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Clogging in subsurface-flow treatment wetlands: assessment and management

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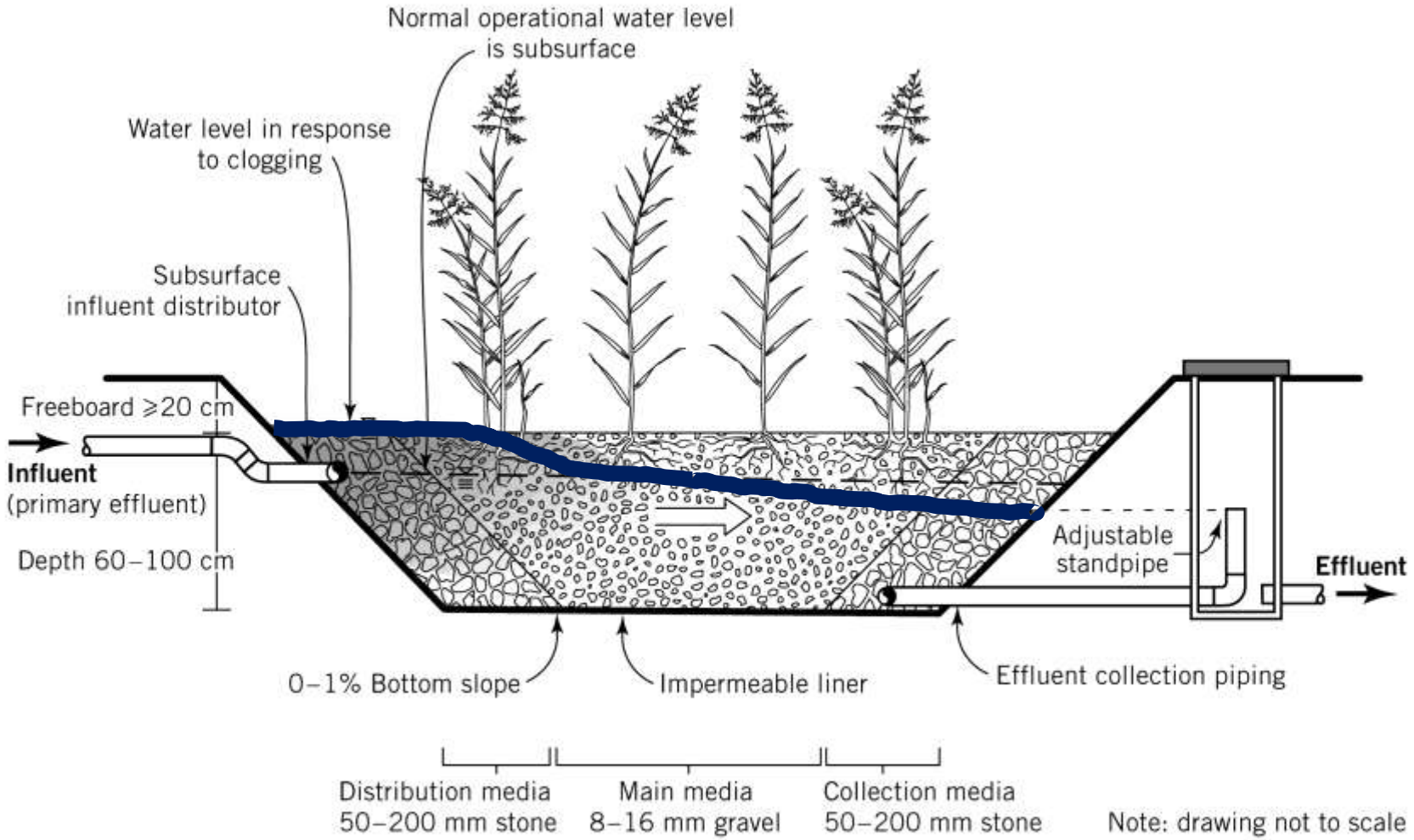
Objectives

1. Present and discuss available techniques to assess the extend of clogging
2. Report and discuss various maintenance strategies

