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Evaluating landfill aftercare strategies: a life-cycle assessment approach

Landfill Aftercare Forum, Birmingham, 9th June 2016

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Introduction

Landfill Aftercare – key issues

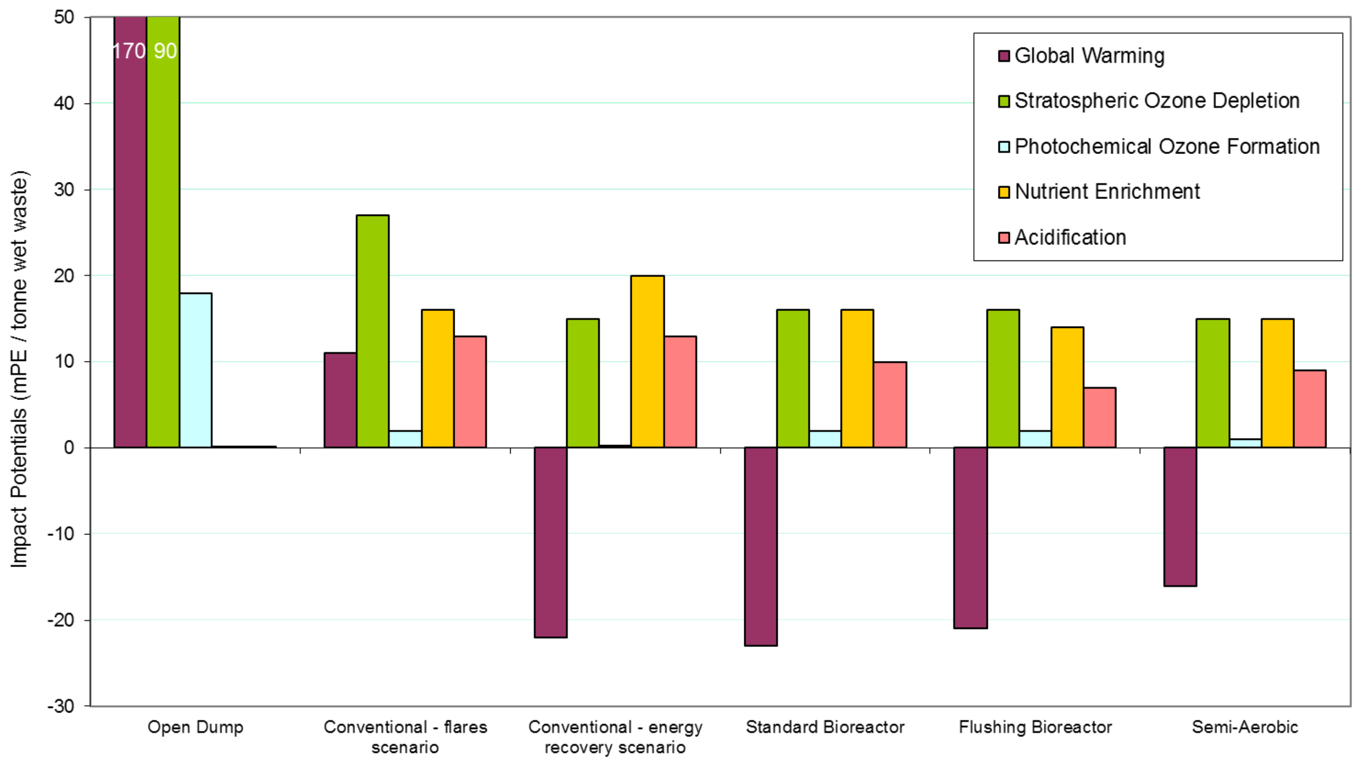
- Landfills have a significant pollution potential & may contribute to a range of environmental impacts[1]
- Typical landfill management leads to aftercare timescales of 100s - 1000s years before FSQ[2,3]
- Unresolved post-landfill closure issues:
  - Uncertain funding[4]
  - Possible **loss of active control systems** for a period of time
  - Burden & impact on future generations

[1] Christensen *et al.*, 2011
[2] Knox, 1990
[3] Knox *et al.*, 2005
[4] Beaven *et al.*, 2014

Introduction

Life cycle assessment (LCA)

- Well-established, standardised methodology (ISO 14040 & 14044)
- Accounts for all resource use & emissions during complete life cycle
- Aggregates emissions into impact categories
- Impacts can be normalised to person equivalents (PE)



Source: Manfredi & Christensen (2009)

Introduction

Life cycle assessment (LCA)

- LCA has been extensively applied to evaluate landfill[e.g. 1,2,3]

- Most previous LCA studies of landfills use 100 year timeframe[e.g. 1,4,5]

- Existing LCA tools (e.g. WRATE & EASETECH) unsuitable for modelling the effect of active control loss on landfill impacts

- No previous LCA studies to evaluate the effect of active control loss on the overall impacts of landfilling

[1] Damgaard *et al.*, 2011
[2] Xing *et al.*, 2013
[3] Turner *et al.*, 2016
[4] Manfredi & Christensen, 2009
[5] Manfredi *et al.*, 2010

Introduction

Goal & scope of the work

Goal

To evaluate the potential impacts of leachate emissions from landfill sites operated with different aftercare strategies, taking into account the effects of potential active control loss

Purpose

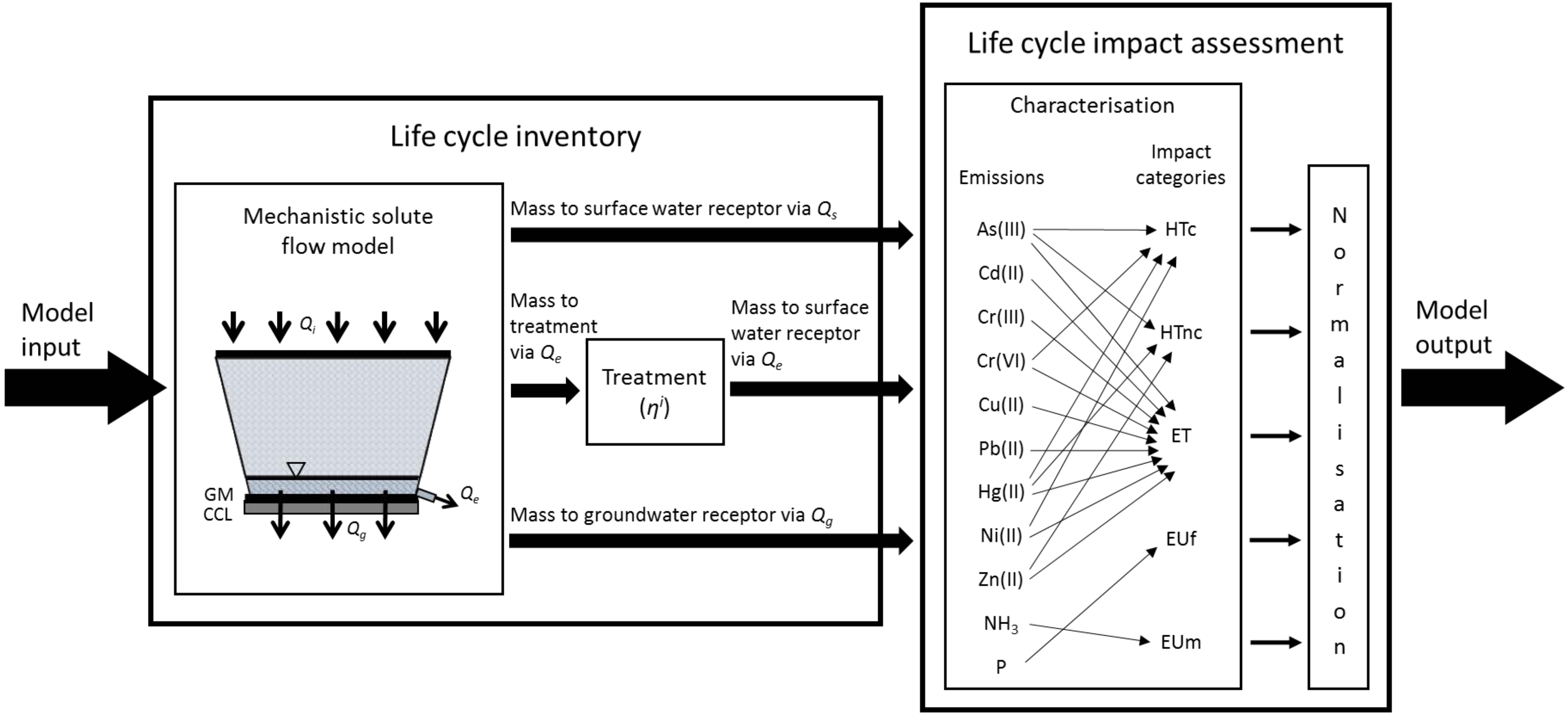
1. To investigate whether LCA can be used to improve our understanding of the long term impacts of landfilling
2. To develop understanding of potential impact of active control loss

