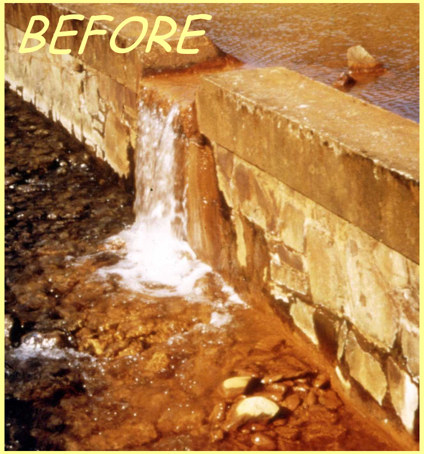
Mine water remediation paradigms and the Water Framework Directive (WFD): addressing diffuse as well as point sources



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Environmental Regulation of Mine Waters in the EU

European Commission Fifth Framework Programme:
Key Action Sustainable Management and Quality of water.
Contract no. EVK1-CT-2000-00078

- OBJECTIVES:
  - Analysis of environmental, social, technical, economic, institutional and legal aspects of mine water regulation for EU and accession states (near + remote)
  - Establishment of stakeholder dialogue networks (national and EU level)
  - Assess options for improved mine water management at catchment scale
  - Propose avenues for better integration of EU policies which influence mine water management

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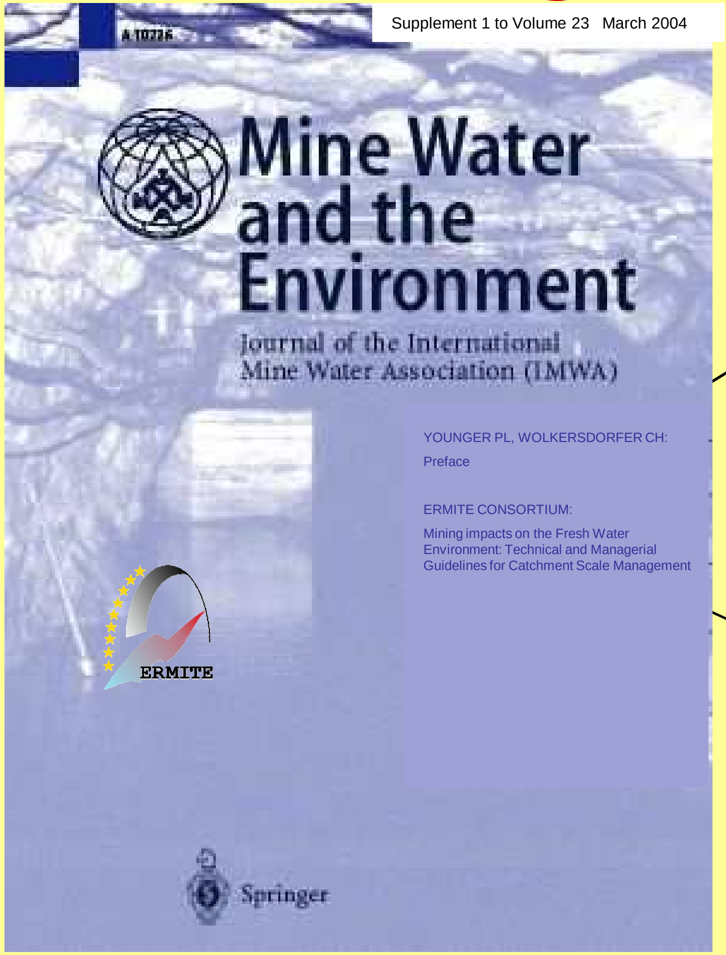
www.minewater.net/ermite

ERMITE Guidelines for catchment-scale management of mining impacts



YOUNGER PL, WOLKERSDORFER CH:

Preface

ERMITE CONSORTIUM:

Mining impacts on the Fresh Water Environment: Technical and Managerial Guidelines for Catchment Scale Management

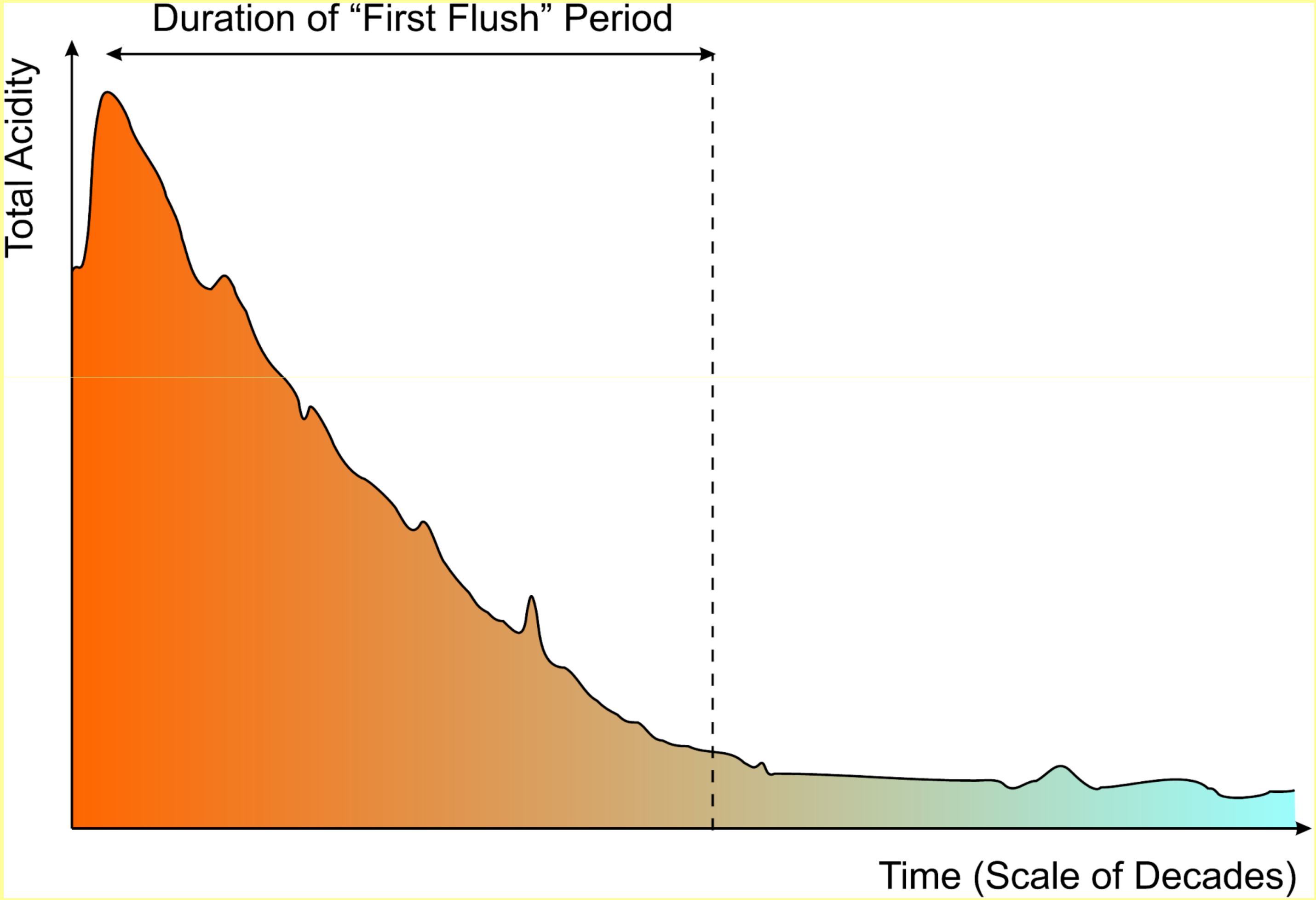
Free download (beware: 20Mb!) from:
www.minewater.net/ermite/ERMITE_D6.pdf