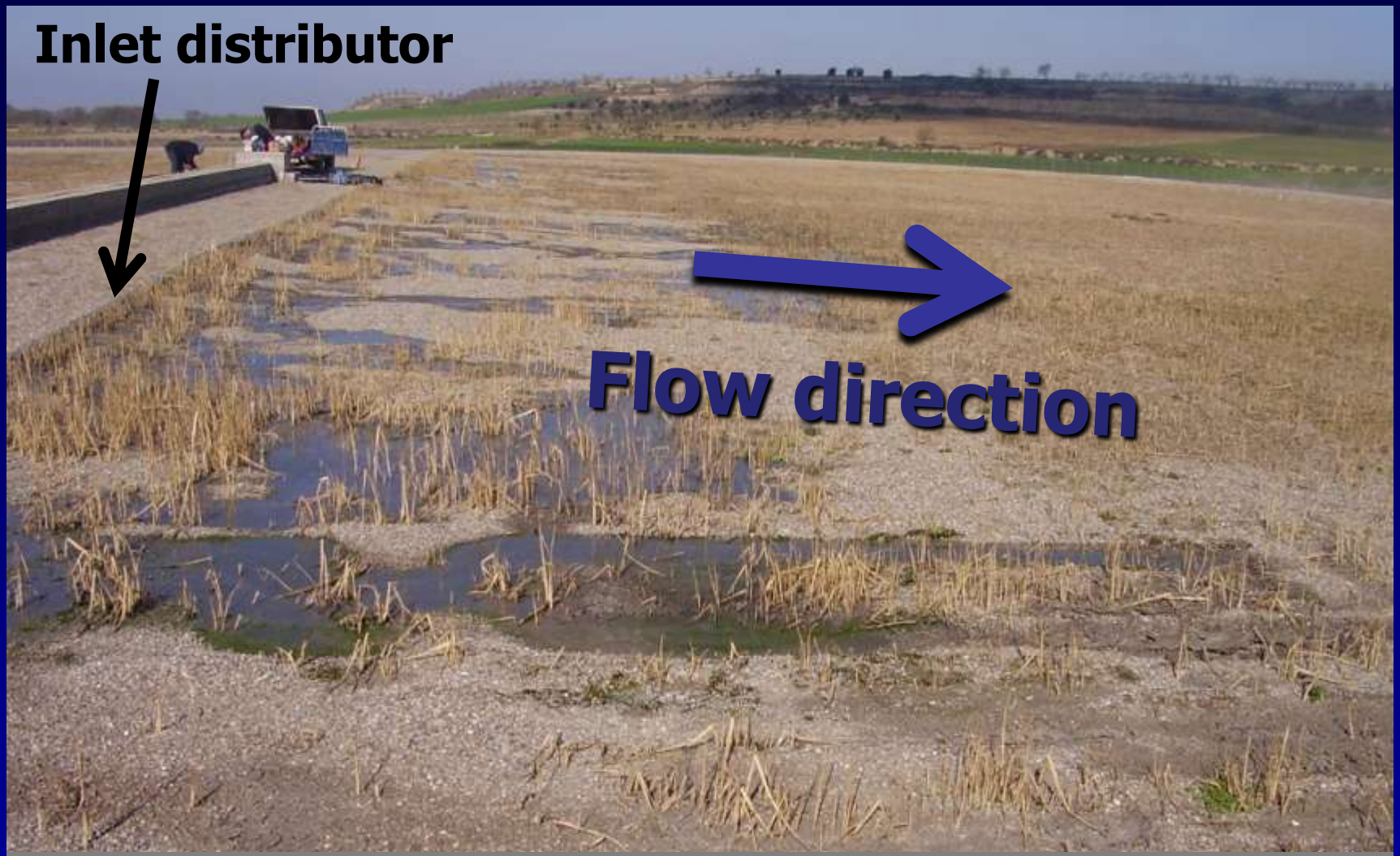
Previous considerations

- Wetlands are nowadays widely used for removing pollutants from wastewater. These systems are mechanically simple and have low O&M costs
- In the last two decades clogging has appeared as a widespread operational problem
- Clogging is a complex process characterised by progressive reduction in porosity of the granular medium

Clogging



Knowles et al. (2011)



- A certain degree of clogging near the inlet zone is inevitable

- The requirement to remediate clogged systems rarely arises from poor treatment performance

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Review

Clogging in subsurface-flow treatment wetlands: Occurrence and contributing factors

