Integrated Constructed Wetland (ICW) Concept:

Reanimating Functional Wetlands

Institution of Civil Engineers
&
Engineers Ireland

Rory Harrington

VESI Environmental Ltd.

Background and Origins

- **A personal empathy for 'nature'**
- **Awareness of lost water quality**
- **The ecosystem concept, analyses and dynamics**
- **What if polluted water sources were intercepted by vegetated marshes?**

ecosystem concept

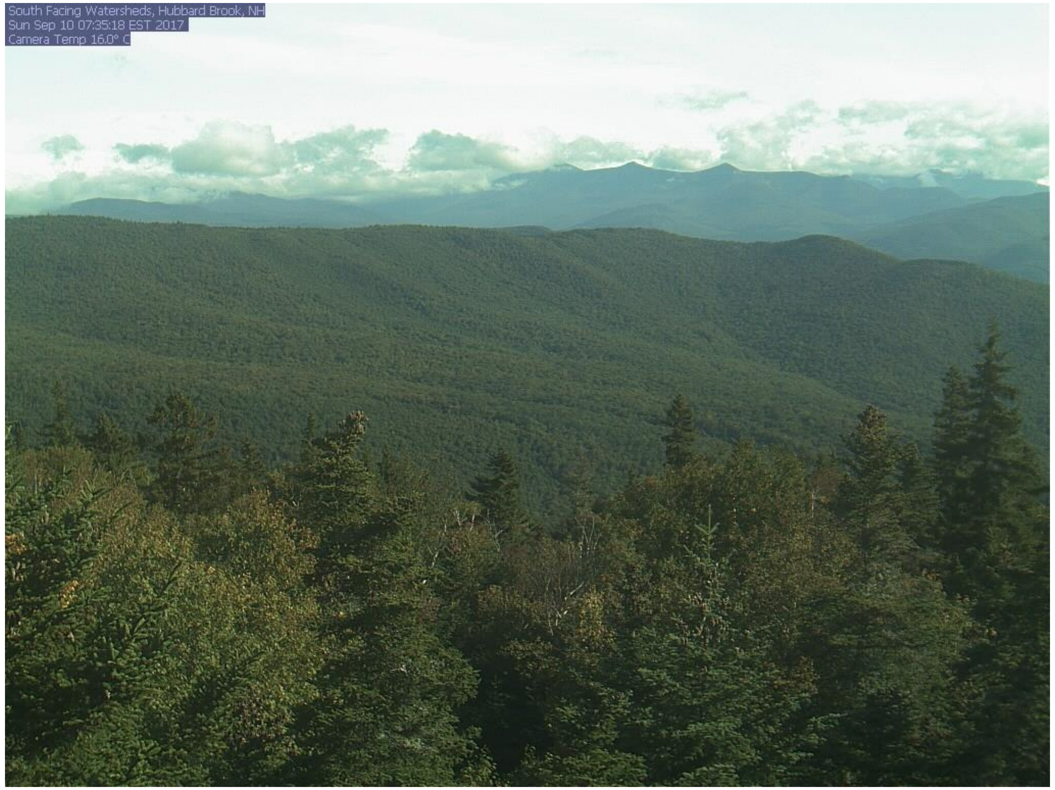
It’s a system with defined boundaries

(ē'kō-sĭs'təm)

A community of organisms together with their physical environment, viewed as a system of interacting and interdependent relationships and including such processes as the flow of energy through trophic levels and the cycling of chemical elements and compounds through living and non-living components of the system.

The American Heritage® Science Dictionary. Retrieved September 10, 2017 from Dictionary.com website http://www.dictionary.com/browse/ecosystem

Hubbard Brook founders (left to right): Dr. Herb Bormann, Dr. Gene Likens, and Dr. Robert Pierce



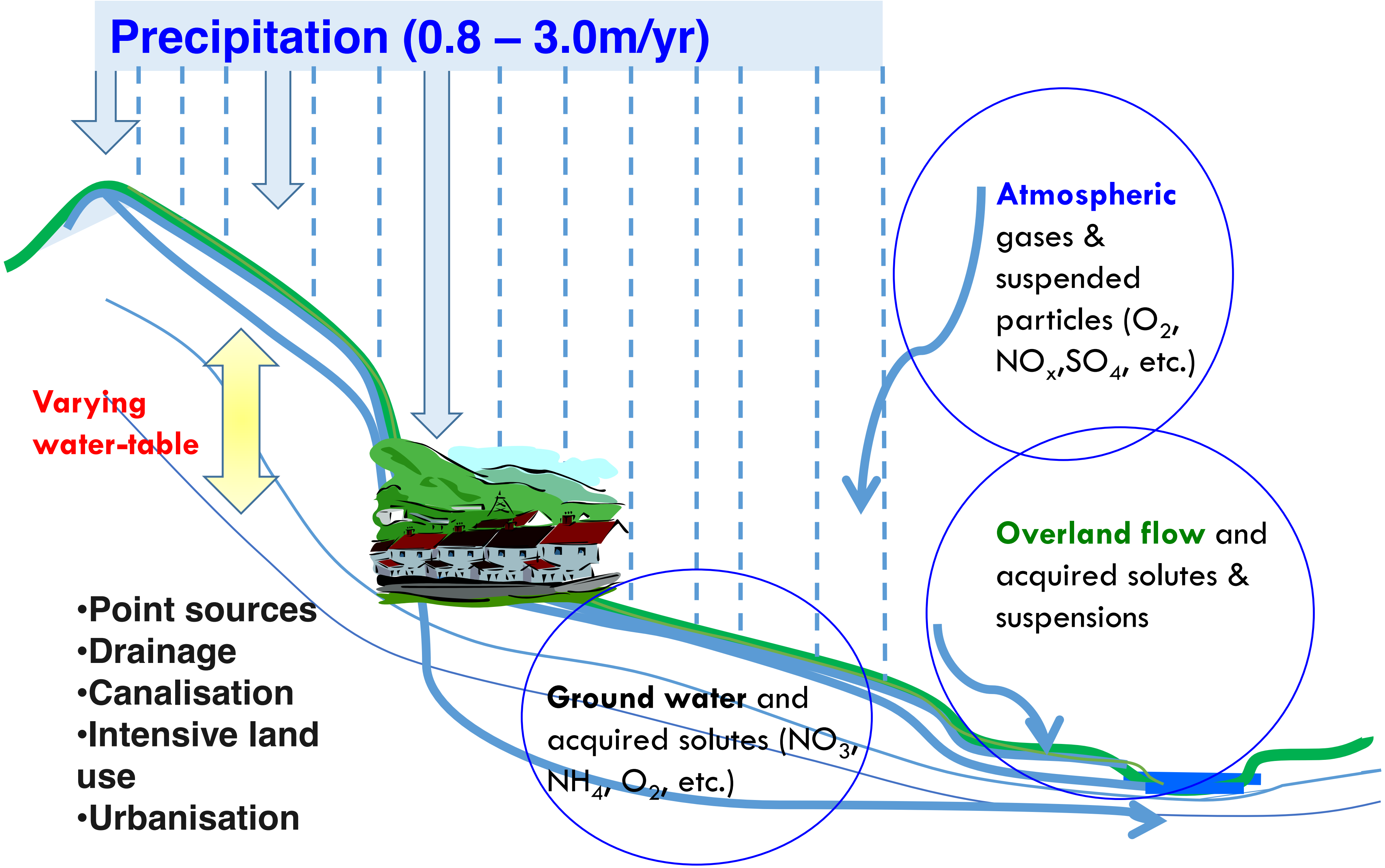
Dr. Tom Siccama

Copy of letter from Herb Bormann to Robert Pierce, then USFS Program Director for **Hubbard Brook Experimental Forest**, written in November **1960**

- Dear Bob,
- The other day, while discussing the problem of **mineral cycling through ecosystems**, the thought came to me that your installation at Hubbard Brook represents a veritable research goldmine in regard to fundamental studies on mineral cycling. One of your small watersheds with a weir at the outlet represents a perfect area for controlled research. If one were to select one to several minerals, such as K+, it would be possible, by taking weekly water samples and analyzing them, to determine quantitatively the amount of K+ leaving the system. **Weekly estimates of K+ per liter multiplied by the liters of water leaving the watershed would give the quantitative figure**. Since the watershed is theoretically tight, all the water falling on the shed appears at the weir (excepting evaporation which would not remove any minerals), [thus,] the quantitative figure would represent total loss of K+ from the watershed (excepting leaf litter blown out, or presumably this would be counterbalanced by leaf litter blown in. The argument goes for other losses and additions due to animals, etc.).

…..the rate at which minerals useful to plant growth are added and lost from the system……might lead into further studies of how treatments affect mineral cycling patterns.

- **Some minerals may be added by rain or snowfall**, therefore both rain and snow would have to be analyzed for the mineral(s) in question. These analyses multiplied by the amount of rain or snow would give the total amount of mineral(s) added to the system.
- By subtracting the total amount added from the total amount lost, it would be possible to estimate steady-state losses from the system. **Theoretically the only place these minerals could come from is the underlying parent material and bedrock**. Thus, the loss represents the rate at which bedrock is wasting away in terms of the mineral(s) under consideration. By knowing the chemical composition of the bedrock, it would be possible to determine the rate at which it is breaking down.
- This figure would seem to be **of considerable consequence because** it would quantify the rate of erosion, it would shed considerable light on the rate of soil formation, and it would tell something about **the rate at which minerals useful to plant growth are added and lost from the system**. **The latter might lead into further studies of how treatments affect mineral cycling patterns.**
- Herb



Water: a vector with 3 phases; gas, liquid and solid

VESI Environmental Ltd.

