Scottish Sanitary Survey Project

Sanitary Survey Report
Traigh Mhor
UB 282
March 2009

Cefas

FOOD STANDARDS AGENCY
SCOTLAND
Buidheann Inbhe-Bidhe an Alba

Report Distribution – Traigh Mhor

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

** Distribution of draft and final reports to harvesters in undertaken by the relevant local authority.

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1. General Description

Traigh Mhor is located off the west coastline of Scotland, on the Isle of Barra, the most southern Western Isle. Traigh Mhor is roughly 1.7 km wide and 2 km long, and is a large gently sloping sandy beach supporting a considerable population of wild cockles. The sand beach is used as the island's airstrip and so parts of it are restricted from use. The beach at Traigh Cille Barra, which lies immediately to the north of Traigh Mhor, received a separate restricted sanitary survey in 2008.

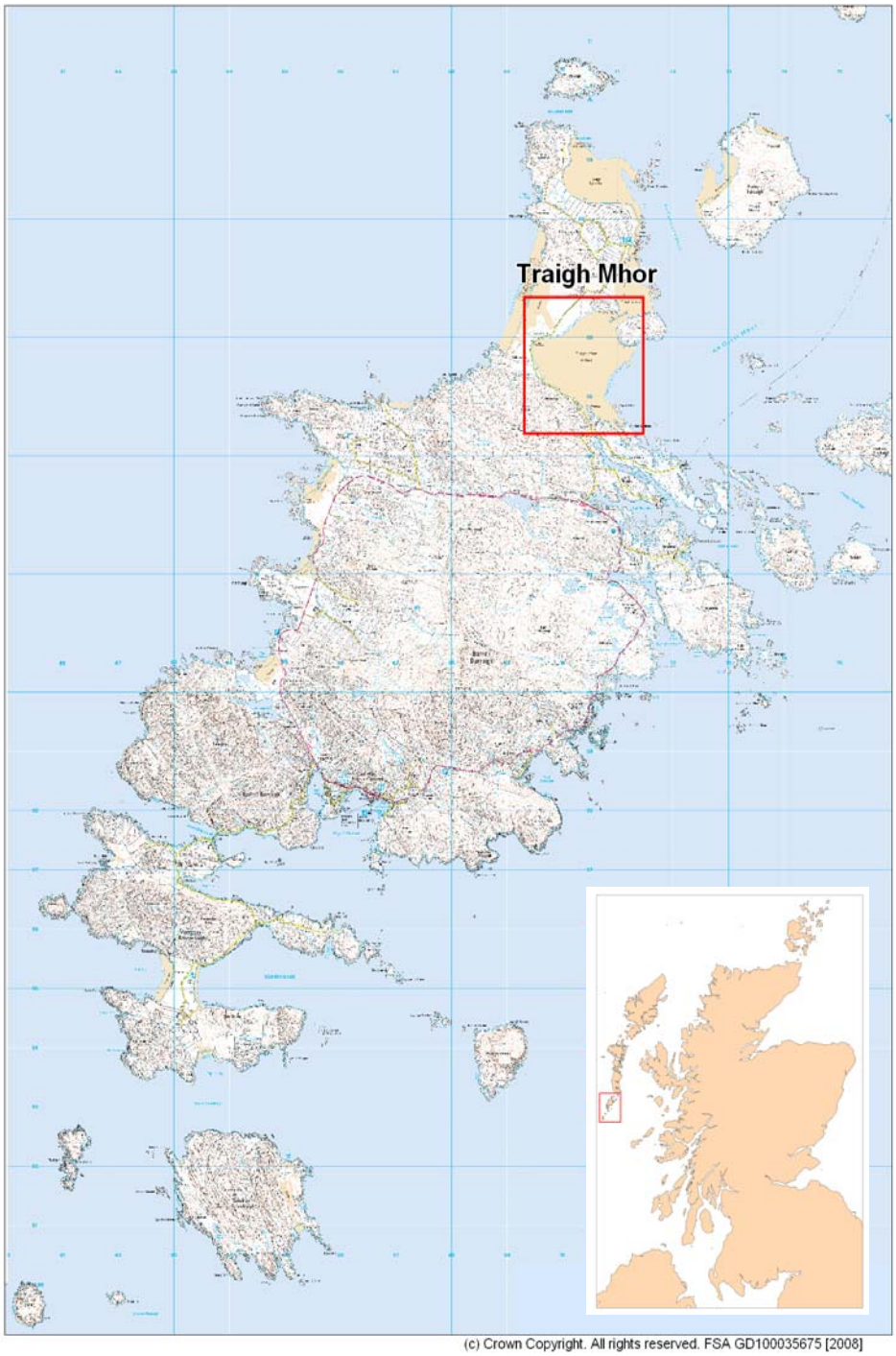

Figure 1.1 Location of Traigh Mhor

2. Fishery

The fishery at Traigh Mhor (UB 282 165 04) production area is comprised of a wild common cockle (*Cerastoderma edule)* bed. Razor clams (*Ensis* sp.) are also found here, but are not harvested commercially at present

The current production area boundaries are listed as the area inshore of lines drawn between NF 7103 0649 and NF 7135 0638 and between NF 7180 0600 and NF 7122 0450.

The RMP for the production area is currently located at NF 705 055.

The cockle bed is mainly fished by groups of local fisherman. Up to 20 local harvesters may be involved in the fishery. The collection method is usually raking, although some gatherers hand pick them whilst snorkelling. Harvesting gangs from further afield occasionally visit the area. Harvesting may occur year round, but is mainly carried out during the better weather in the summer months. Cockles are present in varying densities and sizes on all parts intertidal zone of the beach. The larger cockles are found closer to the low water mark. No harvesting is permitted on the upper part of the beach, which is designated as an airfield but lies within the current production area boundaries.

Figure 2.1 shows the relative positions of the Traigh Mhor production area and RMP.

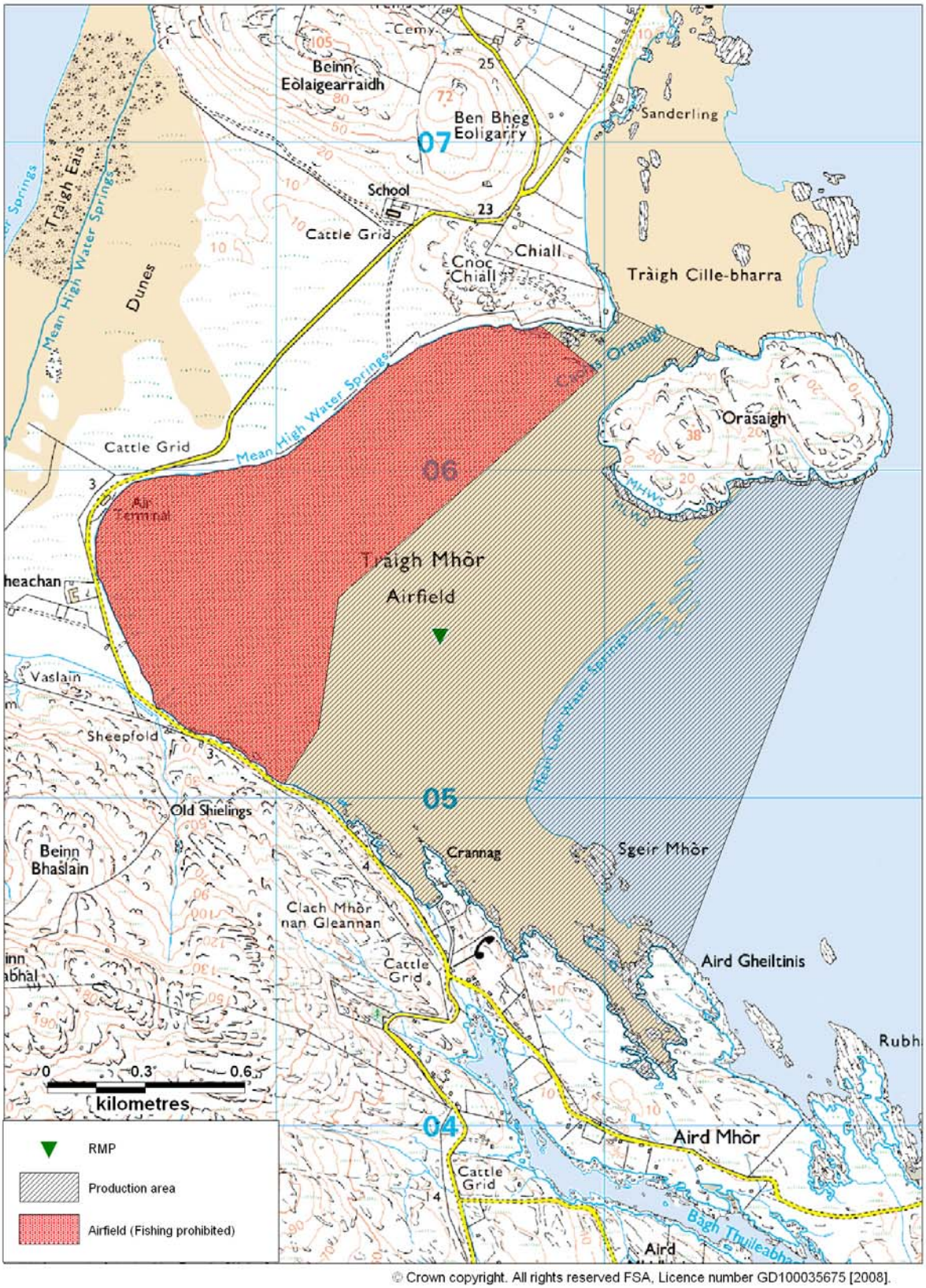

Figure 2.1 Traigh Mhor fishery

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 Traigh Mhor.

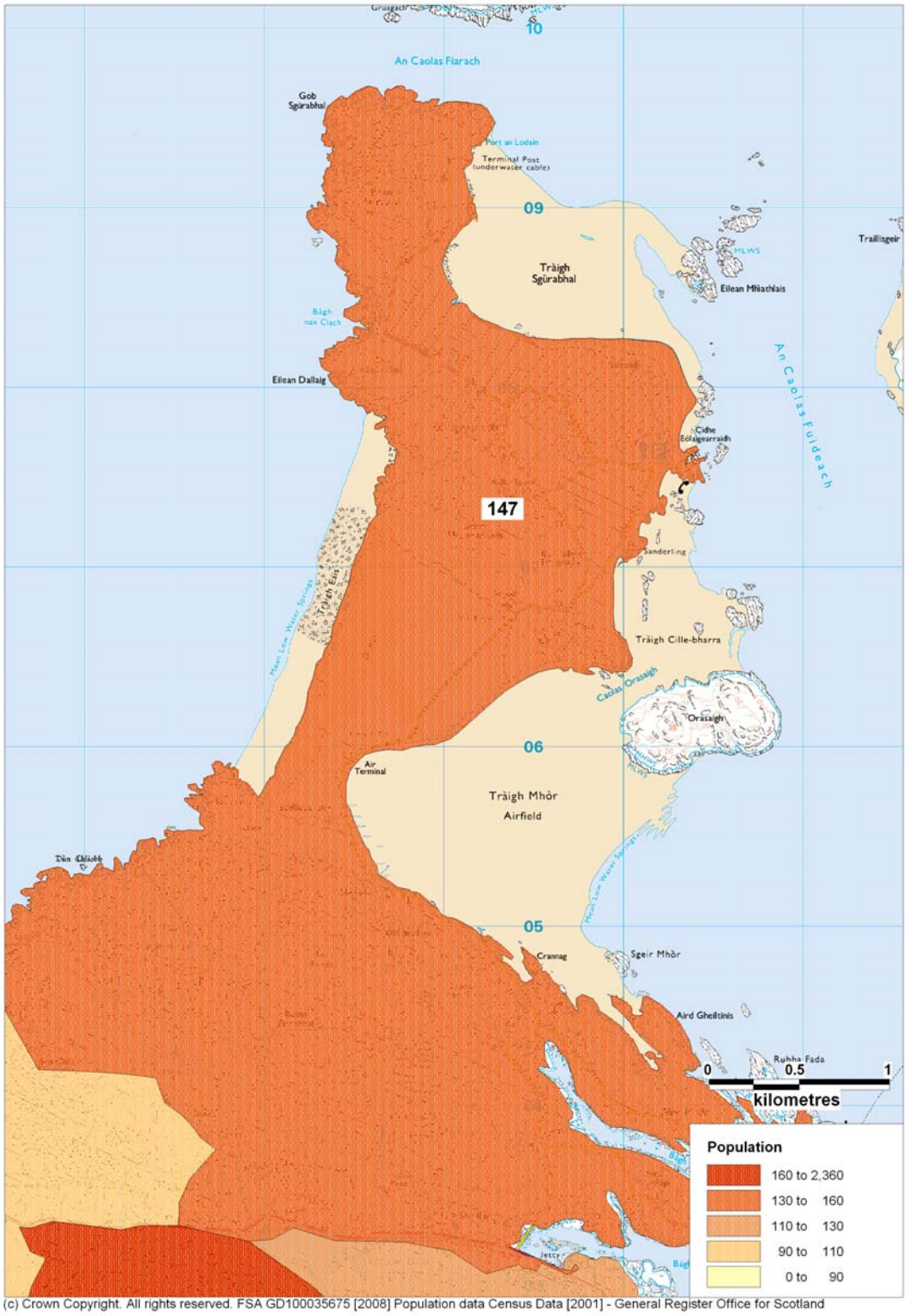

Figure 3.1 Population of Traigh Mhor

There is one population census output area immediately bordering on Traigh Mhor:

60RJ000006	147

There are no specific villages within this area, only scattered dwellings mostly concentrated at the southern end of the production area. At the northern end of the production area, a school and 11 houses under construction were observed, although these were situated further away from the shore than the houses at the southern end. Therefore, faecal pollution from human sources is more likely to impact at the southern end of the production area.

4. Sewage Discharges

No Scottish Water assets or SEPA discharge consents were identified as being located within the survey area. During the course of the shoreline survey, a vent pipe was seen at the air terminal, which was likely to be from the terminal's septic tank, although this could not be confirmed. No overflow pipe was found, implying that this tank either discharged to soakaway or was of the pump out variety. Details are presented in Table 4.1 and its location is shown on Figure 4.1. No discharges direct to the marine environment were found during the shoreline survey.

Table 4.1 Septic tank observed during shoreline survey

No.	Date	NGR	Description
1	03/09/2008	NF 69468 05900	Air terminal, septic tank vents seen in concrete but no overflow pipe.

Houses in the area do not have access to mains sewers, so it is likely that they all have private septic tank systems. As no septic tank overflows discharging to the shore were seen during the shoreline survey, it is likely that these systems either discharge to soakaway or to watercourses. As there has historically been no requirement to register septic tanks within Scotland, there is no record of the age or location of these systems. Likewise, their operational condition is unknown.

Septic tank systems in the area may contribute to pollution levels in and around the fishery if they discharge to watercourses or in the case of soakaway systems, should they become blocked and malfunction. However, as the number and locations of these systems are not known this cannot be taken into account when developing the sampling plan.

An inter-island ferry operates between Ardmore Ferry Terminal, and Eriskay, South Uist to the northeast. The ferry route passes approximately 1.2 km southeast of the production area boundaries. During the winter, the ferry makes 4 daily round trips on weekdays, 2 on weekends. During the summer, up to 5 round trips are made daily. There are unlikely to be pumpout facilities at either terminal, and it is not known where sewage waste from on-board toilet facilities is discharged.

The restricted zone for the airfield lies between the terminal and the cockle harvesting area, so if the septic tank does overflow here it still lies almost 0.5km from the fishery.

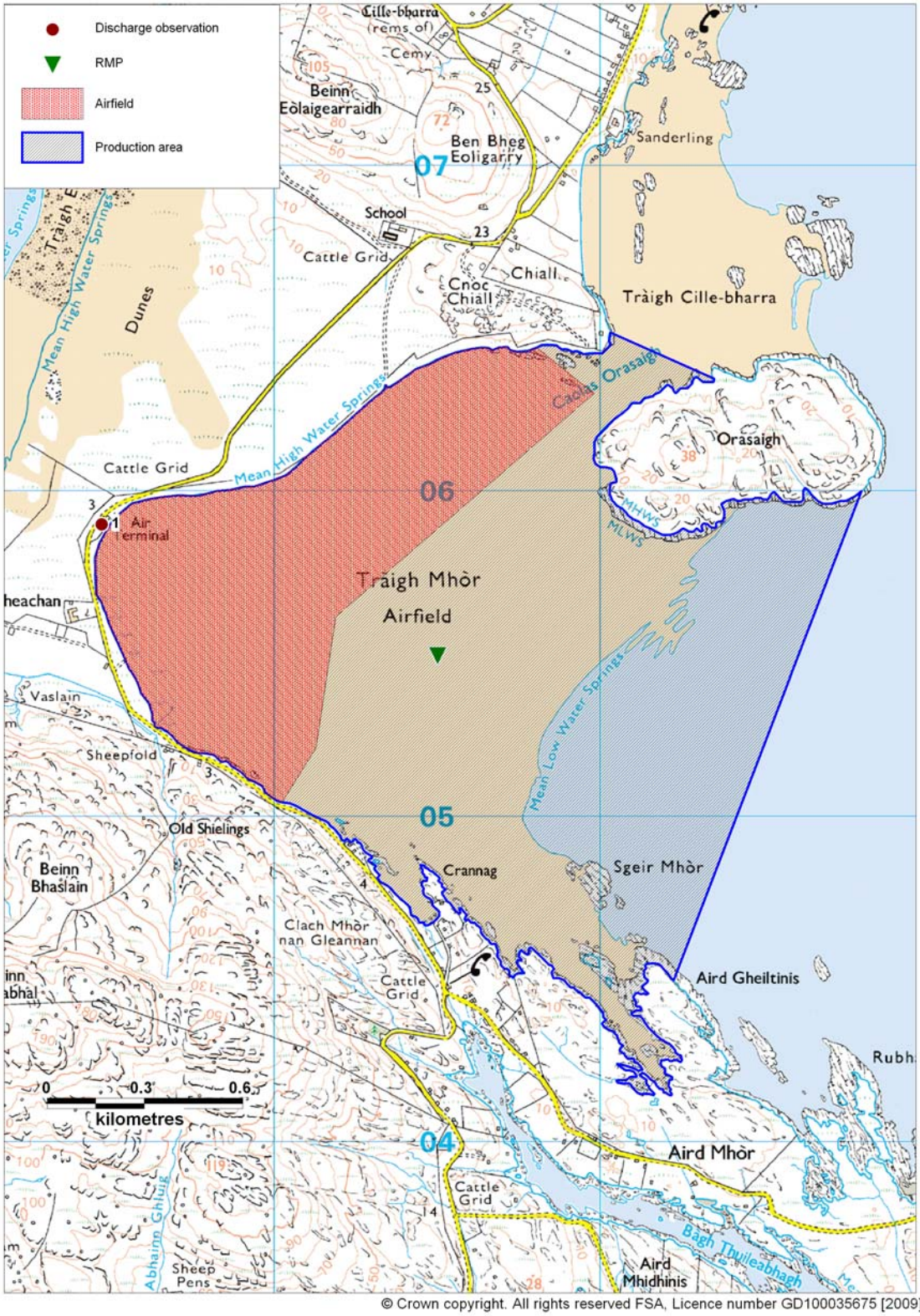

Figure 4.1 Septic tank at Traigh Mhor

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.

