Environmental water quality: Linkages of a whole system in a catchment:
or
What are we trying to manage?

John Crowther, Cheryl Davies, Lorna Fewtrell, Carol Francis, Carl Stapleton, John Watkins, Mark Wyer Chris Kay and David Kay

Centre for Research into Environment and Health, University of Wales, UK

dave@crehkay.demon.co.uk

CREH

Haveloch North

- Epidemiological evidence of disease transmission 2016
- *E.coli* transgressions 2008/12/15/16
- Losing pond observed on drawdown
- Aquifer integrity questioned
- Headworks and bore lining questioned
- Intensive livestock rearing in the general catchment with access to the headworks
- Sanitary survey ‘score’ assumed poor

USA

- ***Federal Water Pollution Control Act***
  - *as amended in 2002*
  - Section 303(d) requires States to identify water bodies that do not meet standards due to '**impairments**'
- A **TMDL** study is then required to investigate the problem and set out a strategy for improvement

US Clean Water Act ‘Impaired Waters’

National Summary
Causes of Impairment in Assessed Rivers and Streams

Description of this table

Cause of Impairment Group	Miles Threatened or Impaired
Pathogens	176,313
Sediment	138,858
Nutrients	117,708
Organic Enrichment/Oxygen Depletion	96,363
Temperature	93,266
Metals (other than Mercury)	93,256
Polychlorinated Biphenyls (PCBs)	81,741
Mercury	68,718

https://ofmpub.epa.gov/waters10/attains_nation_cy.control#total_assessed_waters Accessed 10_09_17 USEPA

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National Summary
Probable Sources of Impairments in Assessed Rivers and Streams

Description of this table

Probable Source Group	Miles Threatened or Impaired
Agriculture	142,776
Unknown	138,626
Atmospheric Deposition	91,660
Hydromodification	88,565
Habitat Alterations (Not Directly Related To Hydromodification)	64,772
Urban-Related Runoff/Stormwater	60,230
Municipal Discharges/Sewage	58,821
Unspecified Nonpoint Source	57,640
Natural/Wildlife	49,760

https://ofmpub.epa.gov/waters10/attains_nation_cy.control#total_assessed_waters Accessed 10_09_17 USEPA

Europe

Water Framework Directive 2000

- **Defines protected areas in Annex 4**

(i) areas designated for the abstraction of water intended for human consumption;
(ii) areas designated for the protection of economically significant aquatic species;
(iii) bodies of water designated as recreational waters, including areas designated as bathing waters;
(iv) nutrient-sensitive areas; and
(v) areas designated for the protection of habitats or species.

MS are required to design a 'Programme of Measures' under Article 11 to achieve compliance with standards defined in daughter Directives (i.e. BWD, SHD, DWD)

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The questions

- What can we do to improve the existing catchment microbial dynamics?

Best UK Comparator
'Small Supplies'

- Oversight by Drinking Water Inspectorate
- Monitoring requirements based on DWD
  - Zero FIOs (*Escherichia coli*) in 100ml
  - Implemented by District Council EHOs
- Generally
  - Disproportionate health impact and non-compliance in the UK

Some UK examples of small supplies quality (2009)

- 34,904 samples from 11,233 small UK supplies
- *E.coli* detected in 32%
- Jan-May low
- June-Dec high
- Springs Surface high
- Groundwaterlow

Predictors:

- Sheep density
- Rainfall previous day
- **Correction for low sample number suggested 54% of UK small supplies would be unsatisfactory**.

Other literature Reports

Fewtrell and Kay (1996)

- 18 PWS outbreaks 1970-87
- 1,388 persons affected

Craun *et al*. (1997)

- 58% US outbreaks ‘Groundwater’ source small community supplies

Fewtrell *et al*. (1998) DWI Project

- 91 UK supplies tested for FIO compliance parameters
- 47% failed for *TC/EC or IE* on at least 1 occasion
- 70% of category 1 supplies failed and 40% of the category 2 supplies the larger were best

Furtado *et al*. (1998)

- UK outbreaks reviewed 1992-5
  - 10 public supplies *Cryptosporidium* spp.
  - 9 private supplies mostly *Campylobacter* spp. (with some Crypto and Giardia)

Lamb *et al*. (1998) and Benton *et al*. (1989)

- PWS caused 21 of 57 outbreaks in Scotland (1945-87)
- 9,362 persons affected in the 21 outbreaks
- Developed source protection through MRA

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Causes of UK PWS Outbreaks 1970-95

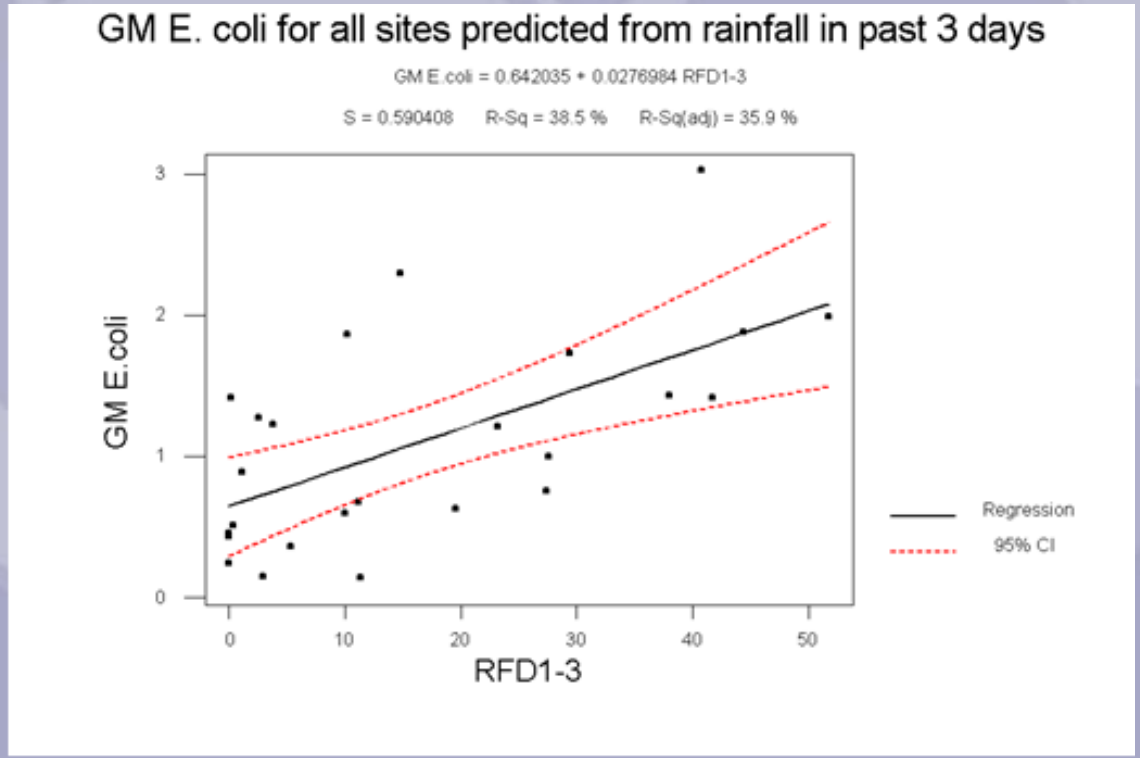
Pathogen	Number of outbreaks	Total cases
Campylobacter species	8	>647
Cryptosporidium	2	15
Cryptosporidium and *Campylobacter*	1	43
Escherichia coli serotype O157	1	4
Giardia	1	31
Paratyphoid fever	1	6
Streptobacillary fever	1	304
Viral gastroenteritis	3	>998
Unknown	1	51
Total:	**19**	**>2,099**

(Sources:- Fewtrell and Kay, 1996; Furtado *et al*., 1998; Galbraith *et al.*, 1987)

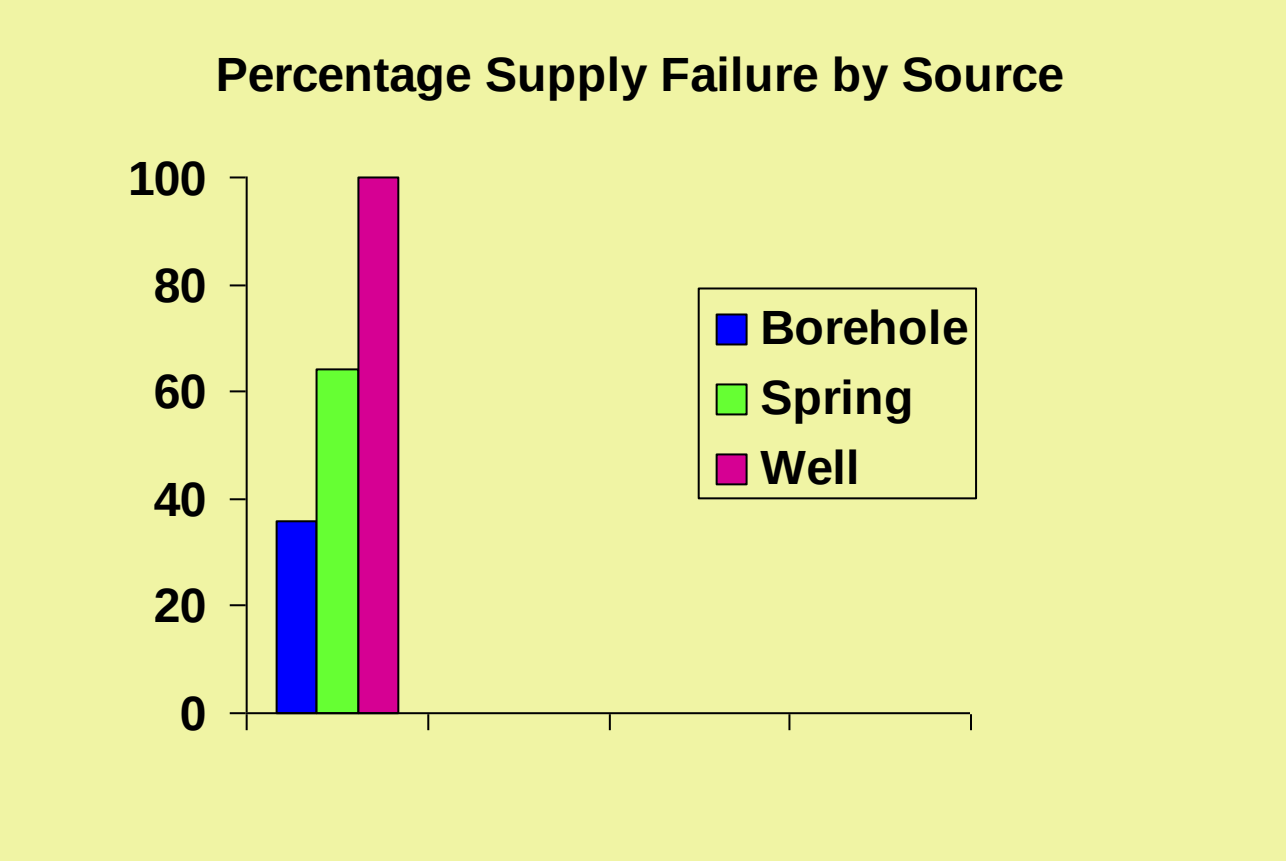
Some Data

Small rural PWS 2000 to 2002

- 42 sites sampled monthly on 18 occasions only 2 sites compliant with zero *E. coli* standard
- High vs Low sanitary risk score sites
  - GeoMean *E.coli* significantly different between high and low sanitary risk sites using ANOVA and 95% confidence level (actual $p < 0.005$)
- Rainfall in the three days prior to sampling was the best predictor of FIO concentration on the day of sampling r = 0.621, $p = 0.001$)

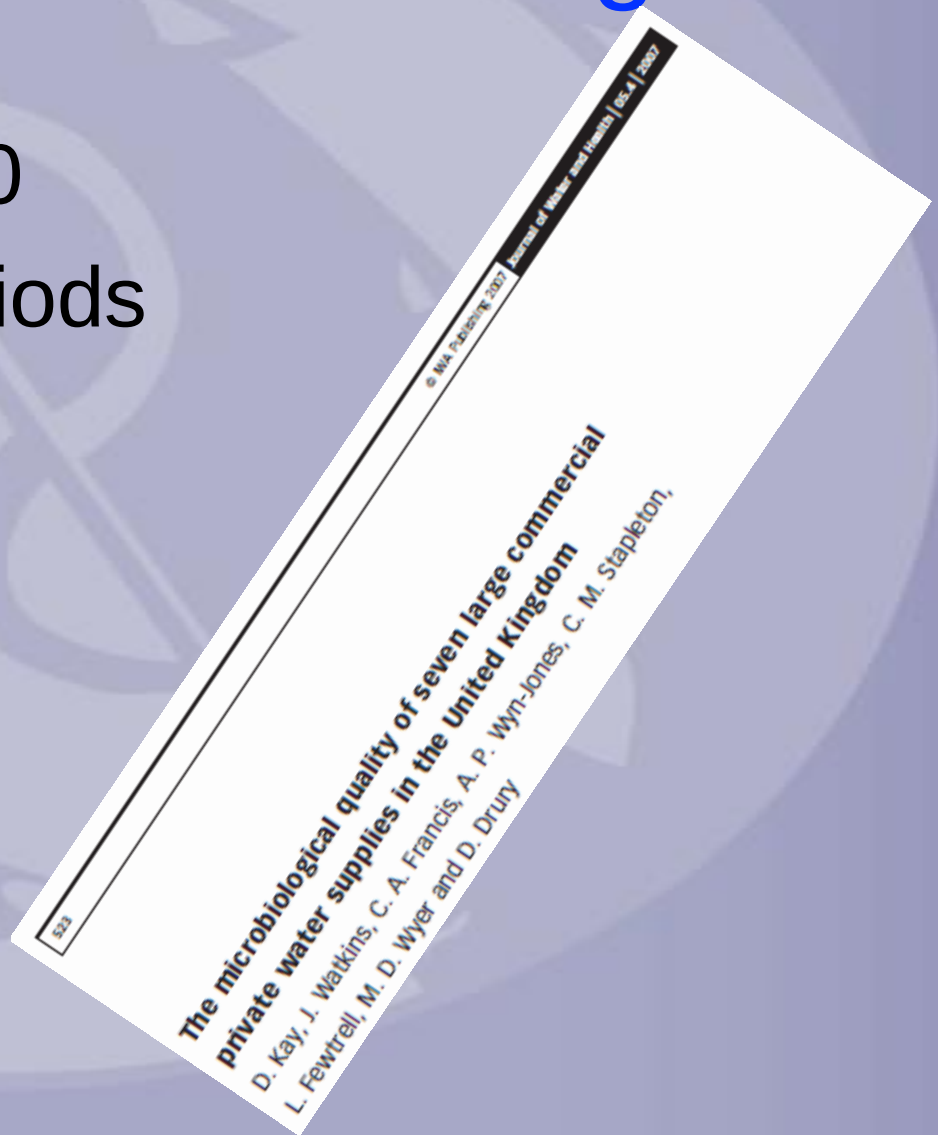


Supply type effects (Fewtrell and Kay, 1998)



Non-compliance and Pathogens

- DWI project Feb-Nov 2000
- 2 x six week sampling periods
- 7 sites in total
  - 2 Wales
  - 2 Scotland
  - 2 England
  - 1 Northern Ireland



Parameters

- Total coliform
- *Escherichia coli*
- enterococci
- *Clostridia*
- *Campylobacter*
- *Giardia lamblia*
- *Cryptosporidium* spp.