Scope ('functional unit')

- Leachate emissions over a 10,000 year time horizon
- Completed non-hazardous MSW landfill site of 10,000 m^2 x 20 m

Method

Integrated solute flow model & LCA approach

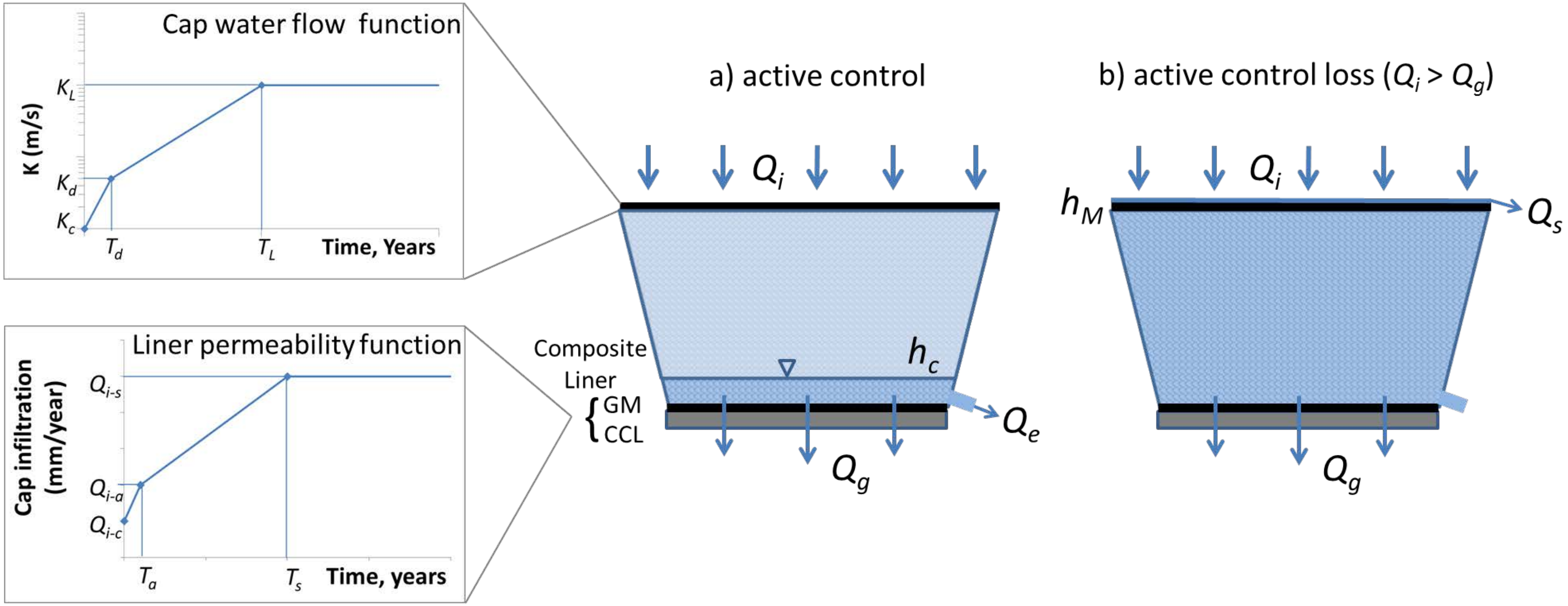


Schematic of integrated solute flow model and LCA approach

Impact categories:
HTc, carcinogenic human toxicity; HTnc, non-carcinogenic human toxicity; ET, ecotoxicity; EUf, freshwater eutrophication; EUm, marine eutrophication

Method

Mechanistic water flow & solute movement model



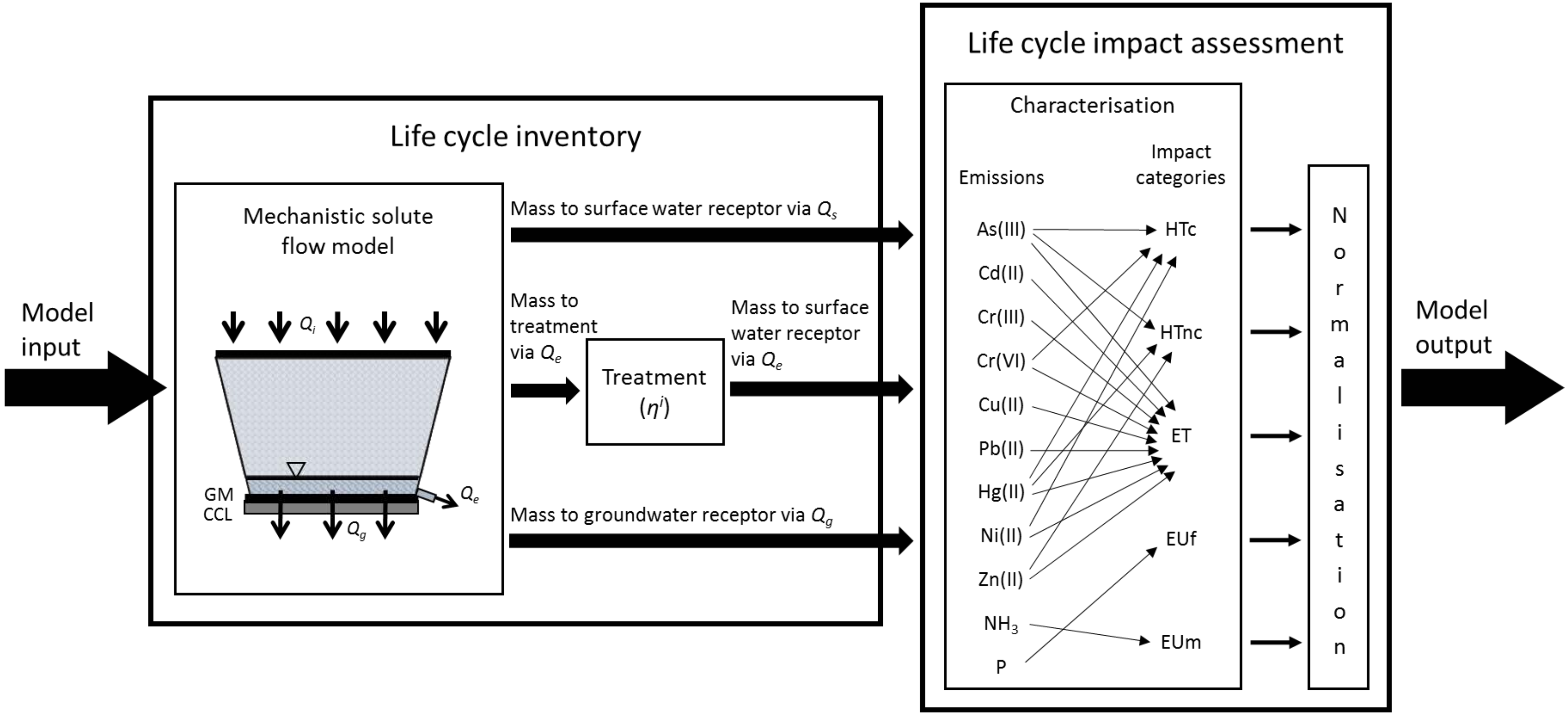
Schematic of the mechanistic model under conditions of:

a) active control (i.e. leachate collected for treatment)

b) active control loss (i.e. leachate not collected for treatment) & where Q_i > Q_g → overtopping

Method

Integrated solute flow model & LCA approach



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Method

Aftercare scenarios

Description of landfill aftercare scenarios

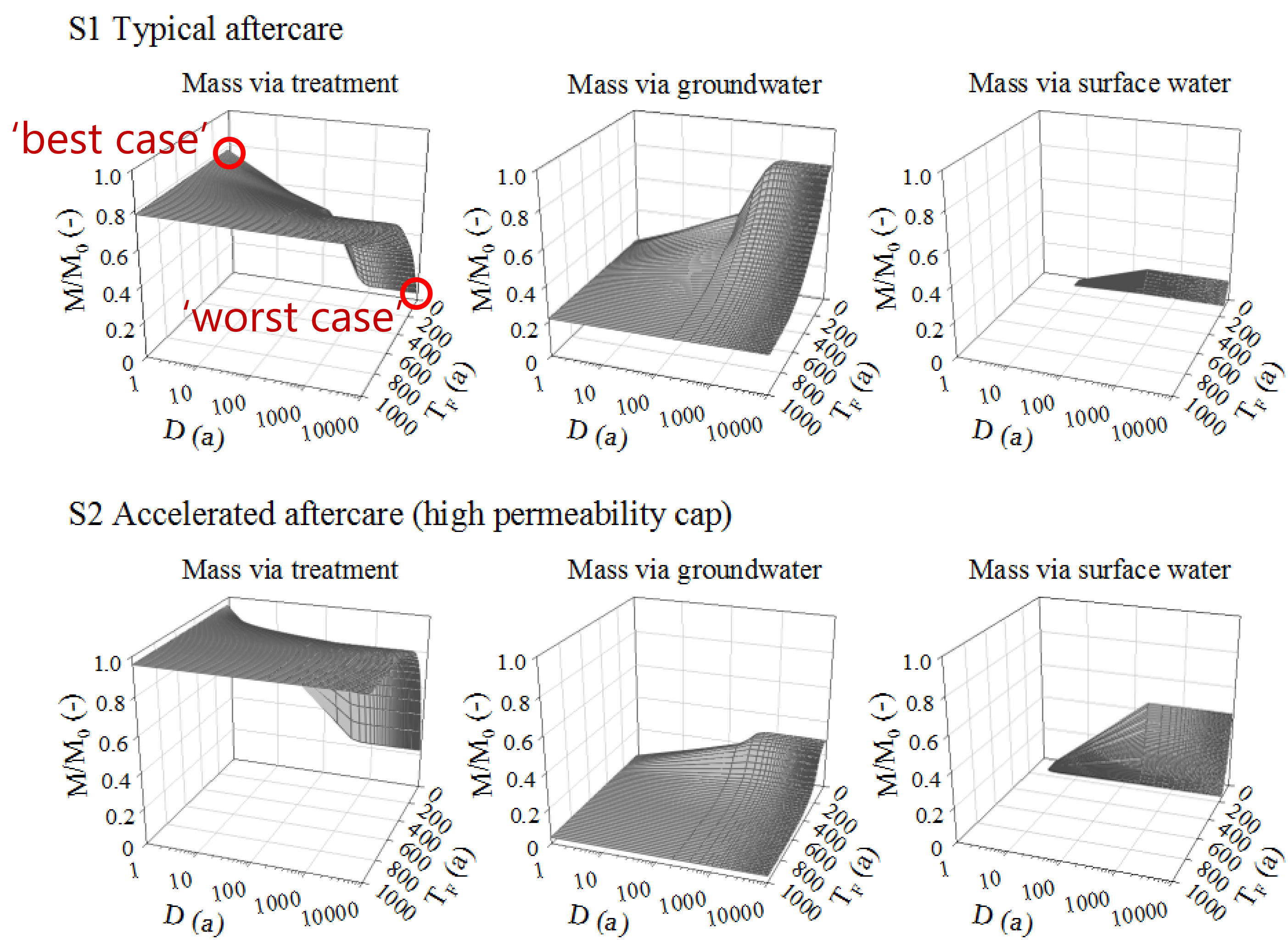
Scenario		Description
S1	Typical aftercare	High quality, low permeability cap
S2	Accelerated aftercare (high permeability cap)	High permeability cap
S3	Accelerated aftercare (30 year moisture injection)	High permeability cap; additional moisture injection during 30 year active aftercare operations period
S4	Accelerated aftercare (60 year moisture injection)	High permeability cap; additional moisture injection during 60 year active aftercare operations period

Model input parameter values assigned for each aftercare scenario

		Value			
Parameter	**Unit**	**S1**	**S2**	**S3**	**S4**
Design flow through cap	mm/a	50	250	1,000	1,000
Flow through cap at end of ‘active aftercare period’	mm/a	60	250	1,000	1,000
Flow after cap has reached end of service life	mm/a	250	250	250	250
Time at end of ‘active aftercare operations period’	a	30	30	30	60
Time at end of cap ‘service life’	a	1,000	30	30	60