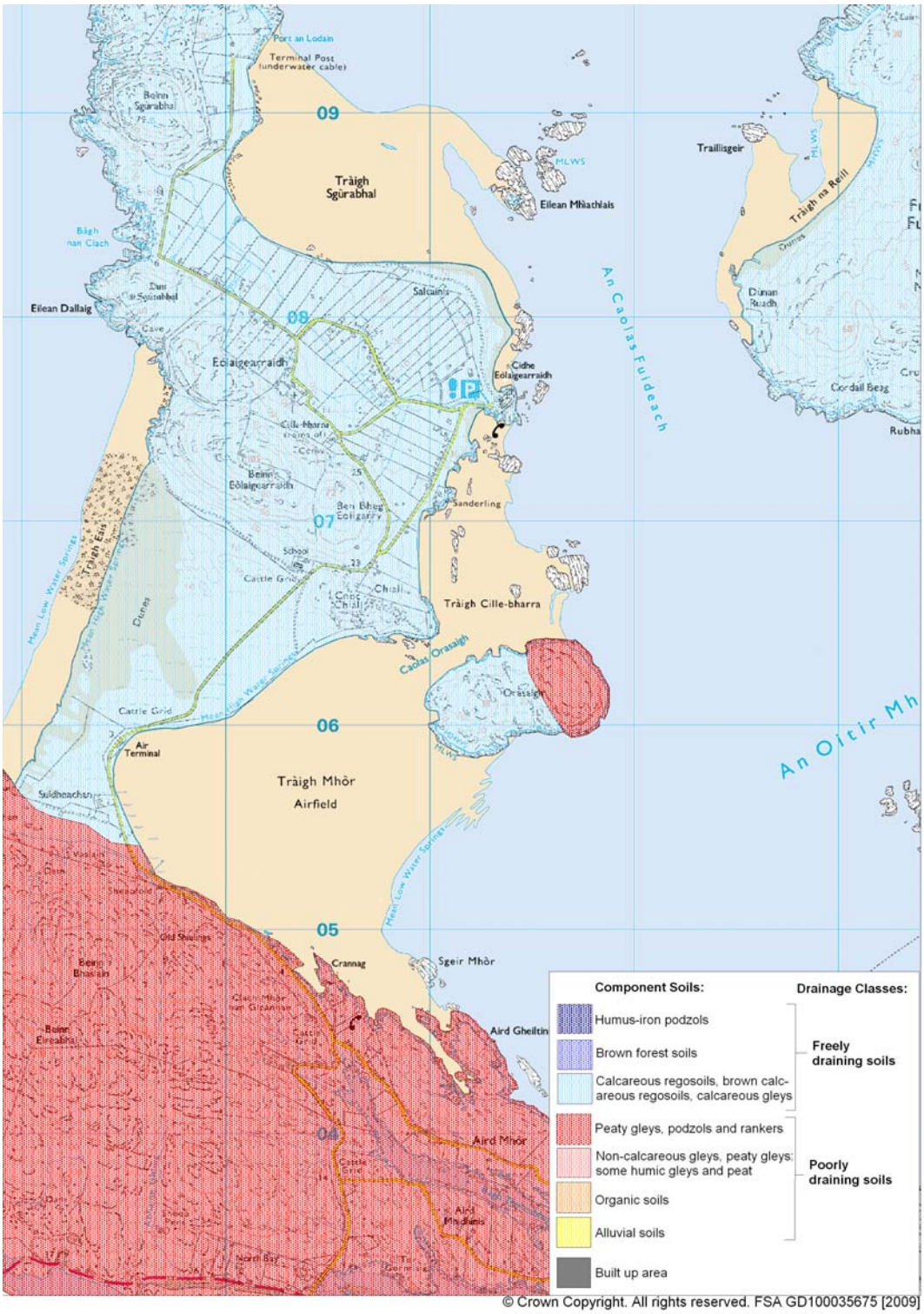

Figure 5.1 Component soils and drainage classes for Traigh Mhor.

Two types of component soils are found in this area. The most dominant soil type is composed of calcareous regosols, brown calcareous regosols and calcareous gleys, which are present all along the lower ground to the north and west of the production area. It was noted on the shoreline survey that the soil here was sandy and hence highly permeable. The second soil type is composed of peaty gleys, podzols and rankers and these occupy the higher ground to the south and west of the production area.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is therefore likely to be higher on the more elevated terrain to the south and west of the production area. This is strongly reflected in the location of streams in the area – all streams draining to the production area drained the area of more impermeable soils to the south and west of the production area.

6. Land Cover

No Land Cover Map 2000 data was available for this area, and no similar substitute data sources could be identified, so no detailed land cover maps could be produced for this area.

Agricultural census data provided by the Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) indicated that in 2008 for the parish of Barra there were a total of 545 farm holdings reporting a total farmed land area of 4122 hectares. Of this, 2076 hectares were used for crops or improved grassland, 2018 hectares were rough grazing, 10 hectares were woodland and 18 hectares were other land, such as hard standing or farm yards. This compares to a total parish land area of 8907 hectares, indicating that nearly half of the land area on the island is farmed or grazed.

The shoreline survey identified that much of the land adjacent to the production area was pasture, with sand dunes further west, and some higher pastures to the south. Some pastures were used for the production of hay, while others were being grazed by cattle and sheep at the time. It was not possible to differentiate between improved and unimproved pasture.

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 increase would be highest, at more than 100-fold, for the improved grassland.

Therefore, on the basis of observed land cover, the potential for contaminated runoff is low to intermediate around Traigh Mhor, depending on whether the pastures were improved or not, and likely to increase after significant rainfall.

7. Farm Animals

Agricultural census data was provided by RERAD for the parish of Barra. This parish covers the islands of Barra and Vatersay, as well as a number of smaller, mostly unpopulated islands to the south and east. Recorded livestock populations for the parish in 2007 and 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data.

Table 7.1 Livestock census data for Barra parish, 2007-2008

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	*	*
Total poultry	15	213	16	244
Total cattle	61	755	59	719
Total sheep	146	10475	144	9926
Horses used in Agriculture	*	*	*	*
Horses and Ponies	*	*	*	*

* Data withheld on confidentiality basis.

The Western Isles Crofters Commission (2007) identified that in 2005, there were an estimated 713 cattle and 10209 sheep on the Isle of Barra. This correlates roughly with the more recent data provided by RERAD. Cattle and sheep population numbers for 2008 represented a slight decline over those recorded in 2007 and those reported by the crofter's commission for 2005. For 2008, the average number of cattle per holding on the island as a whole was 12, and the average number of sheep per holding was 72.

The only source of information specific to the area near the shellfishery was the shoreline survey (see Appendix), which only relates to the time of the site visit on 3rd – 4th September 2008. This identified that much of the area surrounding Traigh Mhor is pasture, some of which is grazed by livestock and some of which is used for the production of hay for winter feed. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. Livestock was most concentrated on pastures by the air terminal, with some on the higher ground and around the crofts towards the south of the production area.

There is no information available concerning the seasonality of livestock populations on Barra, however it is expected that overall numbers of livestock on the island will be higher during the summer and early autumn months following the birth of calves and lambs in spring, decreasing after autumn as animals are sent to market. Generally, livestock on Barra are grazed on the higher areas further from the shore during the summer, and in lower areas nearer the shore during the winter, so livestock impacts to the production area may actually be higher during the winter months when they are closer to the shore.

It is likely that much of the area surrounding the production area is used for grazing at some point during the year.

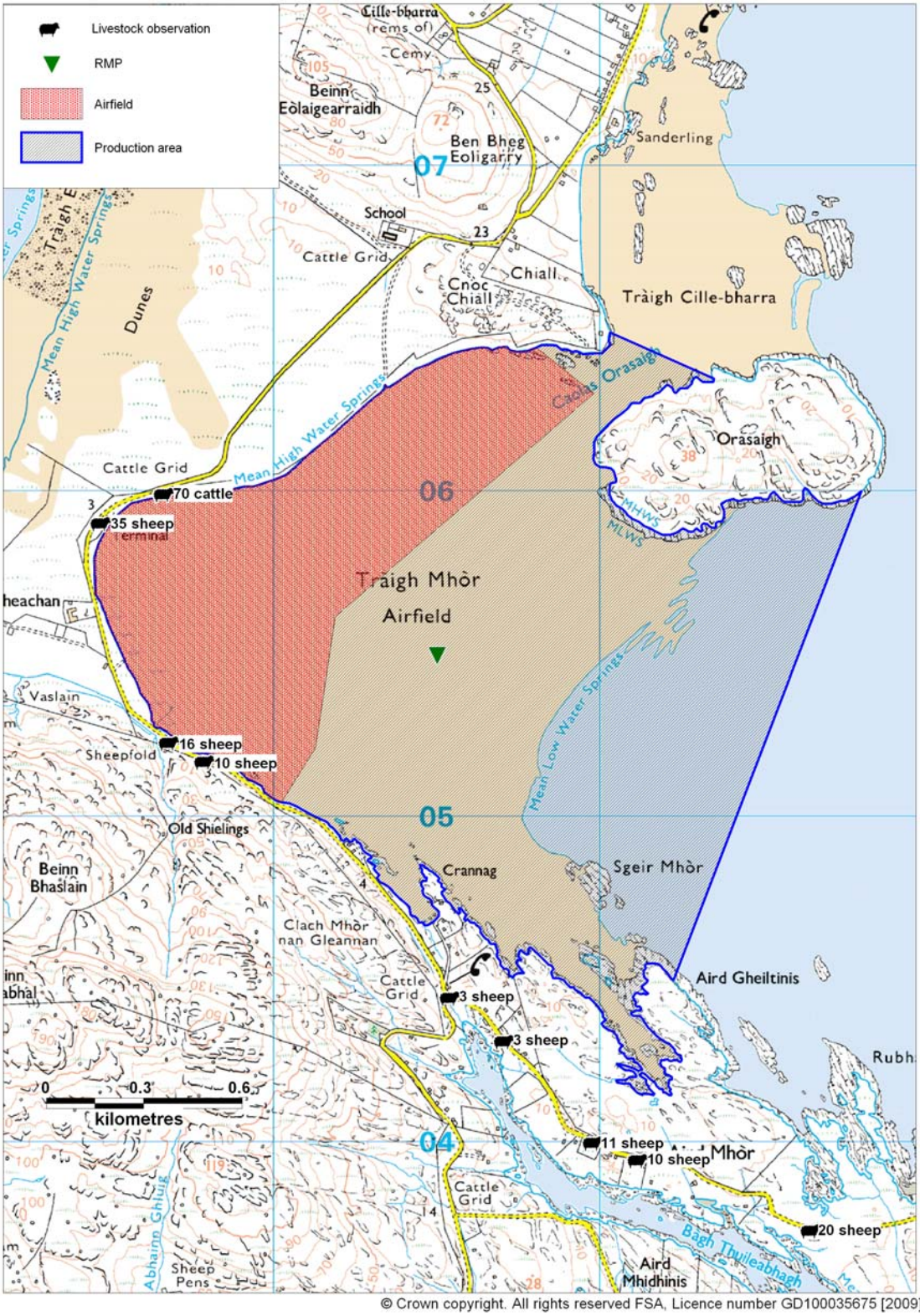

Figure 7.1 Livestock observations at Traigh Mhor

8. Wildlife

General information related to potential risks to water quality by wildlife is given in Appendix 4. A number of wildlife species present or likely to be present at Traigh Mhor could potentially affect water quality around the fishery.

Seals

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.

The Sea Mammal Research Unit has recorded a decreasing number of harbour seals on the Islands of Uist and Barra over the past sixteen years (Table 8.1). The number of Grey seals counted has also declined since 1996. However, there are still a significant number of seals resident around the island.

Table 8.1 Seal counts around Barra

Location	Species	Aug 1992	Aug 1996	Aug 2000	Aug 2003	Aug 2006
South Uist & Barra	**Harbour seals**	1243	921	801	718	605
South Uist & Barra	**Grey seals**	398	1301	1174	805	535

The population of both species is relatively large in relation to the size of the area surveyed. It is not certain exactly where the seals prefer to haul out, but this may be anywhere with good access to a reasonable depth of water at all states of the tide. As the production area consists of a shallow, gently sloping beach it is unlikely that they would favour this area for hauling out, but it is possible they may forage in the area. None were seen during the course of the shoreline survey. Their impact to the fishery is therefore not predictable on the basis of currently available data, but is believed to be minor.

Whales/Dolphins

Whales and dolphins are relatively common off the west coast of Scotland and sightings are recorded by the Hebridean Whale and Dolphin trust. These are reported to the trust by ferry skippers, whale watch boats and other observers and are listed in Appendix 4.

No whales or dolphins (cetaceans) were observed during the course of the shoreline survey though dolphins and porpoises may occasionally be present in the area.

As the area is very shallow it is very unlikely that it would be visited by larger cetaceans. The presence of any cetacean species is likely to be fleeting and unpredictable and so will not be taken into account with regard to establishing a sampling plan.

Birds

Though a number of bird species are found in the Western Isles, seabirds and waterfowl are most likely to occur around or near the fisheries in significant numbers.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census (Mitchell *et al*, 2004). Counts of all species recorded within 5 km of the production area during a survey of the area carried out in sections during late spring of 2001 and 2002 are presented in Table 8.2. The majority of counts were of occupied nesting sites or territories which represent a breeding pair, so actual numbers of seabirds present and breeding in the area will be higher.

Table 8.2 Seabird counts within 5km of the site

Common name	Species	Count	Method
Northern Fulmar	Fulmarus glacialis	366	Occupied sites
Herring Gull	Larus argentatus	346	Occupied nests/territories
Black guillemot	Cepphus grylle	88	Individuals on land
Lesser Black-backed Gull	Larus fuscus	87	Occupied nests/territories
Common Gull	Larus canus	75	Occupied territory
European Shag	Phalacrocorax aristotelis	72	Occupied nests
Great Black-backed Gull	Larus marinus	71	Occupied nests/territories
Great Cormorant	Phalacrocorax carbo	60	Occupied nests
Common Tern	Sterna hirundo	36	Occupied territory
Arctic Tern	Sterna paradisaea	1	Occupied territory

None of these records were from within the production area or within 1 km of its borders. Most were either on the rockier west coast of Barra south of the dune system, or on the small rocky islands to the south and east of the production area. Although none of the nesting sites was in close proximity of the production area, it is likely that the birds forage in and around the area, and a few were seen here during the shoreline survey. Nesting occurs in early summer and after this some species will disperse. However gulls, which form the majority in terms of numbers, are likely to be present in the area throughout the year.

Waterfowl (ducks and geese) are likely to be present in the area at various times from autumn through winter. Few of these birds would be expected to be present during the summer months. Overwintering geese would tend to be found on farm fields and open grassland, such as that bordering the production area.

Wading birds would be concentrated on intertidal areas, such as the Traigh Mhor cockle strand. An aggregation of about 80 oystercatchers was seen on

a rock on the southern shore at high tide during the shoreline survey, and a few small waders were also seen foraging in the intertidal zone.

The impacts of these birds to the fishery is likely to be seasonally significant, with shorebirds and nesting seabirds having a higher impact during summer and migratory geese, should they be present, having a higher impact in autumn and winter. They may cause locally significant levels of contamination on the cockle beds where they have defecated. These impacts are spatially difficult to predict and will not materially affect the sampling plan.

Deer

It is not certain whether deer are present in significant numbers on Barra, as the DCS does not undertake counts there. Red deer are present on South Uist, so it is possible that this species may also be found on Barra. They prefer wooded habitats, of which there is very little on Barra. None were seen during the shoreline survey.

It is possible that some of the indicator organisms detected in the streams feeding into Traigh Mhor may be of deer origin, however it is expected that their contribution would be minor if anything.

Otters

A survey of otters on Barra (International Otter Survival Fund, 2000) estimated that there were between 16 and 23 otters on the island, equivalent to 0.3-0.5 animals per km of coastline. Their presence in a particular area was linked to the presence of freshwater pools in which they must wash their fur frequently to maintain its insulating properties. Small marine fish predominated the diet, indicating that they were foraging in the sea. Therefore, although otters are likely to be present in the area, there are more suitable habitats with deeper water and better access to freshwater pools so their numbers will probably be low and their impact to the fishery negligible.

Summary

Species potentially impacting on Traigh Mhor are likely to primarily be waders and seabirds, via direct deposition on the beach. However, 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 and will not be considered in determination of sampling plans.

9. Meteorological data

The nearest weather station is located at the air terminal at Traigh Mhor, just on the boundary of the production area. Rainfall data was supplied for the period 01/01/03 to 31/12/2005 (total daily rainfall in mm). Insufficient rainfall data was available for 2006 and 2007 which have been excluded from the analysis. Rainfall experienced here will be almost identical to that experienced within the production area due to their close proximity.

The nearest major weather station where wind is measured is located at Tiree, approximately 67 km to the south east of the production area. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/1996 to 31/12/2007. Both Tiree and Barra are low lying islands which are fully exposed to the Atlantic to their west, so it is likely that the wind patterns are broadly similar, but are liable to differ on any given day. No wind data was available for the air terminal.

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 wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

As the rainfall records from Barra are complete for the period 2003 - 2005, total annual rainfall and mean monthly rainfall can be calculated, and are presented in Figures 9.1 and 9.2.

