Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Leven: Upper
HL 171
February 2010

Report Distribution – Loch Leven: Upper

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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 is undertaken by the relevant local authority.

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1. General Description

Loch Leven is located along the northern reaches of Loch Linnhe on the western coast of Scotland, approximately 40 km northwest of Oban. Loch Leven opens to the west via a narrow straight and contains 5 sills. The loch is 13km in length, 0.09 km at its narrowest point and 1.6 km at its widest point, with a maximum depth of 62 metres.

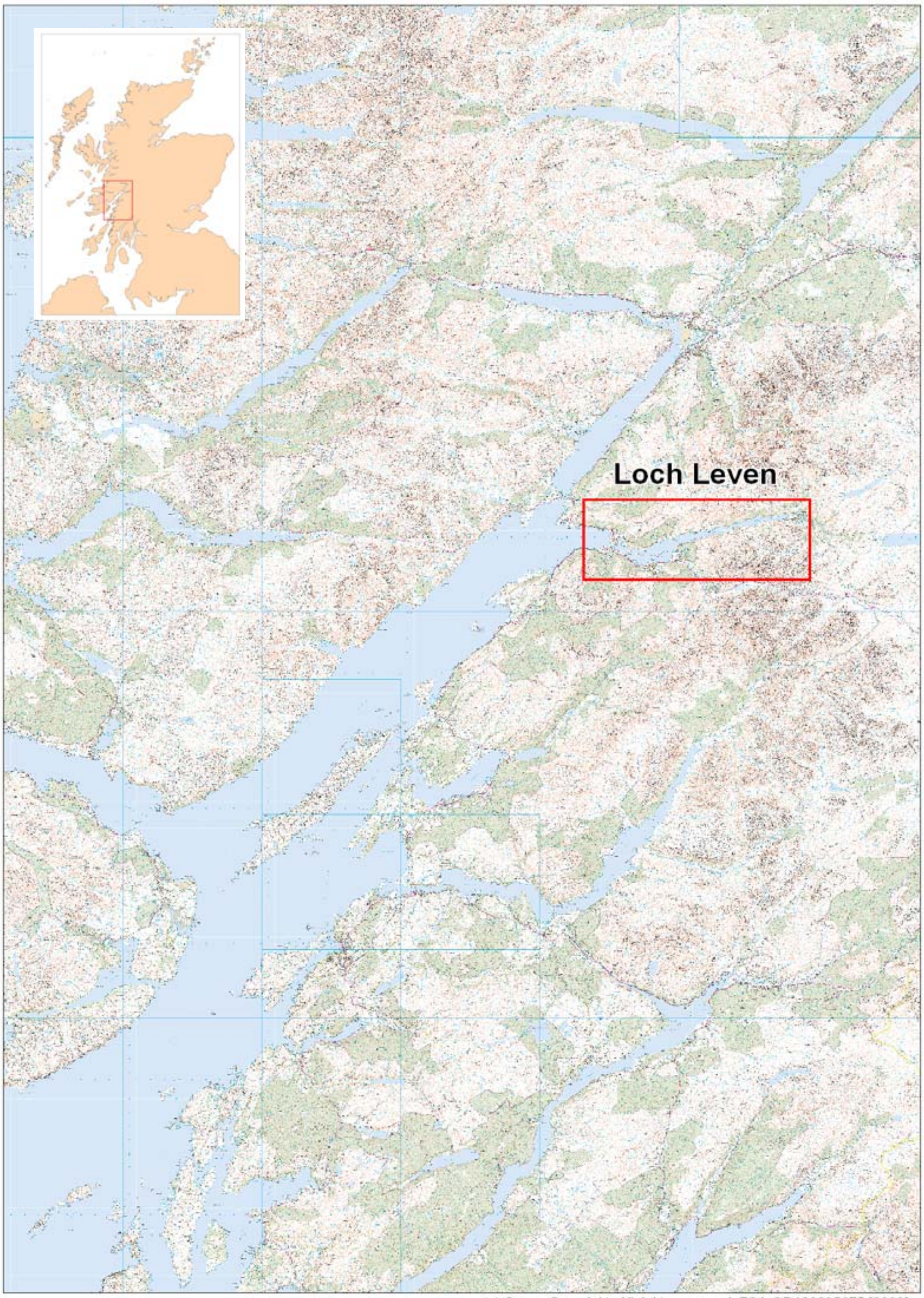

Figure 1.1 Location of Loch Leven

2. Fishery

The fishery at Loch Leven: Upper (HL 171 223 08) production area is comprised of a long line mussel (*Mytilus* sp.) farm.

The Loch Leven: Upper classified production area is described as the area bounded by lines drawn between NN 1400 6120 and NN 1400 6154 and between NN 1750 6186 and NN 1750 6213 extending to MHWS.

The RMP for this site is currently located at NN 146 616. The entire production area falls within a designated Shellfish Growing Water. There is a Crown Estate seabed lease for the fishery.

The fishery currently consists of approximately 20 mussel lines of varying length over an approximately rectangular area of 9,400 square metres. The header lines hang 3 metres below the supporting buoys to avoid the largely fresh water in the upper 3 metres of the water column. The mussels are grown on 4 to 6 metre droppers from the header lines. An extra crop sometimes occurs on the lines supporting the leaders from the buoys. The growth cycle takes from 2.5 to 3 years. Harvesting takes place year round.

Mussels are cleaned and graded from a raft kept between the mussel lines and the north shore of the loch. Mussels from both the Lower (HL 170) and Upper Loch Leven sites are brought here for processing. After processing, mussels are held in holding nets suspended through holes in the raft at a depth of approximately 3 m for between 12 and 48 hours (see Appendix 7, Figure 5). The harvester reports that this to allows the mussels to recover prior to transport. Samples provided by the grower for classification purposes have traditionally been taken from these holding nets. The mussels could have originally been sourced from anywhere within the Upper Loch Leven site.

The location of the RMP plots approximately 50 m to the west of the mussel lines and approximately 40 m to the west of the lease (see Figure 1). It should be noted that RMPs had previously been specified only to 100 metre accuracy.

There is a purification system on the shore above the fishery (Appendix 8, Figure 7). This is operated when the sites are class B. The wastewater from the processing unit and the purification system are both discharged in the vicinity of the fishery.

Figure 2.1 shows the relative positions of the mussel lines, production area, RMP, seabed lease and the shellfish growing water.

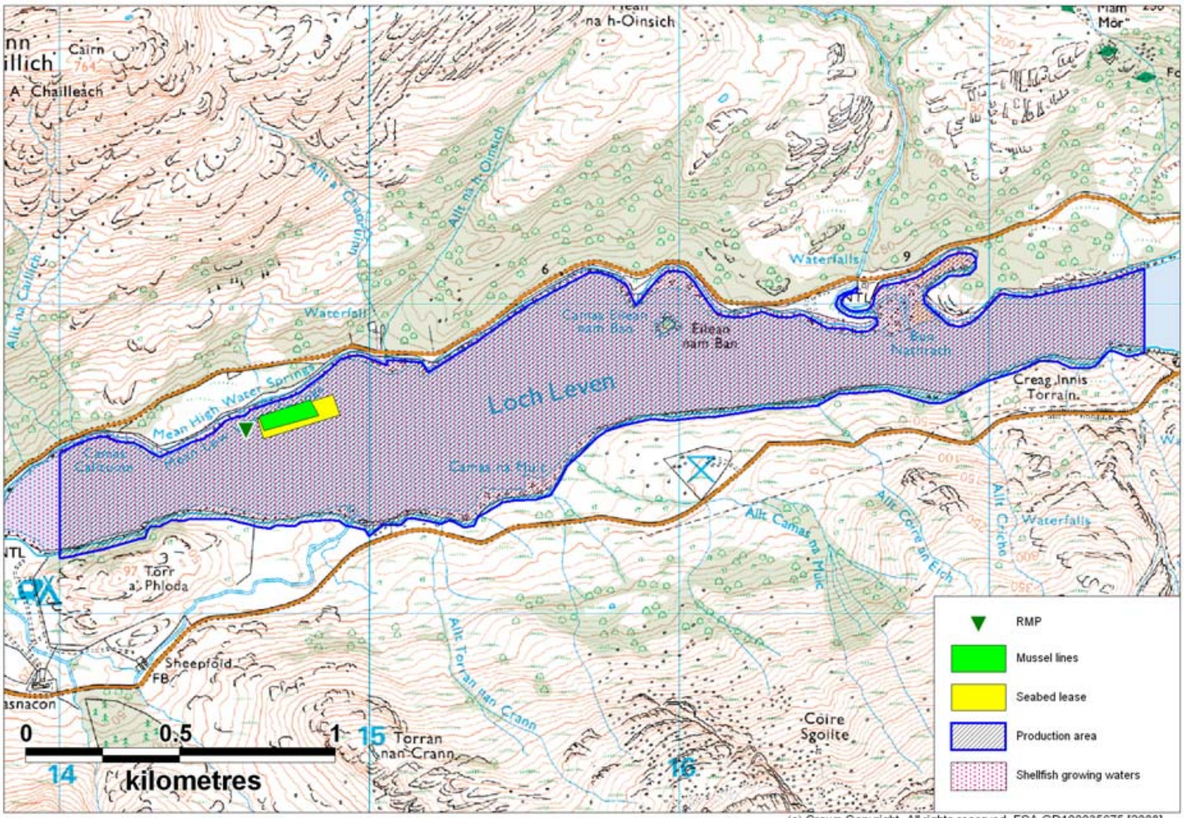

Figure 2.1 Loch Leven: Upper Fishery

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output areas located around Loch Leven. Statistics given are those obtained for the 2001 Census.

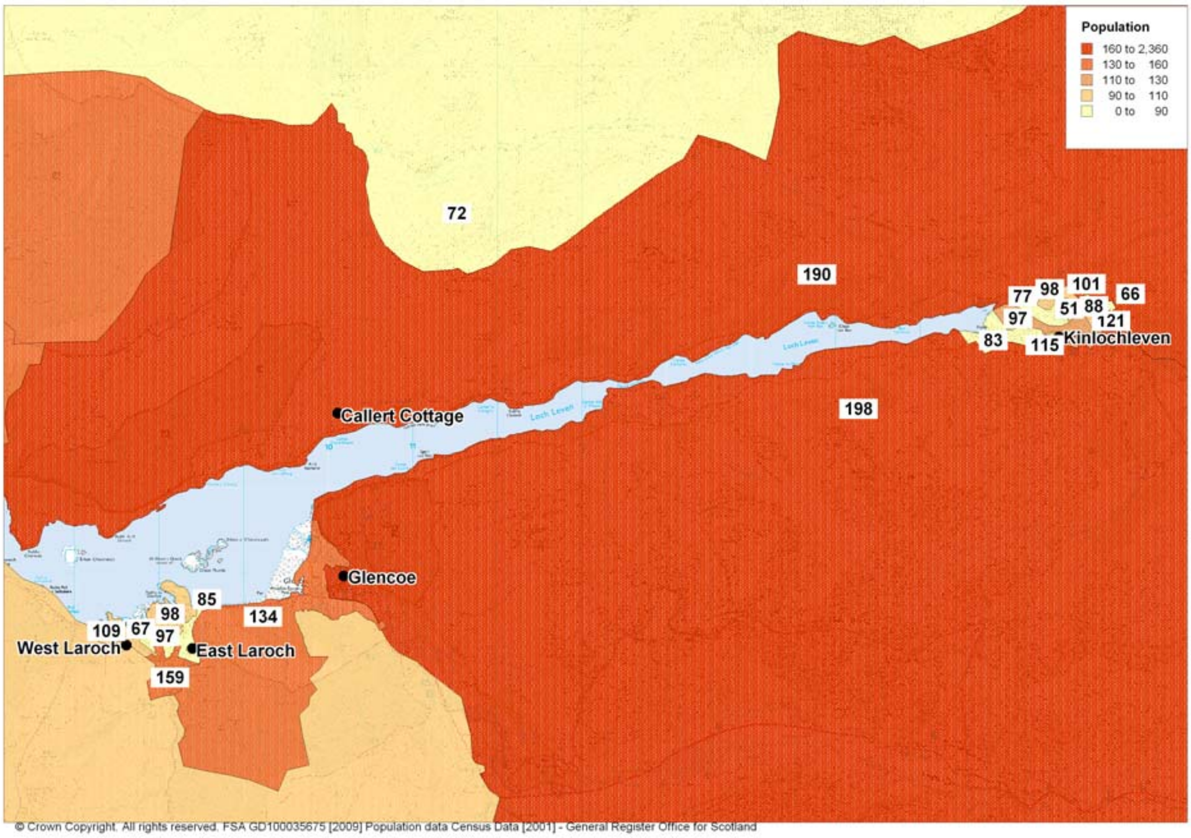

Figure 3.1 Population of Loch Leven

Much of the area around the loch is sparsely populated, with the majority of the local population centred around two main areas: Kinlochleven at the head of the loch and Ballachulish, East and West Laroch and Glencoe on the southwestern shore of the loch. At the 2001 census, Kinlochleven had a population of 897 and Ballachulish, 615. The population for the remaining two census output areas bordering immediately on Loch Leven totals 388 (60QT000142 population 190 and 60QT001323 population 198). It should be noted that the entire extent of these two areas is not displayed on the map and that much of the population actually lies away from the loch.

Loch Leven is a popular tourist destination and a number of hotels and B&Bs cater for visitors to the area. A search of the internet revealed 259 guest beds in the area and 30 campsite pitches with a separate toilet block near the river in Kinlochleven. The town lies along the West Highland Way walking trail and is popular with tourists with most visits between March and October.

The Loch Leven: Upper production area is located in the upper eastern end of the loch nearest Kinlochleven and so population centred at this end of the loch is likely to have the largest impact on water quality at the fishery.

4. Sewage Discharges

Scottish Water identified community septic tanks and sewage discharges for the area surrounding Loch Leven: Upper. These are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Discharge Name	NGR of discharge	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design popn
Kinlochmore West ST	NN 183 620	Continuous	Primary (septic tank)	Not stated	200
Kinlochmore East ST	NN 188 620	Continuous	Primary (septic tank)	Not stated	367
Kinlochleven WWTW	NN 177 619	Continuous	Secondary (trickling filter)	Not stated	900
Kinlochleven WWPS	NN 183 620	Intermittent	None or screen (EO)	Not stated	Not stated

No sanitary or microbiological data were available for these discharges.

SEPA identified that the following discharge consents have been issued in the vicinity of upper Loch Leven. The first three consents apply to the first three discharges listed in Table 4.1.

Table 4.2 SEPA discharge consents:

Ref No.	NGR of discharge	Name of discharge	Discharges to	Discharge Type	Consented flow (DWF) m^3/d	Consented/ design PE
CAR/L/1001630	NN 1830 6205	Kinlochmore West ST	River Leven	Septic Tank	45	200
CAR/L/1001636	NN 1880 6200	Kinlochmore No 2	River Leven	Septic tank		367
CAR/L/1002147	NN 1776 6196	Kinlochleven WWTW	Loch Leven	Secondary		900
CAR/R/1018291	NN 1823 6231	Mamore House	Soakaway	Septic Tank		5
CAR/R/1022131	NN 1817 6225	Lochside cottage	Soakaway	Septic Tank		5
CAR/R/1018296	NN 1813 6228	House 5&6	Soakaway	Septic Tank		10
CAR/R/1018295	NN 1813 6228	House 3&4	Soakaway	Septic Tank		10
CAR/R/1018290	NN 1813 6228	House 1&2	Soakaway	Septic Tank		10

Two of the three Scottish Water treatment works were observed during the shoreline survey. In addition, a number of other potential sources of sewage were observed. Sewage infrastructure recorded during the shoreline survey is listed in Table 4.3.

Table 4.3 Sewage infrastucture observed during shoreline survey

No.	NGR	Description
1	NN 17818 61953	Kinlochleven STW outlet tank; two rotating sprinklers; outfall not visible; strong sewage odour
2	NN 18367 61947	Pumping station; new construction of inlet screens, primary treatment tanks and CSO; no outfall visible
3	NN 16641 61991	Septic tank outlet from house, discharging to river, outlet below water
4	NN 13876 61056	Septic tank at caravan park; toilet block nearby with Elsan disposal point
5	NN 18354 62076	Kinlochleven Riverside Septic Tank
6	NN 18314 62062	Septic tank discharge pipe, end under water in middle of river

Of the observed discharges, numbers 1, 2, 5 and 6 relate to Scottish Water installations at Kinlochleven. Number 3 is a small private discharge to a stream discharging to the north shore of Loch Leven about 2 km to the east of the fishery. Number 4 is a septic tank discharge from a campsite to the south shore about 1 km to the west of the fishery, and is likely to be in heavier use during the summer months.

The main sewage contributions to Upper Loch Leven are from the Scottish Water discharges at Kinlochleven, which comprise of secondary treated effluent from a population of 900 and septic tank (primary) treated effluent from a population of 567. Using an Environment Agency England & Wales estimate of domestic water usage of 180 l/head/day, and published loadings associated with discharges of these sizes and types (Halcrow, 1995) a total loading of 6.7×10^{12} *E. coli*/day is the expected contribution from these discharges. Additional SEPA discharge consents are for 5 small private septic tanks to discharge to soakaway, and all are located at the northern side of Kinlochleven.

Improvement works on the sewage treatment system in the Kinlochleven area were seen at the time of the shoreline survey and SEPA subsequently identified that these had been completed (M. MacKenzie, person. commun.). It is not known what effect these works may have on the microbial content of the discharge.

Further discharges were identified within the lower portion of Loch Leven, the more significant of which, including the continuous discharges from the towns of Glencoe and Ballachulish, were over 5.5 km away from the western border of the Loch Leven: Upper production area.

Boat traffic in the upper loch is confined to a few small boats and some kayaks, so impacts from these sources are likely to be minor at most.

In summary, the vast majority of human sewage inputs are from Kinlochleven, about 3.5 km to the east of the fishery, with an additional 2 small discharges observed closer to the fishery. There is the possibility of contamination from the lower loch impacting on the fishery via movement of water up the loch but this will be markedly restricted by a sill located below the upper and lower basins.

