GOLDER

New Approaches for Direct Measurement of Contaminated Groundwater Discharge to Receiving Surface Water

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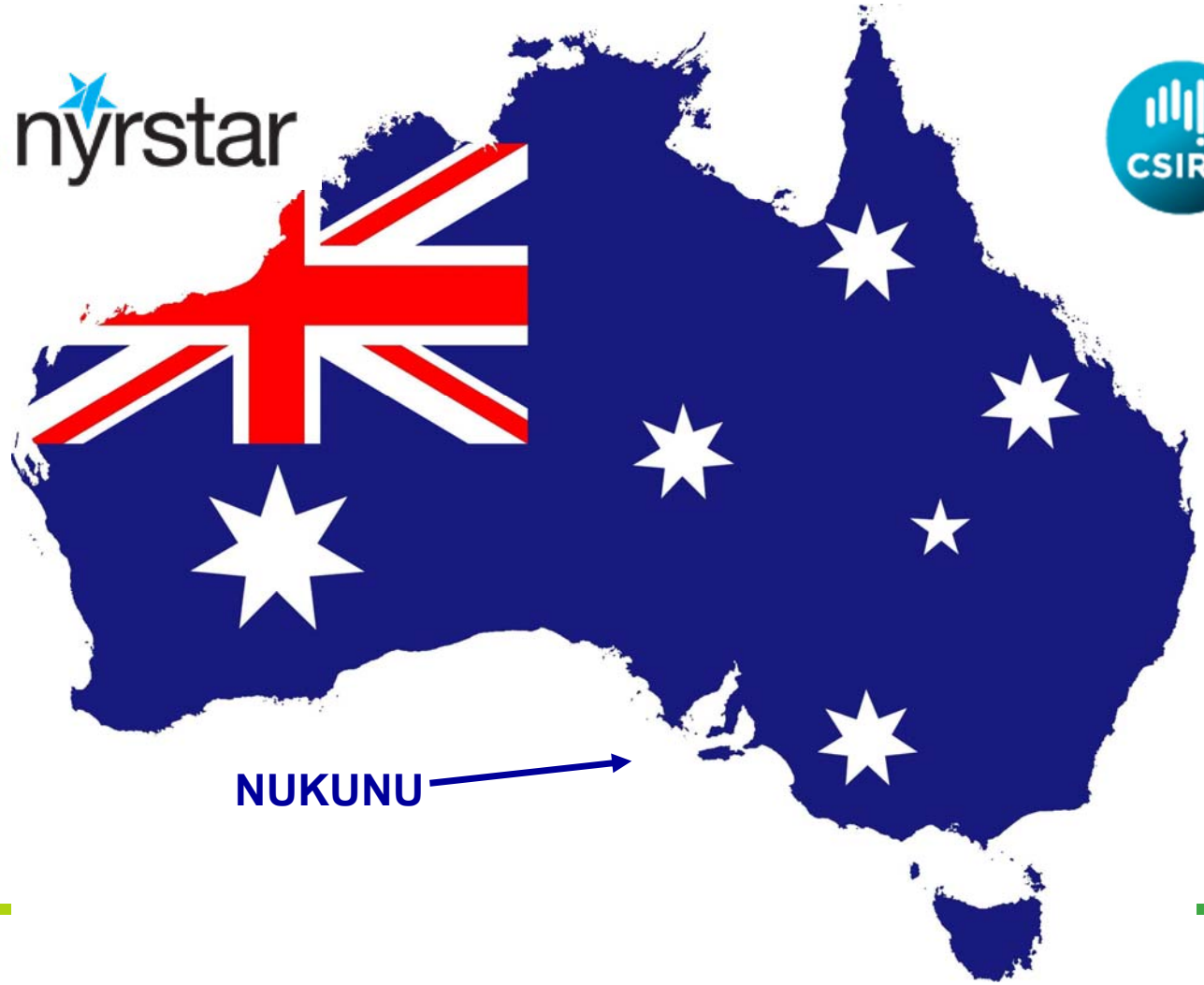
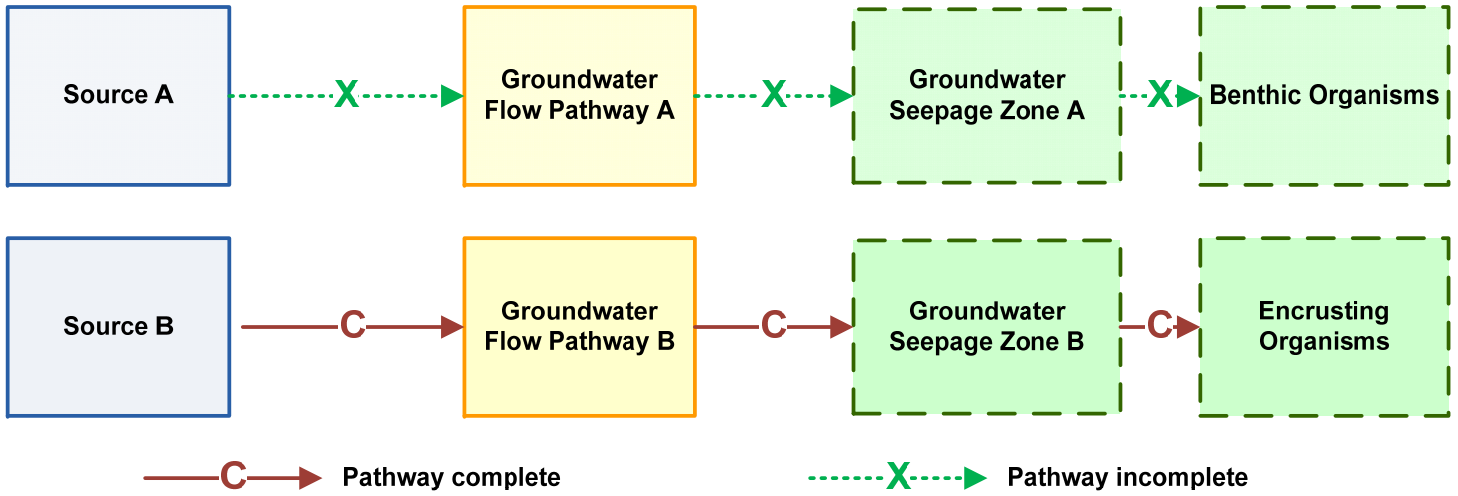
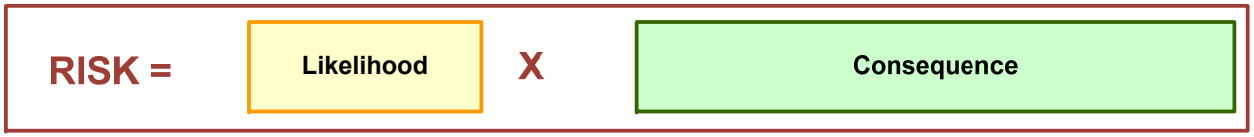
FROM LITTLE THINGS BIG THINGS GROW



