Edge of field nitrogen sinks

Acknowledgements:

- Tim Appleboom, USDA-ARS
- Louis Schipper, Landcare Research (NZ)
- Mimi Wagner, Iowa State
- Art Gold, University of Rhode Island

Funding: USDA NRICGP, NSF-LTER, EPA

OUTLINE:

- Landscape thinking
- Specific advances in landscape nitrogen management.
- Some challenges in landscape nitrogen management.
- Prospects for the future.

Landscape thinking:

- Landscapes can be viewed as aggregations of “source” and “sink” areas, linked by surface and subsurface flows of water.

- Whole-landscape function can be readily measured at the watershed scale.

- First developed in agricultural watersheds in the southeast (GA), with observations of low nitrogen outputs from heavily fertilized watersheds with extensive riparian forest.

- Has lead to lots of research on “edge of field” nitrogen sinks.

Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

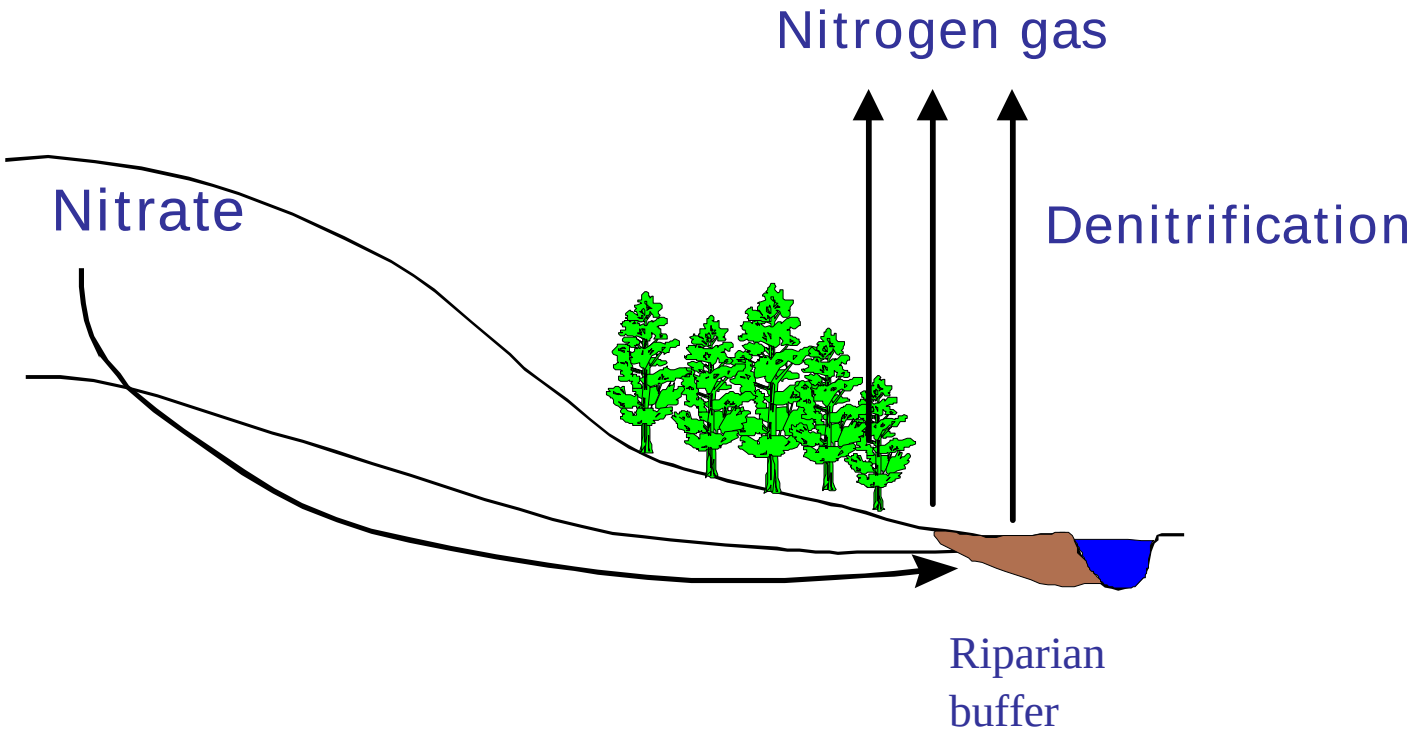
- Anaerobic
- Heterotrophic (requires organic C)

- Expect high rates in wetland soils.
- Key component of the water quality maintenance function of riparian zones.

Edge of field approaches:

- Riparian buffer zones.
- Controlled subsurface drainage
- Constructed wetlands
- Bioreactors:
  - Trench bioreactors (denitrification walls)
  - In-line bioreactors
- In-stream processing.

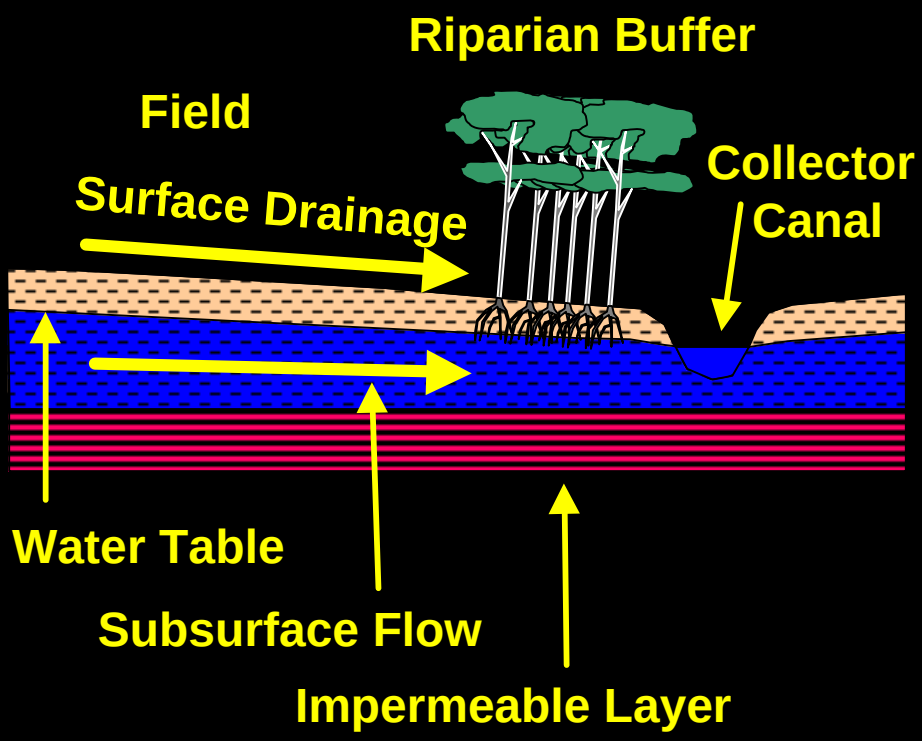
Riparian zones as denitrification "sinks" in the landscape.