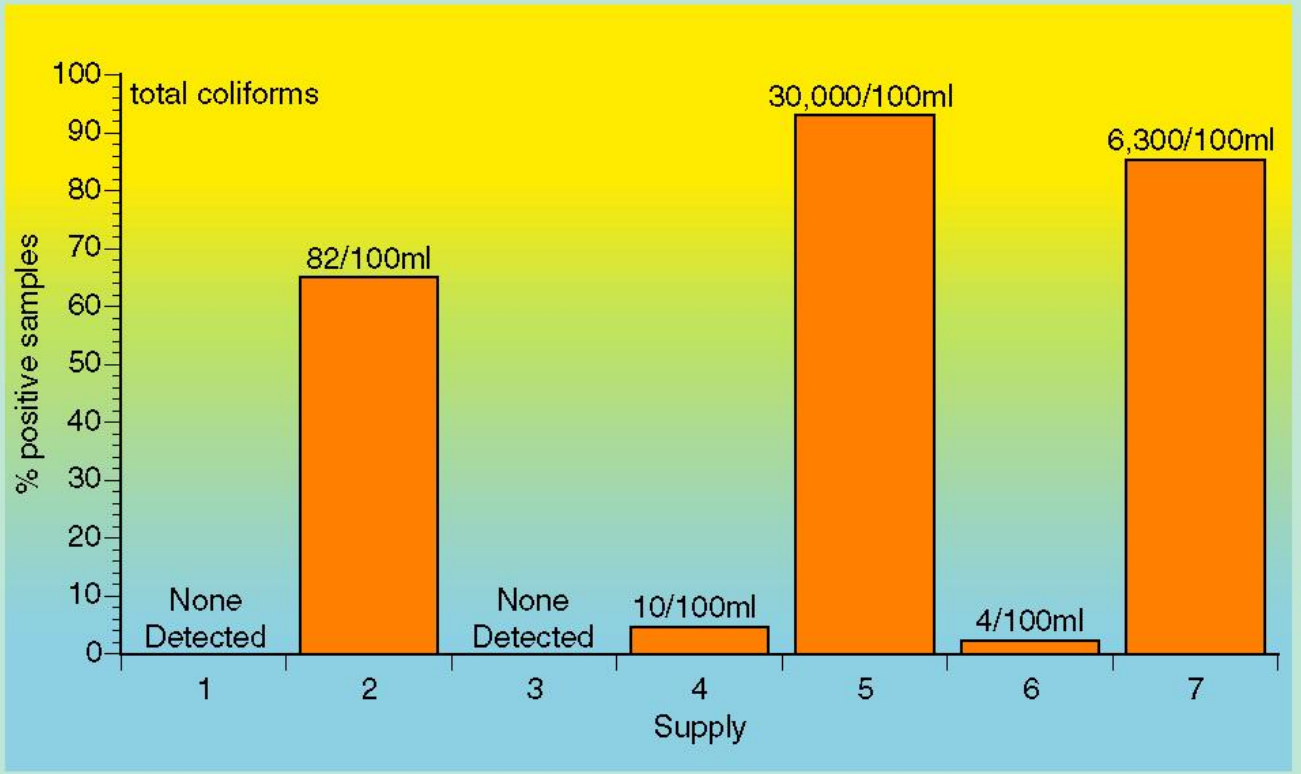
Table 1 | Details of private water supplies included within this study

Site	Source	Treatment	Virus samples
1	Borehole	Chlorination	No
2	Stream	Filtration & UV disinfection	No
3	Well	Filtration & UV disinfection	No
4	Reservoir	Filtration & chlorination	No
5	Springs fed stream	None	14 samples
6	Borehole	Filtration & ozonation	No
7	Resurgent underground stream	Filtration & chlorination*	25 samples†

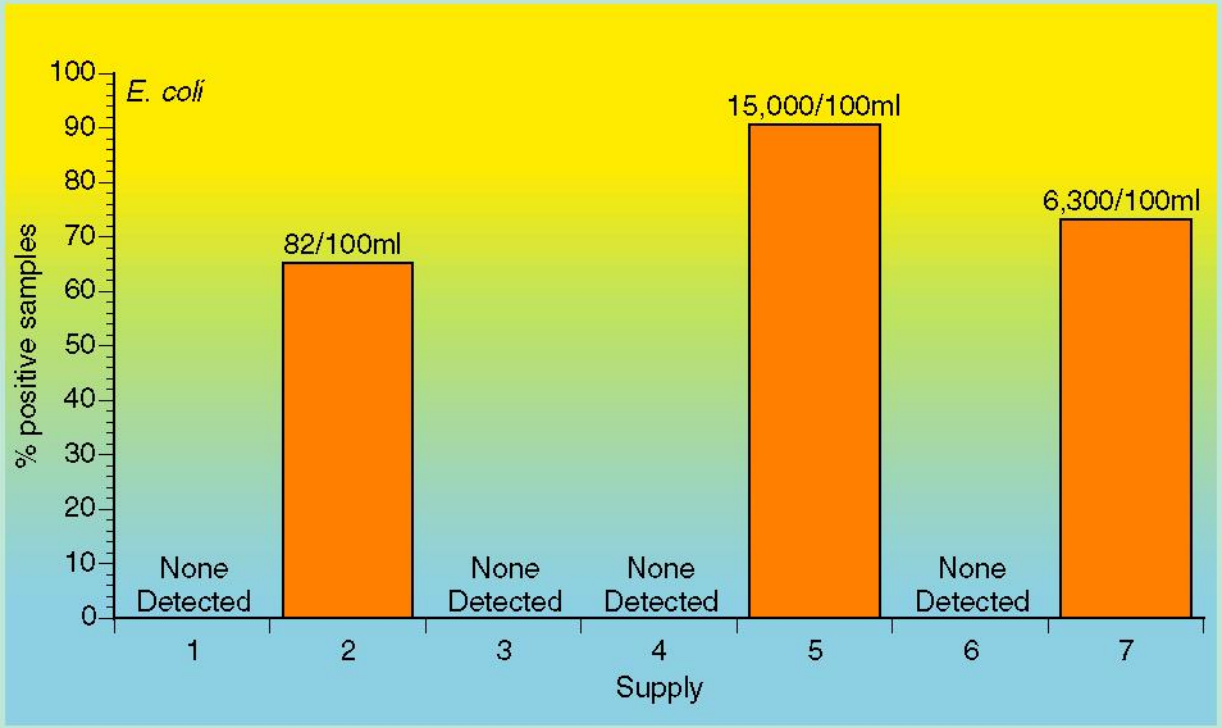
*Treatment installed between spring and autumn sampling phases.
†20 untreated and 5 treated samples tested.

Results

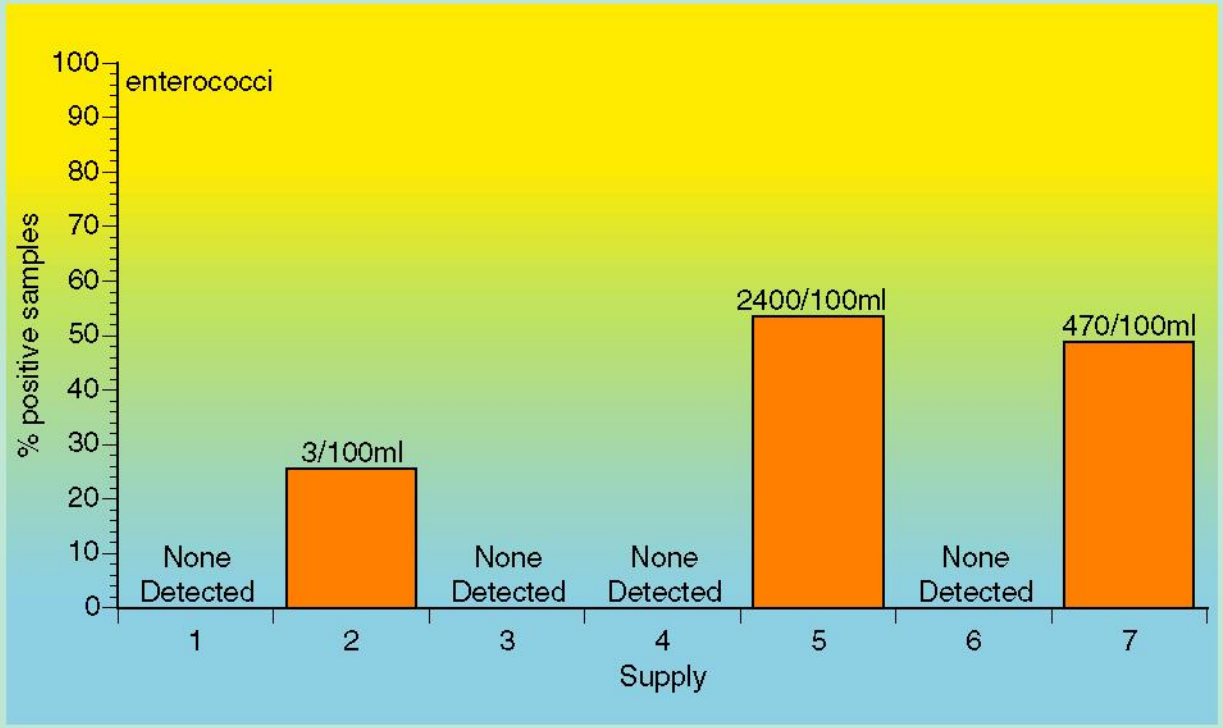
Total coliform



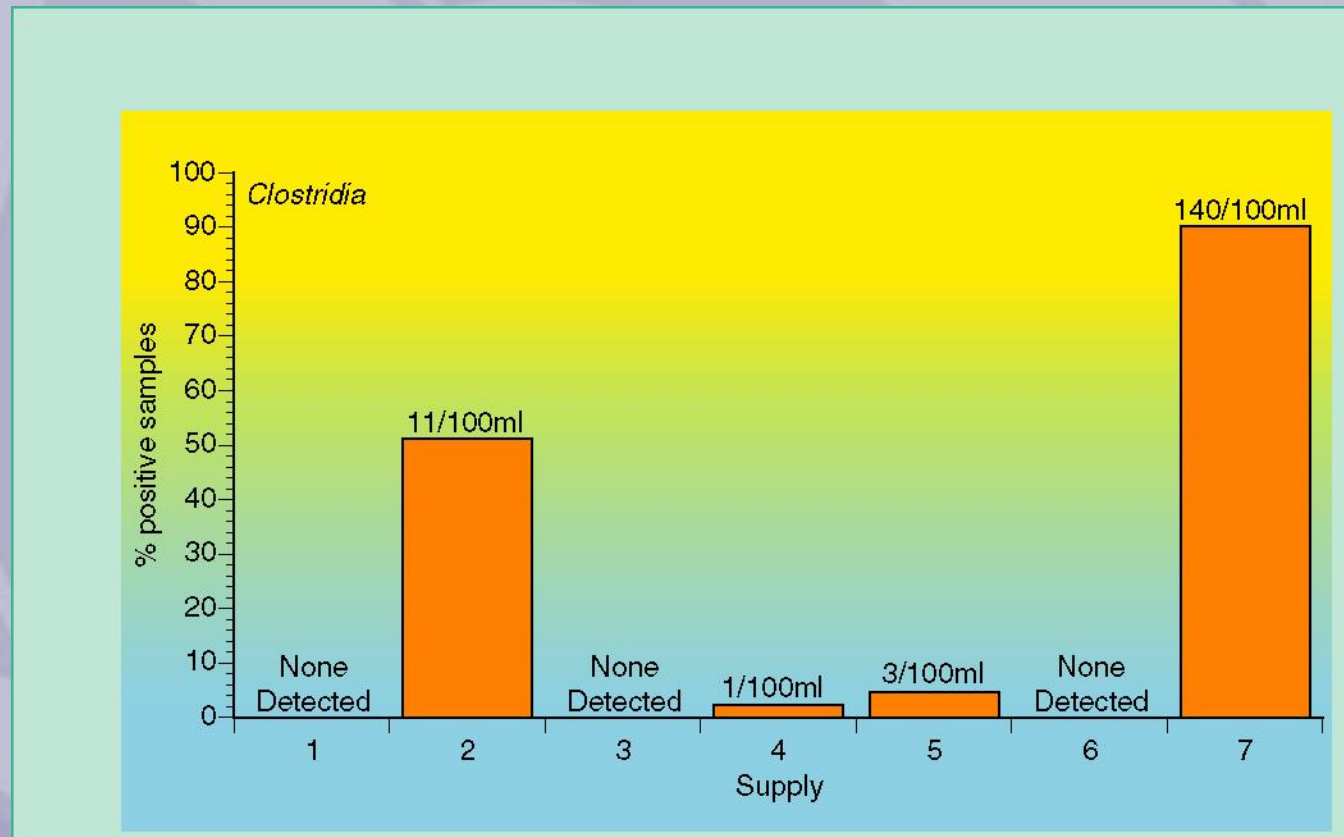
Escherichia coli



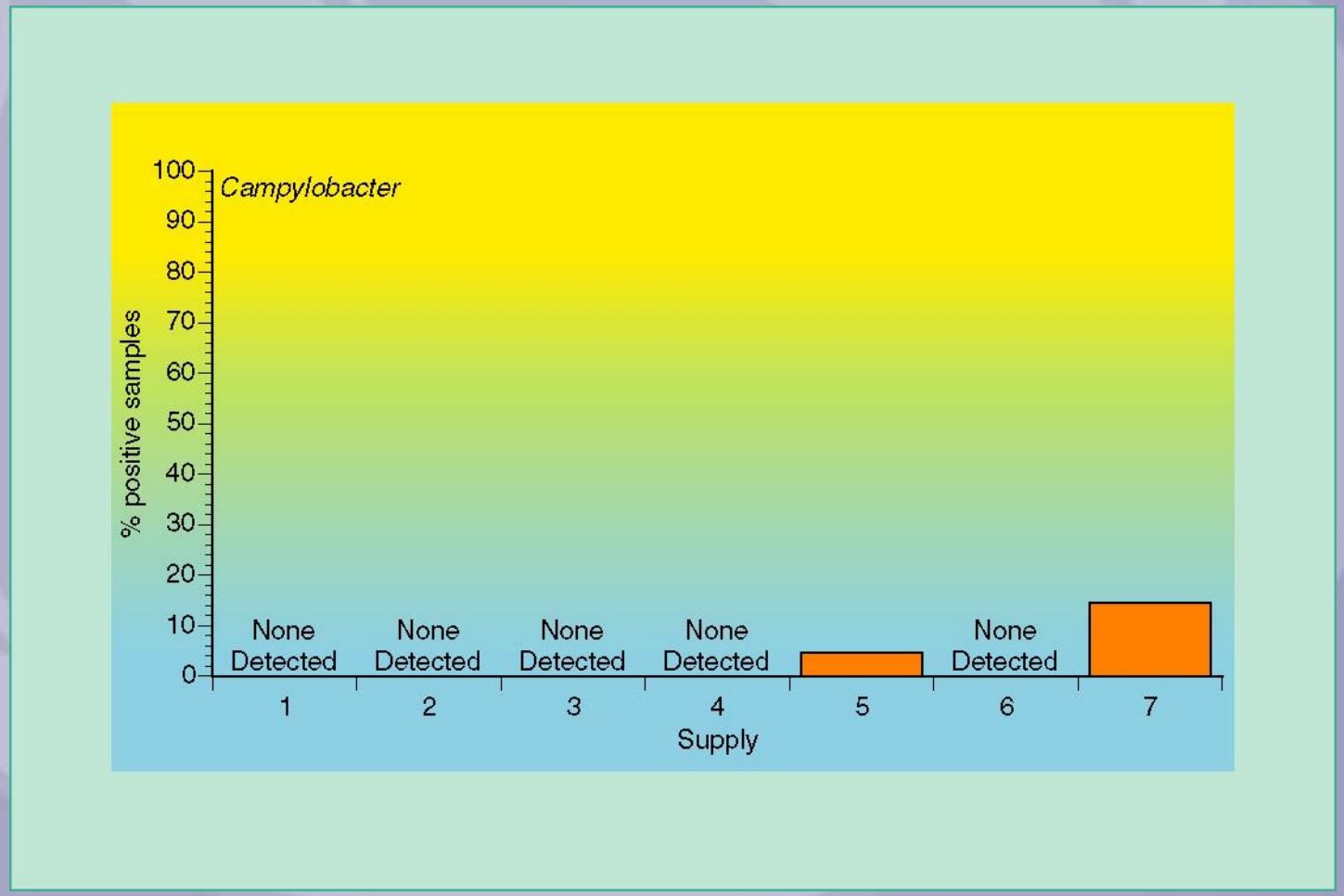
enterococci



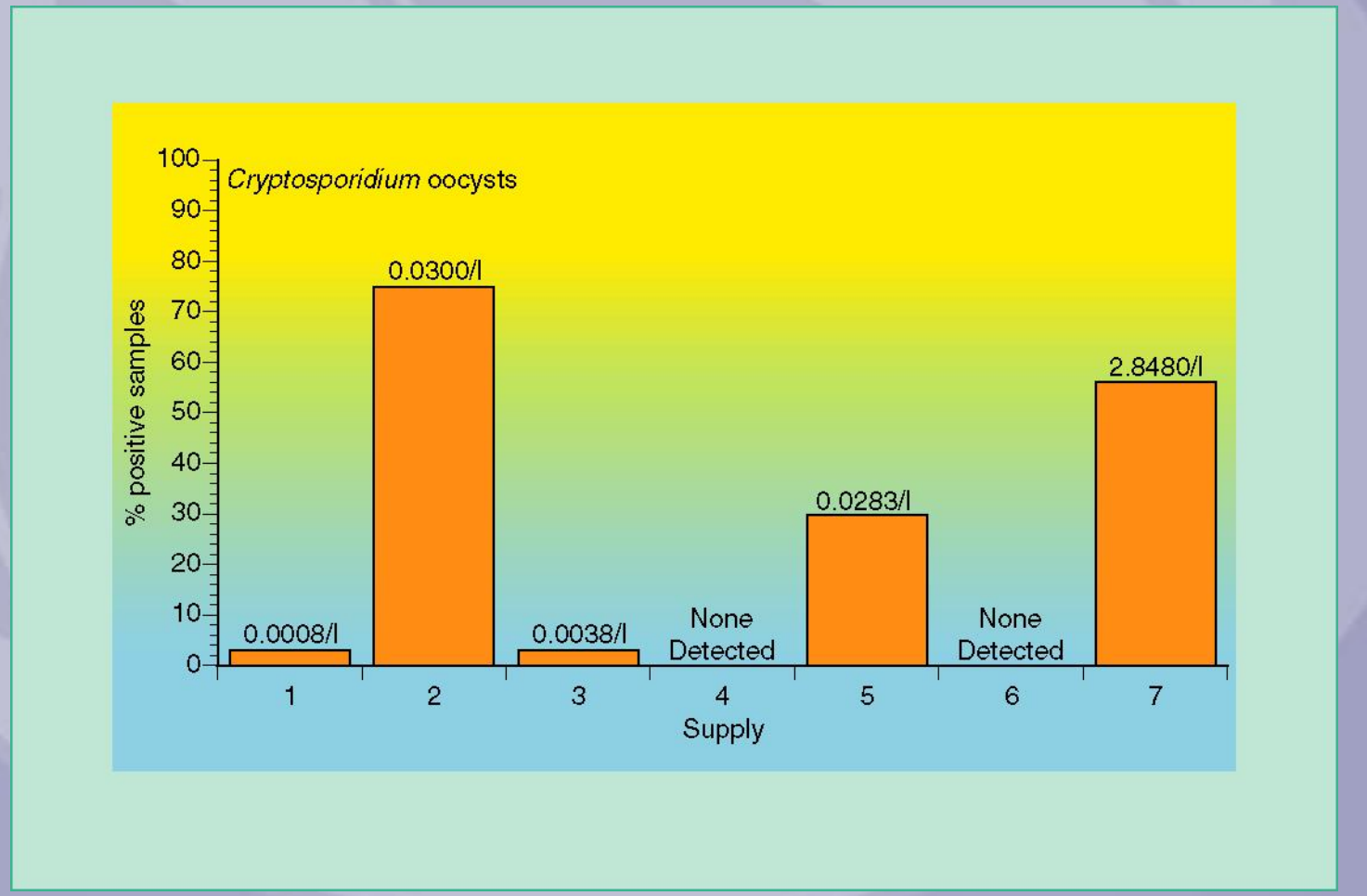
Clostridia


Clostridia
% positive samples
100
90
80
70
60
50
40
30
20
10
0
None Detected
11/100ml
None Detected
1/100ml
3/100ml
None Detected
140/100ml
1
2
3
4
5
6
7
Supply