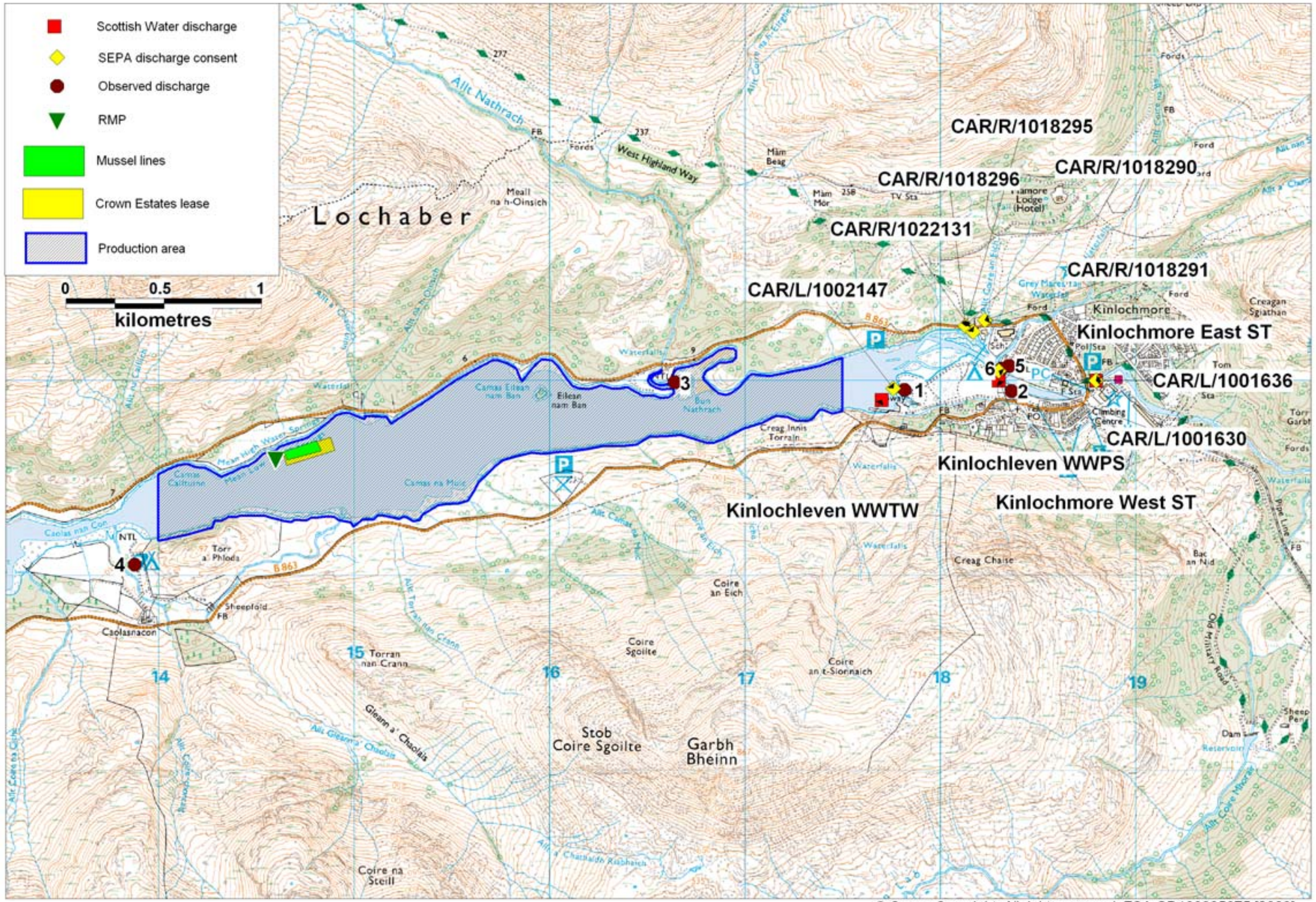

Figure 4.1 Loch Leven discharges

5. Geology and Soils

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

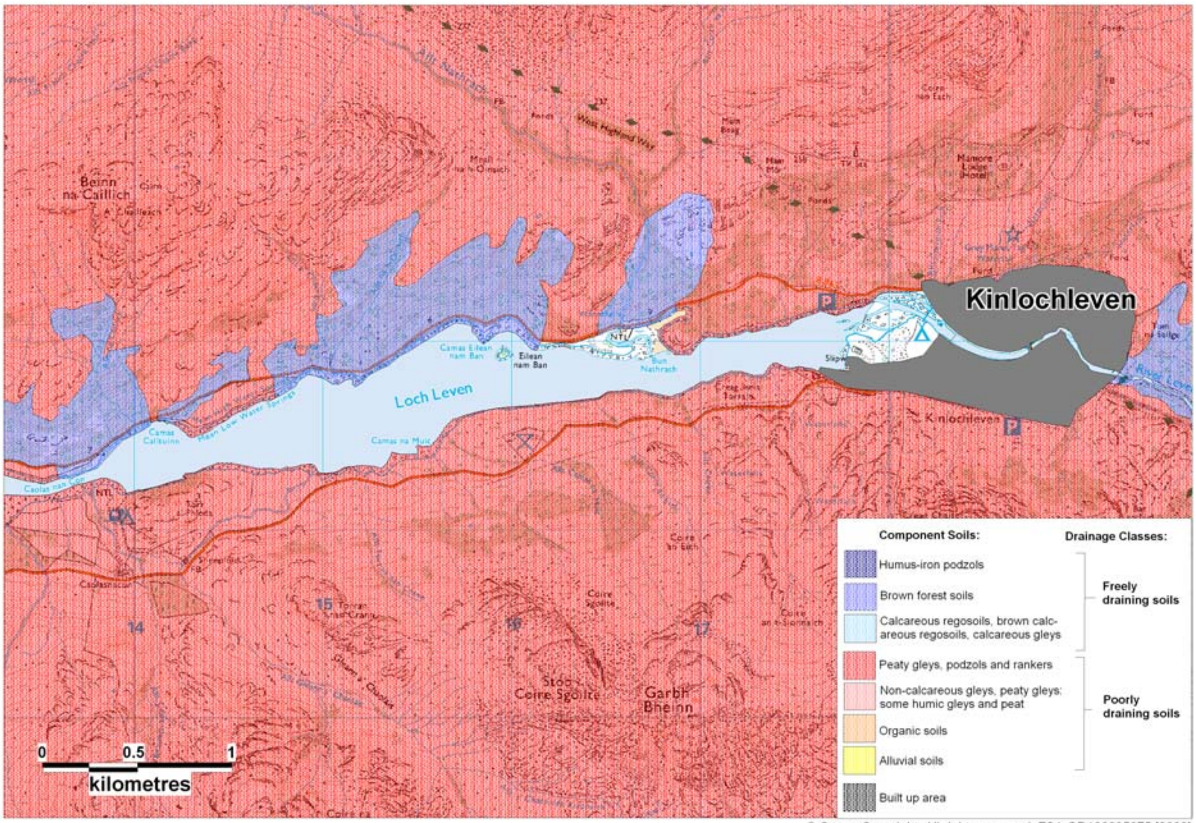

Figure 5.1 Component soils and drainage classes: Upper Loch Leven

There are two main types of component soils present in this area. The most dominant is composed primarily of poorly draining peaty gleys, podzols and rankers. This soil type is predominant along the entire southern coastline and much of the northern coastline of the Loch Leven production area, and surface runoff is likely to be high from these areas. The other main component soil is brown forest soils, found in patches along the northern coastline and also east of the urban development of Kinlochleven. This soil type has a lower potential for surface runoff as it is more permeable. The highest potential for surface runoff is from the impermeable, built-up area at Kinlochleven.

Overall, the potential for runoff contaminated with *E. coli* is high along both sides of the loch, especially the southern side and from the town of Kinlochleven at the head of the loch.

6. Land Cover

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

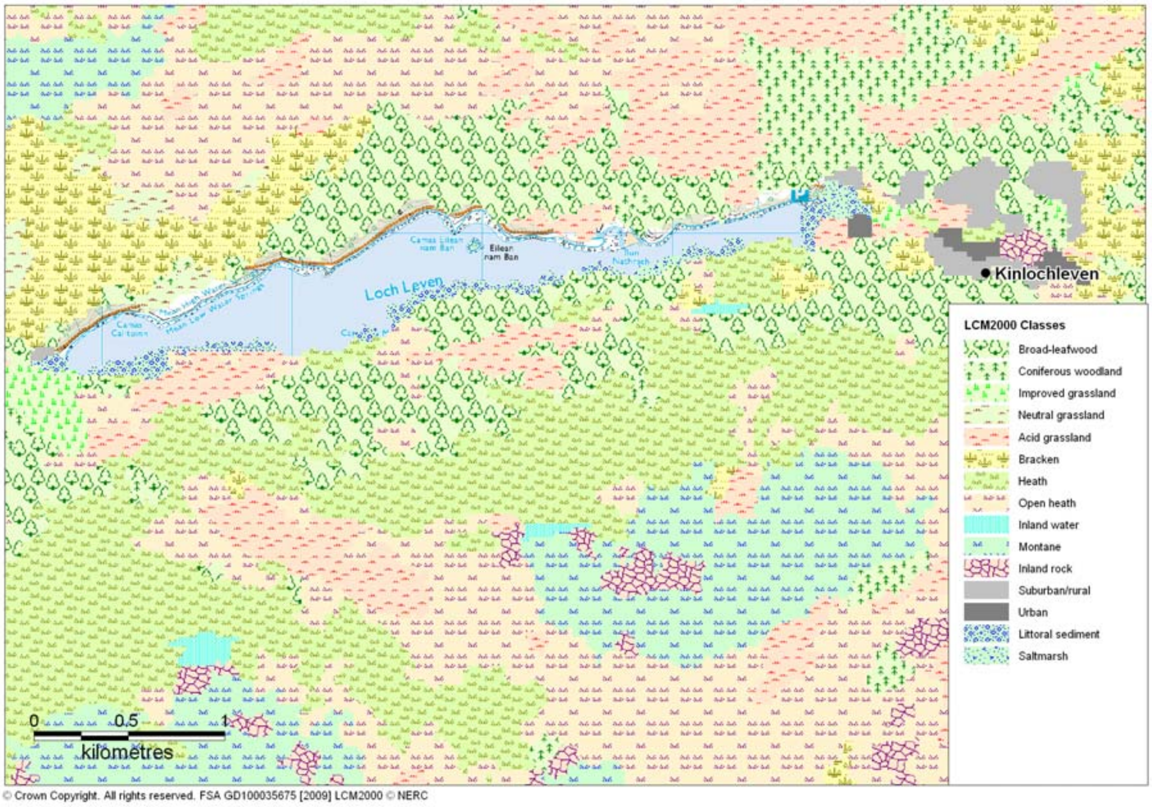

Figure 6.1 LCM2000 class land cover data: Upper Loch Leven

The central coastline of Loch Leven is covered by broad-leaf woodland. The western end of the loch shows a large area of bracken with smaller patches of improved and acid grassland. The eastern end of the loch also has small patches of bracken, acid grassland, improved grassland and heath. Further inland on both sides of the loch there are areas of calcareous grassland, open heath and inland rock. The settlement of Kinlochleven to the east of Loch Leven is the only urban/suburban developed land in the area.

The faecal coliform contribution would be expected to be highest from the developed area of Kinlochleven (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 precipitation events, this being expected to be highest, at more than 100-fold, for the improved grassland.

The majority of land surrounding Loch Leven falls into the category which is expected to give the lowest contribution. Exceptions to this are the developed area at Kinlochleven, and the small patch of improved grassland at the south western extremity of the upper loch.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data was requested from the Scottish Government. Agricultural census data was provided by RERAD for the parishes of Lismore and Appin which adjoin the coastline of Loch Leven. Reported 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 Lismore and Appin parish

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	*	*
Total poultry	20	197	23	212
Total cattle	43	1246	42	1218
Total sheep	53	16806	49	14795
Deer	0	-	0	-
Horses and Ponies	9	54	12	66

* Data withheld on confidentiality basis.

Pigs are farmed somewhere within the parish boundaries, however specific data on numbers could not be provided. Due to the large area of the parish, this data does not provide information on the livestock numbers in the area immediately surrounding Loch Leven. The harvesters noted that, apart from the farm containing the sheep noted in the shoreline survey (see below), all of the farms covered in Table 7.1 are several miles from Loch Leven and any water courses draining into it. They did identify that there is one sheep farm above the north shore of Lower Loch Leven that could have some impact. This was not covered in Table 7.1 as it was located within Lochaber district (E. & G. Salvarli, pers. commun.).

The only information specific to the area near the shellfishery was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on the 12th - 13th November 2008. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This indicated that livestock densities on the land surrounding the production area were low. A total of only 30 sheep and four goats were recorded during the entire survey. The sheep were all found on an area of pasture at the constriction in the loch just to the west of the production area, and the goats were observed on a hillock on the north shore, again just to the west of the production area.

Generally, numbers of livestock in the area would be expected to increase in spring, when lambs are born, and then decrease again in autumn when they are sold off or sent for slaughter.

As the survey was conducted during late autumn, the spatial distribution of animals is not likely to represent that which might be observed in summer when animals have been turned out to summer grazing areas. Much of the rough grassland present around the loch is likely to be grazed at some point by sheep, with local streams carrying any faecal contamination from the grazing areas to the loch.

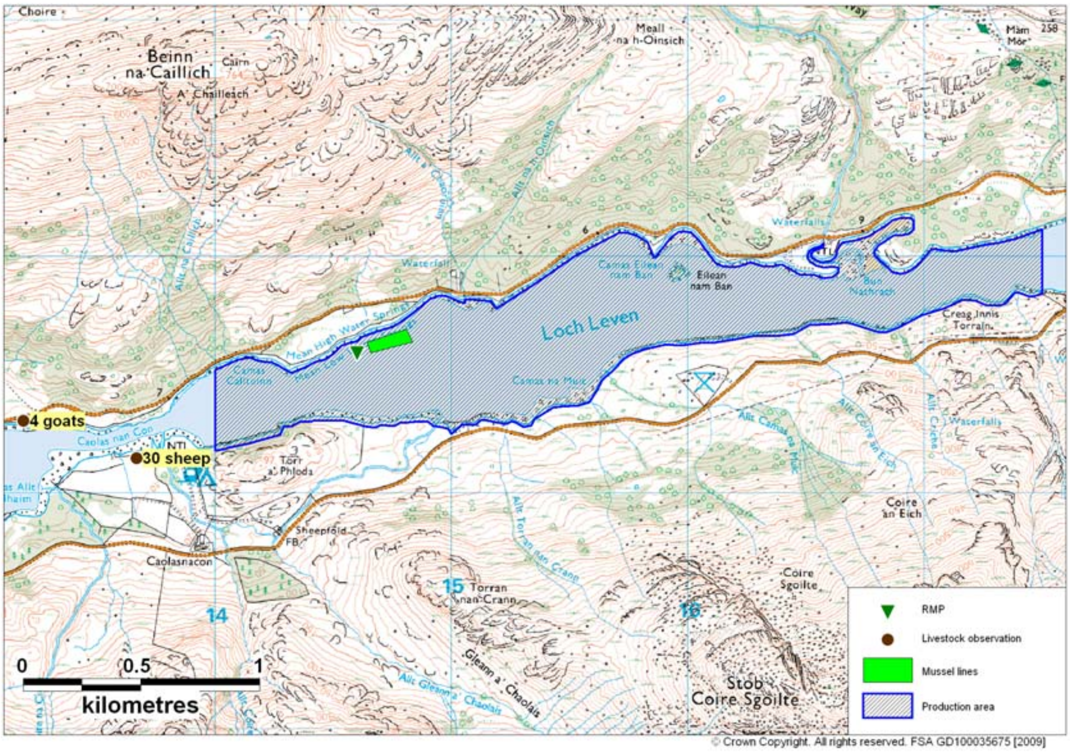

Figure 7.1 Livestock observations at Loch Leven

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present at Loch Leven 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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2000 estimated a population of 158 common seals in the Loch Linnhe. The exact locations of the haul out sites were not specified, and it is uncertain whether they penetrate as far as the upper basin of Loch Leven, although it is possible they may be drawn up here in pursuit of migratory fish running the rivers at certain times of the year. No seals were seen during the course of the shoreline survey.

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.

It is however unlikely that cetaceans, particularly the larger species, penetrate as far as the upper basin of Loch Leven.

Birds

A number of bird species are found around Loch Leven, but seabirds and waterfowl may be expected to occur around or near the fisheries.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census (Mitchell *et al*, 2004). The only records of breeding seabirds in Loch Leven were in the lower loch, more than 5 km from the Loch Leven Upper production area boundaries.

Waterfowl (ducks and geese) may be present in the area at various times, either to overwinter, or briefly during migration, or possibly to breed during the summer. A total of 7 ducks and no geese were seen during the course of the shoreline survey.

Wading birds would be concentrated on intertidal areas, but no aggregations were noted during the shoreline survey. Generally, few birds were seen during the course of the shoreline survey.

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. The most recent count of the area was undertaken in 2006, and a total of 228 deer were recorded within 5 km of the boundaries of the production area, mainly to the south of the production area. The grower also reports that deer occur on hills around the loch, particularly on the southern side. A dead stag and some deer droppings were seen during the shoreline survey.

It can therefore be concluded that the area hosts a considerable population of deer, and it is likely that some of the indicator organisms detected in the streams feeding into the production area will be of deer origin, although their contribution relative to other sources is not known.

Otters

No otters were observed during the course of the shoreline survey, although it is possible that they are present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Summary

The only potentially significant wildlife populations identified in the area is the deer population, which may be larger than the local livestock population. Deer appear to be more numerous on the southern side of the production area, so streams discharging to the south shore may contain more contamination of deer origin. In addition to this it is possible that small numbers of seals and waterbirds use the area, but where and when any impacts from these species may occur is uncertain.

9. Meteorological data

The nearest Meteorological Office weather station is located at Conaglen House, approximately 9.5 km to the north west of the production area. Precipitation data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily precipitation in mm). It is likely that the precipitation experienced at Congalen House is similar to that experienced at the production area due to their close proximity.

The nearest major weather station where wind is measured is located at Glasgow: Bishopton, approximately 95 km to the south 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. It is likely that the overall wind patterns here will be broadly similar to those experienced at Loch Leven, but may differ to some extent given the distance between the two and differences in local topography, and wind speed and direction may differ significantly at any given time due mainly to the distance between the two.

9.1 Precipitation at Congalen House

High precipitation 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). Total annual precipitation and mean monthly precipitation were calculated, and are presented in Figures 9.1 and 9.2.

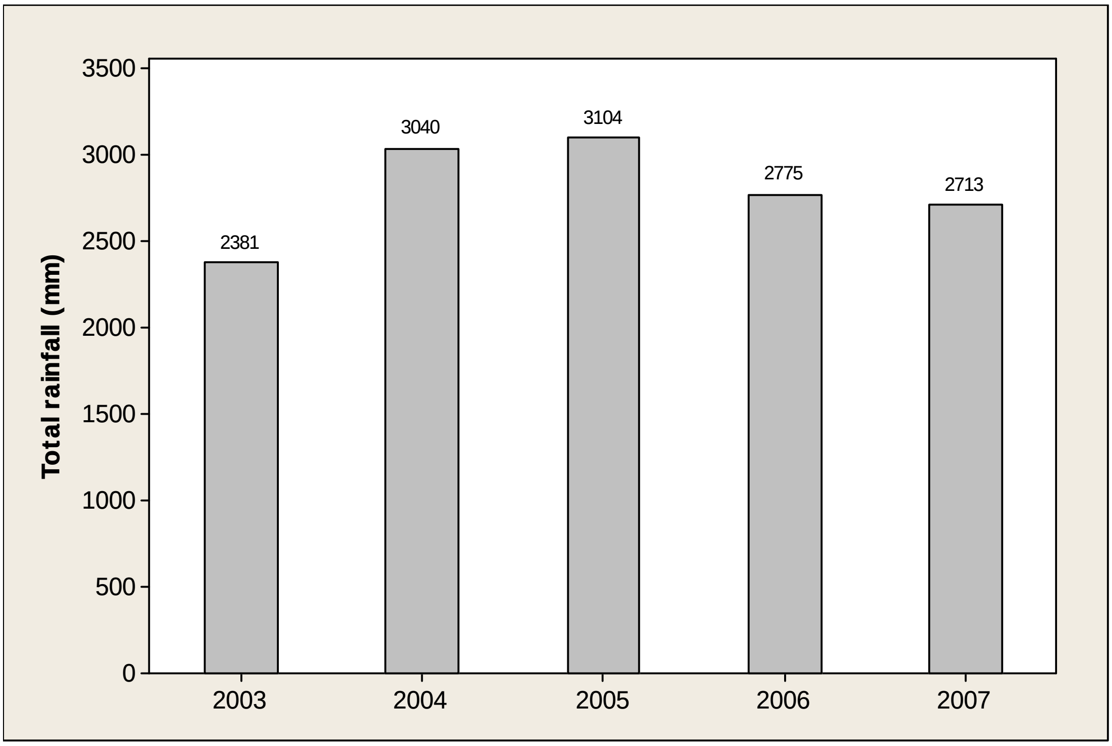

Figure 9.1 Total annual precipitation at Congalen House, 2003 – 2007

Interannual variation in precipitation is much less than the variation observed between months.

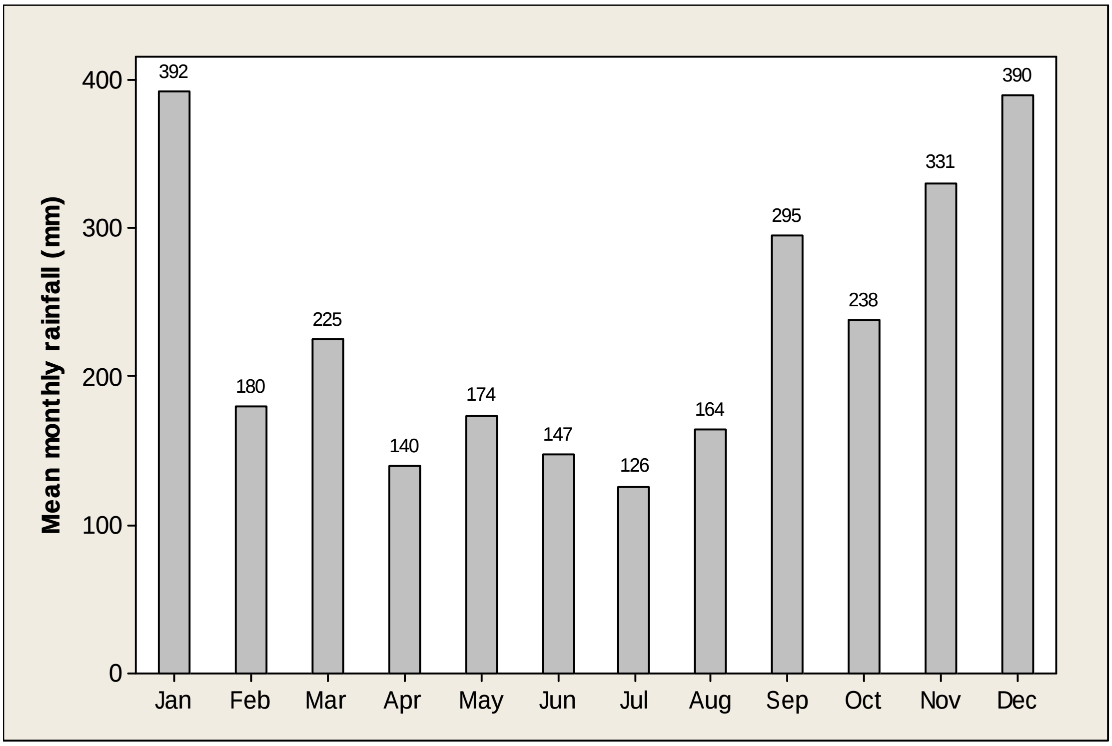

Figure 9.2 Mean total monthly precipitation at Congalen House, 2003 - 2007

The wettest months were January, September, November and December. For the period considered here, 42% of days experienced precipitation of 1 mm or less, and 26% of days experienced rain of 10 mm or more.

It is likely that levels of rainfall-dependent faecal contamination entering the production area from these sources would be higher during the autumn and winter months. However, during the winter much of the precipitation falling on higher grounds will fall as snow, and this will not enter watercourses until it melts in the spring. It is possible that faecal matter can build up on land during the drier spring and summer months, leading to more significant faecal contamination of runoff during high rainfall events at these times or at the onset of the wetter weather in September.