Results

Solute flows by pathway & scenario



T_F = time at which leachate no longer removed to treatment

D = duration of period where leachate not removed

Results

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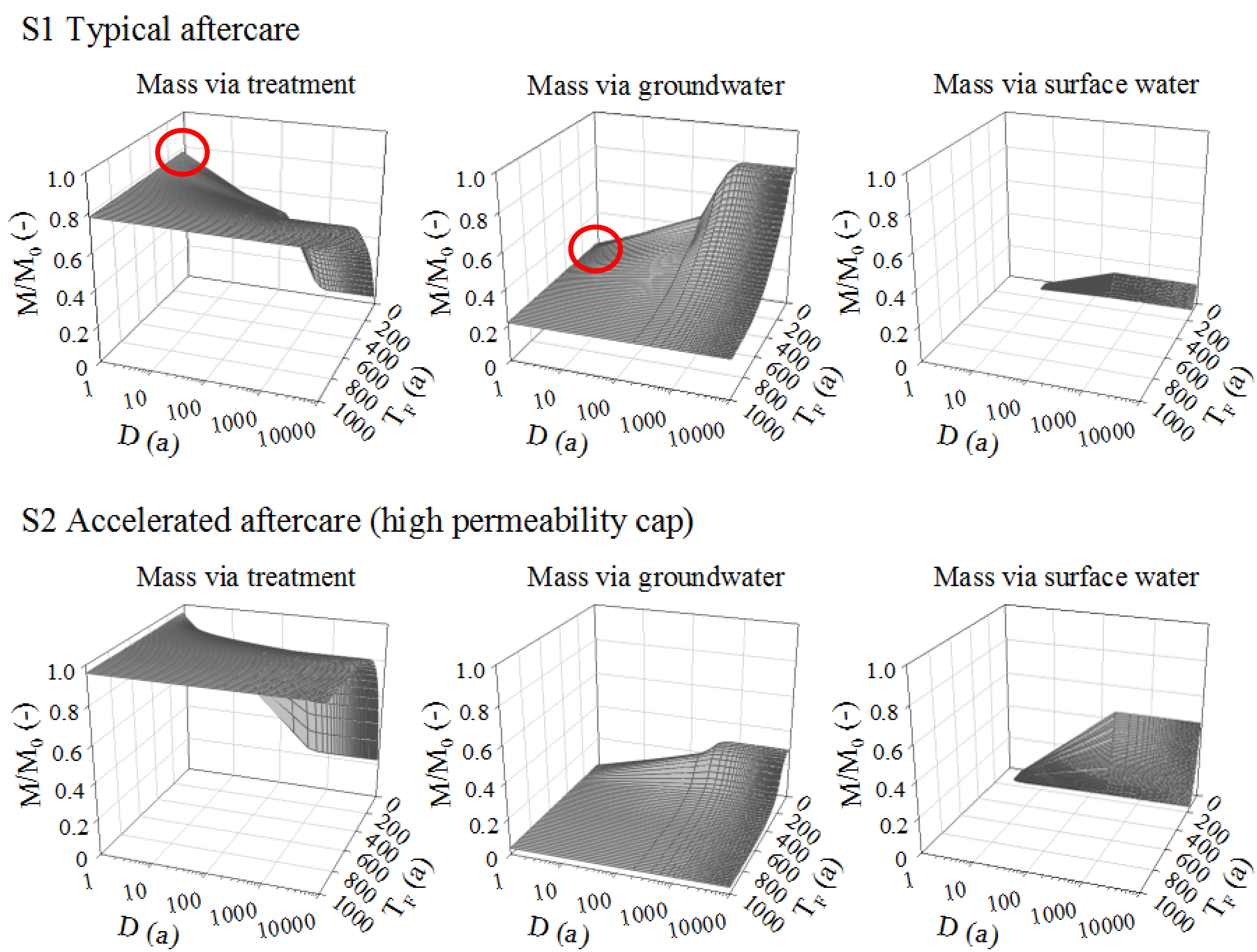

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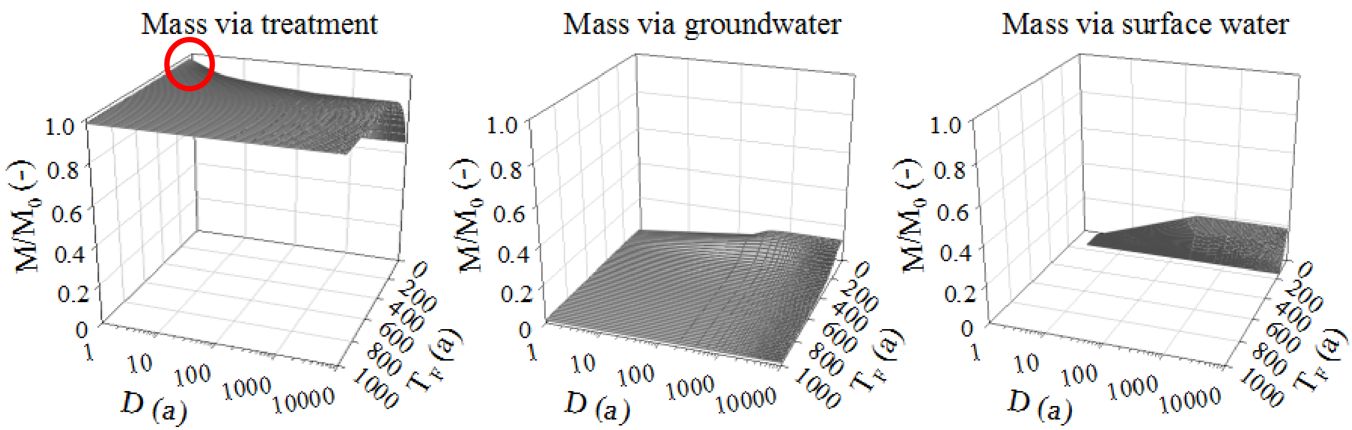
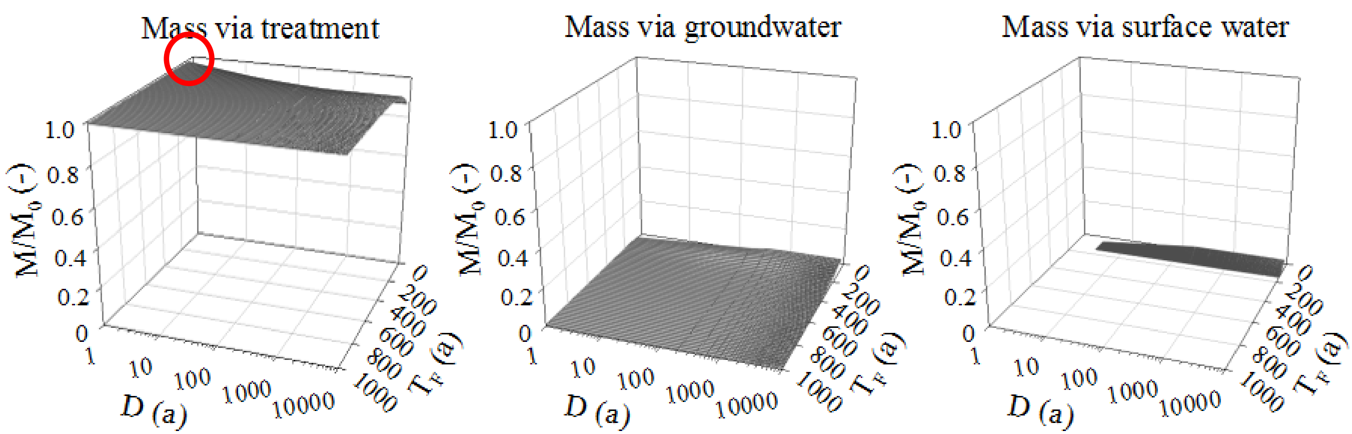
Solute flows by pathway & scenario

S3 Accelerated aftercare (30 year moisture addition)



S4 Accelerated aftercare (60 year moisture addition)