Campylobacter



Cryptosporidium



Giardia

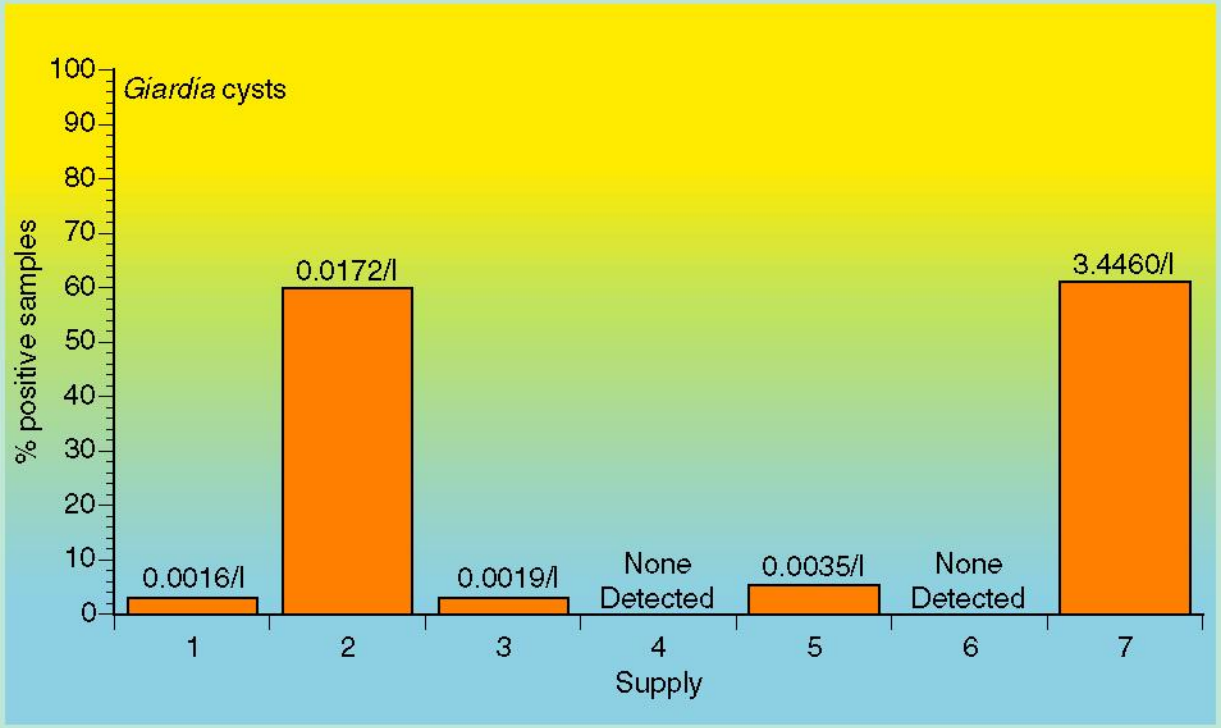

Giardia cysts
% positive samples
100
90
80
70
60
50
40
30
20
10
0
0.0016/l
0.0172/l
0.0019/l
None Detected
0.0035/l
None Detected
3.4460/l
1
2
3
4
5
6
7
Supply

Table 1 | Details of private water supplies included within this study

Site	Source	Treatment	Virus samples
1	Borehole	Chlorination	No
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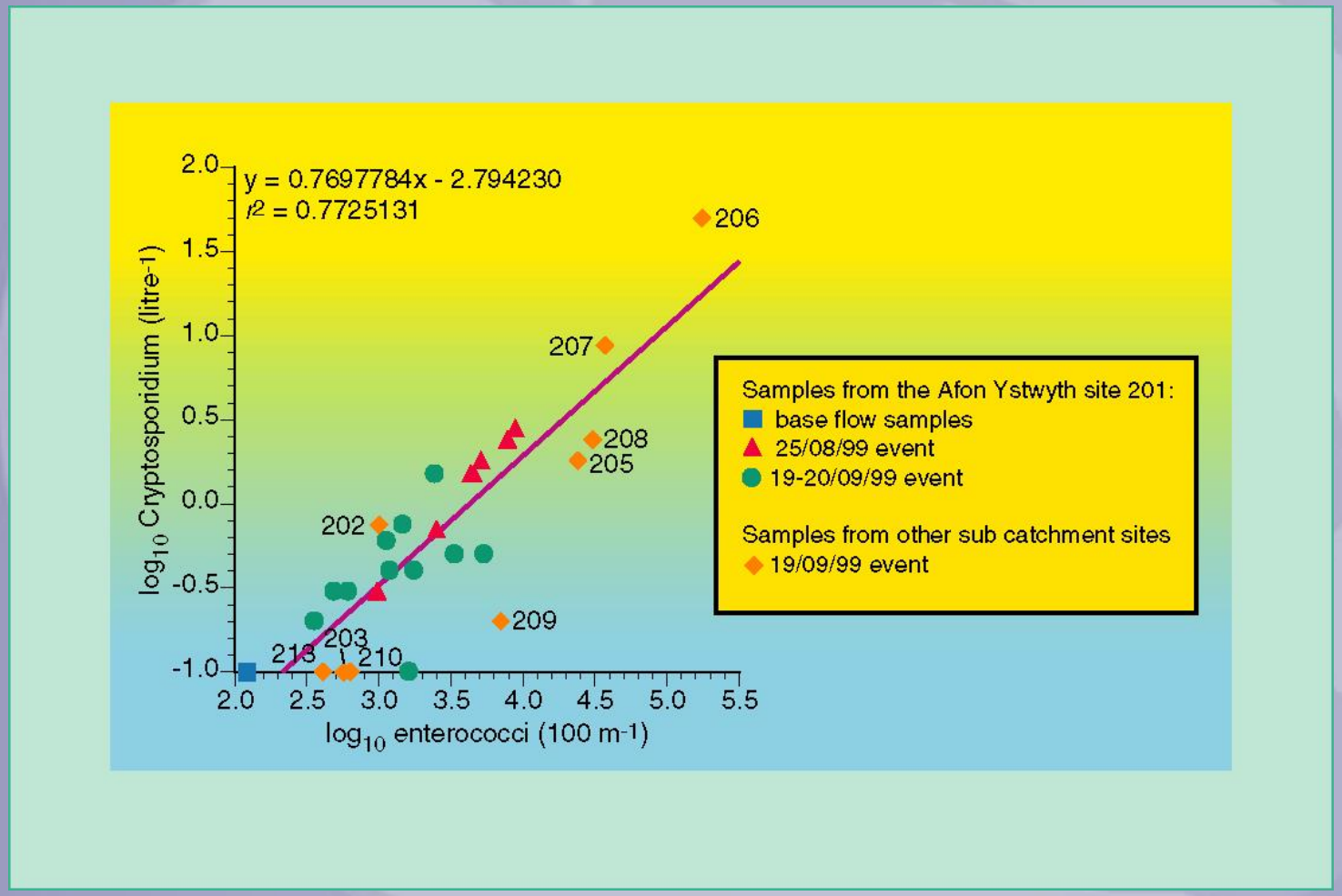
6	Borehole	Filtration & ozonation	No
7	Resurgent underground stream	Filtration & chlorination*	25 samples†

*Treatment installed between spring and autumn sampling phases.
†20 untreated and 5 treated samples tested.

Summary

- Small water supplies have high microbial loadings in every empirical study to date.
- They cause a disproportionate burden of disease
- Catchment control measures offer some reduction in FIO loadings
- The exact impact of such measures on a potable supply is unknown
- Sanitary risk assessment is applied and recommended but empirical evidence for its efficacy is sparse in the UK
- Treatment is recommended in the UK manual

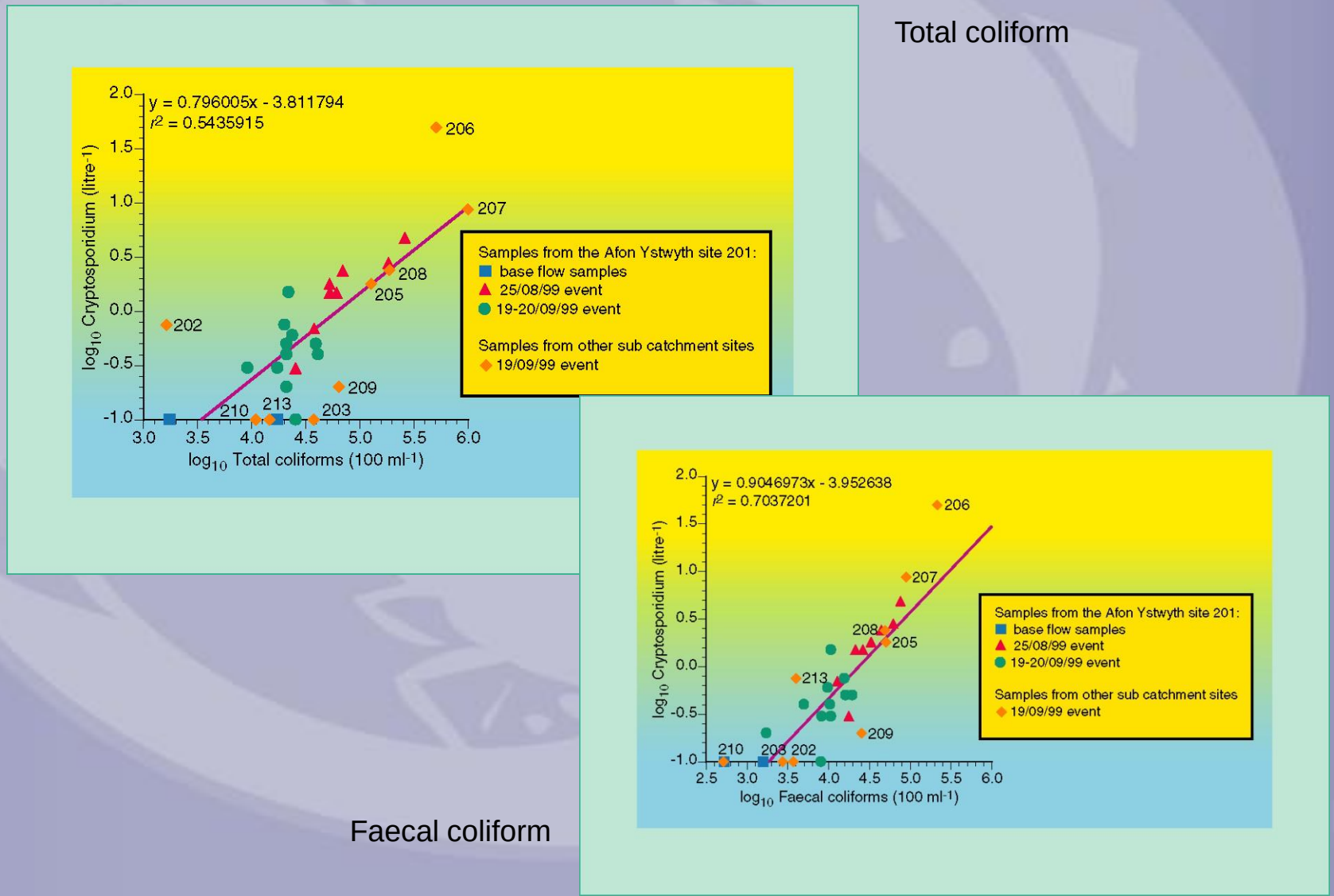
What do UK ‘pristine’ river indicator/pathogen data indicate?



Enterococci

What do UK ‘pristine’ river pathogen data indicate?

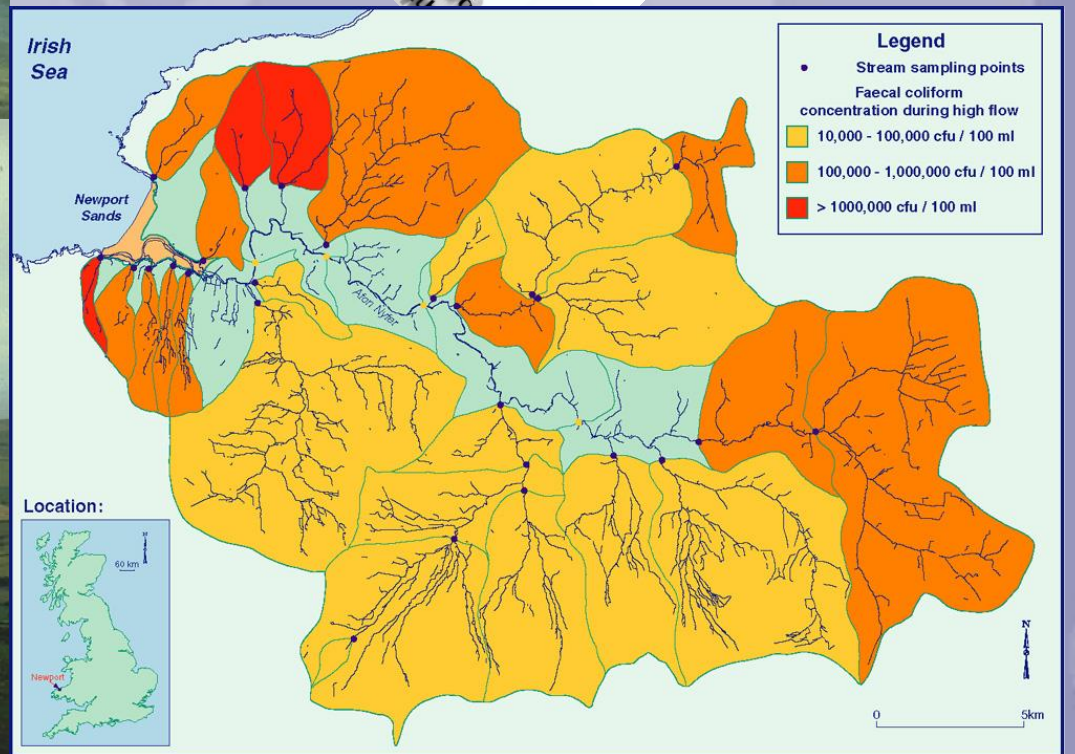
Total coliform



Faecal coliform

Is this to be expected in livestock farming areas like Wales?

Newport, Wales UK



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What is the UK Management Response

Appropriate monitoring is generally impractical for small UK water supplies, however, and therefore a risk assessment of the catchment should be carried out, and protection measures taken.

If there is a **high risk of faecal contamination**, alternative sources of supply will need to be considered. If there is no alternative supply, treatment barriers must be strengthened and assessed against microbial predictions, and contingency plans should be in place for a boil water regime if necessary.