Mine waters and the WFD:

key challenges in planning to attain and maintain 'good status'

- Quality: Fe (benthic smothering), ecotoxics (Zn, Al, H^+), drinking water quality (Mn, SO_4, salinity)
- Time-scales:
  - The quality of many mine water discharges remains poor for centuries (even millennia) after the cessation of mine dewatering
- Extent:
  - Many km of rivers "at risk" of failing WFD due to mine waters (e.g. 2500 km in England and Wales)
  - Large areas of public supply aquifers also at risk (e.g. 9000 km^2 in England and Wales)

Time-scales over which mine water pollution is problematic



What are we now good at?

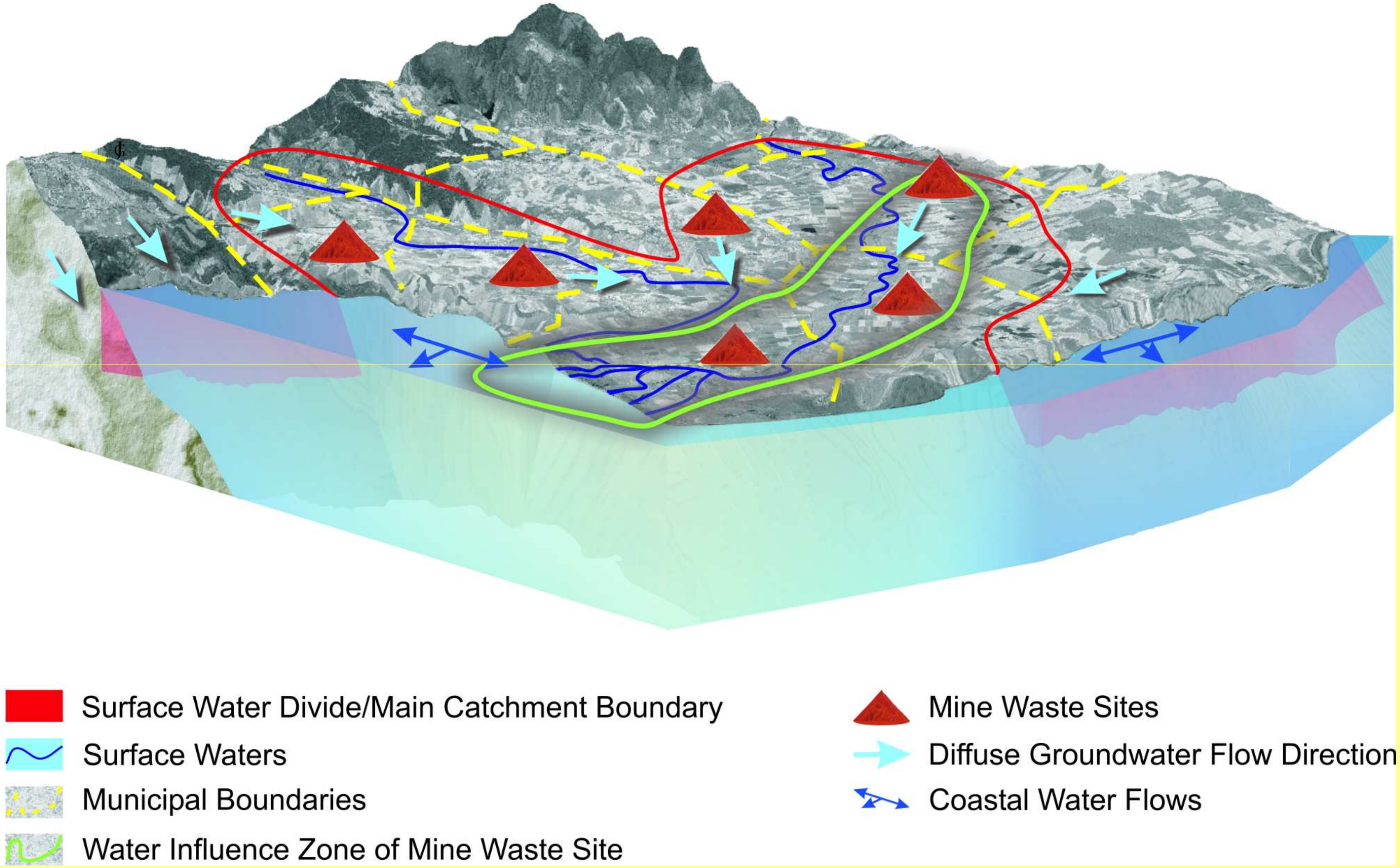
- Treatment of point sources:
  - Active

e.g. UK Coal Authority Horden HDS plant, Durham. (design: Unipure Europe Ltd)