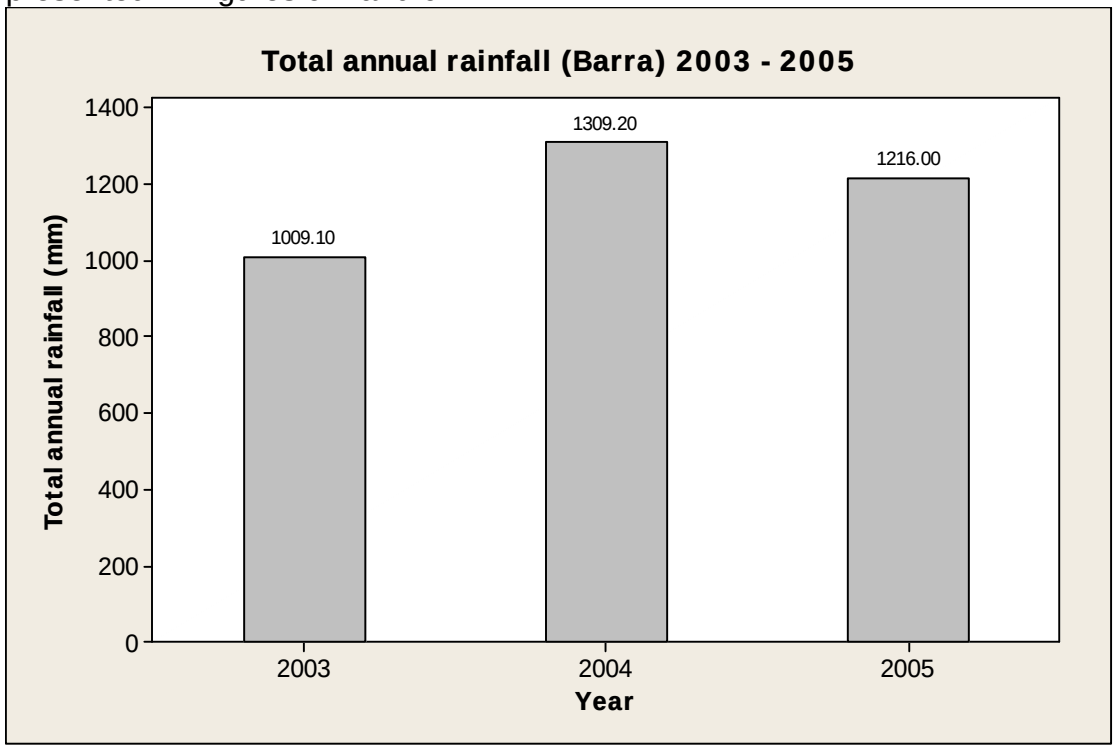

Figure 9.1 Total annual rainfall at Barra 2003 – 2005

Inter annual variability in rainfall was considerably less than monthly variations.

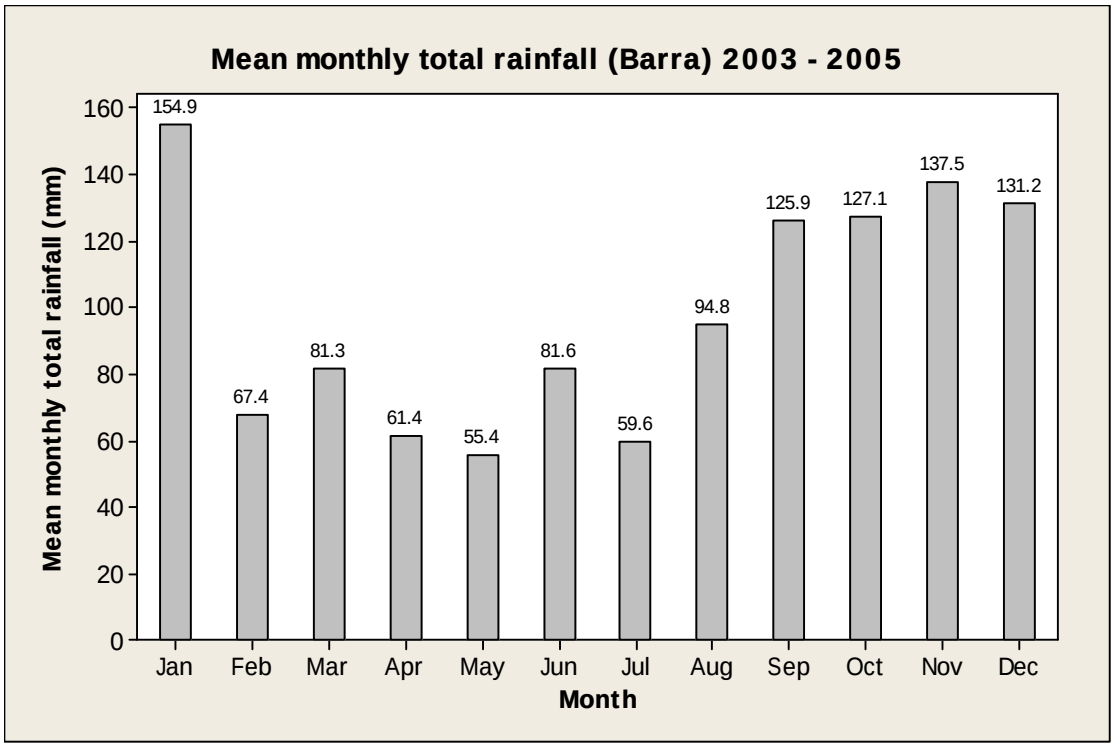

Figure 9.2 Mean total monthly rainfall at Barra 2003 – 2005

The wettest months were from September to January, with the latter being the wettest. For the period considered here (2003 – 2005), 50% of days experienced rainfall of 1 mm or less, and 9% of days experienced 10 mm or more. Increases in average rainfall occurred between May and June, July and August, and August and September.

It can therefore be expected that levels of rainfall dependant faecal contamination entering the production area from these sources will be higher during the autumn and winter months. It is possible that faecal matter can build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff at the onset of the wetter weather in the autumn.

9.2 Wind

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

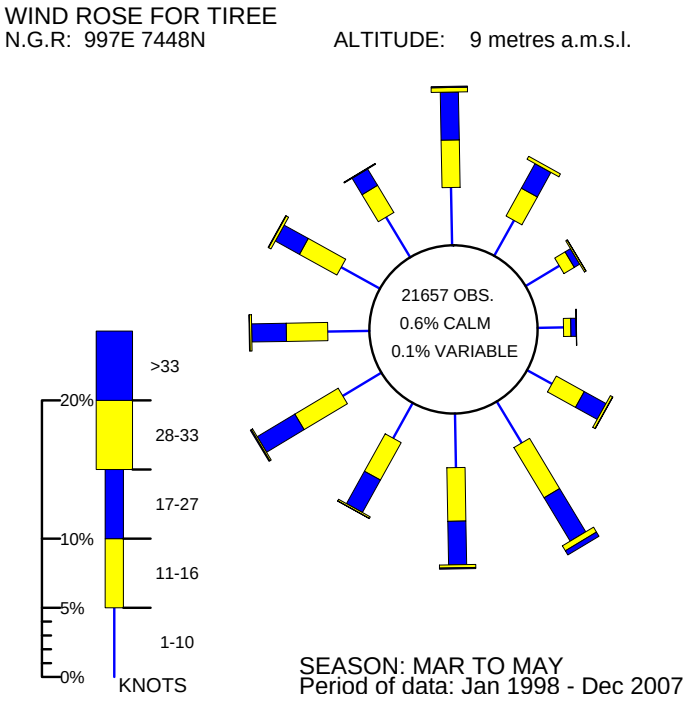

Figure 9.3 Wind rose for Tiree (March to May)

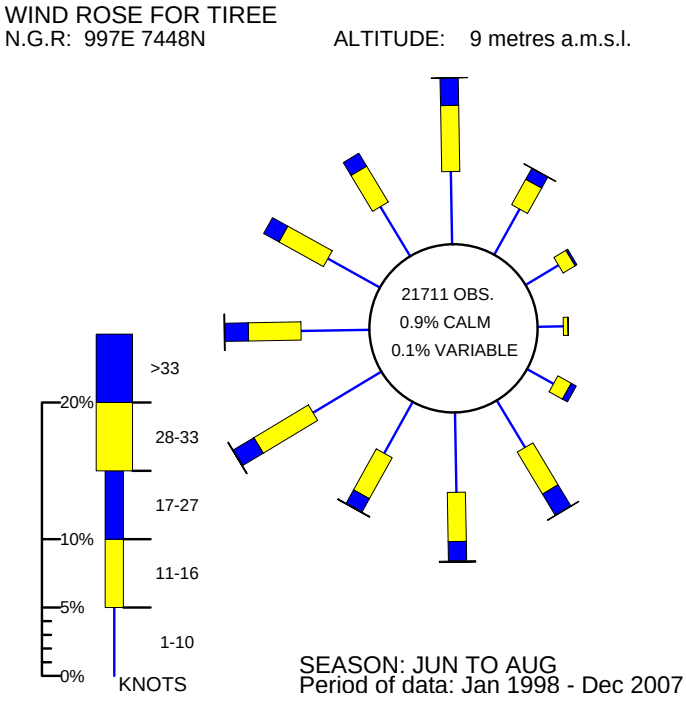

Figure 9.4 Wind rose for Tiree (June to August)

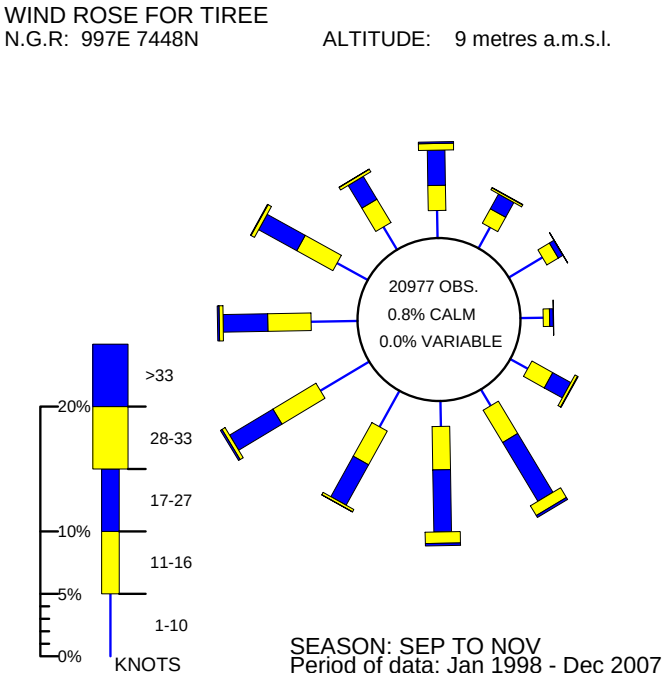

Figure 9.5 Wind rose for Tiree (September to November)

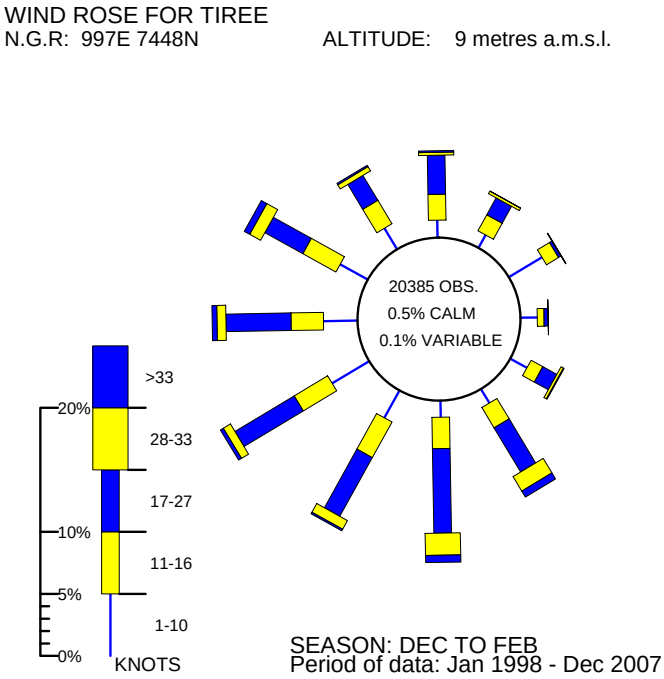

Figure 9.6 Wind rose for Tiree (December to February)

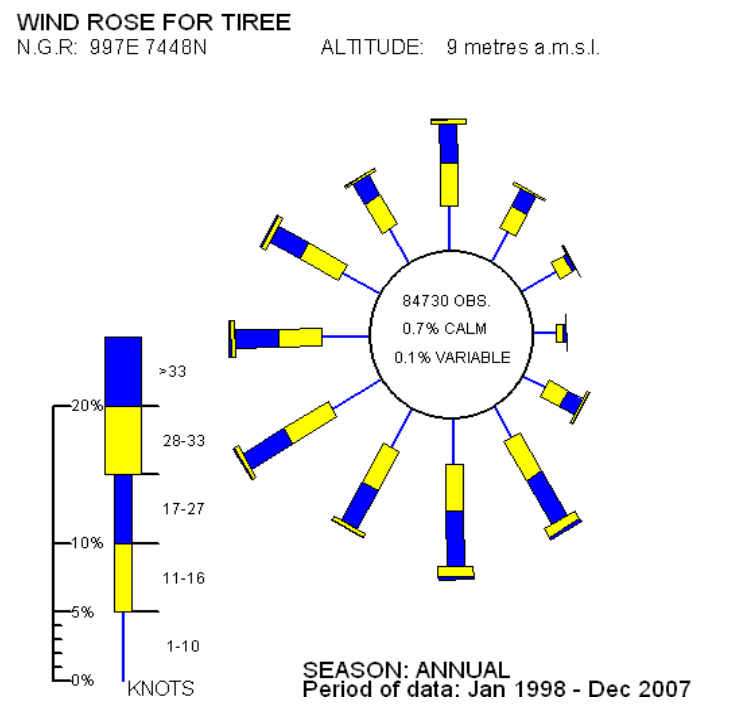

Figure 9.7 Wind rose for Tiree (All year)

The prevailing wind direction at Tiree is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. Winds are lightest in the summer and strongest in the winter.

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. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area.

Traigh Mhor is a large sandy bay on the east coast of Barra, partially sheltered from onshore winds by a number of small islands. The small strip of land to the west of the bay is very low lying, so the production area is quite exposed to westerly winds coming from the Atlantic ocean. The bay is shallow and dries at low tide, so tidal exchange of water is likely to be much more important than wind driven flows. An onshore wind will however result in increased wave action, which may resuspend any organic matter settled in the substrate.

On a larger scale, winds may alter the circulation of water within the surrounding seas in such a way to assist the transport of contamination from further afield. However, no major point sources of contamination have been identified in the vicinity.

10. Current and historical classification status

Traigh Mhor has been classified for the harvest of cockles since 2003. The classification history for cockles is presented in Table 10.1. For all of the period classified, the area received a seasonal A/B classification. The official RMP lies within the production area in the intertidal zone. A map of the current production area is presented in Figure 10.1.

Table 10.1 Classification history, Traigh Mhor cockles

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

The production area was also given a provisional classification for the harvest of razors. This was a seasonal A/B classification, which lapsed after one year as insufficient samples were submitted to continue classifying the area.

Table 10.2 Classification history, Traigh Mhor, razors

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	B	B	B	B	B	A	A	A	A	A	B	B

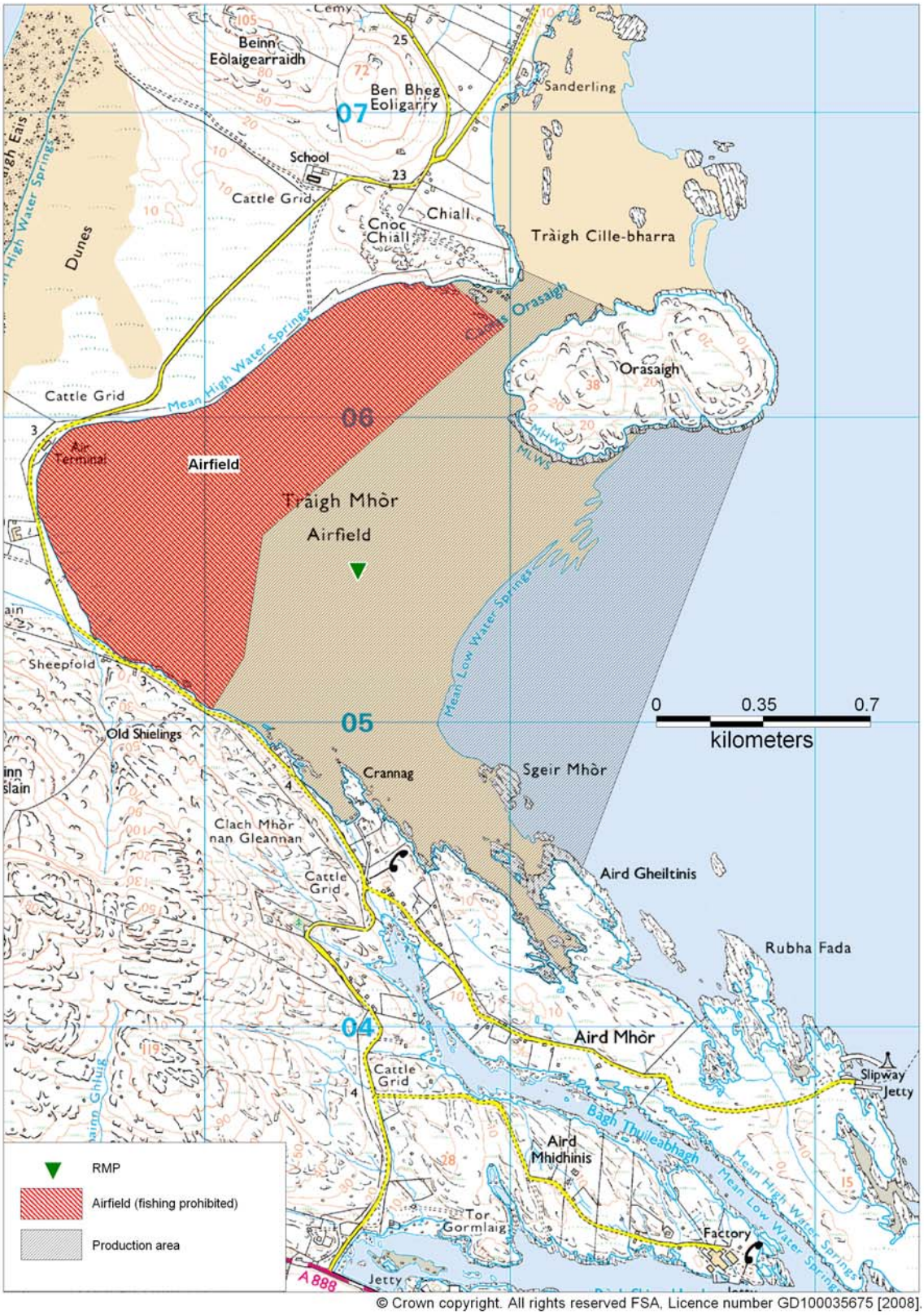

Figure 10.1 Current production area for cockles

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Traigh Mhor 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.