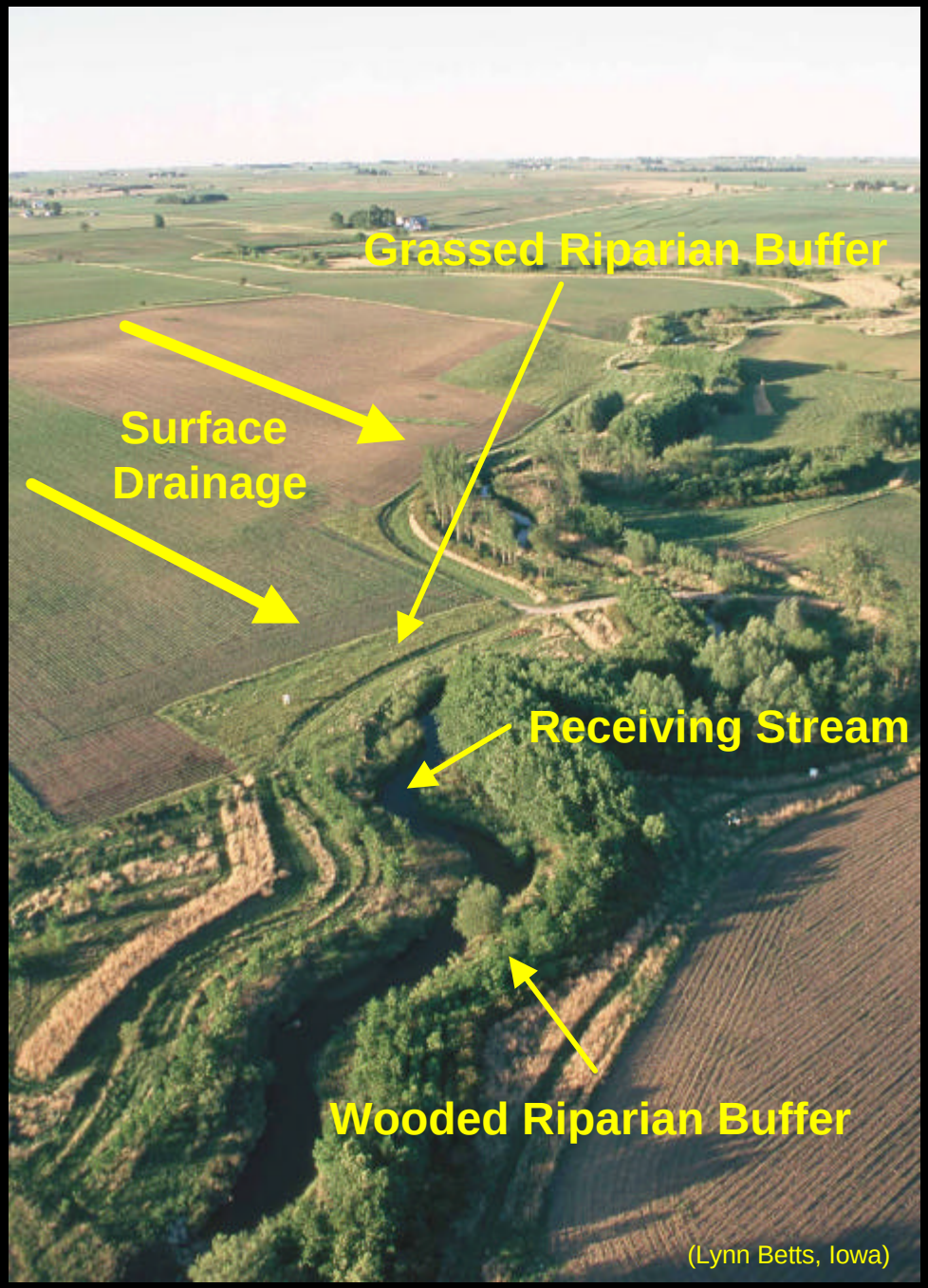


Source: Louis Schipper, Landcare Research

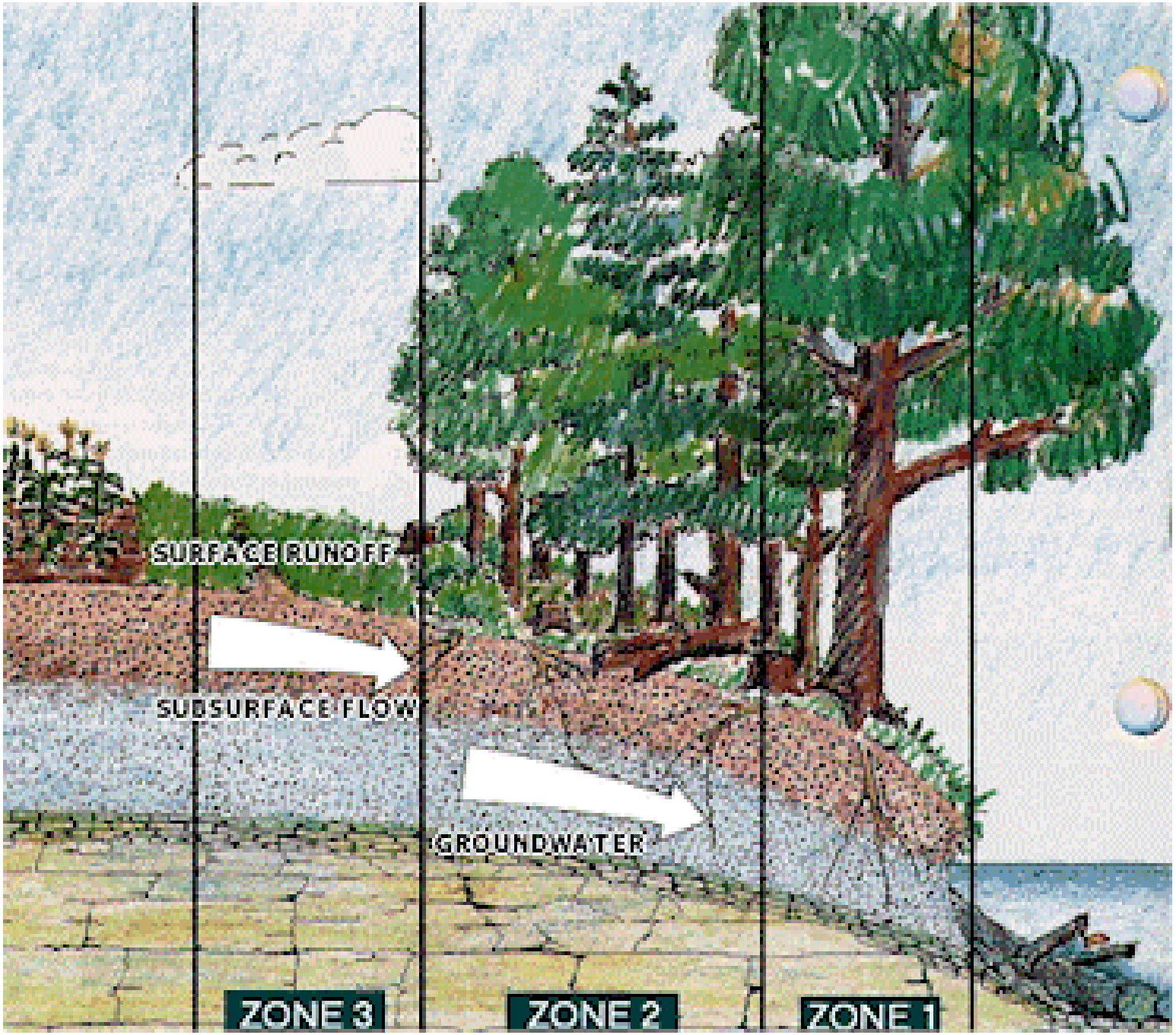
Riparian Buffers

Source: T.W. Appelboom, USDA-ARS

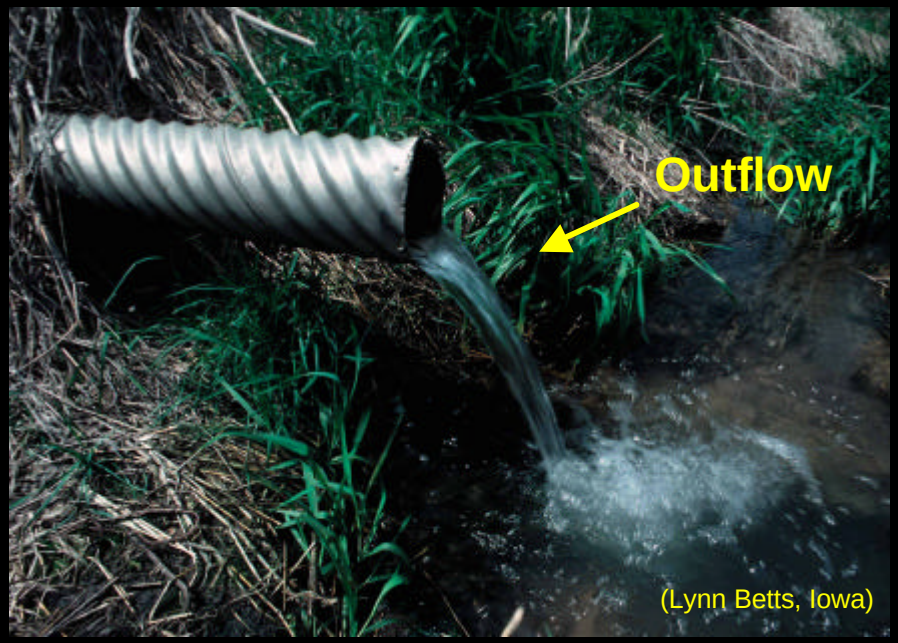