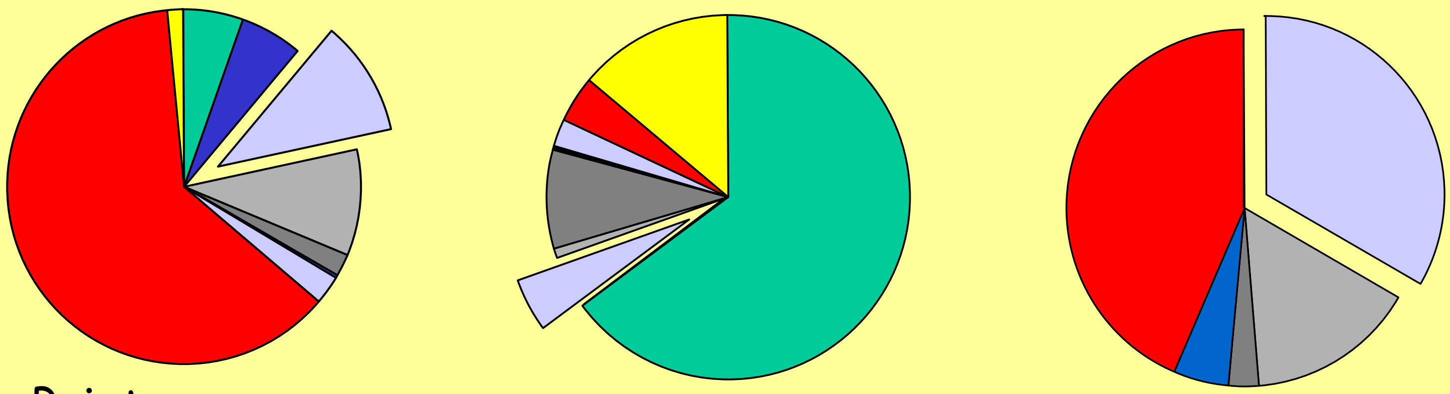
  - Passive

e.g. Pelenna III RAPS and Wetlands, Wales. (design: speaker)

The catchment perspective: point and diffuse mine water pollution sources



Point v diffuse water pollution in Scotland: mines and other sources of pollution



Point sources affecting major rivers

Diffuse sources affecting major rivers

Point sources affecting groundwaters

- Agriculture and forestry
- Operation of fish hatcheries and fish farms, commercial fishing
- Mining and quarrying
- Manufacturing
- Electricity, gas and water supply
- Construction
- Wholesale and retail trade
- Transport, storage and communication
- Sewage and refuse disposal
- Land drainage, land claim, flood defence, urbanisation

What are we still poor at?

- Diffuse mine water pollution:
  - Issues of characterisation
  - Issues of remediation technology
- Inexpensive treatment for "difficult" mine waters. e.g.:
  - Zn-rich, hard mine waters
  - Very saline mine waters
- Decision-making over sub-aquifer rebound:
  - Large and complex systems, often data-sparse
  - Limited experience to date; expertise scarce
  - Generally only one chance to "get it right" for any one aquifer!

focus of this talk

Diffuse mine water pollution

- One of the biggest challenges in relation to mine water remediation to meet the WFD
  - Extent: largely unquantified - has only been rigorously addressed in a few studies to date
    - *Tendency to mis-identify point sources as 'diffuse' due to surveying catchment loadings at too coarse a scale*
  - Unclear liabilities: Complicated 'ownership' issues; vague legal definitions; hinders pursuit of funding
  - Technology gap: lack of technologies to cost-effectively address true diffuse inputs

Estimating the extent of diffuse pollution – some examples

- Coalfields of Wales:
  - judging from Environment Agency data, around 35% of coal mine related pollution is diffuse
- Zn pollution in Nent valley (N England):
  - 35% 'point' (adit outflows)
  - 65% diffuse
    - of this half is "*very diffuse*" (seepage from contaminated land near old smelter), and half "*identifiably diffuse*" (associated with several major tailings dams)