Three cockle samples were rejected as they had no recorded sampling location. A further cockle sample was rejected as the reported sampling location fell 3.7 km outside the production area.

A total of 16 cockle and 5 razor samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results by sampling location and species

A summary of all sampling and results by is presented in Table 11.1. Two locations were sampled for cockles within the production areas. One of these grid references (NF 705055) was a rounded version of the other (NF 7050005475). As these two locations were only 25 m apart, and usually cockle samples have to be raked from an area of several square metres rather than taken from a single point, the results of all cockle samples are presented together on Table 11.1

Table 11.1 Summary of results from Traigh Mhor

Sampling Summary			
Production area	Traigh Mhor	Traigh Mhor	Traigh Mhor
Site	Traigh Mhor	Traigh Mhor	Traigh Mhor
Species	Common cockles	Razors	Razors
SIN	UB-282-165-4	UB-282-165-16	UB-282-165-16
Location	NF7050005475 and NF 705055	NF714053	NF701051
Total no of samples	65	10	3
No. 2002	12	0	0
No. 2003	10	0	0
No. 2004	12	6	3
No. 2005	8	4	0
No. 2006	11	0	0
No. 2007	12	0	0
Results Summary			
Minimum	<20	<20	<20
Maximum	2400	500	20
Median	40	20	<20
Geometric mean	51.4	33.9	12.6
90 percentile	382	329	
95 percentile	660	414.5	
No. exceeding 230/100g	12 (18%)	2 (20%)	
No. exceeding 1000/100g	2 (3%)	0 (0%)	
No. exceeding 4600/100g	0 (0%)	0 (0%)	
No. exceeding 18000/100g	0 (0%)	0 (0%)	

As a total of only 11 razor samples were taken, these results will not be considered in further more detailed analyses of seasonal and environmental influences.

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).

The two reported cockle sampling points fall within 25 m of each other, and were never both sampled on the same occasion. Any differences in mean result between the two sampling points would almost certainly due to conditions on the dates on which they were sampled rather than any geographical differences in water quality. Also, cockle samples are collected from an area rather than a single point, and depending on their density the area may be over ten meters across.

Three of the razor samples were collected from a point close to the high water mark on the south shore all on the same day, and a further 10 were collected from a point below the low water mark in the middle of the bay over the course of about a year. All but two of the razor samples yielded very low *E. coli* results (<50 MPN/100g). The two samples yielding higher results were collected from the point below the low water mark. As the two locations were

never sampled on the same occasion it is not possible to draw any conclusions about any differences in levels of contamination between them. Also, there is a slight uncertainty surrounding the position of the first three samples, as generally razors are found lower down the intertidal zone.

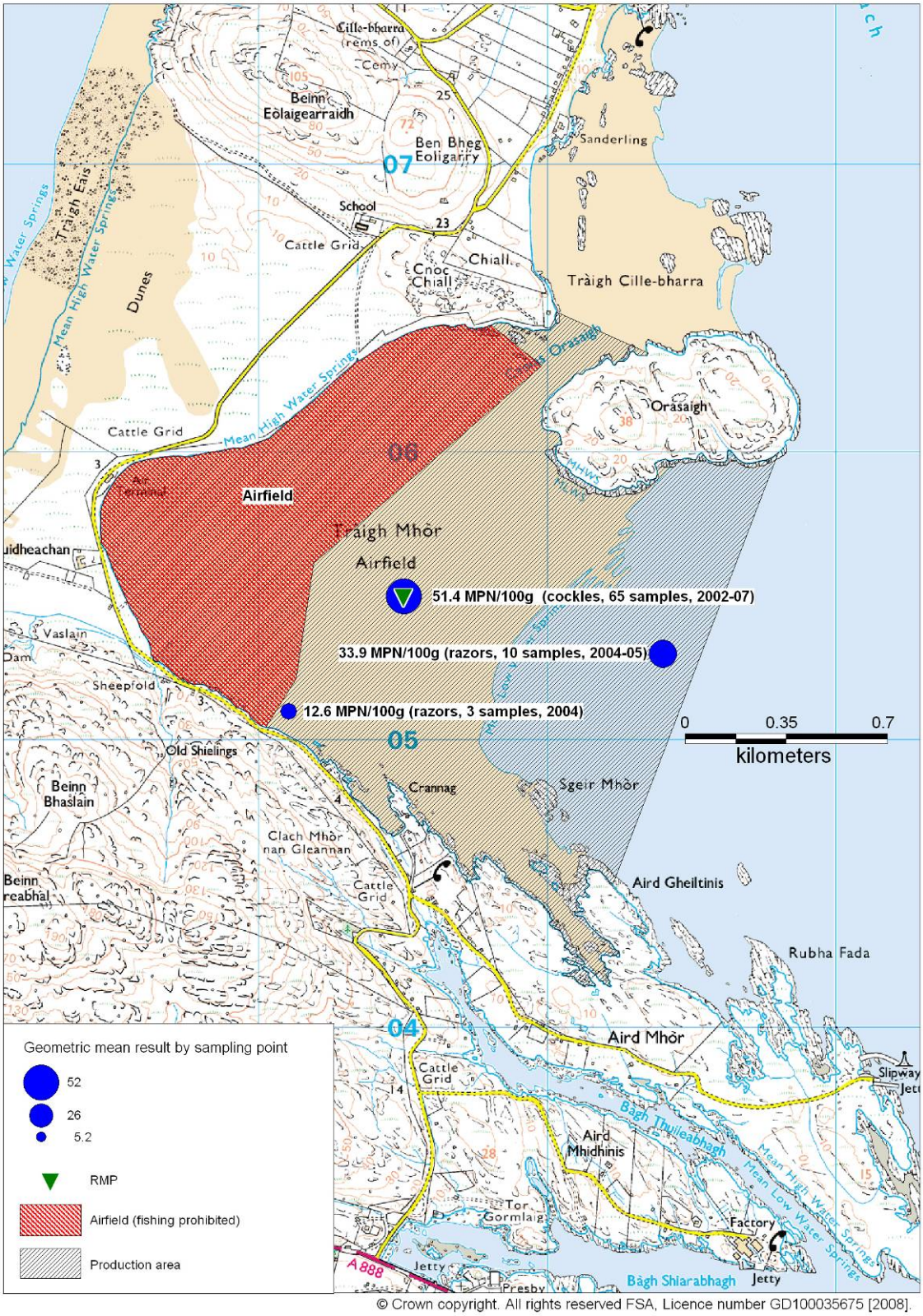

Figure 11.1 Sampling points and geometric mean *E. coli* result

11.4 Overall temporal pattern of results

Figures 11.3 and 11.4 present scatter plots of individual results against date for all cockle samples taken from Traigh Mhor. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.2 is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples. Figure 11.3 is fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software.

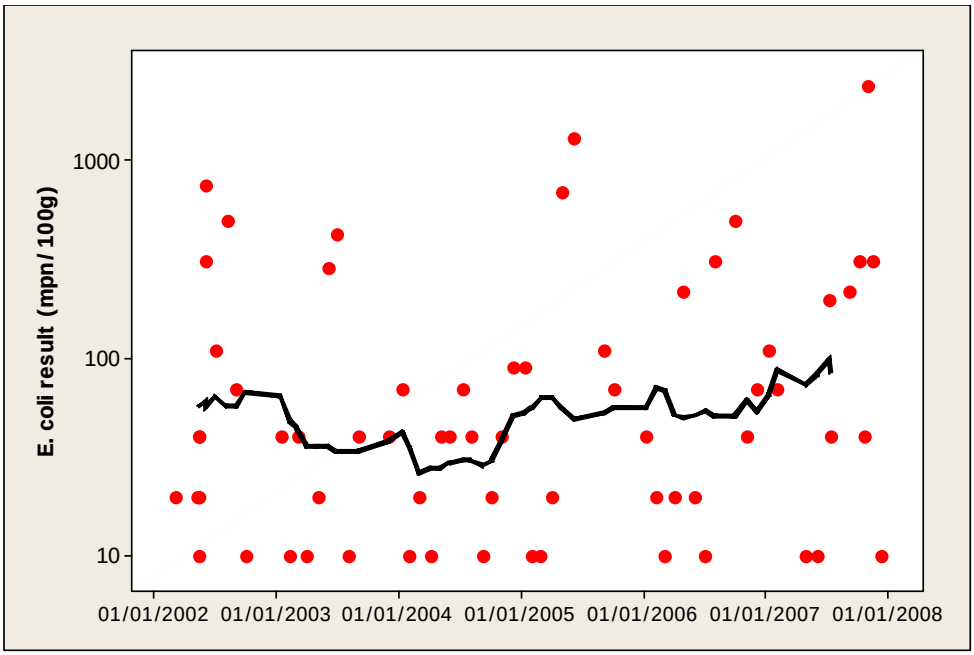

Figure 11.2 Scatterplot of *E. coli* results by date with rolling geometric mean

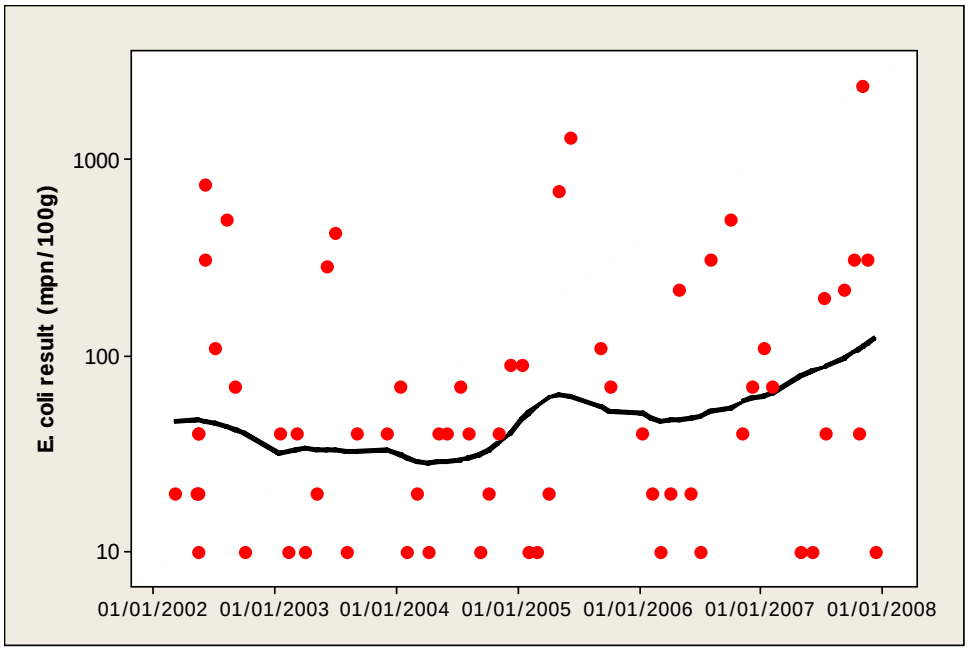

Figure 11.3 Scatterplot of *E. coli* results by date with loess smoother

Figures 11.2 and 11.3 suggest a slight deterioration in results since the beginning of 2005. An increase in peak results is apparent over the time period.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.4 present the geometric mean *E. coli* result by month for all cockle samples (+ 2 times the standard error).

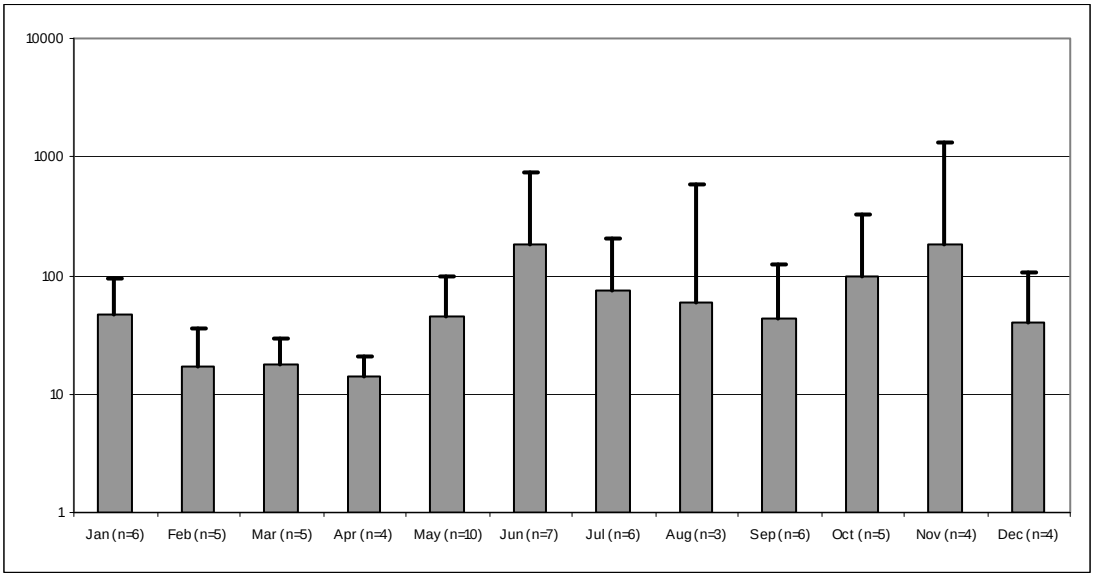

Figure 11.4 Geometric mean *E. coli* result by month

Highest mean results occurred in June and November. Results were lowest during in February, March and April and generally higher between June and November, inclusive.

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

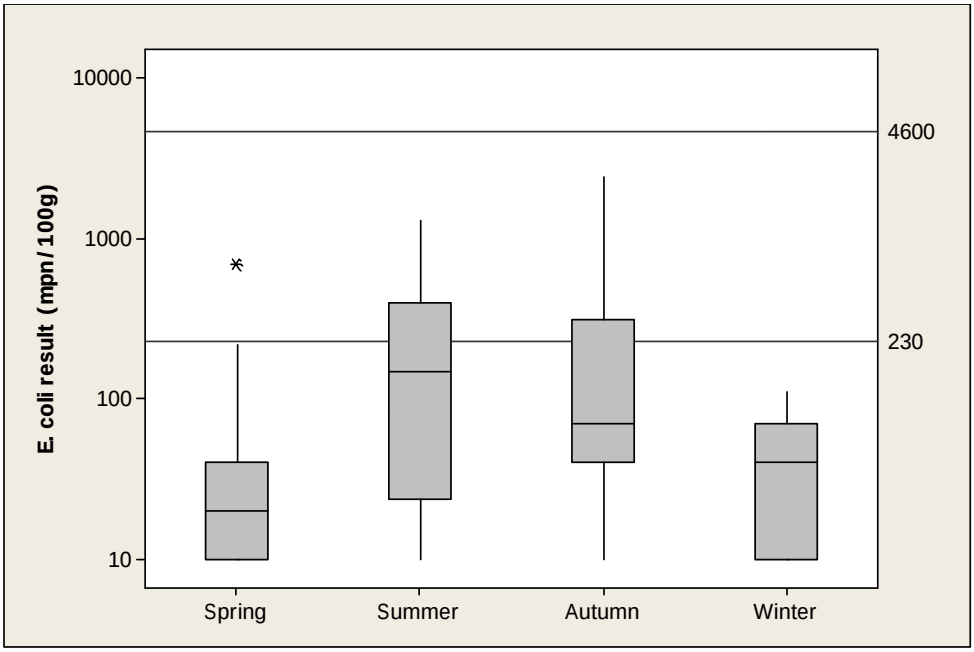

Figure 11.5 Boxplot of *E. coli* result by season

A significant difference was found between results by season (One-way ANOVA, p=0.007, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer were significantly higher than those in the spring (but not autumn or 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 Barra, within 1 km 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). A Spearman's Rank correlation of *E. coli* against rainfall was carried out.

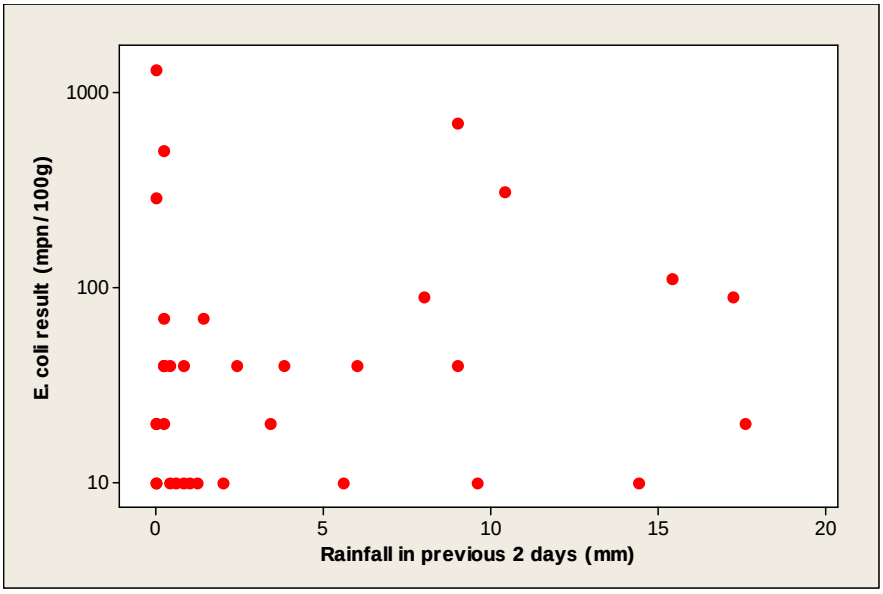

Figure 11.6 Scatterplot of *E. coli* result against rainfall in previous 2 days

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days (Spearman's Rank correlation=0.067, p=0.700, 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 was investigated in an identical manner to the above.

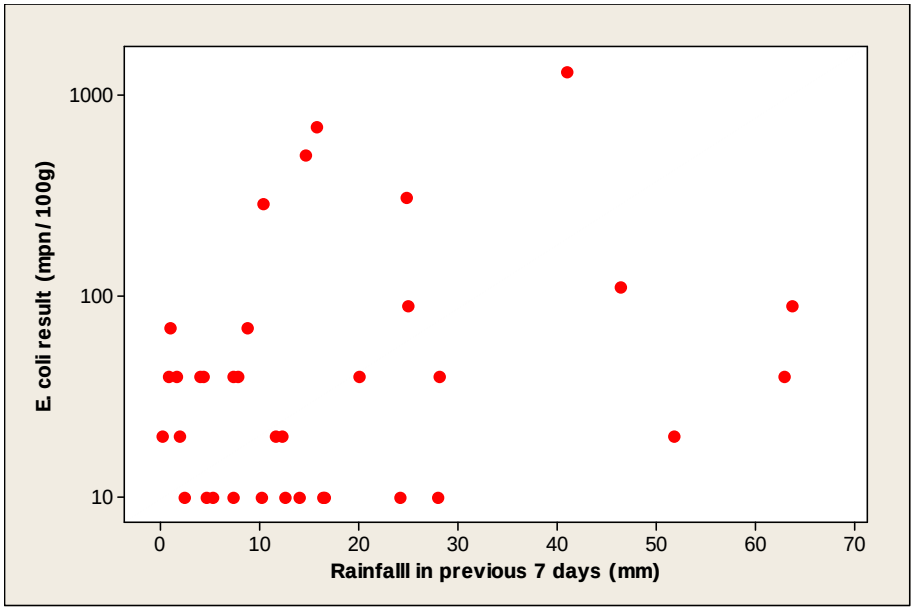

Figure 11.7 Scatterplot of *E. coli* result against rainfall in previous 7 days

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous 7 days (Spearman's Rank correlation=0.218, p=0.207, Appendix 6).