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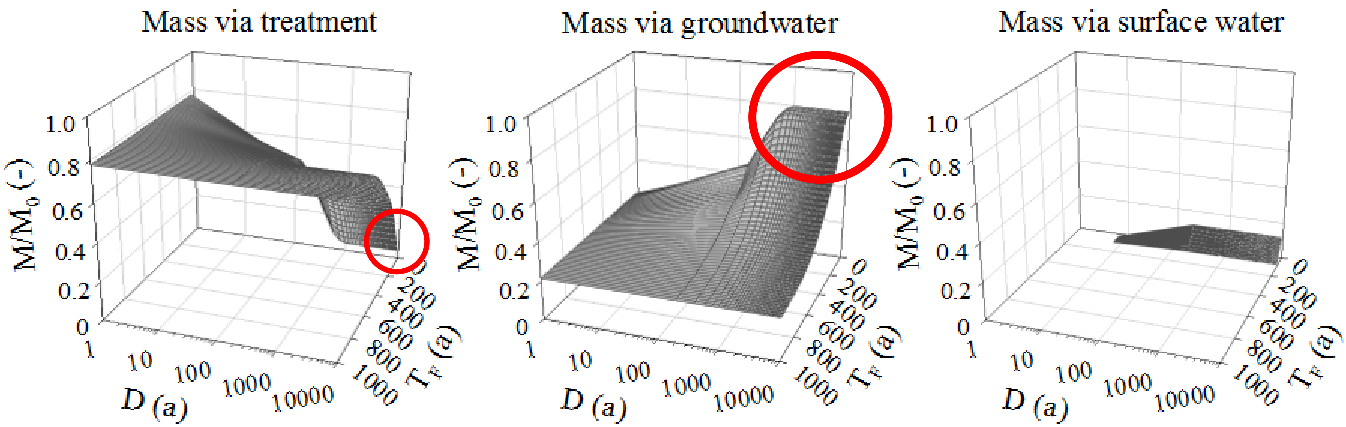
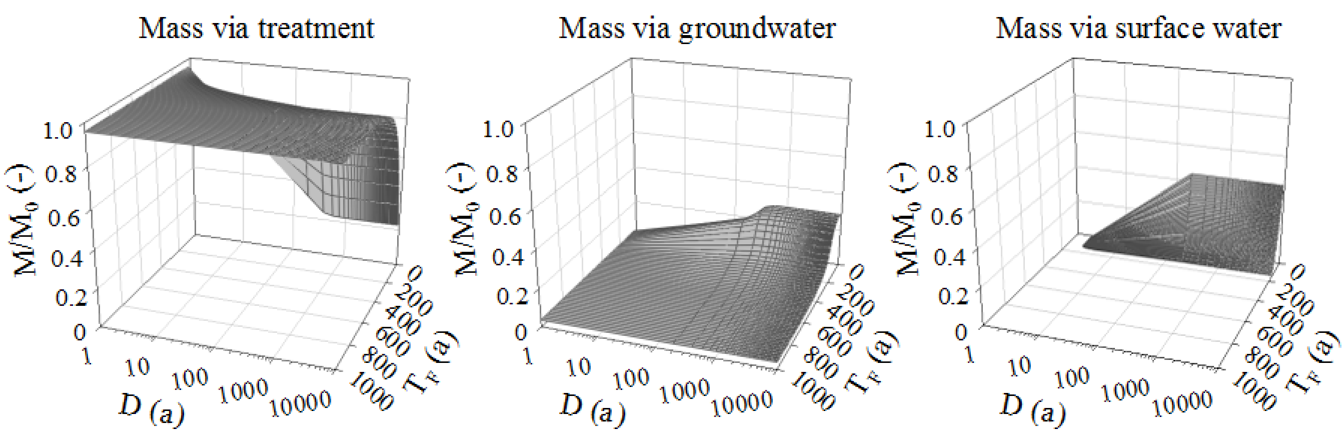


S2 Accelerated aftercare (high permeability cap)



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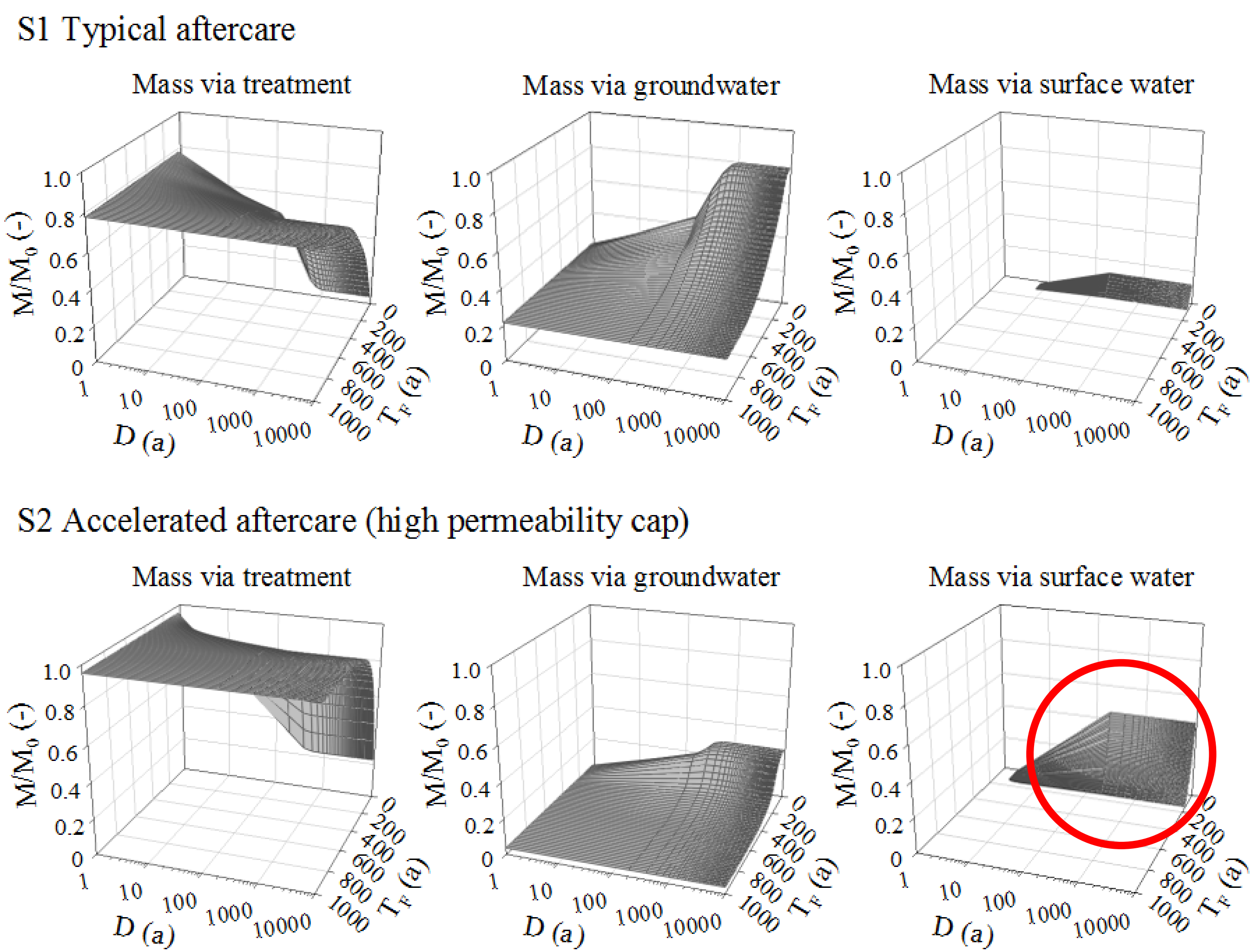

