Point Source Contaminant Exposure and Impacts

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Point source pollution is *still* important

Science & Environment

Sewage discharged into rivers 400,000 times in 2020

By David Brown
BBC News

31 March | Comments

Campaigners are concerned about the impact of sewage discharges on many rivers

SUBSIDIES

NOM

N, P

NH_3

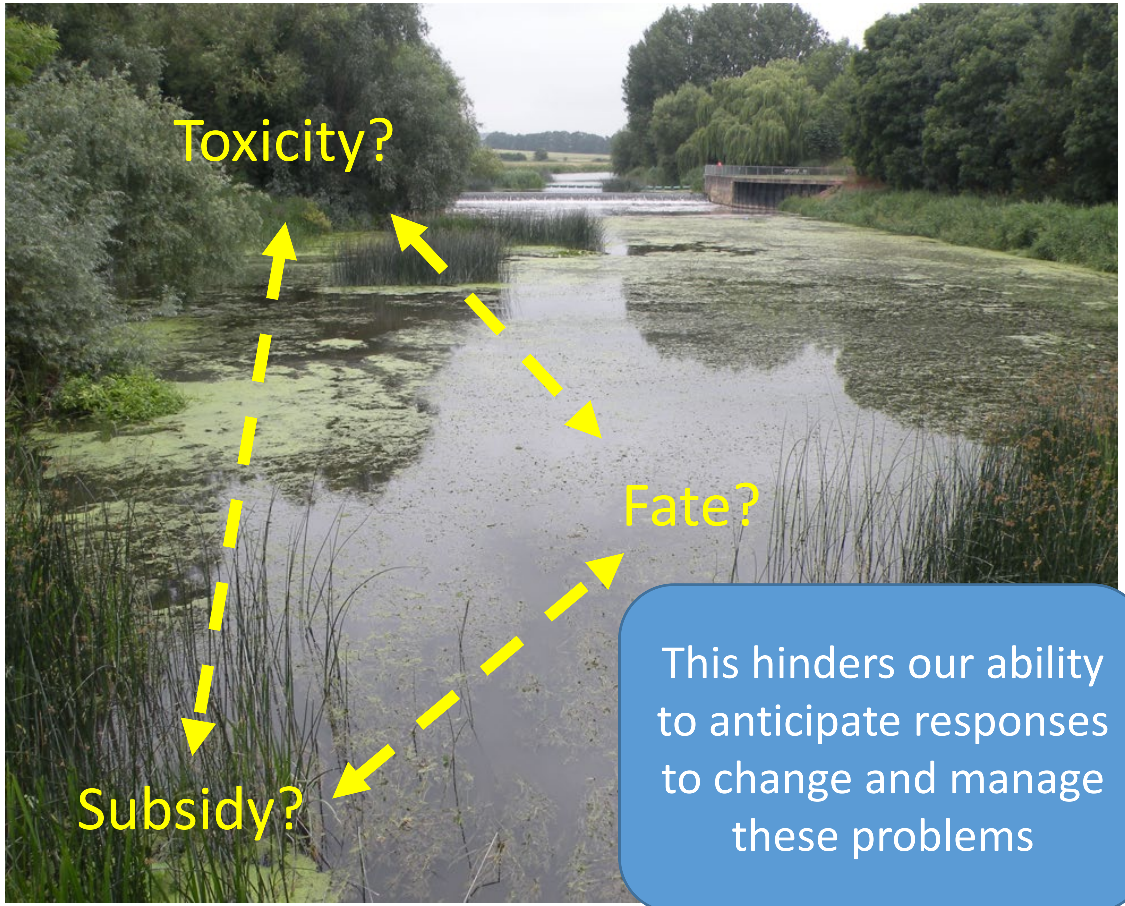
PCPs

PMTs

Hormones

Metals

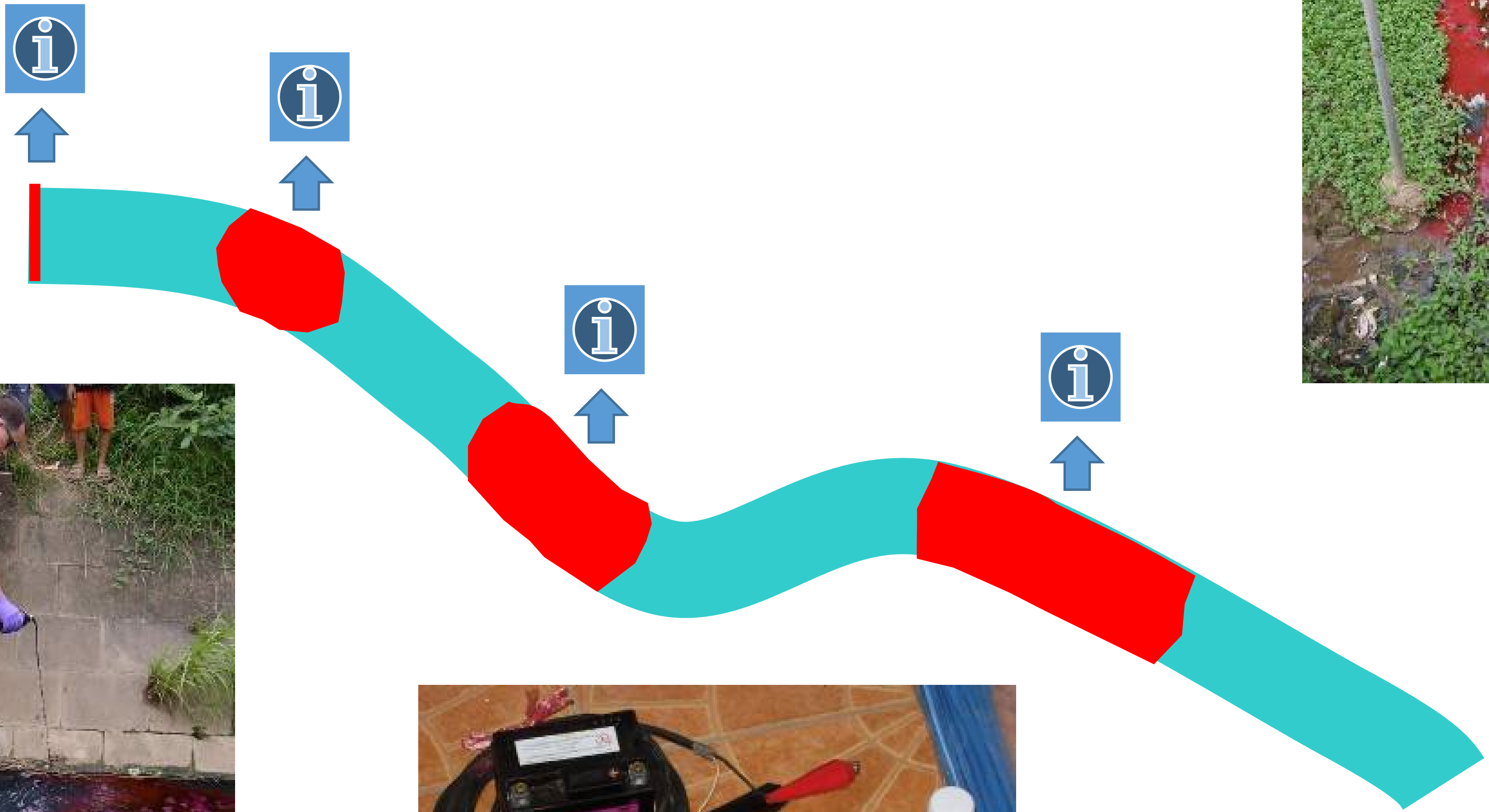
TOXICANTS



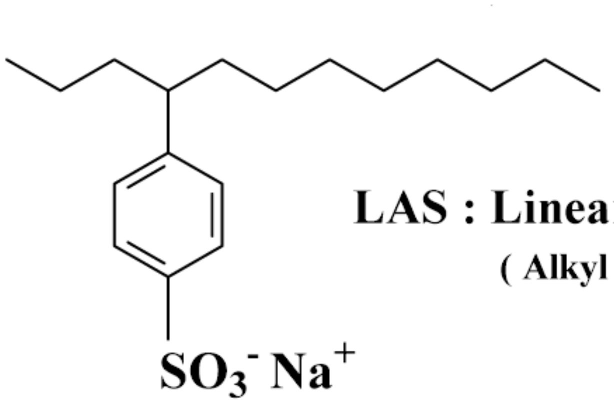
This hinders our ability to anticipate responses to change and manage these problems

Mechanistic understanding of pollutant **behaviour** and **effects** is incomplete

The *only* way to measure in-stream transformation rates?