11.6.2 Analysis of results by spring/neap and high/low tidal cycles

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 production area. Figure 11.8 presents a scatterplot of *E. coli* results by predicted height of the previous high water at North Bay, Barra (predictions from Totaltide tidal prediction software). It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

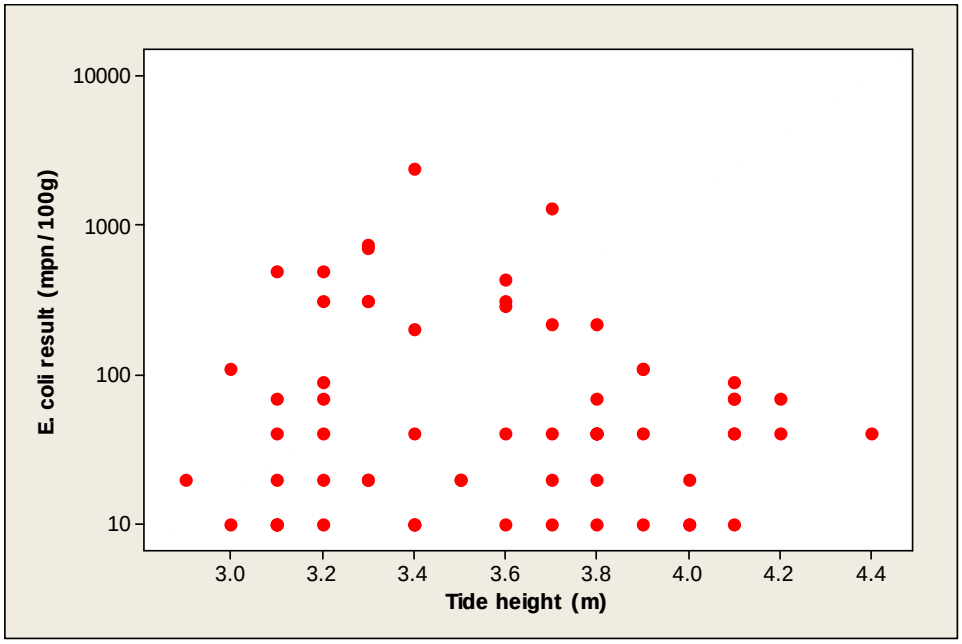

Figure 11.8 Scatterplot of *E. coli* result by tide size

The coefficient of determination indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide (Adjusted R-sq=0.0%, p=0.569, 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 area. However, as sampling had to be undertaken around low tide when the beds were exposed, an analysis of results against tidal state on the high/low cycle was not possible.

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.

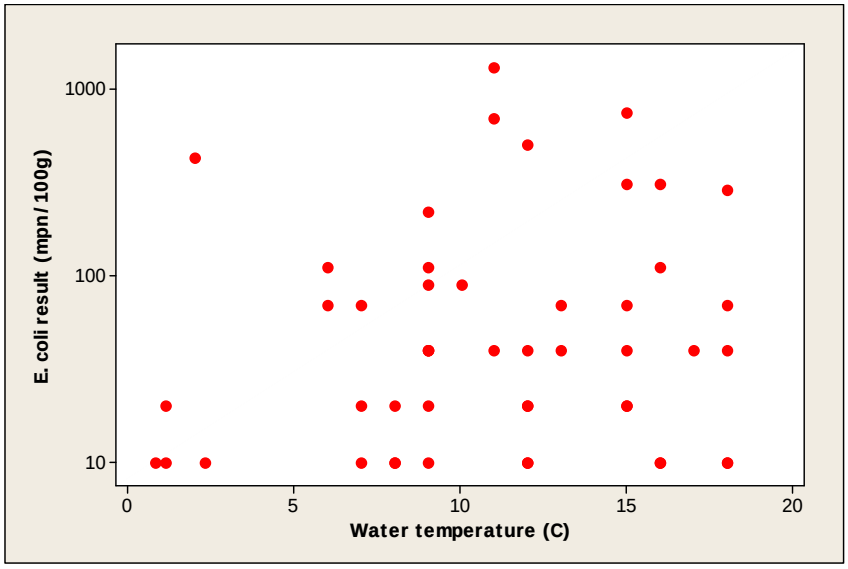

Figure 11.9 Scatterplot of *E. coli* result by water temperature

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature (Adjusted R-sq=0.1%, p=0.315, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production area. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Tiree weather station, and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.10.

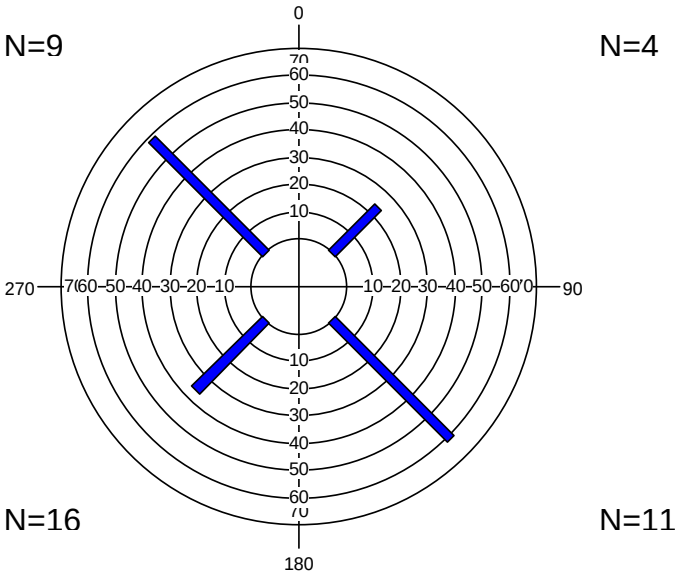

Figure 11.10 Circular histogram of geometric mean *E. coli* result by wind direction

No significant correlation was found between wind direction and *E. coli* result (circular-linear correlation, r=0.118, p=0.598, Appendix 6). It must be noted that number of samples taken during north easterly winds was low, the weather station used was a considerable distance away, and wind speed and variability of wind direction were not taken into account.

11.6.5 Evaluation of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.11 presents a scatter plot of *E. coli* result against salinity, where salinity readings were available.

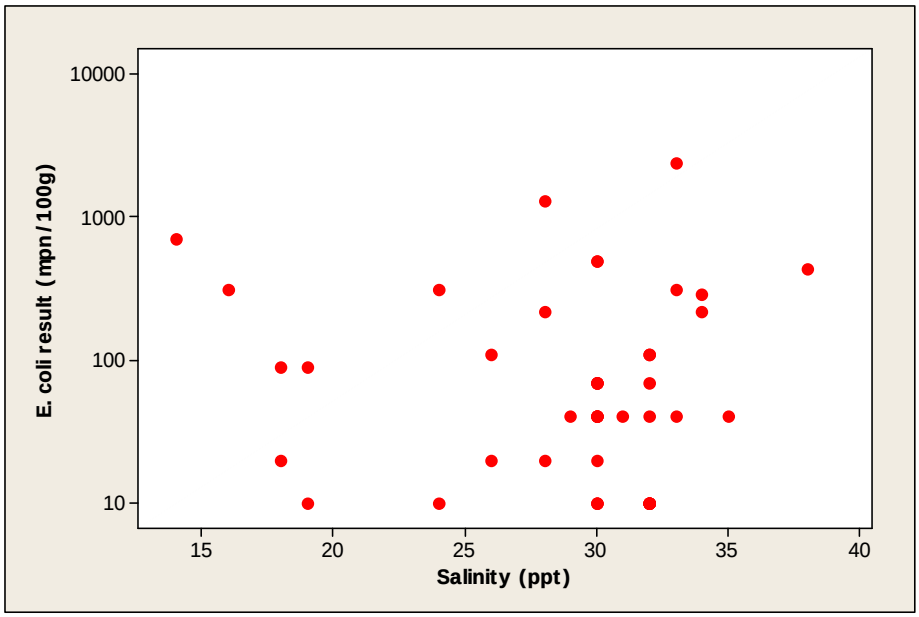

Figure 11.11 Scatterplot of *E. coli* result against salinity

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity (Adjusted R-sq=0.0%, p=0.777, Appendix 6). The range of salinities reported was quite broad considering the limited freshwater inputs to the area.

11.7 Evaluation of peak results

No results over 4600 *E. coli* MPN/100 g were reported. Four results of over 500 *E. coli* MPN/100 g were reported, all for cockle samples. Of these, one was collected in May, two in June and one in November. They were taken under various environmental conditions.

Table 11.2 Historic *E. coli* sampling results over 1000 MPN/100g

Collection date	*E. coli* result (MPN/100g)	Location sampled	2 day rain quartile	7 day rain quartile	7 day wind direction	Previous tide height	Salinity (ppt)	Water temperature (ºC)
03/06/2002	750	NF705055	*	*	*	3.3	*	15
02/05/2005	700	NF705055	Q3	Q2	*	3.3	14	11
06/06/2005	1300	NF705055	Q1	Q4	182º	3.7	28	11
05/11/2007	2400	NF7050005475	*	*	*	3.4	33	*

* Data not available

11.8 Summary and conclusions

No geographic patterns in contamination levels in cockles could be determined as all samples were taken from a small area around the RMP.

There has been a small apparent increase in contamination levels since 2005.

A significant difference was found between results by season, with a significant increase in results obtained during the summer months (Jun-Aug) compared to those for the spring (Mar-May). Of the four highest results, one was collected in May, two in June and one in November, indicating that spikes in contamination levels can occur outside the summer season. No relationship between *E. coli* result and water temperature was found.

No relationships were found between *E. coli* result and recent rainfall or salinity, tide size, or wind direction.

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 this production area it has held seasonal classifications in the last three years.

12. Designated Shellfish Growing Waters Data

Traigh Mhor does not lie within a designated shellfish growing water.

13. River Flow

The following streams were measured and sampled during the shoreline survey. These represent the only significant freshwater inputs into the production area.

Table 13.1 Stream loadings for Traigh Mhor

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/day)	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NF 69783 05180	Stream	1.94	0.14	0.588	13798	<100	$<1.4 \times 10^{10}$
2	NF 70438 04684	Stream	0.14	0.03	0.752	273	<100	$<2.7 \times 10^{8}$
3	NF 71047 04179	Stream	0.38	0.06	0.528	1040	<100	$<1.0 \times 10^{9}$

Only three streams discharge to the area, none of which were particularly large, and all of which had levels of *E. coli* below the limit of detection of the test employed. The calculated loadings presented in Table 13.1 are an estimated figure, and actual loadings may have actually been much lower. Stream 1 had by far the highest volume discharge. All three discharge to the south shore, draining areas of rough pasture, although stream 2 runs adjacent to a few houses, and so may receive inputs from septic tanks. The low levels of *E. coli* in the water sample suggest otherwise, although it is possible that any septic tanks which discharge to the stream were not actually discharging at the time the water sample was collected. No streams were found discharging from the area of sandy pasture to the west and north of the production area, so it is likely that rain falling here soaks into the substrate rather than running off. This is in agreement with the soil drainage characteristics described in Section 5. Therefore greatest impacts from these limited sources may be expected at the southern shore of the production area.

It should be noted that levels of contamination measured in the streams relate to the time of sampling only. Conditions such as time of day, livestock presence, recent application of manure, or higher levels of recent rainfall may materially change the levels of contamination in these streams.

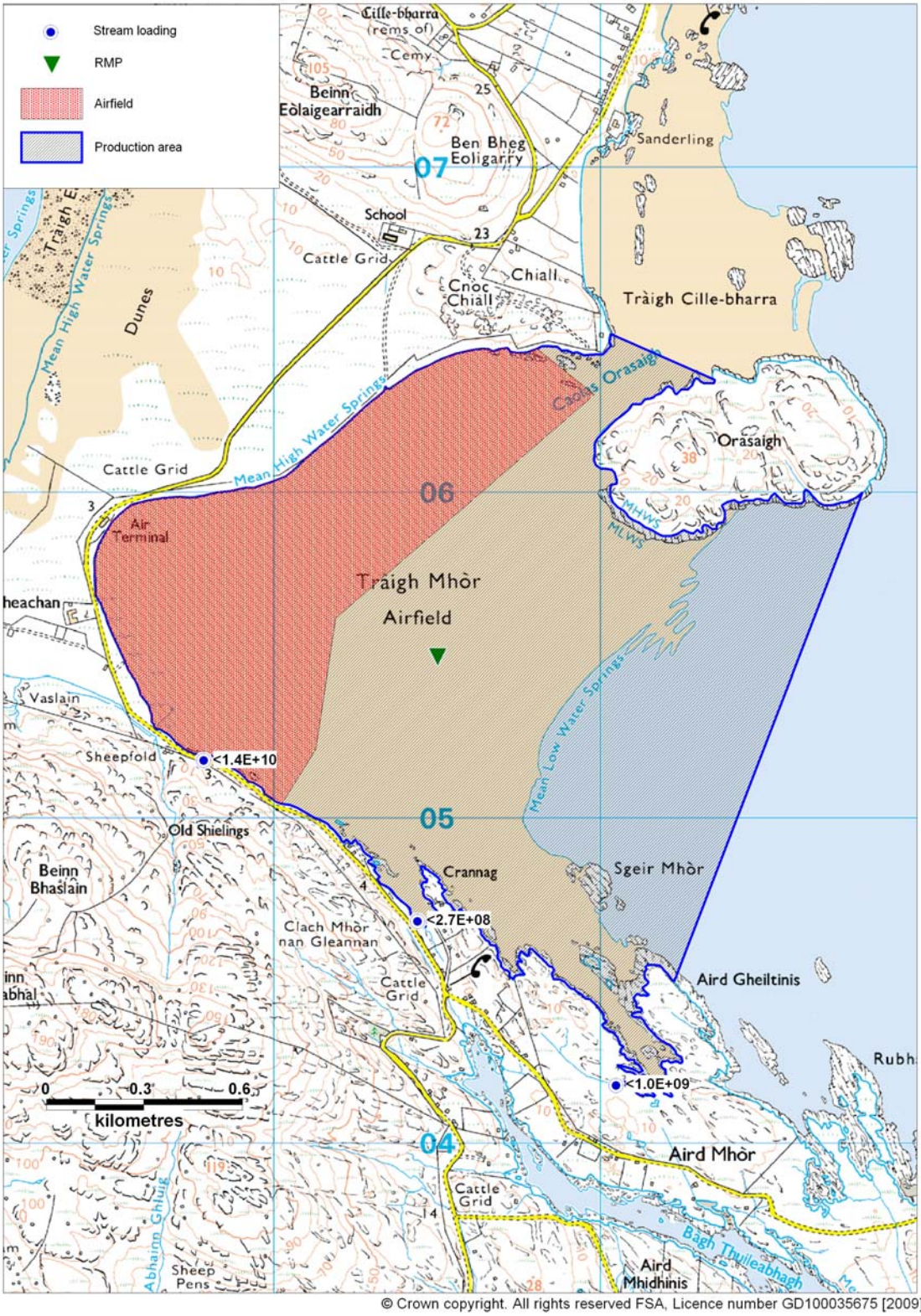

Figure 13.1 Location of streams near Traigh Mhor

14. Bathymetry and Hydrodynamics

Figure 14.1 OS map of Traigh Mhor

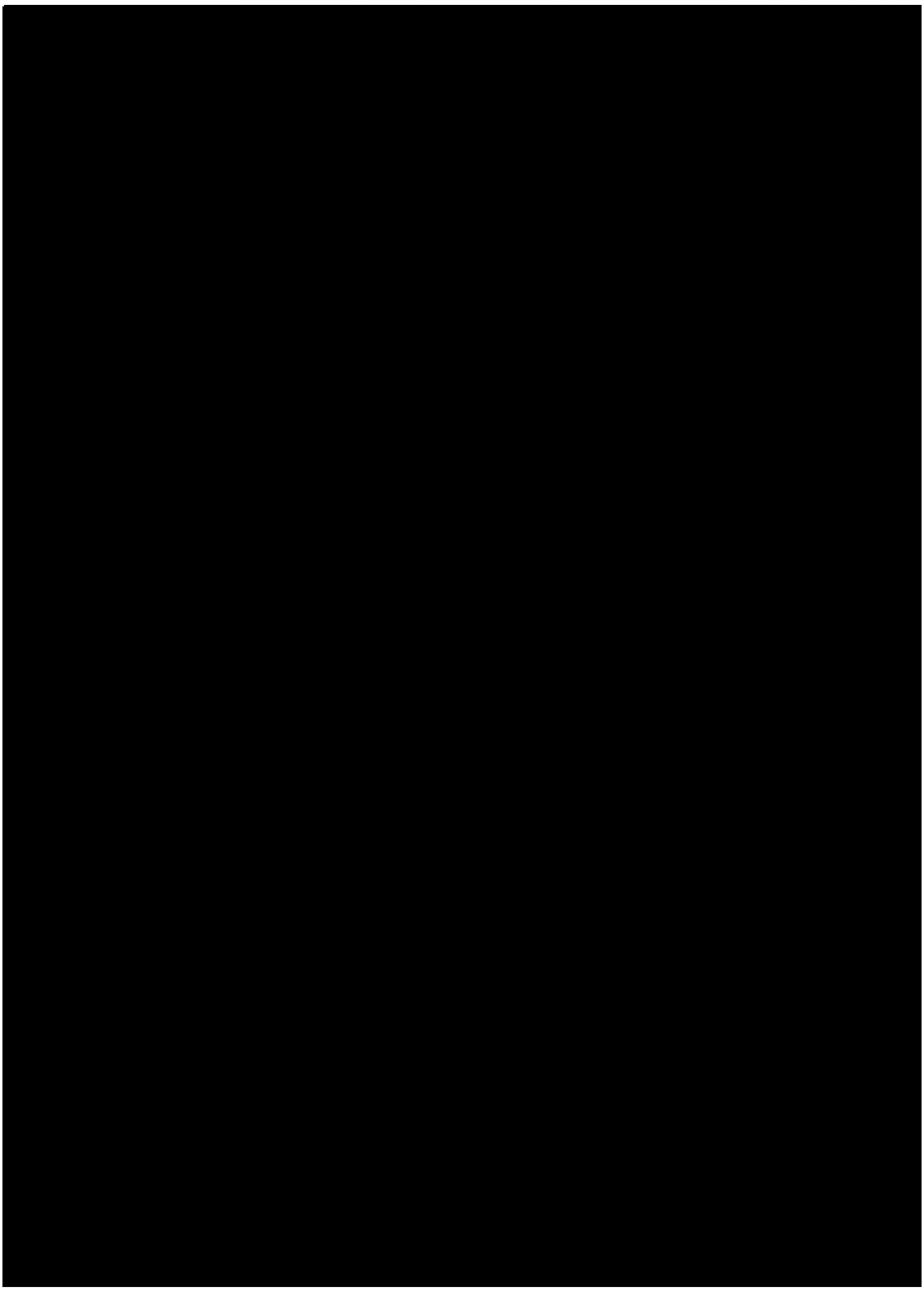

Figure 14.2 Bathymetry of Traigh Mhor

Figure 14.2 shows that the fishery is located on a drying area within a large, shallow bay.