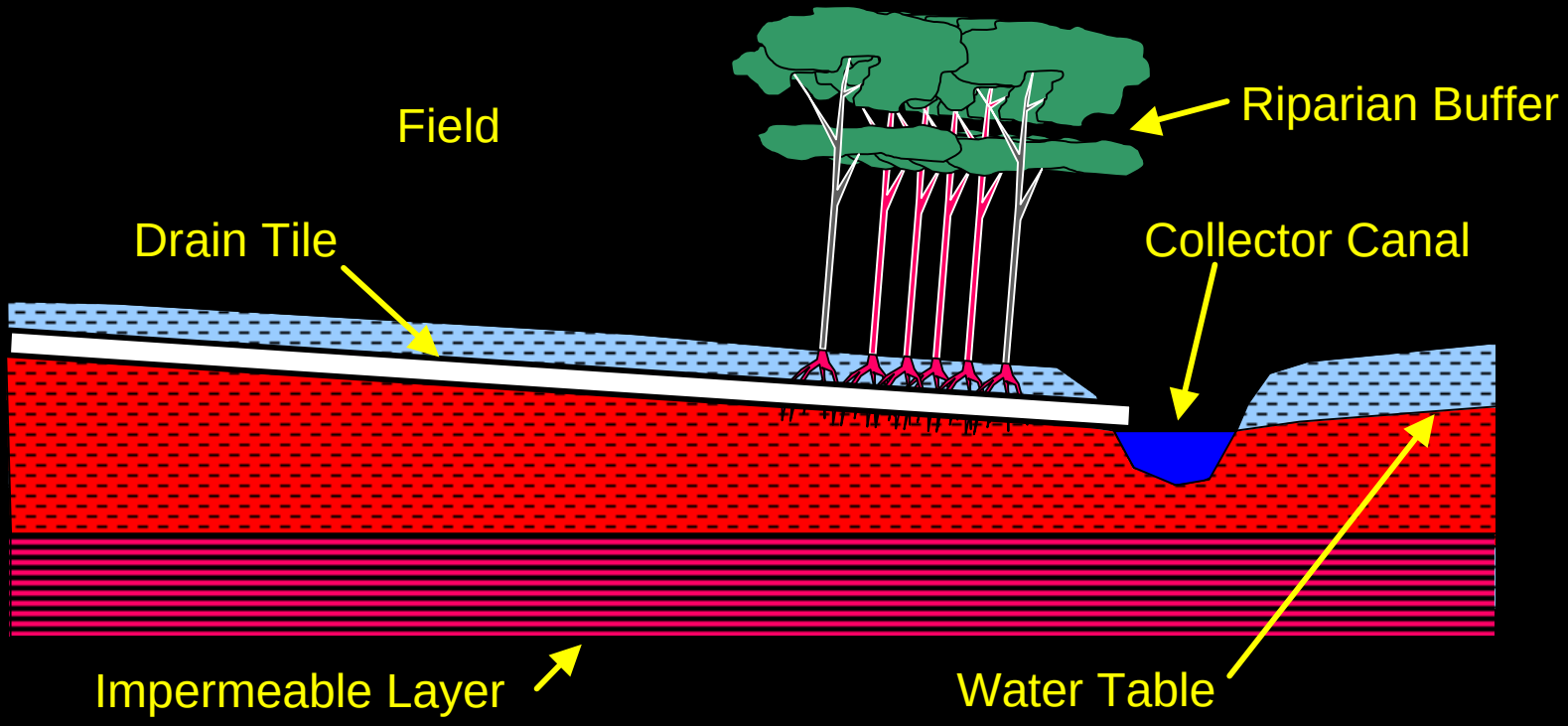
(Lynn Betts, Iowa)


SURFACE RUNOFF
SUBSURFACE FLOW
GROUNDWATER
ZONE 3
ZONE 2
ZONE 1

Subsurface drainage “short circuits riparian buffer zones.