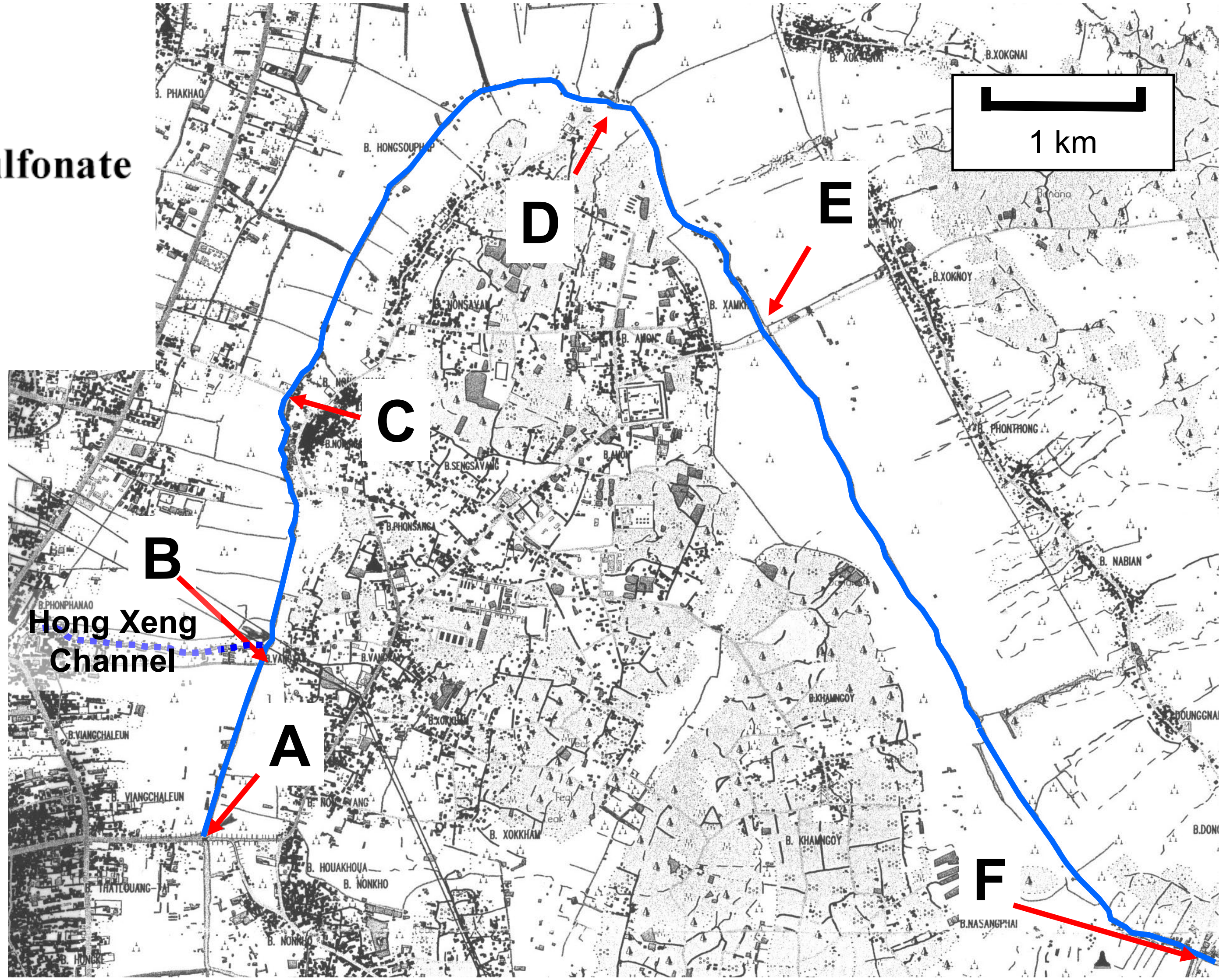


Houay Mak Hiao River (Vientiane) 2006



LAS : Linear Alkyl Benzene Sulfonate

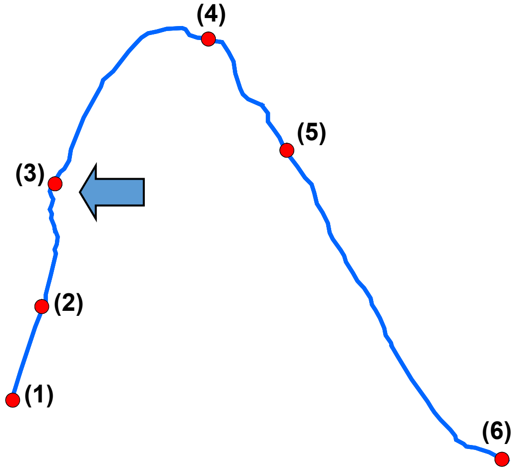
(Alkyl Chain : C_{10} - C_{13})



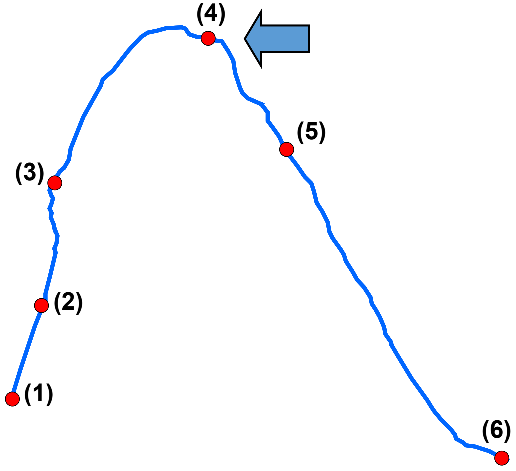
A: Injection: That Luang Market

B: Junction

B: Pepsi Bridge

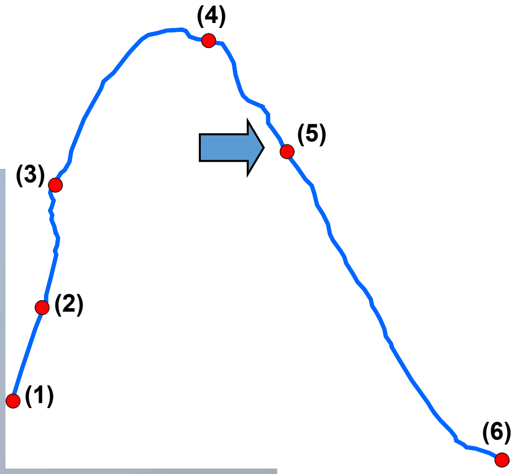


D: “Snake”