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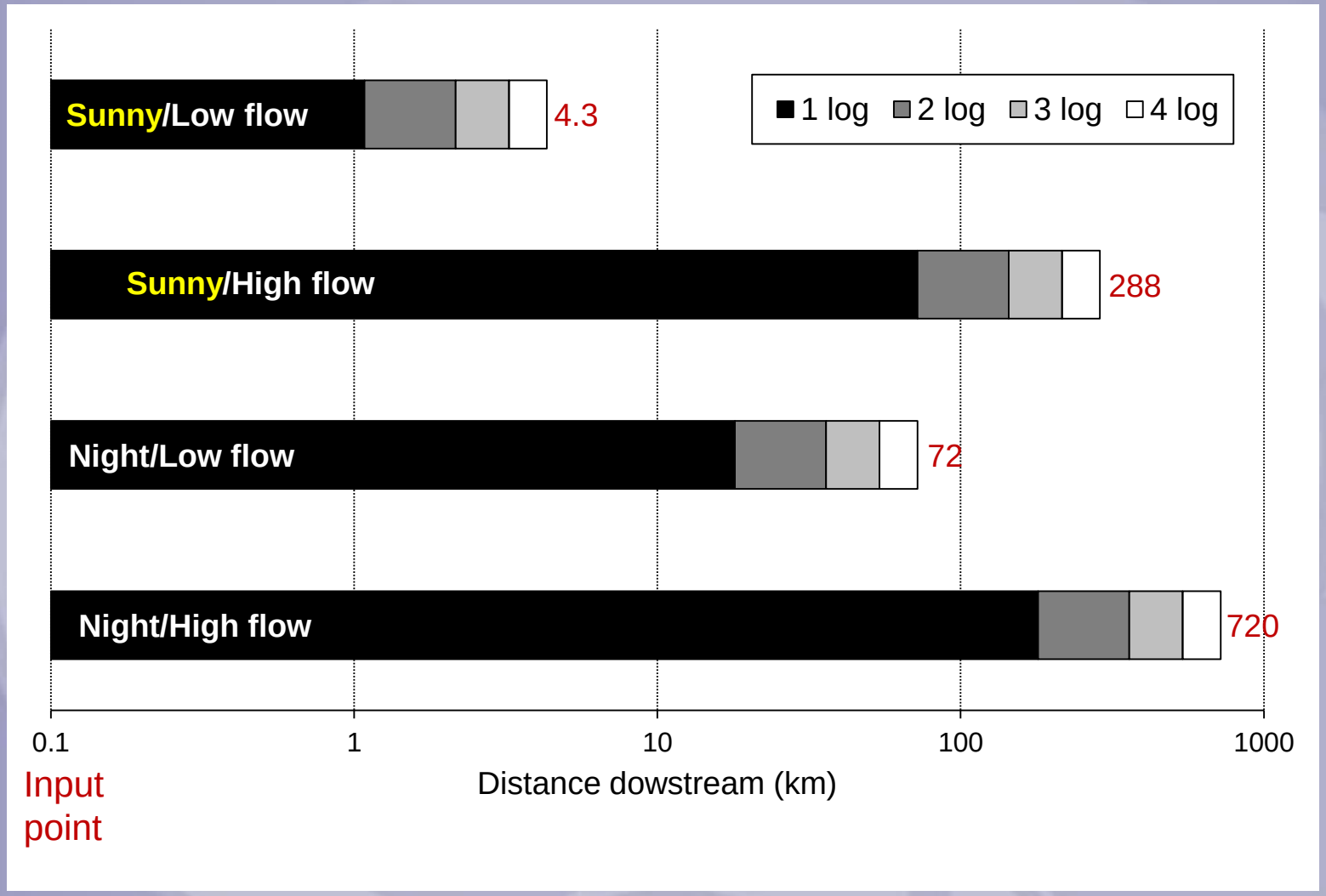
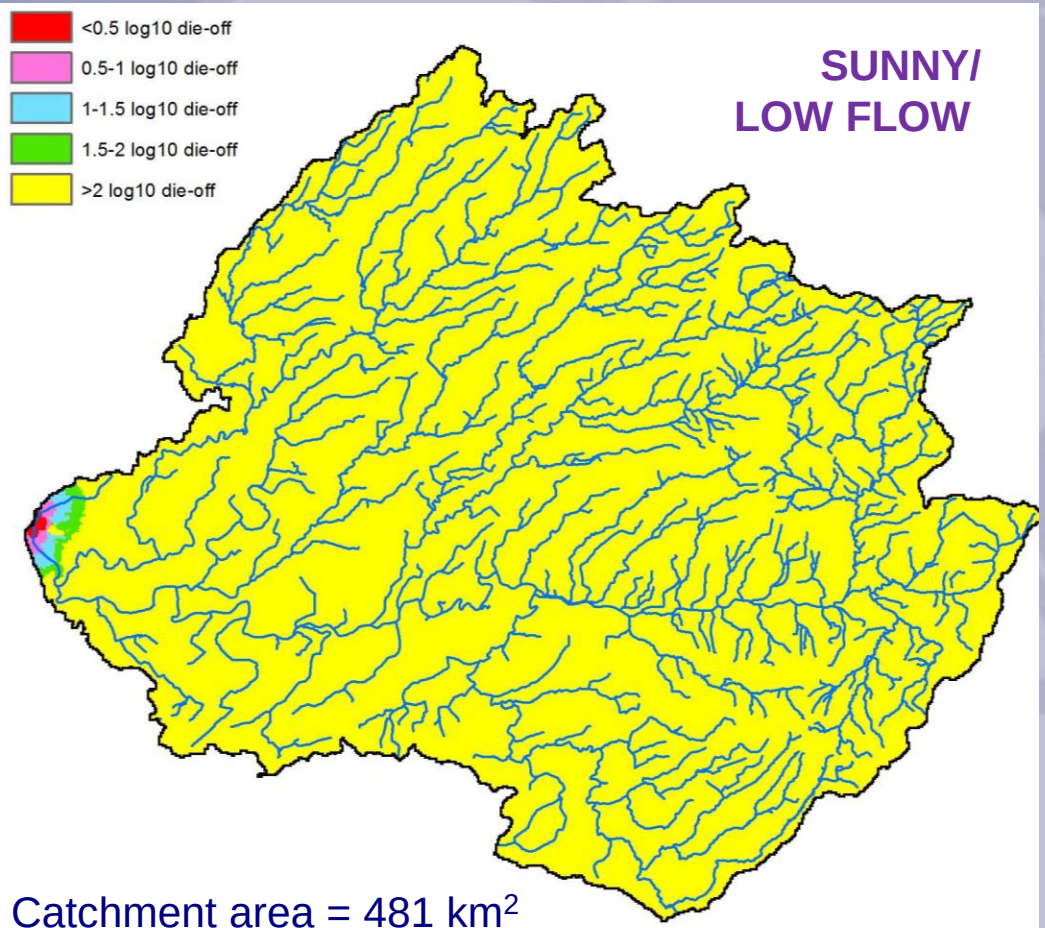
What are the catchment control levers? And **where** should they apply

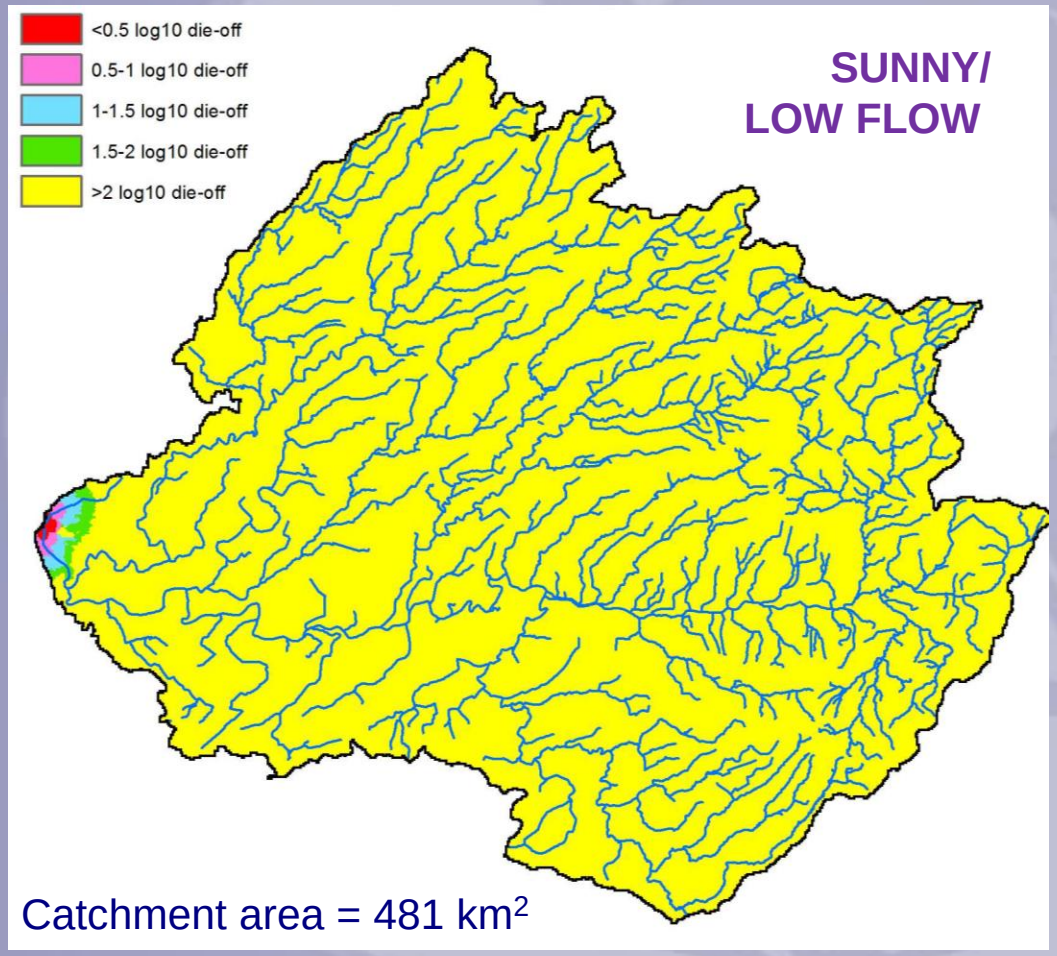


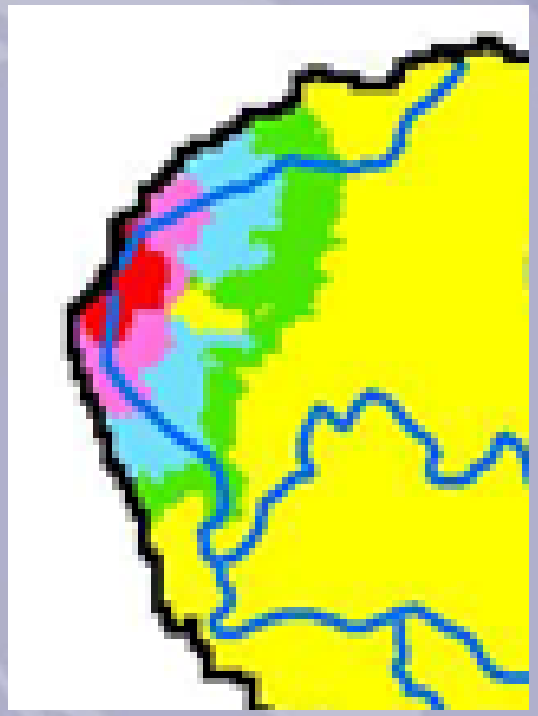
Attenuation of EC (log_{10}) in watercourses with increased distance downstream from input point (based on CREH lab simulation and modelling studies – assumptions: Low flow = low turbidity, flow velocity 0.1 m s^{-1}; High flow = high turbidity, flow velocity 1.0 m s^{-1})

Application to outlet of R. Irvine, W. Scotland

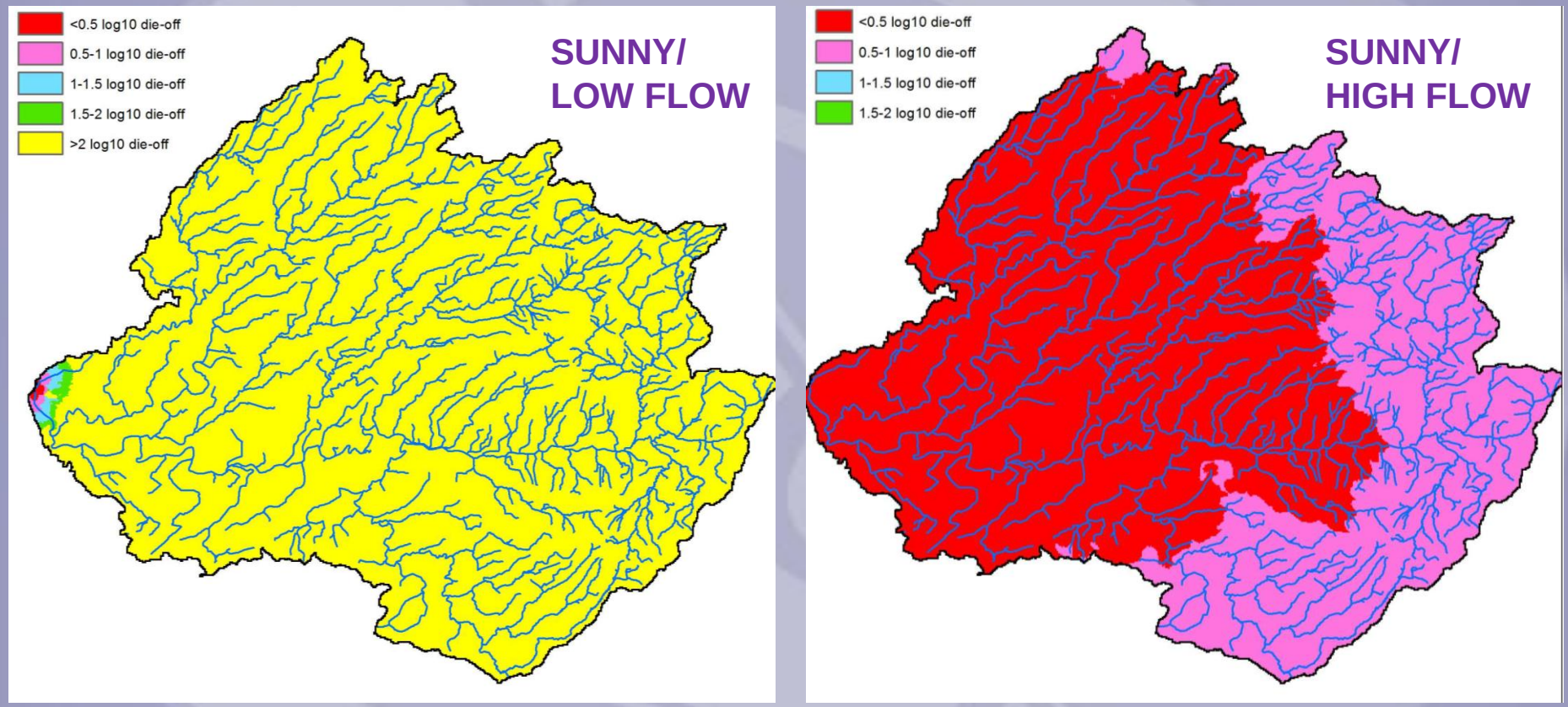


Zone of influence affecting water quality at Irvine catchment outlet: SUNNY/LOW FLOW