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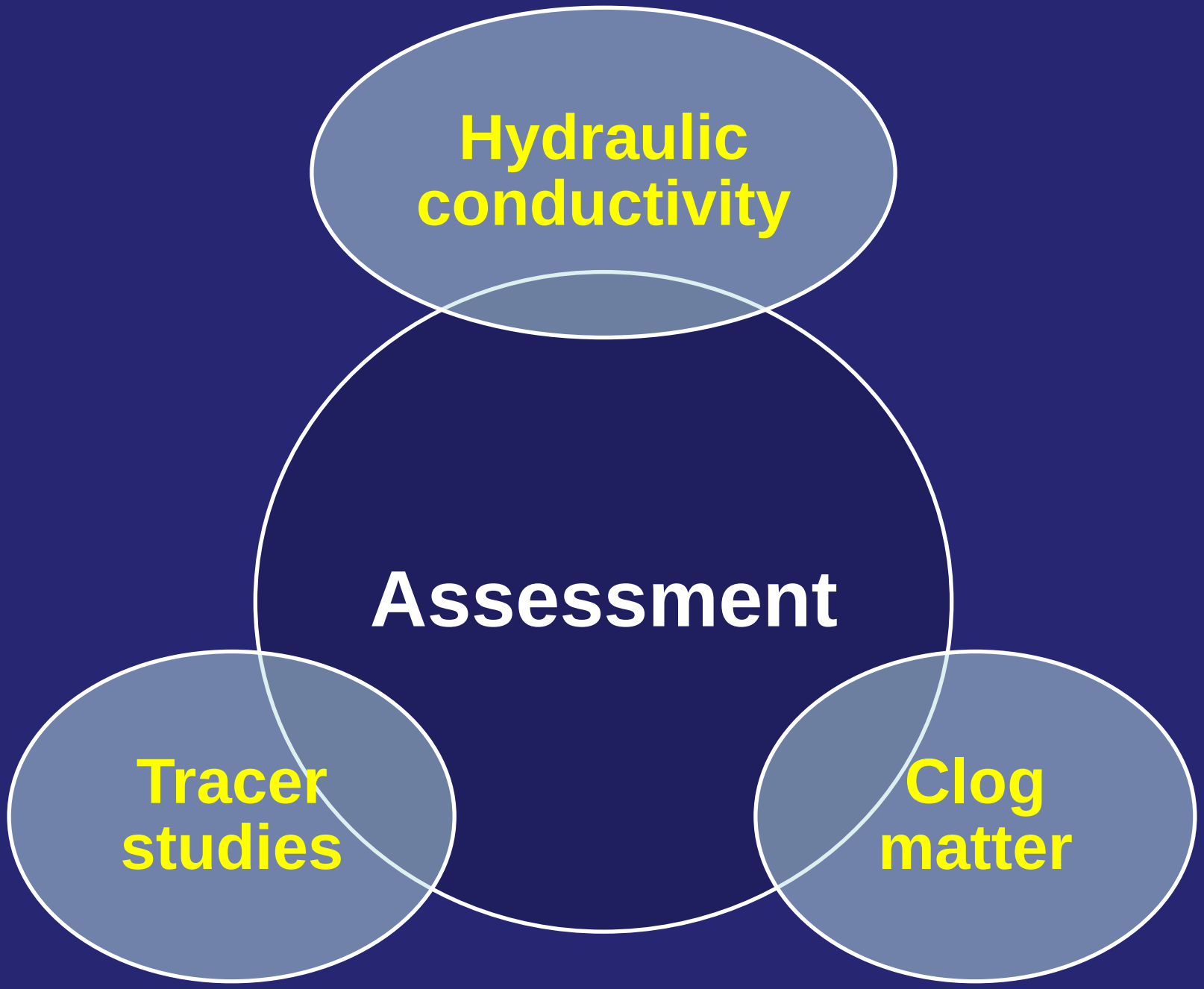
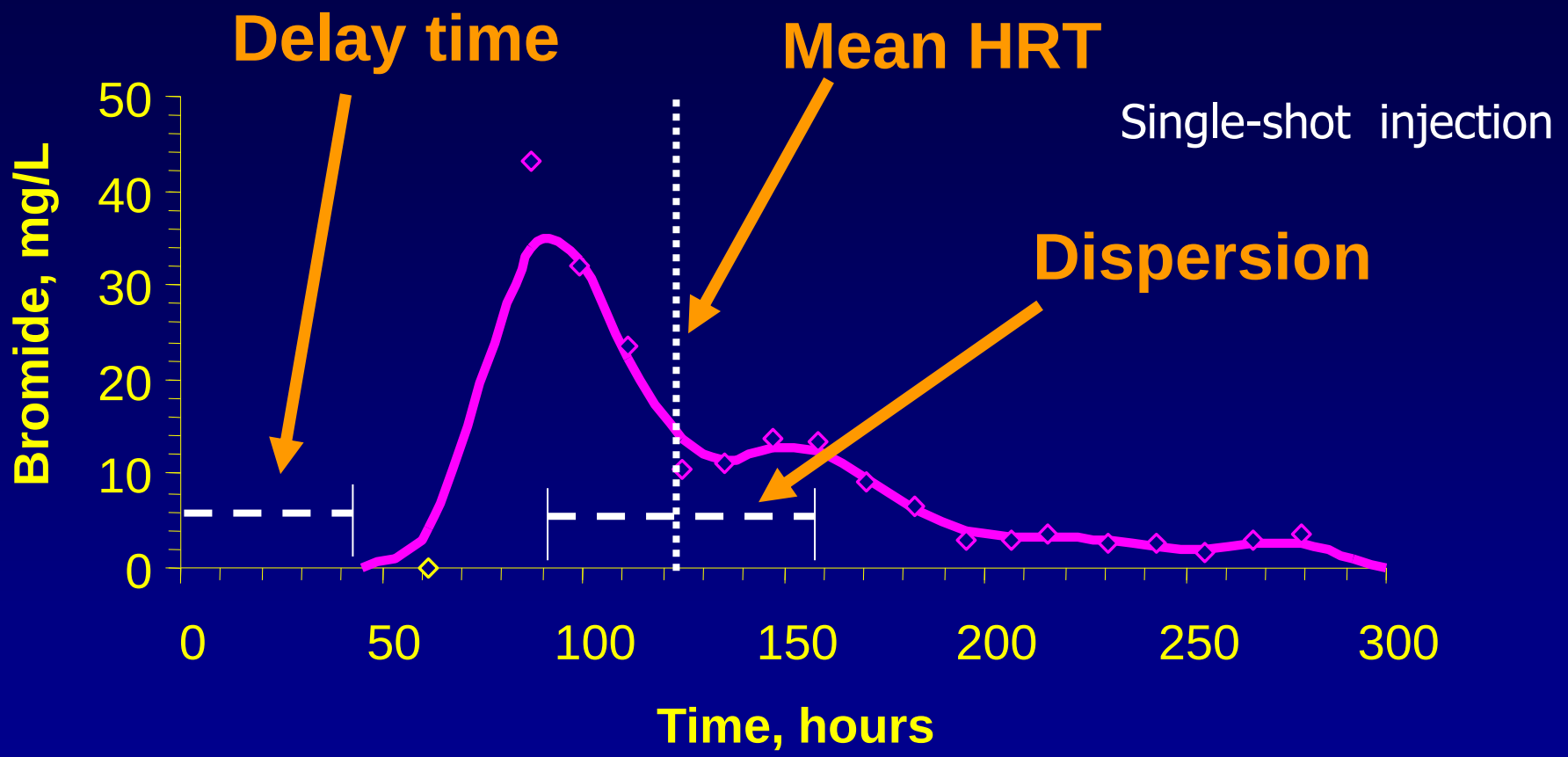
- Different varieties of wetlands clog in different manners