Tidal Curve and Description

The two tidal curves below are for North Bay, approximately 1.5 km to the south of the production area. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 2 September 2008 and the second is for seven days beginning 00.00 GMT on 16 September 208. This two-week period covers the dates of the shoreline survey (3-4 September). Together they show the predicted tidal heights over high/low water for a full spring/neap tidal cycle.

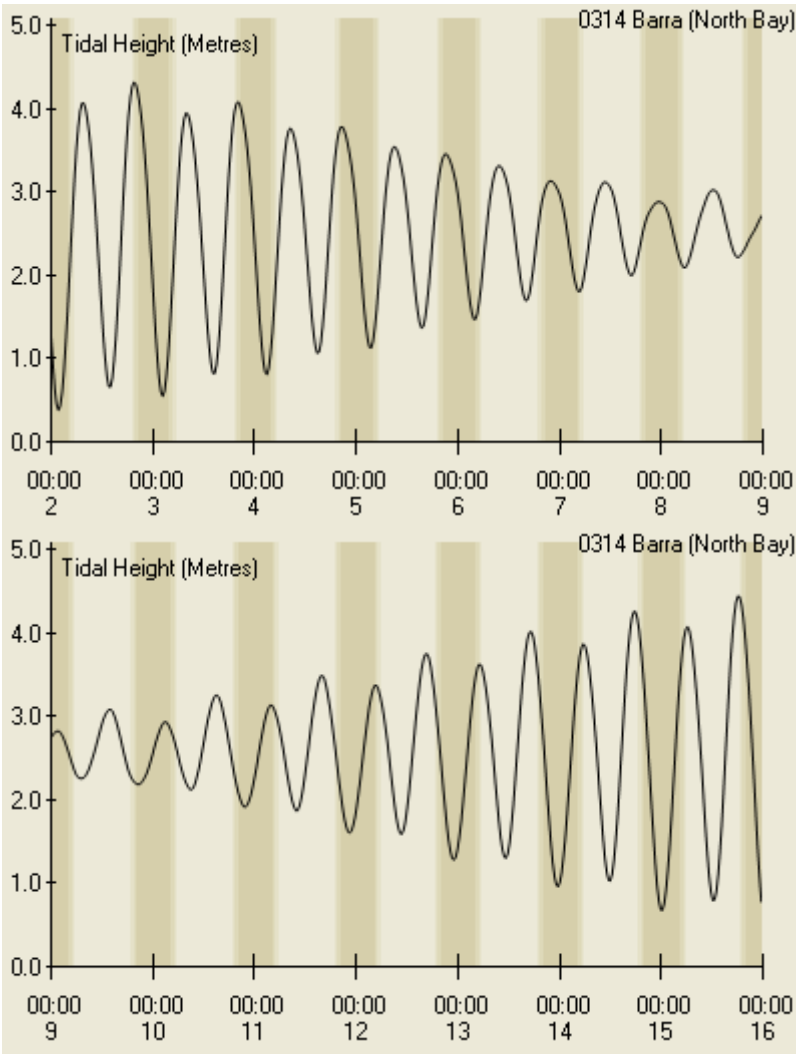

Figure 14.3 Tidal curves for North Bay

The following is the summary description for Barra (North Bay) from TotalTide: Barra (North Bay) is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	4.8 m
MHWS	4.2 m
MHWN	3.2 m
MLWN	1.8 m
MLWS	0.6 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is on average 3.6 m and at neap tide 1.4 m.

Currents

Currents in coastal waters are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area.

Tidal diamonds located in the middle of the Minch and to the South of Barra did not provide sufficient information for a judgement to be made on either speed or direction of flows around Traigh Mhor site at various states of the tide.

Generally, tidal streams around the Outer Hebrides are north-bound on the flood tide and south-bound on the ebb tide. However, in the Sound of Barra, the flood tide flows in from both the NW and SE ends, meeting in the middle before flowing back out both ends again on the ebb (Clyde Cruising Club, 2007). The streams are reported to be weak and variable, meeting to the east of Traigh Mhor and south of the island of Fuday, where the 10 m curve is located on the bathymetry map in Figure 14.2. However, no information was found on measured flows here.

As the flooding tidal streams meet to the east of Traigh Mhor, creating an area of relatively still water, it is expected that the incoming tide will gently push up the beach with limited north-south movement of water. Therefore, contamination such as that originating from the streams on the south shore of Traigh Mhor would be expected to move primarily in an east-west direction with the flooding and ebbing tide. On spring tides, the water in the bay will be almost completely exchanged each tidal cycle, so contamination from sources on the shore will be quickly flushed from the bay. On neap tides however, when the tidal amplitude can be less than 1 m at times, tidal exchange will be much more limited so contamination from sources on the shore will remain in the bay for longer.

Under the latter circumstances, wind driven flows may be of much greater importance. Strong winds will tend to create a surface current in the same direction as the wind, so easterly winds may drive contamination back towards the shore, whereas westerly winds may have the opposite effect. Winds over the shallow waters in this area will increase wave action, which may re-

suspend sediment and contaminants in the water, particularly in the case of an onshore easterly wind.

Density (freshwater) driven flows are likely to be insignificant as the area is relatively unenclosed, shallow, and has very little in the way of freshwater inputs. An unexpectedly large range of salinities were reported when historical *E. coli* monitoring samples were collected (Section 11.6.5). It may be speculated that low salinities may be a localised effect resulting from heavy rain falling on waterlogged sand causing localised salinity reductions at the edge of the water rather than an overall decrease in salinity in the surrounding seas as a whole. However, it is uncertain what method was used to measure salinity, and what the accuracy of this method was, or where exactly the salinity was measured.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 3rd to 4th September 2008.

The beach at Traigh Mhor supports a cockle fishery which is mainly fished by groups of local fisherman. Up to 20 local harvesters may be involved in the fishery. The collection method is usually raking, although some gatherers hand pick them whilst snorkelling. Harvesting gangs from further afield occasionally visit the area. Harvesting may occur year round, but is mainly carried out during the better weather in the summer months. Cockles gathered by local harvesters are usually sold on to wholesalers, and then may be either sent to processors in Glasgow or exported to Spain for depuration. Cockles are present in varying densities and sizes on all parts intertidal zone of the beach. No harvesting is permitted on the upper part of the beach, which is designated as an airfield.

Population on the shores of the area is low. Houses in the area do not have access to mains sewers, so all waste water is likely to be treated by private septic tanks. None of these discharge direct to the production area as they are too far from the shore. A septic tank vent was seen at the air terminal.

At least one of the dwellings seen on the shoreline survey was believed to be a holiday home, but the majority are in year round occupation. A strip of land on the shore immediately to the south of the air terminal is used as a campsite, and a total of 3 tents, one caravan and one motor home were present here at the time of survey. It is probable that most campers staying here use the toilets at the air terminal as they are the closest public toilets available.

Much of the area surrounding the bay is pasture, some of which is grazed by livestock and some of which is used for the production of hay for winter feed. Specifically, 70 cattle and 26 sheep were seen on fields near the air terminal, and 47 sheep were seen on fields and crofts on the south shore. An aggregation of about 80 oystercatchers was seen on the south shore, and a few gulls and waders were seen foraging in the intertidal zone.

As the production area is a gently sloping beach, it is unlikely that boats of any size ever enter it. The Eriskay ferry terminal is located just over 1 km to the south east of the production area, and from here the ferry takes a route north east towards Eriskay. This sails 5 times daily in summer, and 4 times daily during the winter, and was the only boat seen during the course of the survey.

A total of 5 cockle samples were gathered from assorted locations on the cockle bed. Results ranged from <20 to 70 *E. coli* MPN/100 g, and tentatively showed highest results in the centre of the bed. A total of 5 seawater samples were taken on an incoming tide. Results ranged from 2 to 33 *E. coli* cfu/100 ml, again with the highest result in the centre of the bed.

Three streams were sampled during the course of the survey. All three discharge to the south shore, draining areas of rough pasture. The level of

contamination in these streams was low (<100 *E. coli* cfu/100 ml in all cases). No streams were found discharging from the area of low lying sandy pasture to the west and north of the production area.

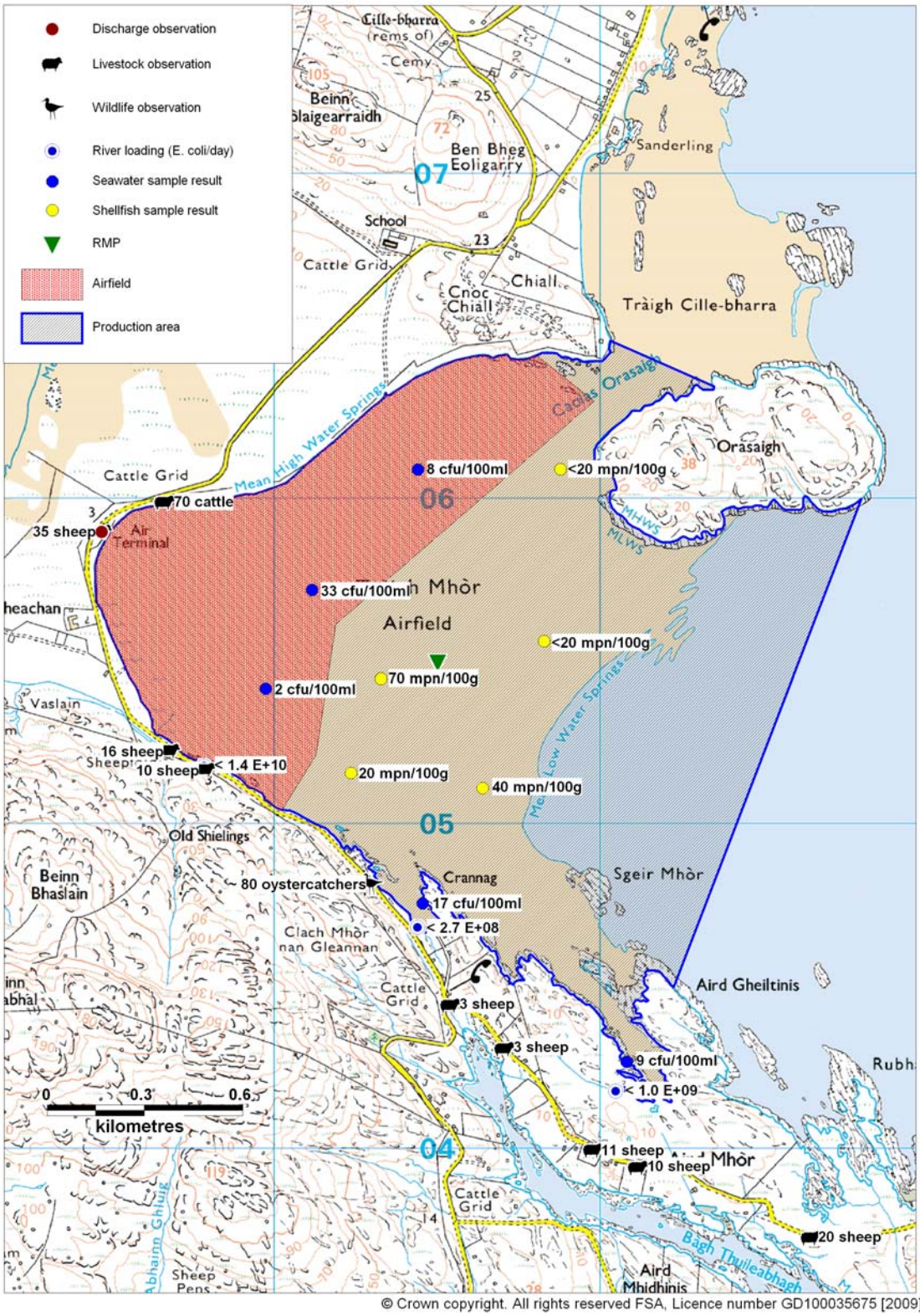

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

There are no known sewage discharges direct to the production area. Houses in the area are mainly concentrated around the southern extremity of the production area. There is no access to mains sewers, so it is likely that they all have private septic tank systems. As no septic tank overflows discharging to the shore were seen during the shoreline survey, it is likely that these systems either discharge to soakaway or to watercourses, although the properties were not closely inspected. Discharges to watercourses will result in contamination being carried into the production area. The three streams in the area had very low levels of contamination, suggesting that they were not subject to significant sewage inputs at the time of shoreline survey, although any sporadic septic tank input may not have been captured by the single water samples.

As the production area is a large intertidal beach, it is unlikely that boats of any size ever enter it. The Eriskay ferry terminal is located just over 1 km to the south east of the production area, and from here the ferry takes a route north east towards Eriskay. This sails 5 times daily in summer, and 4 times daily during the winter, and was the only boat seen during the course of the survey. It is not known where sewage waste from on-board toilet facilities is discharged.

In conclusion, although dwellings in the area are more concentrated around the southern extremity of the production area, no discharges to the shore were recorded from any properties. Impacts from boat traffic are likely to be minor and unpredictable. Therefore, human sewage considerations will have no material bearing on the sampling plan.

Agricultural impacts

Much of the area surrounding the bay is pasture, some of which is grazed by livestock and some of which is used for the production of hay for winter feed. The only source of detailed information on livestock numbers and distribution was the shoreline survey, which only applies to the day of survey. Livestock was most concentrated on pastures by the air terminal, with some on the higher ground and around the crofts towards the south of the production area.

Overall numbers of livestock on the island will be higher during the summer and autumn months following the birth of calves and lambs in spring. Generally, livestock on Barra are grazed on the higher areas further from the shore during the summer and in lower areas nearer the shore during the winter, so livestock impacts to the site may actually be higher during the winter months when they are closer to the shore. Contamination of livestock origin will mainly be carried to the site via the streams draining the area. No streams drain the low lying area of more permeable soils to the west and north of the production area, so although livestock were present on pastures here, contamination deposited here is less likely to be carried into the

production area. Therefore the distribution of livestock and the drainage characteristics of the pastures tentatively indicates livestock inputs may be greater to the southern half of the production area.

Wildlife impacts

Species potentially impacting on Traigh Mhor are likely to primarily be waders and seabirds, and these birds may significantly impact on the fishery via direct deposition on the beach. However, 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 and will not be considered in determination of sampling plans.

Seasonal variation

Tourism will result in an increase in population in the area during the summer months. At least one of the dwellings seen on the shoreline survey was believed to be a holiday home. A few tents and caravans were seen on the strip of land on the shore immediately to the south of the air terminal. Therefore it is expected that the human population in the area will be higher during the summer months.

Livestock numbers will be higher in the summer, but they will generally be kept closer to the shore on lower lying pasture during the winter time. The weather is colder, wetter and windier in the autumn and winter months.

An analysis of historical *E. coli* monitoring data identified a significant seasonal effect, with *E. coli* results in the summer higher than those in the spring.

Rivers and streams

Only three streams discharge to the area, none of which were particularly large, and all of which had levels of *E. coli* below the limit of detection of the test employed when sampled during the shoreline survey. All three discharge to the south shore, draining areas of rough pasture on the more impermeable soils found here. One of them runs adjacent to a few houses, and so may receive inputs from septic tanks, although the low levels of *E. coli* suggested otherwise at the time of sampling.

No streams were found discharging from the area of sandy pasture to the west and north of the production area, so it is likely that rain falling here soaks into the substrate rather than running off. Therefore greatest impacts from these minor sources may be expected at the southern shore of the production area.

Meteorology, hydrology, and movement of contaminants

Currents in coastal waters are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area.

Generally, tidal streams around the Outer Hebrides are north-bound on the flood tide and south-bound on the ebb tide. However, in the Sound of Barra, the flood tide flows in from both the NW and SE ends, meeting in the middle before flowing back out both ends again on the ebb. The streams are reported to be weak and variable, meeting to the east of Traigh Mhor and south of the island of Fuday. As the flooding tidal streams meet to the east of Traigh Mhor, creating an area of relatively still water, it is expected that the incoming tide will gently push up the beach with limited north-south movement of water. Therefore, contamination such as that originating from the streams on the south shore of Traigh Mhor would be expected to move primarily in an east-west direction with the flooding and ebbing tide. On spring tides, the water in the bay will be almost completely exchanged each tidal cycle, so contamination from sources on the shore will be quickly flushed from the bay. On neap tides however, when the tidal amplitude can be less than 1 m at times, tidal exchange will be much more limited so contamination from sources on the shore will remain in the bay for longer.

Under the latter circumstances, wind driven flows may be of much greater importance. Strong winds will tend to create a surface current in the same direction as the wind, so easterly winds may drive contamination back towards the shore, whereas westerly winds may have the opposite effect. Winds over the shallow waters in this area will increase wave action, which may re-suspend sediment and contaminants in the water, particularly in the case of an onshore easterly wind.

Density (freshwater) driven flows are likely to be insignificant as the area is relatively unenclosed, shallow, and has very little in the way of freshwater inputs.

An analysis of historical *E. coli* monitoring data identified no statistically significant relationships between *E. coli* results and water temperature, rainfall, salinity, tide size or wind direction.

Temporal and geographical patterns of sampling results

Historic *E. coli* monitoring results suggest a small increase in contamination levels since 2005, although the reason for this is unclear. No geographic patterns in contamination levels in historic *E. coli* monitoring results could be determined as all cockle samples were taken from a small area around the RMP, so any variation in results was most likely attributable to differences in conditions on the day rather than geographical effects.