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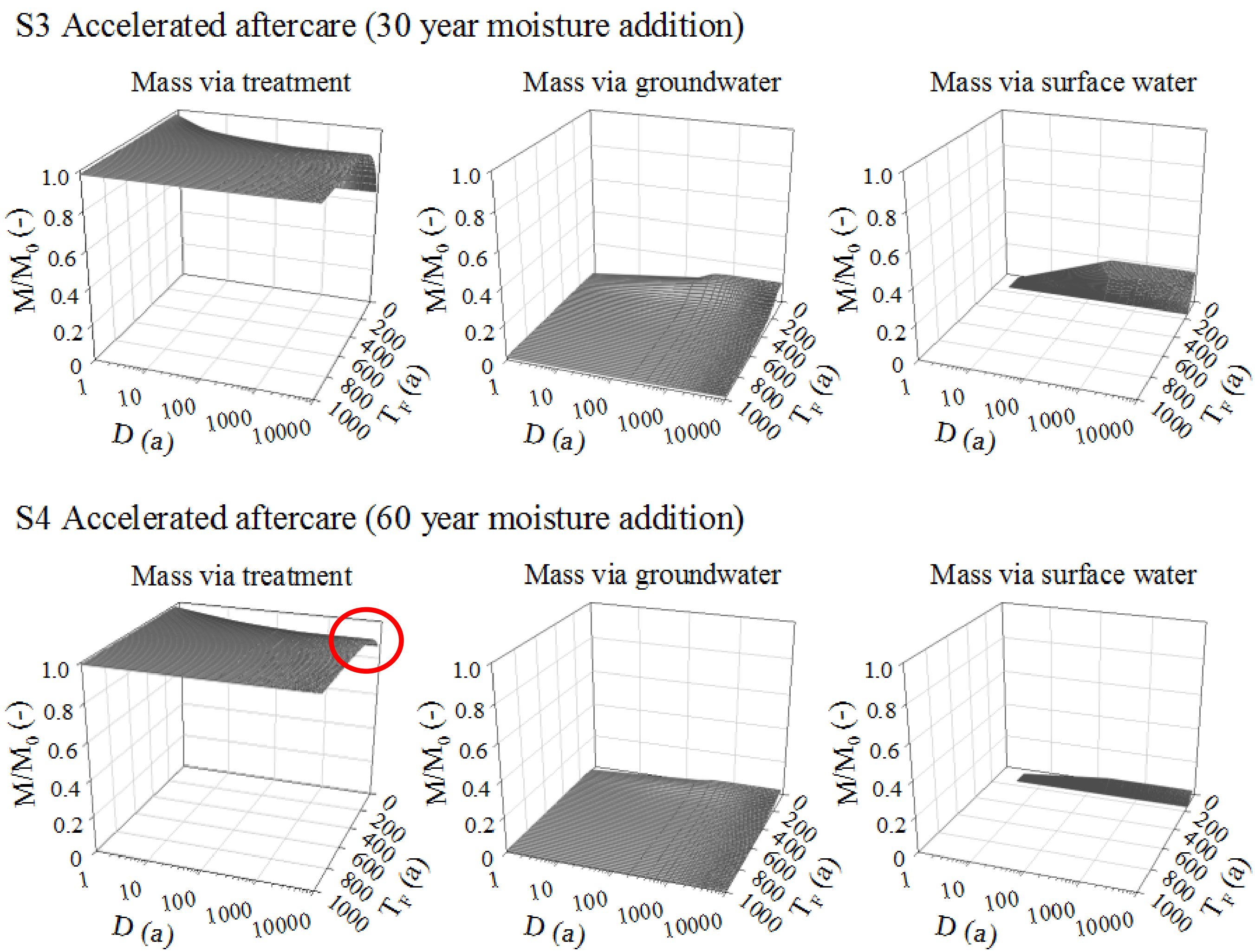

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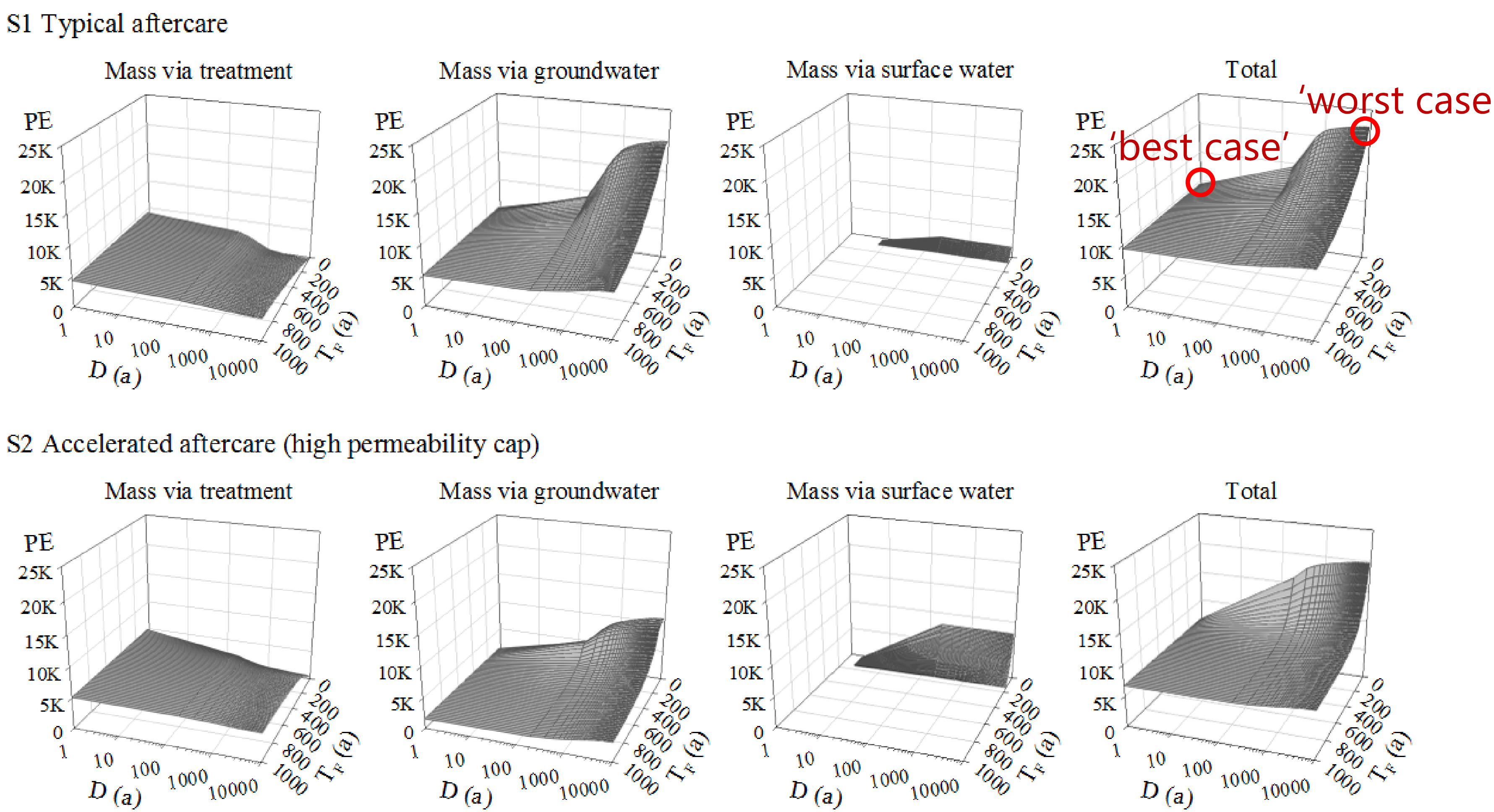
Results