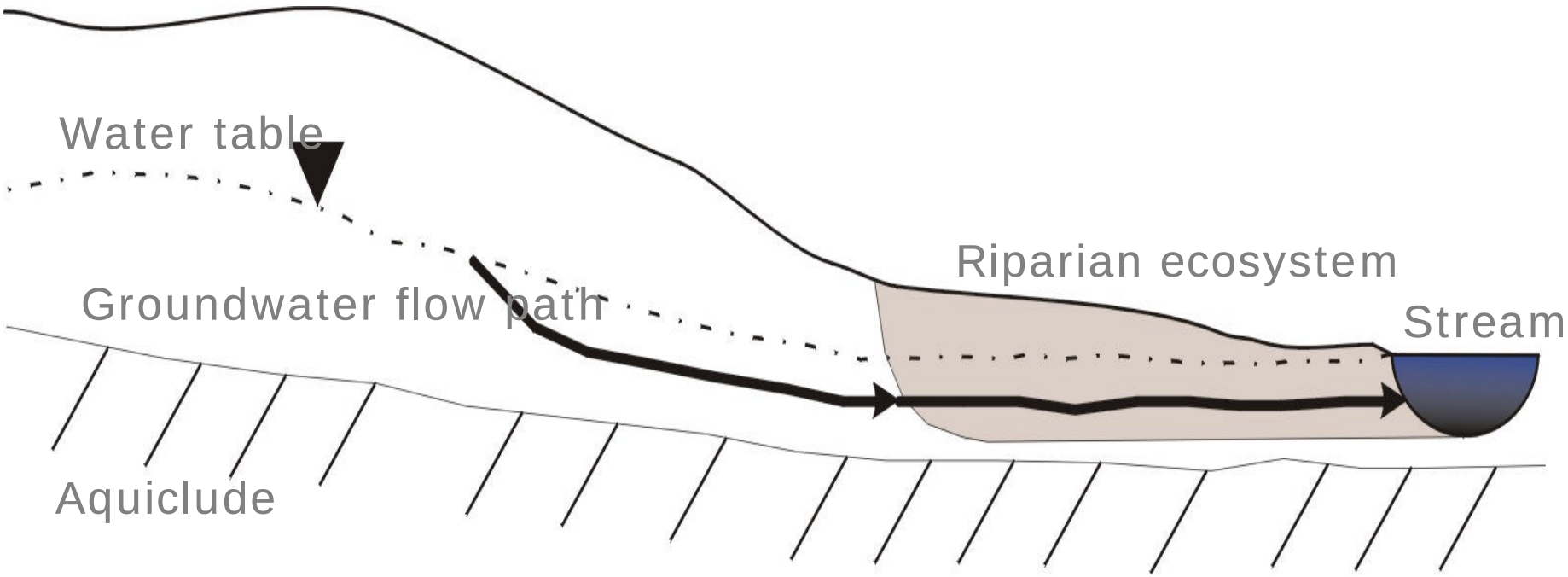
Source: T.W. Appelboom, USDA-ARS



CHALLENGES:

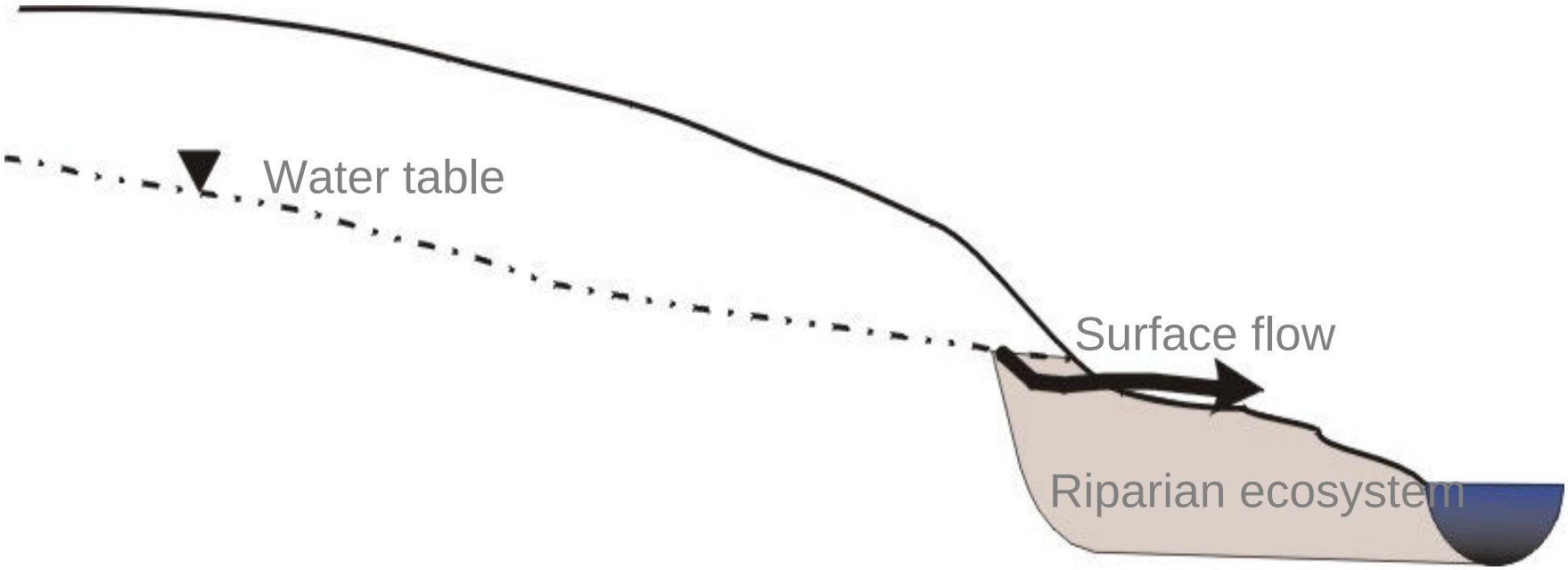
- Flowpaths:
  - Progress in riparian science and management is fundamentally constrained by our ability to understand the connections between the upland, the riparian zone and the stream.
- Hotspots:
  - Need to identify and understand focus on hydro-bio-geo-chemically active “edges,” especially at the riparian/stream interface.
- People:
  - Are people who manage the land apply to think about and apply landscape management concepts and technologies?