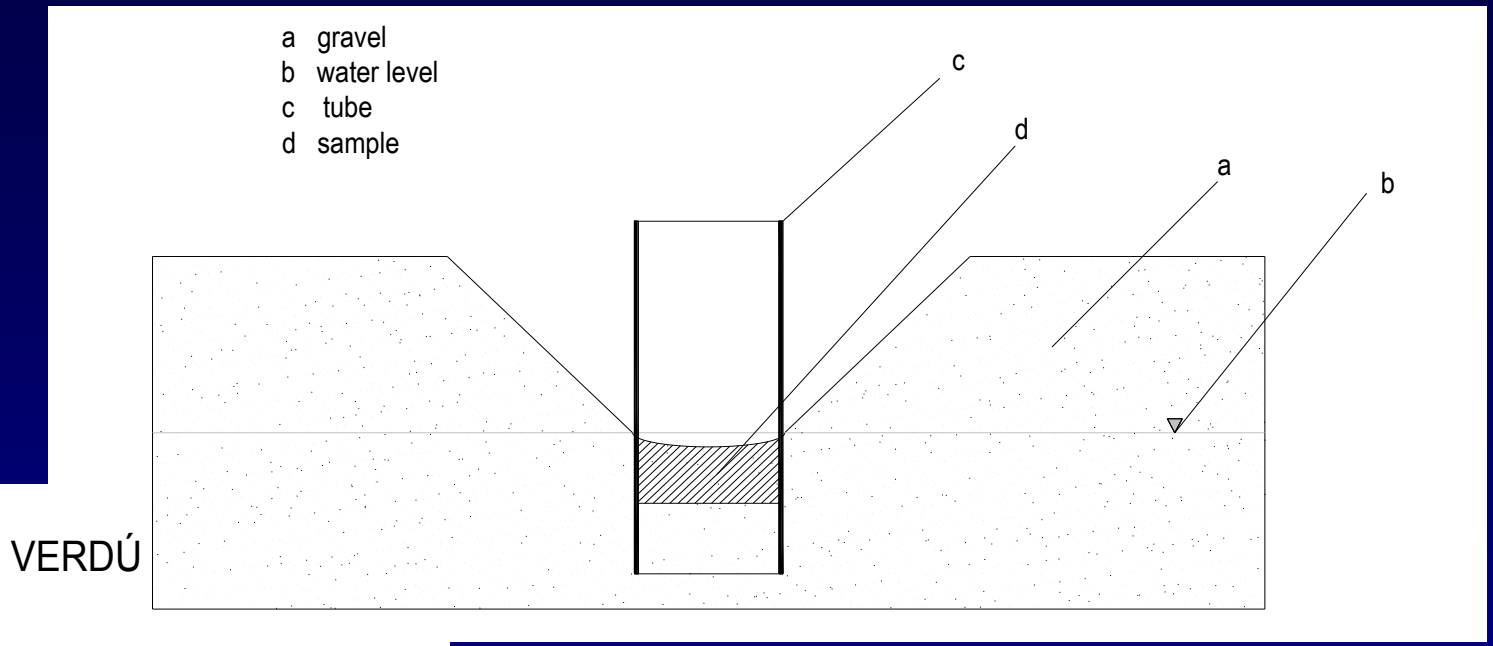

Hydraulic conductivity
Assessment
Tracer studies
Clog matter

Tracer studies

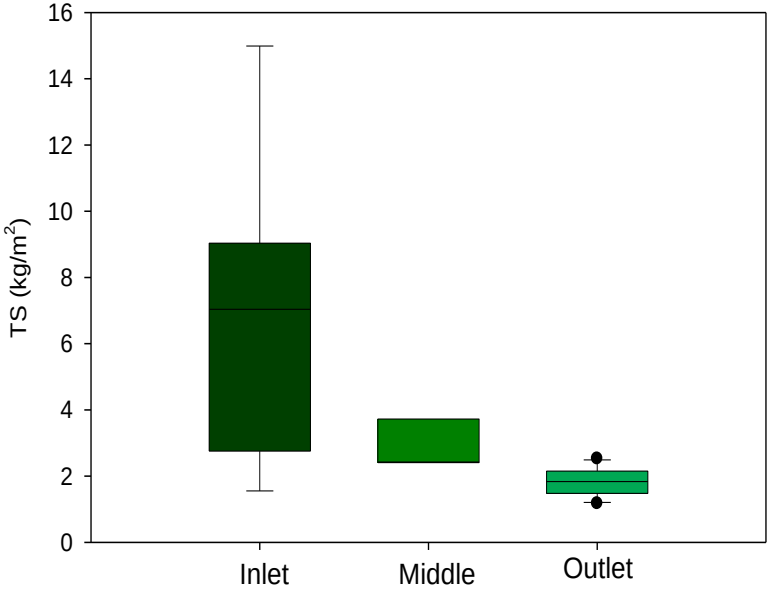


- Allow to identify multiple preferential paths (short-circuiting). Internal studies allow to observe the location of flow paths
- Problem: Hydraulic performance is probabilistic, a single test shows one from a possible range of hydraulic behaviours
- Disadvantage: requiere hard work; sensitive to rain, etc