9.2 Wind at Glasgow

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

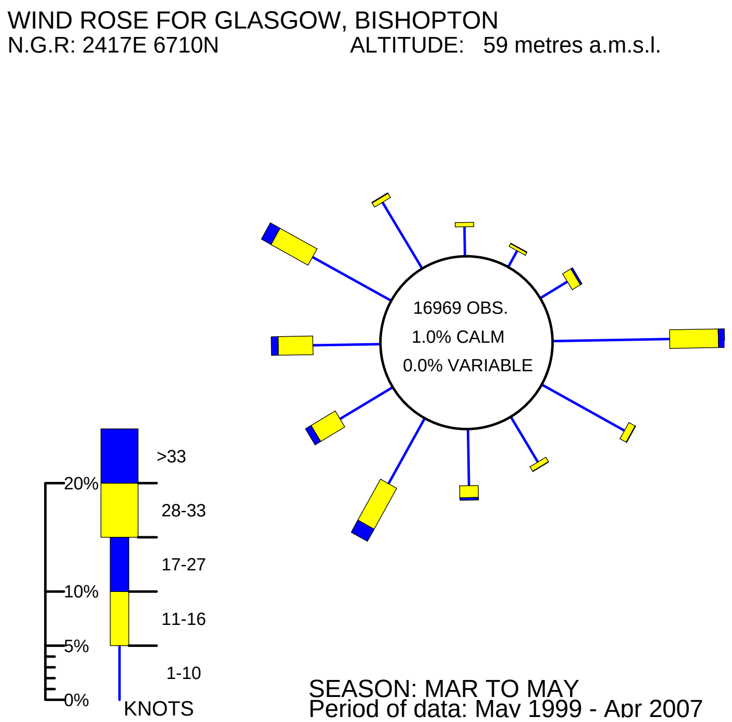

Figure 9.3 Wind rose for Glasgow: Bishopton (March- May)

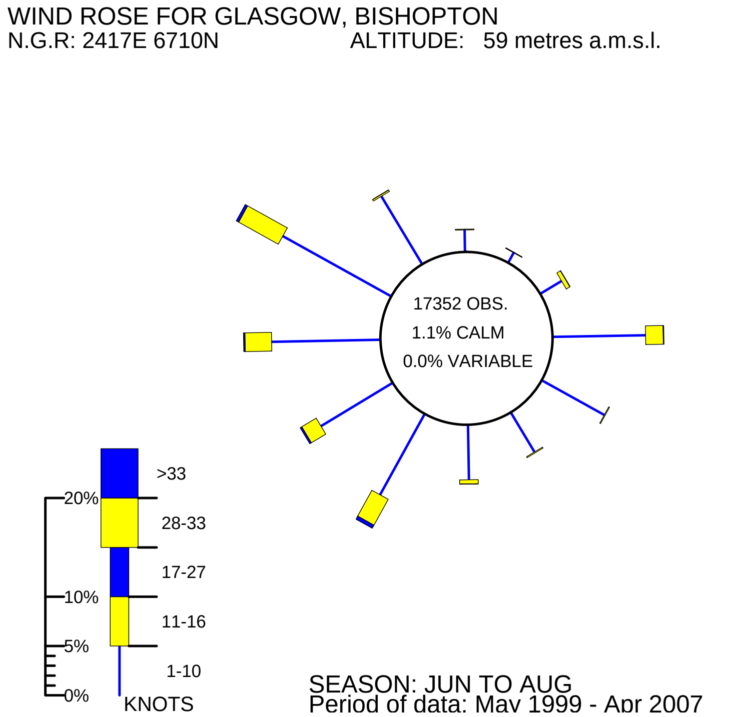

Figure 9.4 Wind rose for Glasgow: Bishopton (June-August)

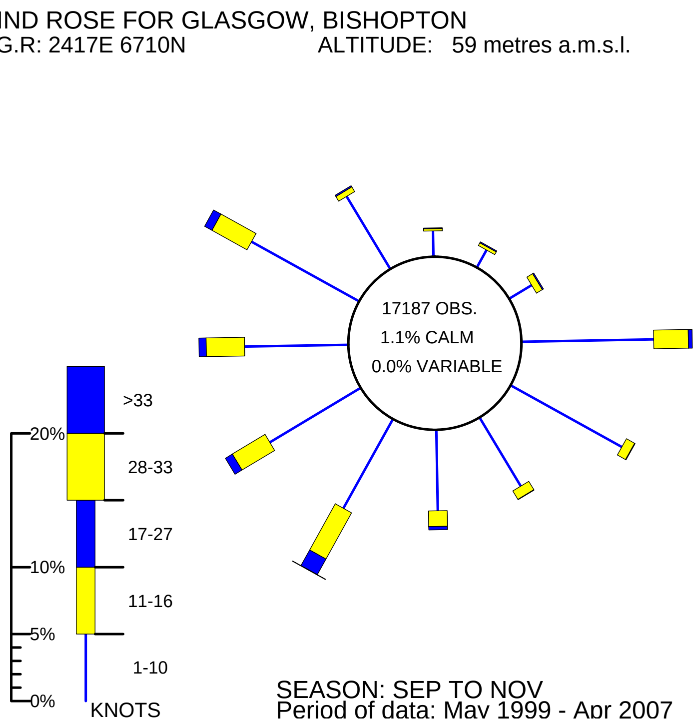

Figure 9.5 Wind rose for Glasgow: Bishopton (September-November)

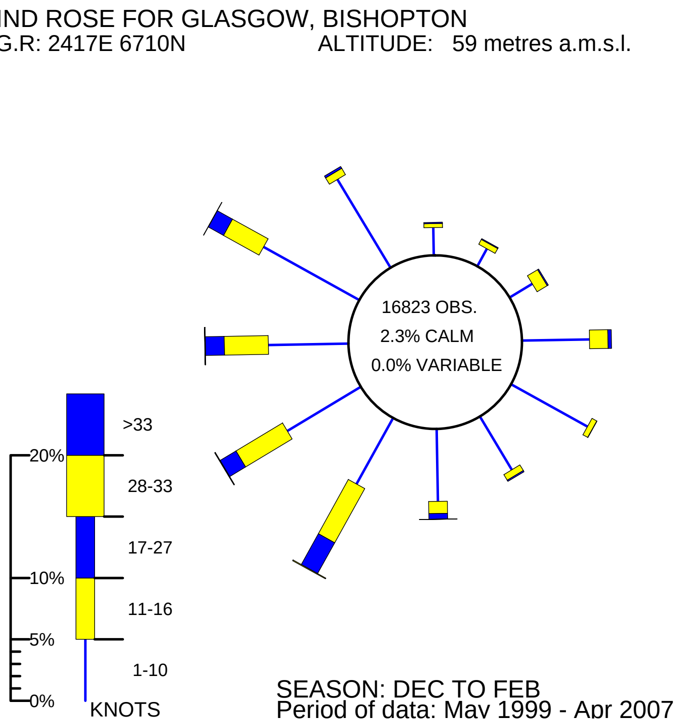

Figure 9.6 Wind rose for Glasgow: Bishopton (December-February)

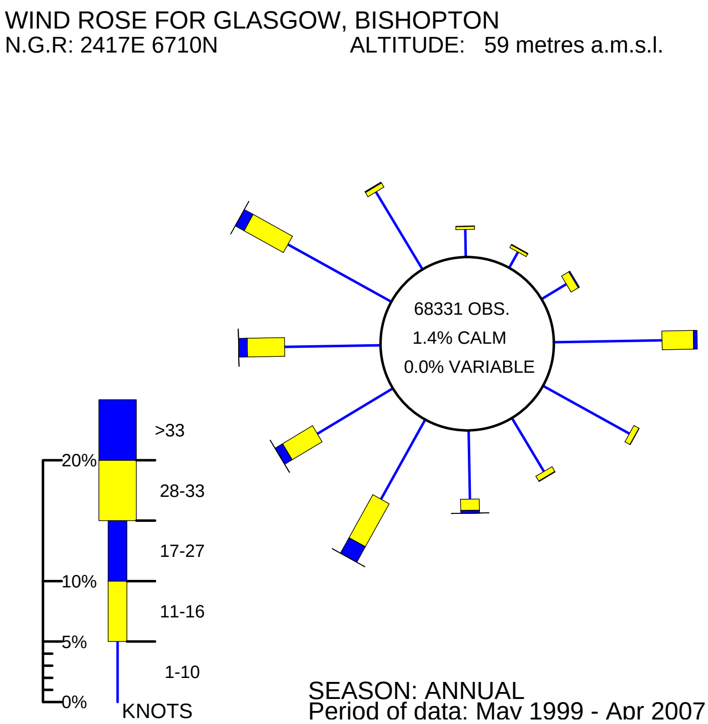

Figure 9.7 Wind rose for Glasgow: Bishopton (All year)

Glasgow is not one of the windier areas of Scotland, with a low frequency of gales compared to places such as the Western Isles and the Shetlands. The wind roses show that the overall prevailing direction of the wind is from the west, and the strongest winds come from this direction. Stronger winds are also experienced from the east, presumably due in part to local topography - Bishopton is in the Clyde Valley, which has a west to east aspect. Winds are generally lighter during the summer months and stronger in the winter.

Loch Leven has a similar west to east aspect, facing Loch Linnhe to the west. There is a constriction at its mouth. It is about 15 km long and less than 1 km wide in most parts, and is surrounded by mountains rising to over 1000 m in places. The loch will receive shelter from winds from the north or the south, but is more open to easterly or westerly winds, which would be funnelled up or down the Loch by the surrounding hills.

Although tidal and density driven circulation of water in the loch is likely to be important, wind effects are may to cause significant changes in water circulation. 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 in the direction of the wind. These surface water currents create return currents which may travel along the bottom or sides of the loch depending on bathymetry. Either way, strong winter winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. There may be some instances where contamination from settlements may be carried to production sites by wind driven currents. An example may be an easterly wind carrying contamination from point sources at the settlement of Kinlochleven towards the fishery.

10. Current and historical classification status

Loch Leven: Upper has been classified for the production of mussels since 1994. The classification history from 2004 onwards is presented in Table 10.1. From 2004-2007 the area was classified as a seasonal A/B, and in 2006 the area was classified as an A. The nominal location given for the RMP lies 50 m away from the nearest mussel line, which is within the 100 m accuracy to which the NGR has been defined previously. A map of the current production area is presented in Figure 10.1.

Table 10.1 Classification history, Loch Leven

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

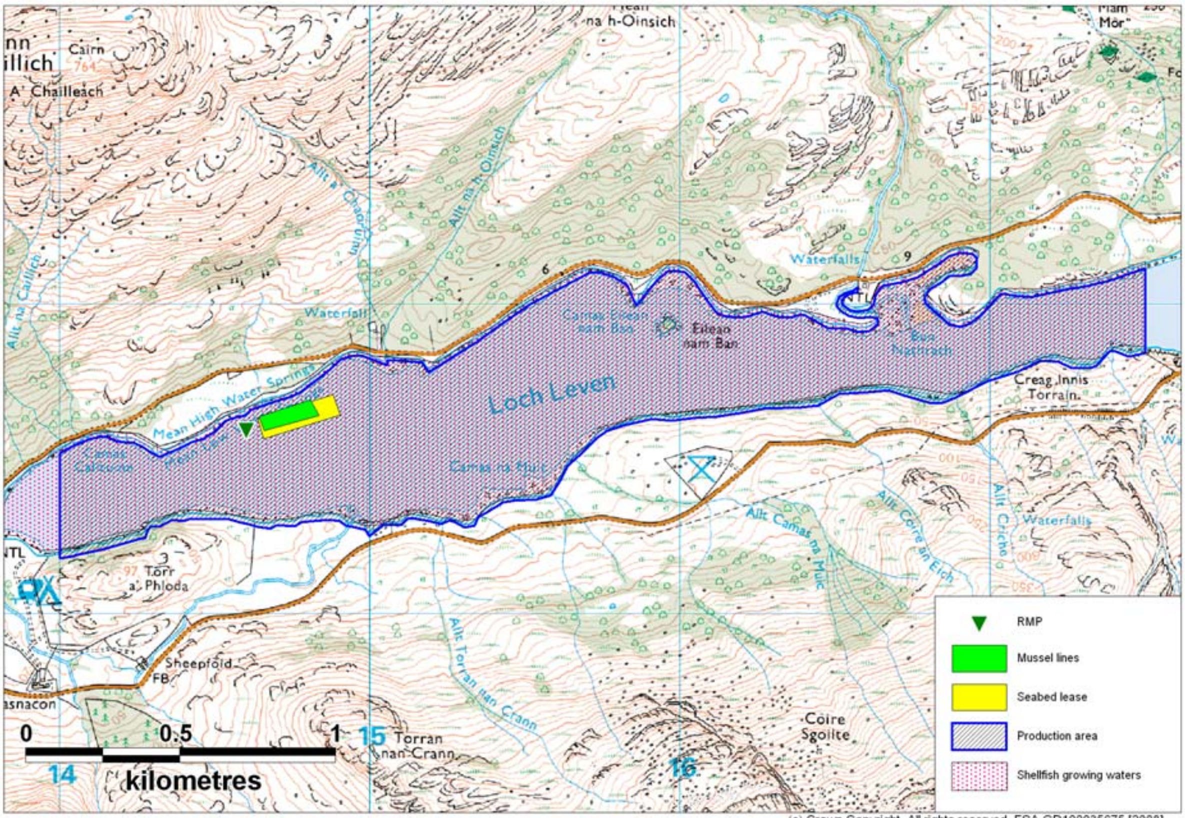

Figure 10.1 Map of current production area

11. Historical E. coli data

11.1 Validation of historical data

All shellfish samples taken from Loch Leven 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.

No samples were rejected on the basis of major geographical or sampling date discrepancies. One sample had the wrong two letter prefix to the reported grid reference, and this was corrected.

A total of 6 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.

All samples from this production area were in fact taken from holding nets where mussels are kept for between 12 and 48 hours after processing, and could have originally been sourced from any part of the Loch Leven Upper siter. As 48 hours may be insufficient time for levels of contamination in mussels to equilibrate with the surrounding waters, particularly during the colder months when their feeding and metabolic rates are slower, the results may not reflect the actual microbiological status of the sampling location but an integration of this and the original harvesting location within the site.

The mussels in the holding nets are at approximately 3 m depth. As they are suspended from the rafts, they will maintain a constant depth relative to the surface even as the tide changes.

11.2 Summary of microbiological results

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

Table 11.1 Summary of results from Upper Loch Leven

Sampling Summary	
Production area	Loch Leven: Upper
Site	Upper
Species	Common mussels
SIN	HL-171-223-8
Location	NN146616 (nominal RMP)
Total no of samples	66
No. 2002	12
No. 2003	11
No. 2004	10
No. 2005	12
No. 2006	10
No. 2007	11
Results Summary	
Minimum	<20
Maximum	1700
Median	110
Geometric mean	108.0
90 percentile	500
95 percentile	1100
No. exceeding 230/100g	19 (29%)
No. exceeding 1000/100g	4 (6%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

11.3 Overall geographical pattern of results

As only one sampling location was reported, it was not possible to investigate geographical differences in levels of contamination within this production area.

11.4 Overall temporal pattern of results

Figure 11.1 presents a scatter plot of individual results against date for all samples taken from Loch Leven Upper and is fitted with a Loess trend line to help highlight any apparent underlying trends or cycles.

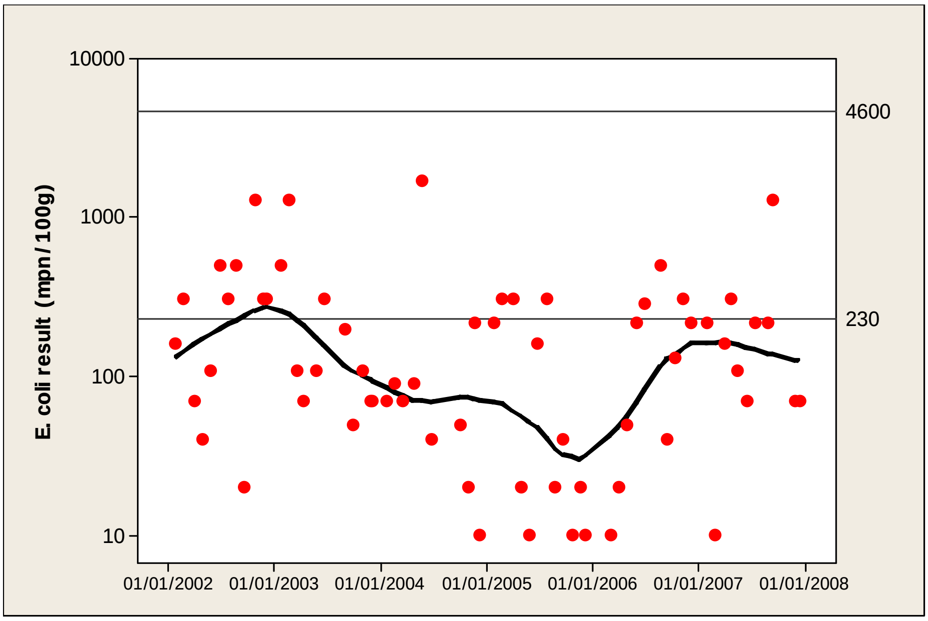

Figure 11.1 Scatterplot of results by site and by date with loess line

The trend line in Figure 11.1 suggests peaks in results at the beginning of 2003 and 2007, and lowest results around the beginning of 2006. Results of greater than 1000 *E. coli* MPN / 100g did not occur between mid 2004 and 2008.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 present the geometric mean *E. coli* result by month (+ 2 times the standard error).

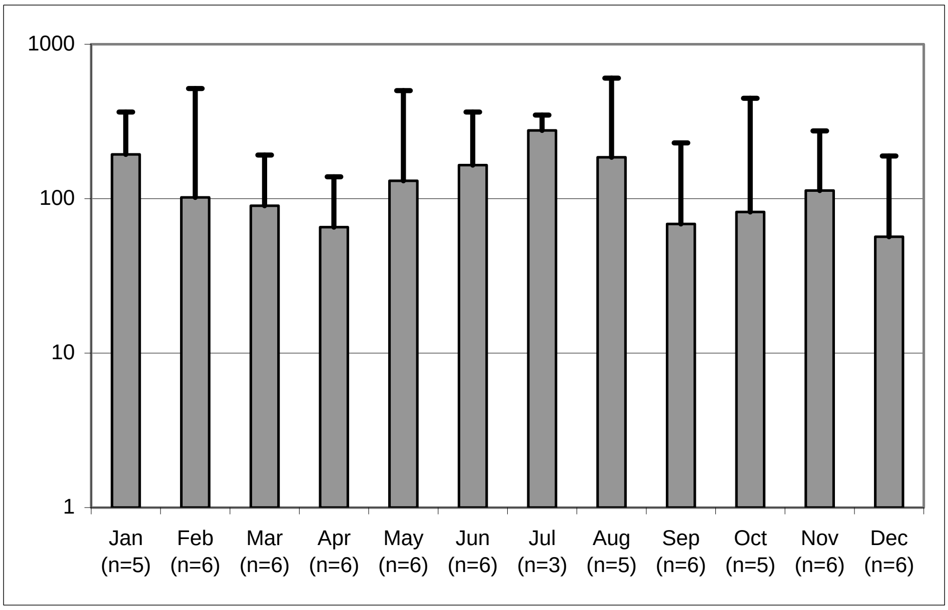

Figure 11.2 Geometric mean result by month

There is no clear pattern apparent in Figure 11.2 and the standard errors indicate that there is little difference in results by month.

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

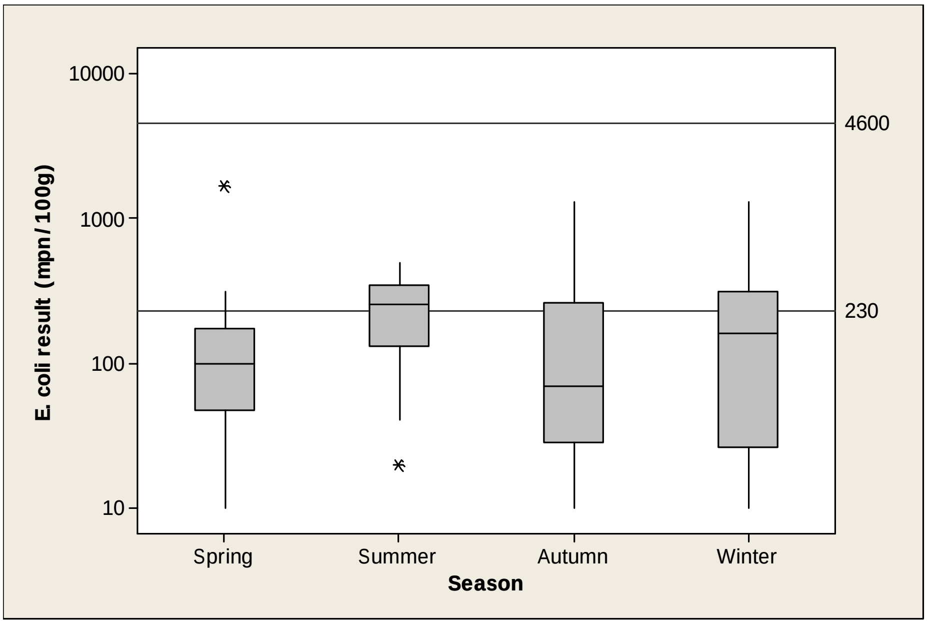

Figure 11.3 Boxplot of result by site and by season

No significant difference was found between mean results by season (One-way ANOVA, p=0.315, Appendix 6). Figure 11.3 does indicate that a higher proportion of results were over 230 *E. coli* MPN/100g during the summer (50%) compared to spring, autumn and winter (17%, 24% and 29% respectively). It was not possible to test whether the difference in proportions of results over 230 *E. coli* MPN/100g was statistically significant as sample numbers were too low.