During the course of the shoreline survey, a total of 5 cockle samples were gathered from assorted locations within the production area. Results ranged

from <20 to 70 *E. coli* MPN/100 g, with the highest result arising in the middle of the bed. A total of 5 seawater samples were taken on an incoming tide. Results ranged from 2 to 33 *E. coli* cfu/100 ml, again with the highest result arising in the middle of the bed. This apparent spatial pattern is very tentative, and is based on small differences over a small number of samples taken on one occasion only.

In conclusion, the historic *E. coli* monitoring results do not provide any firm indication of geographical patterns of levels of contamination within the cockle bed, and the possible pattern observed in samples taken on the shoreline survey is very tentative and should not be used as the sole basis for the definition of the RMP.

17. Recommendations

As the whole of the beach at Traigh Mhor is reported to host harvestable cockles, and no 'hotspots' or point sources of contamination have been identified, there is no reason to alter the boundaries aside from to exclude the airfield, where harvesting is prohibited. Therefore, the recommended production area is the area bounded by lines drawn between NF 7103 0649 and NF 7135 0635, and between NF 7180 0600 and NF 7123 0450, and between NF 7002 0504 and NF 7013 0521 and between NF 7013 0521 and NF 7019 0561 and between NF 7019 0561 and NF 7098 0630 and between NF 7098 0630 and NF 7080 0644 extending to MHWS.

To determine the location of the RMP, consideration must be given to the location of the stock, any geographical patterns in *E. coli* sampling results from the historical *E. coli* sampling and the shoreline survey, and the location of the most important contamination sources. Cockles are reported to be present throughout the intertidal area, albeit at varying densities. No geographical patterns could be determined from the historical *E. coli* monitoring results, and tentatively the shoreline survey results suggest that contamination may have been slightly higher towards the middle of the bed at the time of survey. As the streams all discharge to the southern shore of the production area, and these are likely to be the main route via which contamination from livestock is carried into the production area, so on balance, the RMP should be set somewhere near these sources. Therefore, it is recommended that the RMP be set at NF 7036 0497. The sampling method should be hand rake, the main method used commercially in the area. Only stock of a harvestable size should be sampled. A sampling tolerance of 50 m should allow sufficient area from which a sample can be collected, even if stock density is relatively low here. As seasonal fluctuations in *E. coli* results have been found in historical monitoring results, the sampling frequency should remain monthly.

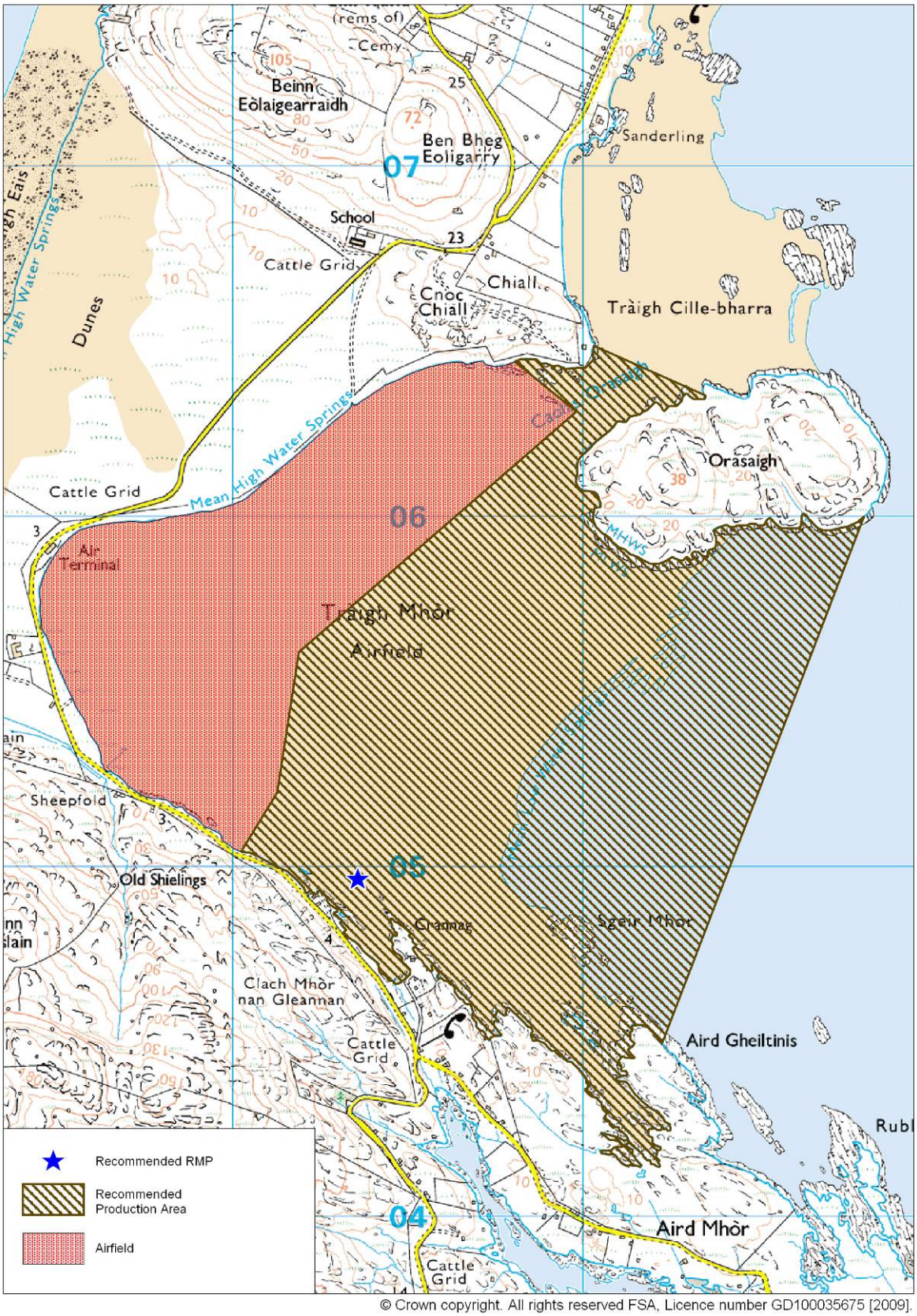

Figure 17.1 Recommendations for Traigh Mhor

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Appendix 1

Sampling Plan for Traigh Mhor

Production Area	Site name	SIN	Species	Type of fishery	NGR of RMP	Eastings	Northings	Tolerance (m)	Depth (M)	Method of sampling	Frequency of sampling	Local authority	Authorised sampler(s)	Local Authority Liaison Officer
Traigh Mhor	Traigh Mhor	UB 282 165 04	Common cockle	Wild	NF 7036 0497	70360	804970	50	NA	Hand rake	Monthly	Comhairle nan Eilean Siar	Samantha Muir	Samantha Muir

Comparative Table of Boundaries and RMPs – Traigh Mhor

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Traigh Mhor	Common cockle	UB 282	Area inshore of lines drawn between NF 7103 0649 and NF 7135 0638 and between NF 7180 0600 and NF 7122 0450	NF 705 055	Area bounded by lines drawn between NF 7103 0649 and NF 7135 0635, and between NF 7180 0600 and NF 7123 0450, and between NF 7002 0504 and NF 7013 0521 and between NF 7013 0521 and NF 7019 0561 and between NF 7019 0561 and NF 7098 0630 and between NF 7098 0630 and NF 7080 0644 extending to MHWS	NF 7036 0497	Boundaries adjusted to exclude airfield where no fishing is permitted, RMP moved south to better capture possible contamination sources.

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.

References

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General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin

faeces, in large part because the animals are widely dispersed and sample collection difficult.

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

Table 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.

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

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28 x 10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77 x 10^8 FC per faecal deposit to a local

reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

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

Deer

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

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

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

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

Otters

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

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

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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 *E. coli* data was log transformed prior to the analyses.

Section 11.5 One Way ANOVA comparison of *E. coli* results by season

```
Source  DF      SS     MS     F      P
Season   3   4.344  1.448  4.42  0.007
Error   61  19.984  0.328
Total   64  24.328

S = 0.5724   R-Sq = 17.86%   R-Sq(adj) = 13.82%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      19  1.4371  0.4728   (--------*--------)
2      16  2.0287  0.7072                     (---------*--------)
3      15  1.9230  0.6588                  (---------*---------)
4      15  1.5062  0.4126    (---------*---------)
                           -+---------+---------+---------+--------
                          1.20      1.50      1.80      2.10

Pooled StDev = 0.5724


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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
2        0.0780  0.5916  1.1052                    (--------*-------)
3       -0.0369  0.4859  1.0087                 (--------*--------)
4       -0.4538  0.0691  0.5919           (--------*--------)
                                 --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.20


Season = 2 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
3       -0.6497  -0.1057  0.4383         (--------*--------)
4       -1.0666  -0.5225  0.0215  (--------*--------)
                                 --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.20


Season = 3 subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
4       -0.9696  -0.4169  0.1359    (--------*--------)
                                 --------+---------+---------+---------+-
                                      -0.60      0.00      0.60      1.20
```

Section 11.6.1 Pearson correlation of ranked *E. coli* results and ranked 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked result = 0.067
P-Value = 0.700
```

Section 11.6.1 Pearson correlation of ranked *E. coli* results and ranked 2 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked result = 0.218
P-Value = 0.207
```

Section 11.6.2 Regression analysis, *E. coli* result vs height of previous high water

```
The regression equation is
logresult = 2.14 - 0.119 tide height


Predictor       Coef  SE Coef      T      P
Constant      2.1358   0.7461   2.86  0.006
tide height  -0.1190   0.2078  -0.57  0.569


S = 0.619809   R-Sq = 0.5%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.1260  0.1260  0.33  0.569
Residual Error  63  24.2022  0.3842
Total           64  24.3283


Unusual Observations

       tide
Obs  height  logresult     Fit  SE Fit  Residual  St Resid
 40    3.70     3.1139  1.6954  0.0814    1.4185      2.31R
 52    4.40     1.6021  1.6121  0.1887   -0.0100     -0.02 X
 63    3.40     3.3802  1.7311  0.0847    1.6491      2.69R

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

Section 11.6.3 Regression analysis, *E. coli* result vs water temperature

```
The regression equation is
logresult for temp = 1.45 + 0.0182 WaterTemp


Predictor     Coef  SE Coef     T      P
Constant    1.4540   0.2142  6.79  0.000
WaterTemp  0.01819  0.01790  1.02  0.315


S = 0.595207   R-Sq = 2.2%   R-Sq(adj) = 0.1%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3659  0.3659  1.03  0.315
Residual Error  47  16.6507  0.3543
Total           48  17.0166


Unusual Observations
```

```
                logresult
Obs  WaterTemp   for temp     Fit  SE Fit  Residual  St Resid
 12        2.0     2.6335  1.4904  0.1819    1.1431      2.02R
 32       11.0     2.8451  1.6541  0.0850    1.1910      2.02R
 33       11.0     3.1139  1.6541  0.0850    1.4598      2.48R

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

Section 11.6.4 Circular linear correlation of *E. coli* result and wind direction