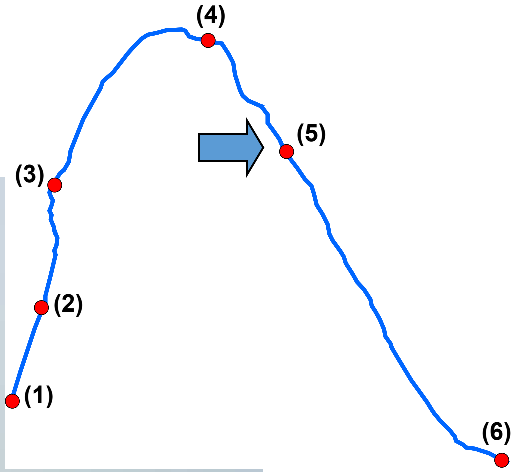


Looking upstream

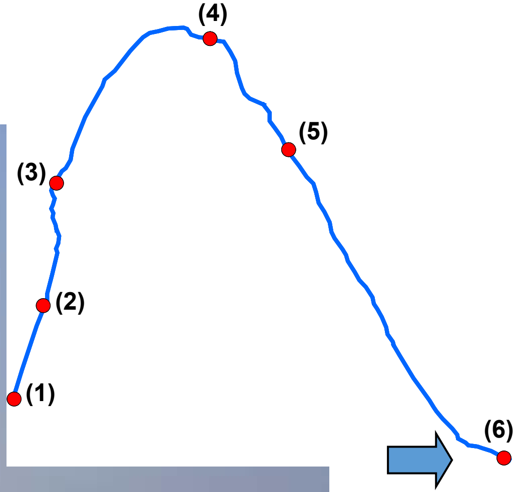
E: Ban Sok



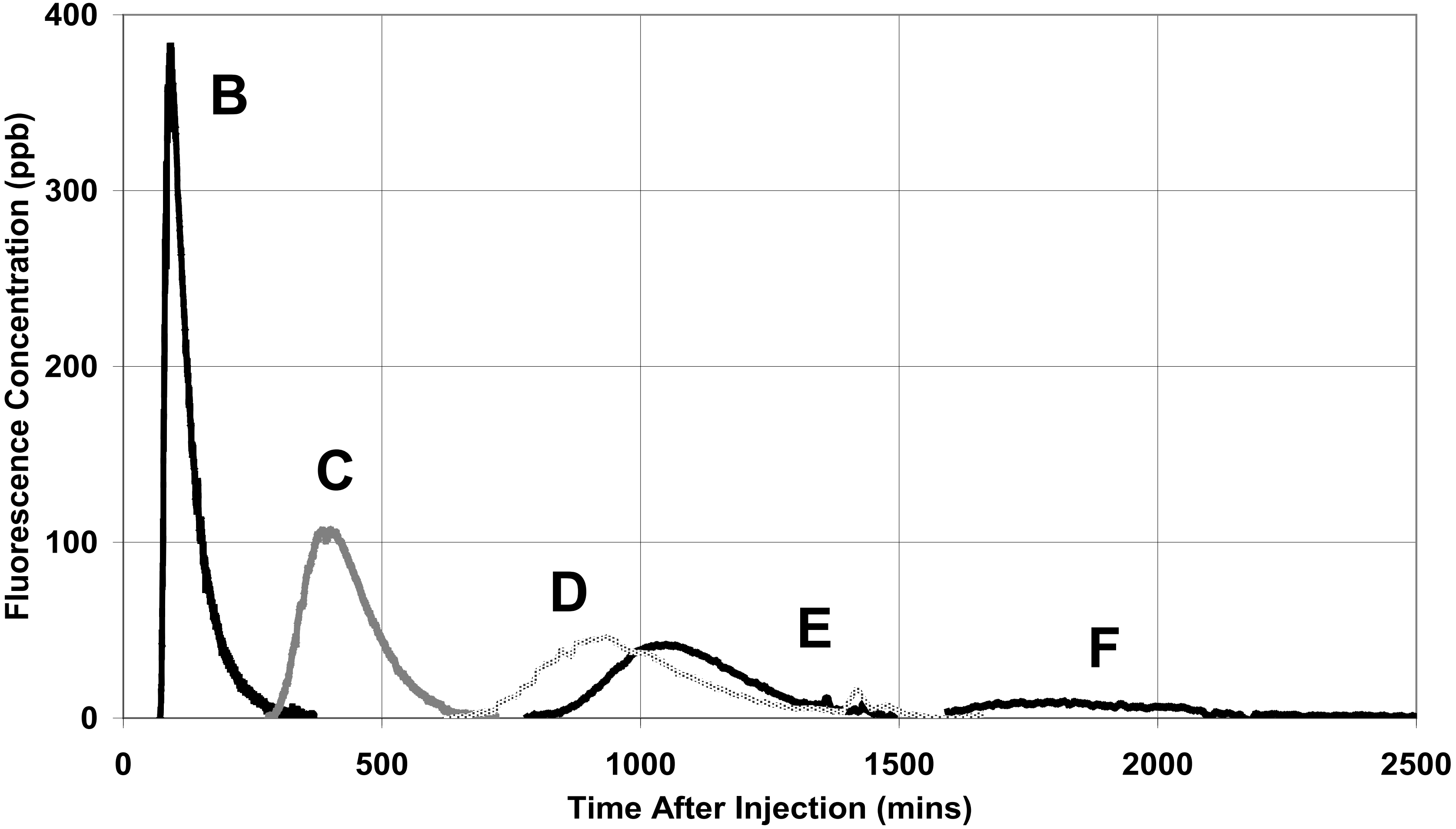
E: Ban Sok



F: Na Kuai



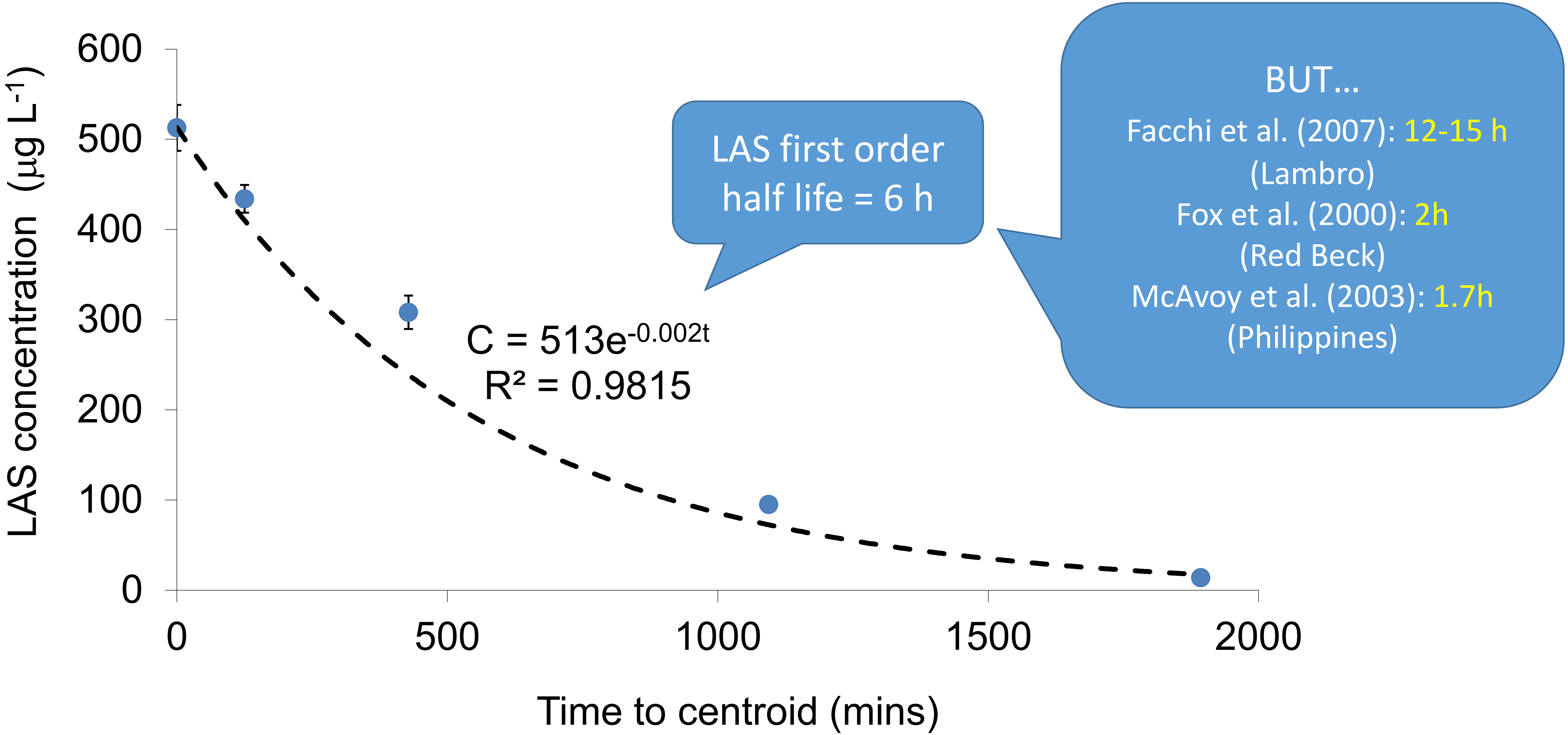
Dye Trace



400
300
200
100
0
Fluorescence Concentration (ppb)
B
C
D
E
F
0
500
1000
1500
2000
2500
Time After Injection (mins)

Water Quality Analysis

LAS concentrations and derived half-life



Factors affecting microbially-mediated transformations (biodegradation, nitrification, denitrification)

Intrinsic Factors

Chemical structure (bonds)

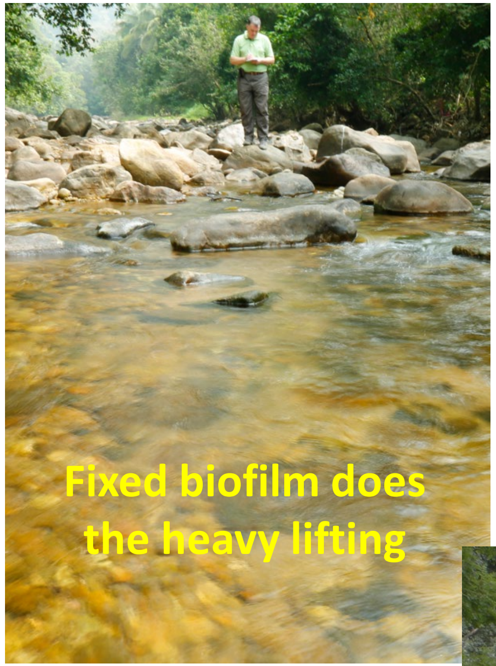
Aqueous solubility
Sorption to organic matter

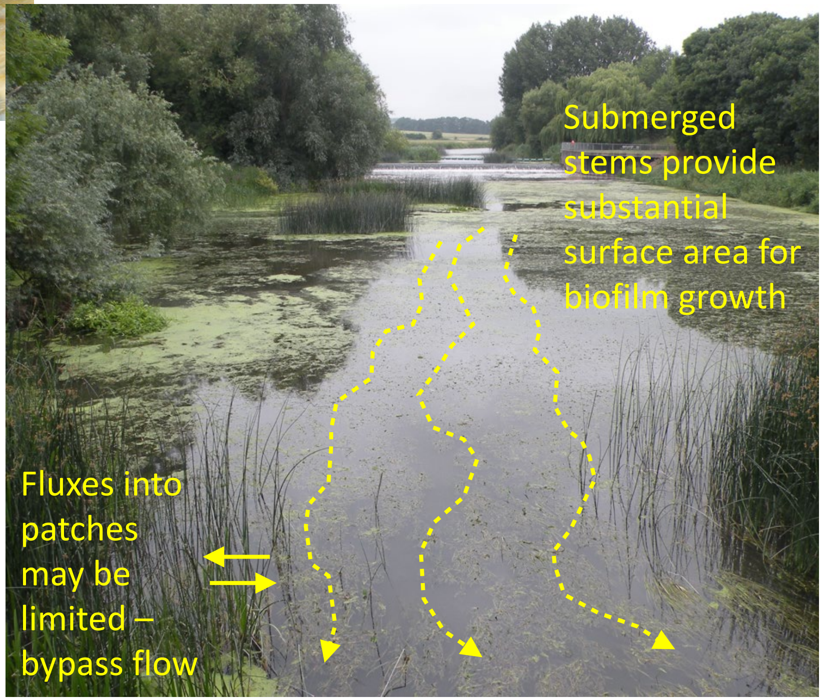
Extrinsic Factors

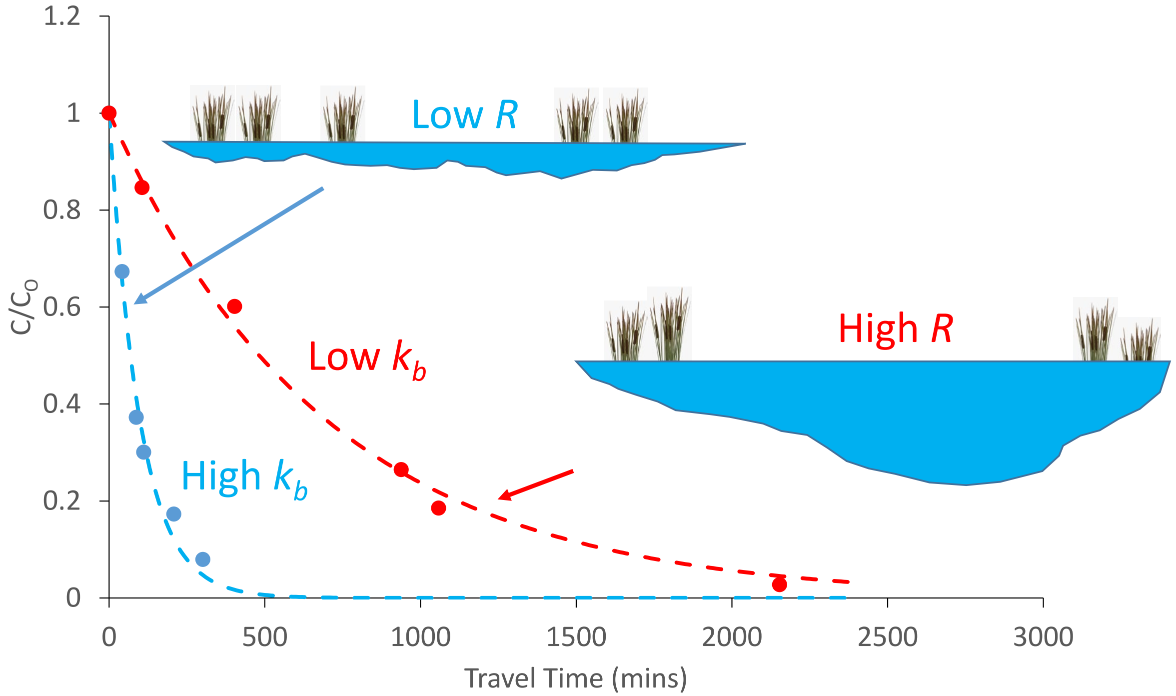
Microbial community composition
Temperature
Nutrient availability
Dissolved Oxygen