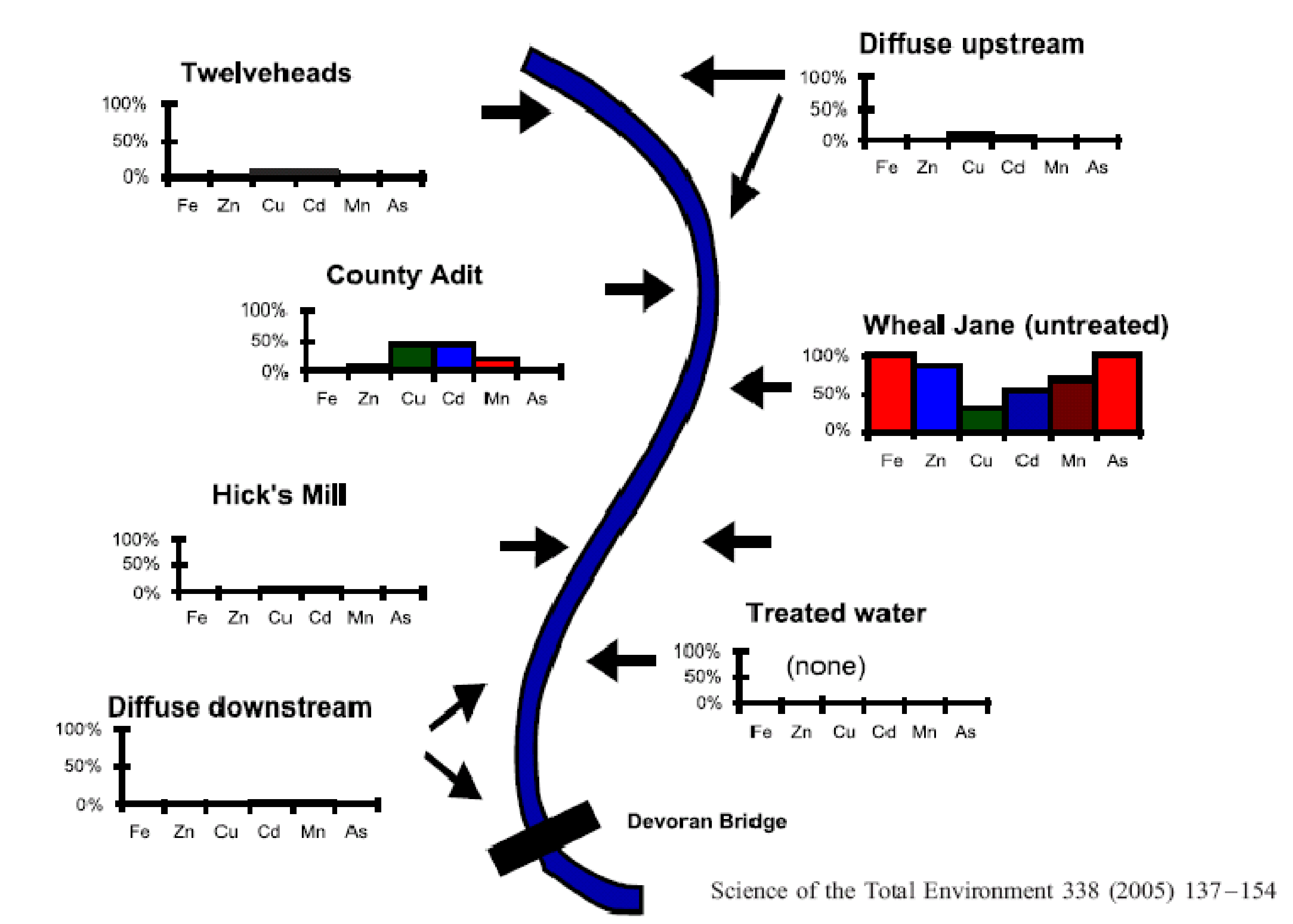
Estimating the extent of diffuse pollution – further examples

- Dal River catchment, Sweden:
  - Falun and Garpenberg sub-catchments have very long metalliferous mining histories
  - Point / diffuse split remarkably consistent between catchments and between contaminants

Sub-catchment		Zn	Cd	Cu
Falun	Point %	90.3	79.7	89.6
	Diffuse %	9.7	20.3	10.4
Garpenberg	Point %	91.1	77.2	58.9
	Diffuse %	8.9	22.8	41.1

Estimating the extent of diffuse pollution – further examples

Carnon Valley, Cornwall (UK)



Science of the Total Environment 338 (2005) 137–154

Does point/diffuse ratio vary dynamically?

- Foregoing examples mainly annual averages
- Given that runoff processes vary seasonally, it is logical to suppose that the ratio of point / diffuse mine water pollution will also vary over the year
- Case study of River Gaunless examines this supposition, using time-series flow and hydrochemical data and distinguishing between dry and wet periods