Clog matter: solids accumulation

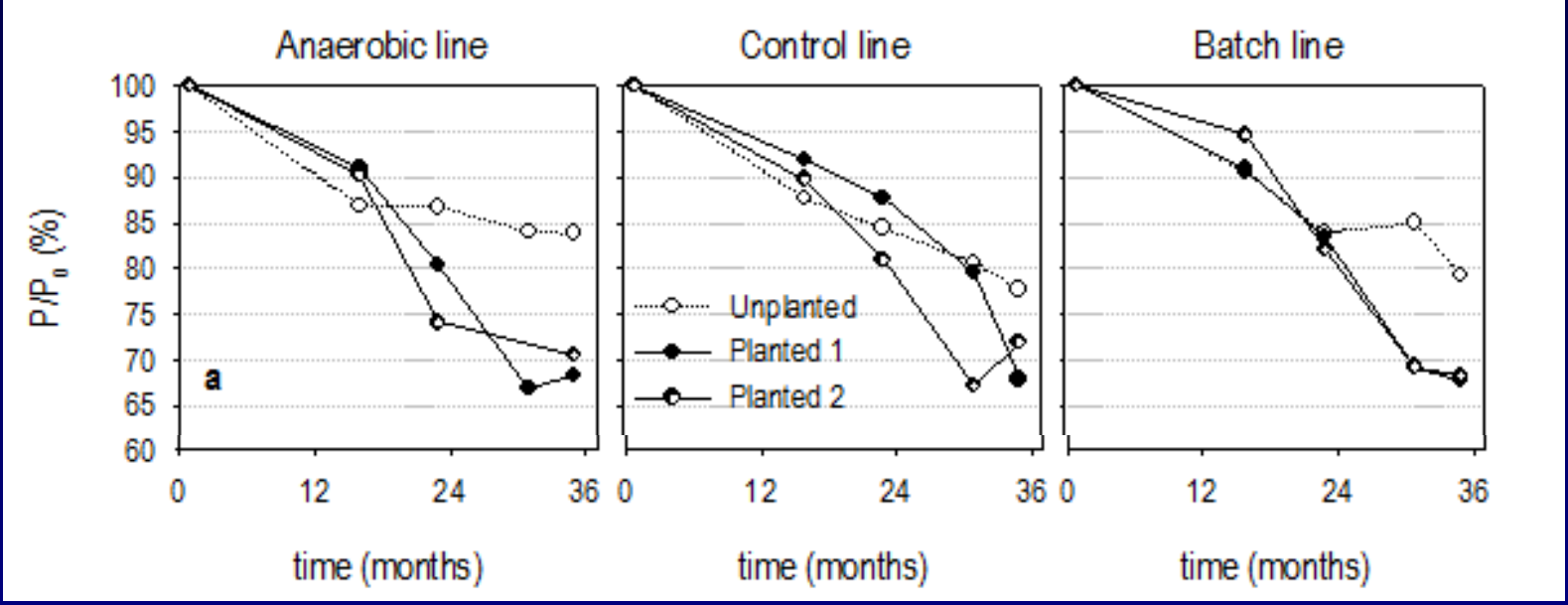


Pedescoll et al. (2009)

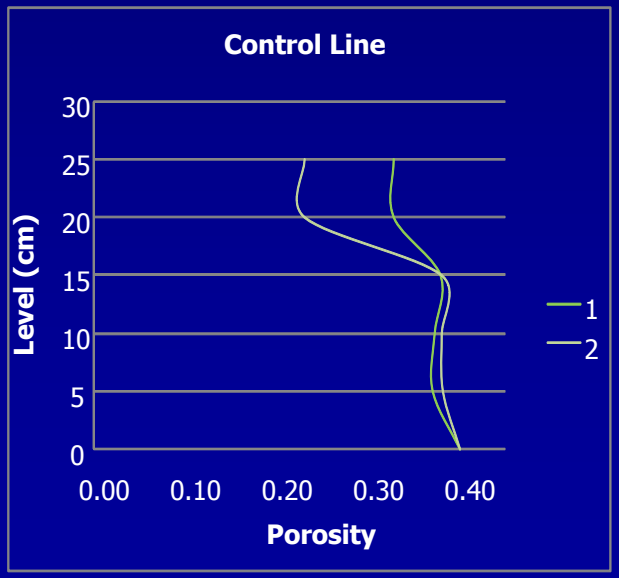


- Medium samples have to be taken out, washed and measured for TS and VS
- Problem: media are non-cohesive and it is very difficult to take out unaltered samples
- Disadvantage: requires hard work; not directly related with hydrology