Intercepted water travels to wetlands, lakes, streams and rivers - vectoring nutrients and pollutants

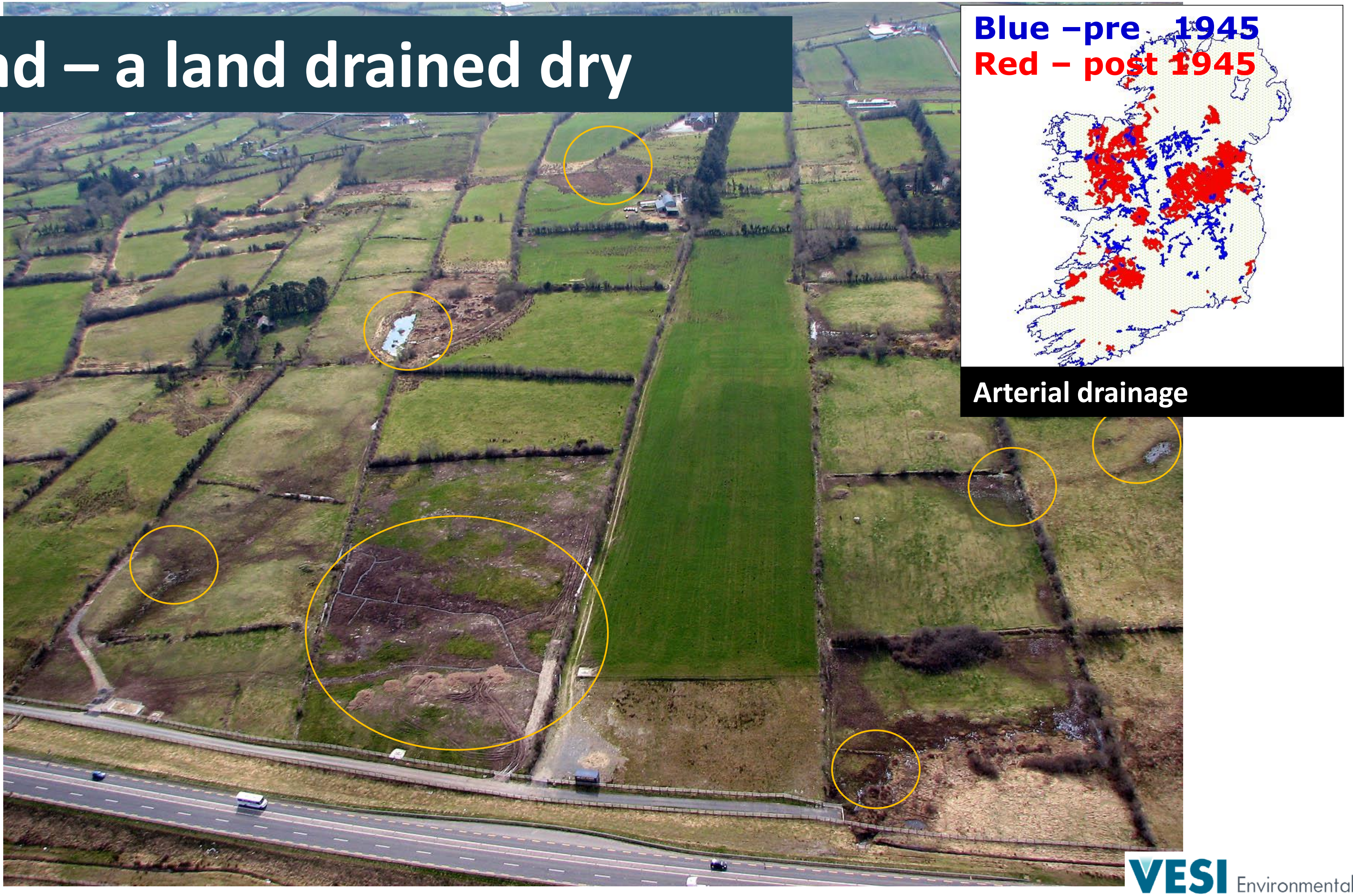
Dec.25th 2025

Rainfall events >10mm
31st Dec - 7.0 mm
5th Jan - 2.5 mm

Jan. 6th 2017

VESI Environmental Ltd.

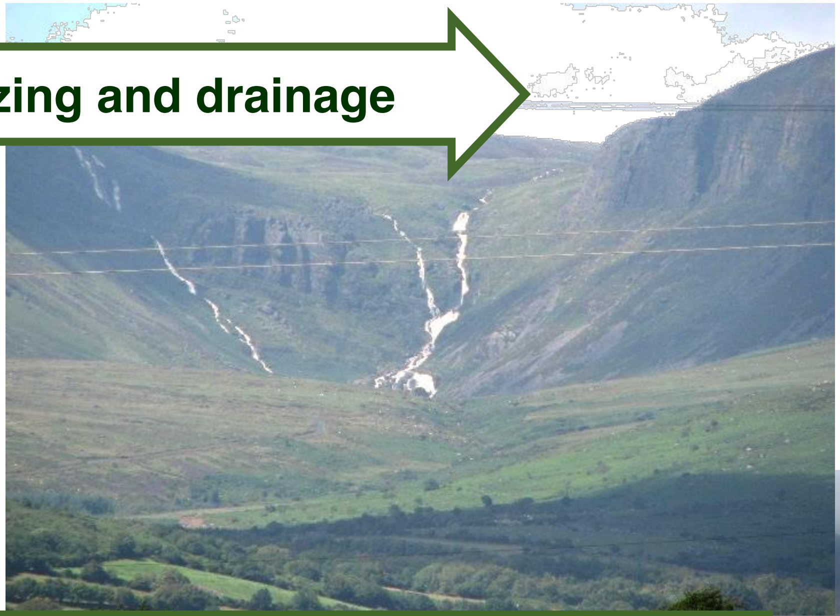
Ireland – a land drained dry



Arterial drainage

VESI Environmental Ltd.

Deforestation, fire, grazing and drainage



Ireland has lost most of its original Natural Capital

- Centuries of ongoing agricultural ecosystem-dysfunctionalities continue to ravage our natural environment.
- Perhaps the only path to environmental reconciliation is `ecological reanimation'

Ecological *restoration or reanimation…….?*

•**<u>Ecological restoration</u>** focuses on facilitating lost **biological assemblages** (within recent evolutionary time lines)

•**<u>Ecological reanimation</u>** focuses on facilitating **bio-geo-chemical processes** delivering sustainable self-managing (and self-facilitating) systems <u>minimising 'leakiness' and entropy</u> -

A concatenation of social, economic and environmental pressures

- **Social: population growth, land ownership, health, community, cohesion, security, politics**

- **Economic: land and capital, labour, energy, maintenance, sustainability, materials, safety**

- **Environmental: nutrient leakiness, carbon/nitrogen, biodiversity, pollution, aesthetics, zoonotic disease, epidemiology**

Marshes, bogs and ponds capture pollutants and attenuate flow

Three basic interlinked objectives for the Anne Valley:

1. Ecological reanimation of the main and tributary watercourses by:

- increasing their hydraulic retention and
- enhancing riparian habitats, including riparian woodland

2. Establishment of parallel wetland/water channels by:

- intercepting surface and ground waters from adjacent higher elevated lands, and
- ecologically augmenting the reanimated riparian channels with aquatic/helophyte vegetation.

3. Intercepting point sources of polluted water from:

- farmyards and the catchment's principle village of Dunhill, including its combined drainage and sewage, and
- using fen-marsh ICWs to remove pollution impacts on the receiving watercourses.

VESI Environmental Ltd.

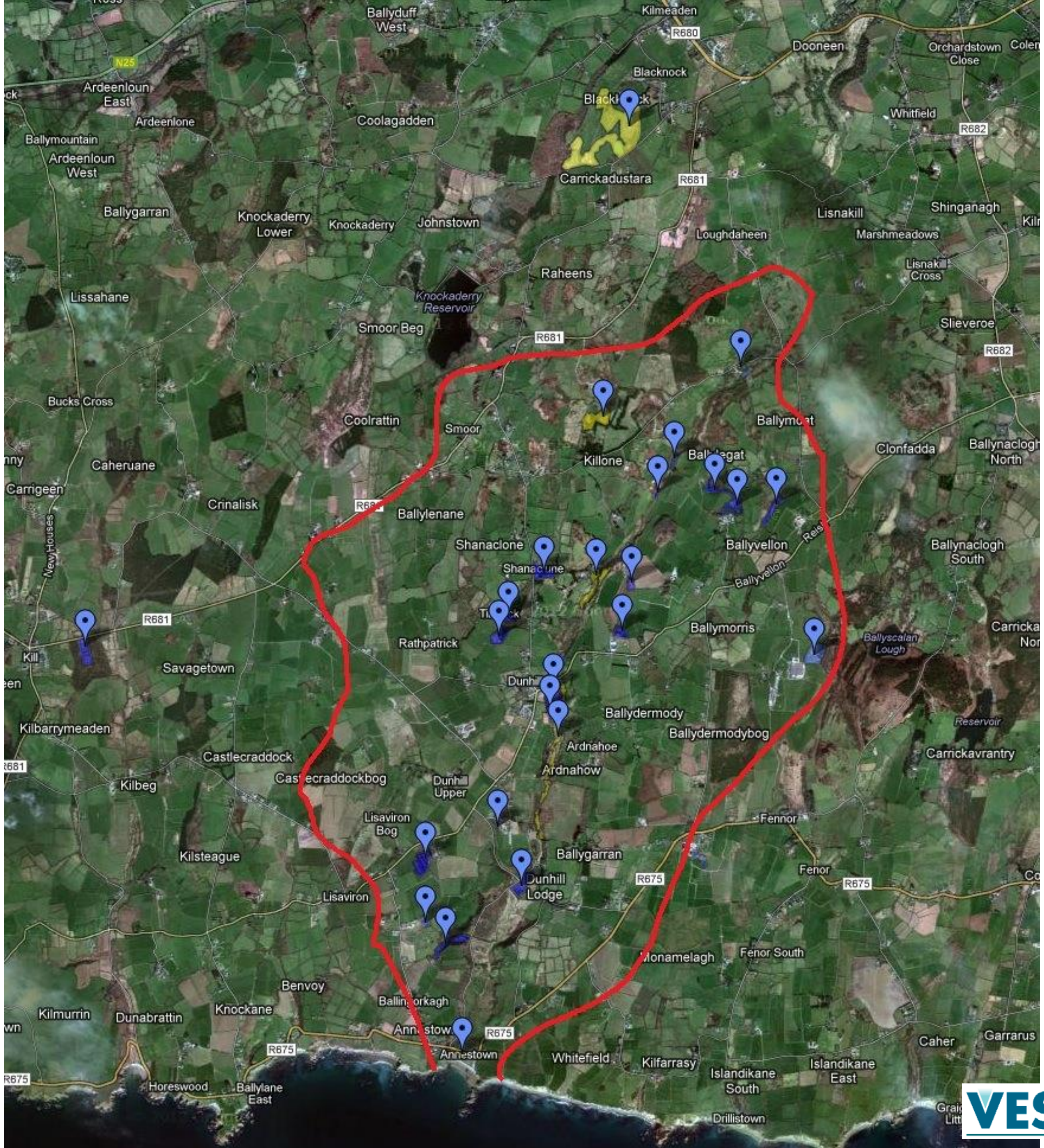
Attenuating flow:

Anne Valley catchment - map shows the most significant reanimated wetlands in the catchment, including ICW systems

Catchment area = 2,500ha:

- 16 large (>1ha) integrated constructed wetland (ICW) systems

- C. 12.5 km re-profiled stream corridor
- C. 200ha forest plantation
- C. 20ha extant woodland



VESI Environmental Ltd.