11.6 Analysis of results against environmental factors

Environmental factors such as precipitation, 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 precipitation

The nearest weather station is Conaglen, 9.5 km NW of area. Precipitation data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily precipitation in mm). A Spearman's Rank correlation of *E. coli* against precipitation was carried out.

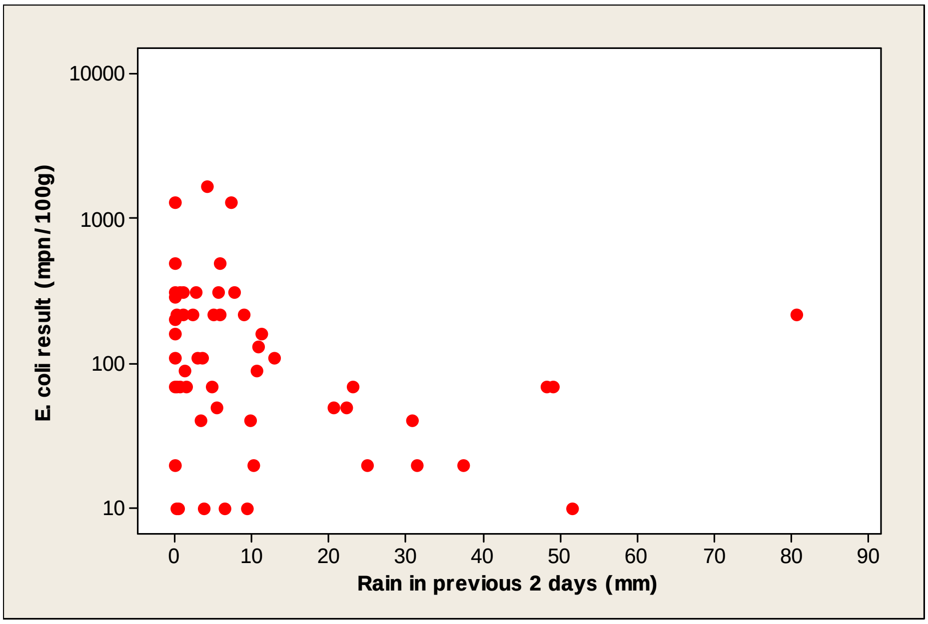

Figure 11.4 Scatterplot of result against precipitation in previous 2 days

A significant negative correlation was found between the ranked *E. coli* result and the ranked precipitation in the previous two days (Spearman's Rank correlation=-0.316, p=0.020, 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 precipitation in the previous 7 days and sample results for Loch Leven was investigated in an identical manner to the above.

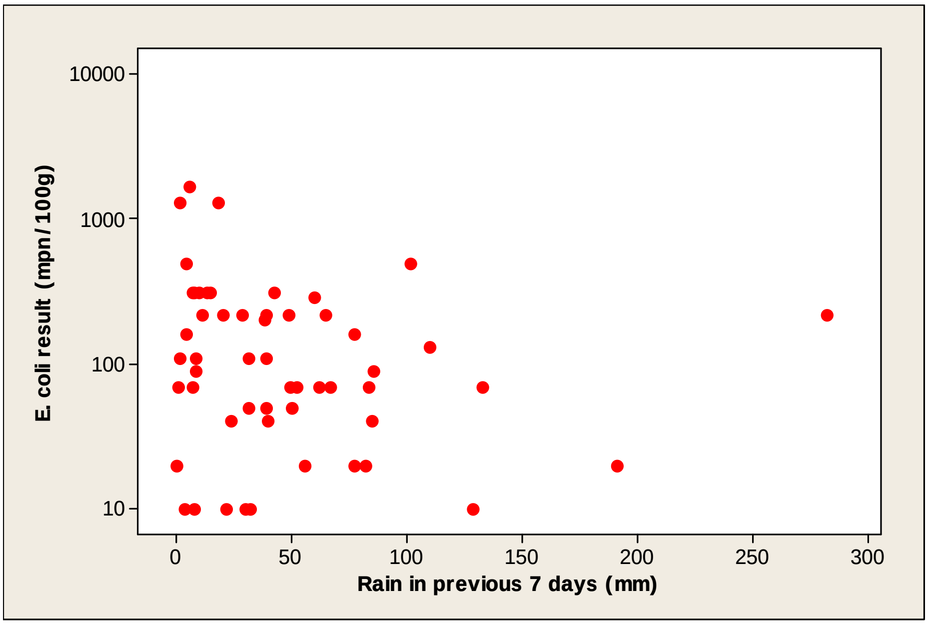

Figure 11.5 Scatterplot of result against precipitation in previous 7 days

No correlation was found between the ranked *E. coli* result and the ranked precipitation in the previous seven days (Spearman's Rank correlation=-0.215, p=0.118, Appendix 6).

11.6.2 Analysis of results by tide height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Figure 11.7 presents a scatterplot of *E. coli* results by predicted height of the previous high water at Corran, near the mouth of Loch Leven (predictions from Totaltide tidal prediction software). Predictions of tidal height at Loch Leven Head were unavailable. Tides at Corran are likely to be larger than those experienced in the upper basin of Loch Leven, but the spring neap cycle will be in phase. 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.

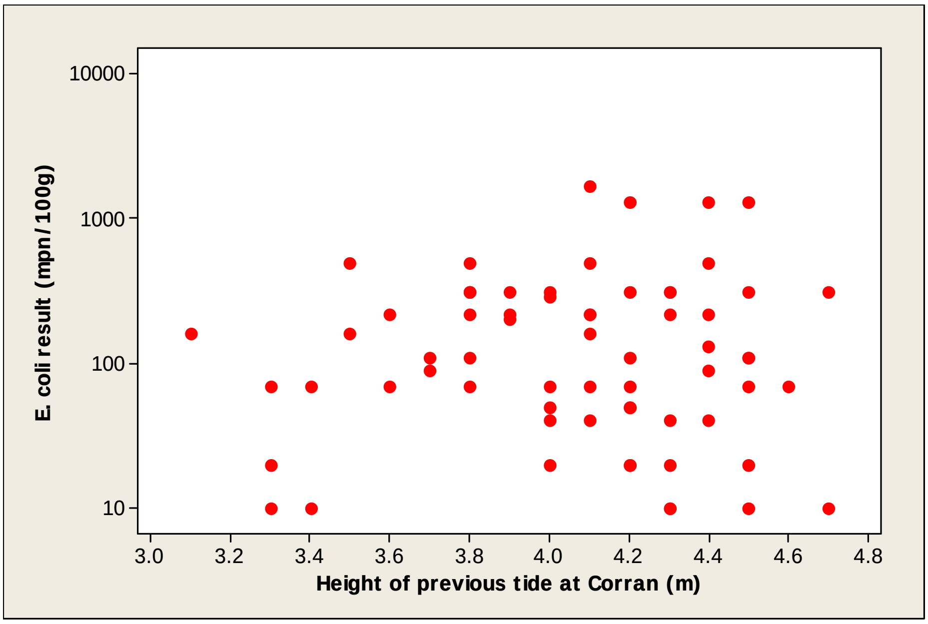

Figure 11.6 Scatterplot of result by tide height

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=0.842, Appendix 6). All 4 results exceeding 1000 *E. coli* MPN/100g occurred on tides greater than 4 m.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in mussels can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water at Loch Leven Head) was compared with *E. coli* results. Loch Leven Head lies within the same basin as the fishery, so times of high water should be very similar between the two.

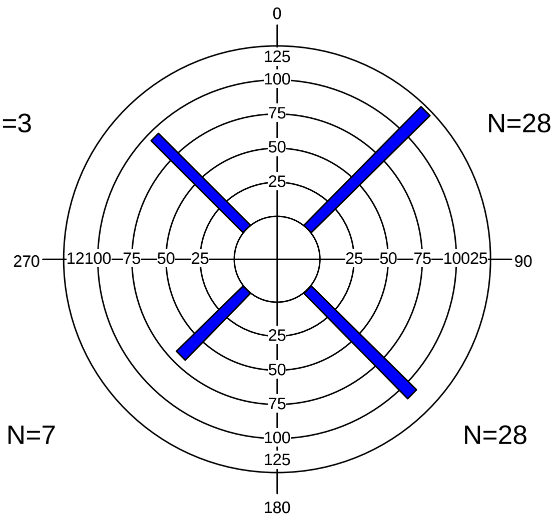

Figure 11.7 Circular histogram of geometric mean *E. coli* result tidal state. High water is at 0 degrees, low water is at 180 degrees.

No significant correlation was found between tidal state and *E. coli* result (circular-linear correlation, r=0.21, p=0.063, Appendix 6). Few samples were collected on the flooding tide.

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 local population numbers.

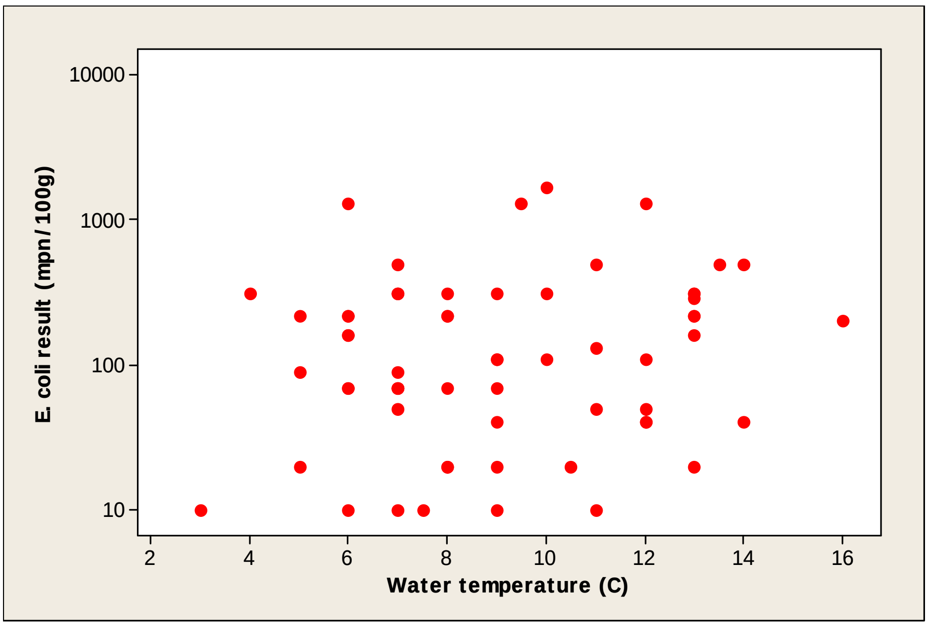

Figure 11.8 Scatterplot of result by water temperature

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature (Adjusted R-sq=1.5%, p=0.173, 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. However, the nearest wind station for which data was available was at Glasgow Bishopton, is 95 km away from the production area so although seasonal patterns in wind strength and direction are likely to be broadly similar to those experienced at Loch Leven Upper, they are likely to differ suignificantly at any given time due to the distance between the two. As a result, Glasgow Bishopton was considered too far away to allow a meaningful comparison with the microbiology results.

11.7 Evaluation of peak results

No results over 4600 *E. coli* MPN/100g were reported. Four results over 1000 *E. coli* MPN/100g were reported. They were collected in October 2002, February 2003, May 2005 and September 2007 all from the same location which was the only reported sampling location. All were collected after a period of light precipitation on the larger (over 4 m) tides during the ebb tide, although it must be noted that very few samples were collected on the flood tide.

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	Time since high water	Height of previous tide
22/10/2002	1300	NN146616	*	*	3 h 14 min	4.4 m
18/02/2003	1300	NN146616	Q1	Q1	2 h 36 min	4.5 m
18/05/2004	1700	NN146616	Q2	Q1	4 h 40 min	4.1 m
11/09/2007	1300	NN146616	Q2	Q2	2 h 5 min	4.2 m

* Data not available

11.8 Summary and conclusions

It was not possible to investigate geographic differences in levels of contamination, as all samples were reported from the same grid reference. Peaks in results occurred at the beginning of 2003 and 2007, and results were lower around the beginning of 2006.

No statistically significant seasonal difference was found. The proportion of results over 230 MPN/100g was highest in the summer, but it was not possible to test whether this effect was statistically significant due to low sample numbers. No significant relationship was found with water temperature.

A negative correlation was found between 2 day precipitation and *E. coli* result, but no correlation was found between 7 day precipitation and *E. coli* result. All results of over 1000 *E. coli* MPN/100g occurred following relatively dry periods. This suggests that levels of contamination are lower during wet weather, possibly due to greater dilution or quicker flushing of contamination from continuous sources.

No statistically significant influence of tide size (i.e. spring or neap) or tidal state at time of sampling (high/low and ebb/flood) was found at either site. It was however noted that the four results exceeding 1000 *E. coli* MPN/100g occurred on the larger tides.

It was not possible to investigate the effects of wind on the sample results as there was no wind data available which could be considered representative of conditions at the loch on the day of sampling.

The relatively small amount of data available 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 a seasonal classification in the last three years.

12. Designated Shellfish Growing Waters Data

The area considered in this report lies within a shellfish growing water which was designated in 2002 and is monitored by SEPA. The growing water encompasses a larger area than that covered by this report. The extent of the growing water is shown on Figure 12.1.

The monitoring requires the following testing:

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

Mussel samples were taken from for faecal coliform analysis from two points within the growing water. The first point sampled corresponds to the RMP for the Loch Leven Upper production area, and this was sampled on two occasions, giving results of 500 faecal coliforms/100g in quarter 4 of 2003, and 1300 faecal coliforms/100g in quarter 1 of 2004.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report.

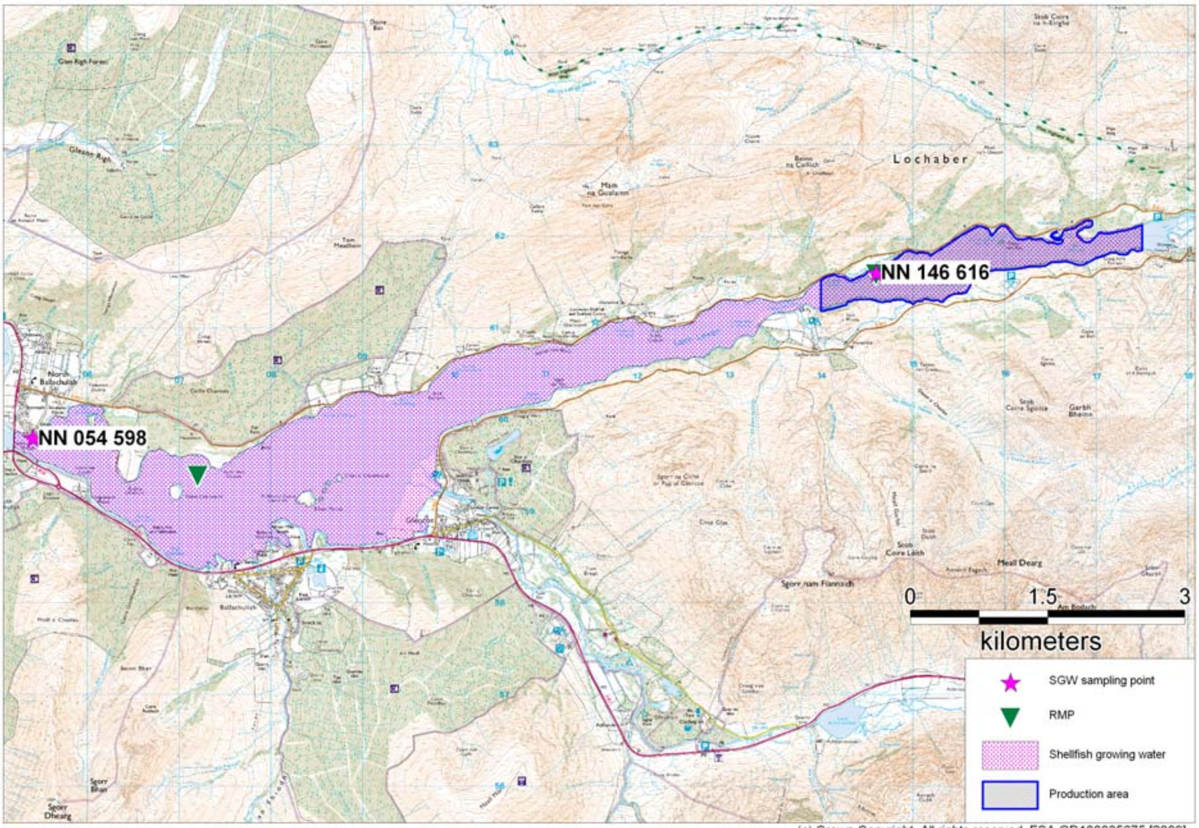

Figure 12.1 Shellfish growing waters and monitoring points

Table 12.1 SEPA Faecal coliform results (FC/100g) for shore mussels gathered from Loch Leven.

	Site	Loch Leven	Loch Leven
	OS Grid Ref.	NN 146 616	NN 054 598
2002	Q1		
	Q2		
	Q3		
	Q4	500	
2003	Q1	1300	
	Q2		
	Q3		110
	Q4		<20
2004	Q1		70
	Q2		160
	Q3		110
	Q4		310

13. River Flow

There are no river gauging stations on rivers or burns along the Loch Leven coastline. The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs to Loch Leven.

Table 13.1 River and stream loadings for Loch Leven

No	Grid Reference	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/day)	*E.coli* (cfu/ 100 ml)	Loading (*E.coli* per day)
1	NN 14895 61827	Stream	0.90	0.10	0.59	4587.8	<100	*
2	NN 14786 61740	Stream	0.60	0.07	0.21	762.0	<100	*
3	NN 14659 61692	Stream	0.80	0.10	0.49	3407.6	<100	*
4	NN 14580 61655	Stream	0.50	0.09	0.26	1026.4	<100	*
5	NN 14269 61543	Stream	0.55	0.06	0.29	821.1	<100	*
6	NN 14152 61593	Stream	0.60	0.12	0.14	852.2	<100	*
7	NN 14092 61571	Stream	0.45	0.09	0.26	913.3	<100	*
8	NN 14069 61563	Stream	1.80	0.16	0.18	4454.1	<100	*
9	NN 13903 61468	Stream	1.90	0.14	0.18	4021.9	<100	*
10	NN 18000 62236	Edge of north river channel	17.0**	0.90	0.17	-	<100	*
11	NN 18038 62260	Other edge of north channel	17.0**	0.51^	0.97	-	200	*
12	NN 16641 61991	River	7.0	0.53^	0.57^	182710.1	1500	$2.7x10^{12}$
13	NN 13783 61221	Stream	3.70	0.30^	0.48^	45842.1	<100	*
14	NN 14928 61260	Stream	5.50	0.40^	0.74^	141039.4	<100	*
15	NN 15232 61246	Stream	0.75	0.15	0.20	1914.8	<100	*
16	NN 15637 61293	Stream	0.80	0.10	1.31	9047.8	<100	*
17	NN 15695 61285	Stream	0.30^	0.20^	0.61^	3136.3	<100	*
18	NN 16077 61343	Stream	0.95	0.19	0.27	4257.5	100	$4.3x10^9$

* Loading not calculated
^ Two measurements provided, mean given
** Estimated from map

In addition to the streams listed above, several others were observed during the shoreline survey but were too small to measure and sample.

The largest freshwater input is the River Leven, which discharges to the head of the loch. One of the two channels was sampled at a point below the normal tidal limit (NTL). An additional water sample was taken from the single channel a small distance upstream just above the NTL. At the NTL, the river channel is approximately 40 m in width. Flow is smoothed by the Blackwater reservoir about 7 km upstream from the NTL, where water is abstracted for power generation, and subsequently returned to the river at Kinlochleven. SEPA consent for the abstraction for the hydroelectric plant allows a maximum abstraction from the river Leven and it tributaries of 1,430,000 m^3

per day, so this represents the absolute minimum base flow of the River Leven at Kinlochleven. In reality, flow will be greater than this as there are other tributaries entering the River Leven between the Blackwater and the head of tide. Observations made during the shoreline survey at the hydroelectric plant outfall suggested that about 50% of the flow of the River Leven at Kinlochleven came from the outfall (Appendix 7, Figure 14). Therefore, a very rough estimate of total discharge from the River Leven at the time of shoreline survey would be in the order of 2,800,000 m^3 per day.

The two water samples taken from the River Leven at Kinlochleven in the north channel below the NTL gave results of <100 and 200 *E. coli* cfu/100ml. These are quite low results, considering that two Scottish Water septic tanks discharge to this river upstream of the point sampled. It is possible that the plume from these discharges was missed, as the majority of it may flow down the other channel which was not sampled. The water sample taken above the NTL gave a result of <100 *E. coli* cfu/100ml. Again, this is a low result considering that one of the Scottish Water septic tank discharges is upstream of where this sample was taken.