CIRCULAR-LINEAR CORRELATION
Analysis begun: 24 October 2008 10:14:54

Variables (& observations)	r	p
Angles & Linear (40)	0.118	0.598

Section 11.6.3 Regression analysis, *E. coli* result vs salinity

```
The regression equation is
logresult for salinity = 2.04 - 0.0097 Salinity


Predictor      Coef  SE Coef      T      P
Constant     2.0406   0.5394   3.78  0.000
Salinity   -0.00969  0.01834  -0.53  0.600


S = 0.645964   R-Sq = 0.6%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.1165  0.1165  0.28  0.600
Residual Error  46  19.1944  0.4173
Total           47  19.3109


Unusual Observations

               logresult
                    for
Obs  Salinity   salinity     Fit  SE Fit  Residual  St Resid
 29      14.0     2.8451  1.9049  0.2898    0.9402      1.63 X
 30      28.0     3.1139  1.7692  0.0949    1.3448      2.10R
 37      16.0     2.4914  1.8855  0.2553    0.6058      1.02 X
 48      33.0     3.3802  1.7207  0.1191    1.6595      2.61R

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

1.0 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.

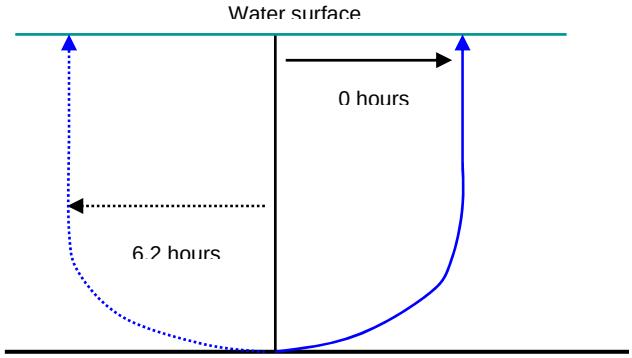
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

2.0 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.

a)



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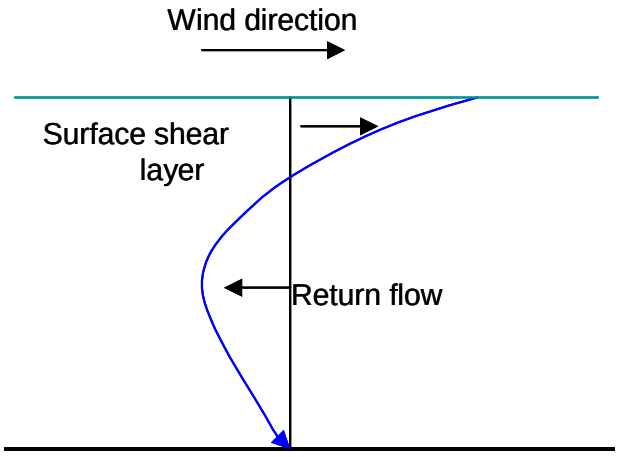

c)

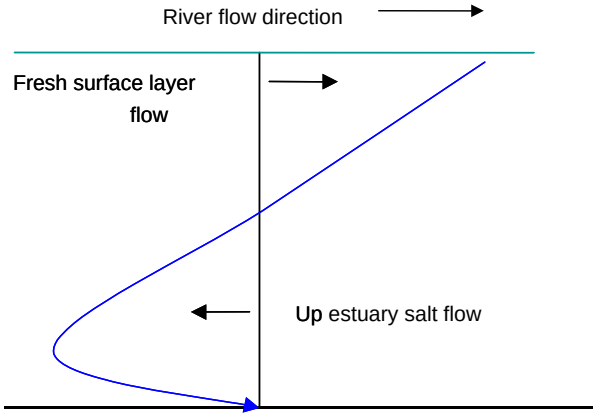

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

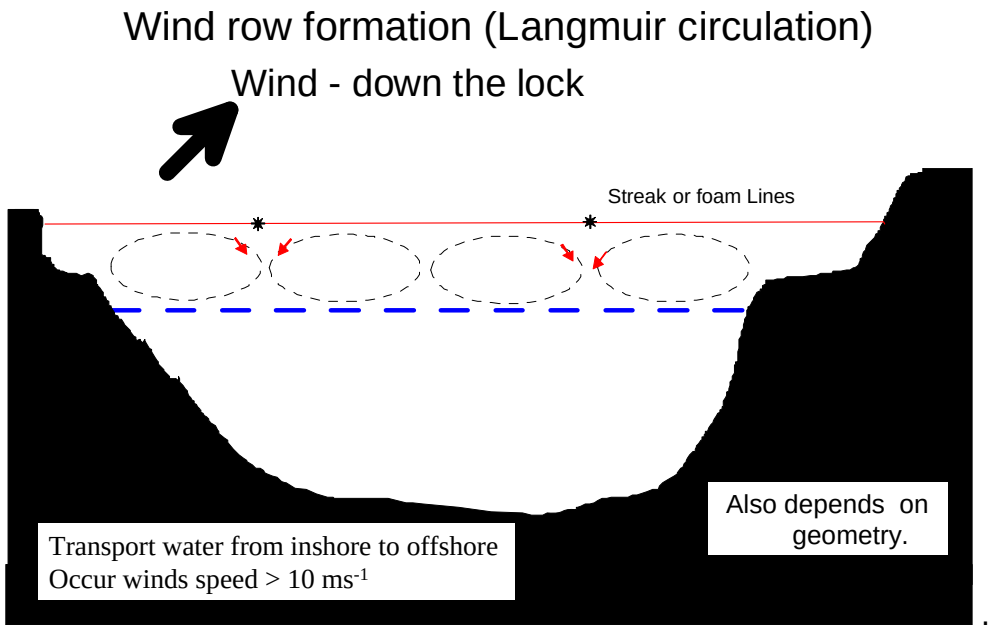

Figure 2: Schematic of wind driven ‘wind row’ currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Traigh Mor
UB 282 165

Scottish Sanitary Survey Project

Shoreline Survey Report

Production Area:

Production Area	Site	SIN	Species
Traigh Mor	Traigh Mor	UB 282 165	Common cockle

Harvesters: Up to 20 local harvesters work this area
Status: Currently classified for harvest.
Date Surveyed: 3/9/08 and 4/9/08
Surveyed by: Samantha Muir, Alastair Cook
Existing RMP: NF 705 055
Area Surveyed: See Figure 1.

Weather observations:
3/9/08 – 7 km/h north easterly wind, 12 ºC, some showers.
4/9/08 – 4 km/h northerly wind, 13 ºC, dry.

Fishery

The beach at Traigh Mor supports a cockle fishery which is mainly fished by groups of local fisherman. Up to 20 local harvesters may be involved in the fishery. The collection method is usually raking, although some gatherers hand pick them whilst snorkelling. Harvesting gangs from further afield occasionally visit the area. Harvesting may occur year round, but is mainly carried out during the better weather in the summer months. Cockles gathered by local harvesters are usually sold on to wholesalers, and then may be either sent to processors in Glasgow or exported to Spain for depuration. Cockles are present in varying densities and sizes on all parts intertidal zone of the beach. The larger cockles are found closer to the low water mark. No harvesting is permitted on the upper part of the beach, which is designated as an airfield, although this area can be used for access when the airfield is not in operation.

Sewage/Faecal Sources

Human
Population on the shores of the bay is low. Houses in the area do not have access to mains sewers, so all waste water goes to septic tank. None of these discharge direct to the production area as they are too far from the shore and the permeable sandy soil in the area would lend itself to effective soakaways.

Livestock
Much of the area surrounding the bay is pasture, some of which is grazed by livestock and some of which is used for the production of hay for winter feed. Specifically, 70 cattle and 26 sheep were seen on fields near the air terminal, and 47 sheep were seen on crofts on the south shore. Generally livestock on

Barra are grazed on the higher areas further from the shore during the summer, and in lower areas nearer the shore during the winter time.

Three streams were sampled during the course of the survey. All three discharge to the south shore, draining areas of rough pasture. The level of contamination in these streams was low (<100 *E. coli* cfu/100ml in all cases). No streams were found discharging from the area of sandy pasture to the west and north of the production area.

Seasonal Population

At least one of the dwellings seen on the shoreline survey was believed to be holiday homes, but the majority are in year round occupation. A strip of land on the shore immediately to the south of the air terminal is used as a campsite, and a total of 3 tents, one caravan and one motor home were present here at the time of survey. It is probable that most campers staying here use the toilets at the air terminal as they are the closest public toilets available.

Boats/Shipping

As the production area is a large intertidal beach, it is unlikely that boats of any size ever enter it. It is likely that the area offshore of the production area is frequented at times by small fishing vessels, but none were noted during the course of the survey. The Eriskay ferry terminal is located just over 1 km to the south east of the production area, and from here the ferry takes a route north east towards Eriskay. This sails 5 times daily in summer, and 4 times daily during the winter. This was the only boat seen during the course of the survey.

Land Use

The area surrounding the production area is pasture, some of which was being grazed, some used for the production of hay.

Wildlife/Birds

An aggregation of oystercatchers was seen on a rock on the south shore of the beach at high water. It is likely that these birds forage on the cockle bed when it is exposed. Aside from these, and a few small waders and gulls seen foraging on the cockle bed, no other aggregations of wildlife were seen.

Records and Sampling

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 4-8. The contiguous area to the north (Traigh Cille Barra) had been the subject of a restricted sanitary survey earlier in the year.

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 production area.

A total of 5 seawater samples were taken on an incoming tide. Results ranged from 2 to 33 *E. coli* cfu/100 ml.

A total of 5 cockle samples were gathered from assorted locations on the cockle bed. Results ranged from <20 to 70 *E. coli* mpn/100g.

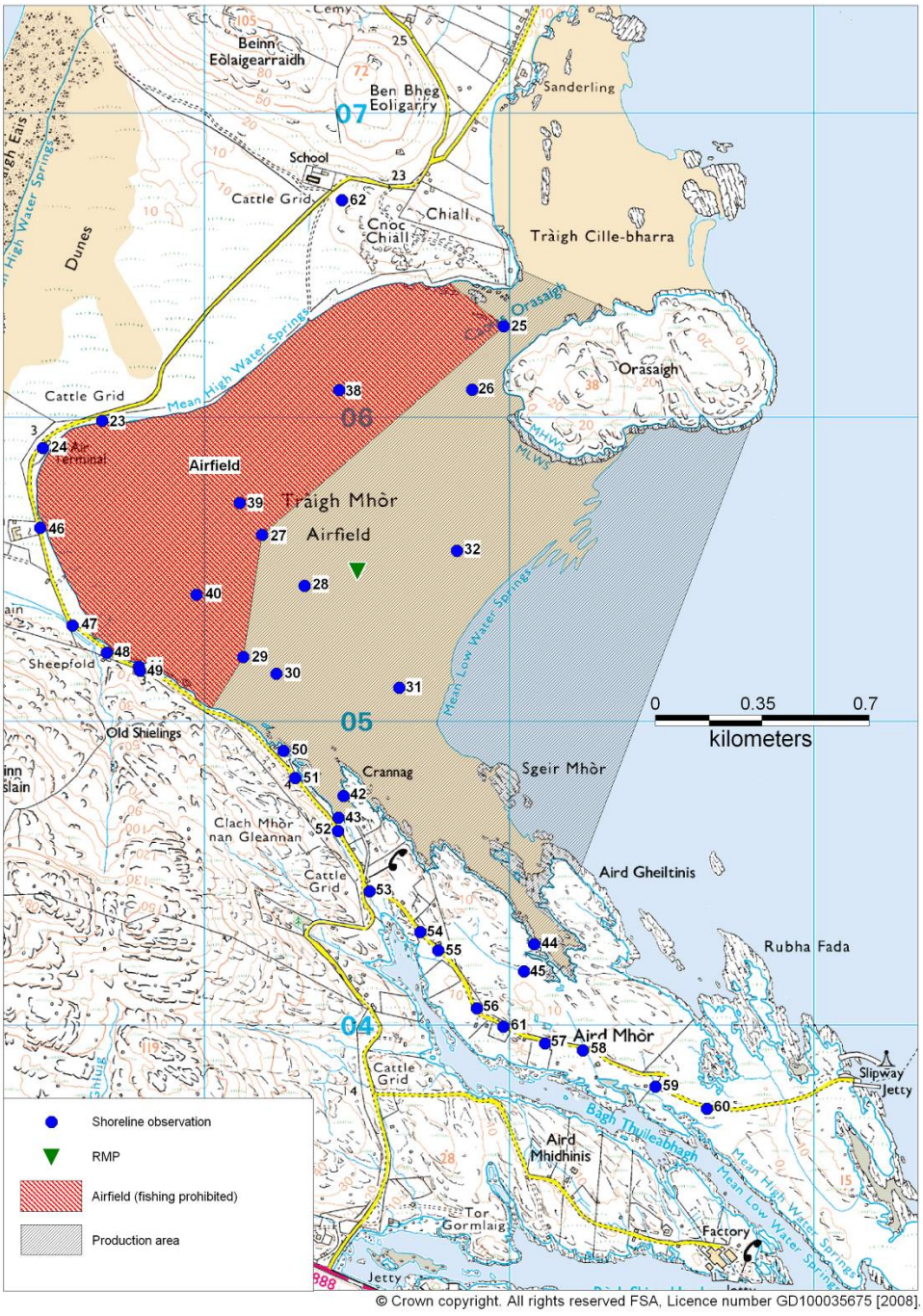

Figure 1. Shoreline Observations

Table 1. Shoreline Observations

No.	Date and time	Position	Photograph	Description
23	03-SEP-08 12:49:35PM	NF 69662 05990		70 cattle (fenced off from shore)
24	03-SEP-08 12:54:57PM	NF 69468 05900	Figure 4	Air teminal, septic tank vents seen in concrete but no overflow pipe. 35 sheep in field opposite
25	03-SEP-08 12:58:58PM	NF 70980 06301		Airfield marker post
26	03-SEP-08 1:00:26PM	NF 70877 06092		Barra cockle sample 1
27	03-SEP-08 1:13:39PM	NF 70187 05614		Airfield marker post. A few waders and gulls on sand.
28	03-SEP-08 1:37:55PM	NF 70326 05447		Barra cockle sample 2
29	03-SEP-08 1:41:39PM	NF 70126 05212		Airfield marker post
30	03-SEP-08 1:42:40PM	NF 70234 05158		Barra cockle sample 3
31	03-SEP-08 1:57:40PM	NF 70638 05111		Barra cockle sample 4
32	03-SEP-08 2:31:22PM	NF 70827 05562		Barra cockle sample 5
38	04-SEP-08 7:01:27AM	NF 70440 06090		Seawater sample 6
39	04-SEP-08 7:03:46AM	NF 70114 05720		Seawater sample 8
40	04-SEP-08 7:06:42AM	NF 69972 05417		Seawater sample 9
41	04-SEP-08 7:13:17AM	NF 69783 05180		Stream 194cmx14cmx0.588m/s. Freshwater sample 10
42	04-SEP-08 7:24:53AM	NF 70454 04756		Seawater sample 11
43	04-SEP-08 7:27:12AM	NF 70438 04684		Stream 14cmx3cmx0.752m/s. Freshwater sample 12
44	04-SEP-08 7:40:46AM	NF 71080 04268		Seawater sample 13
45	04-SEP-08 7:44:06AM	NF 71047 04179		Stream 38cmx6cmx0.528m/s. Freshwater sample 14
46	04-SEP-08 10:12:24AM	NF 69459 05637	Figure 5	Holiday house, campsite, 3 cars and 3 tents.
47	04-SEP-08 10:13:41AM	NF 69565 05316		Motor home and caravan.
48	04-SEP-08 10:14:37AM	NF 69678 05227		16 sheep
49	04-SEP-08 10:15:15AM	NF 69786 05168		10 sheep
50	04-SEP-08 10:20:07AM	NF 70257 04904		House
51	04-SEP-08 10:23:23AM	NF 70296 04814	Figure 6	~ 80 oystercatchers on rocks.
52	04-SEP-08 10:24:38AM	NF 70437 04641		6 houses around bay
53	04-SEP-08 10:25:41AM	NF 70540 04442		3 houses and 3 sheep
54	04-SEP-08 10:27:52AM	NF 70706 04308		3 sheep
55	04-SEP-08 10:28:19AM	NF 70766 04248		4 houses
56	04-SEP-08 10:28:59AM	NF 70892 04057		2 houses
57	04-SEP-08 10:29:46AM	NF 71116 03942		House and 10 sheep
58	04-SEP-08 10:30:36AM	NF 71240 03918		4 houses
59	04-SEP-08 10:31:22AM	NF 71479 03800		New house
60	04-SEP-08 10:32:04AM	NF 71648 03726		20 sheep
61	04-SEP-08 10:34:24AM	NF 70979 03996		11 sheep
62	04-SEP-08 10:41:26AM	NF 70449 06715		School and 11 new houses (some still under construction)

Table 2. Water Sample *E. coli* Results

Name	Date and time	Position	Type	*E. coli* (cfu/100ml)	Salinity (ppt)
Barra 6	04-SEP-08 7:01:27AM	NF 70440 06090	Seawater	8	34.9
Barra 8	04-SEP-08 7:03:46AM	NF 70114 05720	Seawater	33	34.5
Barra 9	04-SEP-08 7:06:42AM	NF 69972 05417	Seawater	2	34.9
Barra 10	04-SEP-08 7:13:17AM	NF 69783 05180	Freshwater	<100	
Barra 11	04-SEP-08 7:24:53AM	NF 70454 04756	Seawater	17	30.9
Barra 12	04-SEP-08 7:27:12AM	NF 70438 04684	Freshwater	<100	
Barra 13	04-SEP-08 7:40:46AM	NF 71080 04268	Seawater	9	33.4
Barra 14	04-SEP-08 7:44:06AM	NF 71047 04179	Freshwater	<100	

Table 3. Shellfish Sample *E. coli* Results

Name	Date and time	Position	Species	*E. coli* (mpn/100g)
Barra 1	03-SEP-08 1:00:26PM	NF 70877 06092	Cockle	<20
Barra 2	03-SEP-08 1:37:55PM	NF 70326 05447	Cockle	70
Barra 3	03-SEP-08 1:42:40PM	NF 70234 05158	Cockle	20
Barra 4	03-SEP-08 1:57:40PM	NF 70638 05111	Cockle	40
Barra 5	03-SEP-08 2:31:22PM	NF 70827 05562	Cockle	<20

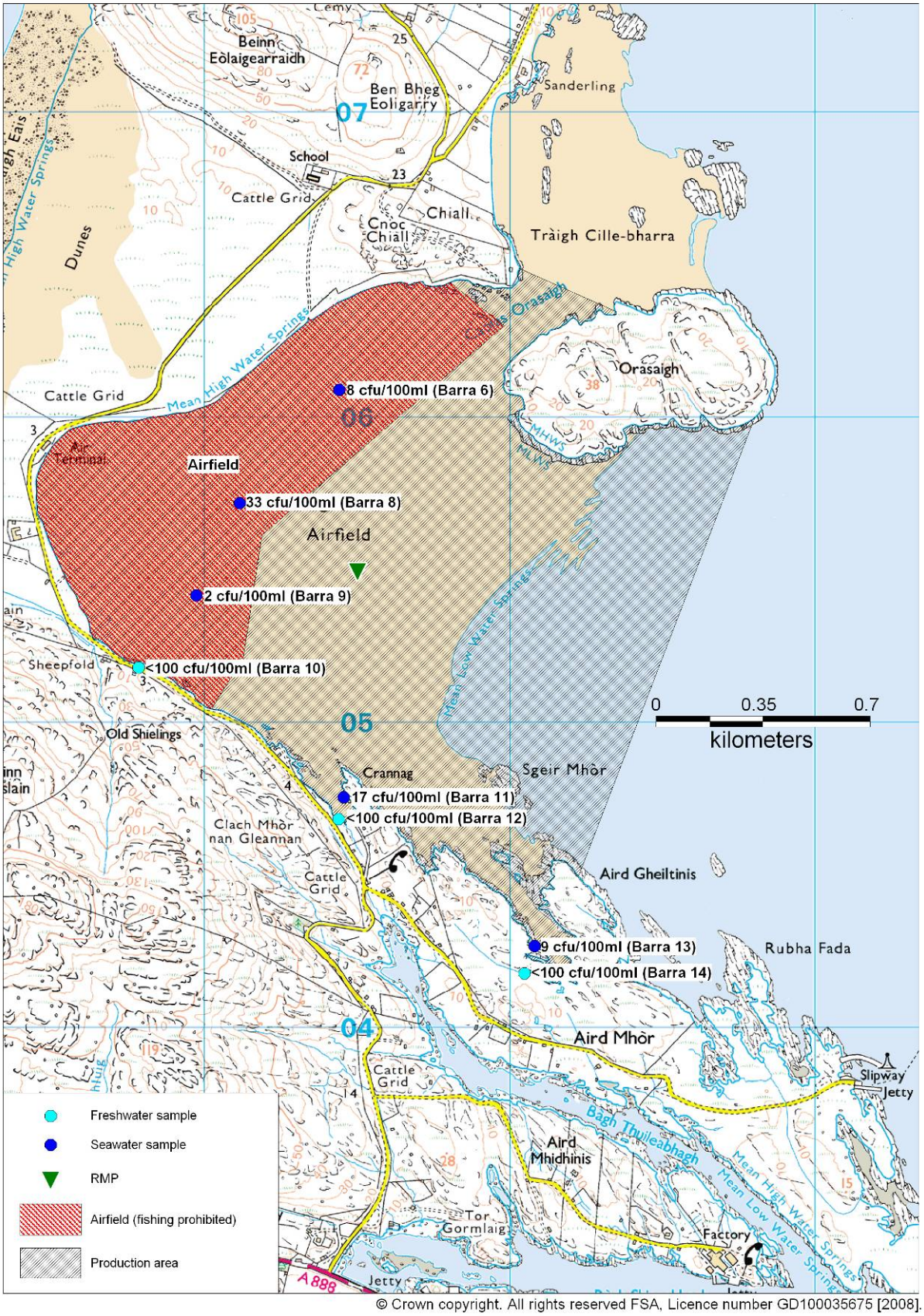

Figure 2. Water sample results

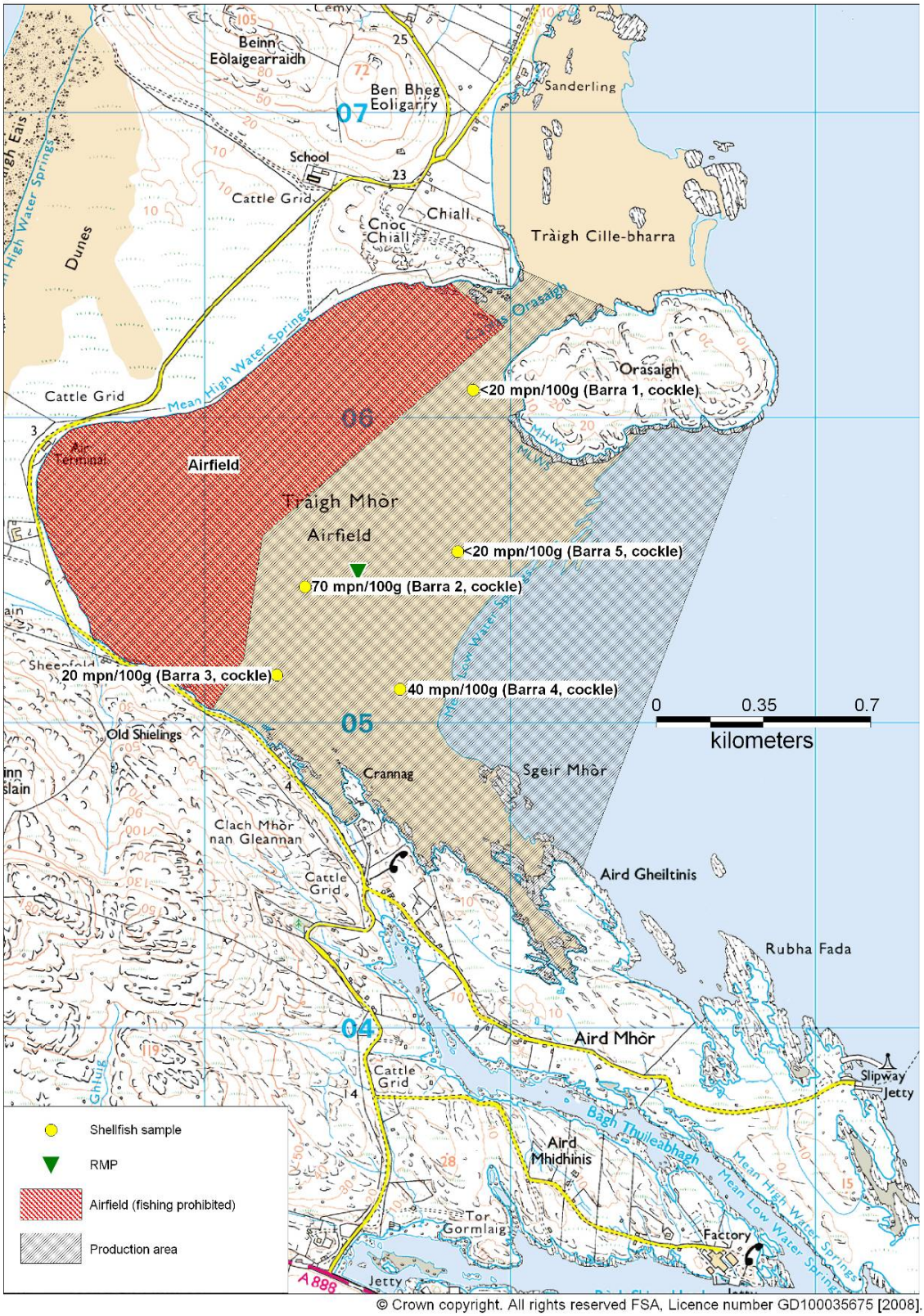

Figure 3. Shellfish sample results

Figure 4 Presumed air terminal septic tank vents

Figure 5 Campsite and large holiday home to the south of the air terminal

Figure 6 Aggregation of oystercatchers on rock at high water

Figure 7 Substrate on cockle bed

Figure 8 Harvesters working cockle bed at low water