An idealized riparian zone, functioning as a denitrification sink for nitrate:



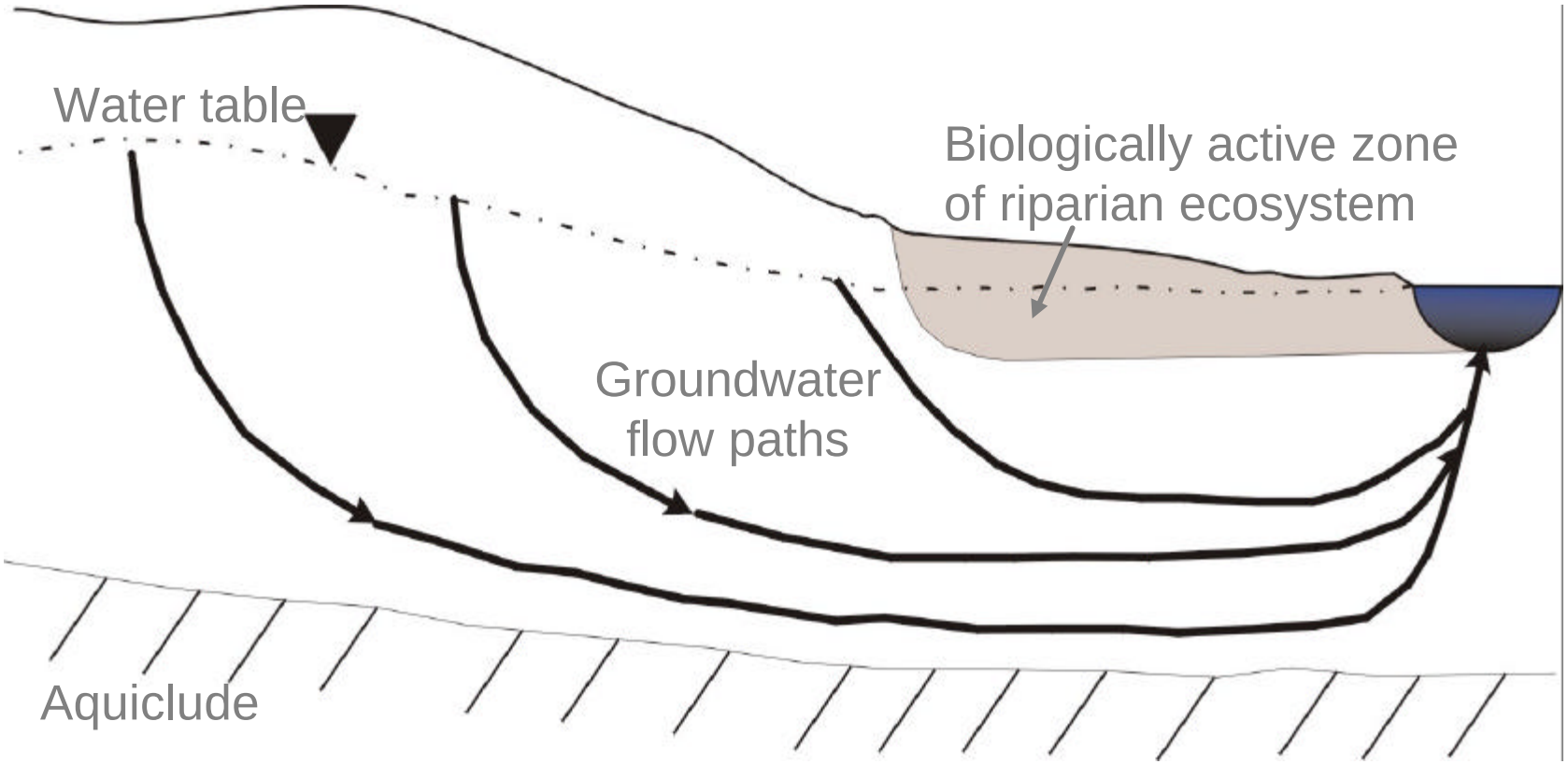
- Shallow groundwater moves through riparian ecosystem with anaerobic, denitrifying soil.

Flow path nightmare #1: seeps



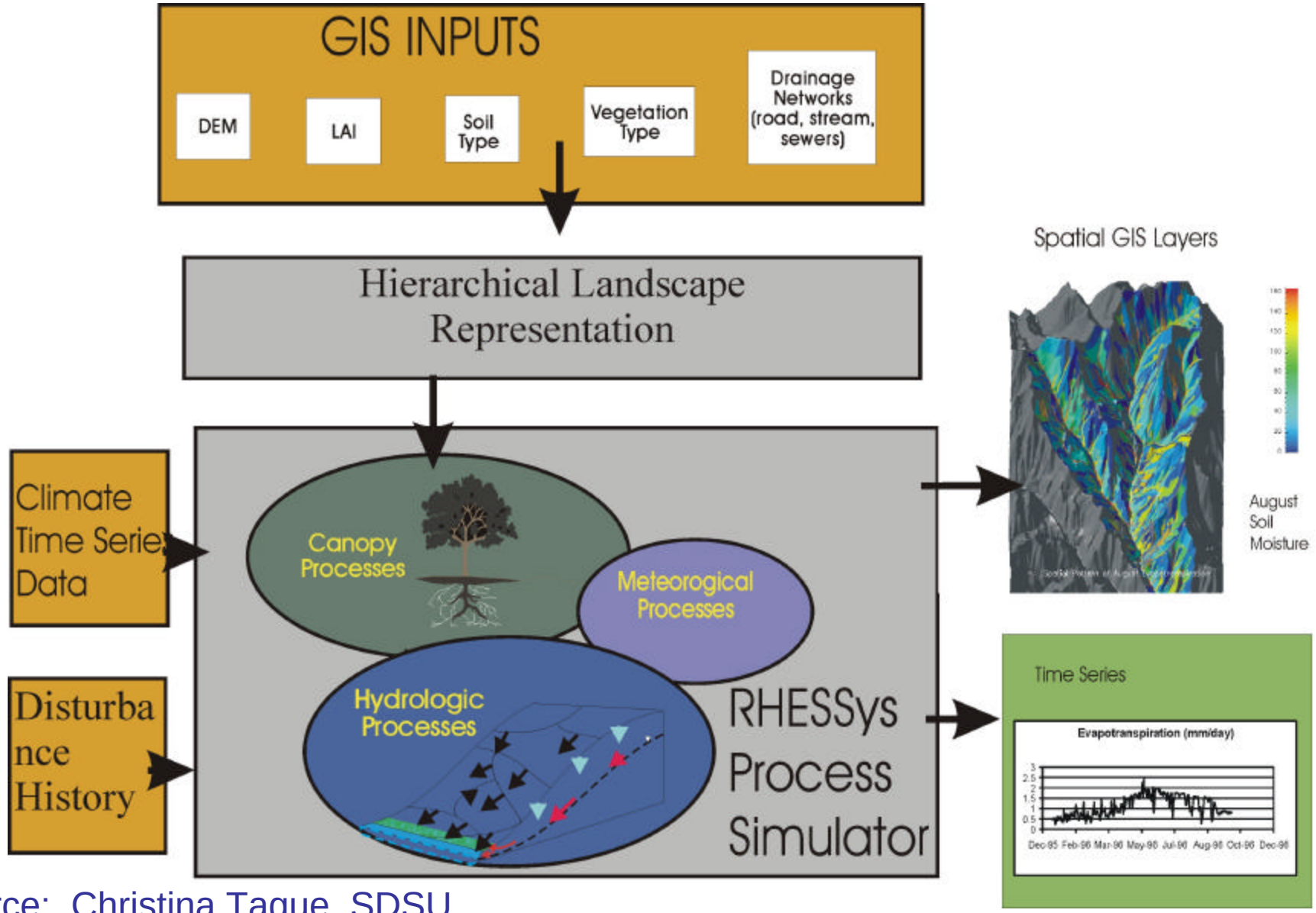
- Groundwater moves as surface flow across riparian ecosystem
- Lower groundwater N removal

Flow path nightmare #2: Deep bypass flow:



- Groundwater moves under riparian ecosystem
- Low groundwater N removal

Ecohydrological models hold promise for depicting upland- riparian- stream connections.