Location of transformation process

System controls on process rates





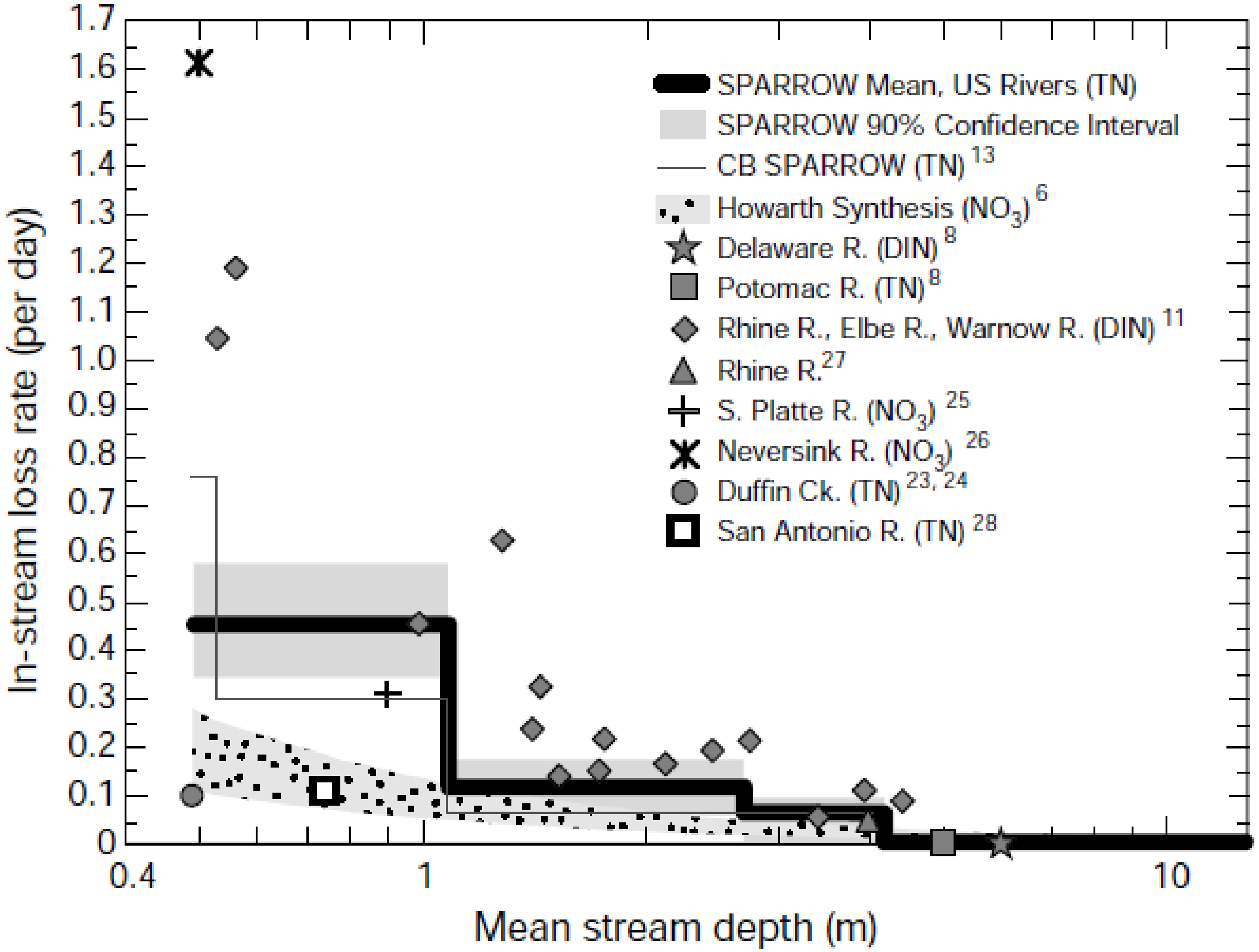


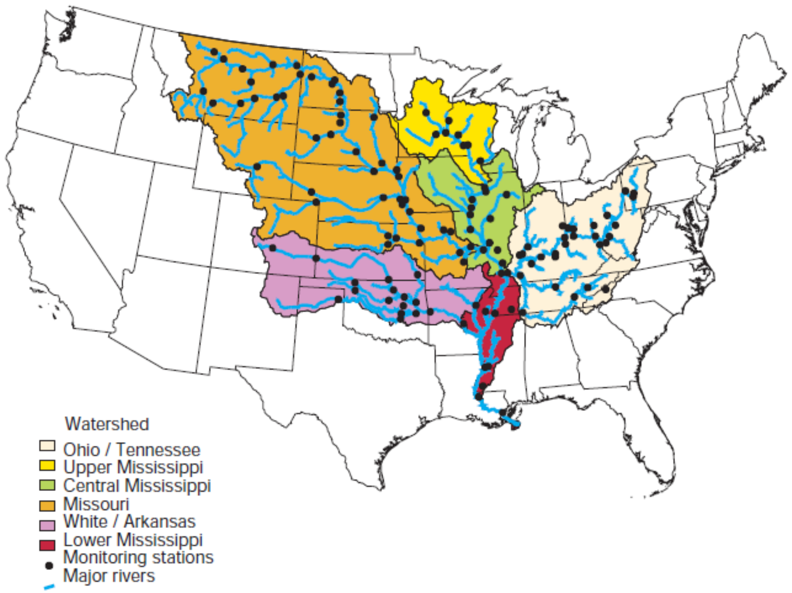
$$k = f(R^{-1}, veg, sediment, T, mixing \ldots.)$$