Total normalised potential impacts by pathway & scenario



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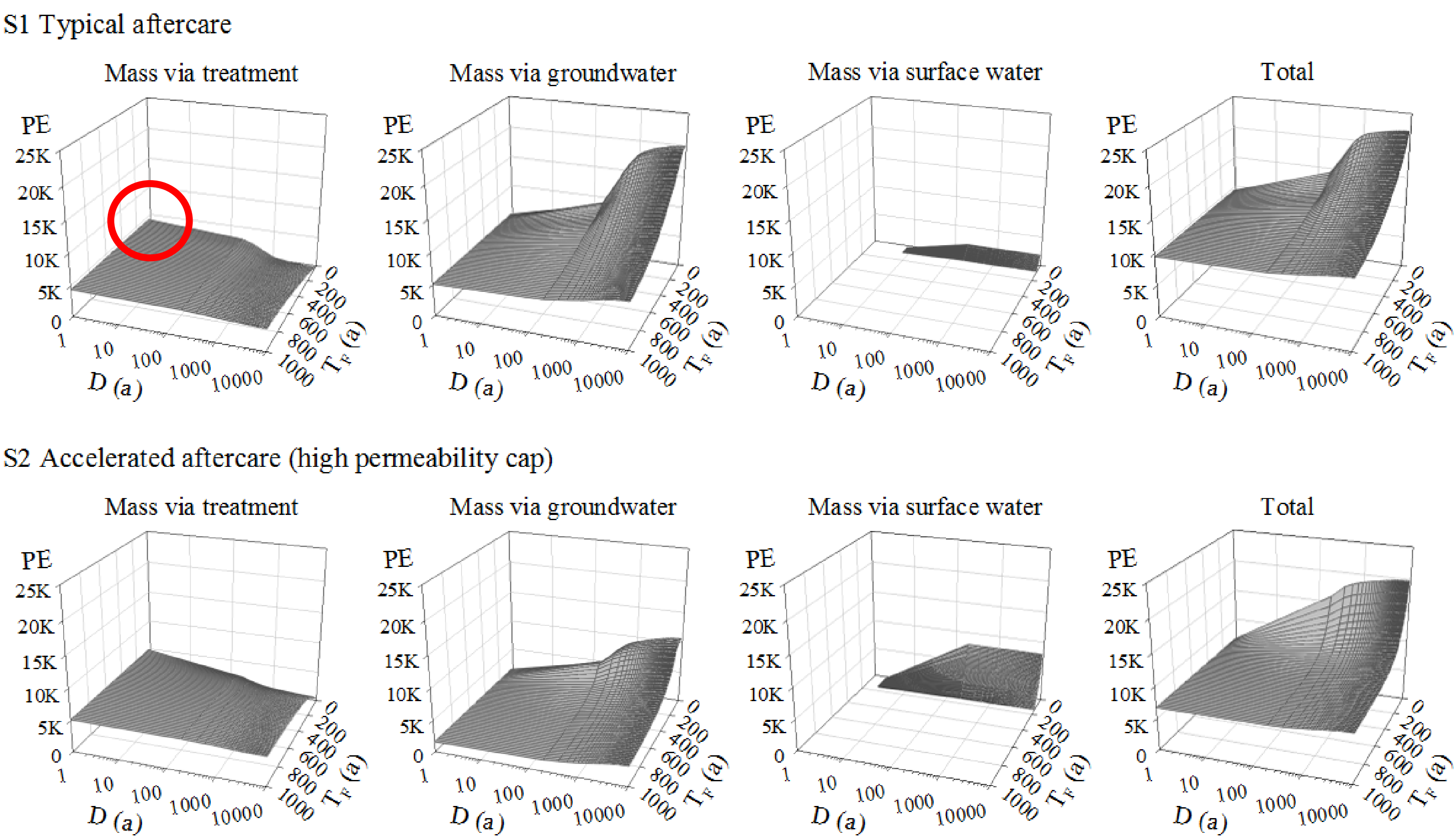

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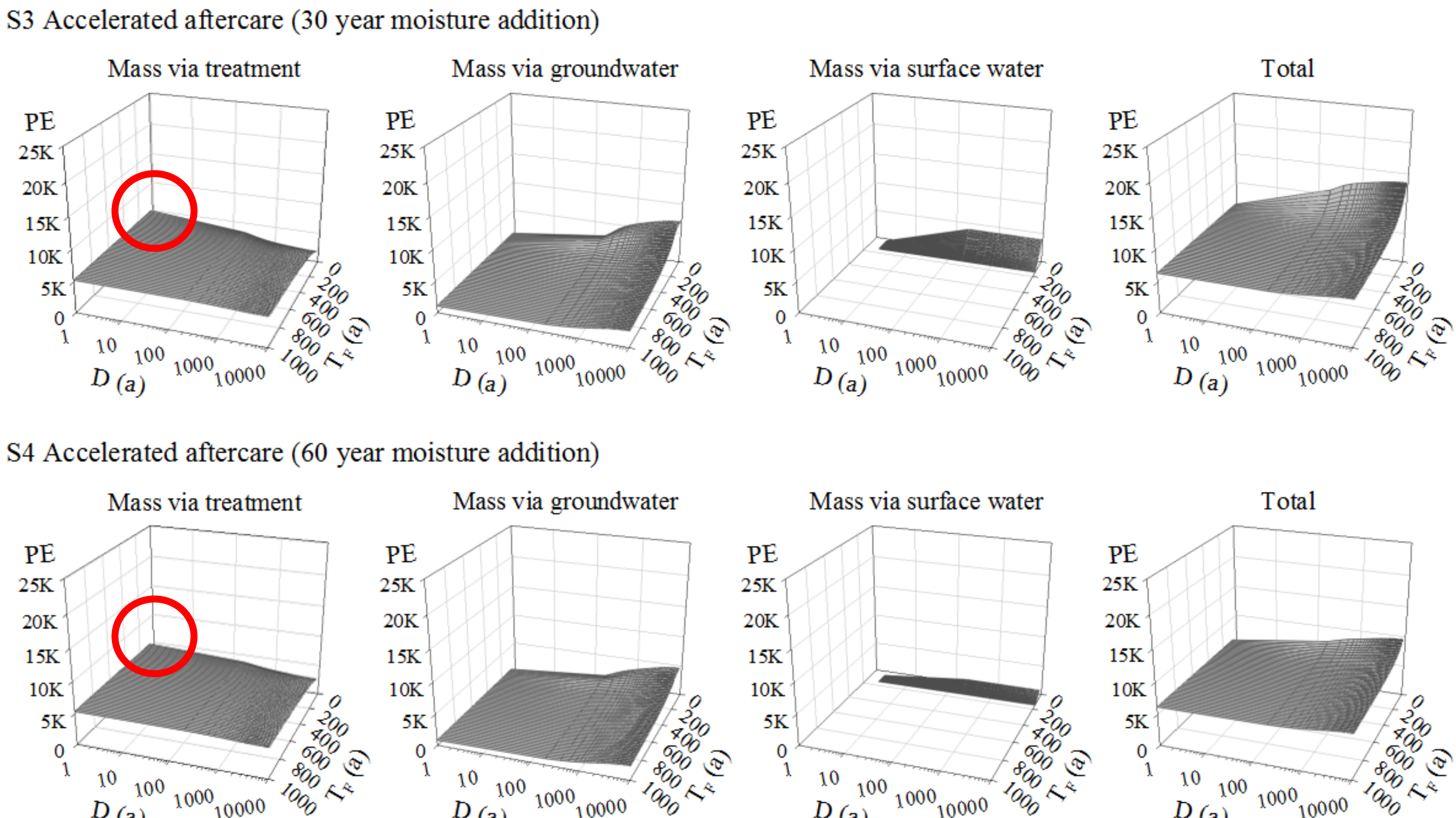