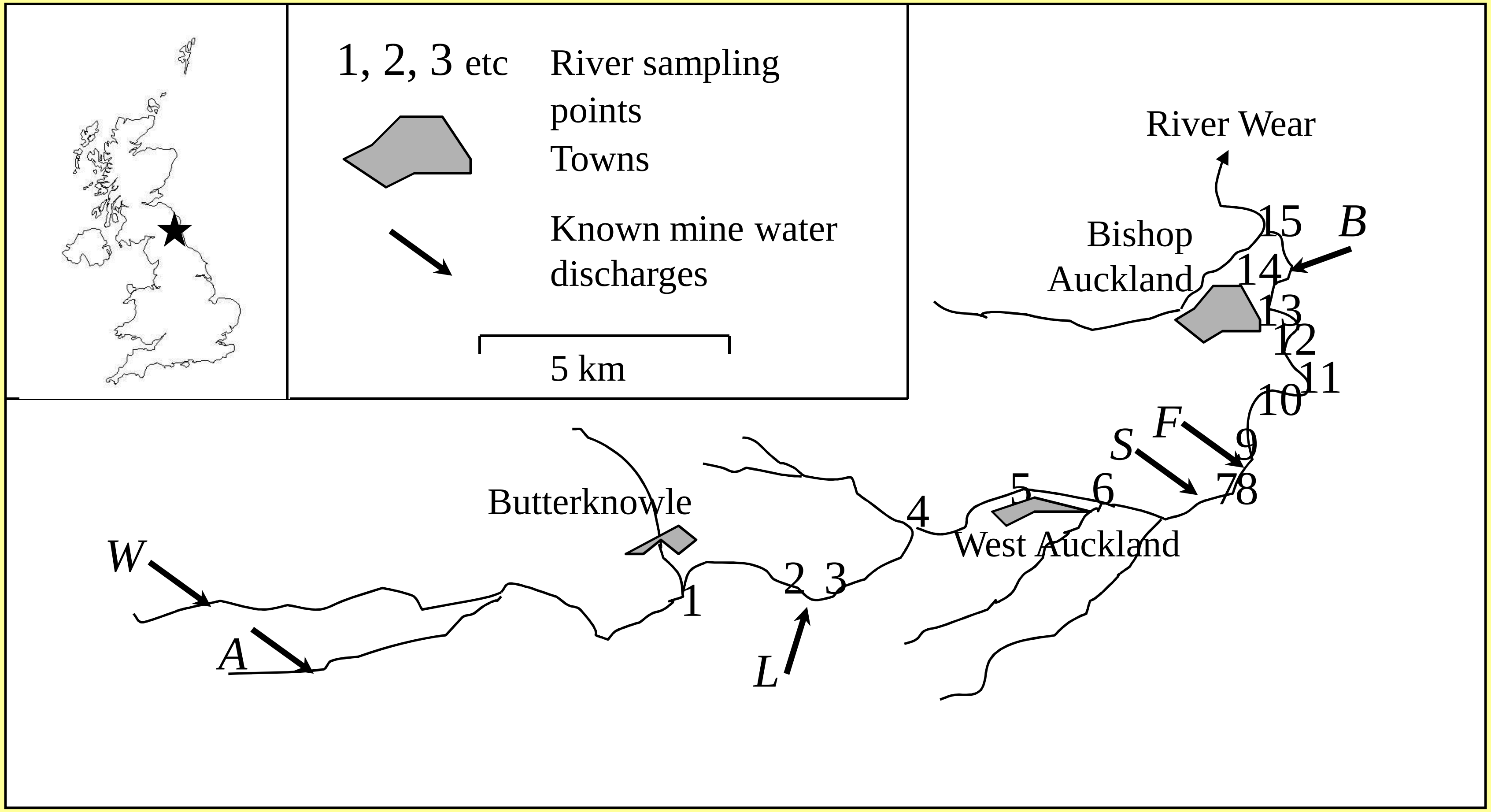
Case study: River Gaunless

- River Gaunless: major tributary of the River Wear, in the southern portion of the Durham Coalfield, County Durham (NE England)
- River Gaunless receives discharges from numerous abandoned mines
- Phases of abandonment in 1920s and 1960s; final cessation of pumping to affect catchment was in 1975, and most recent new discharges commenced flowing in 1981

River Gaunless Catchment Study

- Context: to design more effective remedial measures to address ochre smothering of benthos and Fe-related turbidity in river
- Data collected over many years by Environment Agency and predecessor organisations
- Mass balance study of:
  - dissolved and total Fe at numerous sites within the main river channel, for both dry and wet weather periods
  - Known point sources of Fe (major mine water discharges), with diffuse sources identified by difference

Gaunless Catchment Study



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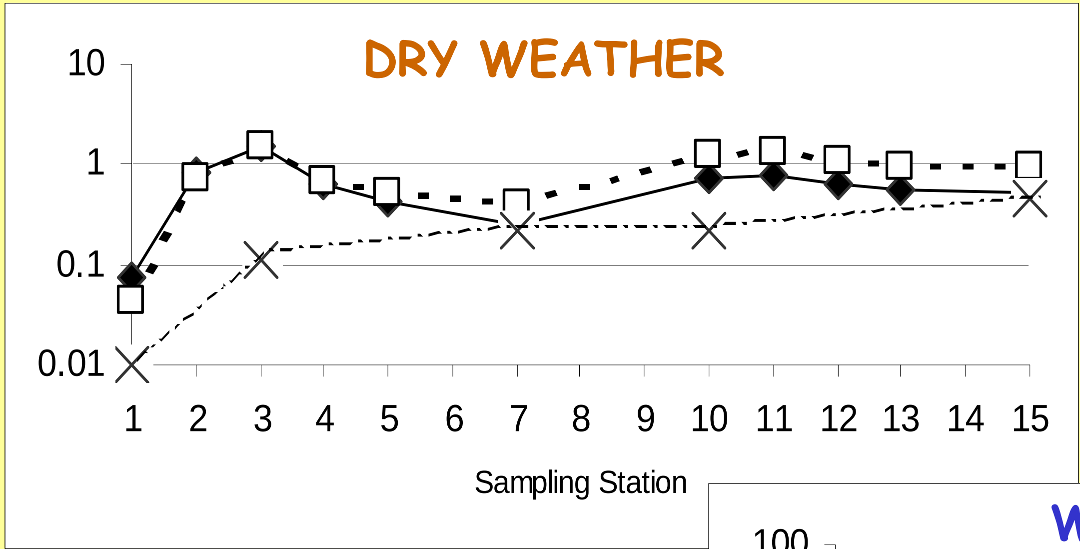
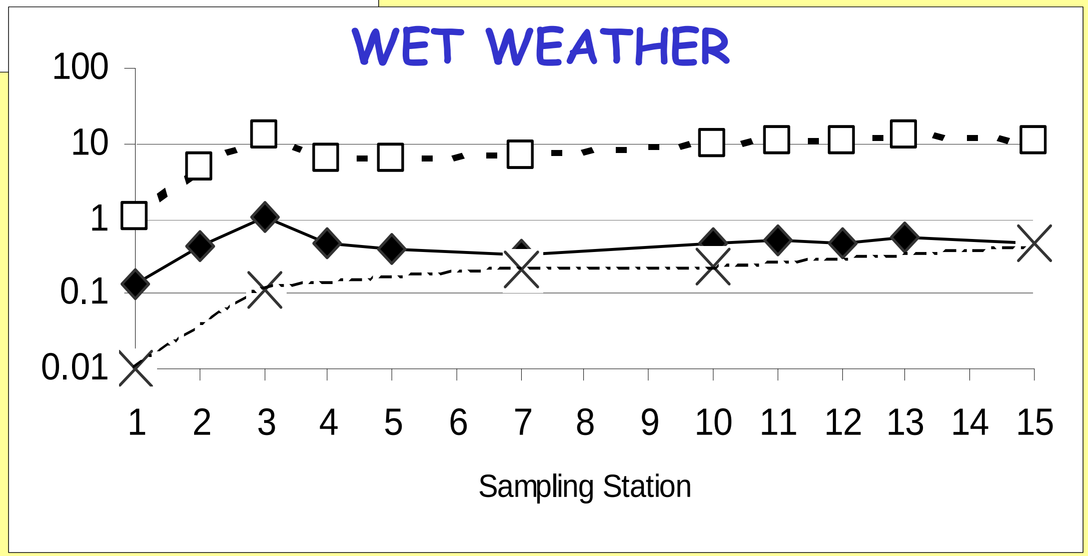
Gaunless Catchment Fe loadings