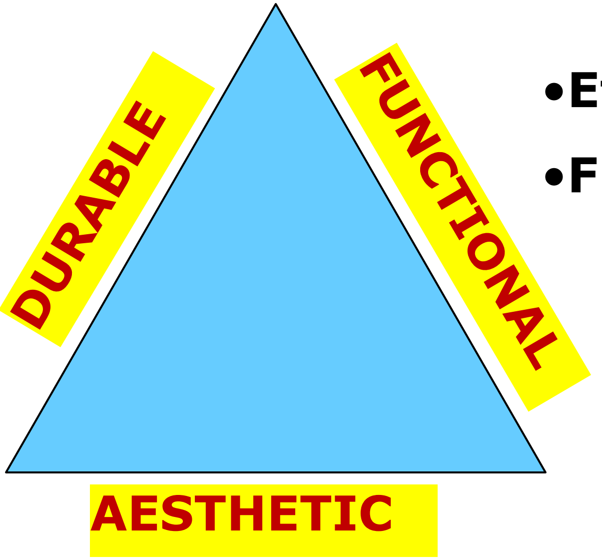
Starting in 1987/8, Annestown stream & catchment:

From a canalised dirty, weedy agricultural drain, to one that now supports trout and salmon

VESI Environmental Ltd.

The importance of applying the ‘universal design’ model

- Sustainable
- Robust
- Soc.Econ.Env. coherent



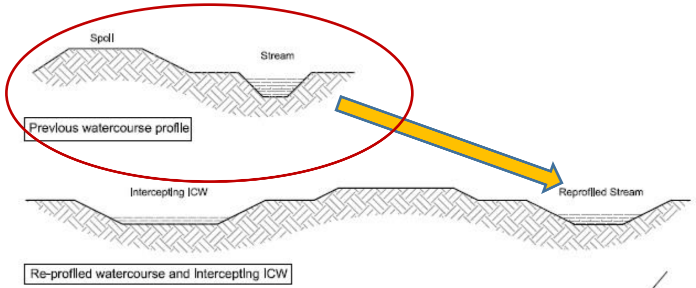
- Effective
- Fit for purpose

- Attractive/Beautiful
- ‘In context’ - as if it had always been there

Constructing wetland and riparian infrastructure

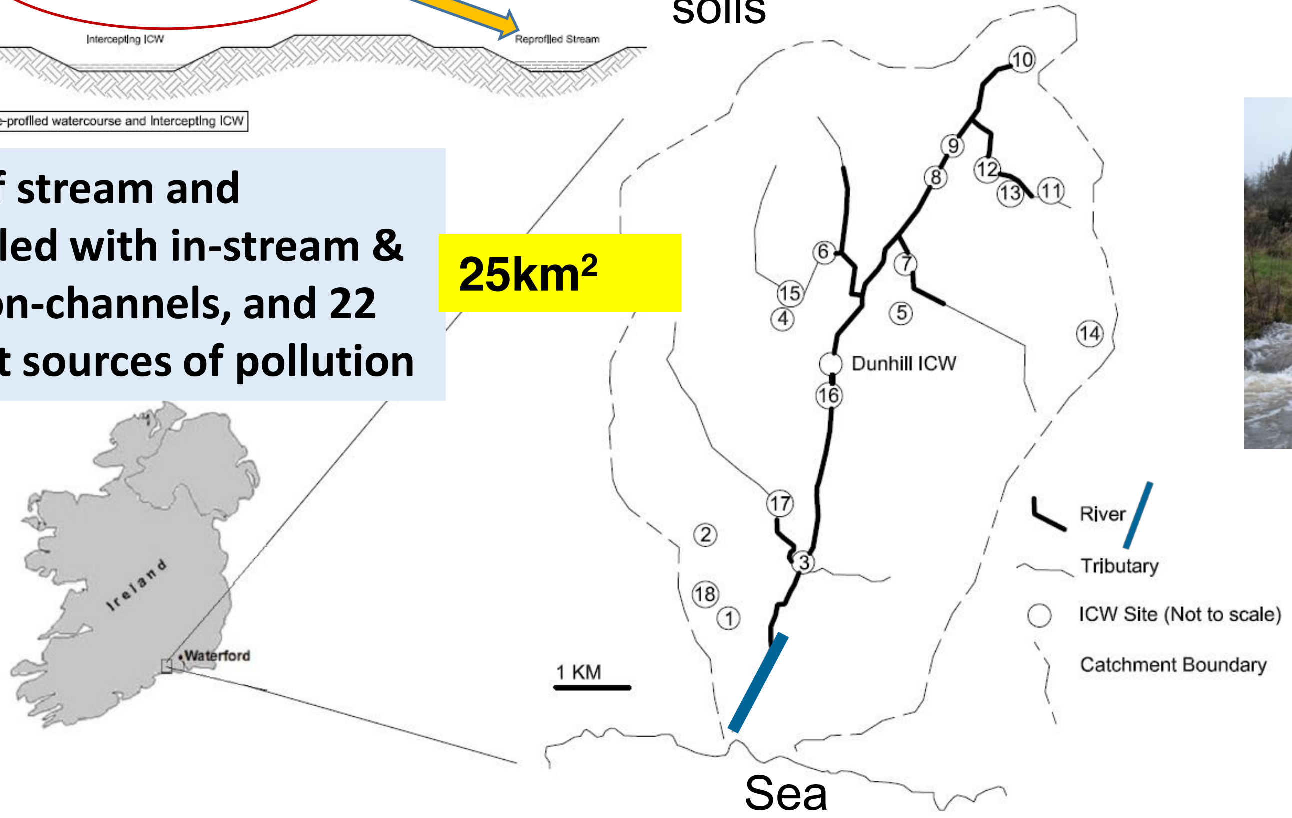
Pre-existing drainage

Re-profiled

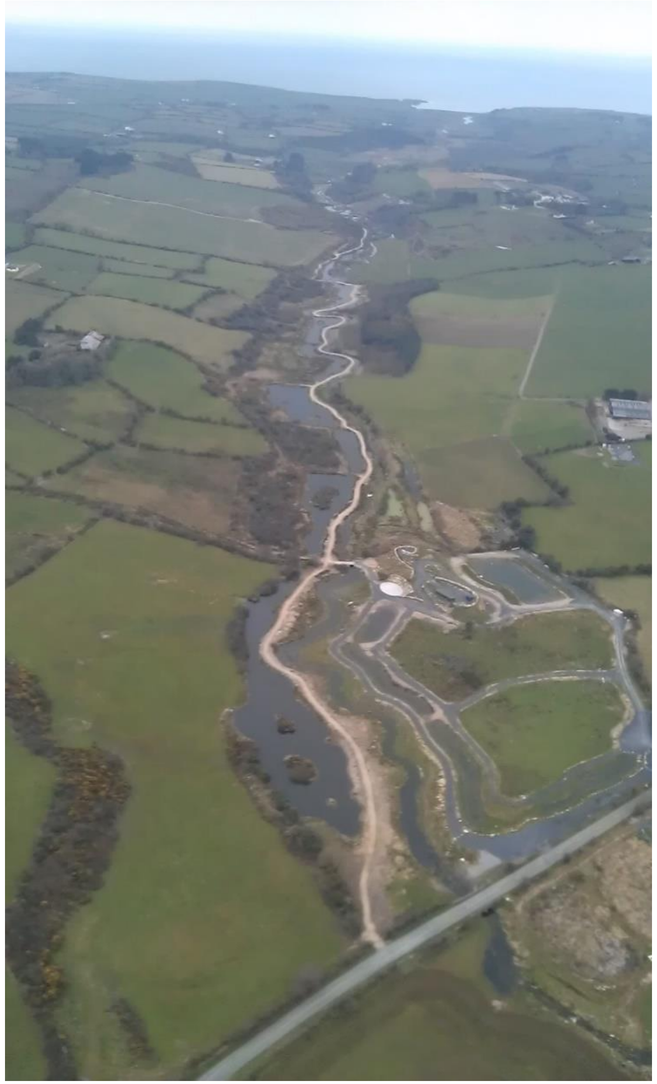


Cut & fill approach – using site characteristics and soils

Approx. 12.5 km of stream and tributaries re-profiled with in-stream & parallel interception-channels, and 22 ICWs treating point sources of pollution



Dunhill – Annestown Stream and Catchment



VESI Environmental Ltd.

VESI Environmental Ltd.