Using an estimated discharge of 2,800,000 m^3 per day, and an *E. coli* level of 100 cfu/100ml, the loading contributed by this river is roughly 2.8×10^{12} *E. coli* per day. This is very similar to the estimated loading contributed from River 12, which had high levels of *E. coli* at the time of sampling (1500 cfu/100ml). River 12 discharges to the north shore, about 2 km east of the fishery, so given its location is likely to be a more significant source of contamination to the fishery than the River Leven. River 12 receives a septic tank discharge just upstream of where the water sample was taken, although it is unlikely that this septic tank is wholly or consistently responsible for such a large loading (an estimated loading for a 10 person septic tank is about 2×10^{10} *E. coli*/day). All other streams had low levels of contamination (100 or <100 *E. coli* cfu/100 ml). The streams draining to the north shore in the near the fishery were all small and contained <100 *E. coli* cfu/100 ml.

The levels of *E. coli* in all but River 12 were actually lower than those found in seawater samples taken around the Loch (range 220 to 520 *E. coli* cfu/100 ml). This suggests the contamination found at the surface of the loch mainly originates from sources other than land runoff, such as the main Kinlochleven community outfall, which discharges direct to Loch Leven by Kinlochleven. Alternatively, if much of it does originate from land runoff then it may be episodic in nature. It also suggests that levels of contamination in the surface layer may actually drop as freshwater inputs increase, for example during the spring snowmelt.

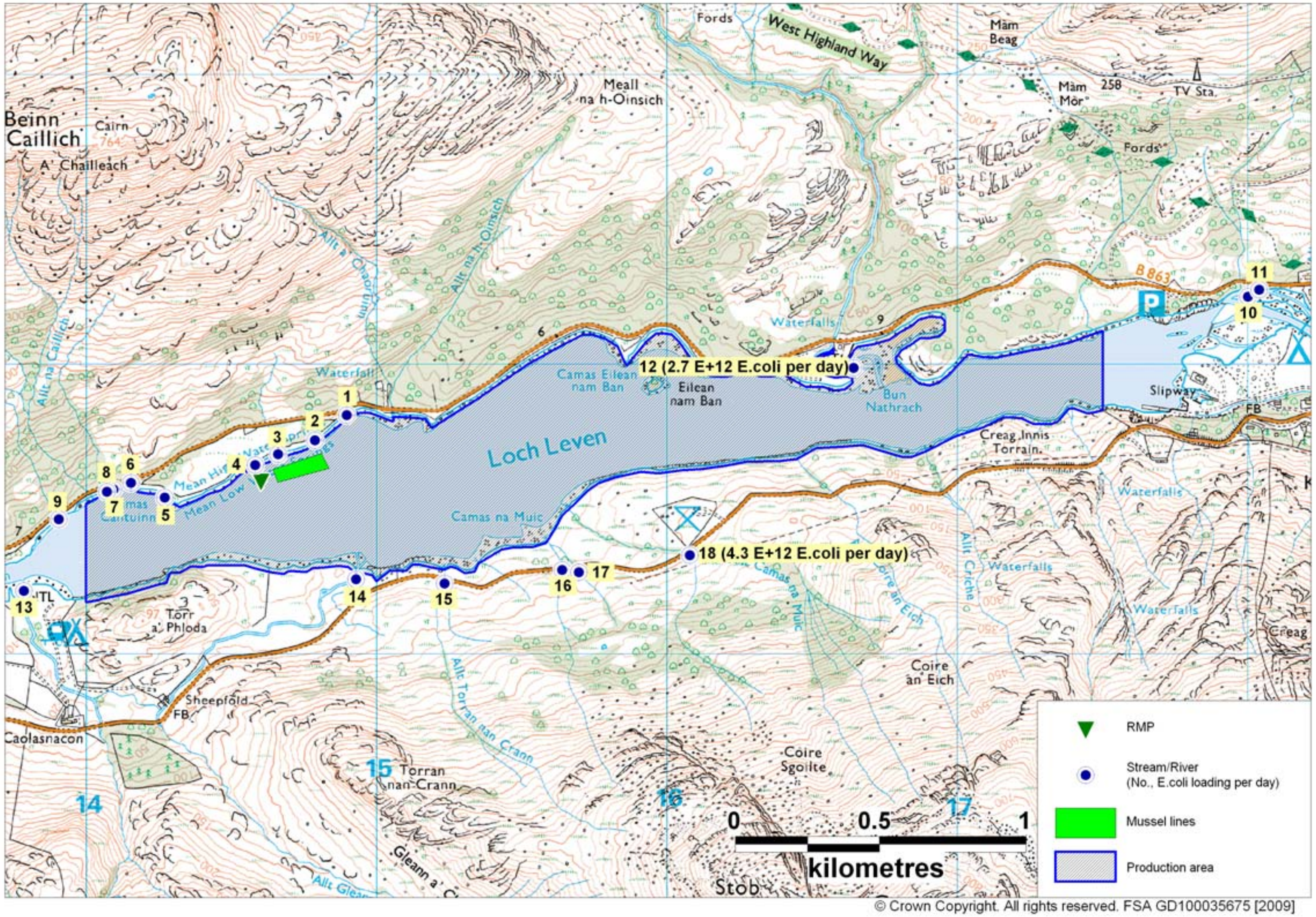

Figure 13.1 Significant streams and loadings

14. Bathymetry and Hydrodynamics

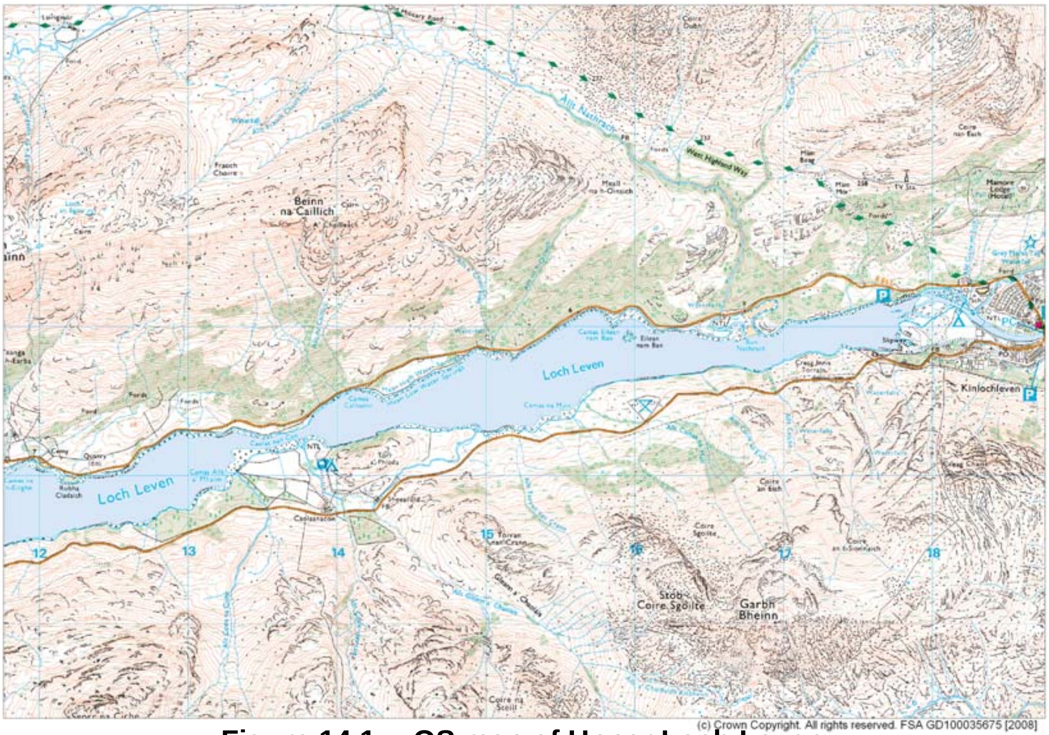

Figure 14.1 OS map of Upper Loch Leven

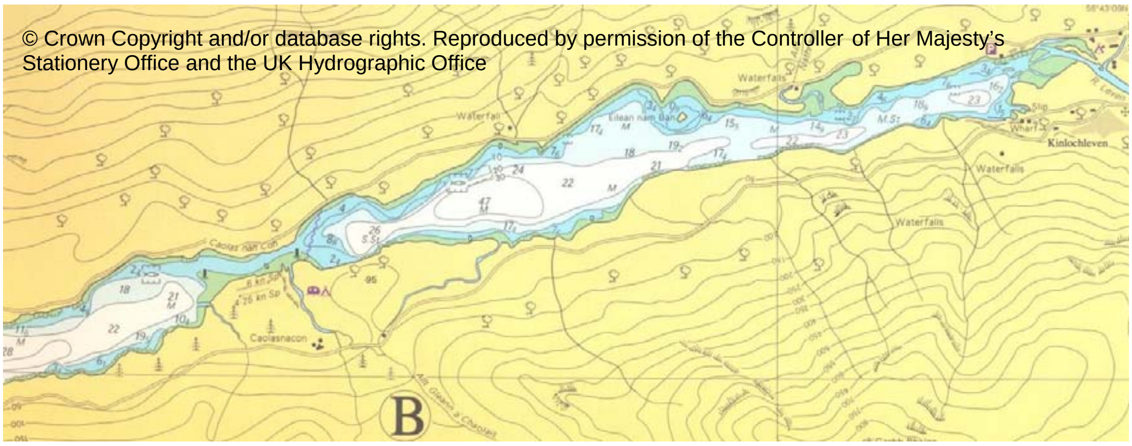

Figure 14.2 Bathymetry Map of Upper Loch Leven

Loch Leven as a whole is 13.5 km long, with an area at high water of 8.6 km^2 and has 5 sills (Edwards & Sharples, 1986). The upper Loch Leven basin in which the fishery is located is about 4 km long, and 0.5 km wide at its widest part and has an area of 1.5 km^2. The maximum depth is 47 m just offshore of the mussel farm. It is separated from lower Loch Leven by a sill just to the west of the production area. At the sill, the loch narrows to 120 m in width, and the average depth across the sill is 3 m, and the sill is 600 m in length, so it is a significant constriction and strong tidal currents will occur there. Another significant feature in the upper basin is the River Leven, which discharges to the head of the loch. The flow of this river is smoothed by a reservoir, where a steady flow of water is abstracted for use in a hydroelectric plant, then subsequently returned to the River at Kinlochleven.

14.1 Tidal Curve and Description

The two tidal curves below are for Corran, in Loch Linnhe just north of the mouth of Loch Leven. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 7/11/2008 and the second is for seven days beginning 00.00 GMT on 14/11/2008, which covers the dates of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

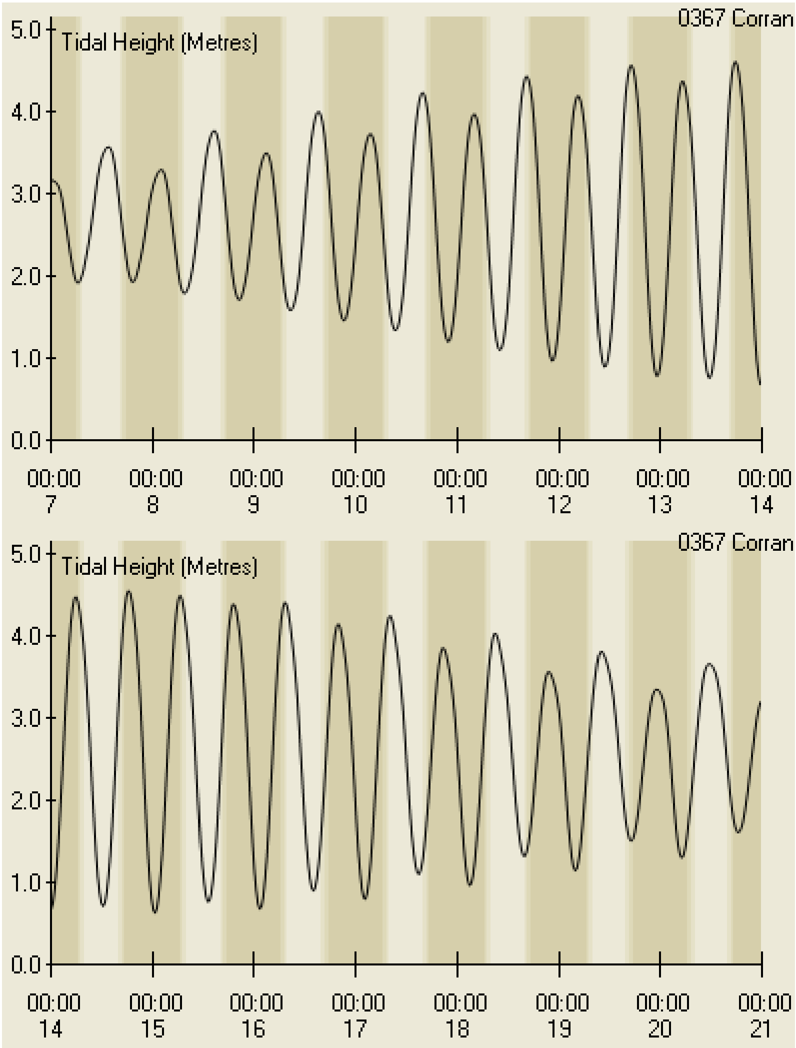

Figure 14.3 Tidal curves for Corran

The following is the summary description for Corran from TotalTide:

Corran is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	4.9 m
MHWS	4.4 m
MHWN	3.3 m
MLWN	1.7 m
MLWS	0.7 m

Predicted heights are in metres above Chart Datum. The tidal range at Corran is 3.7 m on spring tides, and 1.6 m on neap tides, although it is likely that tidal range is smaller in the upper basin of Loch Leven as there are five sills along the length of the loch.

14.2 Currents

Currents in the upper basin of Loch Leven will be driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area based on opinion. There is no tidal stream information available on Total Tide within Loch Leven to assist in these predictions.

The relatively short flushing time of 3 days reported by Edwards & Sharples (1986) for the whole of Loch Leven suggests strong tidal exchange in the loch as a whole. In the upper basin, tidally driven currents are likely to move along the shore in an easterly direction on the flood tide, and a westerly direction on the ebb tide. Currents are likely to be fastest at the sill at the western end of the upper basin which constitutes a significant constriction. Edwards & Sharples (1986) report a current speed of 33 cm/s over this sill. Mixing of waters is likely to occur as it flows across this sill.

The catchment area of Loch Leven as a whole is 338 km^2. The fresh/tidal flow ratio of 41 and the salinity reduction value of 1.4 ppt suggest moderately high freshwater influence in Loch Leven as a whole (Edwards & Sharples, 1986). In the upper basin, there is a significant freshwater input (River Leven). Salinity profiles taken during the shoreline survey indicated high freshwater influence and very strong stratification in the vicinity of the fishery. Salinities at the surface and at 1 m depth were very low (2 ppt or less). At 3 m depth the salinity ranged from 16.6 to 19.4 ppt, and at 5 m depth salinities ranged from 22.8 to 23.8 ppt. These measurements are not believed to be unusual at this site, and the mussel lines are set so that the stock is held below 3 m depth to avoid this freshwater layer. Therefore, freshwater (density) driven currents are likely to be of significance in the upper basin of Loch Leven. A layer of less dense freshwater will float on top of the more saline water lower down in the water column, and will flow in an overall seaward direction. This will create a return flow of more dense higher salinity water. It is likely that contamination from sewage sources at Kinlochleven is carried towards the fishery in the surface layer of freshwater, and that it generally remains in the top 3 m of the water column. Density driven flows will be greater following heavy precipitation, although it must be noted that the discharge from the main freshwater source, the River Leven, is buffered by the presence of the Blackwater Reservoir and associated hydroelectric plant, which will to some extent maintain a steady flow in the river in periods of low or high rainfall or during snowmelt.

Wind driven currents have the potential to significantly alter the circulation of water around the loch, particularly in areas where tidal and density driven flows are weakest such as the deeper calmer water away from sills and constrictions. The nature of these currents will depend on wind strength, direction and variability. Winds from the east and the west are likely to have the greatest effects as the loch is most exposed to winds from these directions. Winds will drive a surface current in the same direction as the wind, so a persistent easterly wind is likely to facilitate the transport of contamination from Kinlochleven towards the fishery. Wind driven surface currents will create return flows lower down in the water column. Strong winds may aligned along the east-west axis are also likely to create wind rows, in which water circulates in a series of cells that draw material across the loch at right angles to the wind direction. This will draw contamination from nearshore sources to further offshore, and may disrupt the stratification to some extent.

14.3 Conclusions

The main identified sources of contamination in the upper basin of Loch Leven are the sewage discharges at Kinlochleven. Tidally driven currents are expected to move in an easterly direction on a flooding tide, and a westerly direction on the ebbing tide, but over an entire tidal cycle they will largely cancel each other out in terms of net particle transport. As the upper basin has considerable freshwater inputs, and is highly stratified, density driven flows are likely to result in a significant net seaward flow of a surface layer of fresher water, with return currents of more saline water at depth. Therefore, this is likely to be a consistently important mechanism resulting in the transport of contaminated freshwater from the head of the loch towards the fishery. This seaward flow of the surface layer may impede the movement of contamination from lower Loch Leven into the upper basin to some extent. An easterly wind will act to accentuate density driven flows, whereas a westerly wind is likely to have the reverse effect.

Strong winds may result in decreased stratification through the formation of wind rows. Of significance to the sampling plan, are the likely differences in current direction and salinity through the water column. Observations made during the shoreline survey suggest that the surface layer of freshwater is generally confined to the top 3 m of the water column. Mussels are grown between 3 and 9 m from the surface. Towards the bottom of the mussel ropes, the water may be much more saline than at the top, and currents will be weaker or possibly flowing in the opposite direction than at the surface. Therefore, it is predicted that the mussels closest to the surface will be more exposed to contamination originating from Kinlochleven.

15. Shoreline Survey Overview

The shoreline survey was undertaken on the 12th-14th November 2008 under varying weather conditions.

The fishery consists of mussel lines covering an area of 9,400 square metres. The header lines hang 3 metres below the supporting buoys to avoid the largely fresh water in the upper 3 metres. The mussels are grown on 4 to 6 m droppers from the header lines. Mussels from both the Lower and Upper Loch Leven sites are brought here for processing, after which they are held in holding nets through holes in the raft at a depth of approximately 3 m for between 12 and 48 h to allow them to recover before transport. Samples for classification purposes have traditionally been taken from a basket within these holding nets – the harvesters indicate that only mussels from Upper Loch Leven were placed in that basket. There is a purification system on the shore above the fishery which is operated when the sites are class B. The waste water from the processing unit and the purification system are both discharged in the vicinity of the fishery.

The main source of sewage in the area is the village of Kinlochleven at the head of the loch. This has a winter population of approximately 1100 and two Scottish Water sewage works were observed during the survey. These and other contamination associated with the River Leven will form the bulk of the contamination at the head of the loch. Two other septic tanks were observed nearer the fishery, one discharging to a river on the northern shore and one serving a campsite on the southern shore by the narrows. There were a number of other hotels, bed and breakfasts and hostels in the area, largely serving walkers of the West Highland Way. The season for visitors lasts from March to October inclusive. Boat traffic in the upper loch is confined to a few small boats and some kayaks.

The surrounding land is predominantly deciduous woodland on the lower hills around the loch with rough grassland and heather above. The only livestock seen during the survey were 4 goats on the northern side of the loch near the narrows and approximately 30 sheep on the southern side of the loch west of the caravan site. A large amount of dog faeces was seen on an area of grass on the southern side of the river in Kinlochleven. A dead stag and deer droppings were seen. The harvesters identified that deer occurred on the hills around the loch, especially on the southern side. The number of birds seen during the survey was small.

Salinities at the surface and at 1 m depth were very low (2 ppt or less). At 3 m depth the salinity ranged from 16.6 to 19.4 ppt, and at 5 m depth salinities ranged from 22.8 to 23.8 ppt. Six seawater samples were taken from the surface, and gave results ranging from 220 to 520 *E. coli* cfu/100 ml, with no apparent spatial pattern. It was not possible to sample to ascertain whether there were similar consistently high levels of *E. coli* in the more saline water lower down in the water column in which the mussels are cultured. The levels of contamination found in freshwater inputs was lower than that found in the surface layer of the loch in all but one case. This stream contained 1500 *E. coli* cfu/100ml in a water sample taken just downstream from a private septic tank discharge. Significant additional run-off will occur in the spring when the snow on the upper hills melts. A total of 10 mussel samples were taken from near the corners of the mussel lines at depths from between 3 to 9 m below the surface. Results were quite variable, and ranged from 20 to 3500 *E. coli* MPN/100g. Figure 15.1 presents a scatterplot of individual results by depth, and Figure 15.2 presents a boxplot of results by the corner sampled.