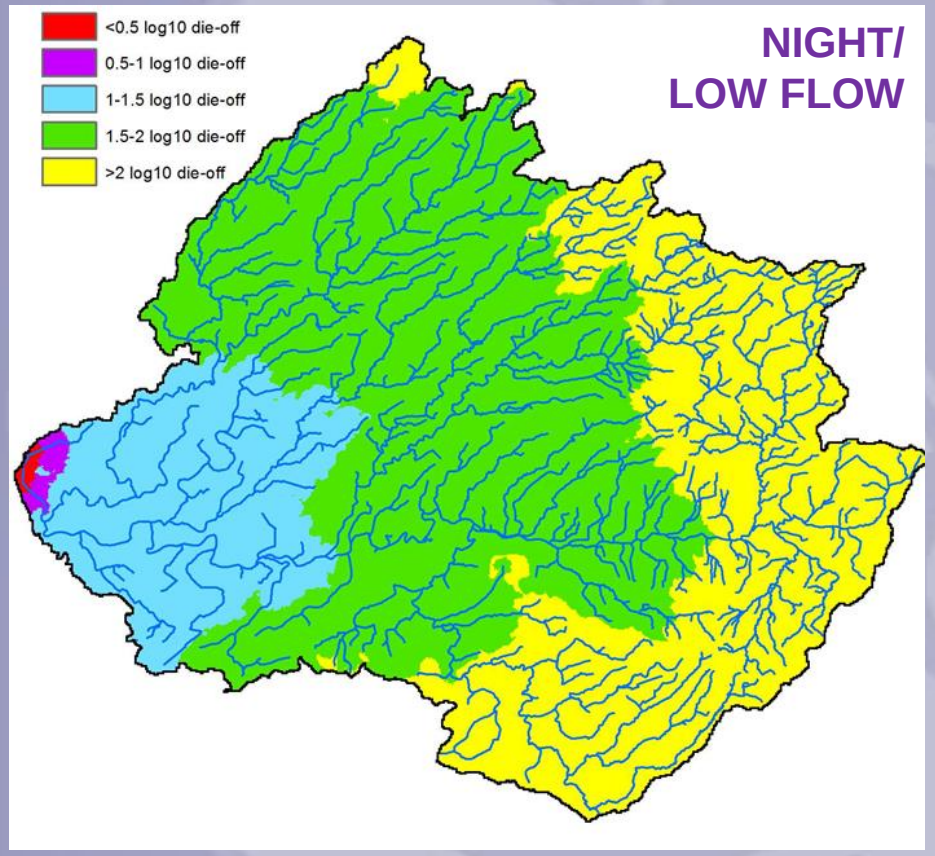


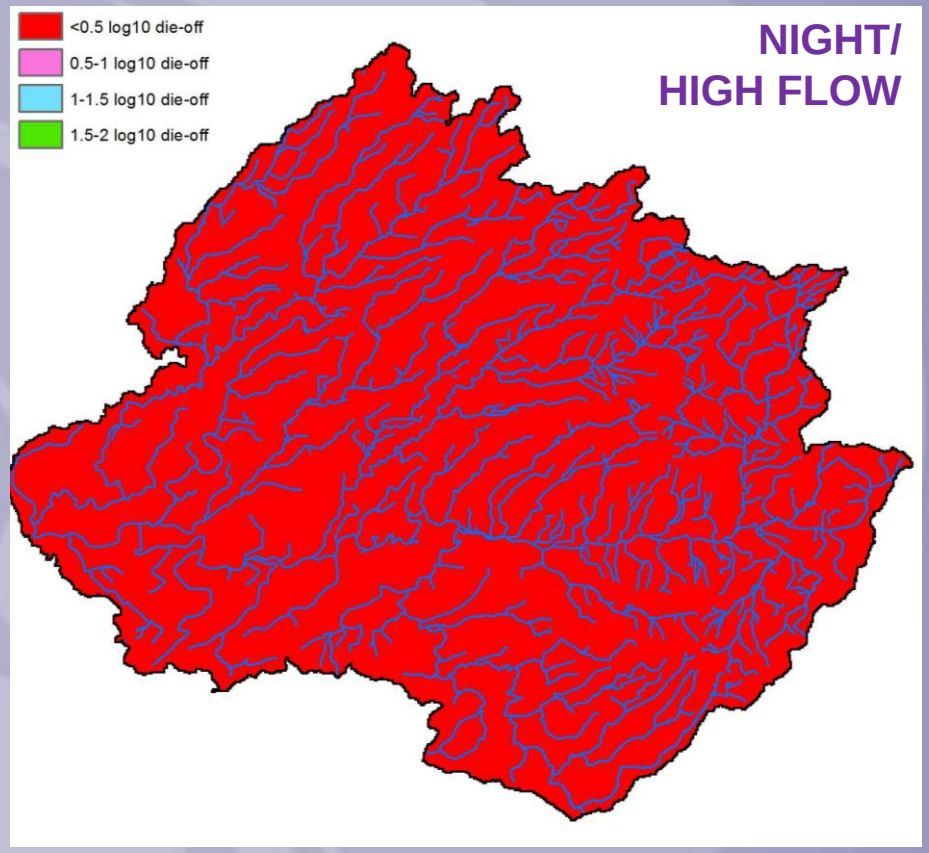
Zone of influence affecting water quality at Irvine catchment outlet: SUNNY/LOW FLOW



Zone of influence affecting water quality at Irvine catchment outlet**: SUNNY**

CREH



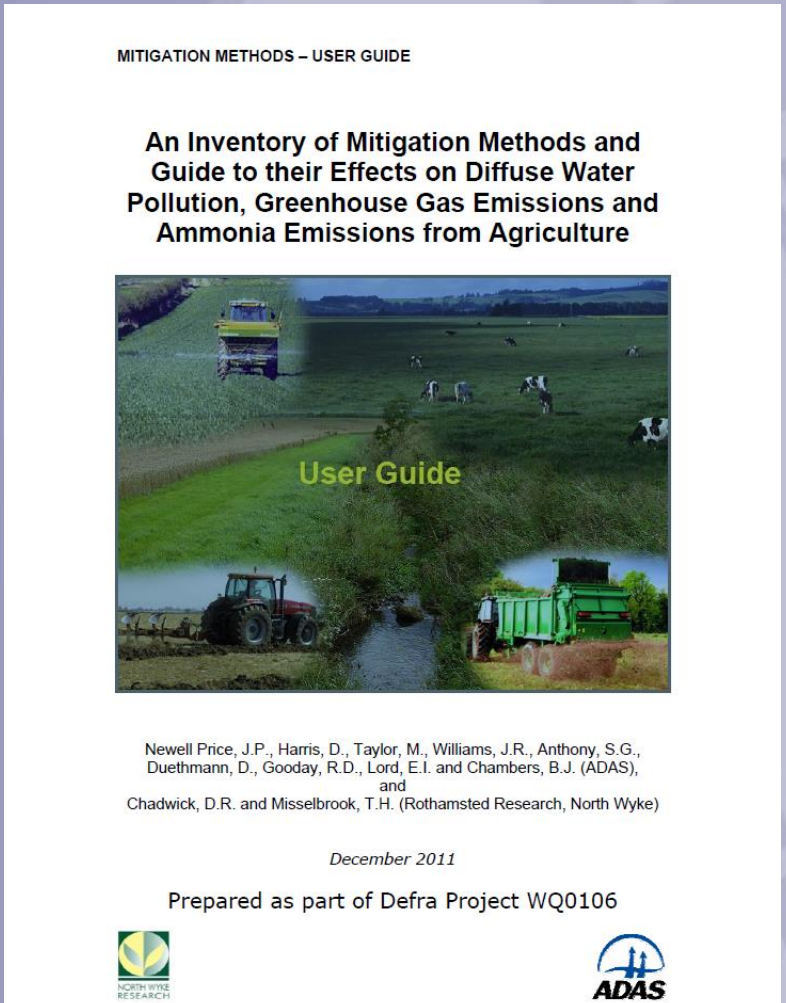


Zone of influence affecting water quality at Irvine catchment outlet**: NIGHT TIME**

CREH

What are the catchment control levers?

‘Expert Judgement’



MITIGATION METHODS – USER GUIDE

An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture

Newell Price, J.P., Harris, D., Taylor, M., Williams, J.R., Anthony, S.G., Duethmann, D., Gooday, R.D., Lord, E.I. and Chambers, B.J. (ADAS), and Chadwick, D.R. and Misselbrook, T.H. (Rothamsted Research, North Wyke)

December 2011

Prepared as part of Defra Project WQ0106

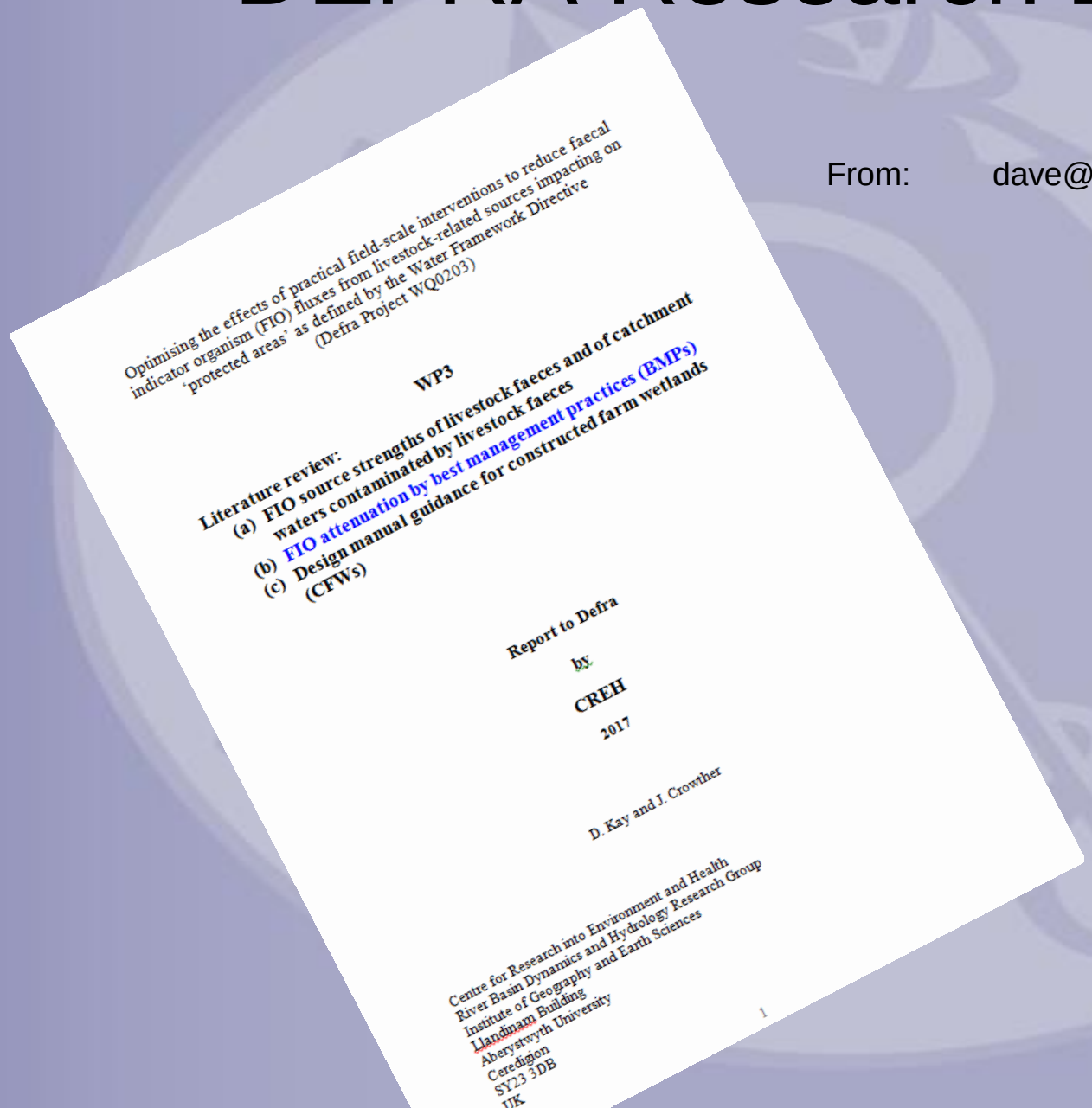
http://www.avondtc.org.uk/Portals/0/Farmscoper/DEFRA%20user%20guide.PDF

Environment Agency

Rural Sustainable Drainage Systems (RSuDS)

https://www.gov.uk/government/publications/rural-sustainable-drainage-systems

DEFRA Research 2010-17



Optimising the effects of practical field-scale interventions to reduce faecal indicator organism (FIO) fluxes from livestock-related sources impacting on 'protected areas' as defined by the Water Framework Directive
(Defra Project WQ0203)

WP3

Literature review:
(a) FIO source strengths of livestock faeces and of catchment waters contaminated by livestock faeces
(b) FIO attenuation by best management practices (BMPs)
(c) Design manual guidance for constructed farm wetlands (CFWs)

Report to Defra

by

CREH

2017

D. Kay and J. Crowther

Centre for Research into Environment and Health
River Basin Dynamics and Hydrology Research Group
Institute of Geography and Earth Sciences
Llandinam Building
Aberystwyth University
Ceredigion
SY23 3DB
UK

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From: dave@crehkay.demon.co.uk