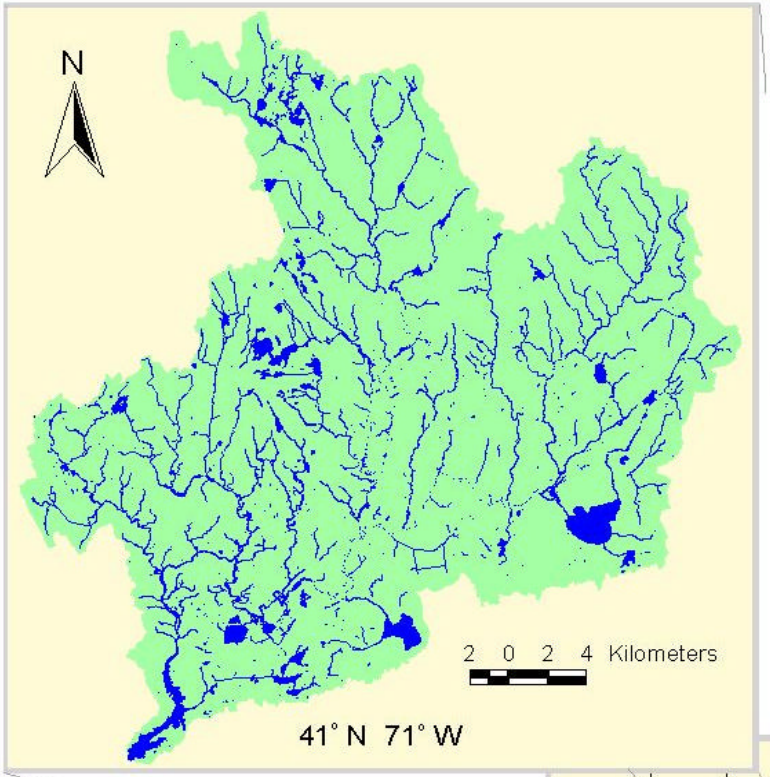
Source: Christina Tague, SDSU

Help is on the way . . .

- CUASHI (Consortium of Universities for the Advancement of Hydrologic Science, Inc.)
  - “Hydrologic Observatories” to improve the predictive understanding of the flow paths, fluxes, and residence times of water, sediments and nutrients across a range of spatial and temporal scales.
  - “Digital Watersheds, ” an assembly and synthesis for a hydrologic region of point hydrologic observations, GIS, remote sensing, and weather and climate gridded data. The intent is to have a comprehensive digital description of the physical environment and water conditions within a CUAHSI observatory.

Pawcatuck Catchment

Rhode Island, USA



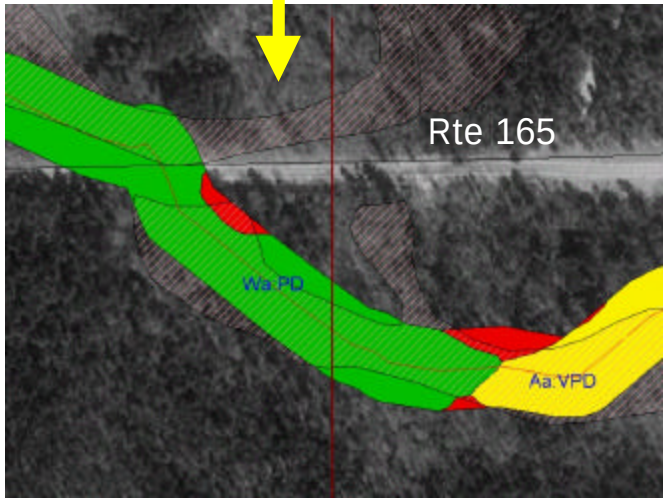
Characteristics:

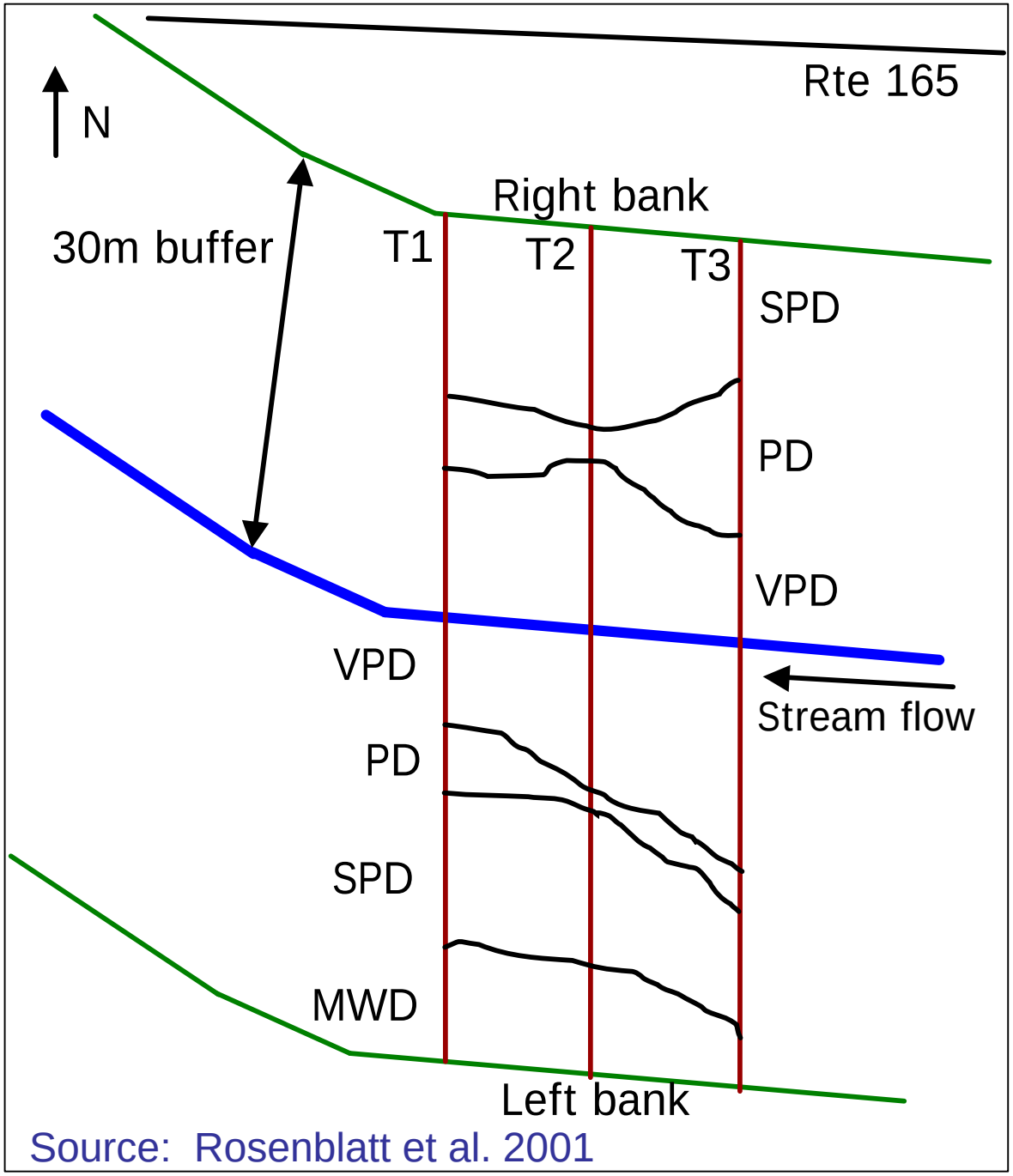
- Size: 850 km^2
- Glaciated deposits
- Least disturbed watershed between Boston and New York City
- Riparian study sites predominately mature red maple forests