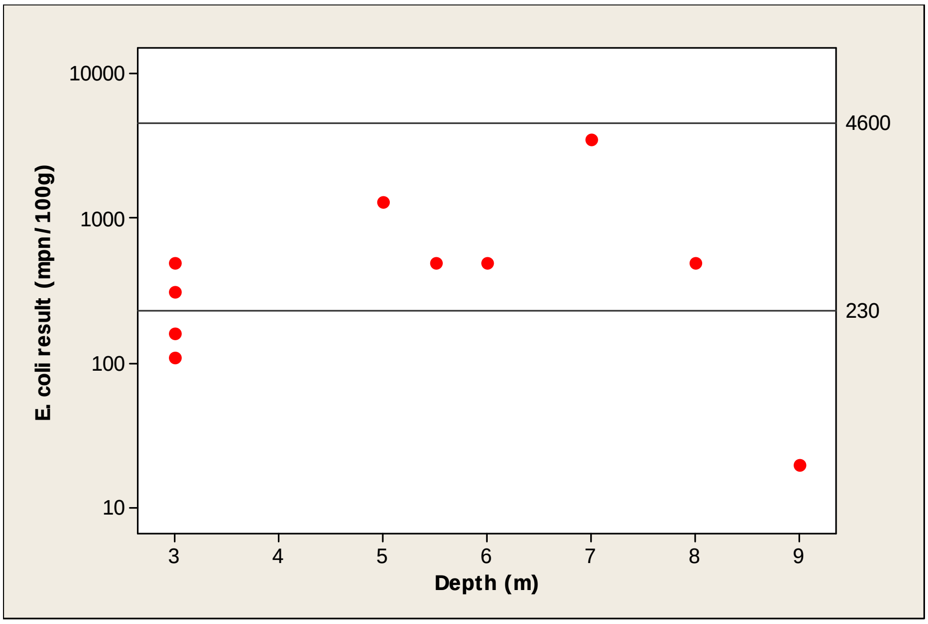

Figure 15.1 Scatterplot of rope mussel results by depth

The highest result occurred at 7 m depth, and the lowest result occurred at 9 m depth. Based on this limited number of samples, results appear highest in the 5-7 m depth band.

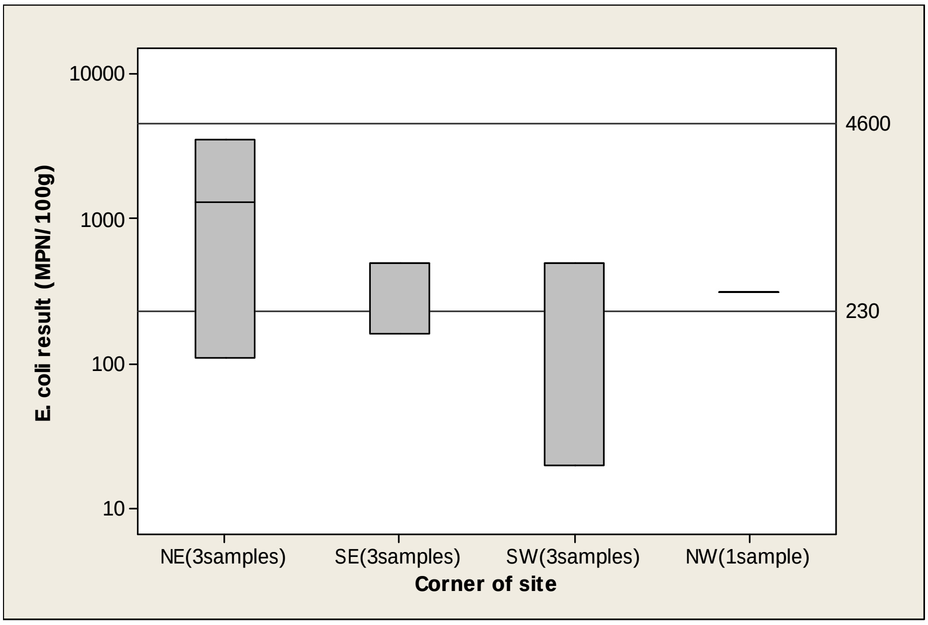

Figure 15.2 Boxplot of rope mussel results by sampling location

Based on this limited number of samples, results appear highest at the north eastern corner, which is closest to Kinlochleven and River 12. It must be noted that all shoreline survey results and observations apply to the time of survey only, so caution must be exercised when drawing conclusions from this data.

Additionally, one wild mussel sample was taken from the rocks in the vicinity of the sill to the west of the fishery. This returned a result of 160 *E. coli* MPN/100g.

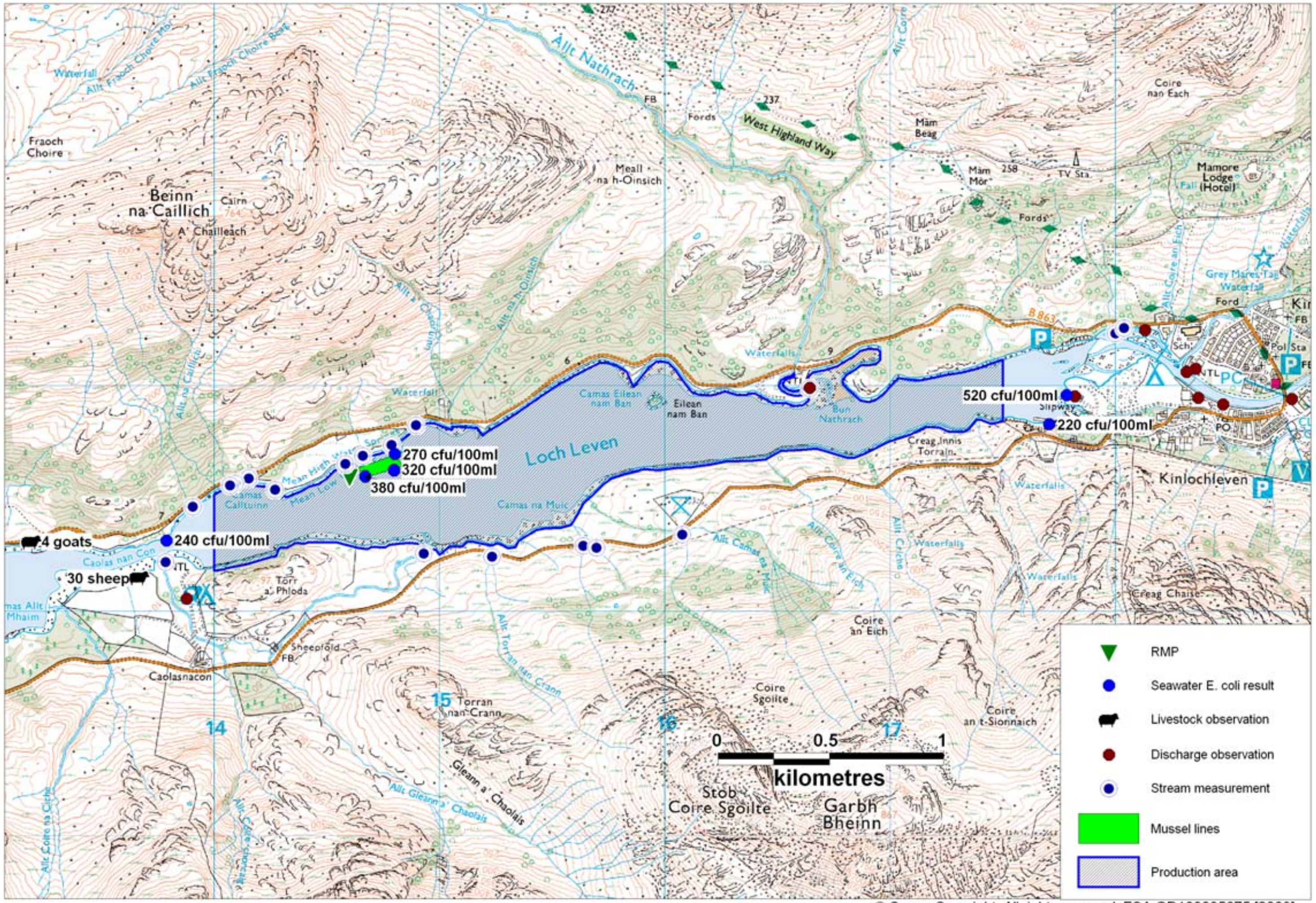

Figure 15.3 Summary of shoreline survey findings for Loch Leven Upper

16. Overall Assessment

Human sewage impacts

The main sewage contributions to Upper Loch Leven are from the Scottish Water discharges at Kinlochleven, about 3.5 km to the east of the fishery. These comprise of secondary treated effluent from a population of 900 and septic tank (primary) treated effluent from a population of 567. Additional SEPA discharge consents are for 5 small private septic tanks to discharge to soakaway, and all are located at the northern side of Kinlochleven. Two smaller private discharges were observed closer to the fishery, one from a campsite on the south shore about 1 km from the fishery, and one from a private house on the north shore about 2 km from the fishery. There are a number of Scottish Water discharges in the lower basins of Loch Leven, the nearest of which was over 5.5 km from the western border of the Loch Leven: Upper production area. Therefore there is the possibility of contamination from the lower loch impacting on the fishery via movement of water up the loch, although the latter will be restricted by the presence of a sill.

Boat traffic in the upper loch is confined to a few small boats and some kayaks, so impacts from these sources are likely to be minor at most.

In conclusion the main sewage discharges of relevance are located at the head of the loch, and so it is possible that levels of contamination at the eastern end of the fishery may be slightly higher than that at the western end, although large differences are not expected in levels of contamination within the site, as the discharges are 3.5 km from the site, and the site is less than 200 m in length.

Agricultural impacts

The surrounding land is predominantly deciduous woodland on the lower hills around the loch with rough grassland and heather above. Agricultural census data indicated that agriculture in the surrounding parishes is dominated by sheep production, with some cattle, poultry, pigs and horses. A total of only 30 sheep and four goats were recorded during the entire shoreline survey however. These were all found on pasture at the constriction in the loch just to the west of the production area. The banks of the River Leven are wooded downstream of the Blackwater reservoir, so little contamination of livestock origin would be expected to enter this river. In conclusion, impacts from livestock are likely to be minor, and on the basis of shoreline observations would be expected to enter the production area to the west of the fishery.

Wildlife impacts

The only potentially significant wildlife populations identified in the area is the deer population, which may be larger than the local livestock population. Deer are more numerous on the southern side of the production area, so streams discharging to the south shore may contain more contamination of deer origin. In addition to this it is possible that small numbers of seals and waterbirds use the area, but where and when any impacts from these species may occur is uncertain. In conclusion, wildlife impacts may be of more importance than livestock impacts, and there may be higher impacts at the south shore where deer populations may be higher. However, due to the unpredictable spatial impact of the wildlife inputs, they will not directly influence the sampling plan.

Seasonal variation

Loch Leven is a popular tourist destination and a number of hotels and B&Bs cater for visitors to the area. A search of the internet revealed 259 guest beds in the area and 30 campsite pitches with a separate toilet block near the river in Kinlochleven. The town lies along the West Highland Way walking trail and is popular with tourists with most visits between March and October.

Weather is wetter and windier in the winter months, so more precipitation dependent contamination may be expected at these times. In the spring, freshwater inputs are likely to be high as the snow melts on the surrounding mountains.

No statistically significant seasonal difference was found in historical *E. coli* results. The proportion of results over 230 MPN/100g was highest in the summer, but it was not possible to test whether this effect was statistically significant due to low sample numbers.

In conclusion, there is likely to be more contamination of human origin during the summer months due to tourism, although analysis of the historic *E coli* monitoring data did not show a significant impact of this on the microbiological quality of the fishery.

Rivers and streams

The land drained by streams flowing into Loch Leven: Upper is predominantly deciduous woodland on the lower hills around the loch with rough grassland and heather above, so levels of contamination in these streams would be expected to be fairly low. This was confirmed during the shoreline survey, as all but one of the freshwater inputs sampled had levels of *E. coli* of 200 cfu/100ml or less, with the vast majority having results of <100 cfu/100ml.

The largest freshwater input is the River Leven, which discharges to the head of the loch. This was too large to safely measure during the shoreline survey. At the NTL, the river channel is approximately 40 m in width. Flow is smoothed to some extent by a reservoir and associated hydroelectric plant. It is estimated from the amount consented abstraction volume for the hydroelectric plant (1,430,000 m^3 per day) and the proportion of the total discharge of the River Leven that the discharge of the River Leven that the hydroelectric outfall comprises (estimated at 50%) that the total discharge from the River Leven was about 2,800,000 m^3 per day at the time of survey

The three water samples taken from this river gave results of <100, <100 and 200 *E. coli* cfu/100ml. Using an estaimated discharge of 2,800,000 m^3 per day, and an *E. coli* level of 100 cfu/100ml, the loading contributed by this river is very roughly 2.8×10^{12} *E. coli* per day. This is very similar to the estimated loading contributed from another smaller river which discharges to the north shore, about 2 km east of the fishery, and had high levels of *E. coli* at the time of sampling (1500 cfu/100ml). A private septic tank discharges to this river just upstream of the sampling point. It is likely that this river contributes to levels of contamination observed at the fishery.

Of interest, the levels of *E. coli* in all but one river were actually lower than those found in seawater samples taken around the Loch, suggesting the contamination found at the surface of the loch mainly originates from sources other than land runoff, such as the largest of the community discharges at Kinlochleven, which discharges direct to Loch Leven.

In conclusion, there are significant freshwater inputs in terms of volumes to the upper basin of Loch Leven. The majority of these lie to the east of the fishery, and all but one had levels of *E. coli* which were actually lower than that in the surface layer of the loch, suggesting that there are other significant sources of contamination to the loch other than land runoff. The River Leven, was largest in terms of volume, but had low levels of *E. coli*, although it is suspected that contamination from the two septic tank discharges to this river may not have been captured by the water samples taken on the shoreline survey. Another significant river discharges 2 km to the east of the fishery, which had high levels of *E. coli*, some of which is presumed to have originated from a private septic tank discharge.

Meteorology, hydrology, and movement of contaminants

The main identified sources of contamination in the upper basin of Loch Leven are the sewage discharges at Kinlochleven. Tidally driven currents are expected to move in an easterly direction on a flooding tide, and a westerly direction on the ebbing tide, but over an entire tidal cycle they will largely cancel each other out in terms of net particle transport.

As the upper basin has considerable freshwater inputs, and is highly stratified with a layer of almost fresh water in the top 3 m of the water column, density driven flows are likely to result in a significant net seaward flow of the surface layer of fresher water, with return currents of more saline water at depth. Therefore, this is likely to be a consistently important mechanism resulting in the transport of contaminated freshwater from the head of the loch towards the fishery. This seaward flow of the surface layer may impede the movement of contamination from lower Loch Leven into the upper basin to some extent.

An easterly wind will act to accentuate density driven flows, whereas a westerly wind is likely to have the reverse effect. Strong winds may result in decreased stratification through the formation of wind rows.

Of significance to the sampling plan, are the likely differences in current direction and salinity through the water column. Observations made during the shoreline survey suggest that the surface layer of freshwater is generally confined to the top 3 m of the water column. Mussels are grown between 3 and 9 m from the surface. Towards the bottom of the mussel ropes, the water may be much more saline than at the top, and currents will be weaker or possibly even flowing in the opposite direction than at the surface. Therefore, it is predicted that the mussels closest to the surface will be exposed to more contamination originating from Kinlochleven.

A negative correlation was found between 2 day precipitation and historic *E. coli* monitoring results, but no correlation was found between 7 day precipitation and *E. coli* result. All results of over 1000 *E. coli* MPN/100g occurred following relatively dry periods. This suggests that levels of contamination are lower during wet weather, possibly due to greater dilution and faster passage of contamination from continuous sources. No statistically significant influence of tide height (i.e. spring or neap) or tidal state at time of sampling (high/low and ebb/flood) was found at either site. It was however noted that the four results exceeding 1000 *E. coli* MPN/100g occurred on the larger tides. It was not possible to investigate the effects of wind on the sample results as there was no wind data available which could be considered representative of conditions at the time of sampling.

Temporal and geographical patterns of sampling results

It was not possible to investigate geographic differences in levels of contamination in historic *E. coli* monitoring samples, as all were reported from the same grid reference. Peaks in results occurred at the beginning of 2003 and 2007, and results were lower around the beginning of 2006, although historic *E. coli* monitoring results must be treated with caution for reasons already discussed.

Therefore, the only source of information on geographical patterns of levels of contamination are the shoreline survey results, which are specific to the conditions encountered at the time of survey. A total of 10 mussel samples were taken from near the corners of the mussel lines at depths from between 3 to 9 m below the surface. Results were quite variable, and ranged from 20 to 3500 *E. coli* MPN/100g. Results appear highest at the north eastern corner, which is closest to Kinlochleven and the more contaminated river described in the rivers section. In terms of depth, the highest result occurred at 7 m depth, and the lowest result occurred at 9 m depth. Higher results occurred in the 5-7 m depth band. Sample numbers were limited, so firm conclusions should not be drawn from these results. Seawater samples taken from the surface gave quite high results, ranging from 220 to 520 *E. coli* cfu/100 ml, with no apparent spatial pattern. It was not possible to sample to ascertain whether there were similar consistently high levels of *E. coli* in the more saline water lower down in the water column in which the mussels are cultured.

17. Recommendations

The recommended production area boundaries are the area bounded by lines drawn between NN 1400 6153 and NN 1400 6119 and between NN 1500 6184 and NNH 1500 6127 extending to MHWS. This restricts the production area so new sites cannot be deployed in the immediate vicinity of the main identified sources of contamination without a separate classification.

The location of the important sources (Kinlochleven and associated discharges, the River Leven, and the contaminated river about 2 km to the east of the fishery), the likely pattern of water circulation around the loch, and results from the shoreline survey suggest that the RMP should be set at the north eastern corner of the fishery. Therefore, it is recommended that the RMP be set at NN 1480 6168. Samples taken during the shoreline survey suggested that contamination was higher at 5-7 m depth, although results were quite variable, and sample numbers considered were low. It is likely that the fresher water nearer the surface is more contaminated than the more saline water towards the bottom of the mussel ropes, so the recommended sampling depth is 3 m. To avoid the issue uncertain sample origin, it is recommended that samples be taken directly from the mussel ropes by the sampling officer in person. Only stock of a harvestable size should be sampled, and a sampling tolerance of 30 m should be applied to allow for movement of the lines and to ensure that there is marketable stock within the tolerance.

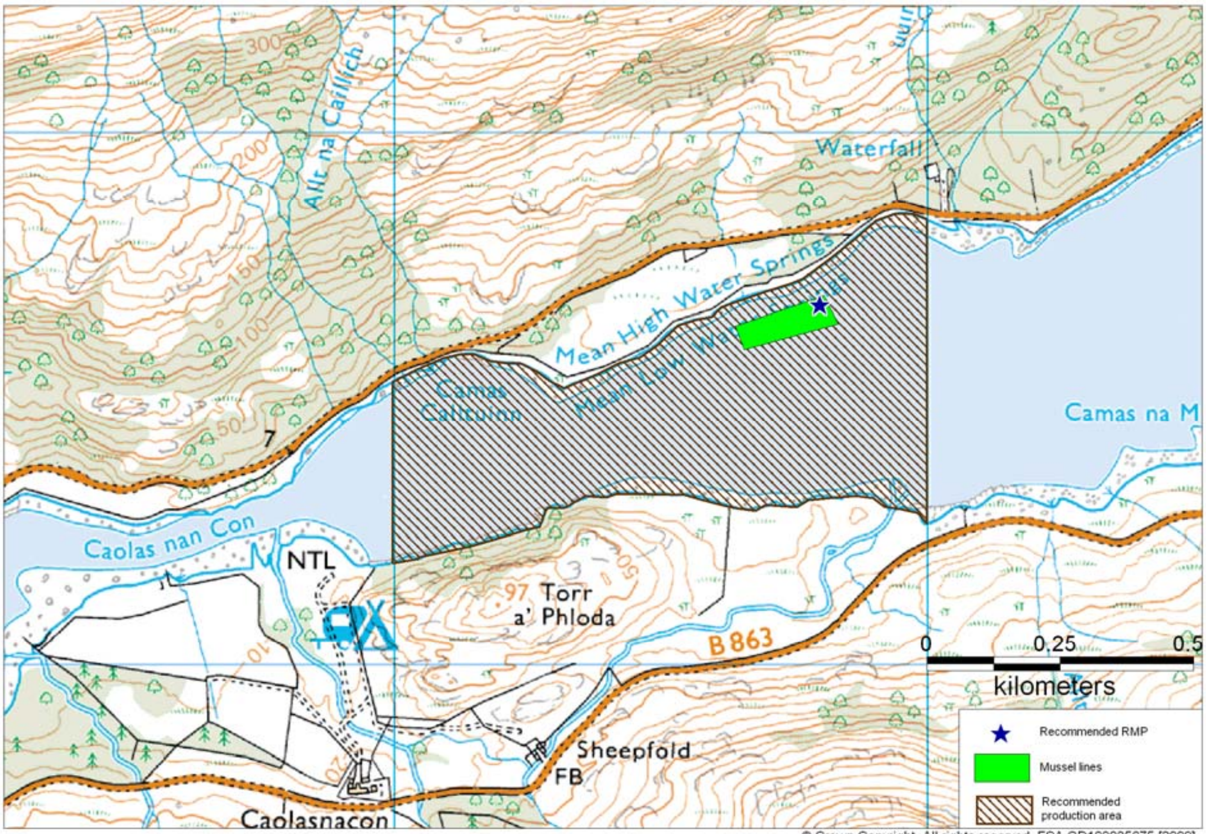

Figure 17.1 Map of recommendations for Loch Leven Upper

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Sampling Plan for Loch Leven: Upper

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch Leven: Upper	Upper	HL 171 223 08	Common mussel	Longline	NN 1480 6168	214800	761680	30	3	Hand	Monthly	Higland Council Lochaber	Stephen Lewis	Alan Yates

Table of Proposed Boundaries and RMPs– Loch Leven: Upper

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Loch Leven: Upper	Common mussel	HL 171 223 08	Area bounded by lines drawn between NN 1400 6120 and NN 1400 6154 and between NN 1750 6186 and NN 1750 6213 extending to MHWS	NN 146 616	Area bounded by lines drawn between NN 1400 6153 and NN 1400 6119 and between NN 1500 6184 and NNH 1500 6127 extending to MHWS.	NN 1480 6168	RMP moved to northeastern corner of farm, eastern area boundary moved closer to the site.

