawater), mussel samples 6 (7m depth), 7 (4m depth) and 8 (1m depth). Salinity profile 3.
54	05-JUN-08 10:28:25AM	HU 26811 48750		Corner 1 of lines (6 lines, 12 m droppers)
55	05-JUN-08 10:30:19AM	HU 26812 48740		Water sample 15 (seawater), mussel samples 9 (12m depth), 10 (6m depth) and 11 (1m depth). Salinity profile 4.
56	05-JUN-08 10:43:05AM	HU 26915 48745		Corner 2 of lines
57	05-JUN-08 10:44:10AM	HU 26950 48531		Corner 3 of lines. 50 ducks disturbed. Water sample 16 (seawater). Mussel sample 12 (1m depth). Salinity profile 5.
58	05-JUN-08 10:55:38AM	HU 26838 48534		Corner 4 of lines
59	05-JUN-08 12:06:50PM	HU 26150 51045		Dry stream. 24 sheep
60	05-JUN-08 12:13:09PM	HU 26167 50768	Figure 12	Dry stream.
61	05-JUN-08 12:14:28PM	HU 26167 50709		Dry stream.
62	05-JUN-08 12:16:20PM	HU 26181 50678		Stream 30cmx2.5cmx0.037m/s. Water sample 17 (freshwater)
63	05-JUN-08 12:22:32PM	HU 26128 50425		16 sheep back from here
64	05-JUN-08 12:24:22PM	HU 26116 50368		Toothbrush in tideline (not considered to be sewage related debris)
65	05-JUN-08 12:29:24PM	HU 26073 50141		Dry stream. Water sample 18 (seawater)
66	05-JUN-08 12:44:57PM	HU 26227 50589		Water sample 19 (seawater)

Table 2. Water Sample *E. coli* Results

Sample ID	Date and time collected	Grid reference	Type	*E. coli* (cfu/100ml)
Sample 1	04-JUN-08 11:22:09AM	HU 26005 51538	Freshwater	110
Sample 2	04-JUN-08 11:35:51AM	HU 26152 51225	Seawater*	100
Sample 3	04-JUN-08 11:44:44AM	HU 26413 51046	Seawater*	100
Sample 4	04-JUN-08 12:32:35PM	HU 27161 50948	Freshwater	140
Sample 5	04-JUN-08 12:55:53PM	HU 26618 50571	Seawater*	1
Sample 6	04-JUN-08 1:02:02PM	HU 26607 50340	Freshwater	600
Sample 7	04-JUN-08 1:13:17PM	HU 26892 49943	Seawater*	8
Sample 8	04-JUN-08 1:46:16PM	HU 27876 49843	Seawater*	1000
Sample 9	04-JUN-08 2:00:51PM	HU 28221 49693	Freshwater	500
Sample 10	04-JUN-08 2:42:09PM	HU 27411 48985	Seawater*	13
Sample 11	04-JUN-08 2:52:13PM	HU 27455 48644	Freshwater	20
Sample 12	05-JUN-08 9:27:17AM	HU 26678 49722	Seawater*	<1
Sample 13	05-JUN-08 9:52:11AM	HU 26283 50329	Seawater*	<1
Sample 14	05-JUN-08 10:21:47AM	HU 26391 50018	Seawater*	<1
Sample 15	05-JUN-08 10:30:19AM	HU 26812 48740	Seawater*	<1
Sample 16	05-JUN-08 10:44:10AM	HU 26950 48531	Seawater*	<1
Sample 17	05-JUN-08 12:16:20PM	HU 26181 50678	Freshwater	300
Sample 18	05-JUN-08 12:29:24PM	HU 26073 50141	Seawater*	5
Sample 19	05-JUN-08 12:44:57PM	HU 26227 50589	Seawater*	4

