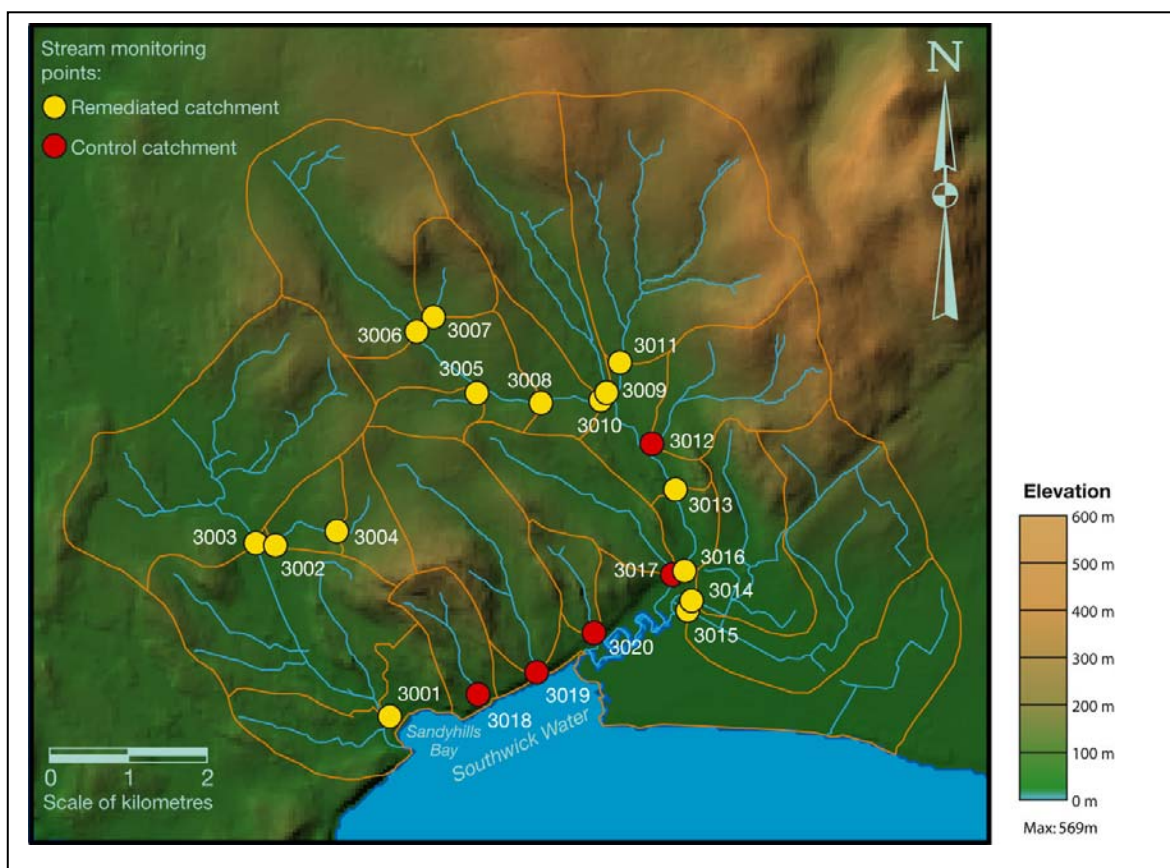


## 4 Results of the Sandyhills monitoring

Figure 4.1 Sandyhills monitoring sites



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### 4.1 Catchment characteristics

Catchment land use in the Sandyhills subcatchments is shown in Table 4.1 and the extent of remedial measures is presented in Table 4.2. The total study area of 5,969 ha contained thirty livestock enterprises dominated by beef and sheep units with some dairying. On ten of these, field-based remedial measures were implemented. The bathing water compliance point has never achieved the Directive 76/160/EEC *Guide* (recommended) level which is required to achieve a 'Blue Flag' seaside award and in six years, since sampling began in 1988, it has failed to achieve the mandatory standards specified in Directive 76/160/EEC.