Clog matter: drainable porosity

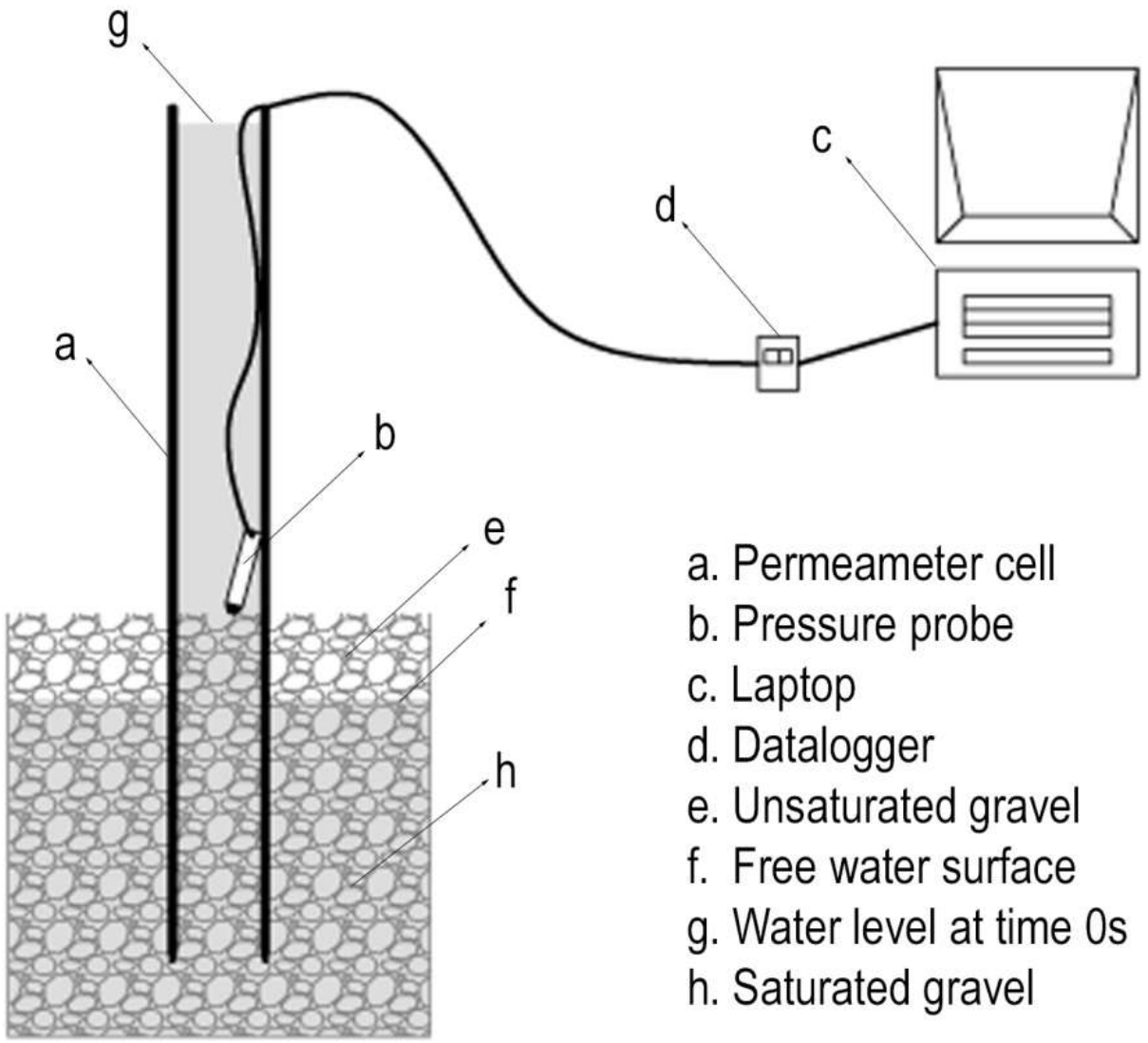


Pedescoll et al. (2011)



- Allow to have a general measure of clogging. Vertical porosity also can be measured.
- Problem: not applicable to field scale
- Advantage: easy to measure in experimental systems

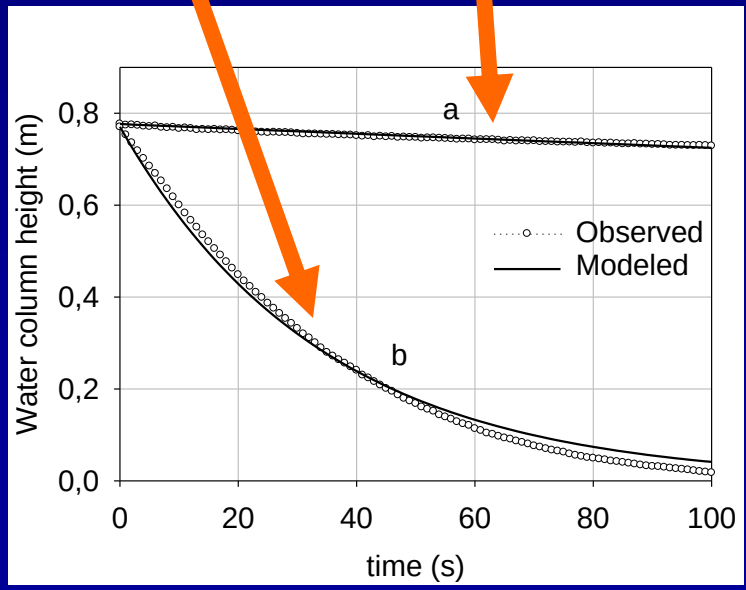
Hydraulic conductivity (falling head)



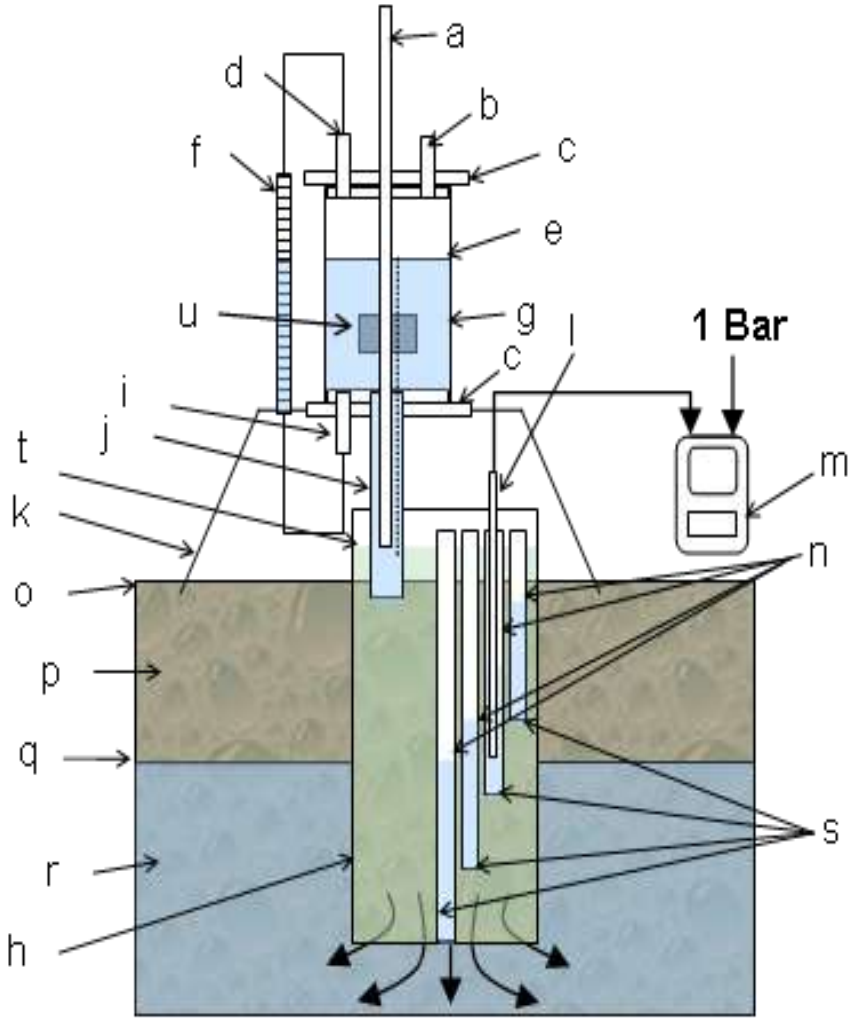
a. Permeameter cell
b. Pressure probe
c. Laptop
d. Datalogger
e. Unsaturated gravel
f. Free water surface
g. Water level at time 0s
h. Saturated gravel