□ Total Fe loading (g/s)

X Cumulative total Fe loading (g/s) from known point sources

◆ Total Fe conc. (mg/l)

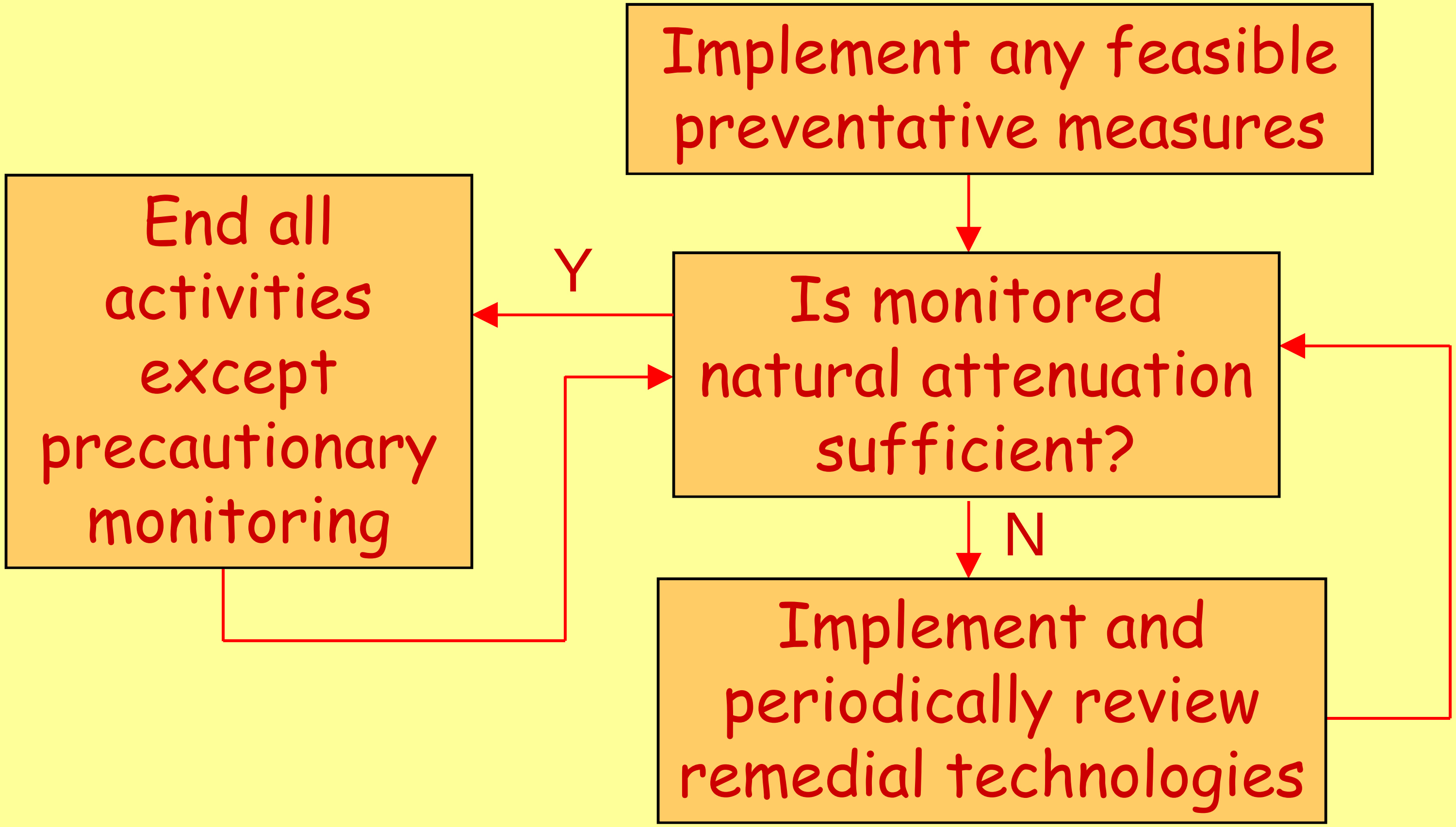
Gaunless Study: Findings

- Proportion of Fe loading which is diffuse varies with weather:
  - During dry weather periods, around half (52%) of total Fe load diffuse in origin
  - In wet periods, as much as 95% is diffuse in origin

Gaunless Study: processes?

- *52% diffuse in dry weather flow*:
  - suspected mechanisms for entry to channel are by seepage from shallow workings (locally visible) and via alluvial groundwater contaminated by upflow from underground workings
- *95% during wet periods*:
  - Suggests considerable remobilisation of Fe from bed sediments by scouring when flow velocities are high