*Salinty measurements not available

Table 3. Shellfish Sample *E. coli* Results

No	Species	Date and time collected	Grid reference	Depth (m)	*E. coli* result (mpn/100g)
Mussel 1	Rope mussel	05-JUN-08 9:27:17AM	HU 26678 49722	7	140
Mussel 2	Rope mussel	05-JUN-08 9:27:17AM	HU 26678 49722	4	330
Mussel 3	Rope mussel	05-JUN-08 9:27:17AM	HU 26678 49722	1	50
Mussel 4	Rope mussel	05-JUN-08 9:52:11AM	HU 26283 50329	5	230
Mussel 5	Rope mussel	05-JUN-08 9:52:11AM	HU 26283 50329	1	80
Mussel 6	Rope mussel	05-JUN-08 10:21:47AM	HU 26391 50018	7	220
Mussel 7	Rope mussel	05-JUN-08 10:21:47AM	HU 26391 50018	4	1300
Mussel 8	Rope mussel	05-JUN-08 10:21:47AM	HU 26391 50018	1	16000
Mussel 9	Rope mussel	05-JUN-08 10:30:19AM	HU 26812 48740	12	50
Mussel 10	Rope mussel	05-JUN-08 10:30:19AM	HU 26812 48740	6	790
Mussel 11	Rope mussel	05-JUN-08 10:30:19AM	HU 26812 48740	1	170
Mussel 12	Rope mussel	05-JUN-08 10:44:10AM	HU 26950 48531	1	490

Table 4. Salinity profiles

Profile No.	Date and time	Grid reference	Depth (m)	Salinity (ppt)	Temperature (ºC)
1	05-JUN-08 9:27:17AM	HU 26678 49722	0	34.7	11.8
1	05-JUN-08 9:27:17AM	HU 26678 49722	2.5	34.8	11.8
1	05-JUN-08 9:27:17AM	HU 26678 49722	5	34.8	11.5
1	05-JUN-08 9:27:17AM	HU 26678 49722	7.5	34.8	11.4
1	05-JUN-08 9:27:17AM	HU 26678 49722	10	34.8	11.2
2	05-JUN-08 9:52:11AM	HU 26283 50329	0	34.7	12.4
2	05-JUN-08 9:52:11AM	HU 26283 50329	2.5	34.7	12.3
2	05-JUN-08 9:52:11AM	HU 26283 50329	5	34.7	11.8
2	05-JUN-08 9:52:11AM	HU 26283 50329	7.5	34.7	11.6
3	05-JUN-08 10:21:47AM	HU 26391 50018	0	34.6	12.4
3	05-JUN-08 10:21:47AM	HU 26391 50018	2.5	34.7	12.2
3	05-JUN-08 10:21:47AM	HU 26391 50018	5	34.7	11.9
3	05-JUN-08 10:21:47AM	HU 26391 50018	7.5	34.7	11.8
3	05-JUN-08 10:21:47AM	HU 26391 50018	10	34.7	11.4
4	05-JUN-08 10:30:19AM	HU 26812 48740	0	34.8	11.6
4	05-JUN-08 10:30:19AM	HU 26812 48740	2.5	34.8	11.5
4	05-JUN-08 10:30:19AM	HU 26812 48740	5	34.8	11.4
4	05-JUN-08 10:30:19AM	HU 26812 48740	7.5	34.8	11.3
4	05-JUN-08 10:30:19AM	HU 26812 48740	10	34.8	10.7
5	05-JUN-08 10:44:10AM	HU 26950 48531	0	34.7	11.5
5	05-JUN-08 10:44:10AM	HU 26950 48531	2.5	34.8	11.4
5	05-JUN-08 10:44:10AM	HU 26950 48531	5	34.8	11.4
5	05-JUN-08 10:44:10AM	HU 26950 48531	7.5	34.8	11.3
5	05-JUN-08 10:44:10AM	HU 26950 48531	10	34.8	10.7