$$k_b \propto k_n \propto k_d$$

Biodegradation Nitrification Denitrification

Evidence



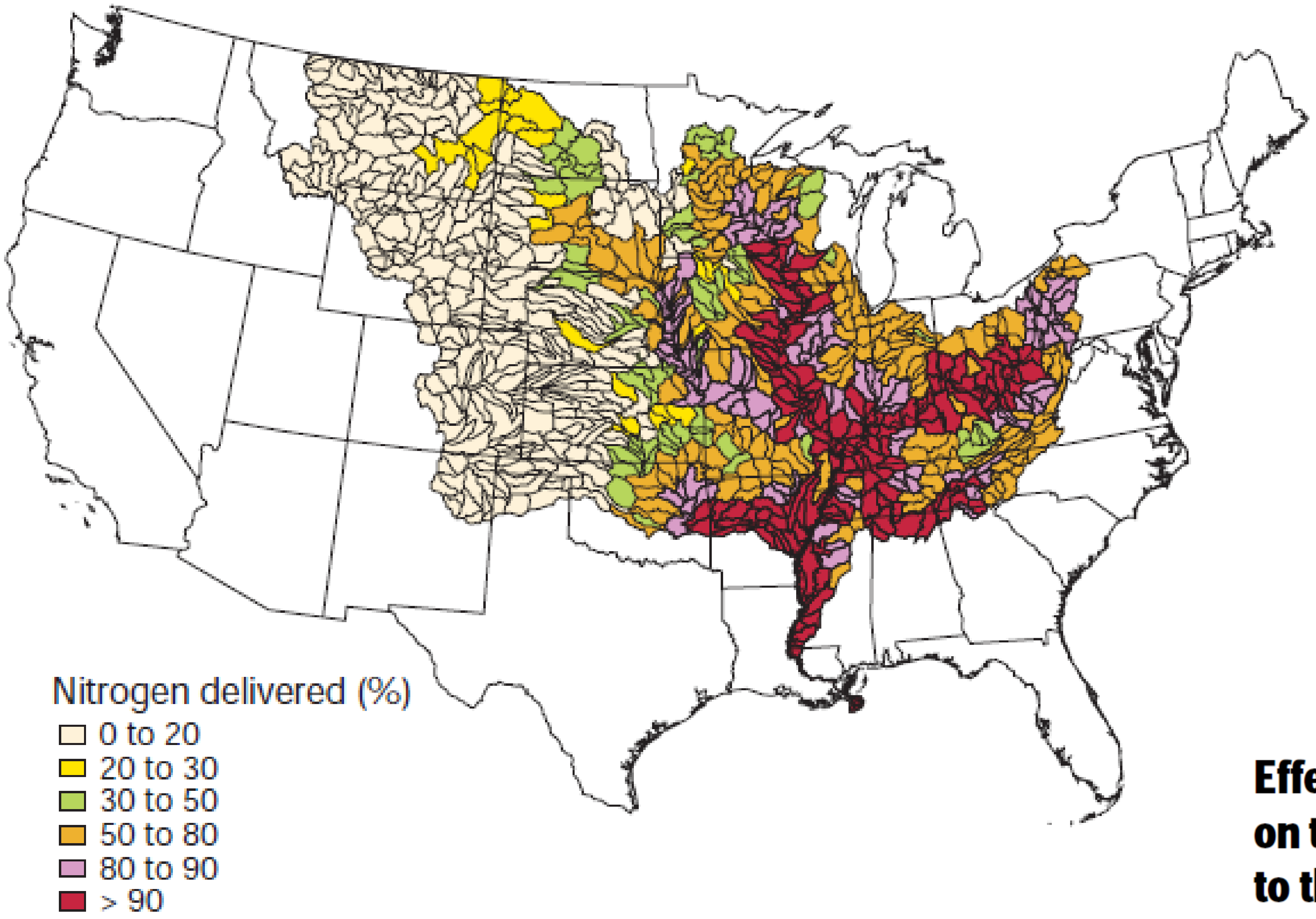


Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico

Richard B. Alexander, Richard A. Smith & Gregory E. Schwarz

U. S. Geological Survey, 413 National Center, Reston, Virginia 20192, USA

NATURE | VOL 403 | 17 FEBRUARY 2000 | www.nature.com



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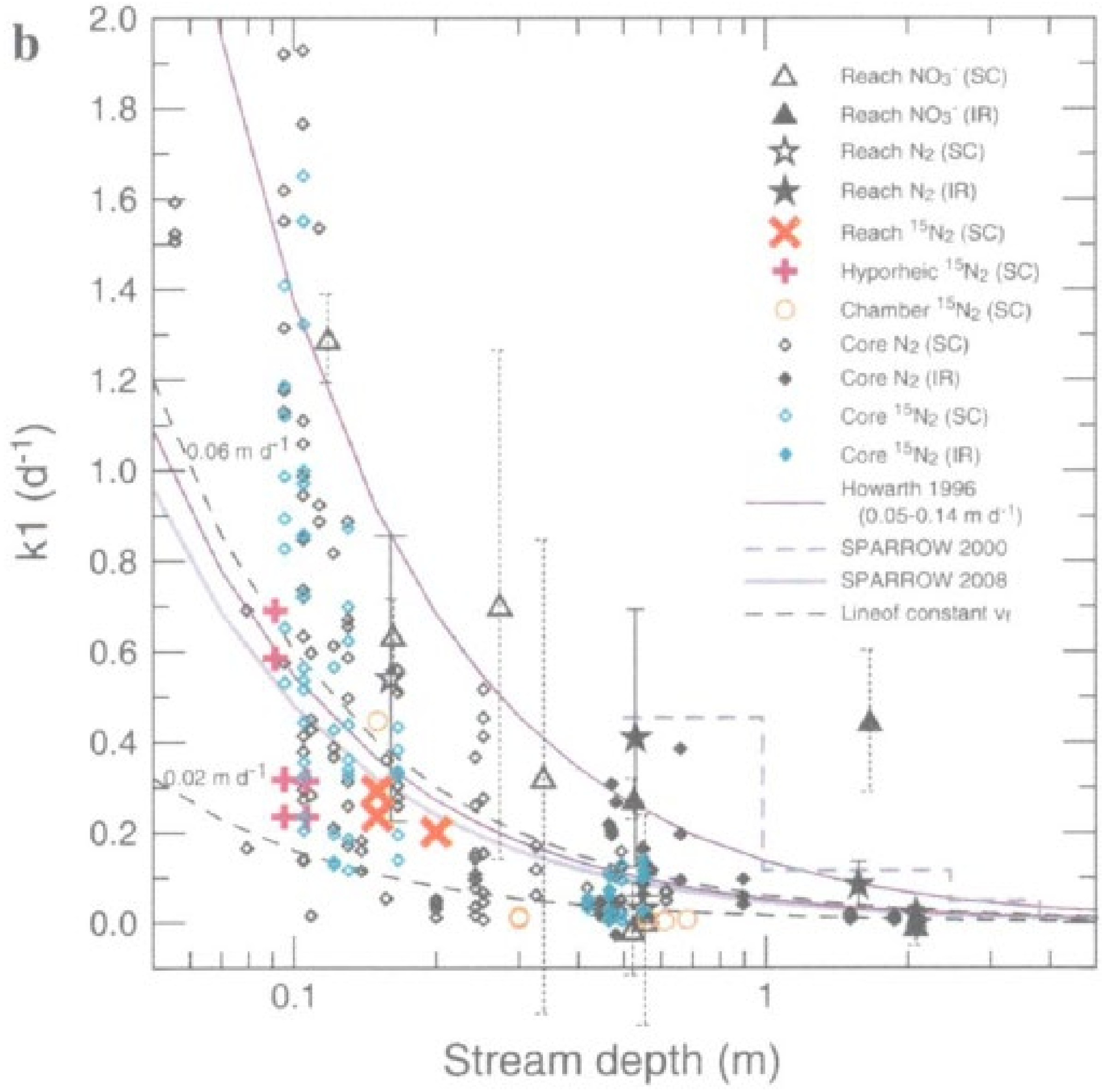
More evidence

Denitrification rate constant



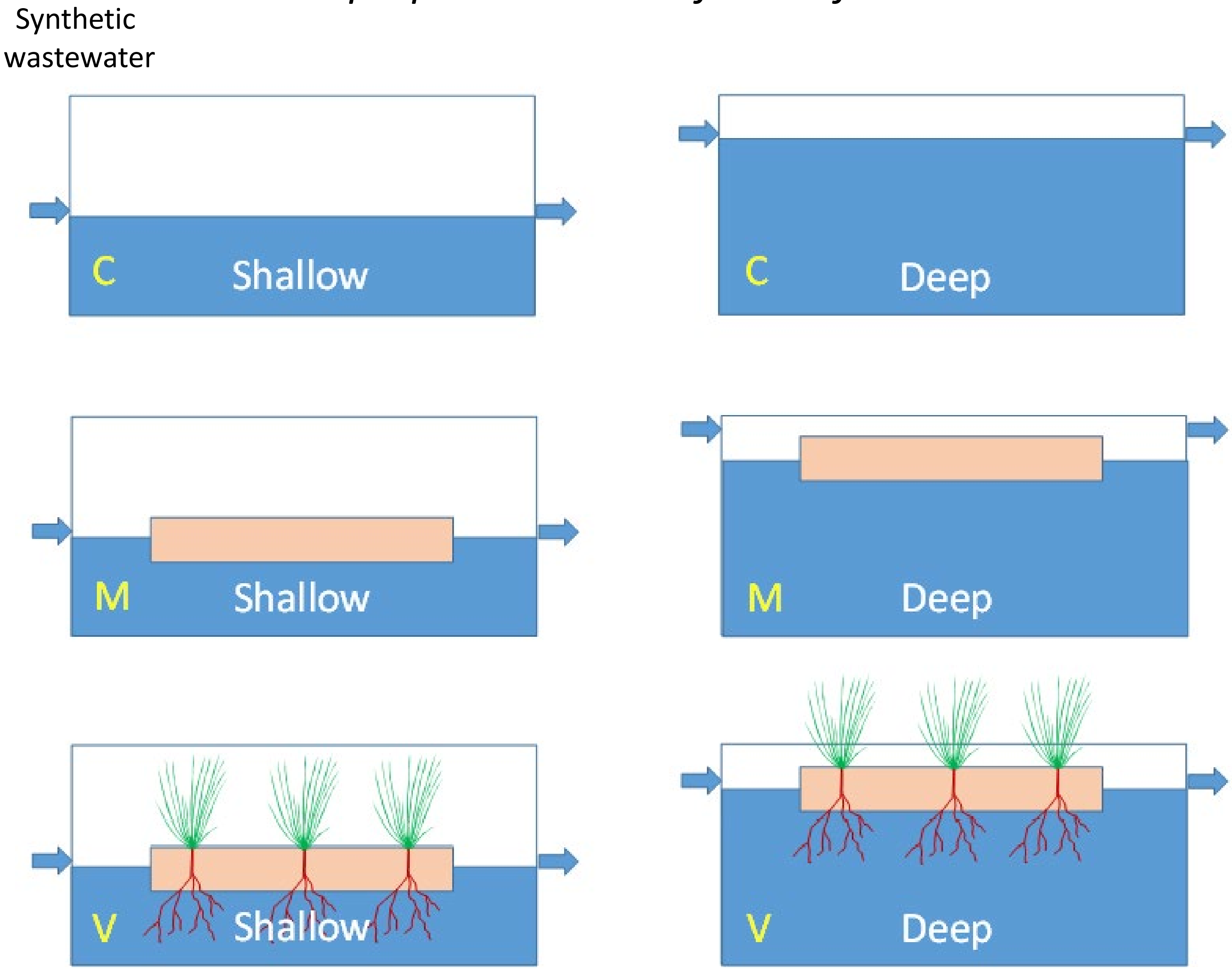
Biogeochemistry (2009) 93:117–141
DOI 10.1007/s10533-008-9282-8

Multi-scale measurements and modeling of denitrification in streams with varying flow and nitrate concentration in the upper Mississippi River basin, USA

John Karl Böhlke · Ronald C. Antweiler ·
Judson W. Harvey · Andrew E. Laursen ·
Lesley K. Smith · Richard L. Smith · Mary A. Voytek

“Floating island” effects in FSCWs

Nitrification rate constants will be proportional to biofilm surface area



Muwafaq Al Lami
PhD University of Leicester

Treatment Description	Water depth (m)	Mat cover (%)	Plants per mat	k_{vol} x f_{FREE} (d^{-1})	k_{up} (d^{-1})	k_{nit} (d^{-1})
Shallow Control	0.2	0	0	5.4 x 10^{-5}	0	0.49
Deep Control	0.4	0	0	2.7 x 10^{-5}	0	0.3
Shallow Mat 50%	0.2	50	0	5.4 x 10^{-5}	0	1.55
Deep Mat 50%	0.4	50	0	2.7 x 10^{-5}	0	0.78
Shallow Mat 100%	0.2	100	0	5.4 x 10^{-5}	0	3.11
Deep Mat 100%	0.4	100	0	2.7 x 10^{-5}	0	1.55
Shallow Veg Mat 50%	0.2	50	2	5.4 x 10^{-5}	0.0302	1.55
Deep Veg Mat 50%	0.4	50	2	2.7 x 10^{-5}	0.0302	0.78
Shallow Veg Mat 100%	0.2	100	4	5.4 x 10^{-5}	0.0603	3.11
Deep Veg Mat 100%	0.4	100	4	2.7 x 10^{-5}	0.0603	1.55

