Easdale
Dispersion studies – June 2017 addendum

1. Scottish Water (SW) currently operates an outfall discharging treated sewage effluent to Balvicar Bay, Sound of Seil, which is within a designated Shellfish Water Protected Area. Serving customers predominantly along the eastern coast of Seil Island, this was installed in 2008-9 to replace a number of raw private discharges, but has struggled to deliver the expected performance. As a consequence of a significant risk of spills from the network it must be changed or modified to consistently capture and treat sufficient flows within the network to protect the quality of the shellfish water and the environment. Currently, raw sewage from Seaview Cottages is collected and discharged untreated via a short sea outfall directly into Easdale Bay. This has been the case for many years and, hence requires first time treatment provision. The project is included within Scottish Water's 2015-21 Regulatory Business Plan.

2. Scottish Water's appraisal of the options available to deliver sustainable wastewater treatment solutions on the Isle of Seil has considered a total of 12 options overall, spread across six principal types of option, with sub-options through some of them. These start with a 'zero' option based on retaining the existing works, of which there are 3 variants (A, B and C). This addendum to a previous dispersion study October 2016) considers dispersion and water quality implications of Option 3, which is characterised as follows:

Option	Existing Clachan Balvicar STW	Seaview Terrace
3	Transfer Option. Replace existing WwTW with modified pumping station, storage and rising main. Transfer flows to new septic tank (240m3) located at Seaview site. New outfall to meet environmental standards	Existing outfall removed and Seaview network connected to new septic tank capable of serving the island
3A	As Option 3	Variant on Option 3 with provision of additional UV disinfection
3B	As Option 3	Variant on Option 3 with relocation of outfall to a location to the south of the reef features

3. A dispersion study was carried out in 2016, including acquisition of hydrographic and bathymetric data, which assessed dispersion characteristics at two outfall locations (corresponding to Options 3/3A and 3B) in relation to:

- Appropriate length, and associated water depth, of an outfall to achieve regulatory compliance within the mixing zone

- Wider dispersion of the effluent plume, in particular the potential for entrainment within rapid tidal flows through Easdale Sound and Cuan Sound

- Potential for trapping of effluent within Easdale Bay under adverse weather conditions; and likely microbiological concentration impact at the current raw outfall location.

4. No microbiological environmental quality standards are applicable at the proposed Option 3 discharge locations. However, following stakeholder consultation and review of the dispersion study, further modelling has been carried out to show where bathing and shellfish standards would be met, for a septic tank discharge (Options 3, 3B) which meets other regulatory compliance requirements; and following UV disinfection (Option 3A).

5. As previously, the EPA model Visual Plumes, module UM3 with Brooks far-field solution has been used to run integrated initial and secondary dilution analyses, based on hydrographic survey results. The effluent flow, 6 l/s, was based on network modelling which shows a revised Flow to Full Treatment (FFT) requirement of 5.8 l/s. As noted below, a relatively small proportion of FFT comprises domestic foul flow.

6. Recent revisions to microbiological standards[1] reflecting changes to the European Bathing Water Directive, have included changes in terminology for faecal indicator coliform bacteria (previously Faecal Coliforms, FC; now *Escherichia coli*, EC) and enterococci (previously Faecal Streptococci, FS; now Intestinal Enterococci, IE). In practice, the terms FC/EC and FS/IE are effectively synonymous.

7. Previously, SEPA have recommended that, as a minimum, modelling of bacterial dispersion from septic tank discharges be carried out using a loading of 1 x 10^6 faecal coliforms (FC)/100ml, unless evidence can be presented that bacterial loading will be lower. No recommendations are available for loadings for EC or enterococci (FS or IE). This assessment therefore uses an EC load for the domestic component of effluent flow equivalent to the previous FC loading; and an IE load for secondary or septic tank effluent of 1E+04 cfu/100ml (based on a value of 1E+05 in untreated sewage, from Boehm & Sassoubre (2014)[2] and assuming that treatment mortality is similar for all faecal indicator bacteria). This is consistent with World Health Organisation (2003) guidelines[3] for safe recreational water environments, faecal pollution and water quality (Table 4.1), which give faecal streptococci/intestinal enterococci concentrations in raw sewage as 4.7E+03 – 4.0E+05 /100ml. These loading values have been agreed with SEPA (Ted Schlicke and Brian O'Keefe email correspondence 08/03/2017).