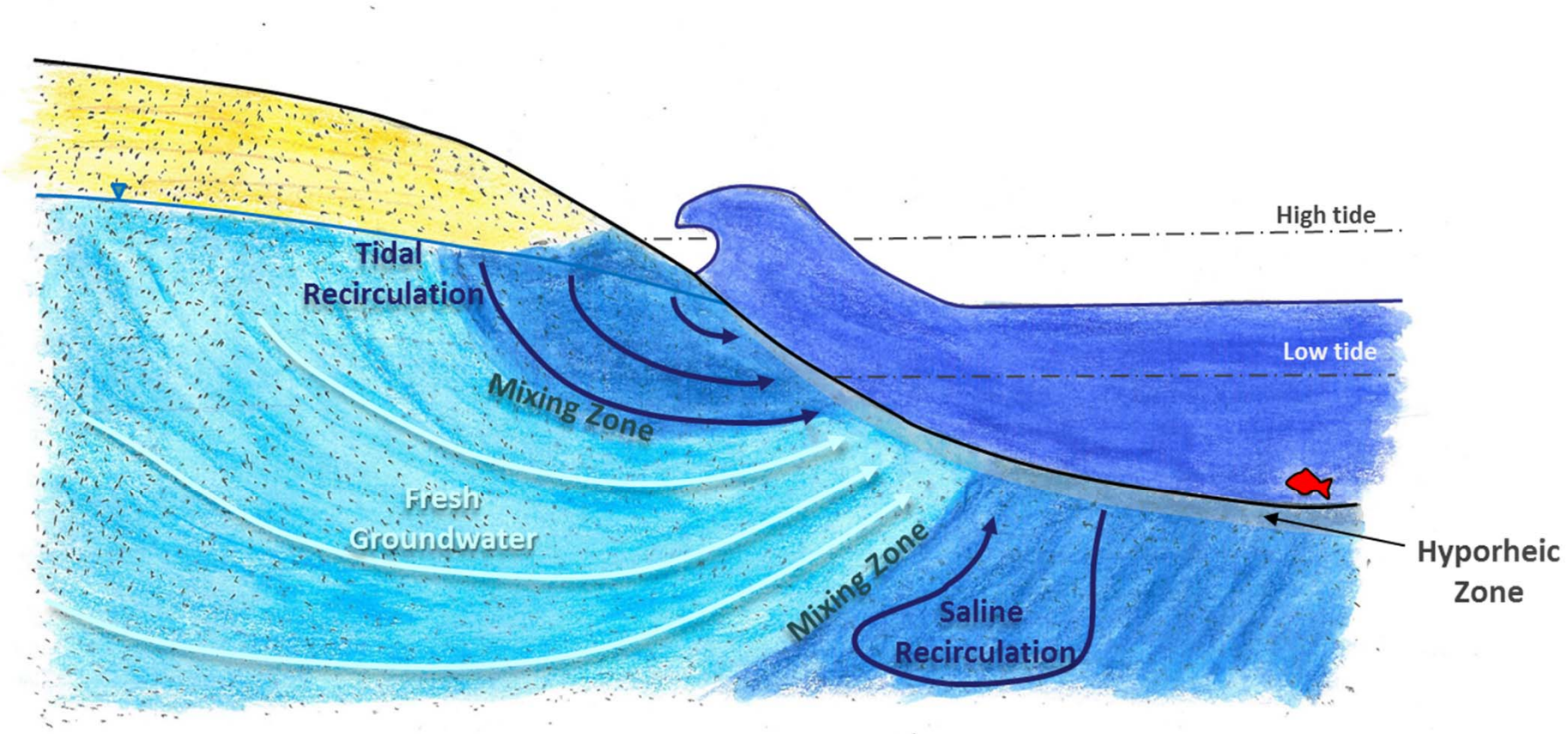
GOLDER

IS THE PATHWAY COMPLETE?