Shallow k_{nit} > Deep k_{nit}

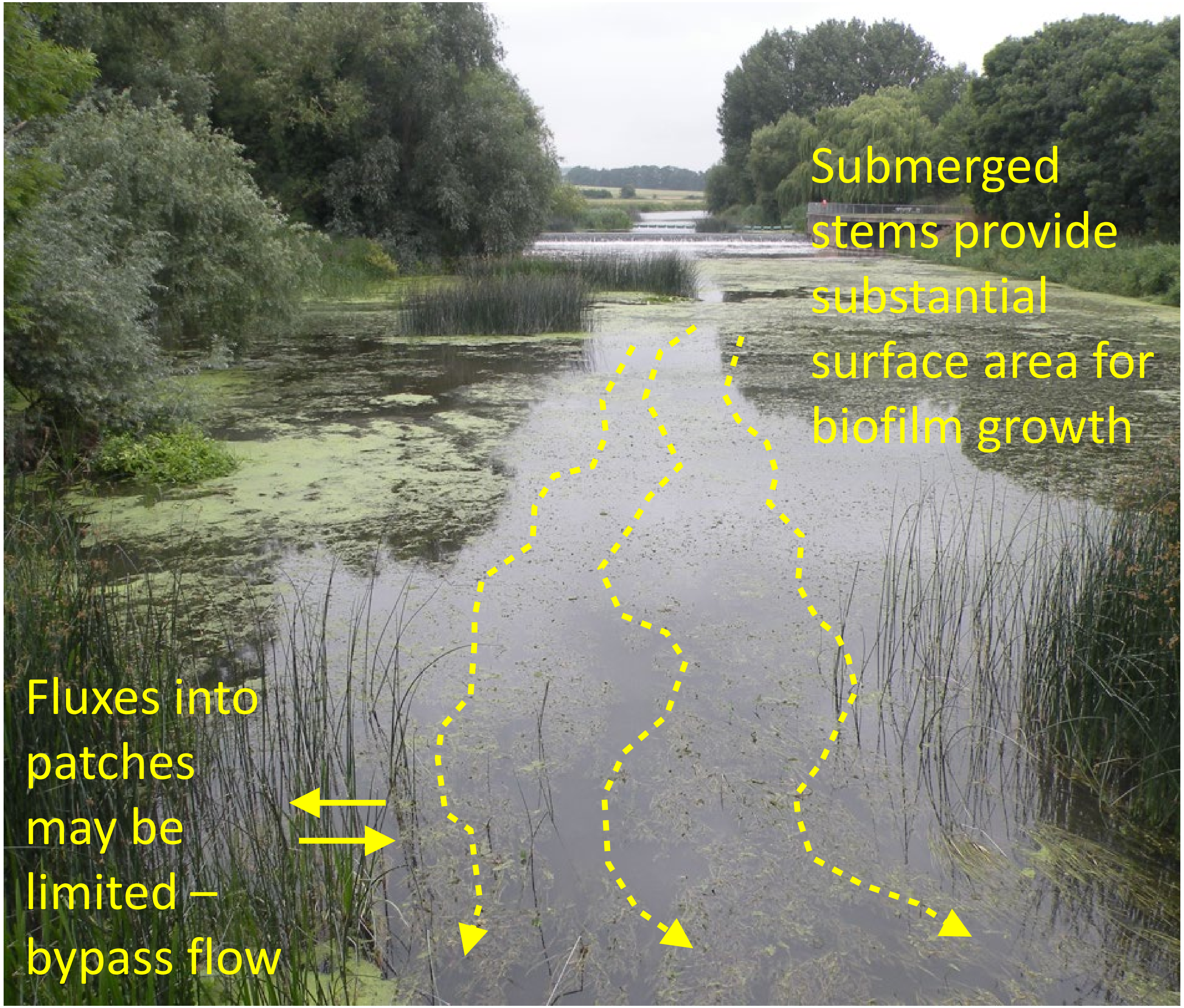
Mat cover enhances k_{nit}

Volatilisation is negligible

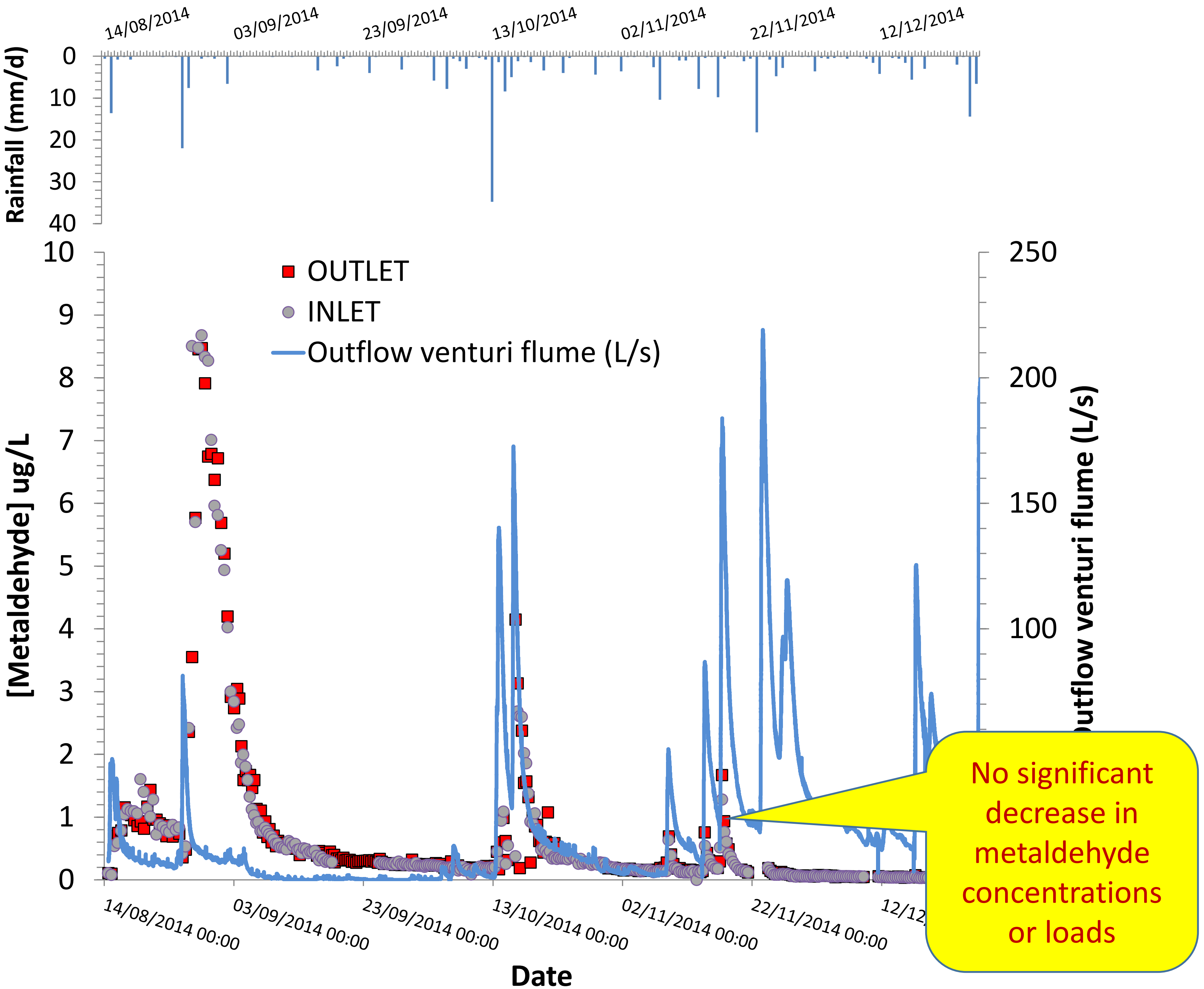
...so is uptake

k_{nit} derived from simple scaling of shallow control rates assuming all transformations occur via biofilm