Motivating land owners (private, corporate and State) through:

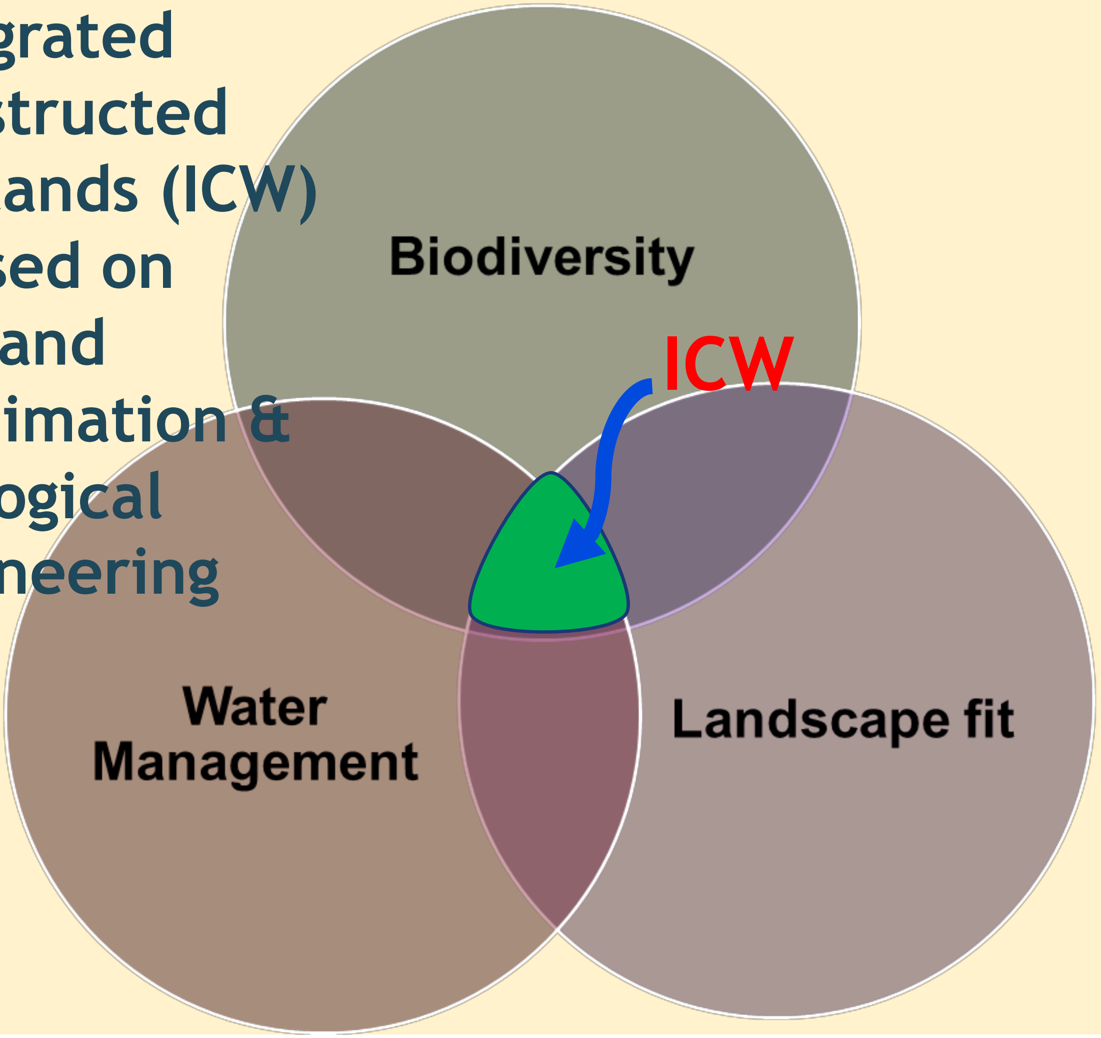
1. The <u>Demonstration</u> of what might and could be done with land and water for <u>their</u> benefit

2. <u>State/EU financial support</u> (typically about 80% of construction costs)

3. <u>Prospect of penalties</u> resulting from traceable pollution

Integrated Constructed Wetland (ICW) - a concept of explicit integration

Integrated Constructed Wetlands (ICW) - based on wetland reanimation & ecological engineering



VESI Environmental Ltd.

Recently enlarged Dunhill village ICW (operational - 12 July 2012)

'Old' (1999) ICW

Functional treatment area = 2670m^2

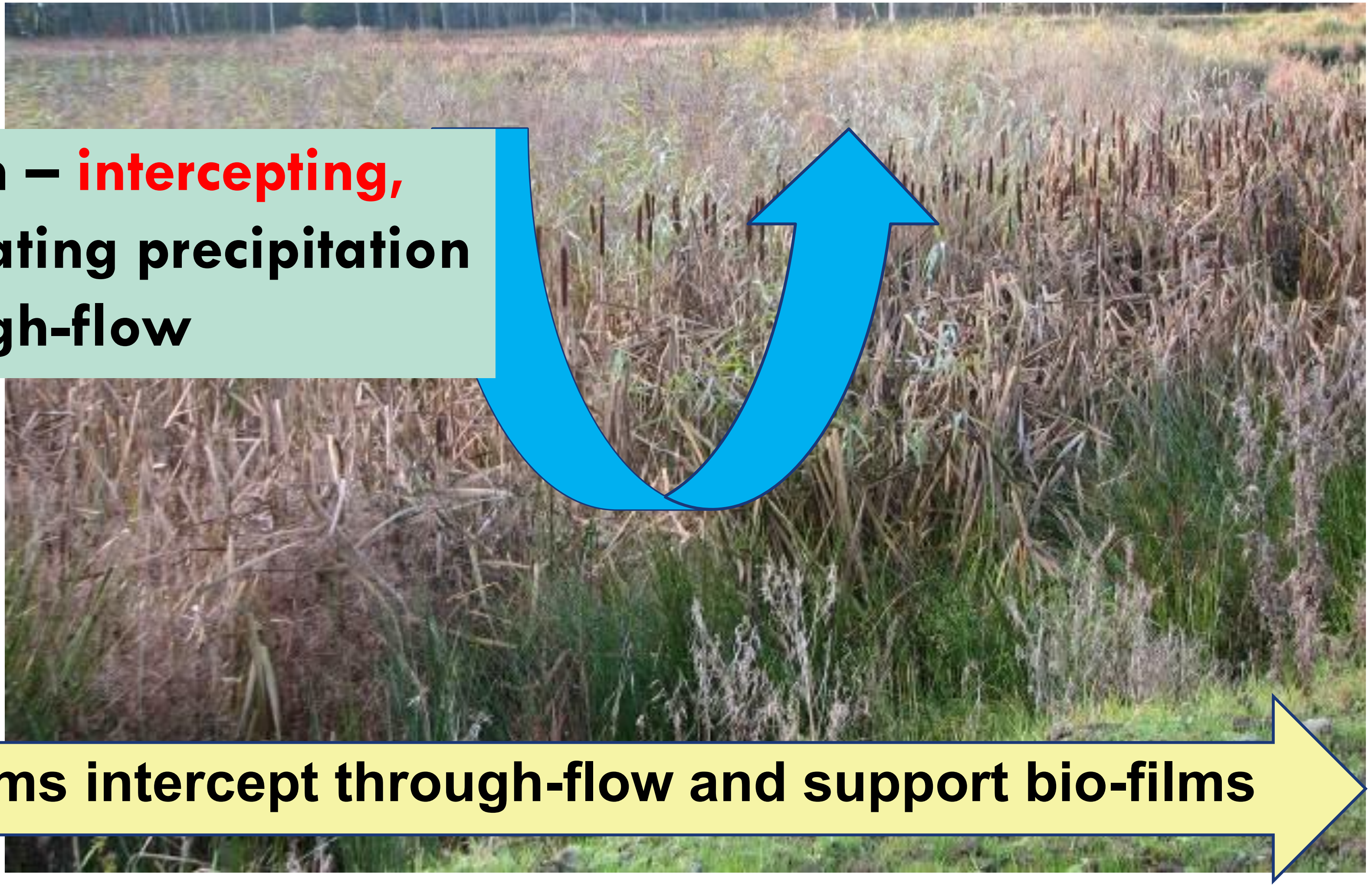
Newly extended (July 2012) ICW

Additional functional treatment area = 9678m^2

Total functional treatment area = 12348m^2 Flow/PE capacity = c.500)

VESI Environmental Ltd.

Level areas with tall, dense, emergent (helophytes) vegetation increases hydraulic impedance to through-flowing water



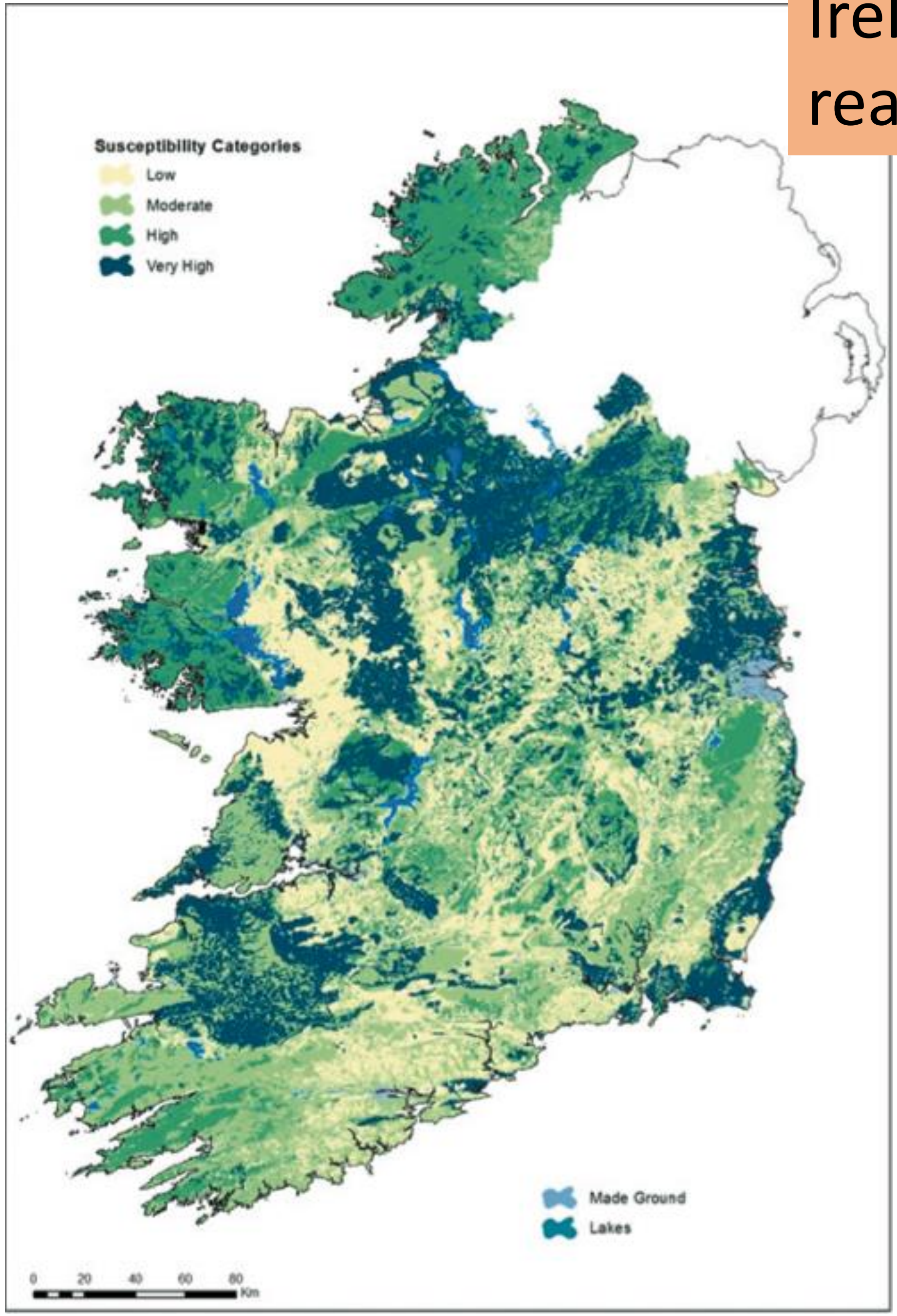
VESI Environmental Ltd.