8. Proposed septic tank provision is sized to ensure that it will not wash out or compromise settlement when the 6l/s storm flows are being passed to the tank. The system cannot therefore generate significantly more bacteriological load output than the input from the catchment (350pe) foul flow input element. Final effluent loads have accordingly been factored to account for the relatively small domestic component of total flow (0.61 l/s based on 350pe) and high surface drainage component (5.39 l/s), which is assumed to have negligible bacterial load. Resultant EC loading in final septic tank effluent is 1.13E+05 cfu/100ml, and IE loading 1.13E+03 cfu/100ml.

9. Bacteriological loads for effluent following UV disinfection (Option 3A) are calculated assuming a 2 log reduction, i.e. septic tank effluent EC loading 1E+04 cfu/100ml and IE

[1] SEPA guidance on requirements for discharges to waters identified as required to meet microbiological environmental quality standards (i.e. shellfish and bathing waters) is set out in Regulatory Method (WAT-RM-13) Microbiological Discharges (v4.2 Apr 2015). Standards for *Escherichia coli* (EC) in Coastal and Transitional Waters are: excellent 250/100ml as a 95%ile; good 500/100ml as a 95%ile; sufficient 500/100ml as a 90%ile. Standards for Intestinal enterococci (IE) in Coastal and Transitional Waters are: excellent 100/100ml as a 95%ile; good 200/100ml as a 95%ile; sufficient 185/100ml as a 90%ile. For those standards assessed for classification at a 90%ile they should be modelled for achievement at the 94%ile and likewise for those standards requiring 95%ile compliance these should be modelled to achieve the standard at a 97.5%ile to ensure the required level of confidence.

[2] Boehm AB and Sassoubre LM (2014). Enterococci as Indicators of Environmental Fecal Contamination. In: Gilmore MS, Clewell DB, Ike Y, et al., editors. Enterococci: From Commensals to Leading Causes of Drug Resistant Infection [Internet]. Boston: Massachusetts Eye and Ear Infirmary; 2014-
.https://www.ncbi.nlm.nih.gov/books/NBK190421/#_ncbi_dlg_citbx_NBK190421

[3] http://www.who.int/water_sanitation_health/bathing/srwg1.pdf

loading 1E+02 cfu/100ml.

10. Bacterial concentration is also influenced by mortality (i.e. concentration is non-conservative). The major influences on decay rate are solar irradiance (highly seasonal and depth-dependant) and salinity. The effect of current velocity on bacterial transport is therefore a product of the interaction between secondary plume mixing and bacterial mortality (a function of elapsed time, which decreases with current velocity). The SEPA recommendation for FC mortality is a 15h T90.

11. IE are generally considered to be more persistent than coliforms in seawater. A T90 of 22.9h is used in this assessment, based on a published decay rate for *Enterococcus* spp. from wastewater inoculum of -1.05 $\log_{10}$(cfu/100ml)/day.

12. Calculated EC and IE concentrations at various distances downstream of the discharge, estimated from overall dilutions, specified loadings for septic tank effluent and mortality as discussed above, are graphed and tabulated below, together with an indication of compliance / failure of regulatory standards.

13. For Option 3, interpolation of these results indicate that the sufficient and good EC standards will be achieved 109m and 133m downstream of the discharge; and that the excellent EC standard will be achieved within a modelled range of 410m. Excellent IE standard will be achieved within 50m of the outfall (i.e. within the 100m mixing zone).

14. For Option 3A, these results indicate that the excellent EC and IE standards will both be achieved within 50m of the outfall (i.e. within the 100m mixing zone).

15. For Option 3B, interpolation of these results indicate that the sufficient EC standard will be achieved 92m downstream of the discharge (i.e. within the 100m mixing zone); good EC standard will be achieved 114m downstream of the discharge; and that the excellent EC standard will be achieved within a modelled range of 353m. Excellent IE standard will be achieved within 50m of the outfall (i.e. within the 100m mixing zone).