The Role of Vegetation



Pesticide remediation in FSCWs

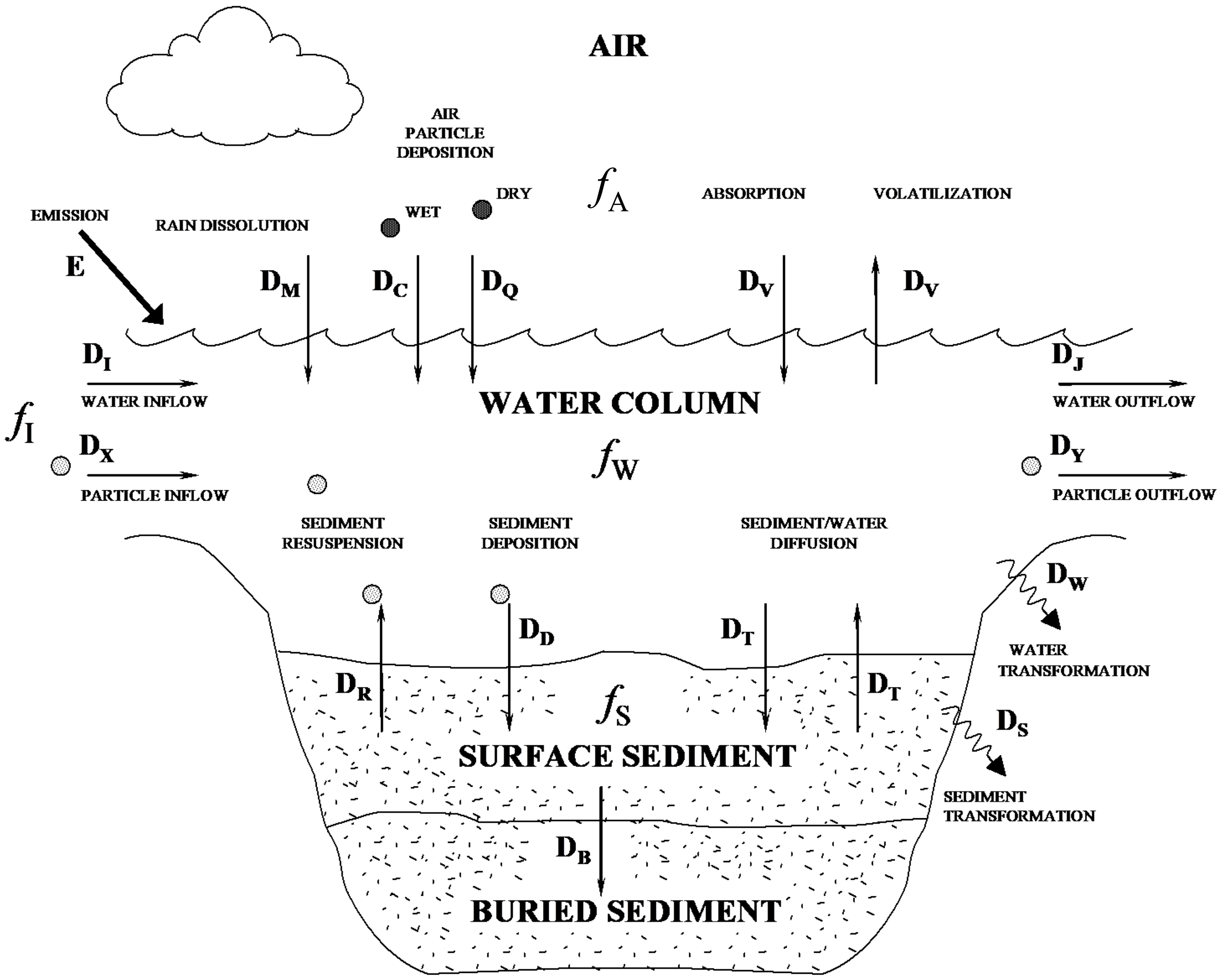


14/08/2014
03/09/2014
23/09/2014
13/10/2014
02/11/2014
22/11/2014
12/12/2014
Rainfall (mm/d)
0
10
20
30
40
OUTLET
INLET
Outflow venturi flume (L/s)
[Metaldehyde] ug/L
Outflow venturi flume (L/s)
250
200
150
100
14/08/2014 00:00
03/09/2014 00:00
23/09/2014 00:00
13/10/2014 00:00
02/11/2014 00:00
22/11/2014 00:00
Date
No significant decrease in metaldehyde concentrations or loads

Modelling

Quantitative Water Air Sediment Interaction Model

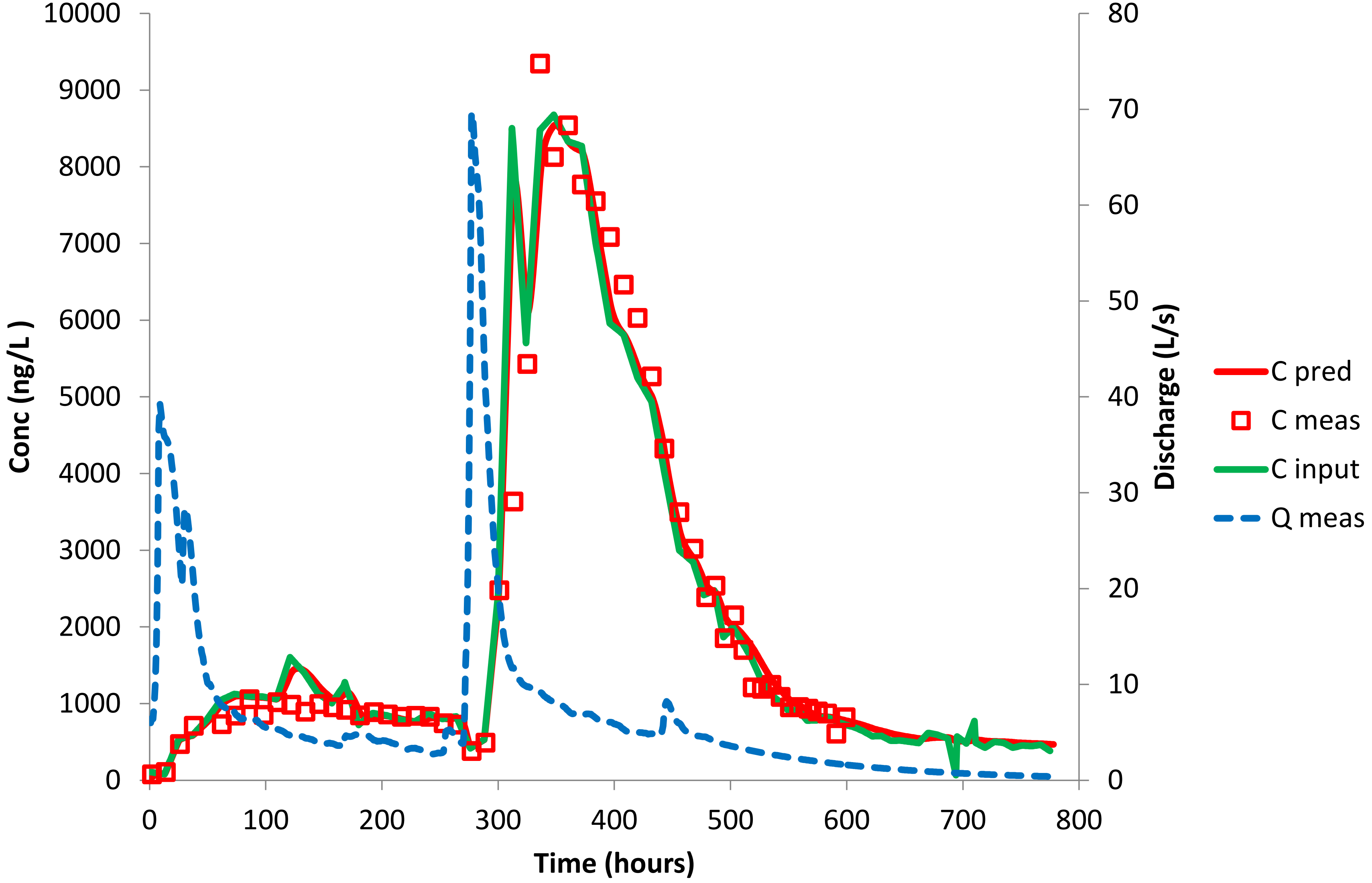
Dynamic non equilibrium (Level IV)



Measured input loads used for Emissions

Mackay *et al.* (1983)