Comparison:

Observe:

- **Ground-truth map:** 3-4 drainage classes
- **SSURGO** composed of 1 soil map unit?



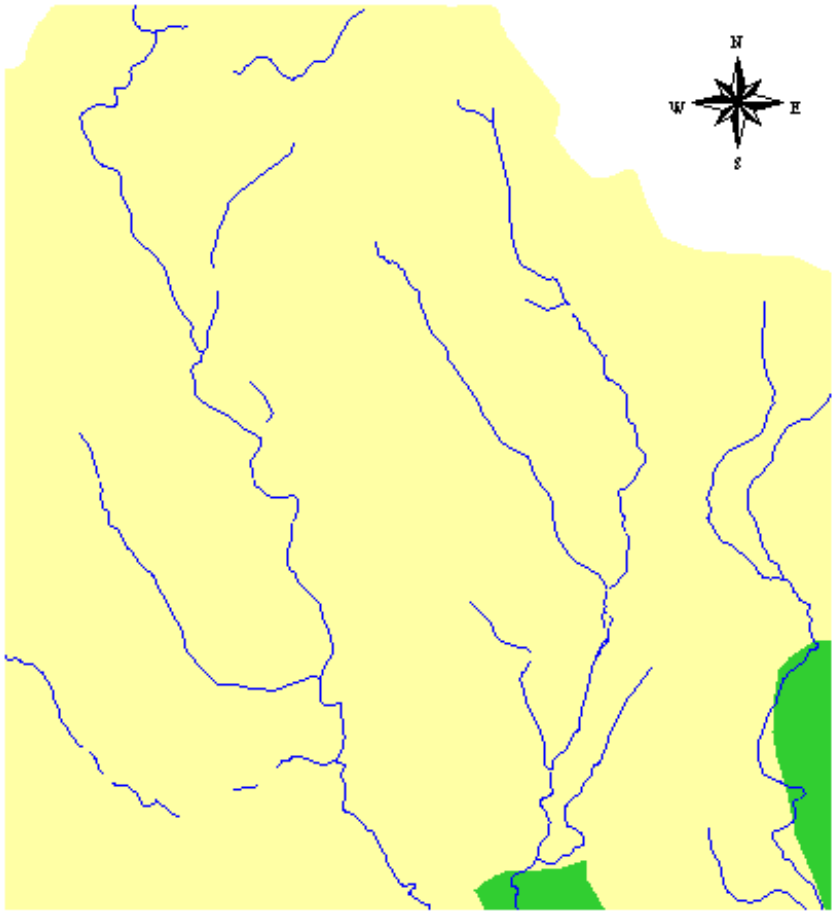


Source: Rosenblatt et al. 2001

Original Scale of GIS Data Base Can Alter Inputs & Outputs to Watershed Models

Proportion of stream length bordered by hydric soils

5%

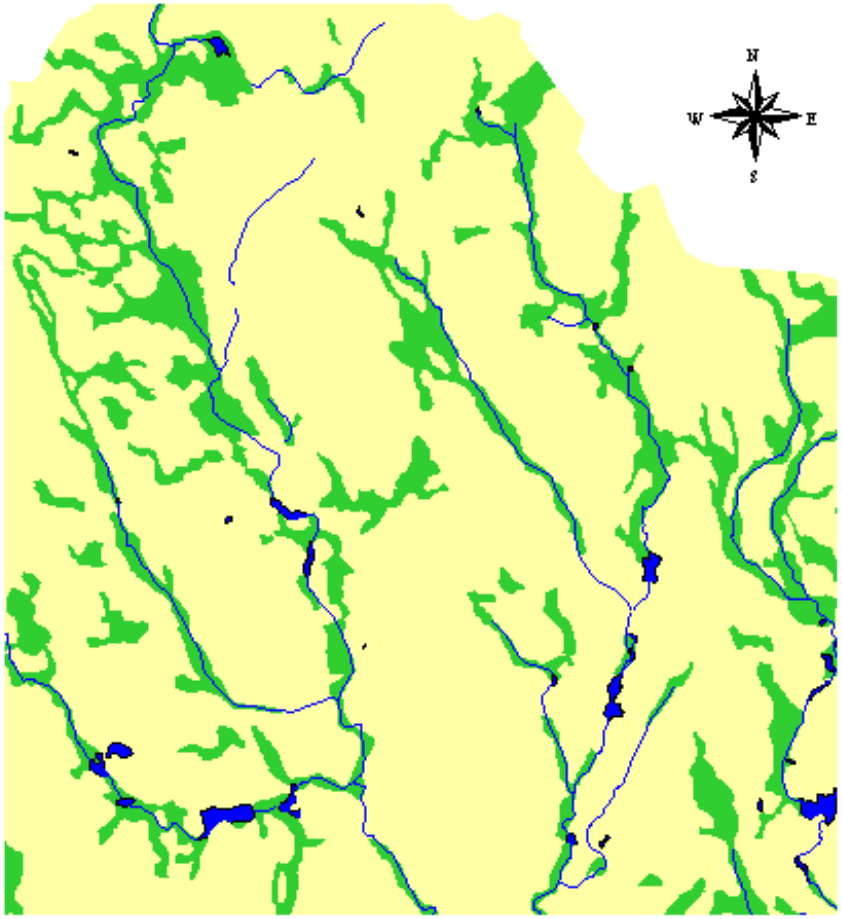


1 0 1 Kilometers

STATSGO
Original scale 1:250, 000

STATSGO Legend
- hydric soils
- nonhydric soils