Pedescoll (2010)

Hydraulic conductivity (falling head)



Hydraulic conductivity (constant head)

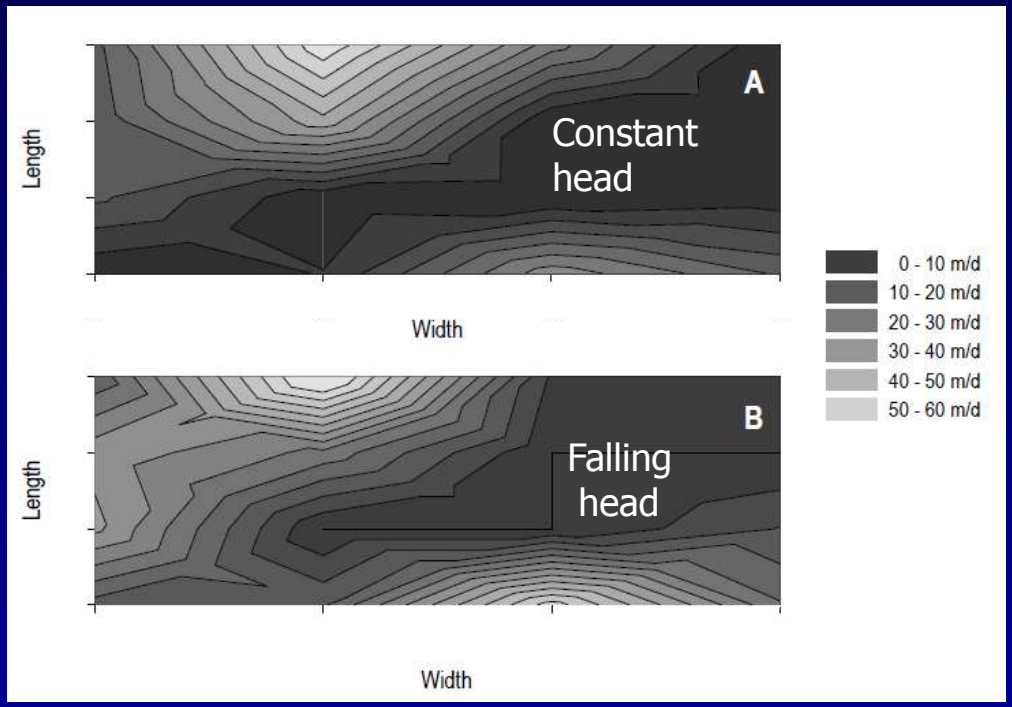


a. Air Inlet Pipe
b. Filling port
c. End cap
d. Air Port
e. Fluid Level in reservoir
f. Graduated measuring tube
g. Reservoir
h. 50cm long Permeameter Cell
i. Drain Port
j. Down pipe
k. Tripod
l. Graduated Depth Gauge
m. Digital Differential Manometer
n. Levels in manometer takeoff tubes
o. Gravel Surface
p. Unsaturated gravel
q. Free water surface
r. Saturated gravel
s. Manometer takeoff tubes
t. Mariotte Siphon Level
u. Stop cap