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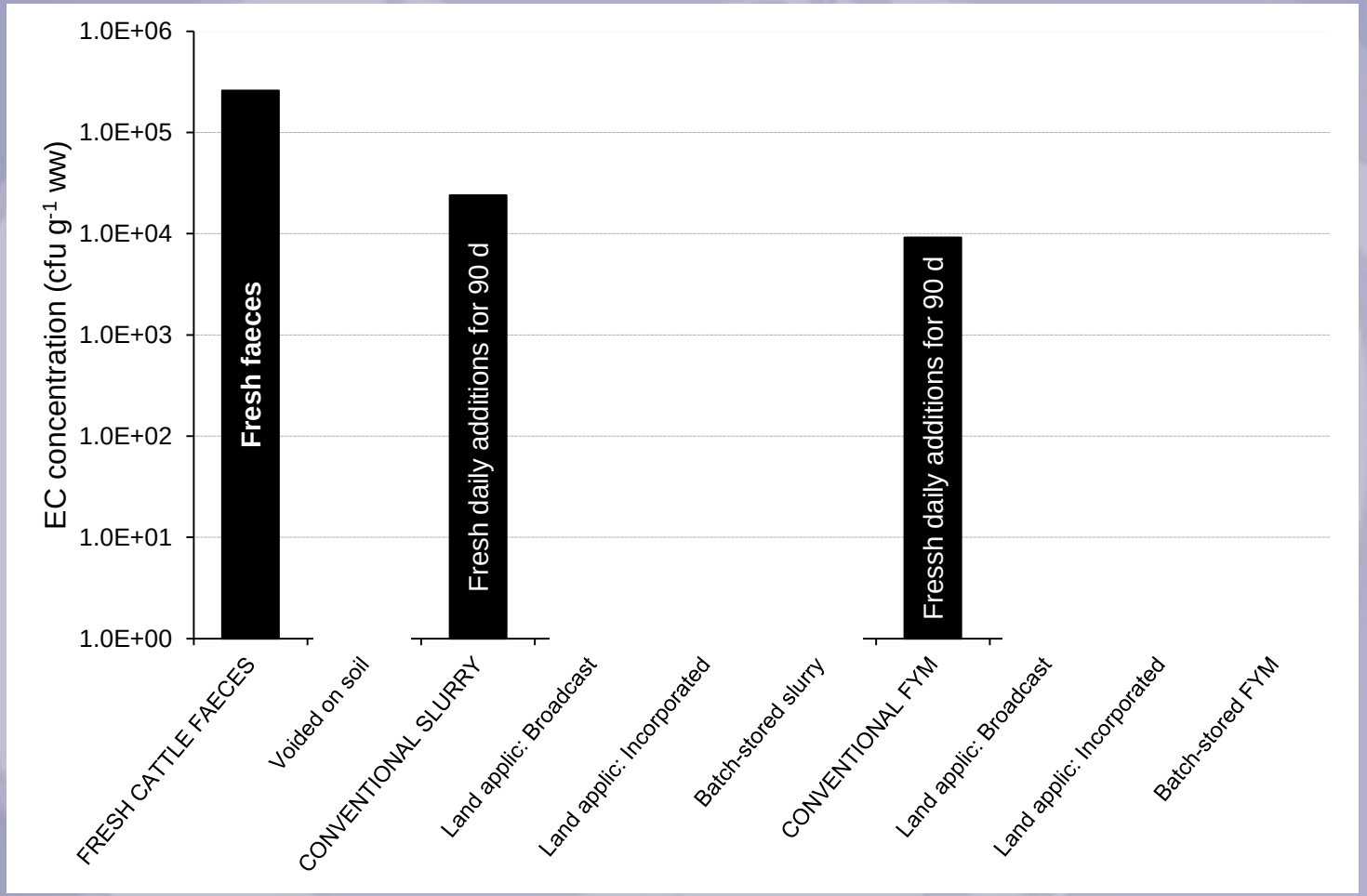
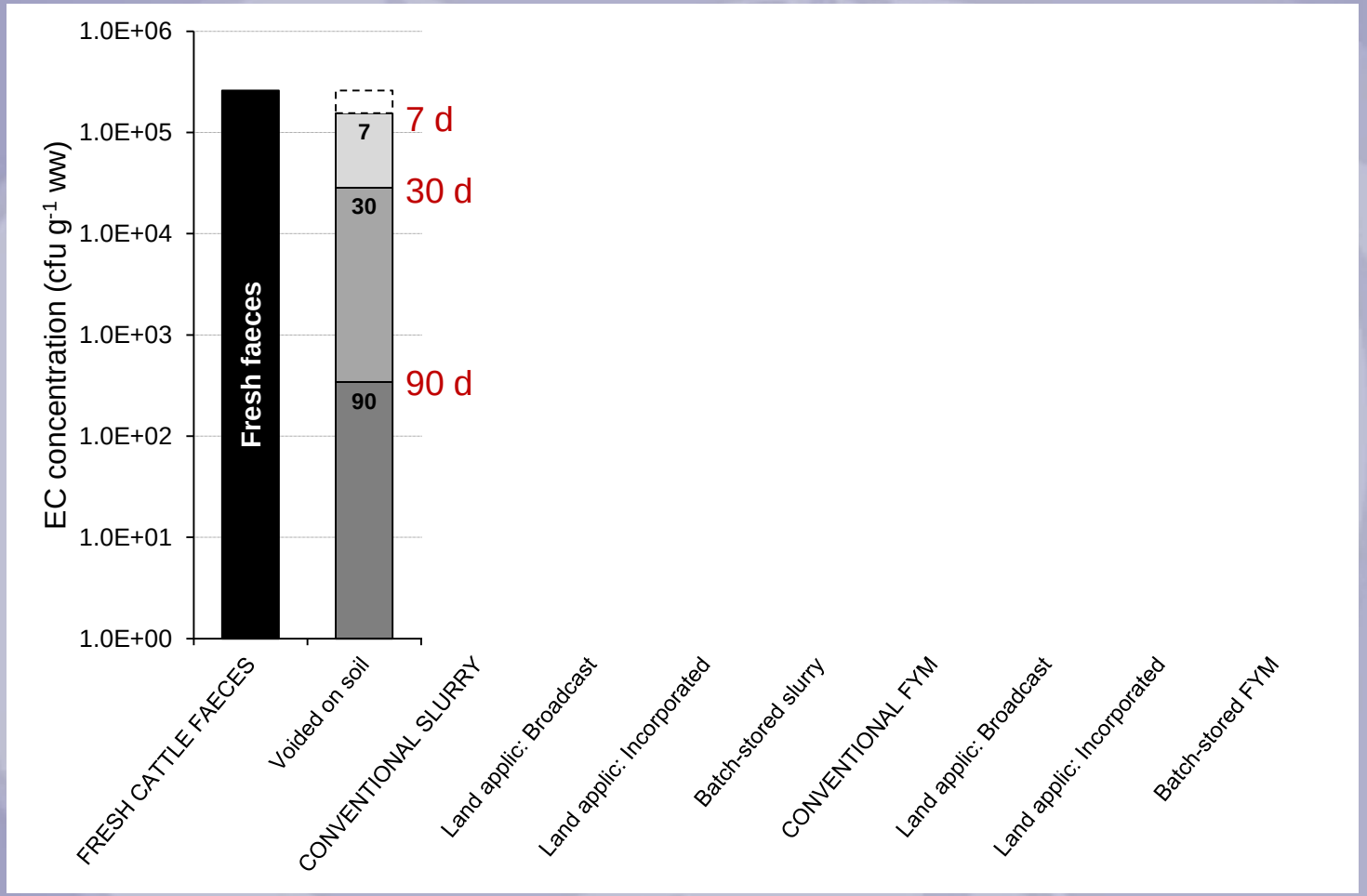
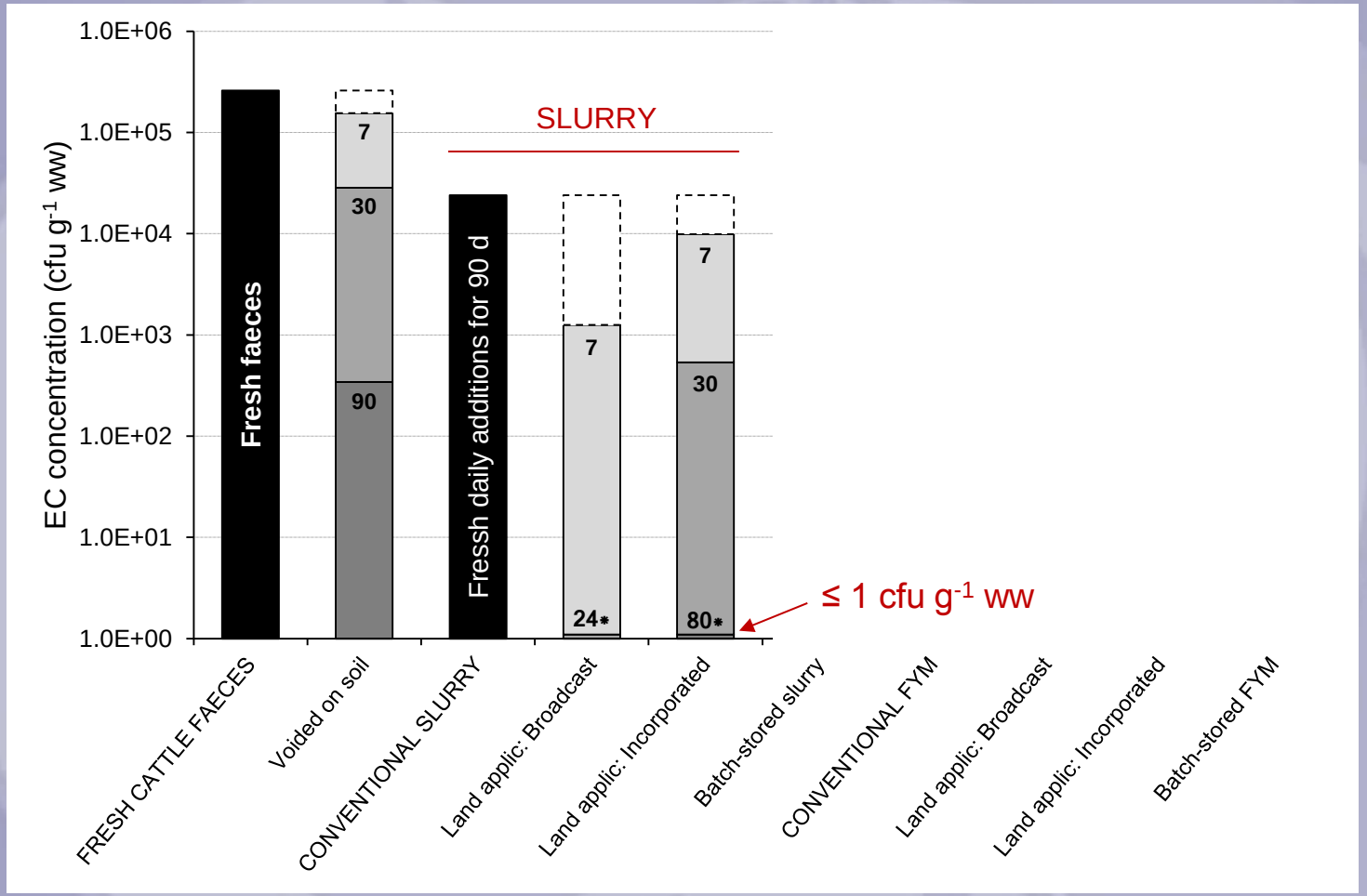


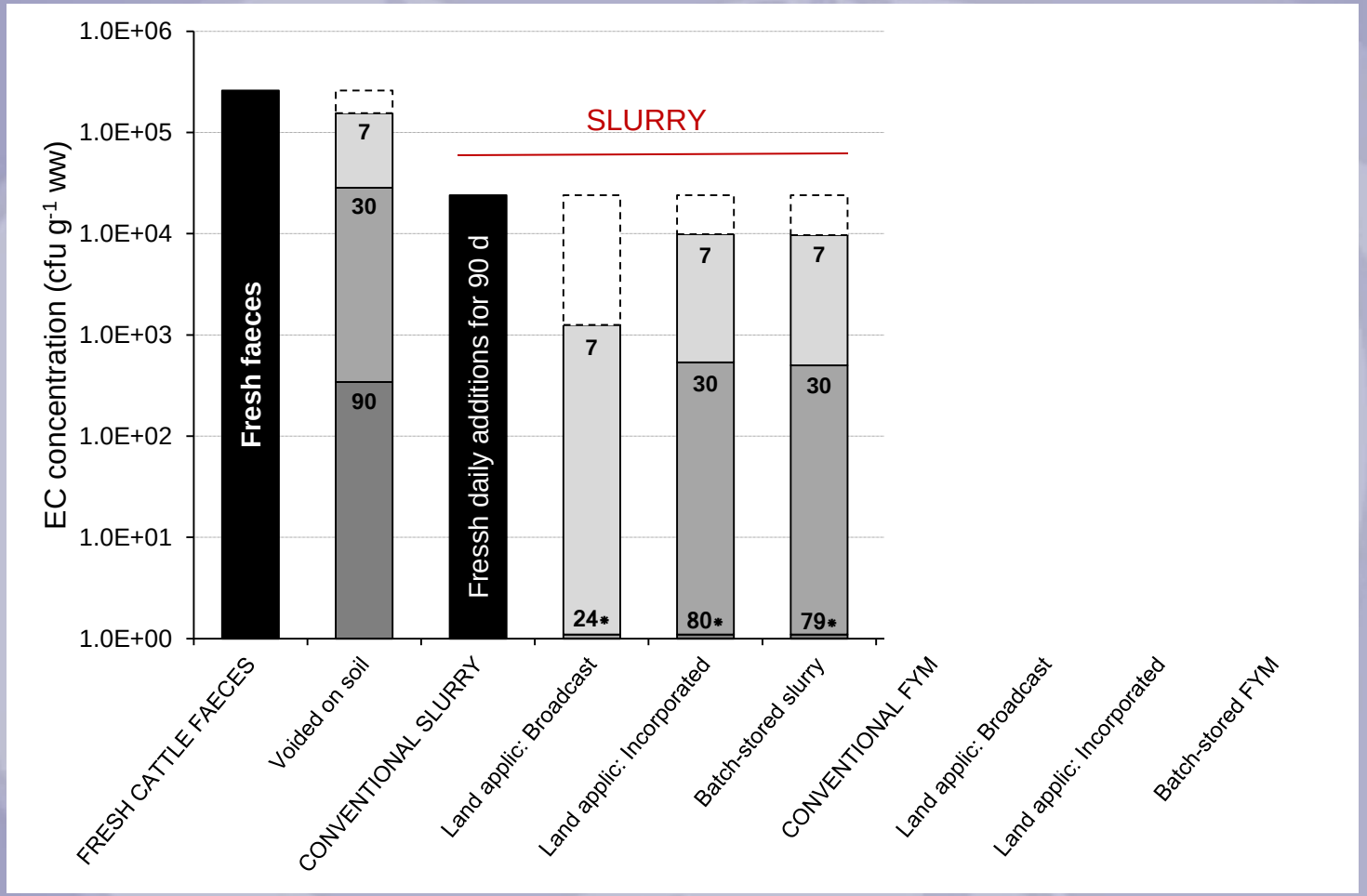
EC concentrations: Fresh faeces and conventional slurry & FYM



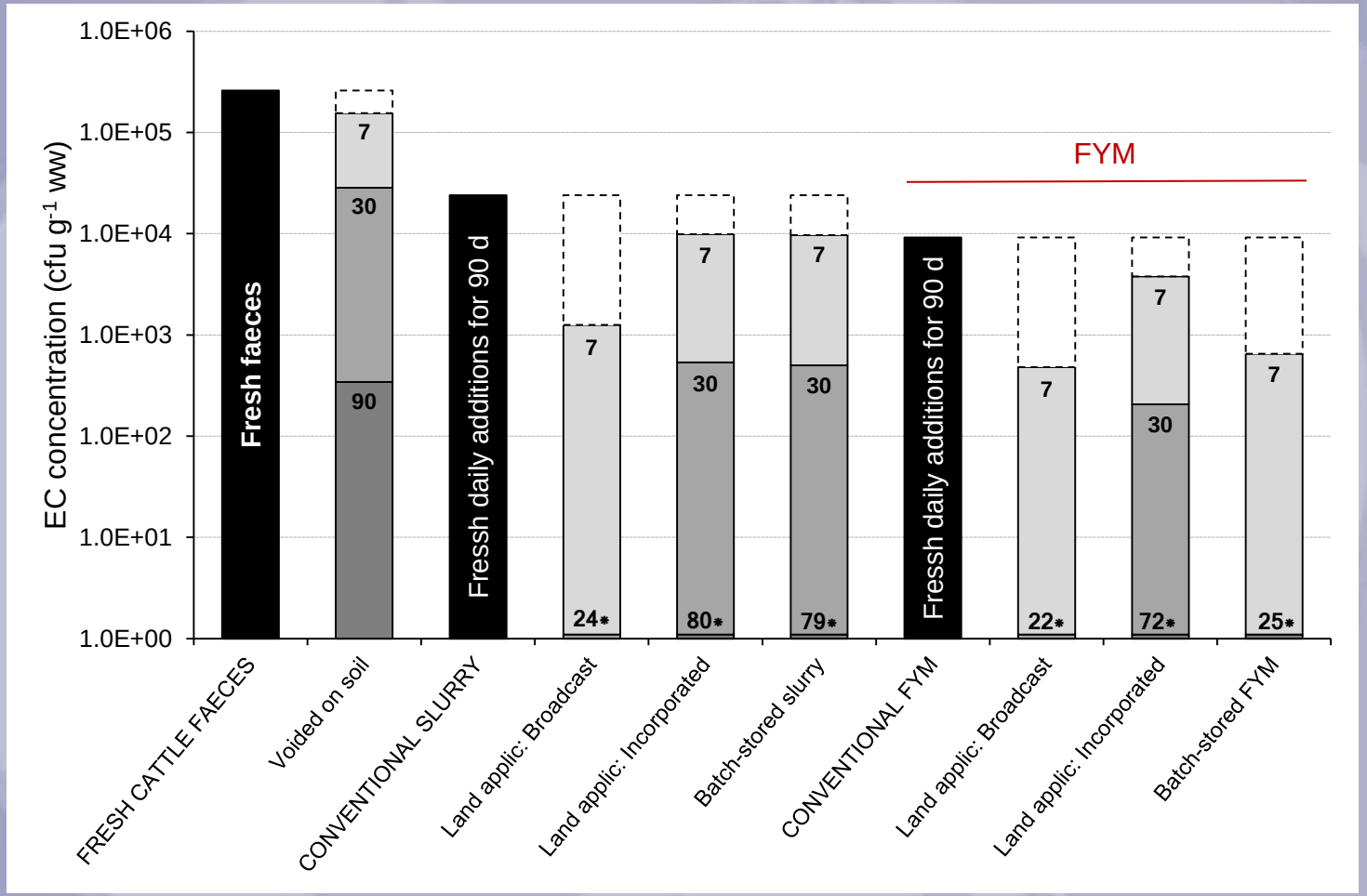
EC concentrations: Fresh faeces voided on soil after 7, 30 and 90 d



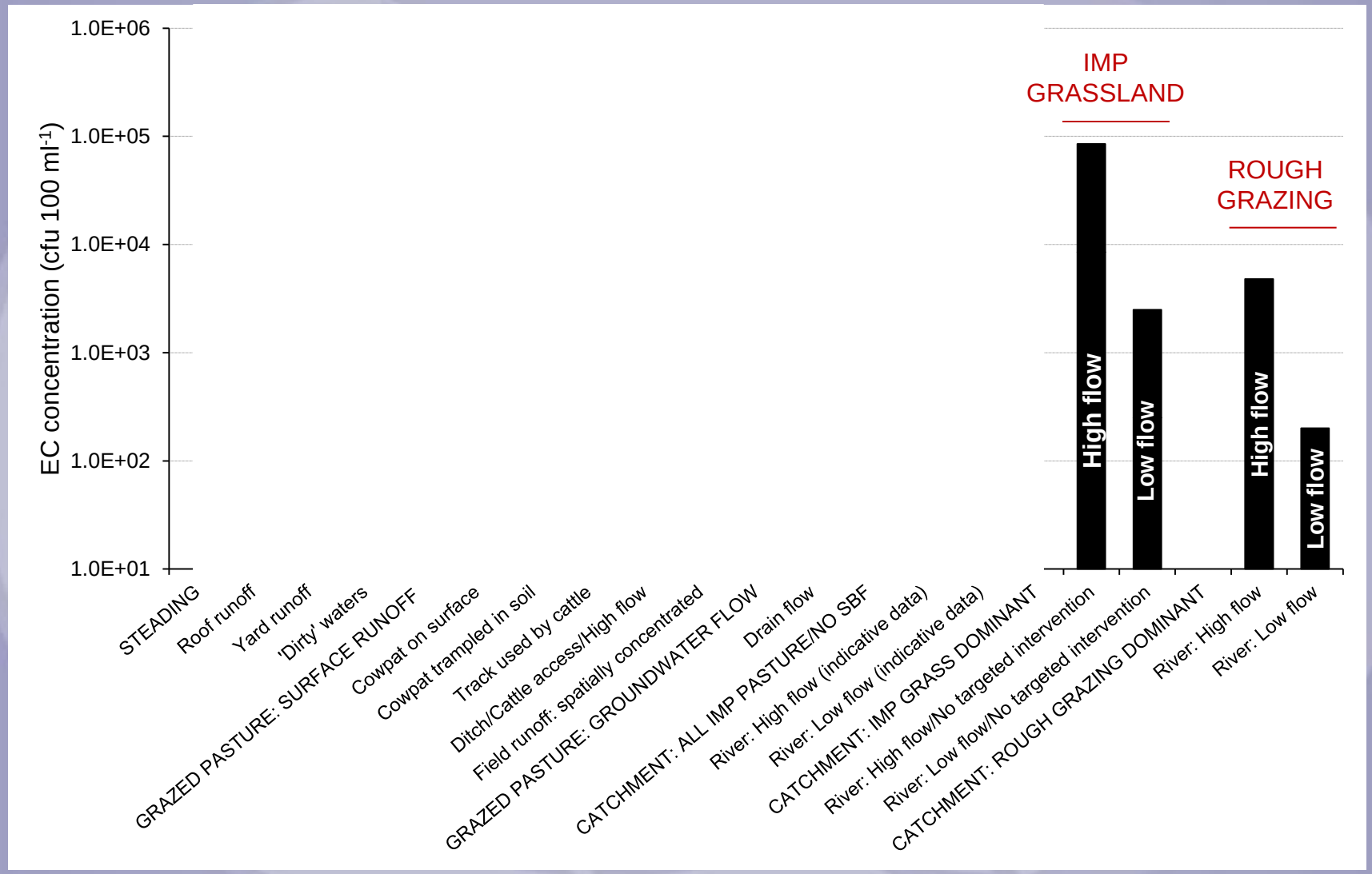
EC concentrations: Conventional slurry applied to land (* = time required for virtual elimination)