Generalised mine water remediation paradigm

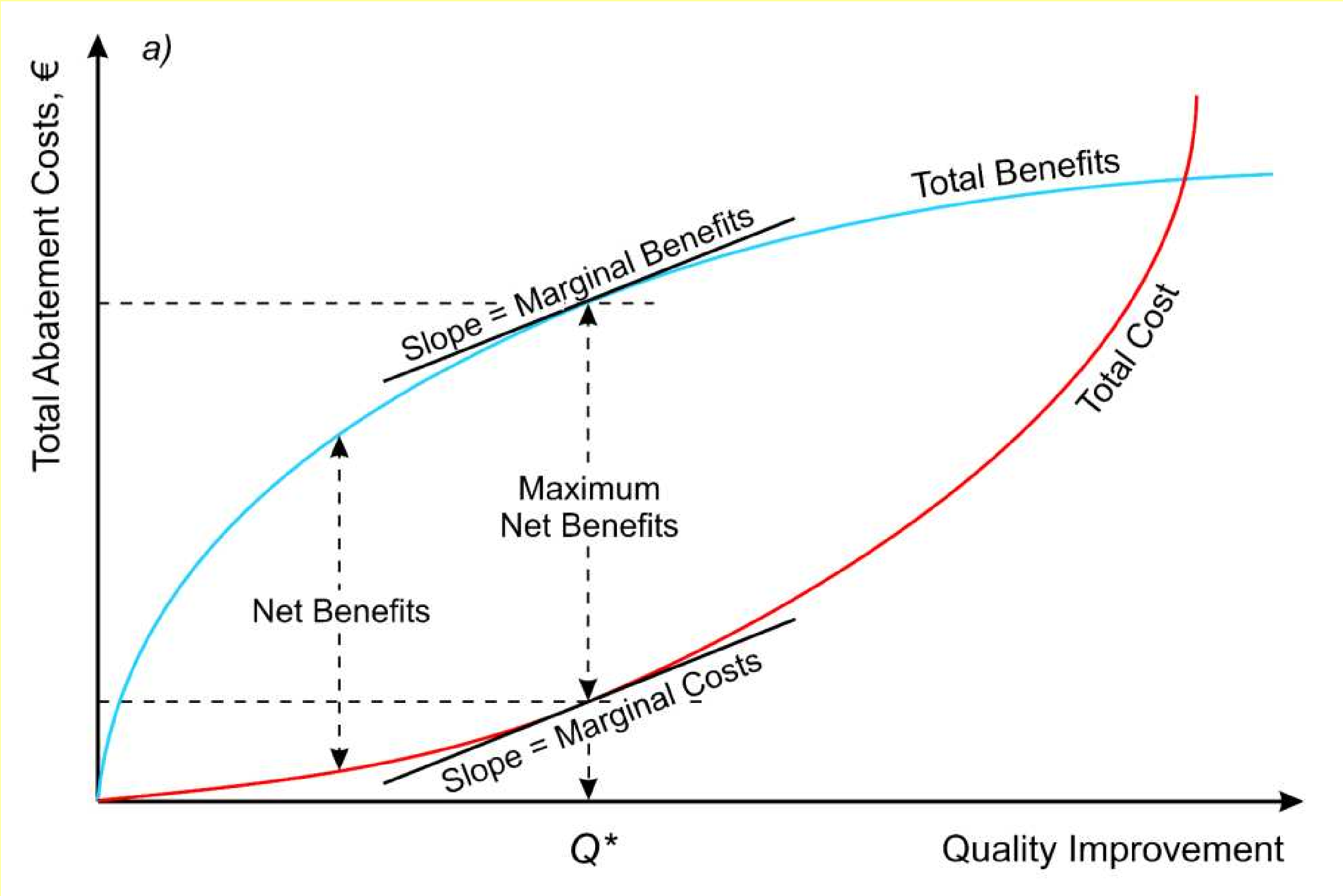


Technologies for diffuse mine water pollution control

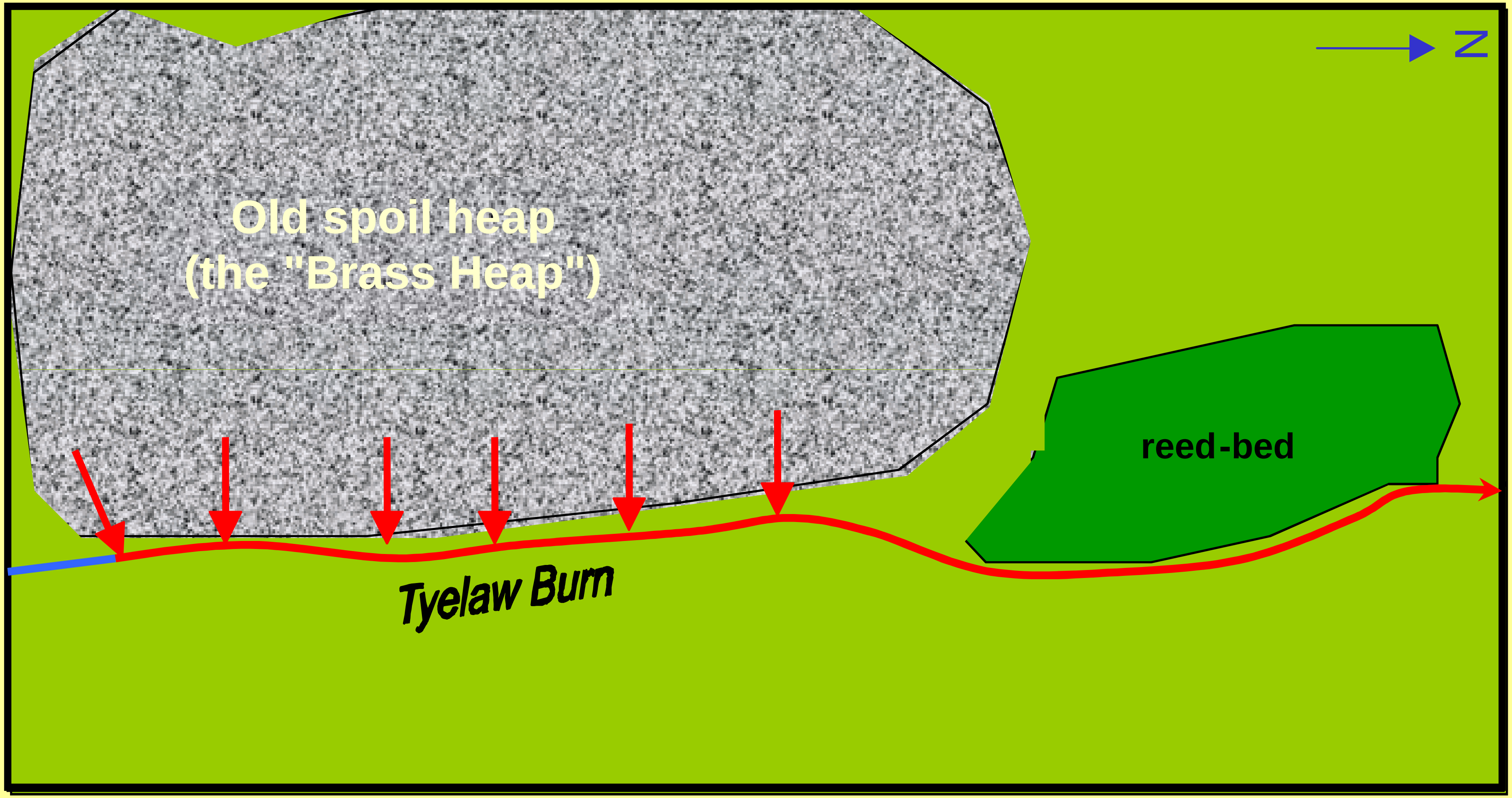
- **Monitored natural attenuation (MNA)** – using natural processes to achieve best overall environmental result
  - Recognises that remediation itself has environmental costs
  - Requires well-designed monitoring and modelling coupled to rigorous economic analyses
- **Permeable reactive barriers (PRBs)**
  - good for "identifiably diffuse" pollution (e.g. long seepage zones along toes of tailings dams / spoil heaps etc (e.g. Shilbottle example)
- **Other technologies?**
  - Exfiltration galleries
  - Gradient control pumping (low flow)