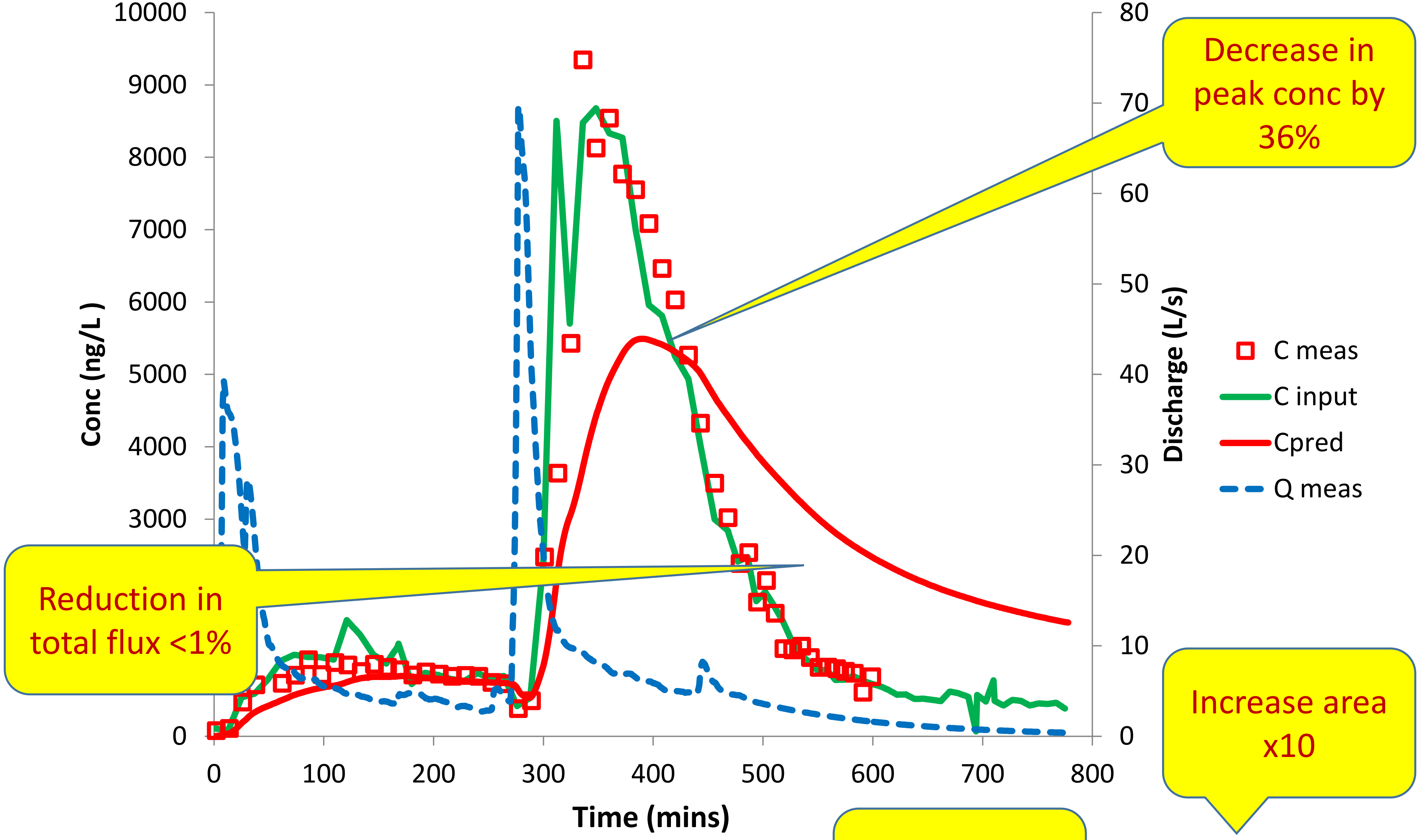
Expectations



DT50 sed = 122 d
DT50 wat = 12.2 d

A = 210 m^2
z = 0.5 m

Increasing residence time

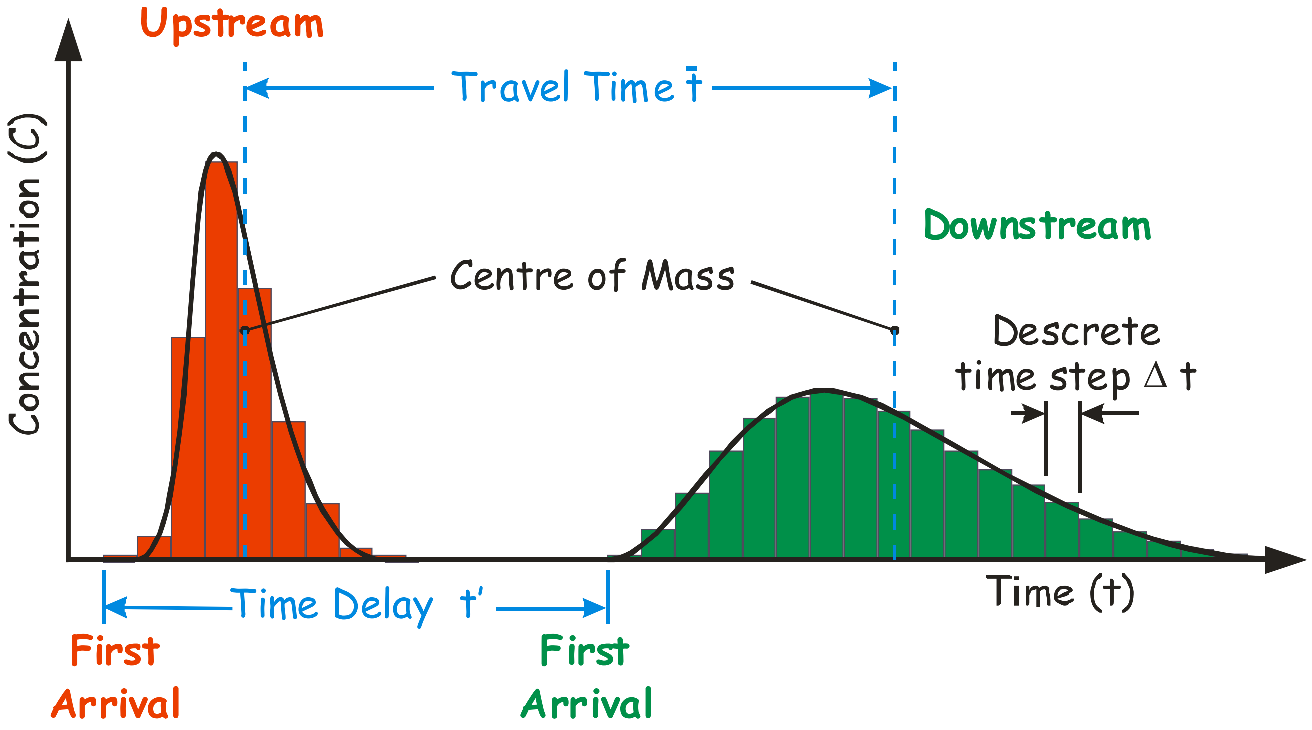


DT50 sed = 122 d
DT50 wat = 12.2 d

$A = 2100\ m^2$
$z = 1\ m$

Mixing considerations: Dispersive fraction from ADZ model

(Wallis, Young & Beven)

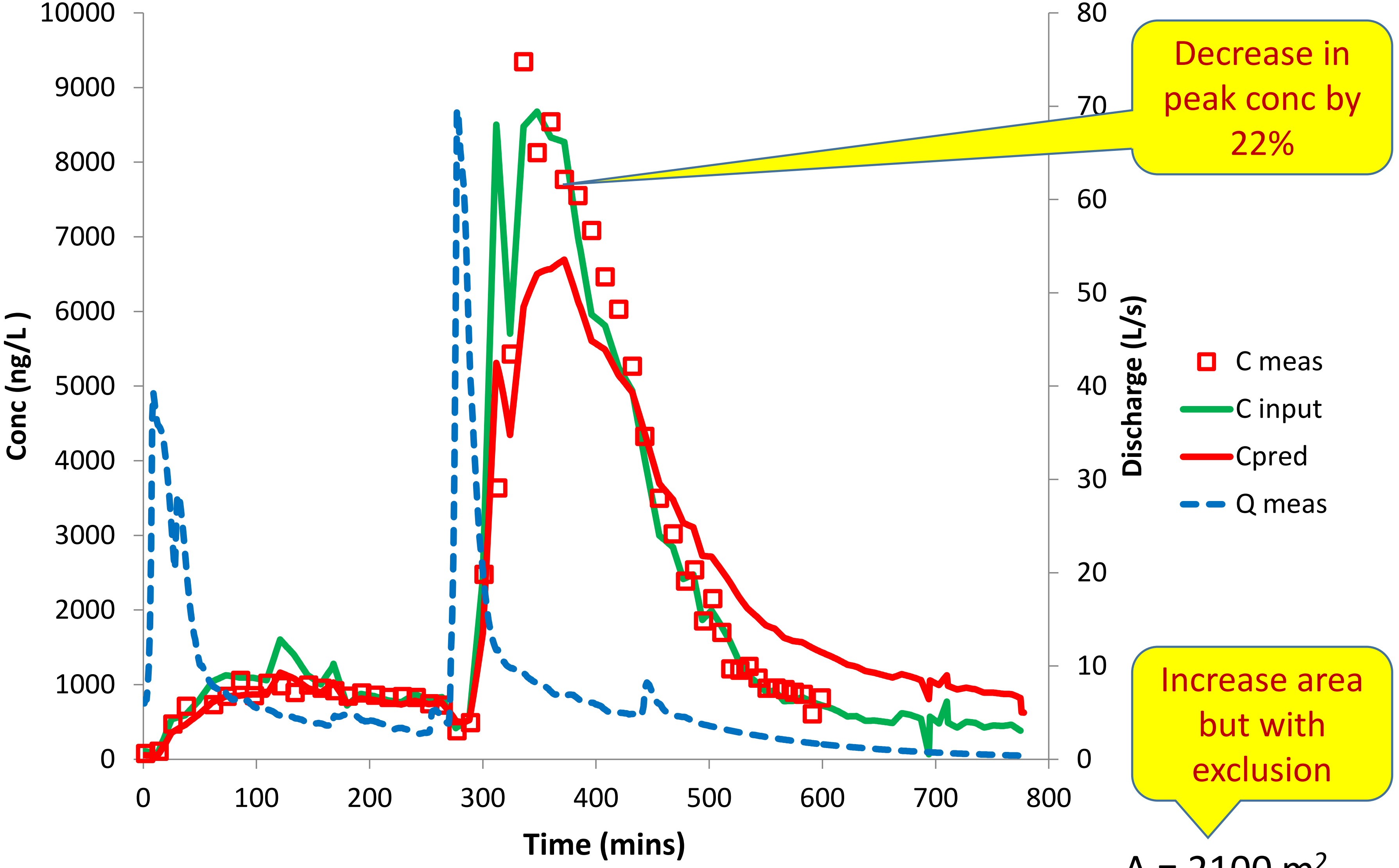


Apparent mixing volume 42-50%

….. Assume 50% of inflow is directly advected to the outflow and mixing volume is 50%

Fred Sonnenwald (University of Sheffield)

Expectations accounting for incomplete mixing



DT50 sed = 122 d
DT50 wat = 12.2 d

A = 2100 m^2
z = 1 m
50% excluded

Future prospects

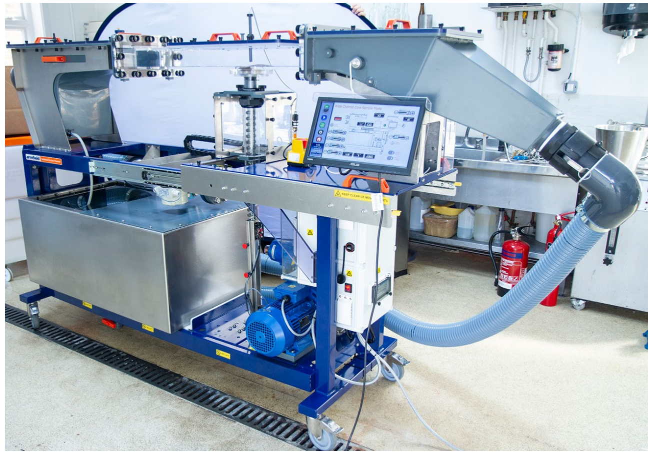
An Interdisciplinary Approach is Needed

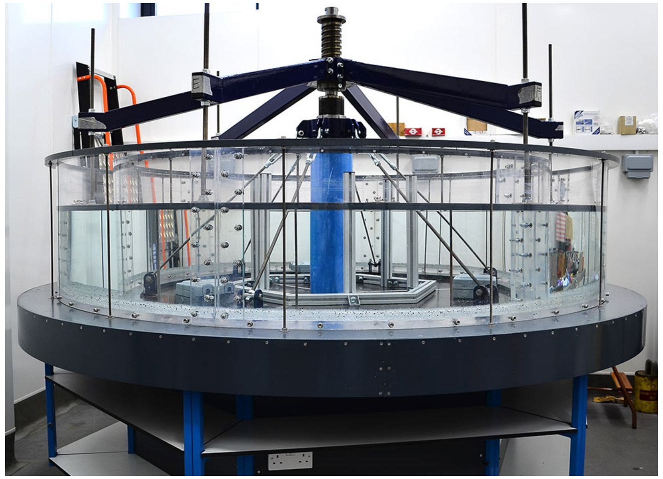
NUMERICAL MODELLING

ANALYTICAL CHEMISTRY

REACH CHARACTERISATION & LAGRANGIAN SAMPLING

MANIPULATIVE EXPERIMENTS





BIOFILM COMMUNITY CHARACTERISATION

CLIMATE AND DEMOGRAPHIC CHANGE MODELLING

Conclusions

- Understanding of pollutant **fate** remains uncertain
- Transformation rates will be affected by extrinstic (system-specific) controls including:
  - Hydraulic geometry
  - Sediment characteristics
  - Vegetation
- Microbially mediated rate constants will be correlated
- Essential to better-understand mixing and fluid interactions
- Comprehensive understanding requires multi-disciplinary collaboration

Please contact me if you have data on chemical behaviour in ponds or wetlands and would like to collaborate

(mjw72@le.ac.uk)