Animal slurry: waste and polluted water is both a danger and opportunity!

Water and its constituents can be recycled

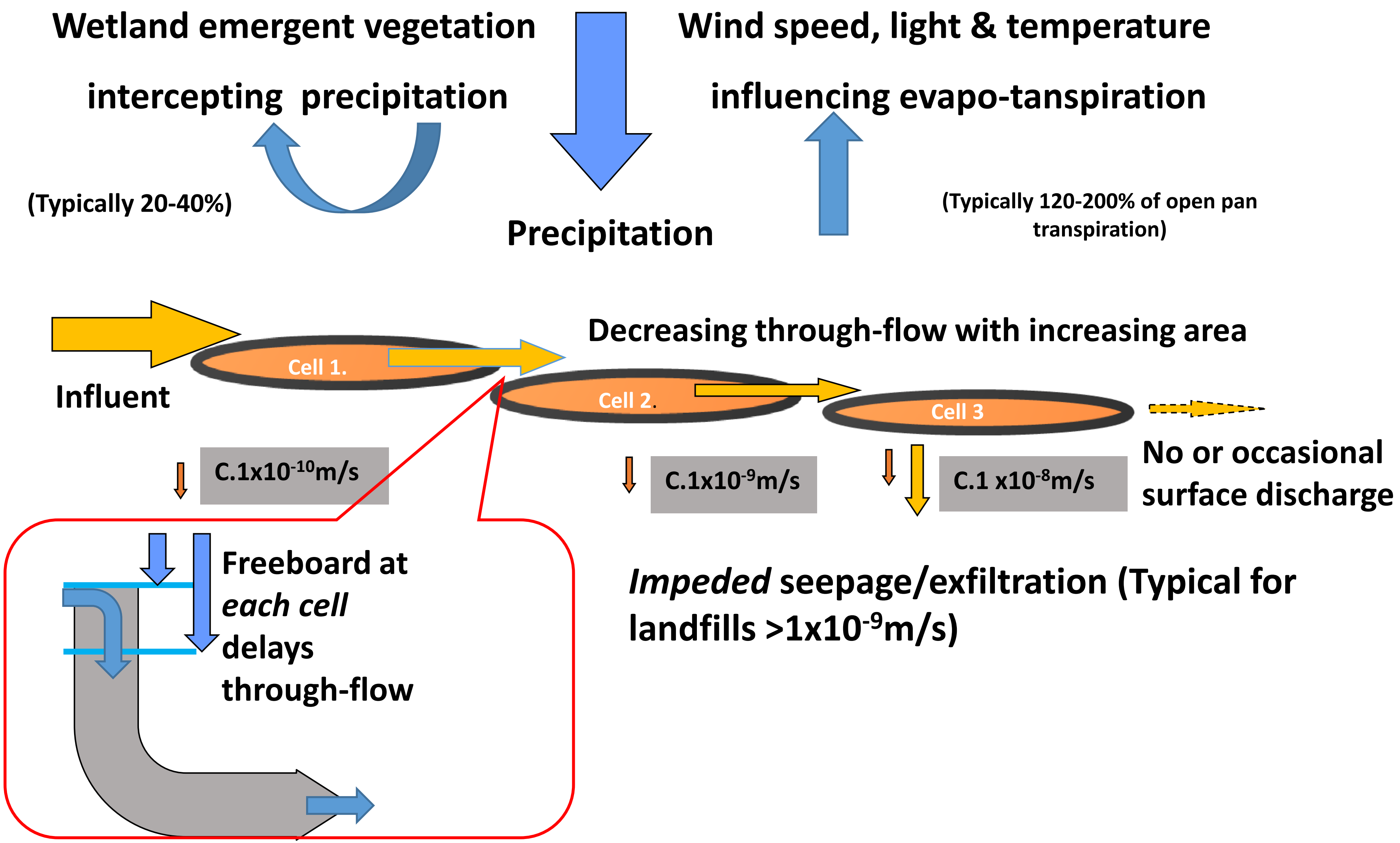
- Municipal waste water
- Farmyard drainage
- Landfill leachate
- Industrial waste water
- Mine drainage

Ireland's soils are well disposed to the reanimation of wetlands



VESI Environmental Ltd.

Basic ICW's multi-cell hydraulic model



VESI Environmental Ltd.

The main factors fundamental to ICW systems are:

- **Underlying soils** and ground conditions limiting through-flow exfiltration and permit-ting construction.
- **Influent toxicity** limiting/influencing vegetation growth at the point of inflow.
- **Hydraulic loading** determining the area of wetland required and its configuration to treat the influent, including that from precipitation.
- **Topography** and the challenges of constructing level ground.
- **Attenuation capacity of receiving waters**, whereby the expected discharge concentration of specific effluent parameters from the wetland are achieved. Zero surface dis-charge is possible with the required wetland area and appropriate vegetation cover.
- **Surrounding landscape and ecology** - to meet the aesthetic/ecological potential of the surrounding area and habitats.

(Additional information on the above six factors are to be found at: http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownLoad%2C24931%2Cen.pdf)

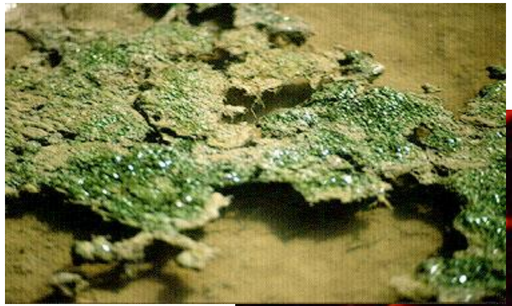
VESI Environmental Ltd.

First ICW built in 1996 (21 yrs.)
(Photo from 2012) - recently (2017)
sampled, discharge within set limits

VESI Environmental Ltd.

‘Tapping into’ > 4 billion years of (microbial) evolution

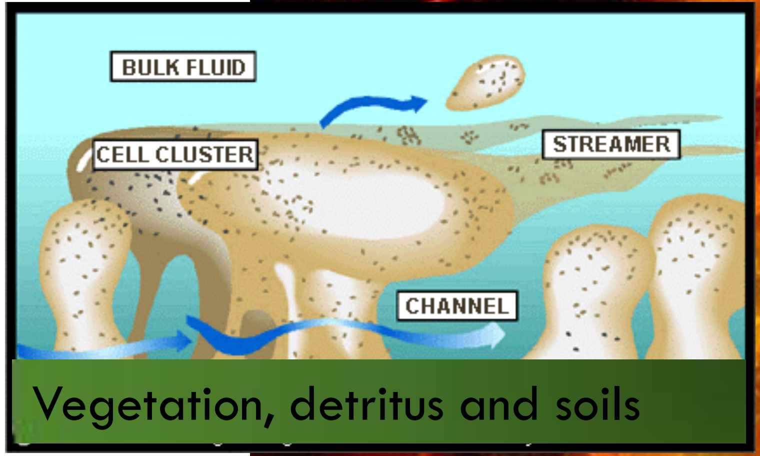
Biofilms active on all support strata



On: solid substrates (soils and rock – and organic)