#### 4.1.1 Monitoring sites

In the Sandyhills catchment, five sites offered potential as unmodified (or only slightly modified) controls, site 3012 and sites 3017 to 3020. Sites 3017 to 3020 were additional sites identified by the field team because they all discharged to the sea adjacent to the bathing zone. Site 3012 was a left bank tributary of Boreland Burn.

Hydrological instrumentation was concentrated on the inland sites which would be affected by remedial measures and adjacent control locations. For sites 3017 to 3020,

flow was modelled by scaling the flow of the nearest adjacent site by the relative catchment area of the two catchments taken from the GIS.

**Table 4.1 Area and percentage of different land use types (for selected sites) within the Sandyhills subcatchments studied**

Subcatchment	Area (ha)*	Percentage land use:				
		Improved Pasture	Rough grazing	Forest	Arable	Built-up
3001	1,587.25	No data				
3002	179.58	64.37	6.98	25.17	0.00	3.48
3003	761.19	25.09	24.42	49.77	0.00	0.72
3004	98.92	56.86	2.04	39.87	0.00	1.24
3005	74.22	76.40	0.00	18.87	0.00	4.74
3006	528.11	26.56	9.86	62.99	0.00	0.59
3007	105.01	9.85	61.78	27.51	0.00	0.86
3008	895.93	38.54	14.93	44.77	0.48	1.28
3009	438.09	No data				
3010	1,005.67	41.92	14.37	41.20	1.18	1.33
3011	774.94	12.48	9.14	78.10	0.00	0.28
3012**	308.78	12.06	27.85	59.36	0.39	0.35
3013	2,677.22	No data				
3014	256.42	No data				
3015	518.42	No data				
3016	2,745.66	No data				
3017**	242.48	57.05	10.81	27.25	3.56	1.33
3018**	134.12	10.80	17.75	70.57	0.00	0.88
3019**	385.65	52.22	12.55	33.35	0.00	1.88
3020**	75.70	15.96	39.42	44.41	0.00	0.21

\* As these catchments were nested, the area of all subcatchments summed together is greater than the total study area, this is true of each of 4 study sites.

\*\* Potential control sites

The pre-remediation period, during which flow was measured, spanned the 2002 Christmas break and covered a period of six weeks. In the post-remediation monitoring, the team commenced sample collection in early July but, because of the lack of rainfall in the Sandyhills area, the Project Steering Group requested that the team be deployed in Ettrick Bay and Killoch Burn in late July. Here, high flows were experienced in mid-August and, following this period, the team were once again deployed in the Sandyhills catchment until 25<sup>th</sup> August, when it was necessary to move the field team to the Nairn catchment. However, there had been insufficient high flow events in the Sandyhills catchment and further opportunistic sampling was continued until 30<sup>th</sup> September, facilitated by the deployment of additional staff to acquire samples during ‘event’ conditions. The stream level recorders and rainfall collectors operated over this period.

**Table 4.2 Fencing measures within selected Sandyhills subcatchments**

Sub*** Catchment	Stream length (m)	New fencing (m)**	New fencing/ stream length (%)	New fencing/ area (m/ha)	Improved pasture fencing (m)	Imp past fencing/imp past area (m/ha)	Rough grazing fencing (m)
3002	1,553	539	17.35	3.00	362	3.12	177
3003	10,044	2,512	12.50	3.30	2,225	11.89	287
3004	650	454	34.92	4.59	233	4.08	221
3005	690	1000	72.46	13.47	1000	17.66	0
3006	4,150	980	11.81	1.86	980	6.91	0
3007	650	120	9.23	1.14	120	11.11	0
3008	7,790	3,990	25.61	4.45	3,990	11.44	0
3010	8,670	4,250	24.51	4.23	4,250	10.13	0
3011	11,106	1,450	6.53	1.87	1,450	14.29	0
3012*	5,218	0	0	0	0	0	0
3017*	3,103	150	2.42	0.62	150	1.09	0
3018*	4,045	0	0	0	0	0	0
3019*	4,027	0	0	0	0	0	0
3020*	1,482	0	0	0	0	0	0