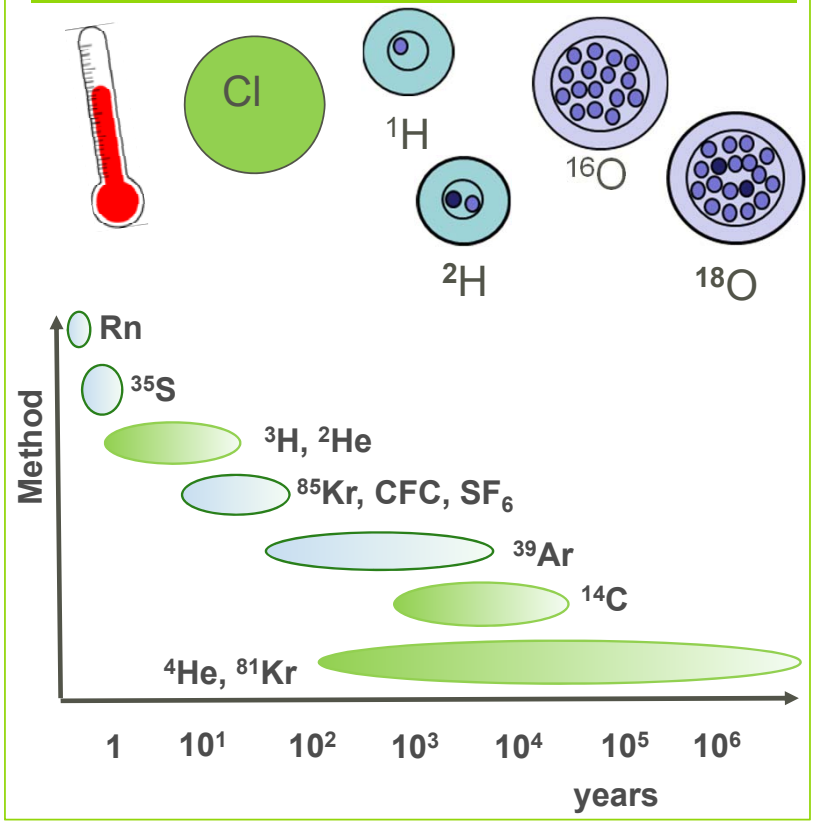


FUNDAMENTALS

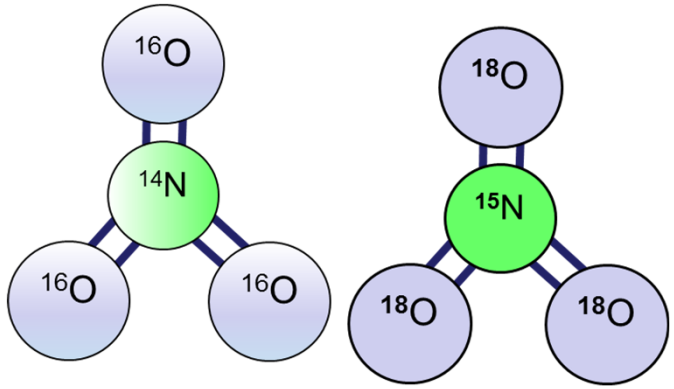


APPLIED AND ENVIRONMENTAL TRACERS

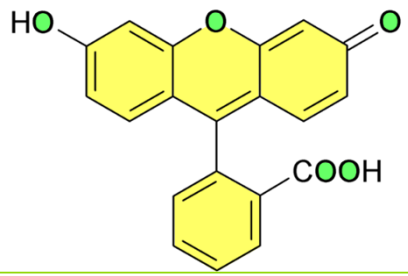
Environmental Tracers