16. As noted in the main text of the dispersion assessment, the Seaview locality can be characterised as unusual in terms of representing a small area of low TIDAL energy within a wider context (i.e. Cuan and Easdale Sounds, and the Firth of Lorn generally) of high tidal energy. Furthermore, it is recognised that the area has topographic features which may result in localised tidal eddy and gyre formation nearshore; and that there are likely to be significant dispersion and transport mechanisms associated with breaking waves and wind-driven flows during periods of strong southwest winds. For these reasons, direct tracer study, over a range of spatial and temporal scales, is the preferred approach to assessing both widescale transport and localised accumulation of Faecal Indicator Bacteria (FIB) in this location. As stated in the assessment report, under the influence of onshore wind and waves, tracer released from the Option 3 outfall location persisted along the shoreline of Easdale Bay over relatively long periods. Dye and drogue advection also indicated shoreward transport in the majority of cases. However, observed tracer dilutions in relation to shoreline accumulation increased from approximately 4,800,000 (2 days after release) to 187,000,000 (15 days); 1000 to 46,000 times greater than required to achieve microbiological quality standards. Concern that dispersion observations made from a single release are difficult to relate to the effects of a continuous release (such as a sewage discharge), are mitigated by consideration of bacterial mortality which exceeds 99.9% after 2 days. It was therefore concluded that microbiological risks associated with long-term accumulation from continuous discharge are insignificant, and that there is high confidence in assessment of risk based on single-release dispersion studies.

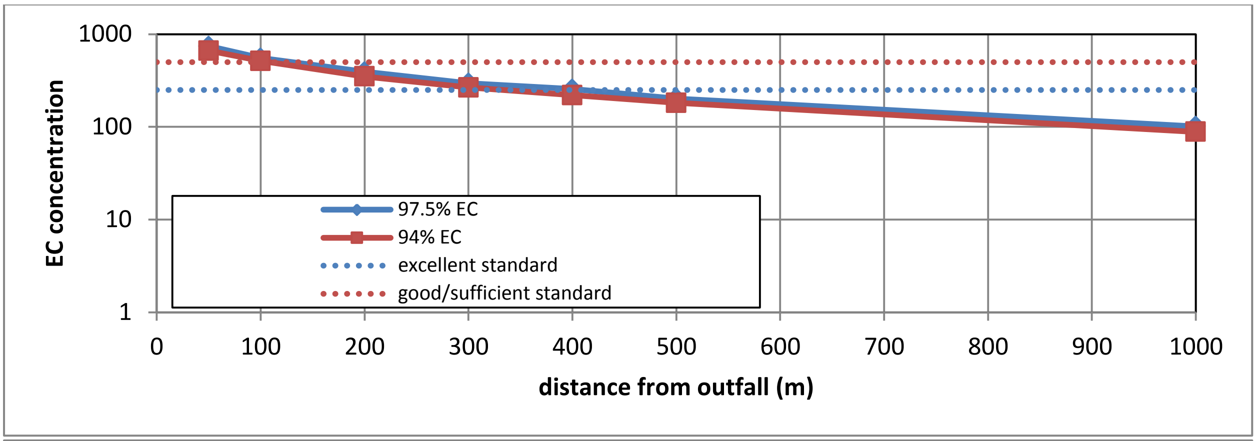
17. Various concerns in relation to specific dispersal and mortality processes influencing FIB have been raised by the stakeholder consultation process. These include a selective