Figure 3. Water sample results map

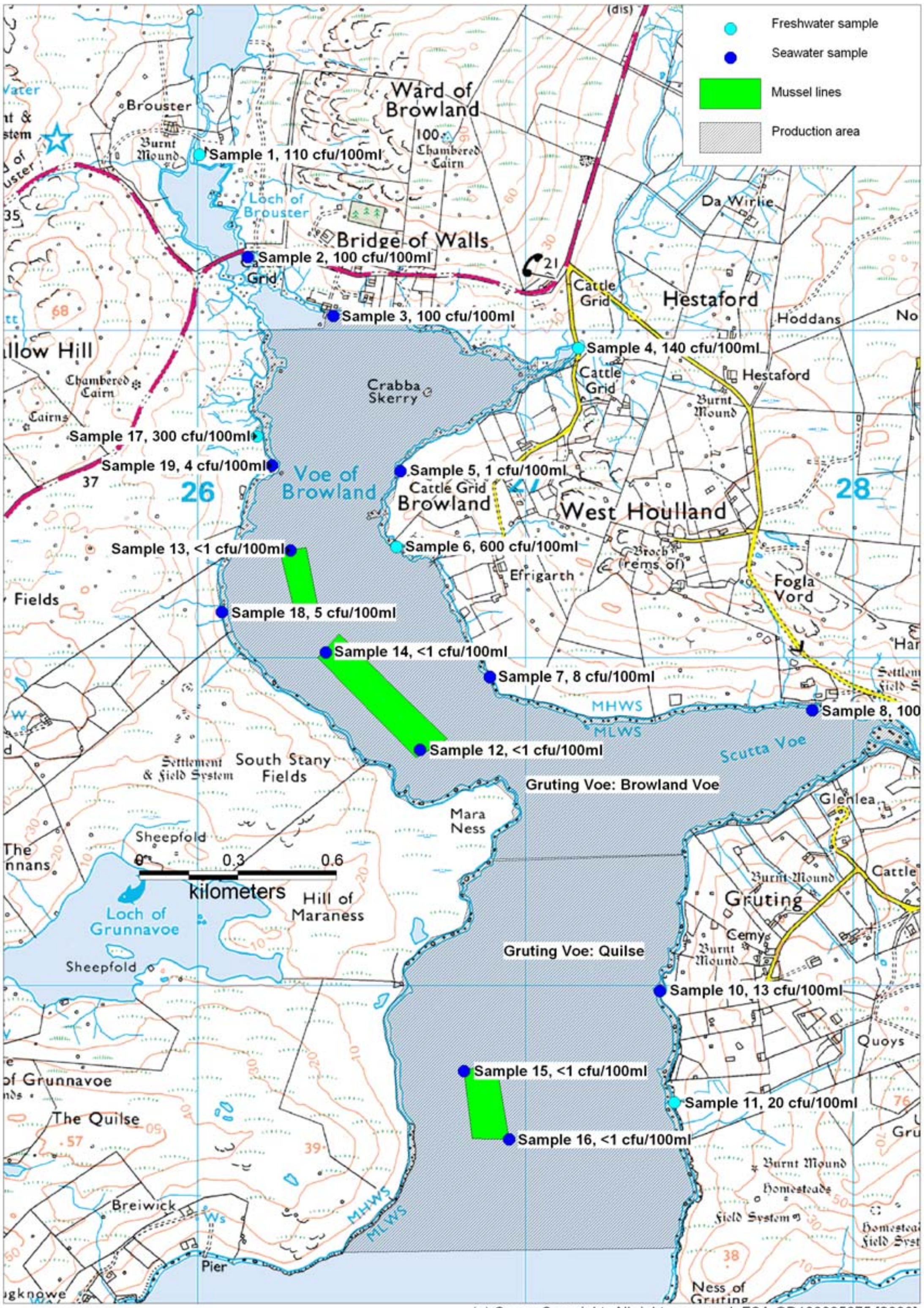


Figure 4. Shellfish sample results map

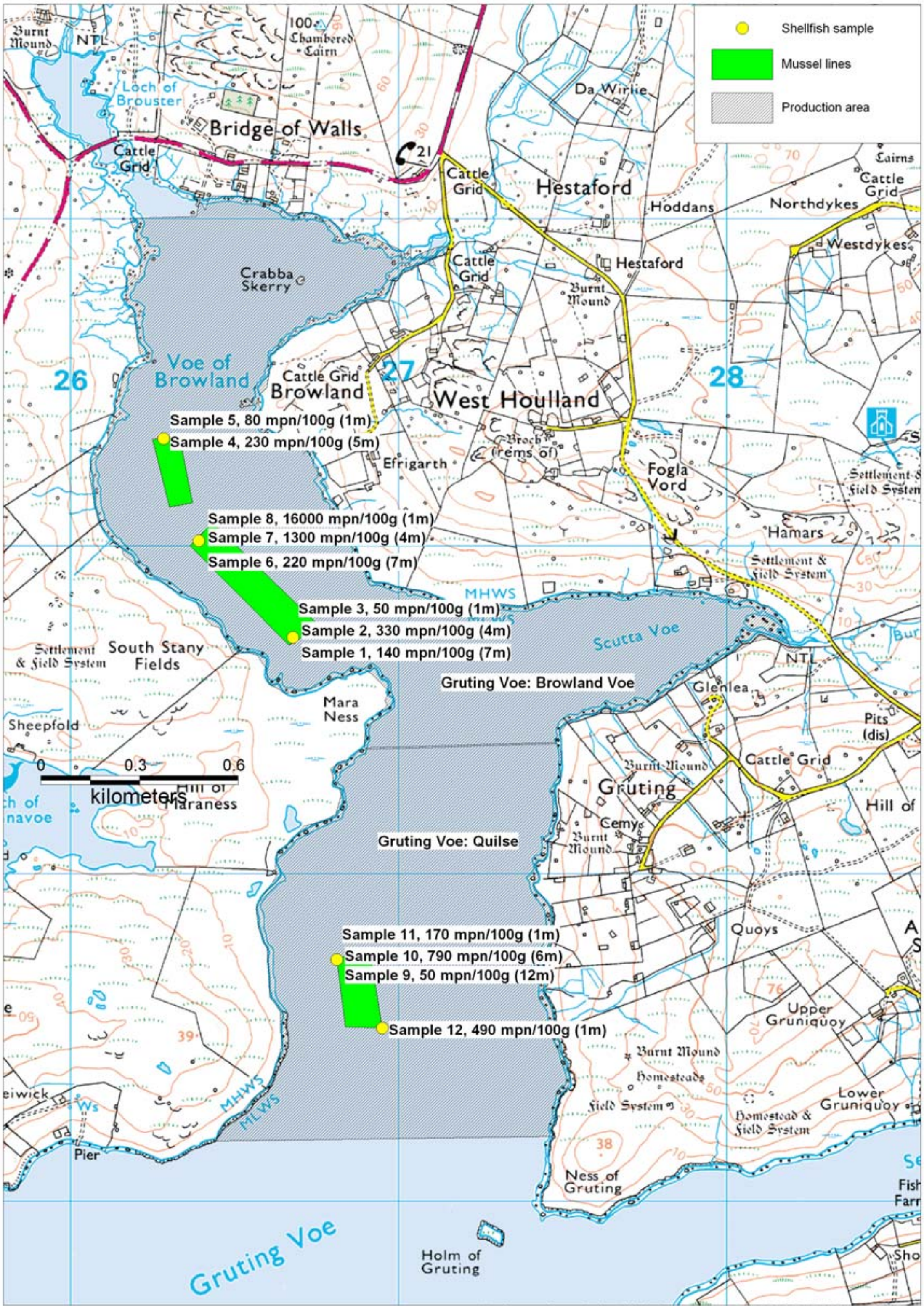

Shellfish sample
Mussel lines
Production area
Sample 5, 80 mpn/100g (1m)
Sample 4, 230 mpn/100g (5m)
Sample 8, 16000 mpn/100g (1m)
Sample 7, 1300 mpn/100g (4m)
Sample 6, 220 mpn/100g (7m)
Sample 3, 50 mpn/100g (1m)
Sample 2, 330 mpn/100g (4m)
Sample 1, 140 mpn/100g (7m)
Gruting Voe: Browland Voe
Gruting Voe: Quilse
Sample 11, 170 mpn/100g (1m)
Sample 10, 790 mpn/100g (6m)
Sample 9, 50 mpn/100g (12m)
Sample 12, 490 mpn/100g (1m)
0 0.3 0.6
kilometers
Bridge of Walls
Voe of Browland
Browland
West Houlland
Hestaford
Scutta Voe
Gruting
Gruting Voe
Holm of Gruting
Ness of Gruting
Mara Ness

Figure 5. Wastewater discharge at Bridge of Walls

Figure 6. Septic tank at Bridge of Walls

Figure 7. Wastewater discharge at Bridge of Walls

Figure 8. Seals off Browland

Figure 9. Pasture under improvement works

Figure 10. Wastewater discharge to Scutta Voe

Figure 11. Sheep droppings on beach at head of Scutta Voe

Figure 12. Dry stream bed