\* *potential control sites*

\*\* *Please note for the new fencing length is the summation of new fencing in areas of improved pasture and rough grazing i.e. for site 3002 362 + 177 = 539*

\*\*\* *There was no arable land use in the subcatchments*

The Sandyhills sampling sites ranged from very small flows draining farm yards (site 3007) through to large riverine flows (site 3016). Site 3001 discharged closest to the compliance location and sites 3014 and 3015 drained a flat tidal marshy area and were also affected by tidal ‘locking’ on each tidal cycle. These two catchments (i.e. 3014 and 3015) differed, in terms of, hydrology, relief and morphometry, when compared with all other Sandyhills subcatchments.

#### **4.1.2 Remediation measures**

All remediation ‘measures’ in the Sandyhills and Nairn subcatchments were ‘field-based’ (mostly fencing) as opposed to the steading-based measures undertaken in the Ettrick and Killoch investigations. Table 4.2 contains data on the extent of stream bank fencing and the fenced length by land use in the Sandyhills catchment. The fencing and land use data were provided by staff of the Scottish Executive who took this information from GIS, OS and other sources including the records of work undertaken by their contractors. The subcatchments for which these data were acquired were decided by the Steering Group in September 2004.

## 4.2 Data analysis

The Sandyhills investigation produced relatively low faecal indicator concentrations under summer high flow conditions, with only 6 of the 20 sites monitored having summer geometric mean presumptive *E. coli* concentrations exceeding  $10^4$  cfu 100 ml<sup>-1</sup>. This was exceeded by all Etrick and Killoch sites (see Tables 2.2 and 3.2).

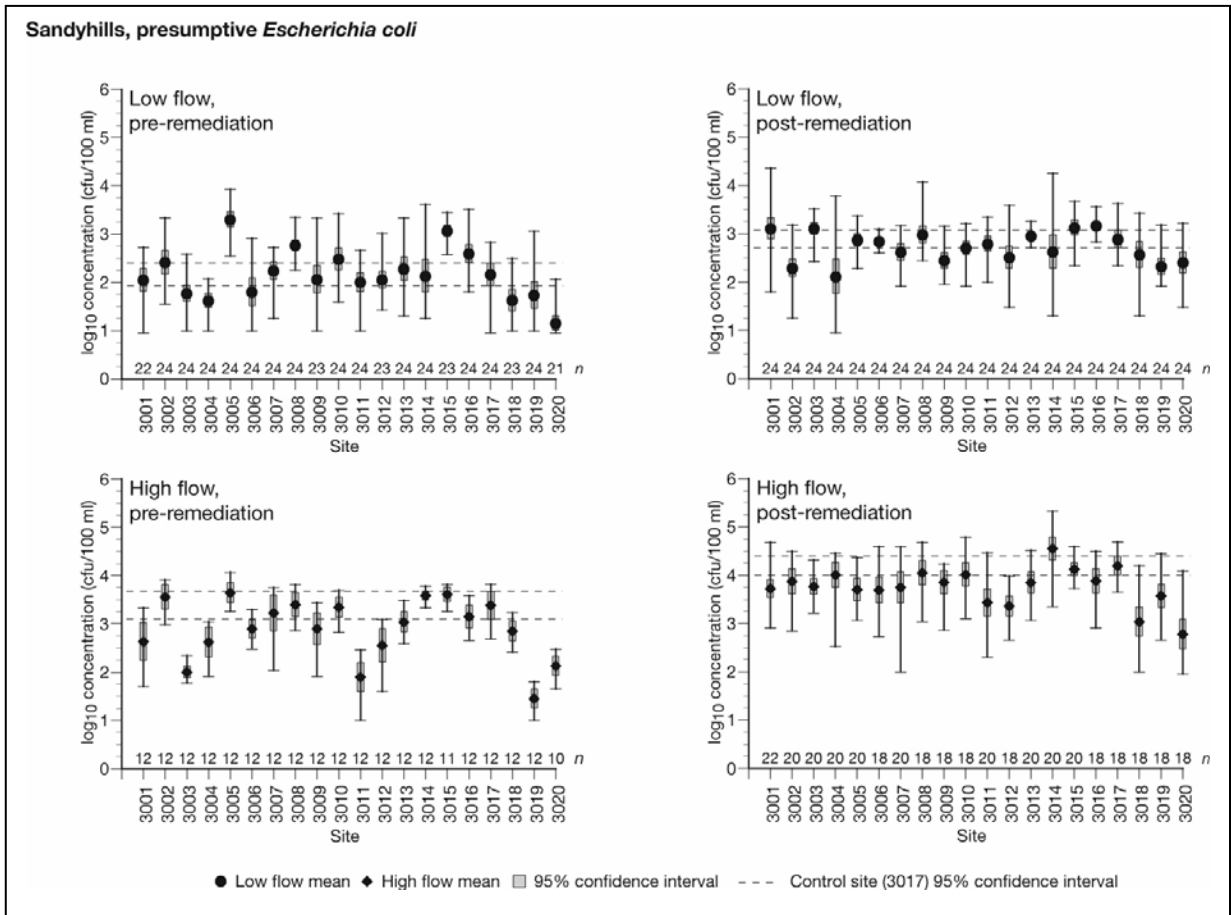
### 4.2.1 Selection of the most appropriate ‘control’ catchment