CSIA – Compound Specific Isotope Analysis



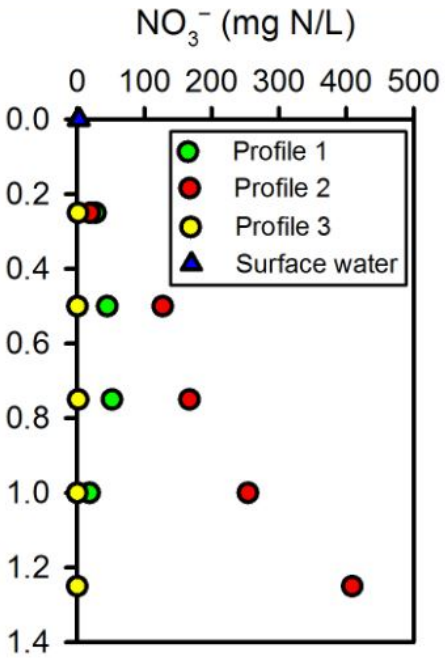
Applied Tracers

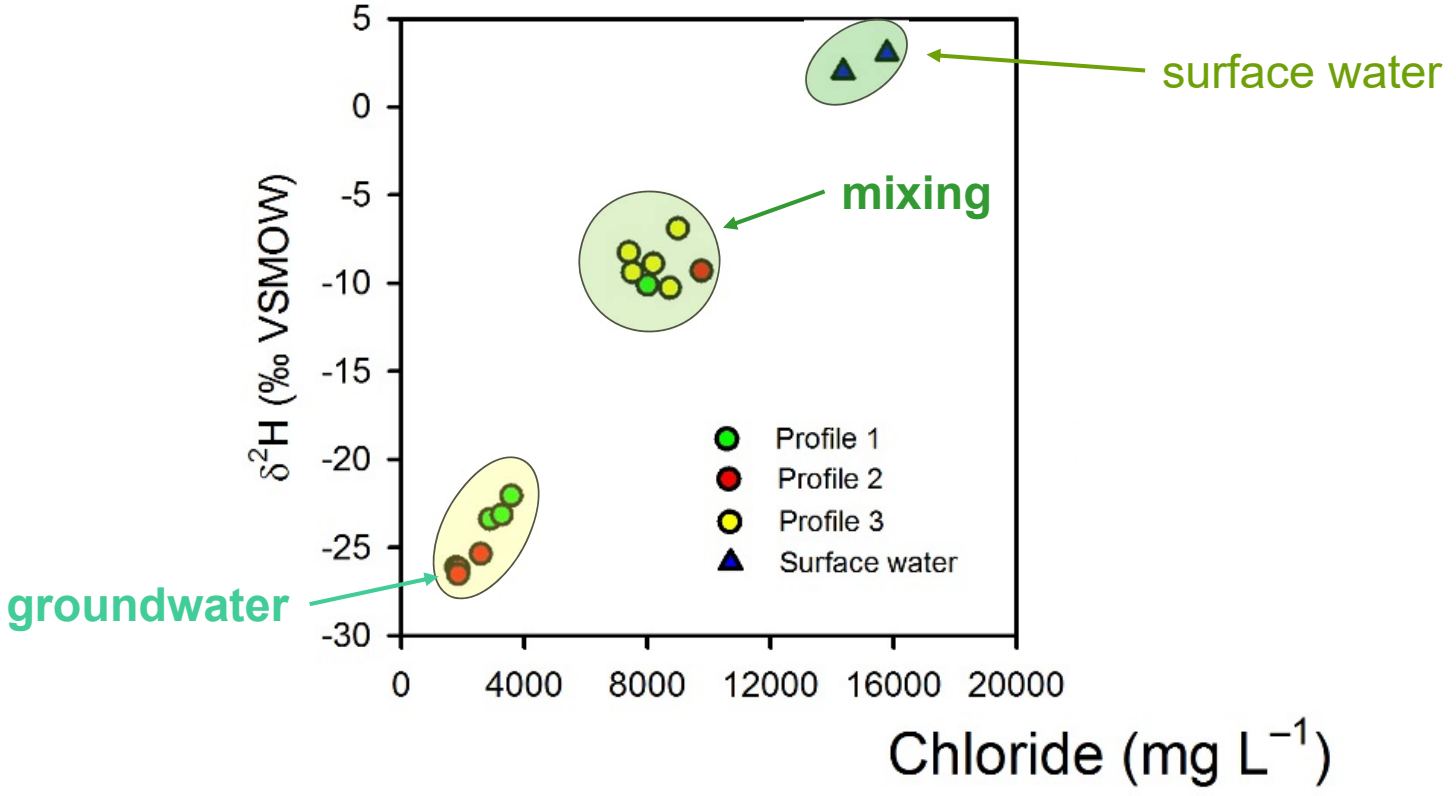


HIGH RESOLUTION VERTICAL PROFILES

ENVIRONMENTAL TRACERS