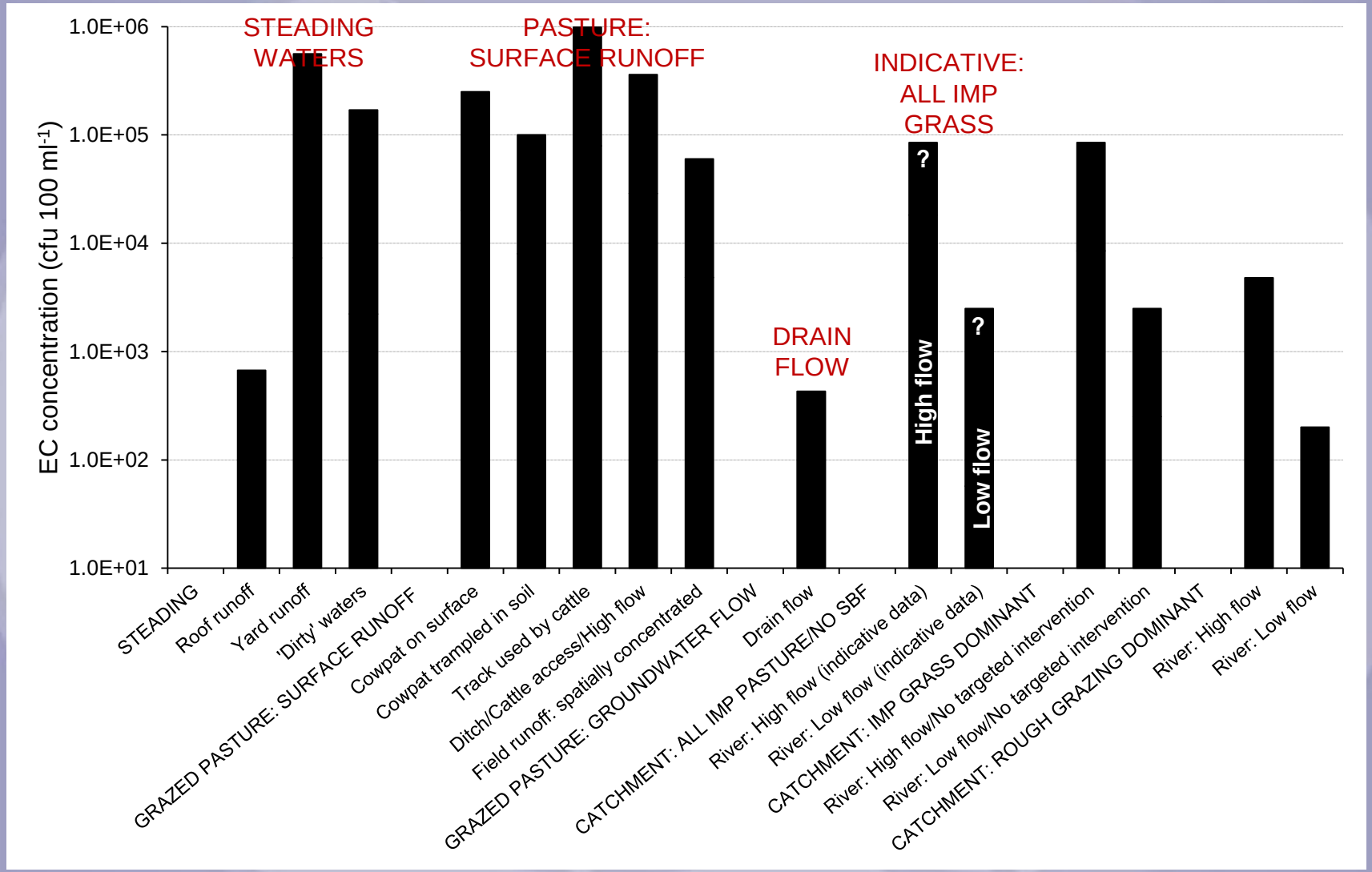
EC concentrations: Conventional slurry with subsequent batch storage



EC concentrations: Conventional FYM with land application and subsequent batch storage



EC concentrations with no targeted improvement: Rural catchments dominated (≥ 66.7%) by improved grassland and rough grazing



EC concentrations with no targeted improvement: Rural catchments dominated (≥ 66.7%) by improved grassland and rough grazing

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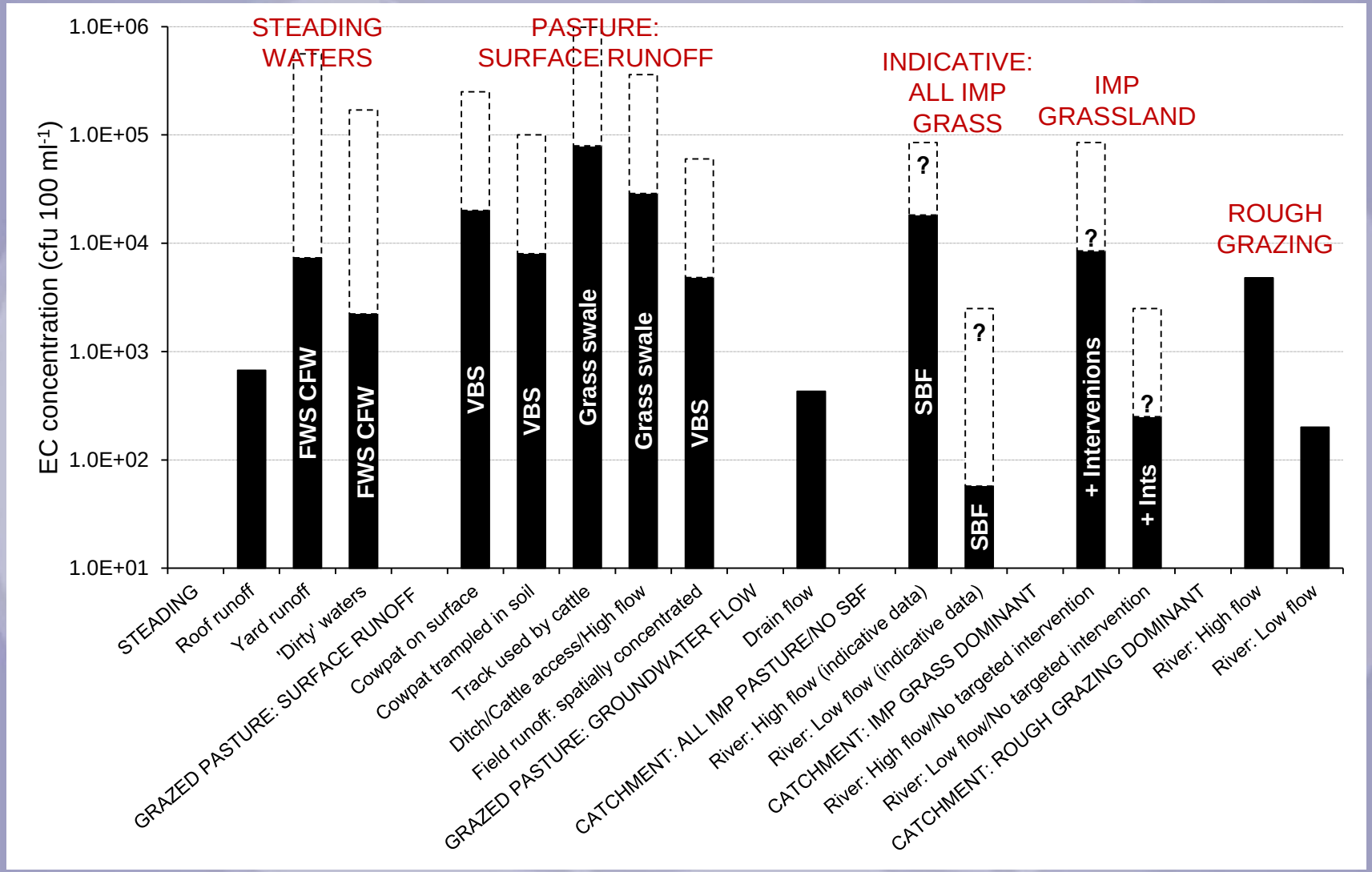

EC concentrations in catchment waters: Effectiveness of intervention measures

Case Study?

- Brighouse Bay Scotland
- Paired catchments
- Before and after study
- Mature and immature BMPs

Available online at www.sciencedirect.com
ScienceDirect
Environmental Pollution 147 (2007) 138–149
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Reducing fluxes of faecal indicator compliance parameters to bathing waters from diffuse agricultural sources: The Brighouse Bay study, Scotland

D. Kay [a,*], M. Aitken [b,1], J. Crowther [a], I. Dickson [b], A.C. Edwards [c,2], C. Francis [d], M. Hopkins [a], W. Jeffrey [b], C. Kay [a], A.T. McDonald [e], D. McDonald [a], C.M. Stapleton [a], M.D. Wyer [a], J. Wilkinson [f]

[a] River Basin Dynamics and Hydrology Research Group, IGES, University of Wales, Llandinam Building, Aberystwyth SY23 3DB, UK
[b] SAC Environmental, SAC, Bush Estate, Penicuik EH26 0PH, UK
[c] The Macaulay Institute, Craigiebuckler, Aberdeen AB15 8QH, UK
[d] CREH Analytical, Hoyland House, Hoyland, Barnsley S74 9BT, UK
[e] School of Geography, University of Leeds, Leeds LS2 9JT, UK
[f] Department of Earth Sciences, Flinders University, GPO Box 2100, Adelaide 5001, Australia

Received 3 August 2006; accepted 10 August 2006

Diffuse microbiological pollution from farming activities can be reduced by protected riparian zones.

Abstract

CREH

Sampling Periods

Study Period	Timing	No.
Pre-remediation	15th Oct to 14th Nov 2003	430
Post-remediation	6th-23rd July 9th-20th Aug 2004	595
Post-maturation	1st August to 4th October 2007	435

SAC

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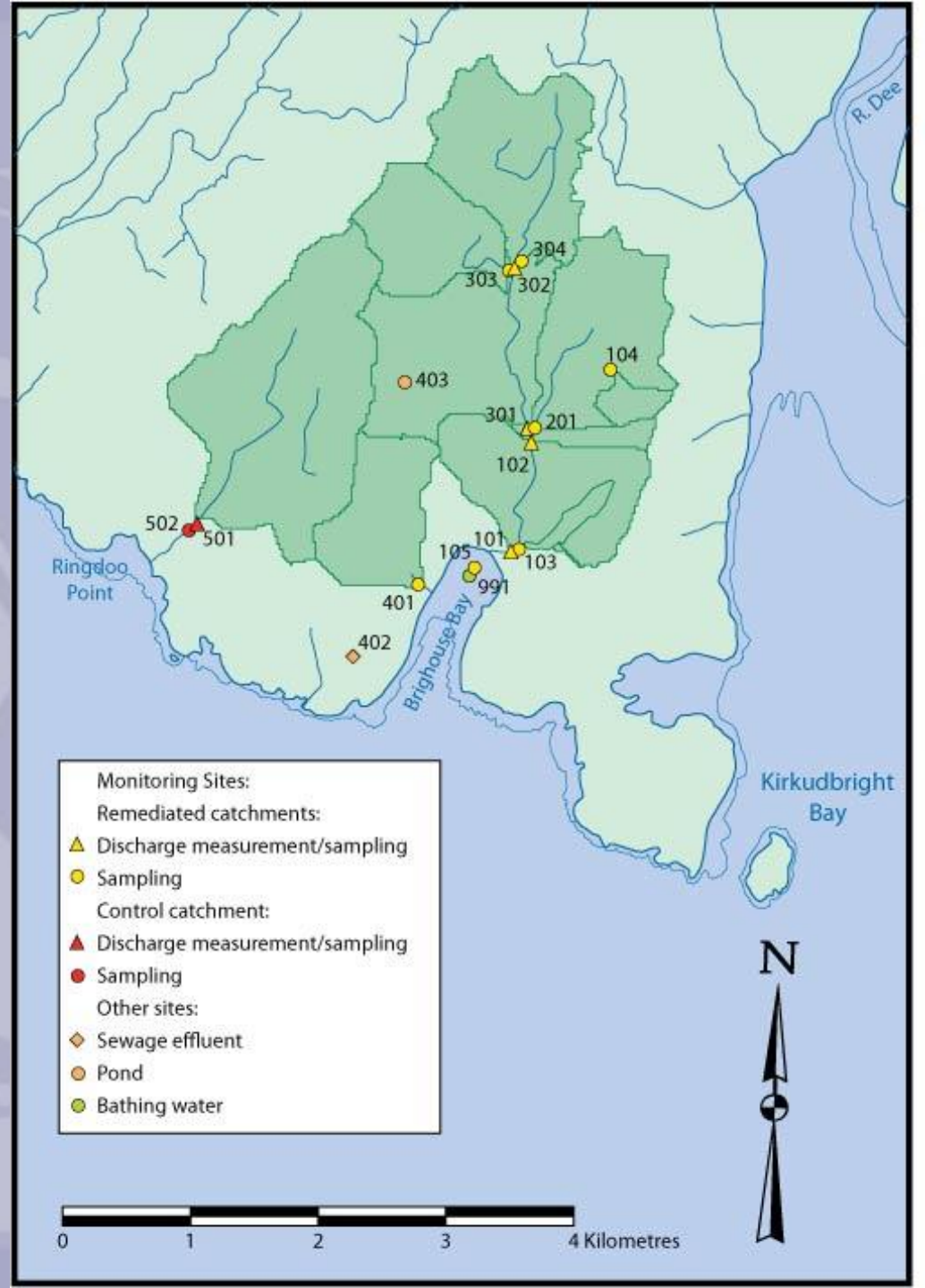
Sample locations in the Brighouse Bay and Borness Burn Catchments