The five potential control sites had a range of land uses and many were characterised by a high percentage of afforestation. This land use is known to produce very low concentrations of faecal indicators in catchment streams. Further to examine which of the potential controls offered the most appropriate comparator for the other Sandyhills subcatchments, an analysis of variance (ANOVA) was conducted to investigate which of the controls best typified the other subcatchments in the pre-remediation monitoring period (see Appendix III). This suggested that site 3017 was the most similar to the other Sandyhills subcatchments having no significant difference between its pre-remediation geometric mean *E. coli* concentration and 13/15 of the subsequently remediated catchments. For the other potential controls, the same analysis suggested that site 3012 was not significantly different to 11/15 modified sites (i.e. four sites had significantly higher EC concentrations than site 12), site 3018 9/15 (i.e. four sites cleaner than site 3018 and two sites with higher FIO concentrations), site 3019 1/15 (i.e. fourteen sites were all significantly cleaner than site 19) and site 3020 5/15 (i.e. ten sites significantly cleaner than site 20).

### 4.2.2 Results

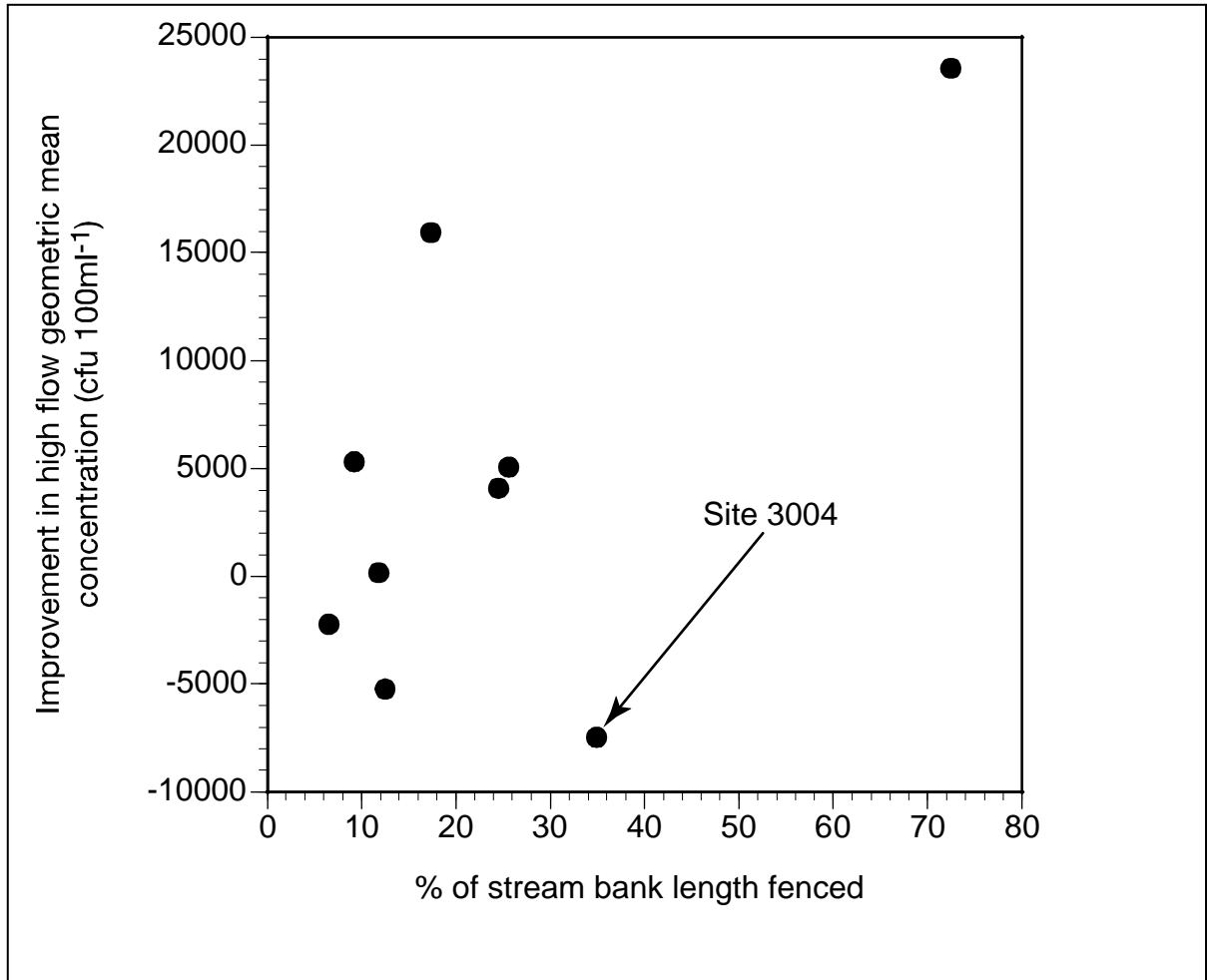