SOURCE: LAMONTAGNE ET AL, 2018

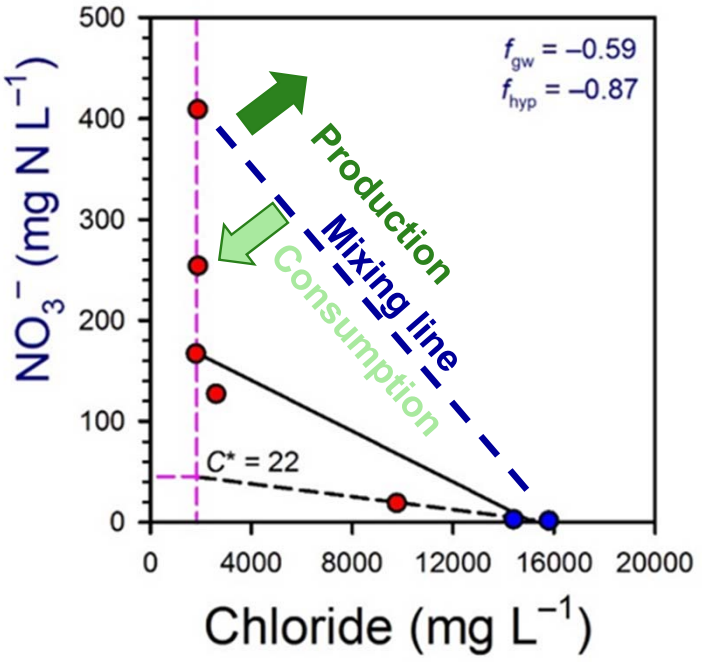


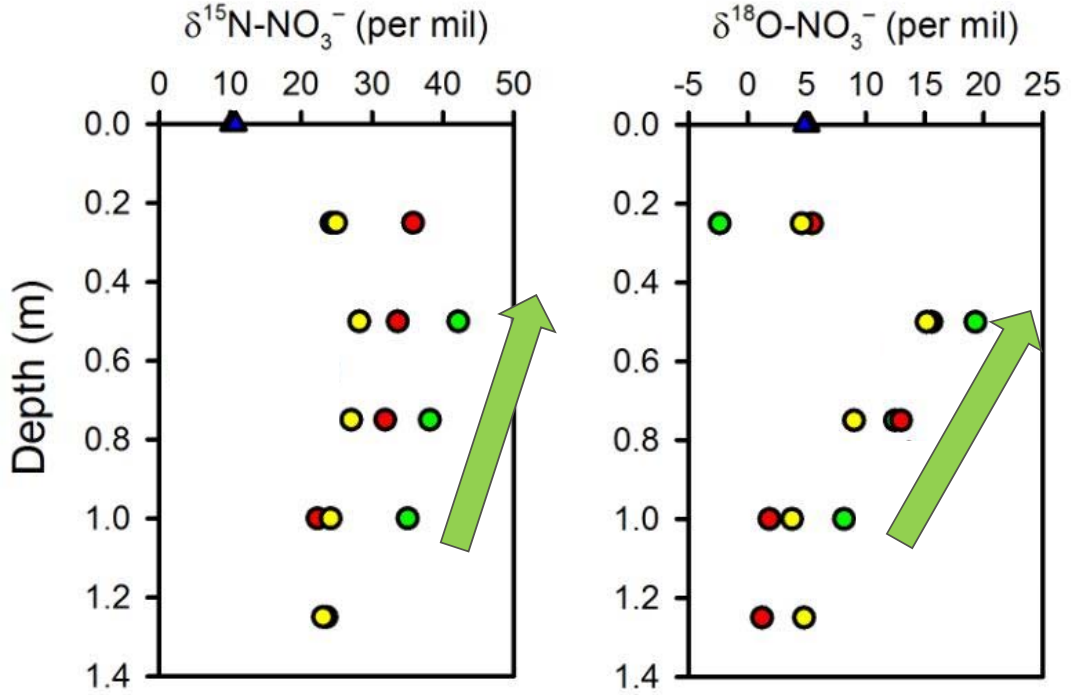


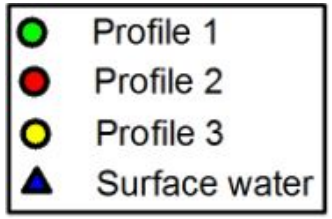
HIGH RESOLUTION VERTICAL PROFILES (CONT'ED)