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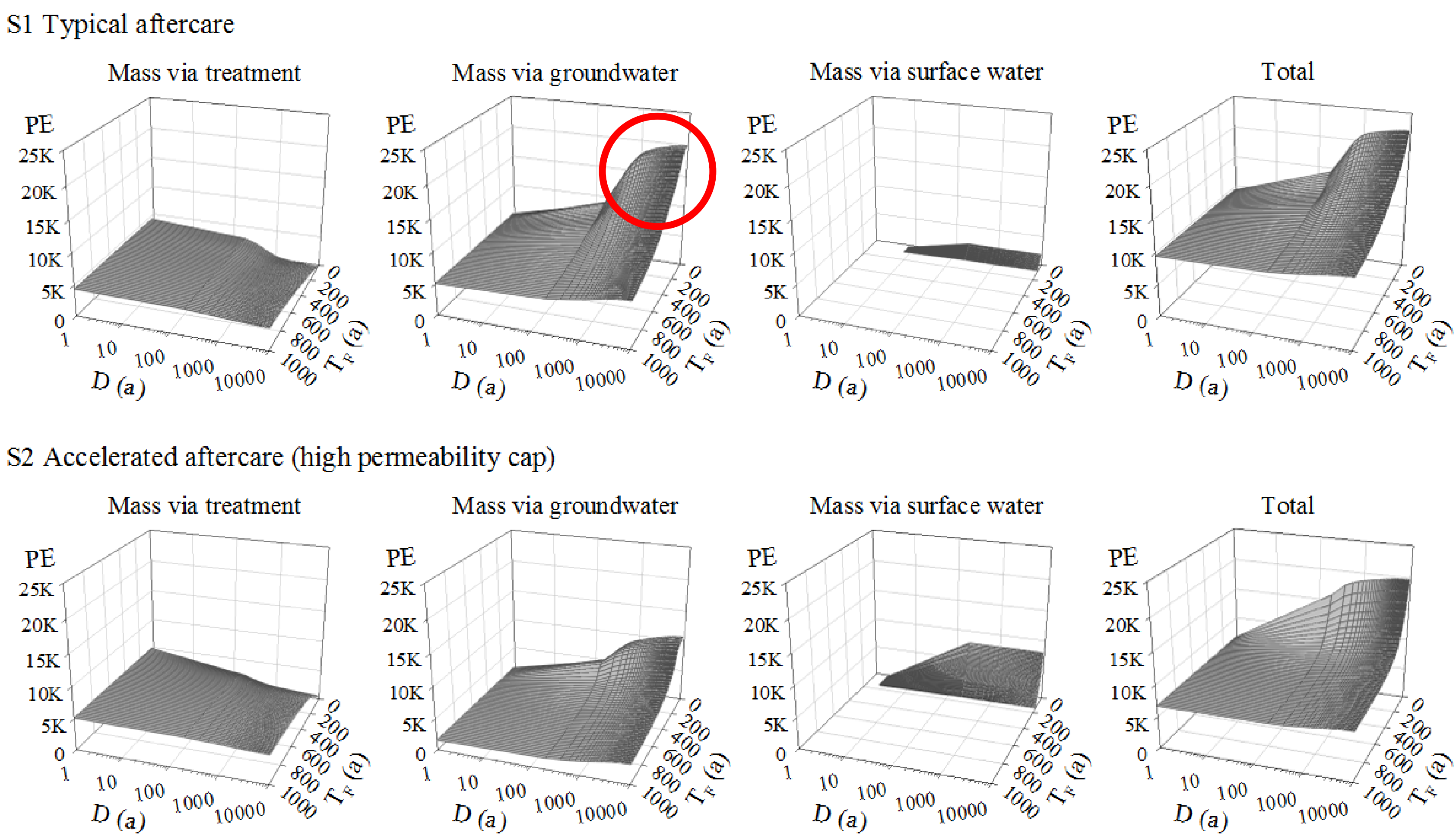

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Results

Comparison of scenarios

	Active control situation				
	'Best case' (PE[a])	'Best case' (PE/t)	'Worst case' (PE)	'Worst case' (PE/t)	Increase on 'best case' (%)
S1 Typical aftercare	**9,530**	**0.060**	**22,560**	**0.14**	**136**
Ecotoxicity	4,390	0.027	8,080	0.051	84
Marine eutrophication	2,640	0.017	10,600	0.066	302
S2 Accelerated aftercare (high permeability cap)	**6,760**	**0.042**	**20,050**	**0.13**	**197**
Ecotoxicity	3,750	0.023	7,660	0.048	104
Marine eutrophication	630	0.004	8,590	0.054	1263
S3 Accelerated aftercare (30 year moisture injection)	**6,400**	**0.040**	**13,880**	**0.087**	**117**
Ecotoxicity	3,640	0.023	6,440	0.040	77
Marine eutrophication	400	0.003	3,870	0.024	868
S4 Accelerated aftercare (60 year moisture injection)	**6,210**	**0.039**	**10,220**	**0.064**	**65**
Ecotoxicity	3,560	0.022	5,410	0.034	52
Marine eutrophication	300	0.002	1,430	0.009	377

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Discussion

The use of LCA to evaluate aftercare strategies

- Platform to compare and contrast different aftercare strategies
- LCA can provide a more complete indication of the environmental performance of a site
- BUT life cycle impact assessment purely mass based
  - Potential impacts of a fully controlled landfill only ~3 times better than those of a landfill with no active controls (!)
- Lack of toxicity-related characterisation factors

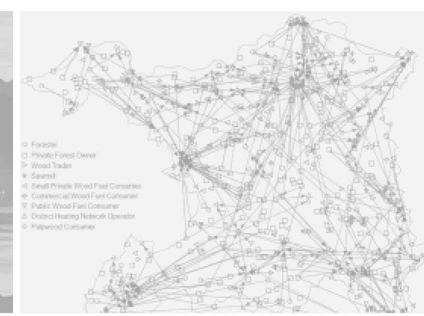
Conclusions
Key findings

- 100 y timeframe insufficient to evaluate impacts of landfilling
- Active control loss found to significantly influence the long-term potential impacts of landfilling
- Largest potential impacts in both the ‘best case’ and ‘worst case’ resulted from the typical aftercare scenario
- Need for more sophisticated life cycle impact assessment

Acknowledgements

- Research undertaken at the University of Southampton
- Financial support provided by EPSRC
- Thanks to Keith Knox & Kerry Rowe for input into the methodology and to Jan Gronow & Terry Coleman for feedback on the paper



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