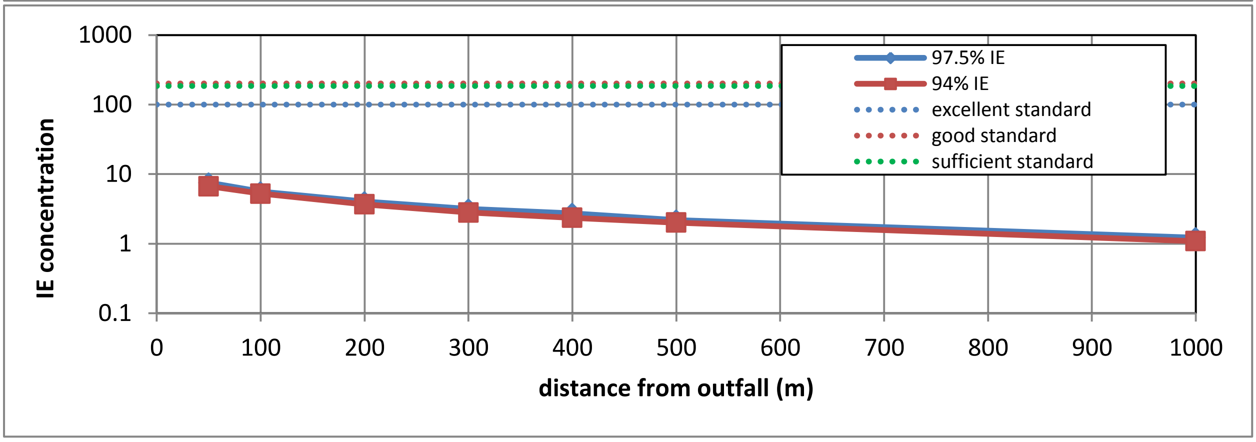
review of literature sources describing FIB dynamics under physical conditions which are not comparable with Easdale Bay, and which therefore do not result in comparable hydrographic processes (for example, rip cell development on extensive Pacific surf beaches is not analogous to topographically-induced eddy formation in along-shore tidal flow). There is also an apparent confusion between variability in advection and diffusion-driven decay (*sensu* Rippy et al. 2013,a,[4]b[5]) in FIB numbers in receiving water, and "concentration" of pathogens due to various speculative hydrodynamic processes (e.g. "funnelling effects" and "recirculating doughnuts of contaminated water"). While this assessment explicitly recognises the probability of local advection and wind/wave-driven effects on plume dispersion inshore of the proposed outfall locations, it is considered, from risk management and regulatory compliance perspectives, that the modelled initial dilution and secondary plume advection/diffusion from proposed outfalls in 4-5mCD depth (Options 3 and 3B) will reasonably predict the spatial extent of compliance with microbiological water quality standards. Under conditions of dominant shoreward surface transport (i.e. strong SW winds), turbulent diffusion, vertical and horizontal current shear and cross-slope bedflows associated with breaking waves will all result in higher than modelled rates of FIB decay. It is also noted that under these conditions, shear will also increase entrainment into the wider-scale tidal flows via Cuan and Easdale Sounds.

[4] Rippy MA, Franks PJS, Feddersen F, Guza RT and Moore DF (2013a). Physical dynamics controlling variability in nearshore fecal pollution: Fecal indicator bacteria as passive particles. Marine Pollution Bulletin 66 (2013) 151–157

[5] Rippy MA, Franks PJS, Feddersen F, Guza RT and Moore DF (2013b). Factors controlling variability in nearshore fecal pollution: The effects of mortality. Marine Pollution Bulletin 66 (2013) 191–198

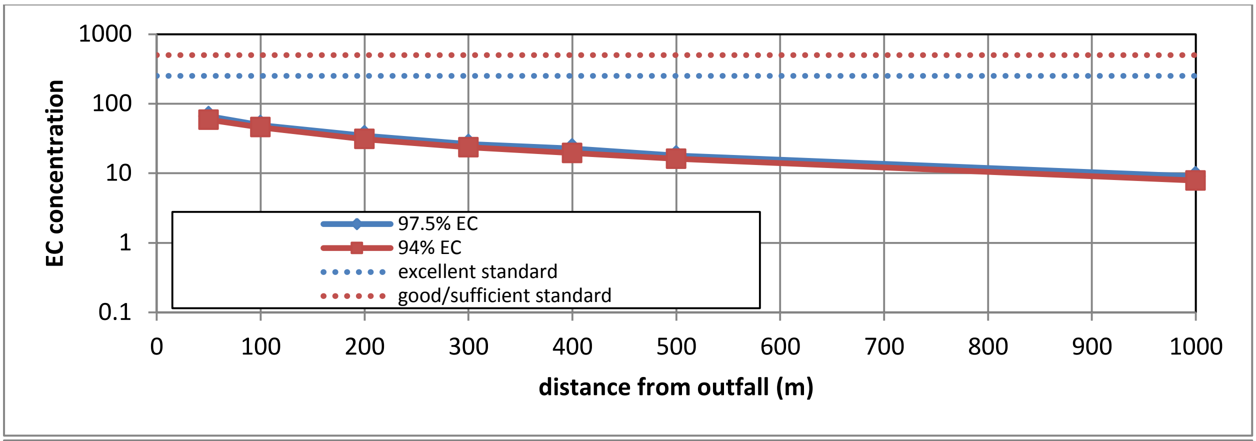
OPTION 3. Outfall depth 4mCD, septic tank discharge