Before

After

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Some BMPs in 2007

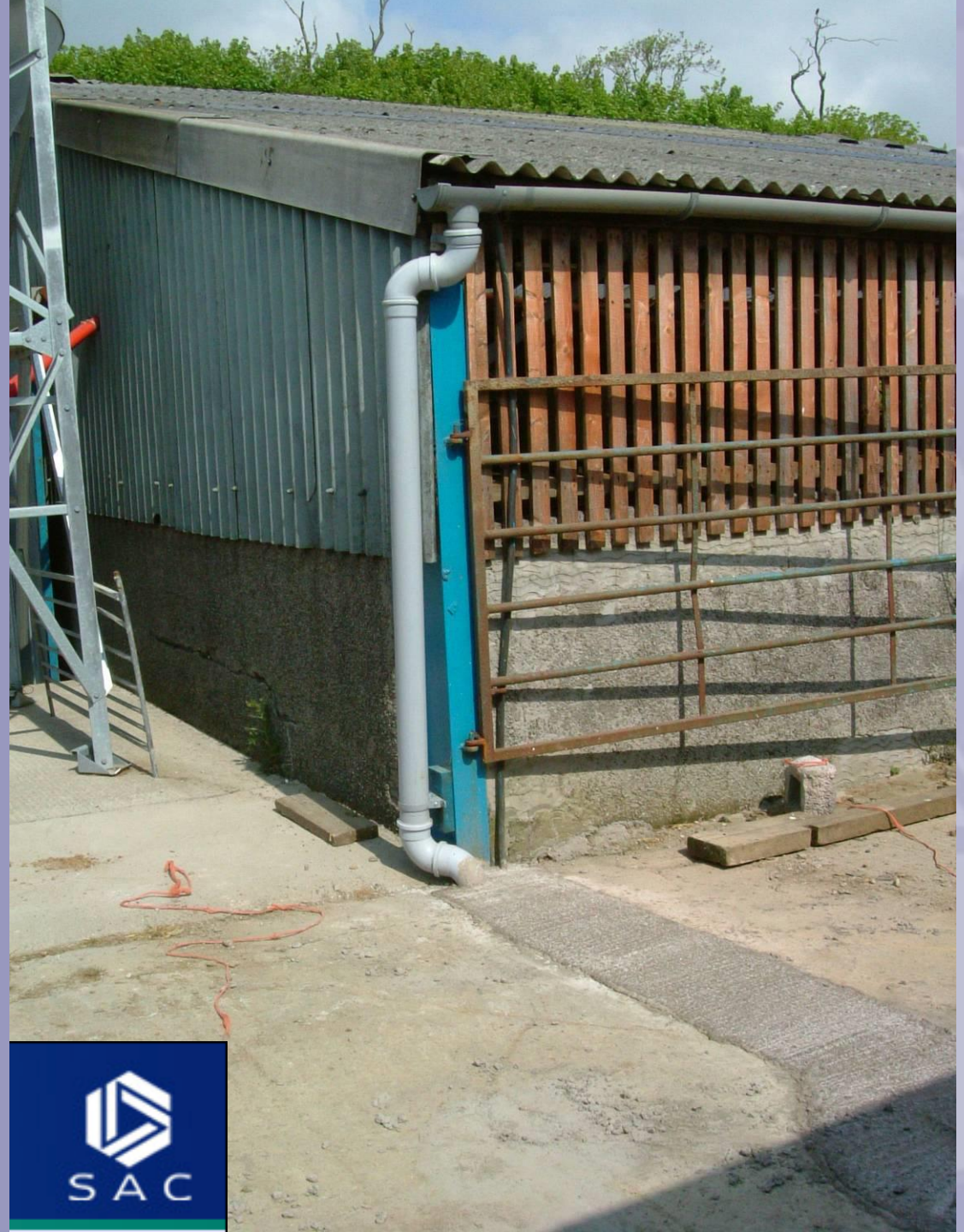
CREH


Site 304


R. Dee
304
303
302
104
403
301
201
102
502
501
101
105
103
991
401
402
Brighouse Bay
Kirkudbright Bay
Monitoring Sites:
Remediated catchments:
Discharge measurement/sampling
Sampling
Control catchment:
Discharge measurement/sampling
Sampling
Other sites:
Sewage effluent
Pond
Bathing water
N
0
1
2
3
4 Kilometres

SAC

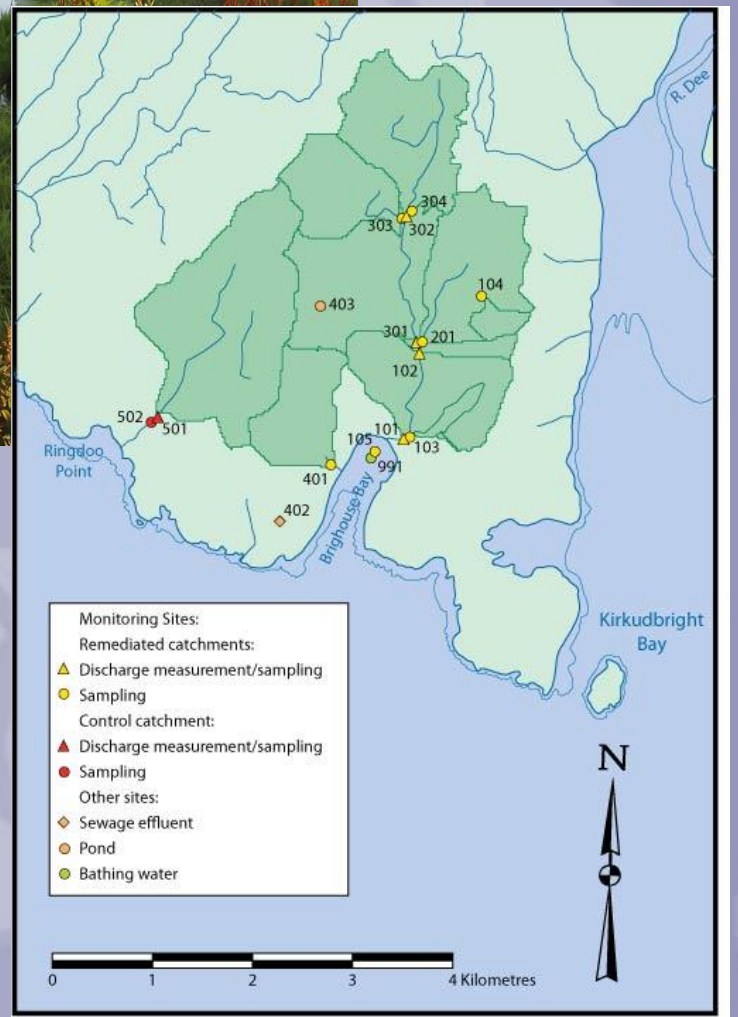
CREH



Roof drainage collection to prevent mixing and transport with faecal matter on yards.

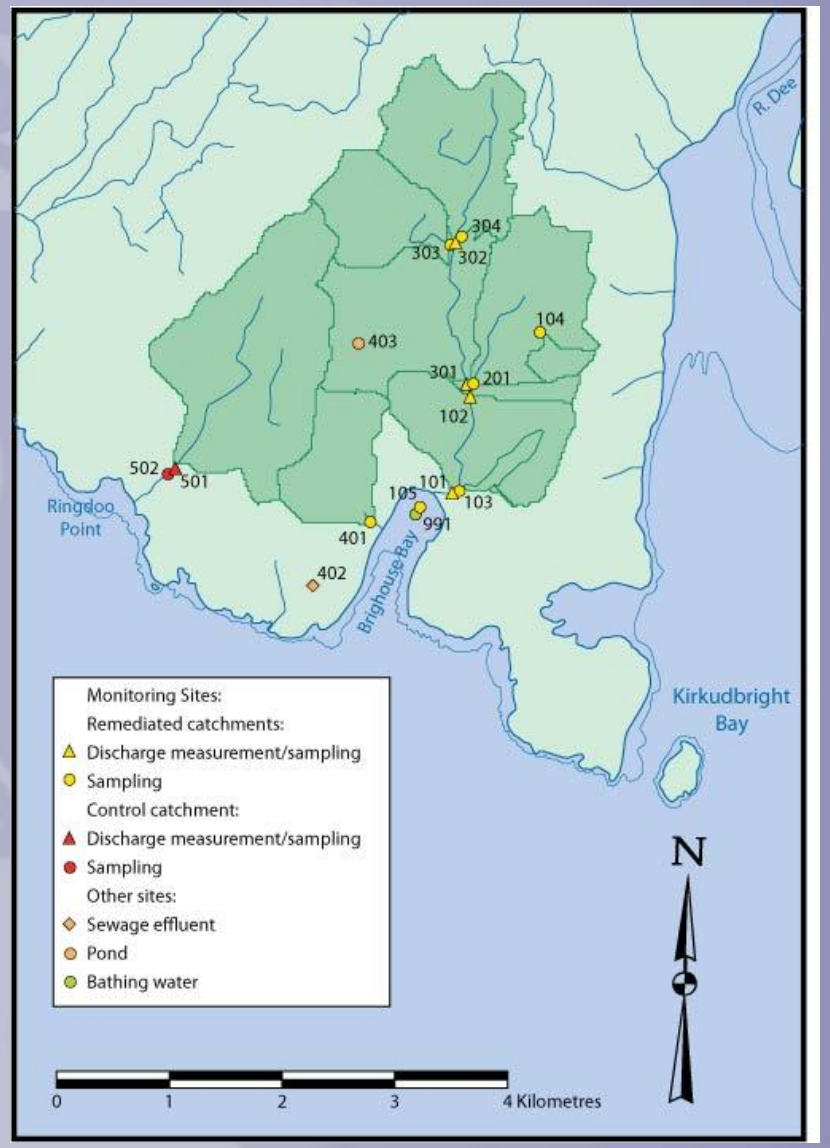
Site 403 2007

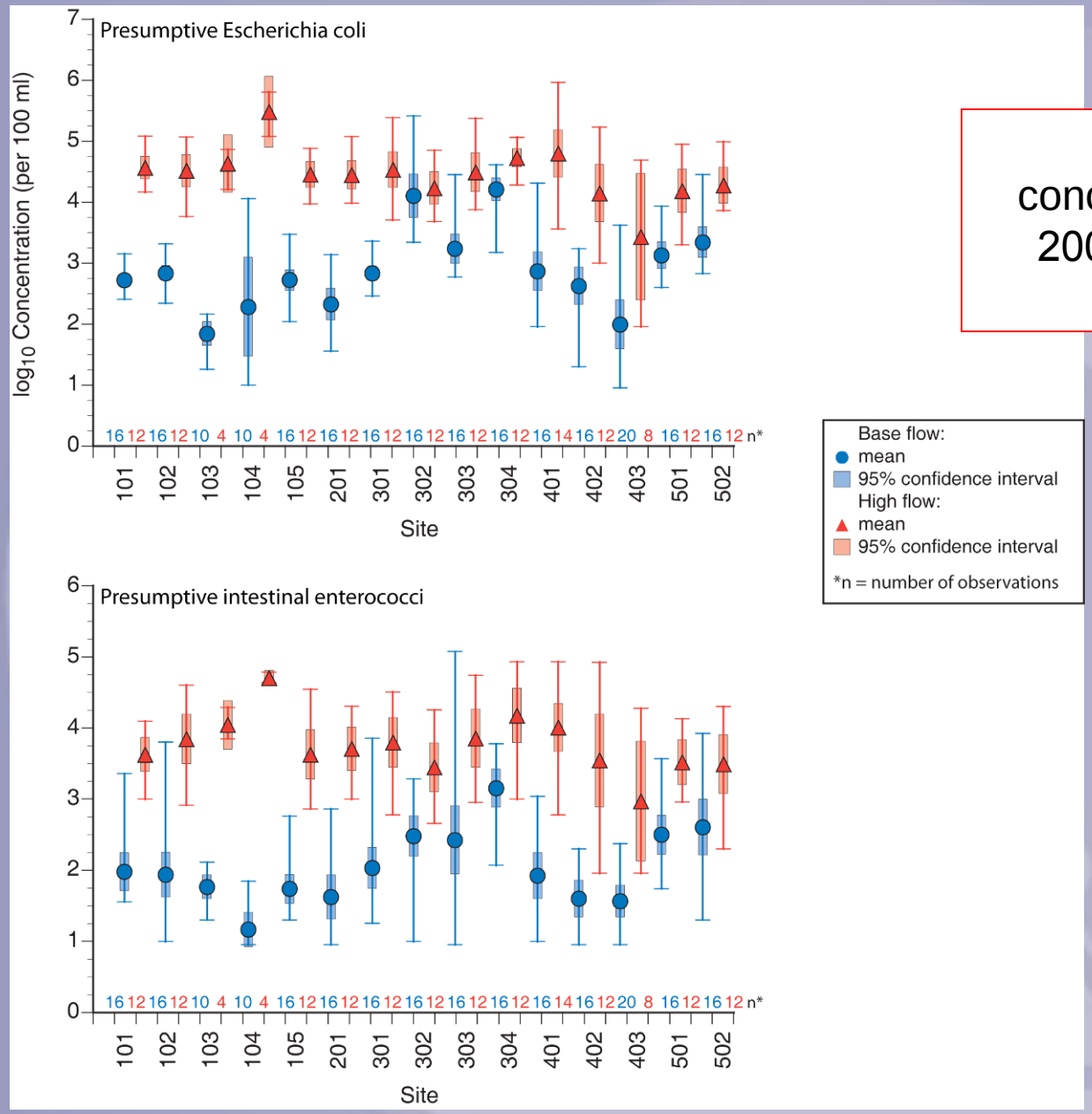
26th May 2004



SAC

Site 501


R. Dee
304
303
302
104
403
301
201
102
502
501
101
105
103
991
401
402
Ringdoo Point
Brighouse Bay
Kirkudbright Bay
Monitoring Sites:
Remediated catchments:
Discharge measurement/sampling
Sampling
Control catchment:
Discharge measurement/sampling
Sampling
Other sites:
Sewage effluent
Pond
Bathing water
N
0
1
2
3
4 Kilometres



Faecal indicator concentrations during the 2007 ‘mature’ sampling phase

SAC

CREH

Summary

- The Brighouse Bay study does provide empirical evidence that:
  - after remediation stream high flow
    - 10^{4-5} *E. coli*/100ml
    - 10^{3-4} IE/100m
  - the installed BMPs (principally stream bank fencing) can significantly reduce FIO flux to protected areas by ~ 80%; and
  - FIO flux at catchment outlets responds quickly to stock management BMPs.

Conclusion

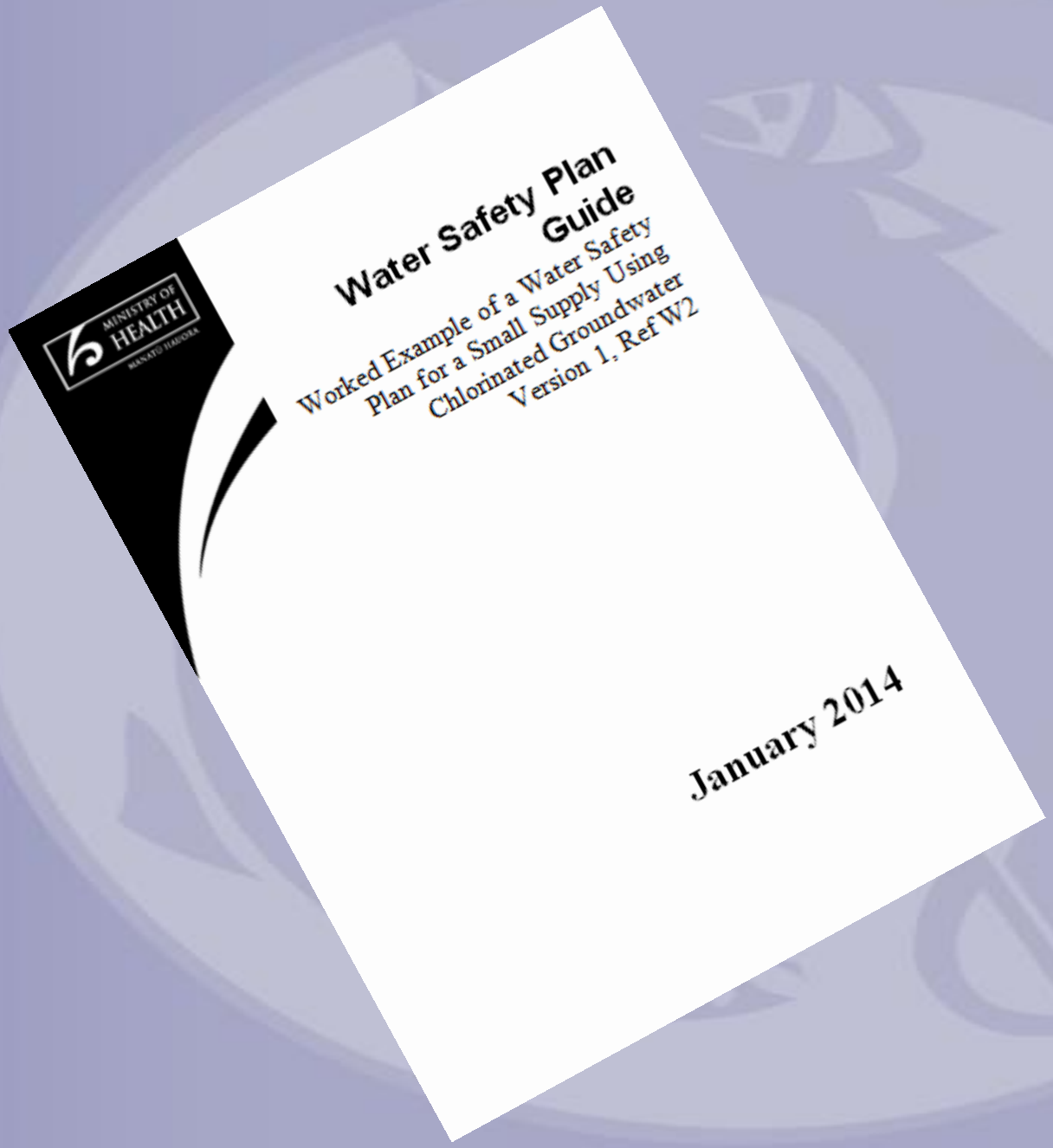
In livestock farming areas:

- Sanitary profiling and intensive BMPs will may not produce potable water quality

For a high risk supply like Haveloch North:

- Treatment to potable standards would still be advised given implementation of all feasible BMPs excluding de-stocking.

thence


MINISTRY OF HEALTH
MANATŪ HAUORA
Water Safety Plan Guide
Worked Example of a Water Safety Plan for a Small Supply Using Chlorinated Groundwater
Version 1, Ref W2
January 2014

Reports and Papers

dave@crehkay.demon.co.uk

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