NITRATE CSIA

Heavy isotope enrichment indicative of denitrification







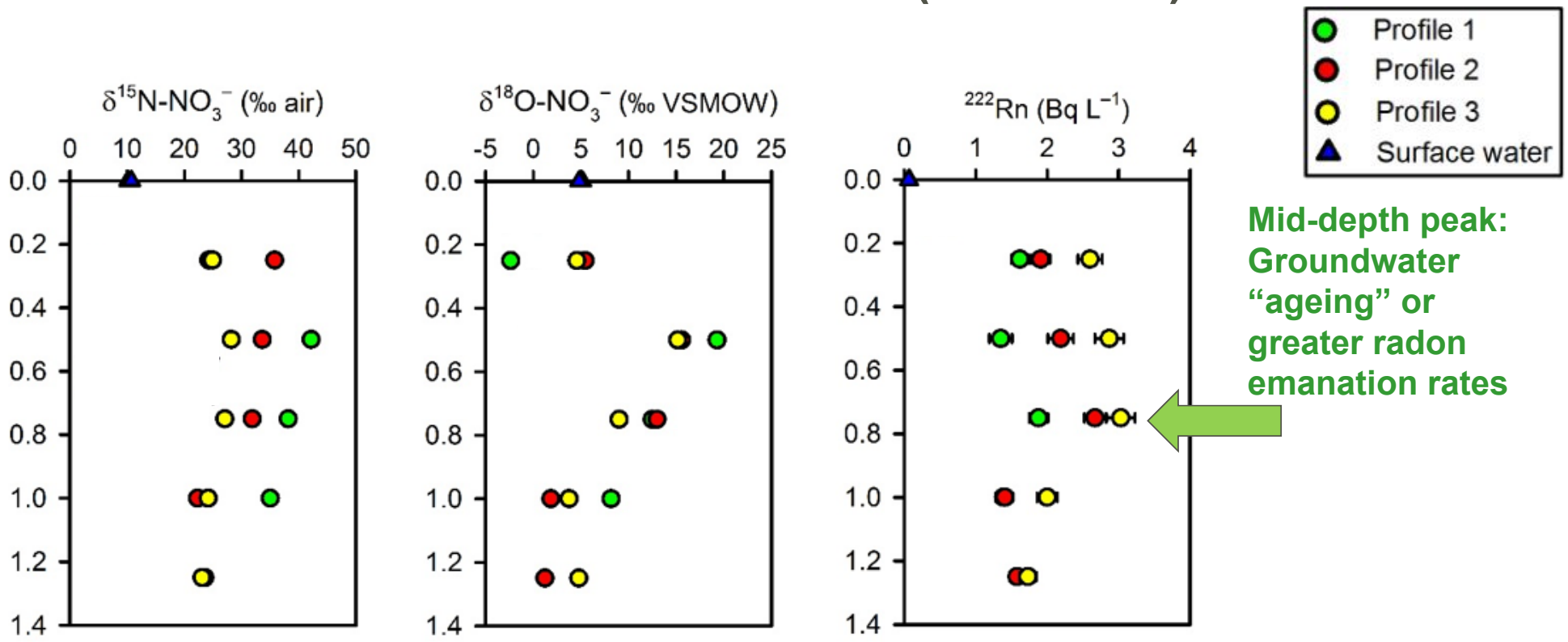
Importance of Annamox

- **Data supported development of mass balance modelling (Officer model)**

➢ **up to 80 % of the N load in impacted groundwater is removed in the riverbed**

HIGH RESOLUTION VERTICAL PROFILES (CONT'ED)