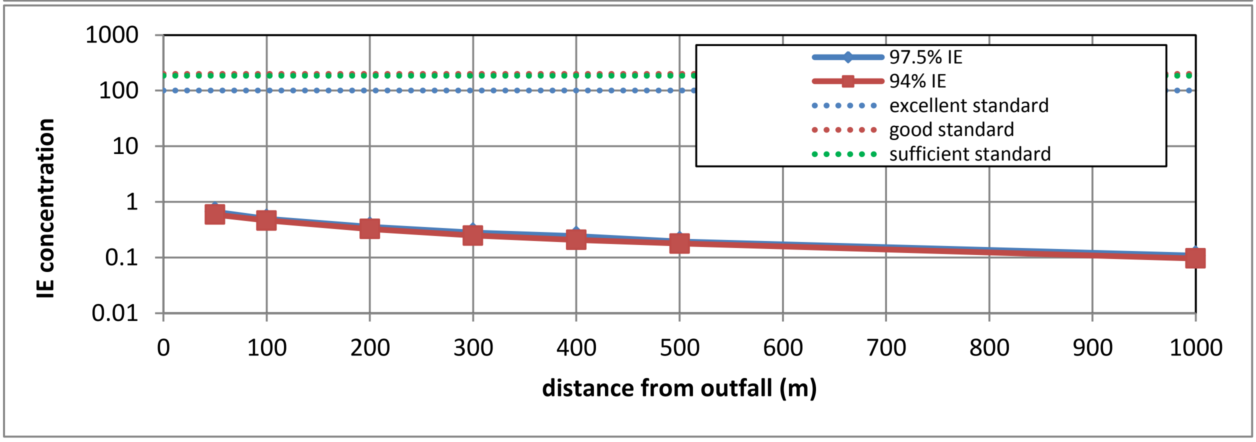




	50m	100m	200m	300m	400m	500m	1000m
median dilution	264	352	467	590	668	743	1048
median time (h)	0.24	0.48	1.0	1.4	1.9	2.4	4.8
98.2% EC	742	552	392	296	255	202	101
89.6% EC	662	515	349	266	220	182	88
EC excellent standard	FAIL	FAIL	FAIL	FAIL	FAIL	PASS	PASS
EC good standard	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS
EC sufficient standard	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS
98.2% IE	8	6	4	3	3	2	1
89.6% IE	7	5	4	3	2	2	1
IE excellent standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IE good standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IE sufficient standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS

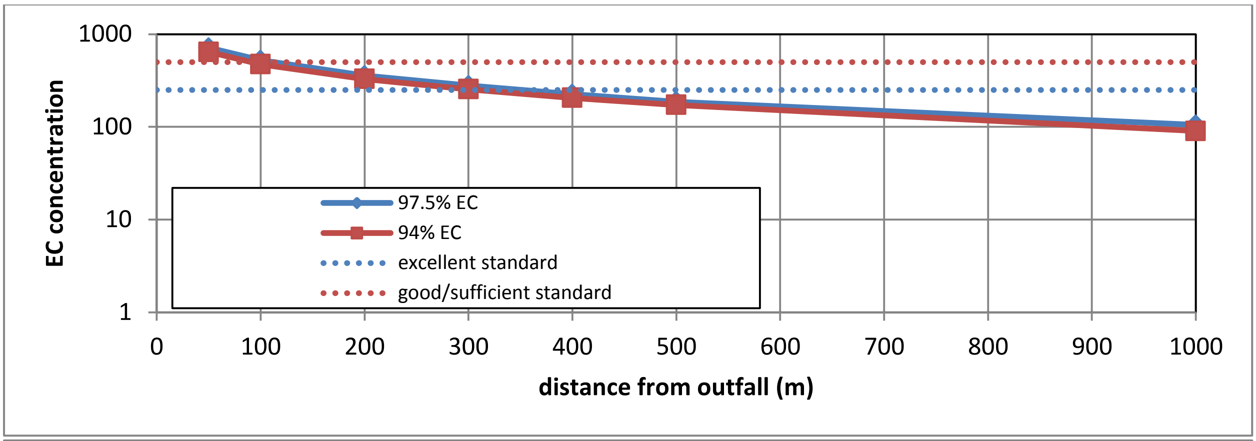
OPTION 3A. Outfall depth 4mCD, UV disinfection