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.

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

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

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

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

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

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens and birds are known to carry *Salmonella*.

Deer

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

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

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

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

Other

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

Otters leave faeces (also known as spraint) along the shoreline or along streams.

Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical Data

All results were log-transformed prior to analysis.

Section 11.5 – ANOVA comparison of results by season

```
Source  DF      SS     MS     F      P
Season   3   1.150  0.383  1.21  0.315
Error   62  19.711  0.318
Total   65  20.860

S = 0.5638   R-Sq = 5.51%   R-Sq(adj) = 0.94%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
1      18  1.9621  0.5109    (---------*----------)
2      14  2.2837  0.4220             (-----------*-----------)
3      17  1.9355  0.6143  (----------*----------)
4      17  2.0005  0.6577     (----------*----------)
                           ----+---------+---------+---------+-----
                             1.75      2.00      2.25      2.50

Pooled StDev = 0.5638
```

Section 11.6.1 Spearmans Rank correlation of result against precipitation in previous 2 days

```
Pearson correlation of result for rain ranked and 2 day rain ranked = -0.316
P-Value = 0.020
```

Section 11.6.1 Spearmans Rank correlation of result against precipitation in previous 7 days

```
Pearson correlation of result for rain ranked and 7 day rain ranked = -0.215
P-Value = 0.118
```

Section 11.6.2 Regression analysis of result vs height of previous tide

```
The regression equation is
LogResult = 1.88 + 0.038 Height of HW (m)


Predictor           Coef  SE Coef     T      P
Constant          1.8795   0.7699  2.44  0.017
Height of HW (m)  0.0379   0.1888  0.20  0.842


S = 0.570734   R-Sq = 0.1%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0131  0.0131  0.04  0.842
Residual Error  64  20.8472  0.3257
Total           65  20.8603


Unusual Observations

     Height
      of HW
Obs     (m)  LogResult     Fit   SE Fit   Residual   St Resid
```

28	4.10	3.2304	2.0348	0.0706	1.1956	2.11R
58	3.10	2.2041	1.9970	0.1945	0.2072	0.39 X

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

Section 11.6.2 Circular linear correlation of result and tidal state

CIRCULAR-LINEAR CORRELATION

Analysis begun: 25 September 2008 12:33:54

Variables (& observations)	r	p
Angles & Linear (66)	0.21	0.063

Section 11.6.3 Regression analysis of result vs water temperature

The regression equation is
Logres for temp = 1.71 + 0.0349 WaterTemp

Predictor	Coef	SE Coef	T	P
Constant	1.7073	0.2414	7.07	0.000
WaterTemp	0.03491	0.02530	1.38	0.173

S = 0.578250   R-Sq = 3.1%   R-Sq(adj) = 1.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.6369	0.6369	1.90	0.173
Residual Error	59	19.7280	0.3344		
Total	60	20.3649			

Unusual Observations

Obs	WaterTemp	Logres for temp	Fit	SE Fit	Residual	St Resid
12	6.0	3.1139	1.9168	0.1075	1.1972	2.11R
16	16.0	2.3010	2.2659	0.1900	0.0351	0.06 X
25	10.0	3.2304	2.0564	0.0776	1.1740	2.05R

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

Hydrographic Methods

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.

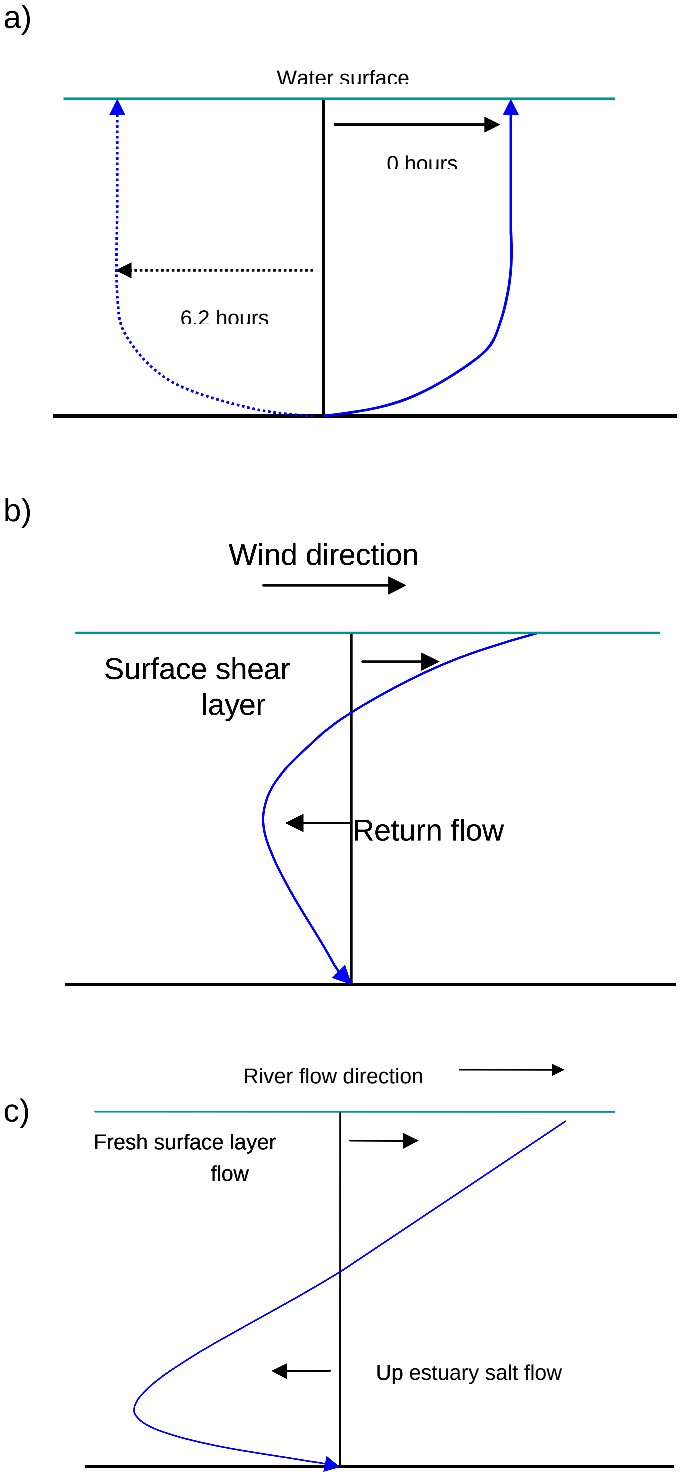


Figure 1 Typical vertical profiles for water currents.
The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

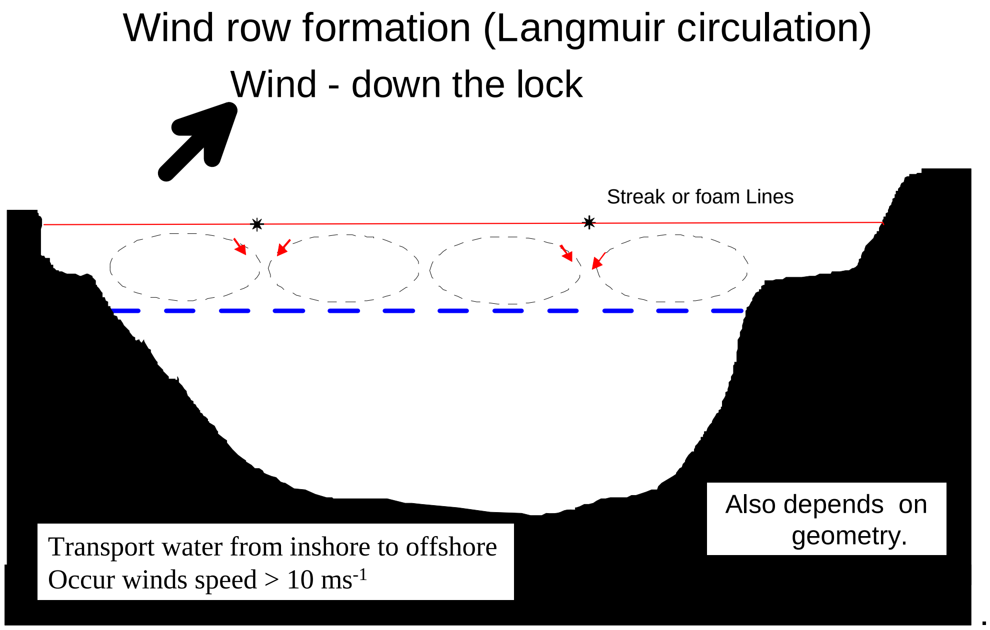


Figure 2 Schematic of wind driven 'wind row' currents.
The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Loch Leven: Upper
HL 171

Scottish Sanitary Survey Project Cefas

Shoreline Survey Report

Prod. area: Loch Leven: Upper (HL 171)
Site name: Upper (223)
Species: Common mussels
Harvester: E & G Salvarli, Glencoe Shellfish
Local Authority: Highland Council (Lochaber)
Status: Risk Matrix

Date Surveyed: 12, 13 and 14 November 2008
Surveyed by: Ron Lee (Cefas) and Stephen Lewis (Highlands Council)
Existing RMP: NN072594
Area Surveyed: See Map in Figure 1

Weather observations
12 November: Bright but cloudy. Light breeze.
13 November: Light to moderate rain. Mainly light wind.
14 November: Overcast with rain developing later. Moderate wind.

We wish to thank Mr and Mrs Salvarli for the contribution of their time and boat access to the mussel farm and surrounding area on the 12 November.

Site Observations

Fishery

The fishery consists of approximately 20 mussel lines of varying length over an approximately rectangular area of 9,400 square metres. The header lines hang 3 metres below the supporting buoys to avoid the largely fresh water in the upper 3 metres. The mussels are grown on 4 to 6 m droppers from the header lines. The growth cycle takes from 2.5 to 3 years. On the shore side of the lines is a raft on which the cleaning/grading machine is operated. Mussels from both the Lower and Upper Loch Leven sites are brought here for processing. After processing, they are held in holding nets through holes in the raft at a depth of approximately 3 m for between 12 and 48 h to allow them to recover before transport (see Figure 5). Samples for classification purposes have traditionally been taken from these holding nets – the mussels will have originally been sourced from either of the sites. The location of the presently specified RMP plots approximately 50 m to the west of the mussel lines and approximately 40 m to the west of the lease (see Figure 1). It should be noted that RMPs used to be specified to only 100 m accuracy.
There is a purification system on the shore above the fishery (Figure 7). This is operated when the sites are class B. The waste water from the processing unit and the purification system are both discharged in the vicinity of the fishery.

Sewage/Faecal Sources

Kinlochleven is a village at the head of the loch with a winter population of approximately 1100 (according to Kinlochleven Community Library) and two Scottish Water sewage works (one a secondary treatment system and one a septic tank) were observed during the survey (obs 32 and 74). These and other contamination associated with the River Leven will form the bulk of the contamination at the head of the loch. Two other septic tanks were observed nearer the fishery, one on the northern side (obs 58) and one on the southern side (obs 62).

Seasonal Population
One caravan site was seen during the survey. There are also a number of other hotels, bed and breakfasts and hostels in the area, largely serving walkers of the West Highland Way. The season for visitors lasts from March to October inclusive.

Boats/Shipping
There is a disused trawler moored near the old Kinlochleven wharf (obs 29). Some small boats were seen along the shore. Only a small number of buoys were seen during the survey, two in the middle of the loch off the old wharf and one near the caravan site. There are two barges used for the mussel farm. Kayakers are reported to use the upper loch during the summer months: a small bay to the east of the mussel farm is used for practising skills.

Land Cover and Use
Land cover is predominantly deciduous woodland (with an undercover largely of fern and bracken) on the lower hills around the loch with rough grassland and heather above. The only livestock seen during the survey were 4 goats on the northern side of the loch near the narrows (obs 28) and approximately 30 sheep on the southern side of the loch west of the caravan site (obs 60).

An area of grass on the southern side of the river in Kinlochleven was obviously used extensively for dog walking but no poop-scoop disposal facilities were seen – there was a large amount of dog faeces on the grass.

Wildlife/Birds
A dead stag was seen near the old wharf (obs 34) and the harvesters identified that deer occurred on the hills around the loch, especially on the southern side. No live deer were seen at the time of the survey. Deer droppings were noted at one point on the survey (obs. 23). The number of birds seen during the survey was small.

Other
Significant additional run-off will occur in the spring when the snow on the upper hills melts.

Specific observations taken on site are mapped in Figure 1 and listed in Table 1.

Figure 1 Map of Shoreline Observations

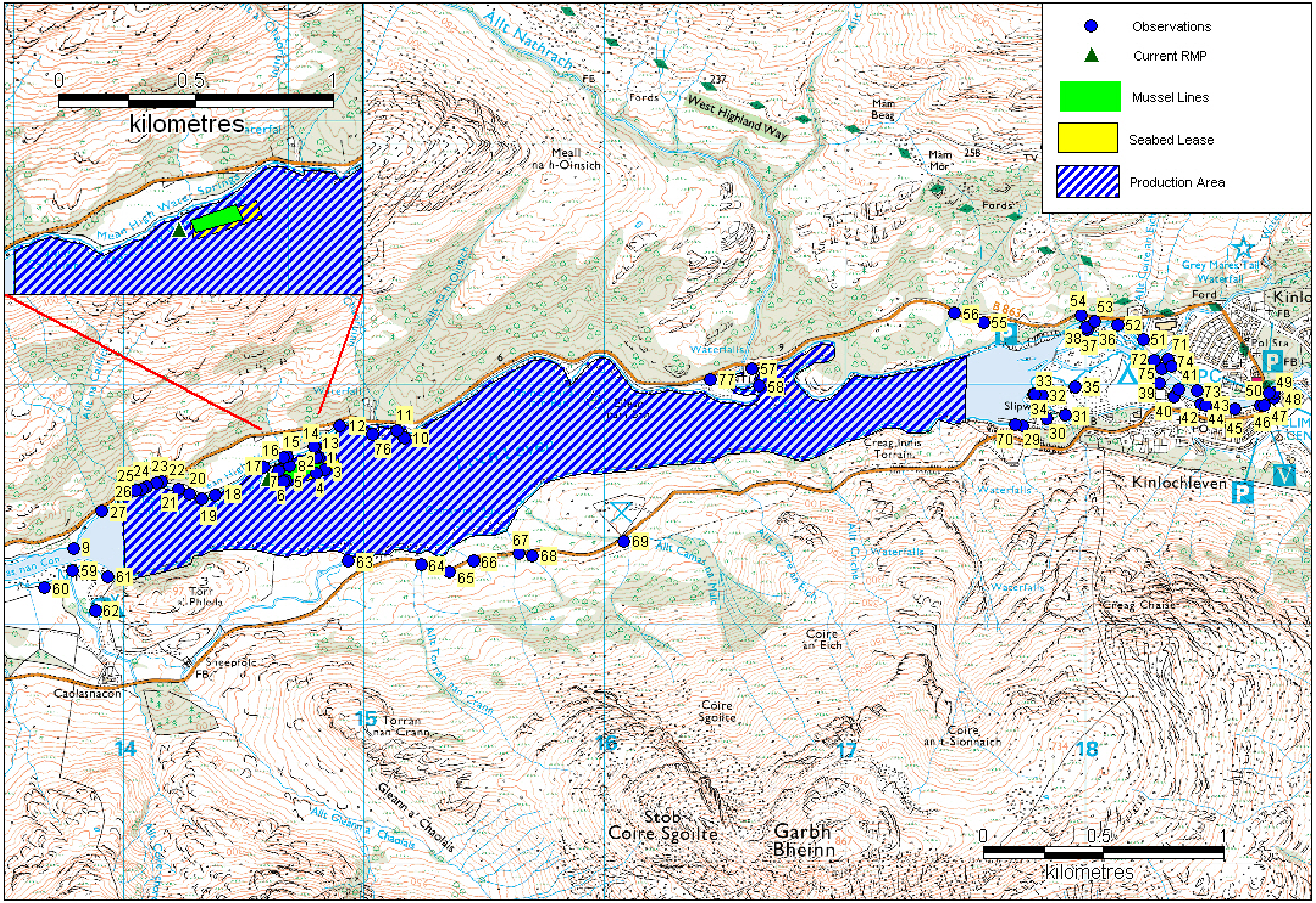


Table 1 Shoreline Observations

No.	Date	Time	Grid reference	Easting	Northing	Associated photograph	Description
1	12/11/2008	10:04	NN 14807 61693	214807	761693		Corner of mussel lines
2	12/11/2008	10:07	NN 14799 61696	214799	761696	Figure 4	Salinity profile; seawater sample LLW1; mussel samples LLS1, LLS2, LLS3
3	12/11/2008	10:25	NN 14834 61641	214834	761641		Corner of mussel lines
4	12/11/2008	10:27	NN 14796 61627	214796	761627		Salinity profile; seawater sample LLW2; mussel samples LLS4, LLS5, LLS6
5	12/11/2008	10:45	NN 14668 61599	214668	761599		Salinity profile; seawater sample LLW3; mussel samples LLS7, LLS8, LLS9
6	12/11/2008	10:59	NN 14657 61593	214657	761593		Corner of mussel lines
7	12/11/2008	11:00	NN 14640 61637	214640	761637		Corner of mussel lines
8	12/11/2008	11:02	NN 14683 61660	214683	761660	Figure 5	Holding area; mussel sample LLS11 (taken 11.24)
9	12/11/2008	11:12	NN 13786 61315	213786	761315	Figure 6	Seawater sample LLW4; wild mussel sample LLS10
10	12/11/2008	13:32	NN 15161 61777	215161	761777		Start of shoreline survey; deciduous woodland with some coniferous on lower slopes; heather above
11	12/11/2008	13:35	NN 15132 61805	215132	761805		Seepage from land
12	12/11/2008	13:47	NN 14895 61827	214895	761827		Stream; width 90cm; depth 10cm; flow 0.59 m/s; water sample LLW5
13	12/11/2008	13:50	NN 14791 61736	214791	761736		Two seepages from land 10m apart
14	12/11/2008	13:51	NN 14786 61740	214786	761740		Small stream; width 60cm; depth 7cm; flow 0.21 m/s; water sample LLW6
15	12/11/2008	13:58	NN 14677 61697	214677	761697	Figure 7	Rafts associated with shellfish farm just offshore; purification system above shore
16	12/11/2008	13:59	NN 14659 61692	214659	761692	Figure 8	Small stream; width 80cm; depth 10cm; flow 0.493 m/s; water sample LLW7; Rocky foreshore with bracken above
17	12/11/2008	14:06	NN 14580 61655	214580	761655		Very small stream; width 50cm; depth 9cm; flow 0.264 m/s; water sample LLW8
18	12/11/2008	14:16	NN 14377 61538	214377	761538		Gravel and rocks on foreshore; deciduous trees and heather on hills above
19	12/11/2008	14:17	NN 14321 61519	214321	761519		2 mallard ducks by foreshore

20	12/11/2008	14:19	NN 14269 61543	214269	761543		Small stream; width 55cm; depth 6cm; flow 0.288 m/s; water sample LLW9
21	12/11/2008	14:25	NN 14225 61561	214225	761561		Seepage from land
22	12/11/2008	14:29	NN 14152 61593	214152	761593		Very small stream; width 60cm; depth 12cm; flow 0.137 m/s; water sample LLW10
23	12/11/2008	14:33	NN 14133 61586	214133	761586		Small amount of deer droppings
24	12/11/2008	14:36	NN 14092 61571	214092	761571		Very small stream; width 45cm; depth 9cm; flow 0.261 m/s; water sample LLW11
25	12/11/2008	14:40	NN 14069 61563	214069	761563		Stream; width 1.8m; depth 16cm; flow 0.179 m/s; water sample LLW12
26	12/11/2008	14:46	NN 14044 61559	214044	761559		Seepage from land
27	12/11/2008	14:57	NN 13903 61468	213903	761468	Figure 9	Stream; width 1.9m; depth 14cm; flow 0.144 m/s & 0.206 m/s; water sample LLW13; marked tide line
28	12/11/2008	15:05	NN 13187 61307	213187	761307		4 goats on hillock by western end of narrows
29	13/11/2008	08:33	NN 17735 61824	217735	761824		Rocky foreshore with rock cliff above; deciduous tress and heather on hill. Old 6" iron pipe - no flow; old disused wharf; old trawler by jetty; small boats on opposite bank of loch
30	13/11/2008	08:43	NN 17840 61854	217840	761854		Small stream entering wharf through culvert - not measured or sampled
31	13/11/2008	08:45	NN 17914 61871	217914	761871		Old Nissan hut marked Kinlochleven Boat Club
32	13/11/2008	09:01	NN 17818 61953	217818	761953	Figure 10	Kinlochleven STW outlet tank; two rotating sprinklers on site; outfall not visible; strong sewage odour
33	13/11/2008	09:12	NN 17782 61958	217782	761958		Seawater sample LLW14 (salinity 0 ppt); water approximately 15cm deep; buoy at least 200m offshore
34	13/11/2008	09:14	NN 17786 61960	217786	761960	Figure 11	Dead stag
35	13/11/2008	09:22	NN 17955 61989	217955	761989		5 ducks by shore
36	13/11/2008	09:31	NN 18007 62225	218007	762225		River bank
37	13/11/2008	09:31	NN 18004 62228	218004	762228		Edge of shallow part of river; 10cm deep
38	13/11/2008	09:32	NN 18000 62236	218000	762236		Edge of main river channel; depth 90cm; flow 0.165 m/s; water sample LLW15
39	13/11/2008	09:44	NN 18304 62004	218304	762004		Village outskirts