RADON



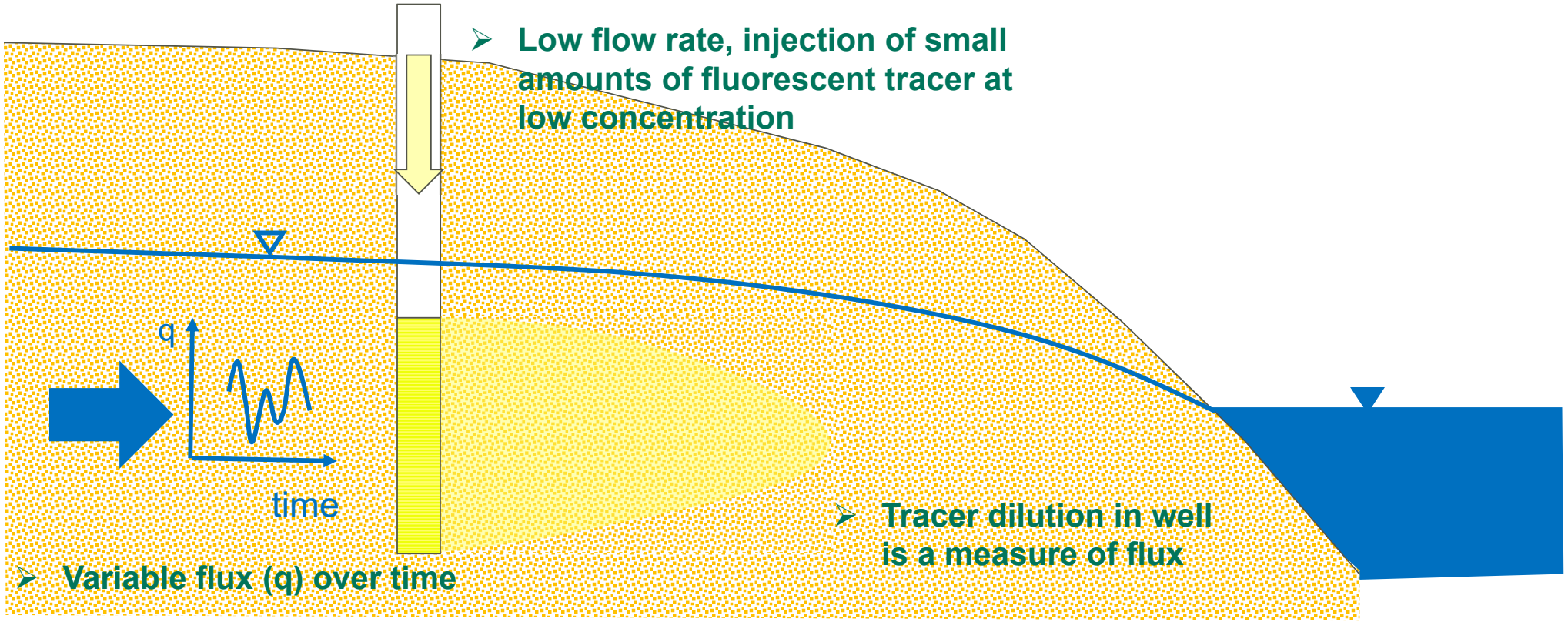
$A_x = A_o(1 - e^{-\lambda t})$ with A = radon activity

- Use to derive groundwater residence time and average groundwater flow velocity (0.07 to 0.11 m/day)

GROUNDWATER FLUX MEASUREMENT

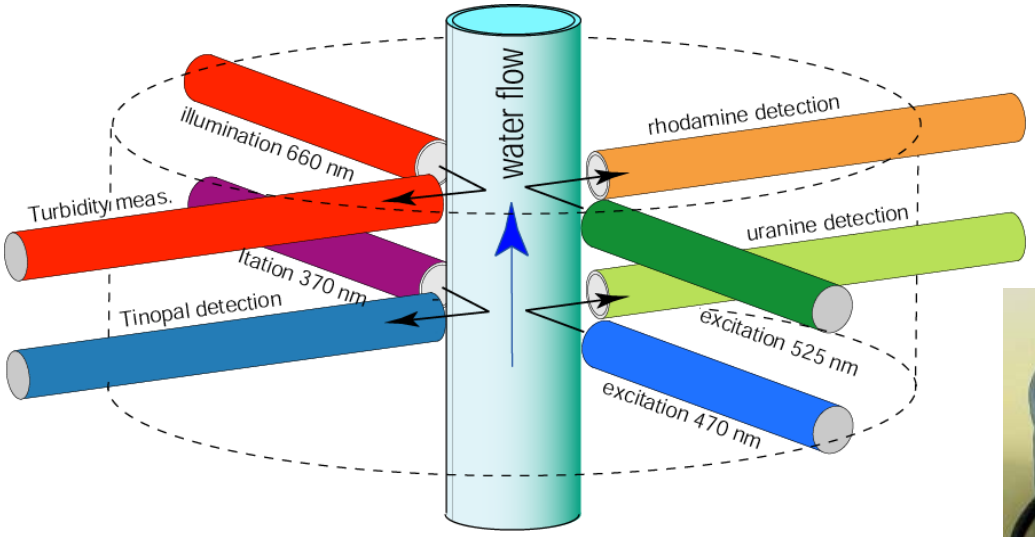
FINITE POINT VOLUME DILUTION METHOD

SOURCE: BROUYERE ET AL, 2008



GROUNDWATER FLUX MEASUREMENT (CONT'ED)

FLUORESCENT DYES



- Can detect up to three tracers simultaneously
- Turbidity can be a limiting factor
- Has data-logger and telemetry option