Figure 4.2 illustrates the shift analysis for *E. coli*. The shift analysis for the other FIOs are presented in Appendix II. Using site 3017 as the control catchment in the log<sub>10</sub> shift analysis, produced the predicted geometric mean FIO concentrations in Table 4.3 below. Figure 4.3 plots the intensity of stream bank fencing (in terms of the percentage of the existing stream bank length along which new fencing was constructed) against the observed ‘improvement’ in *E. coli* concentration. There is the suggestion of a trend in these data except for site 3004 which has 34.9% of its stream bank length fenced. However, this site is anomalous with a wetland area immediately upstream of the sampling point which can attenuate FIO flux and, thus, confound direct comparisons of land use effects with other ‘more normal’ subcatchments (Kay *et al.*, 2005b, Edwards *et al.*, 2004, Crowther *et al.*, 2003). The Sandyhills ‘fencing’ results are comparable to the Brighthouse Bay study and provide a further data resource supporting the efficacy of this intervention although it is important to note: (i) the limited number of sites examined in both studies; and (ii) the even more limited number of subcatchments where a significant proportion of the stream bank length has been fenced to date.

**Figure 4.2 Seasonal shift analysis plots for Sandyhills subcatchments, presumptive *E. coli*, using control site 3017<sup>1</sup>**



<sup>1</sup> *E. coli* data are presented in this Figure and throughout the main body of this report. Similar plots for total coliform organisms and intestinal enterococci are located in Appendix II which commences on Page 67 of this report.