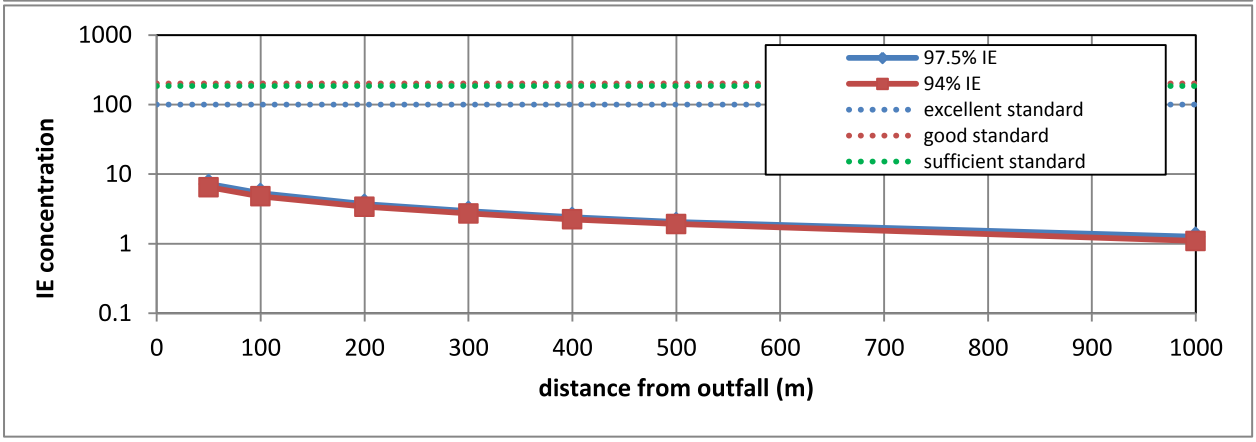




	50m	100m	200m	300m	400m	500m	1000m
median dilution	264	352	467	590	668	743	1048
median time (h)	0.24	0.48	1.0	1.4	1.9	2.4	4.8
98.2% EC	66	49	35	26	23	18	9
89.6% EC	59	46	31	24	20	16	8
EC excellent standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
EC good standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
EC sufficient standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
98.2% IE	1	0	0	0	0	0	0
89.6% IE	1	0	0	0	0	0	0
IE excellent standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IE good standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IE sufficient standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS

OPTION 3B. Outfall depth 5mCD, south location, septic tank discharge





	50m	100m	200m	300m	400m	500m	1000m
median dilution	333	442	603	728	823	934	1309
median time (h)	0.18	0.39	0.8	1.2	1.6	2.0	4.2
98.2% EC	712	523	357	278	225	187	105
89.6% EC	641	472	328	255	205	173	90
EC excellent standard	FAIL	FAIL	FAIL	FAIL	PASS	PASS	PASS
EC good standard	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS
EC sufficient standard	FAIL	PASS	PASS	PASS	PASS	PASS	PASS
98.2% IE	7	5	4	3	2	2	1
89.6% IE	6	5	3	3	2	2	1
IE excellent standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IE good standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS
IE sufficient standard	PASS	PASS	PASS	PASS	PASS	PASS	PASS