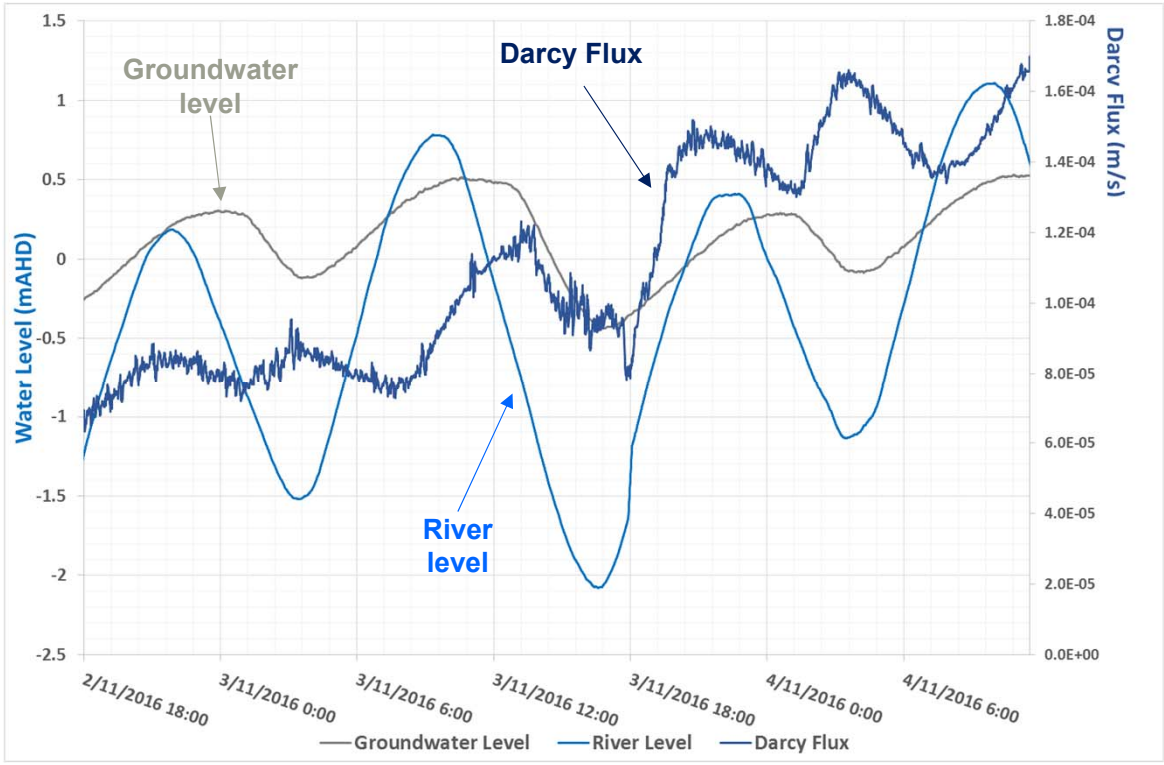
Fluorescent tracer	Limit of detection (µg/L)
Fluorescein	0.002
Sulforhodamine B	0.006
Eosine	0.01
Tinopal	0.01
Amino G acid	0.02
Pyranine	0.02
Naphthionate	0.05
Photine	1

GROUNDWATER FLUX MEASUREMENT (CONT'ED)

APPLICATION TO TIDAL ZONE

- Groundwater flux measurement depends on:
  - Detection limit of tracer (0.01 μg/L to 1 μg/L)
  - Control on tracer injection and sampling flow rates (< 0.1 L/min)
- Basis of accuracy
- Real-time measurement

➢ Particularly suited to dynamic environments (e.g. tidal zones, discharge to surface water, active remediation)



CONCLUSIONS

- Vertical pore water profiles demonstrated that risk from contaminated groundwater discharge can be markedly reduced by groundwater–surface water mixing and attenuation
- Groundwater flux measurements formed a critical piece to develop priorities for a source reduction program
- Tools used enabled an improved characterisation of transport, mixing and attenuation before discharge in the receiving environment
- Benefits:
    - Improved understanding of risk of site impacts
    - Supported engagement with regulators
    - Formed basis for assessing practicability of remedial options

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QUESTIONS?

References

IN ORDER OF APPEARANCE

Lamontagne S., Cosme F., Minard A. and Holloway A, 2018. *Nitrogen attenuation, dilution and recycling at the groundwater – surface water interface of a subtropical estuary inferred from the stable isotope composition of nitrate and water.* Hydrology and Earth System Sciences (Under review). European Geosciences Union.

Brouyere S., Batlle-Aguilar J., Goderniaux P. and Dassargues A, 2008. *A new tracer technique for monitoring groundwater fluxes: The finite volume point dilution method.* Journal of Contaminant Hydrology 95 (2008) 121 – 140.