**Fig. 4.3** Plot of inferred improvement in high-flow GM *E. coli* concentrations (-ve values indicate a deterioration in water quality) based on log<sub>10</sub> shift analysis against percentage of stream bank length fenced in the Sandyhills region



**Table 4.3 Log<sub>10</sub> seasonal shift analysis for high flow data from Sandyhills subcatchments using site 3017 as the control**

SITE	PARAMETER	PRE		n	POST		Improvement cfu 100ml <sup>-1</sup>
		n	GM cfu 100ml <sup>-1</sup>		GM cfu 100ml <sup>-1</sup>	Predicted cfu 100ml <sup>-1</sup>	
3001	total coliform	12	1,406	22	7,472	5,114	-2,358
	<i>E. coli</i>	12	431	22	5,300	2,796	-2,503
	enterococci	12	183	22	1,933	591	-1,342
3002	total coliform	12	7,082	20	11,404	25,758	14,354
	<i>E. coli</i>	12	3,607	20	7,476	23,430	15,954
	enterococci	12	1,507	20	2,754	4,864	2,110
3003	total coliform	12	473	20	6,053	1,719	-4,334
	<i>E. coli</i>	12	101	20	5,872	654	-5,218
	enterococci	12	36	20	1,801	115	-1,686
3004	total coliform	12	1,222	20	12,355	4,445	-7,910
	<i>E. coli</i>	12	422	20	10,192	2,738	-7,454
	enterococci	12	87	20	477	280	-197
3005	total coliform	12	22,631	20	9,324	82,317	72,994
	<i>E. coli</i>	12	4,408	20	5,054	28,627	23,574
	enterococci	12	1,499	20	701	4,839	4,138
3006	total coliform	12	2,417	18	7,445	8,791	1,346
	<i>E. coli</i>	12	789	18	4,948	5,127	178
	enterococci	12	666	18	504	2,151	1,647
3007	total coliform	12	3,436	20	8,508	12,499	3,990
	<i>E. coli</i>	12	1,683	20	5,608	10,931	5,323
	enterococci	12	154	20	1,231	497	-733
3008	total coliform	12	7,775	18	15,949	28,282	12,333
	<i>E. coli</i>	12	2,508	18	11,212	16,291	5,078
	enterococci	12	1,670	18	1,073	5,391	4,319
3009	total coliform	12	3,868	18	13,379	14,070	692
	<i>E. coli</i>	12	794	18	7,184	5,154	-2,030
	enterococci	12	1,083	18	936	3,497	2,561
3010	total coliform	12	5,788	18	15,229	21,052	5,824
	<i>E. coli</i>	12	2,221	18	10,330	14,424	4,094
	enterococci	12	2,010	18	1,267	6,490	5,223
3011	total coliform	12	1,656	20	4,664	6,023	1,360
	<i>E. coli</i>	12	79	20	2,722	513	-2,209
	enterococci	12	297	20	358	960	603
3013	total coliform	12	4,832	20	10,139	17,577	7,438
	<i>E. coli</i>	12	1,095	20	7,088	7,111	24
	enterococci	12	1,238	20	977	3,996	3,019
3014	total coliform	12	6,039	20	60,764	21,965	-38,799
	<i>E. coli</i>	12	3,881	20	35,931	25,207	-10,724
	enterococci	12	4,386	20	6,448	14,159	7,711
3015	total coliform	11	22,395	20	28,612	81,458	52,846
	<i>E. coli</i>	11	4,068	20	13,325	26,419	13,095
	enterococci	11	5,955	20	2,934	19,225	16,291
3016	total coliform	12	7,073	18	11,741	25,726	13,985
	<i>E. coli</i>	12	1,422	18	7,620	9,236	1,616
	enterococci	12	1,159	18	1,077	3,741	2,664