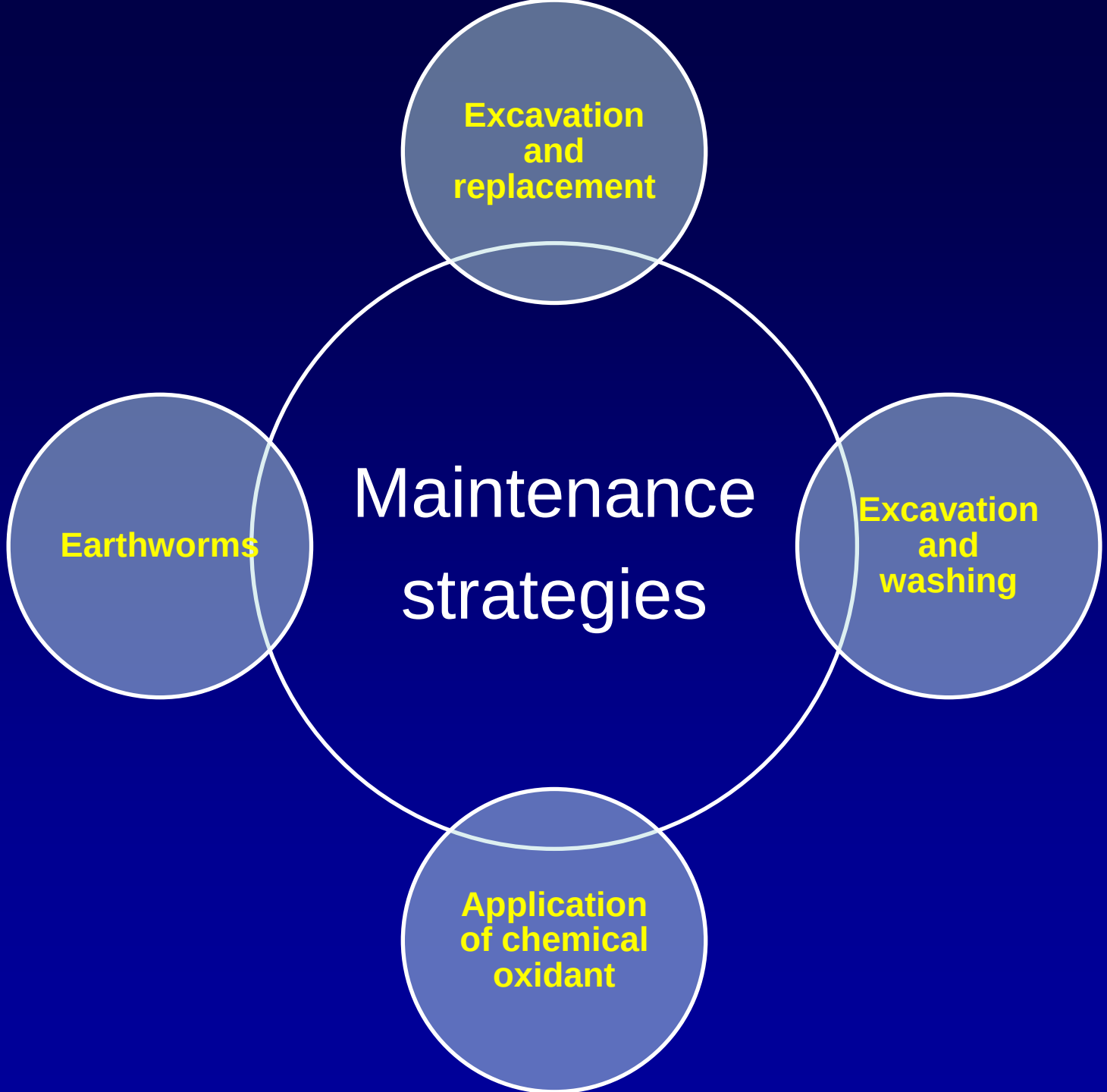
Knowles (2011)

Hydraulic conductivity

Bed at Fenny Compton, UK, 12.5 x 35 m



Pedescoll et al. (2011)


Excavation and replacement
Earthworms
Maintenance strategies
Excavation and washing
Application of chemical oxidant

Excavation and replacement

- Partial excavation and replacement is possible if clogging is only in the inlet zone. Usually coarser medium than the original is chosen

Costs of excavation and replacement		
Type of wetland, country	Cost	Reference
HSSF (secondary), USA	10-20% of initial cost	Kadlec and Wallace (2009)
HSSF (secondary, 1,600 m^2), Spain	81 €/m^2	Pedescoll et al. (2009)
HSSF (tertiary, 300 m^2), UK	75 €/m^2	Griffin et al. (2008)

Costs distribution (Griffin et al., 2008)

Excavation and washing

- Novel restoration option developed in UK
- Washing machine consists in a wash tank, grit trap and lamella settler used in conjunction with a rotating screen bucket
- Allows reuse of the media and eliminates the cost of landfilling dirty gravel. Savings of 55% are reported (Murphy et al., 2009)

Excavation and washing

Courtesy of Clodagh Murphy (ARM, UK)

Application of a chemical oxidant

- Gaining attention because is non-invasive and cost-effective

Nivala and Rousseau (2009)

Nivala and Rousseau (2009)

Application of a chemical oxidant

Examples at field scale		
Type of wetland (surface), country, chemical	Cost, results	Reference
HSSF (670 m^2), Minnesota, USA, 1,600 L concentrated H_2O_2	5,3 €/m^2, good results, short term change in water quality	Nivala and Rousseau (2009)
VSSF (670 m^2), Geel, Belgium, 100 L concentrated H_2O_2	7,5 €/m^2, most of the peroxide reacted with the surface clog media and little change was observed	Nivala and Rousseau (2009)

Earthworms

- Vermifiltration of sludge is well doccumented, so application of earthworms to clogged sytems is not a surprise. Davison et al (2005) reported a reduction of 56% of clog matter.

Courtesy of Isabel Martín (CENTA, Spain)

Conclusions: Assessment

- Numerous methods have evolved to allow wetland practioners to assess the extend of clogging
- Each method has its own limitations but can provide information that other methods cannot. Hydraulic conductivity measurements developed in recent years have many advantages for field scale studies (quick and not labour intensive)
- Other techniques that measure content of water and that can be related to clogging are being tested (nuclear magnetic resonance and electrical resistivity tomography)
- Preventive design strategies are also being implemented

Conclusions: Maintenance strategies

- Strategies based on excavation require caution to avoid damage of the liner. Also they are labour intensive and the costs are high (70-80 €/m^2). Dirty gravel washing avoids the cost of disposal and saves half of the money
- Application of chemical oxidants is cost-effective (5-8 €/m^2), however different degrees of success have been reported and more research is needed. Application of these substances requires strict safety measures.
- Use of earthworms is a new remediation option, and seems to be competitive (0.75 €/m^2 using 0.5 kg/m^2, according to Li et al. (2011)).

Review Paper

- Authors:

Jaime Nivala, Paul Knowles, Gabriela Dotro, Joan García and Scott Wallace

- Title:

Clogging in subsurface-flow constructed wetlands: Measurement, modeling and management

- Journal:

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