40	13/11/2008	09:47	NN 18367 61947	218367	761947	Figures 12 & 13	Pumping station; new construction of inlet screens, primary treatment tanks and CSO; no outfall visible
41	13/11/2008	09:51	NN 18384 61976	218384	761976		Water sample LLW16
42	13/11/2008	09:56	NN 18476 61918	218476	761918		Piped surface water outlet; slight sewage odour nearby
43	13/11/2008	09:57	NN 18495 61912	218495	761912		Dog faeces on grass
44	13/11/2008	09:58	NN 18544 61902	218544	761902		Piped surface water outlet
45	13/11/2008	09:59	NN 18618 61895	218618	761895		Piped surface water outlet
46	13/11/2008	10:02	NN 18727 61910	218727	761910		Piped surface water outlet; lots of dog faeces along grass bank above outlets
47	13/11/2008	10:03	NN 18742 61913	218742	761913		Cairn
48	13/11/2008	10:05	NN 18782 61941	218782	761941		Public toilets with man-hole cover outside - no visible outlet to river
49	13/11/2008	10:07	NN 18782 61963	218782	761963		River depth marker - at 70cm
50	13/11/2008	10:12	NN 18763 61961	218763	761961	Figure 14	On bridge - outlet from hydro-electric plant joins approximately 100m upstream
51	13/11/2008	10:26	NN 18239 62187	218239	762187		Holiday chalets next to stream; stream feeds into large pond; two canoes on bank
52	13/11/2008	10:31	NN 18130 62249	218130	762249		3 pipes through bank from pond into sidearm of river; one piece of sanitary waste on side of bank
53	13/11/2008	10:35	NN 18038 62260	218038	762260	Figure 15	Other bank of main river; depth 36cm (1 m out) & 65cm (2m out); flow 0.967 m/s; water sample LLW17
54	13/11/2008	10:43	NN 17981 62287	217981	762287		Stream; not measured or sampled
55	13/11/2008	10:49	NN 17571 62259	217571	762259		Hotel off road from here
56	13/11/2008	10:51	NN 17453 62297	217453	762297		Stream; not measured or sampled
57	13/11/2008	11:02	NN 16611 62062	216611	762062		House called "Narrach Bridge"
58	13/11/2008	11:04	NN 16641 61991	216641	761991	Figure 16	River with septic tank outlet from house (outlet below water); width 7m 70cm; depth 75 cm (far) 30cm (near); flow (0.714 m/s (far) 0.425 m/s (near); water sample LLW18 above outlet; water sample LLW19 below outlet
59	13/11/2008	12:29	NN 13783 61221	213783	761221		Stream below caravan park and farm; width 3m 70cm; depth 35cm & 25cm; flow 0.429 m/s & 0.527 m/s; water sample LLW20; 19 static caravans; 18 touring caravans in storage; 2 small boats

60	13/11/2008	12:36	NN 13666 61149	213666	761149		Approximately 30 sheep in field 50m to west; confierous trees behind field; heather on hills
61	13/11/2008	12:45	NN 13927 61196	213927	761196		Buoy 10 m offshore - no obvious purpose
62	13/11/2008	12:48	NN 13876 61056	213876	761056	Figure 17	Septic tank in caravan park; Toilet block nearby with Elsan disposal point
63	13/11/2008	13:03	NN 14928 61260	214928	761260		Stream; width 5m 50cm; depth 30cm & 50cm; flow 0.685 m/s & 0.799 m/s; water sample LLW21
64	13/11/2008	13:16	NN 15232 61246	215232	761246		Small stream; width 75cm; depth 15cm; flow 0.197 m/s; water sample LLW22
65	13/11/2008	13:21	NN 15352 61219	215352	761219		Very small stream; not measured or sampled
66	13/11/2008	13:23	NN 15450 61260	215450	761260		Very small stream; not measured or sampled
67	13/11/2008	13:28	NN 15637 61293	215637	761293		Stream; width 80cm; depth 10cm; flow 1.309 m/s; water sample LLW23
68	13/11/2008	13:32	NN 15695 61285	215695	761285		Stream; two flows; width1 45cm; depth1 20cm; flow1 0.626 m/s; width2 15cm; depth2 20cm; flow2 0.584 m/s; water sample LLW24
69	13/11/2008	13:41	NN 16077 61343	216077	761343		Stream; width 95cm; depth 19cm; flow 0.273 m/s; water sample LLW25
70	13/11/2008	14:15	NN 17705 61830	217705	761830		Seawater sample LLW26 (salinity 1ppt)
71	14/11/2008	10:13	NN 18341 62107	218341	762107		Kinlochleven garden waste recycling point
72	14/11/2008	10:14	NN 18284 62102	218284	762102		Junction of two rivers
73	14/11/2008	10:19	NN 18461 61971	218461	761971	Figure 18	Photograph - view across to two large surface water outfalls
74	14/11/2008	10:22	NN 18354 62076	218354	762076	Figure 19	Kinlochleven Riverside Septic Tank
75	14/11/2008	10:25	NN 18314 62062	218314	762062	Figure 20	Septic tank discharge pipe - end under water in middle of river
76	14/11/2008	11:08	NN 15032 61790	215032	761790		Glencoe Shellfish slipway
77	14/11/2008	11:20	NN 16435 62020	216435	762020		On road - Caravan on shoreside approximately 150m south-east

Photographs referenced in Table 1 can be found attached as Figures 4-20.

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 loch.

Sampling

Water and shellfish samples were collected during the survey. Samples were transferred to cool boxes for transport to the laboratory. All samples were analysed for *E. coli*. Two sea water samples were tested on site for salinity using a hand held refractometer. These readings are shown in the "Description" column of the relevant observations in Table 1 as salinity in parts per thousand (ppt).

Sea water samples were also tested for total chloride in the laboratory and these values were converted to salinity expressed in grams per litre (g/l) (equivalent to parts per thousand). These salinity results are presented in Table 2.

The location of water sampling sites are shown in Figure 2 and the bacteriology results are presented in Table 2. The location of shellfish sampling sites are shown in Figure 3 and the bacteriology results are presented in Table 3.

Salinity profiles were determined on site using a meter and a probe on a 30 m cable. The results of salinity profiles recorded in the vicinity of the mussel lines are given in Table 4.

Table 2 Water Sample Results

No.	Sample	Sample Type	*E. coli* (cfu/100ml)	Salinity (g/L)
1	LLW1	Sea water	270	1.4
2	LLW2	Sea water	320	1.5
3	LLW3	Sea water	380	1.5
4	LLW4	Sea water	240	3.2
5	LLW5	Fresh water	<100	
6	LLW6	Fresh water	<100	
7	LLW7	Fresh water	<100	
8	LLW8	Fresh water	<100	
9	LLW9	Fresh water	<100	
10	LLW10	Fresh water	<100	
11	LLW11	Fresh water	<100	
12	LLW12	Fresh water	<100	
13	LLW13	Fresh water	<100	
14	LLW14	Sea water	520	1.3
15	LLW15	Fresh water	200	
16	LLW16	Fresh water	<100	
17	LLW17	Fresh water	1500	
18	LLW18	Fresh water	<100	
19	LLW19	Fresh water	<100	
20	LLW20	Fresh water	<100	
21	LLW21	Fresh water	<100	
22	LLW22	Fresh water	<100	
23	LLW23	Fresh water	<100	
24	LLW24	Fresh water	100	
25	LLW25	Fresh water	<100	
26	LLW26	Sea water	220	4.1

Table 3 Shellfish Sample Results

No.	Sample	Type	*E. coli* (MPN/100g)	Depth
1	LLS1	Mussel	110	3
2	LLS2	Mussel	1300	5
3	LLS3	Mussel	3500	7
4	LLS4	Mussel	160	3
5	LLS5	Mussel	500	5.5
6	LLS6	Mussel	500	8
7	LLS7	Mussel	500	3
8	LLS8	Mussel	500	6
9	LLS9	Mussel	20	9
10	LLS10	Wild mussel	160	From rocks
11	LLS11	Mussel	310	3

Table 4 Salinity Profiles

Profile	Date	Waypoint	Grid Ref	Easting	Northing	Depth (m)	Salinity (ppt)	Temp C
1	12/11/2008	2	NN 14799 61696	214799	761696	Surface	1.3	7.0
1	12/11/2008	2	NN 14799 61696	214799	761696	1	1.4	6.3
1	12/11/2008	2	NN 14799 61696	214799	761696	3	16.6	8.6
1	12/11/2008	2	NN 14799 61696	214799	761696	5	22.8	10.0
2	12/11/2008	4	NN 14796 61627	214796	761627	Surface	1.4	6.3
2	12/11/2008	4	NN 14796 61627	214796	761627	1	2.0	6.3
2	12/11/2008	4	NN 14796 61627	214796	761627	3	17.5	8.6
2	12/11/2008	4	NN 14796 61627	214796	761627	5	23.8	10.1
3	12/11/2008	5	NN 14668 61599	214668	761599	Surface	1.3	6.2
3	12/11/2008	5	NN 14668 61599	214668	761599	1	1.5	6.2
3	12/11/2008	5	NN 14668 61599	214668	761599	3	19.4	8.6
3	12/11/2008	5	NN 14668 61599	214668	761599	5	23.8	10.4

Figure 2 Water sample results map

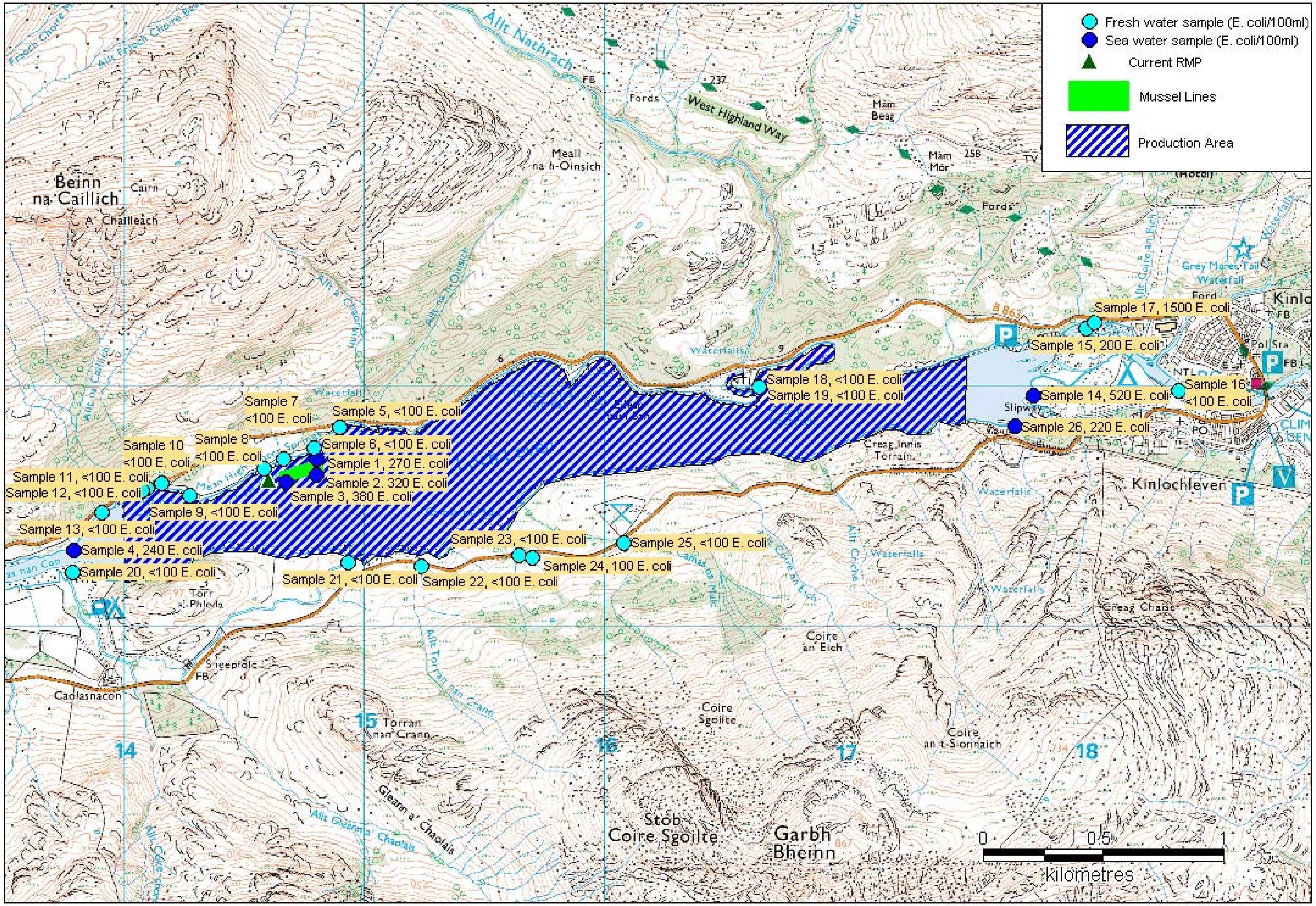
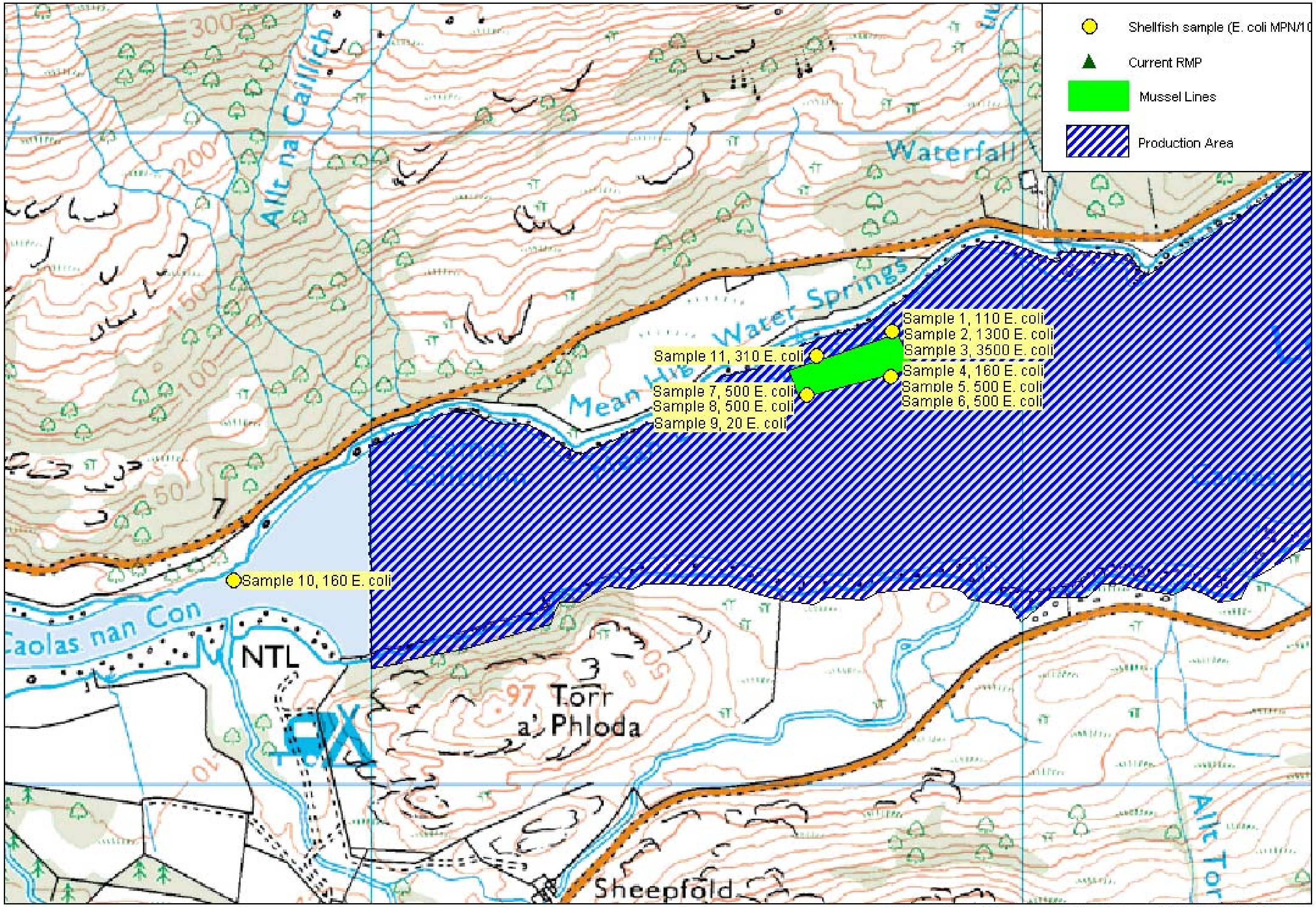


Figure 3 Shellfish sample results map


Shellfish sample (E. coli MPN/10
Current RMP
Mussel Lines
Production Area
Sample 1, 110 E. coli
Sample 2, 1300 E. coli
Sample 3, 3500 E. coli
Sample 4, 160 E. coli
Sample 5, 500 E. coli
Sample 6, 500 E. coli
Sample 11, 310 E. coli
Sample 7, 500 E. coli
Sample 8, 500 E. coli
Sample 9, 20 E. coli
Sample 10, 160 E. coli
Waterfall
Water Springs
Mean High Water
Allt na Cailleach
Caolas nan Con
NTL
Torr a' Phloda
Sheepfold
Allt Tor

Photographs

Figure 4 View of the mussel lines

Figure 5 Part of the mussel holding area

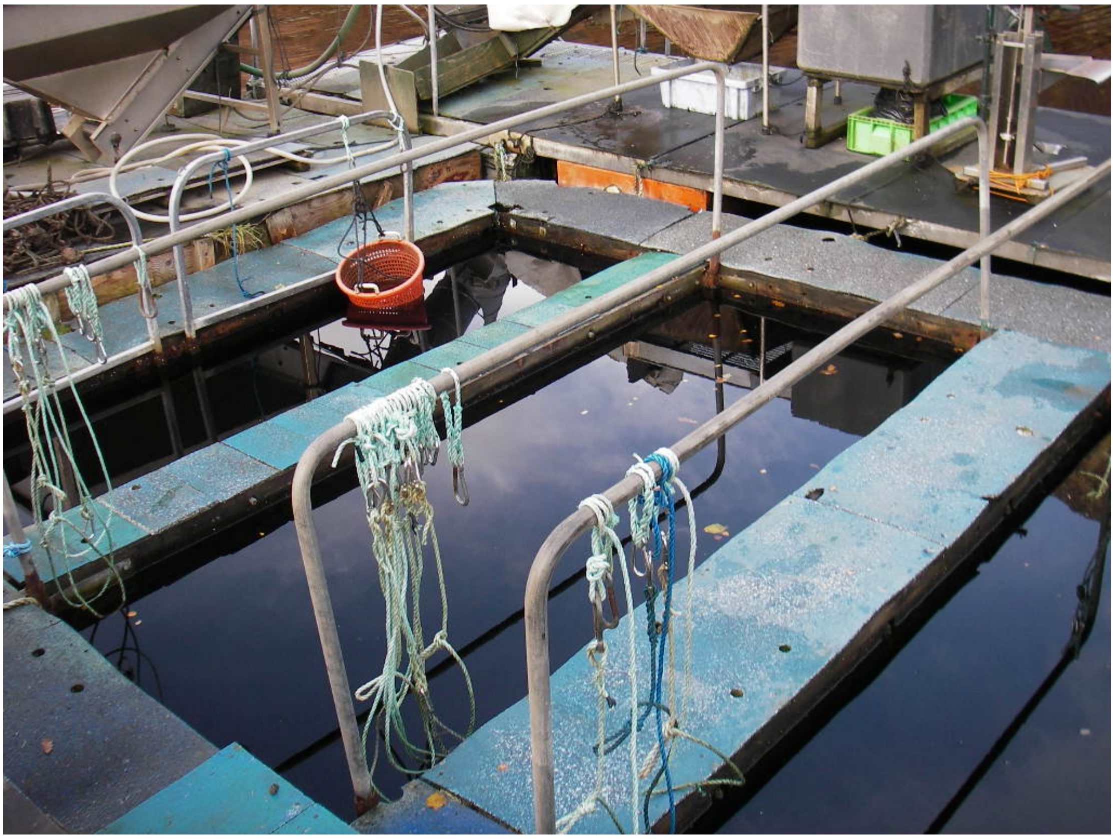


Figure 6 Wild mussels at the narrows

Figure 7 Purification system above the fishery

Figure 8 One of two small streams near mussel farm

Figure 9 Tide line near narrows

Figure 10 Kinlochleven Wastewater Treatment Plant

Figure 11 Dead stag on shoreline

Figure 12 Pumping station for Kinlochleven Wastewater Treatment Plant

Figure 13 New Combined Sewer Overflow for Kinlochleven WTP

Figure 14 Hydroelectric plant inflow to River Leven

Figure 15 River Leven at measuring/sampling point

Figure 16 Septic tank outlet

Figure 17 Septic tank in caravan park

Figure 18 Surface water outfall

Figure 19 Kinlochmore Riverside Septic Tank

Figure 20 Kinlochmore Riverside Septic Tank discharge pipe