liquid – air (atmosphere) interfaces

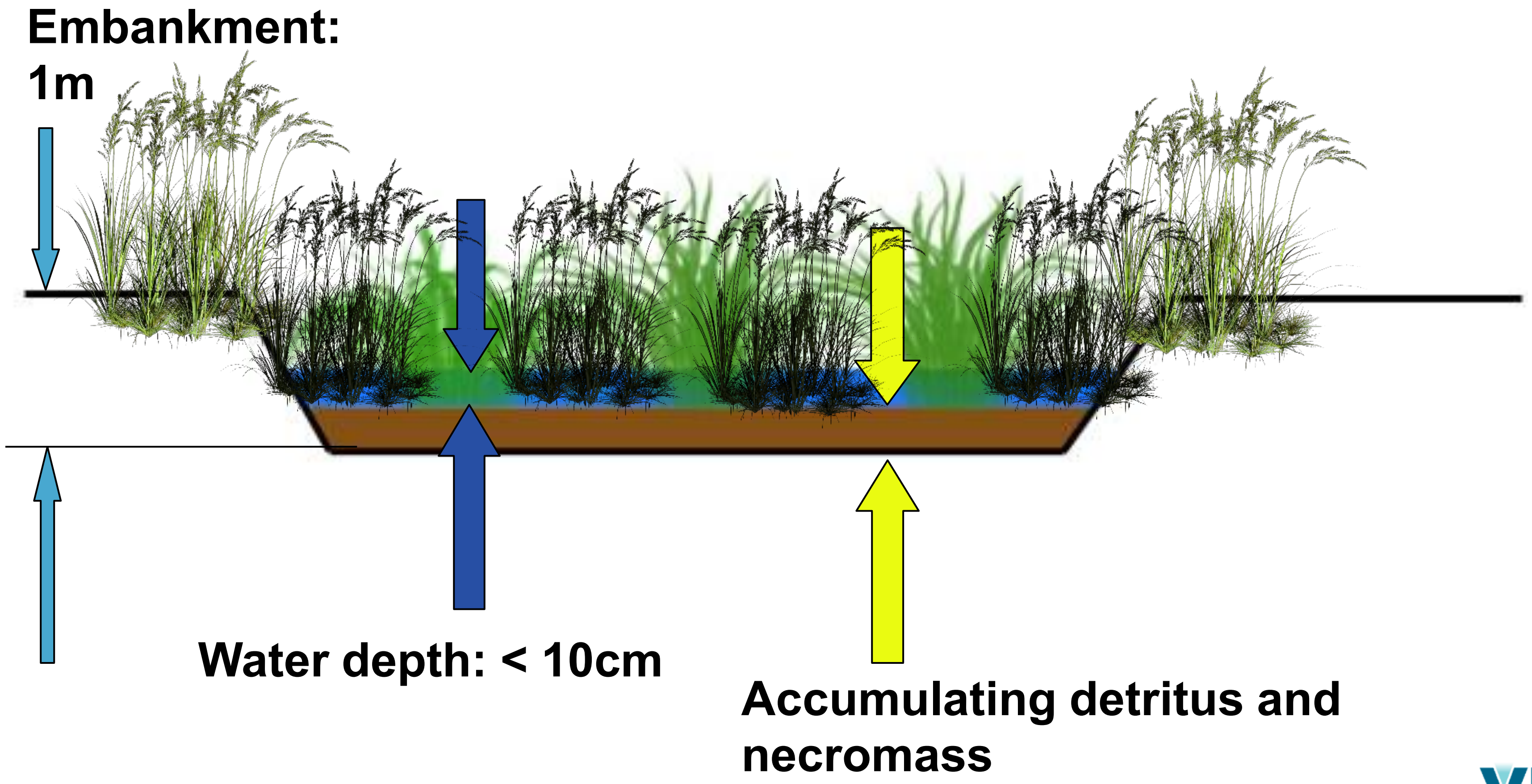
soft tissue of living organisms



Vegetation, detritus and soils

Commensal, symbiotic and parasitic

Cross sectional view of wetland cell showing vegetation, embankment and water depth



VESI Environmental Ltd.

ICW proximal cells - “marsh” (not pond) with helophyte vegetation

Dense productive vegetation – transpiring & intercepting rain

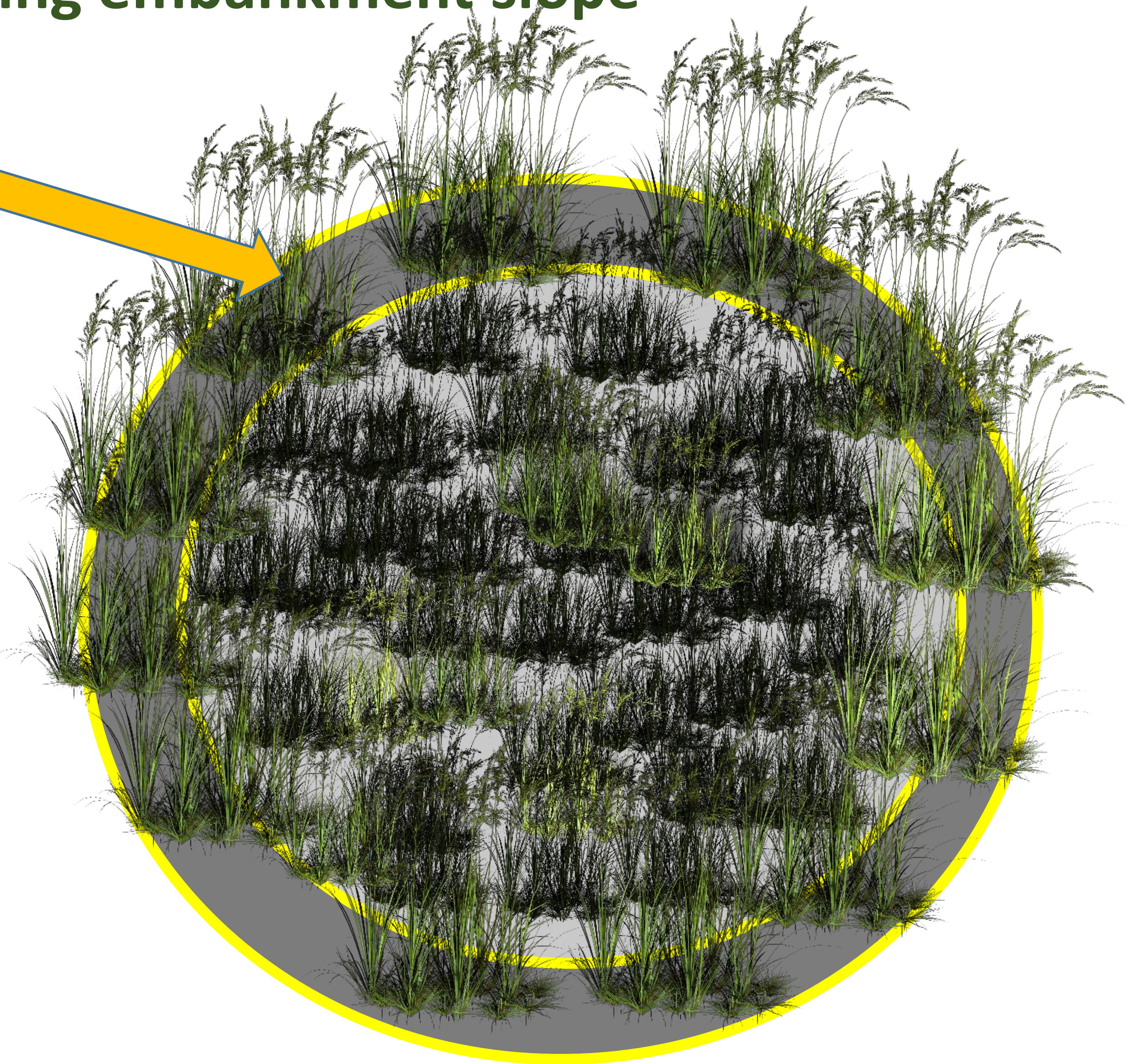
Complex detritus and peat formation

Water depth typically < 10 cm

VESI Environmental Ltd.

Accounting for and using embankment slope

Terrestrial embankment slope, typically 1.5 - 2.0 m



Intercepting and draining to cell marsh increasing:

- effective rainfall interception
- transpiration
- habitat diversity and
- biosafety

VESI Environmental Ltd.

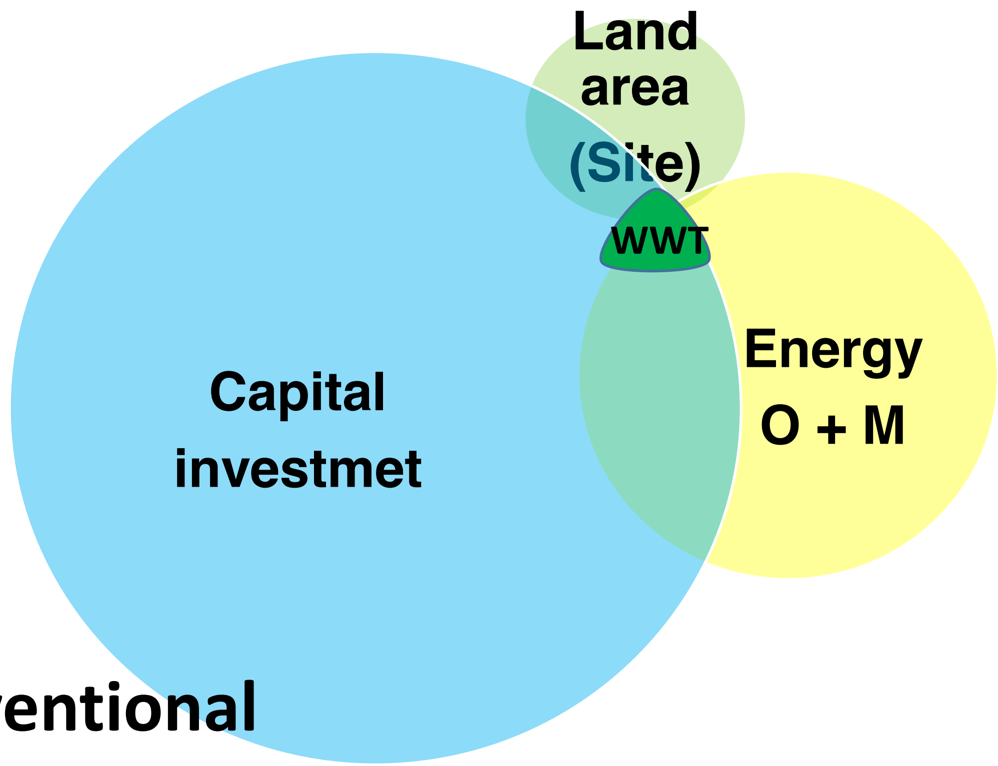
Motivating land owners (private, corporate and State) through:

1. The Demonstration of what might and could be done with land and water for their and society's benefit

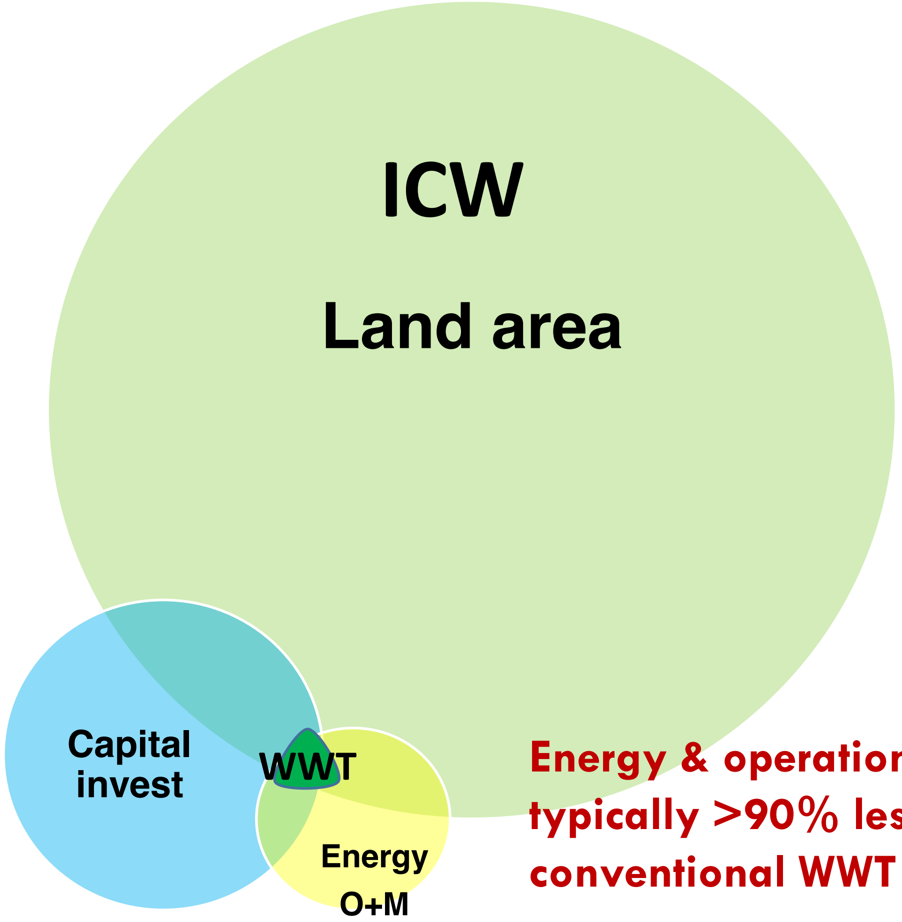
2. State/EU financial support (typically about 80% of construction costs)

3. Prospect of penalties resulting from traceable pollution

Primary cost factors for wastewater treatment systems



Conventional electro-mechanical wastewater treatment (WWT) systems

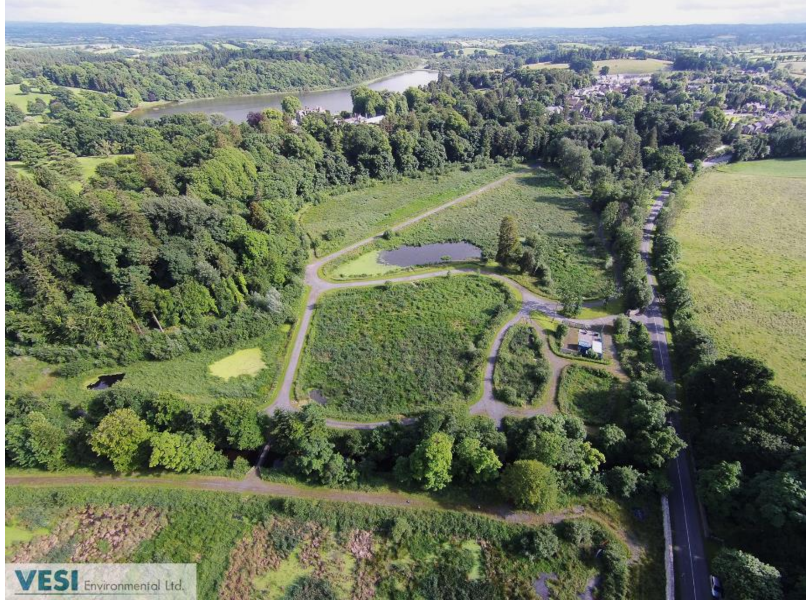


Energy & operations typically >90% less than conventional WWT

Capital investment typically 60 – 80% less than conventional WWT
(including land cost)

VESI Environmental Ltd.

Water management through the coherent reanimation of wetland habitats

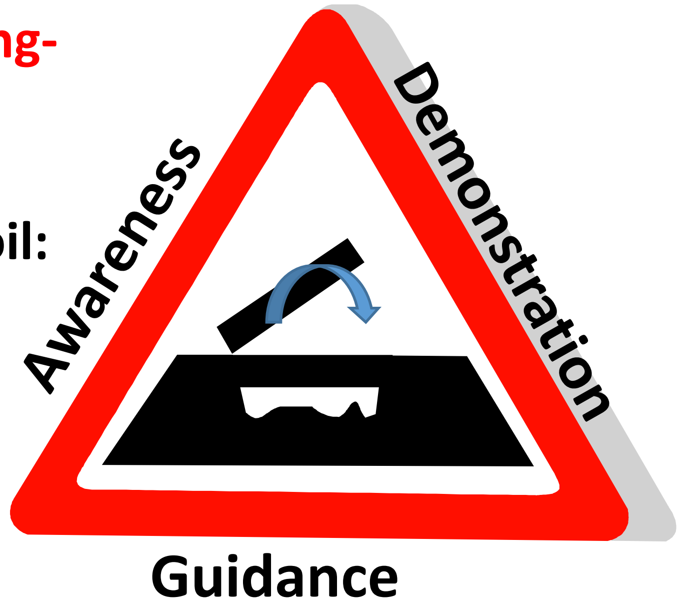


A lesson in <u>reconciliation</u>: bridging *needs with wants*

Societal needs (its long-term welfare)

Clean Air, Water & Soil:

- EU:WFD
  - BWD
  - UWWD
  - SD
  - Etc.
- Ramsar (1971)
- UN:EP
  - CBD
  - Climate change