} New ideas: not yet prototyped

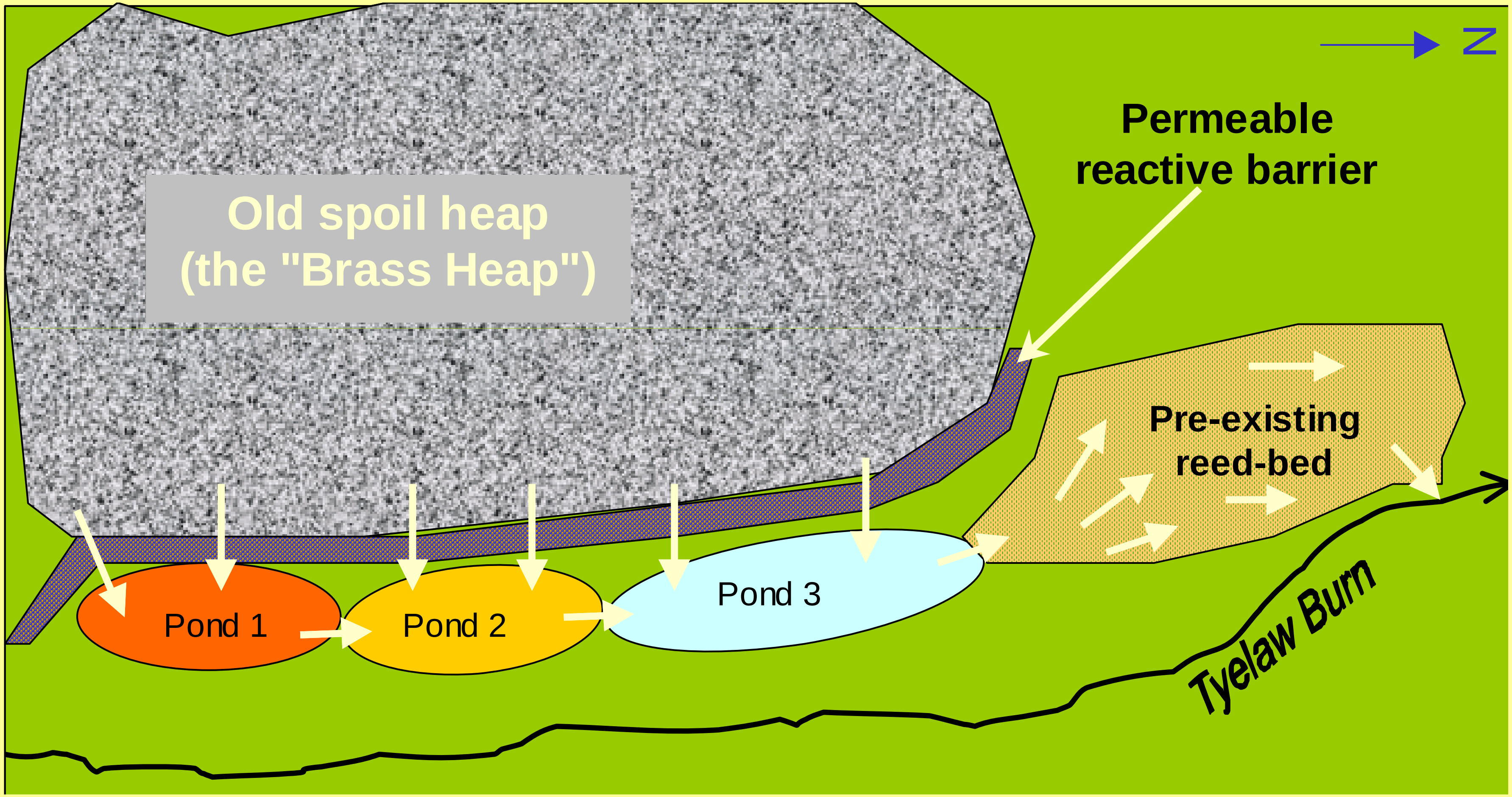
Economic assessment:
key to MNA (and other remedial interventions)



Shilbottle Colliery – original situation



Shilbottle PRB system



Shilbottle PRB (a CoSTaR site)

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Coal Mine Sites for Targeted Remediation Research

The COAL AUTHORITY

CL:AIRE

CoSTaR

Facility

Partnership

Funding

Sites

HERO

Contact: costar@ncl.ac.uk

IRES

Concluding remarks

- Diffuse mine water pollution is a significant contributor to the risk of failing to comply with the WFD in many catchments
- The proportion of mine water pollution which is diffuse varies from catchment to catchment, and over time within any one catchment; 0% diffuse apparently rare
- Rigorous economic analysis is a pre-requisite for rational, defensible remediation planning
- Planning for remediation requires a more nuanced appreciation of the modes of diffuse pollution release:
  - Groundwater outflows versus surface runoff?
  - 'new' polluted water or remobilised pollutants?
- New technologies will be needed if we are to become as successful in combating diffuse sources as we are now at remediating point sources of mine water pollution