Sectoral wants

Agriculture

Development:
- Urban
- Rural

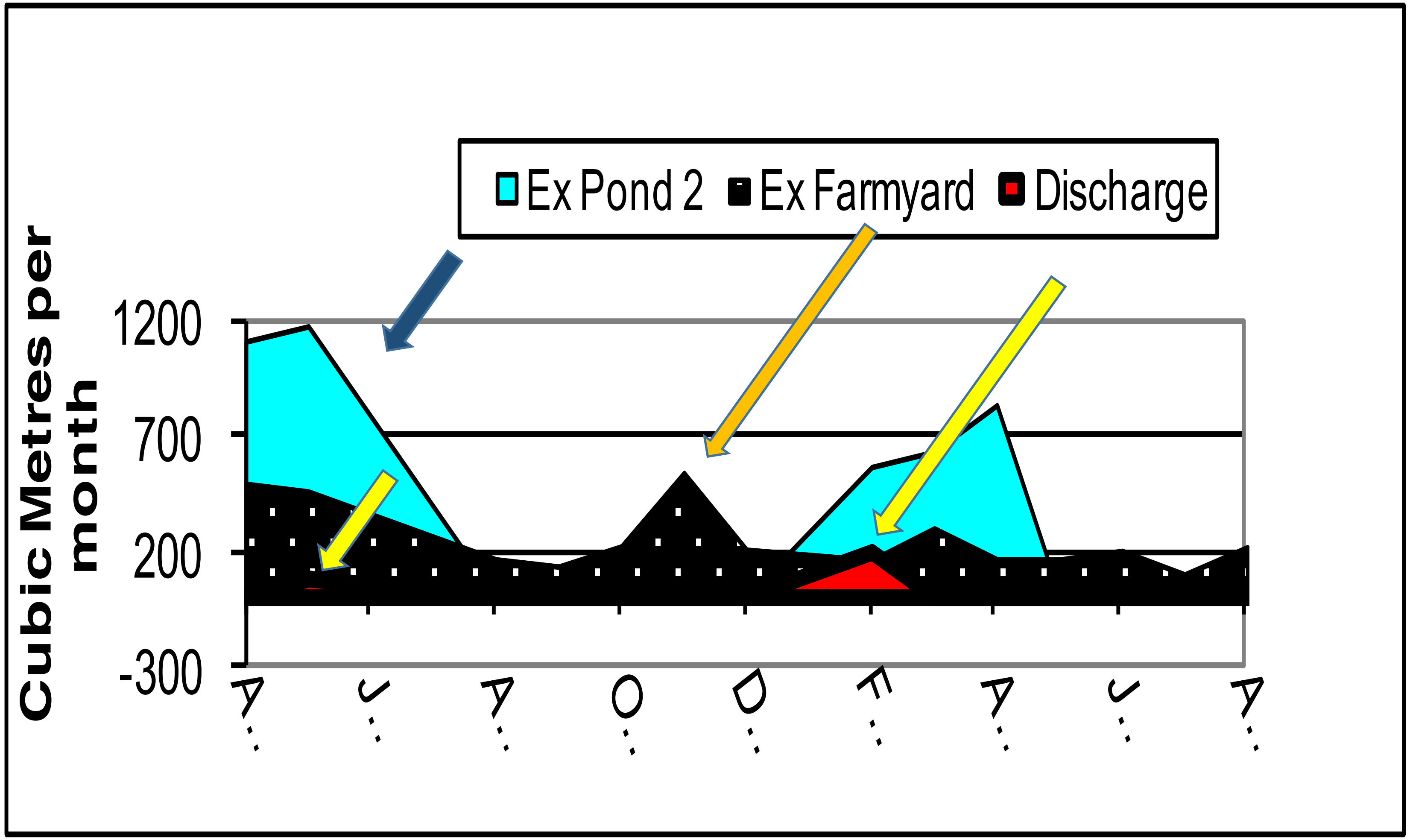
Forestry:
- Timber
- Biomass

Fishing

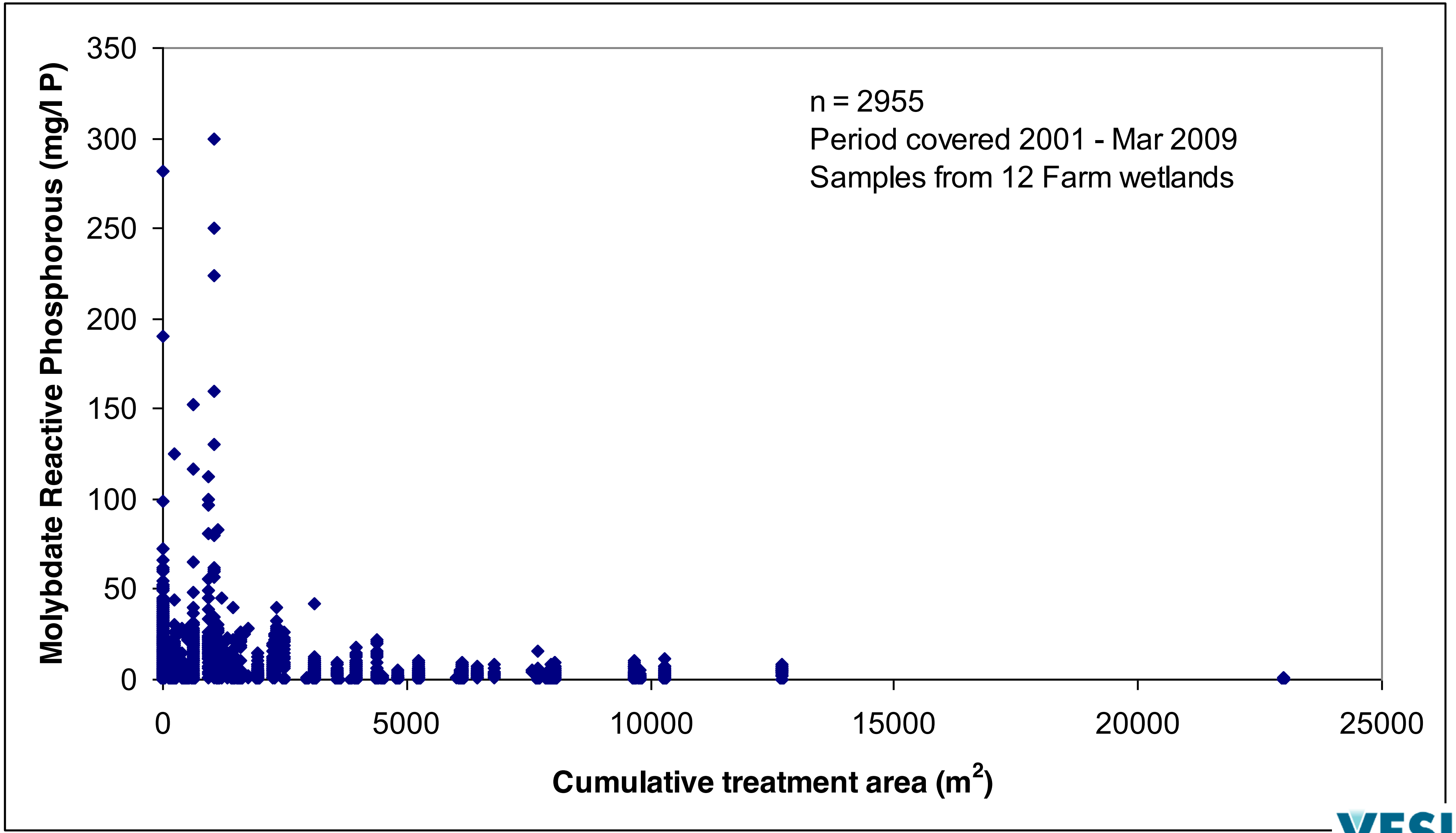
Recreation

Nature 'conservation'

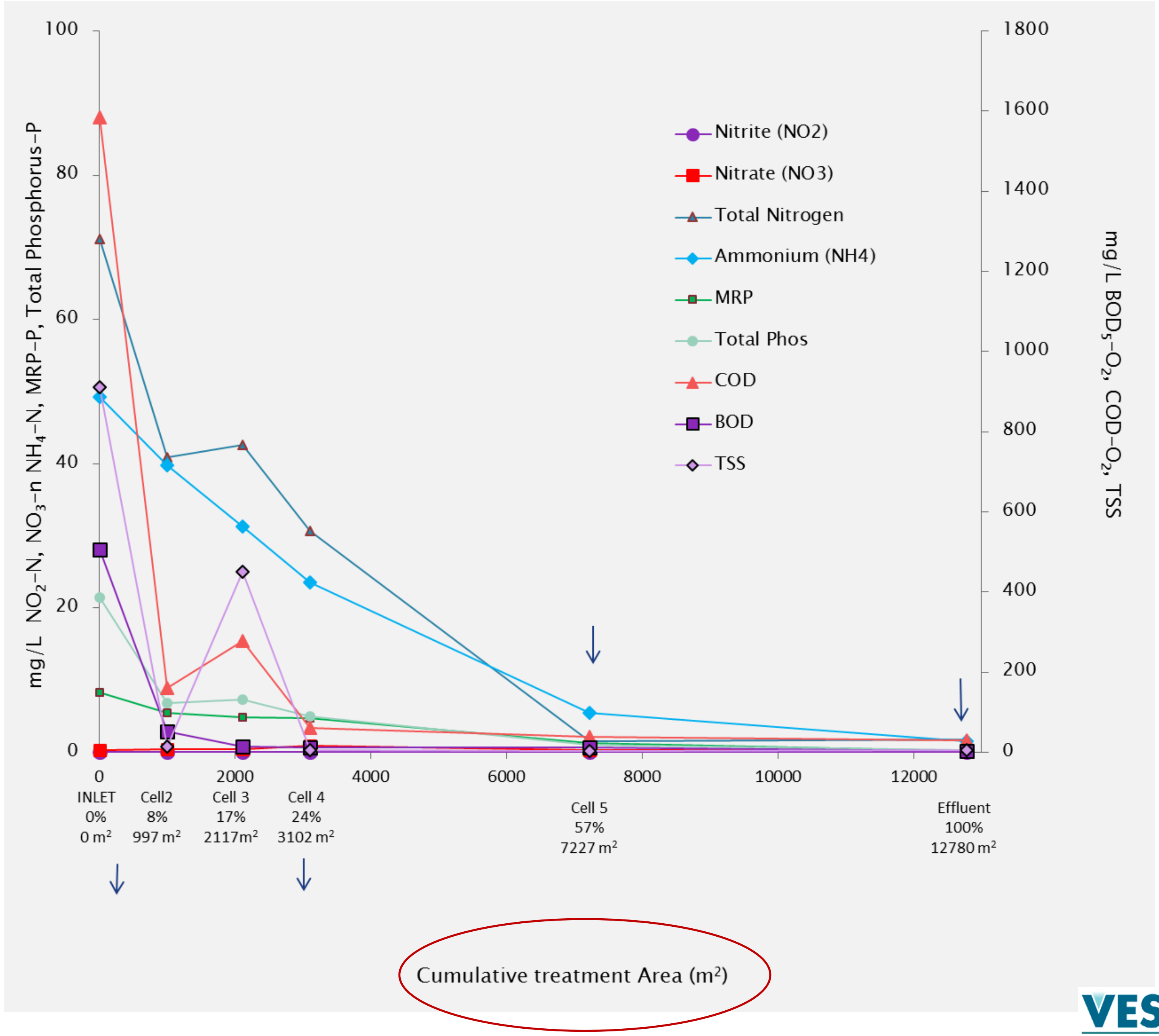
Monthly water-flow over 1 year for Farm ICW #11 with 4 cells



12 farmyard ICW systems in the Anne Valley Catchment, Co. Waterford, showing increasing performance with increasing area



VESI Environmental Ltd.



VESI Environmental Ltd.

Bio-safety of ICW systems (coliform results (20/01/09)) - Glaslough ICW, Co Monaghan

CELL NUMBER	SAMPLING POINT	**ECOLI (Fecal Coliforms) per 100 mls**	TOTAL COLIFORMS per 100 mls	**ACCUMULATIVE PERCENTAGE OF ICW AREA**
Sludge pond	INLET	**559950**	>1209800	**1.2**
1	INLET	**86640**	>241960	**15**
2	INLET	**20924**	48392	**29**
3	INLET	**292**	1074	**67.5**
4	INLET	**<10**	63	**96**
5	OUTLET	**<5**	**49**	**100**
Mountain River Upstream	RIVER	**698**	2897	
Mountain River Downstream	RIVER	**429**	2737.5	

ICW sequester carbon, phosphorous and nitrogen




VESI Environmental Ltd.

Enhanced biodiversity

VESI Environmental Ltd.

Dunhill, Co. Waterford ‘Integrated Constructed Wetland’ (ICW)

Building *empathy* with nature

VESI Environmental Ltd.

Ecological reanimation requires the combined **collaboration** of:

- **Landowners**
- **Experienced direction** and planning (science and engineering)
- **State engagement** - including that of Local/Regional Government - towards **reducing entropy**
- **Community** – increasing awareness & **empathy**

Key words: landowners, science, government and community

Conclusions

1. **What if** - innovative demonstration of what can be done is the initial priming factor.

2. **Coherency** - building of secure and effective water-retentive and treatment structures is possible using local material (soil) with minimal 'hard' construction and embedded carbon at relatively little cost.

3. **Bioeconomy** - Recognising the residual values of used or polluted water, and its vectored constituents, provides opportunities for their reuse and recycling, including that necessary for the sequestration of carbon and other key ecosystem services.

4. **Ecosystem services** – facilitating social and ancillary environmental needs

VESI Environmental Ltd.

The key challenge:

An "…….underlying principle is that social and economic factors will override natural factors unless the public is educated to understand the relationship between nature and their own long-term welfare."

F. H. Bormann 2008

ACKNOWLEDGEMENTS

- Communities of Dunhill-Annestown, County Waterford, Ireland.
- Colleagues: Paul Carroll, Susan Cook and Pat McCarthy, Waterford City and County Council.
- Monaghan County Council, Laois County Council, Kerry County Council, Dublin City Council, Donegal County Council and Leitrim County Council.
- Irish Water
- VESI Environmental Ltd. Ireland.

“Nature never did betray the heart that loved her.”

William Wordsworth, 1770 – 1850

“Thank you for your attention”