- rivers and streams

75%

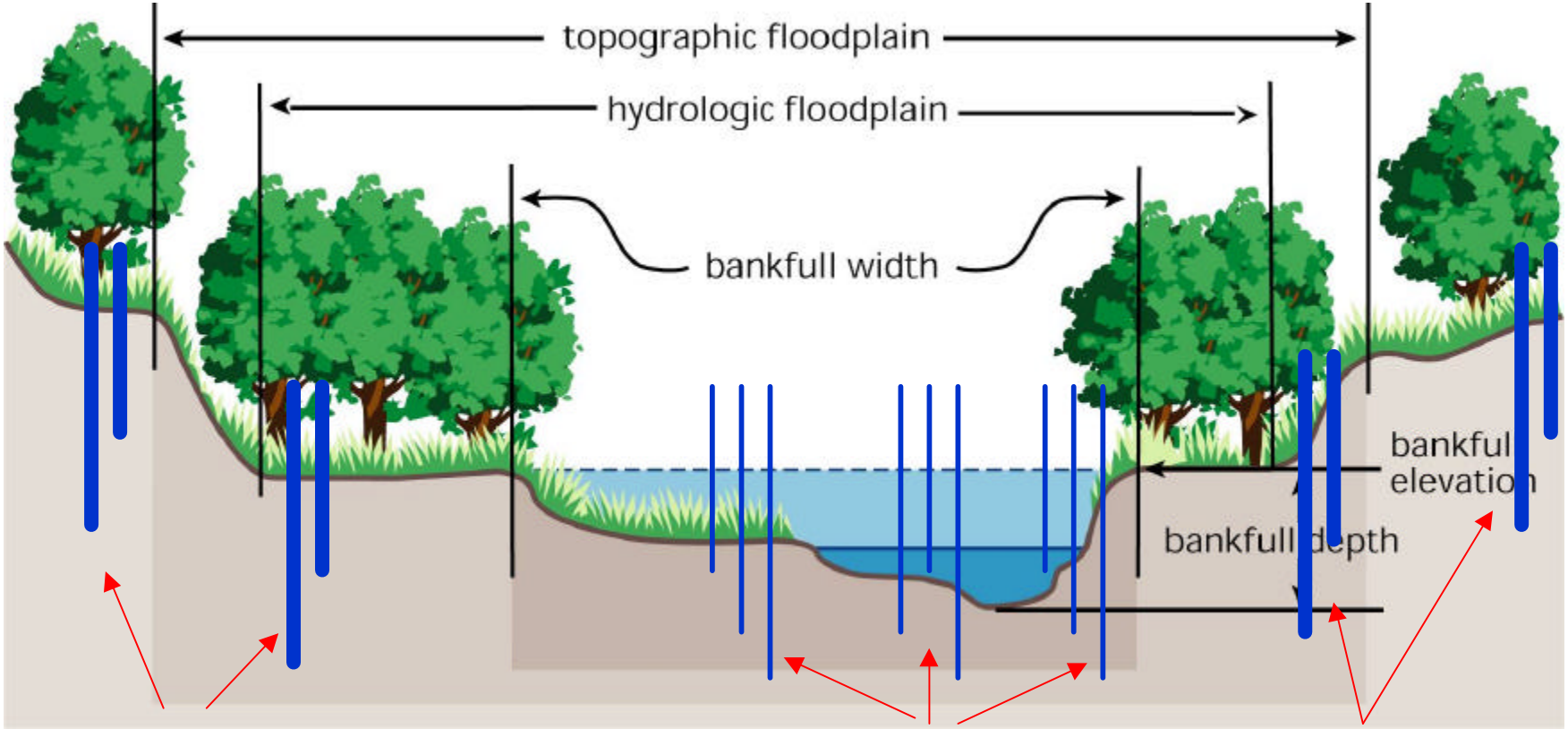


1 0 1 Kilometers

SSURGO
Original scale 1:15, 840

SSURGO Legend
- hydric soils
- nonhydric soils
- water
- rivers and streams

Hotspots: Focus on hydro- bio- geo- chemically active “edges” between riparian zones and streams.

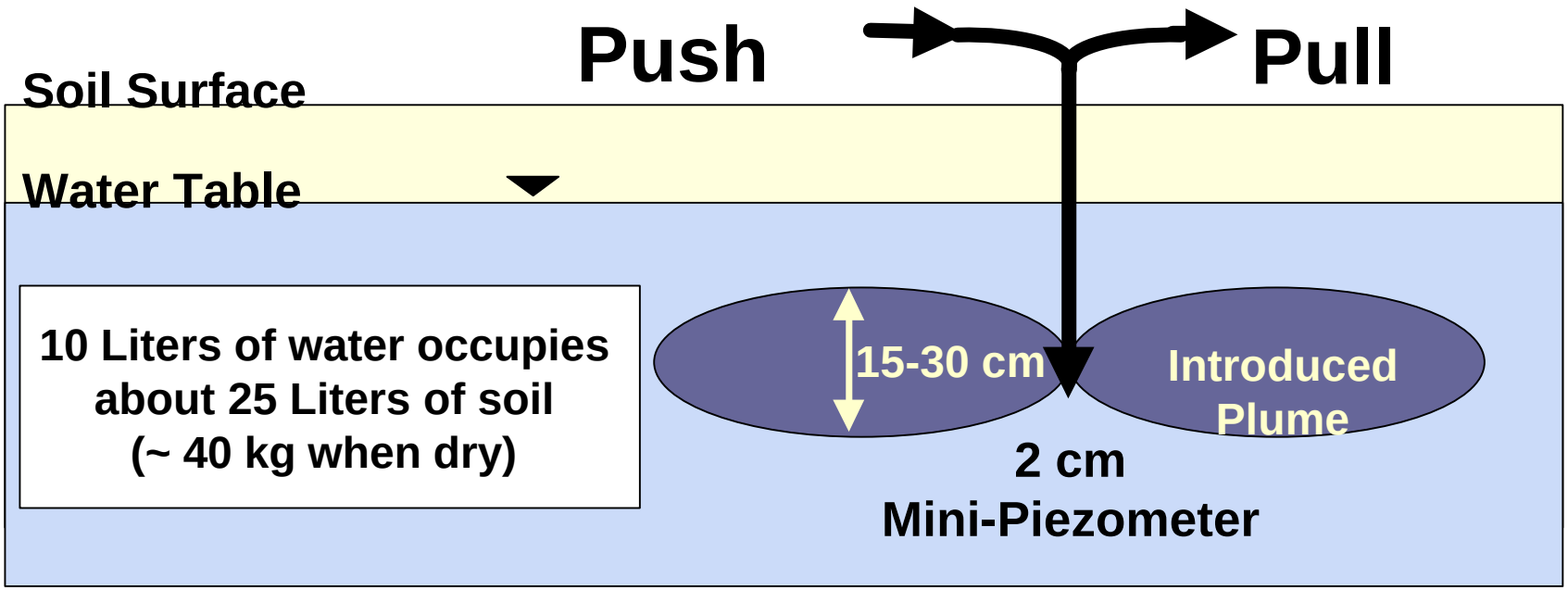


Flood Plain
Shallow/deep
monitoring wells

Stream Unit
Piezometer well nests

Flood Plain
Shallow/deep
monitoring wells

Source: Paul Mayer, EPA

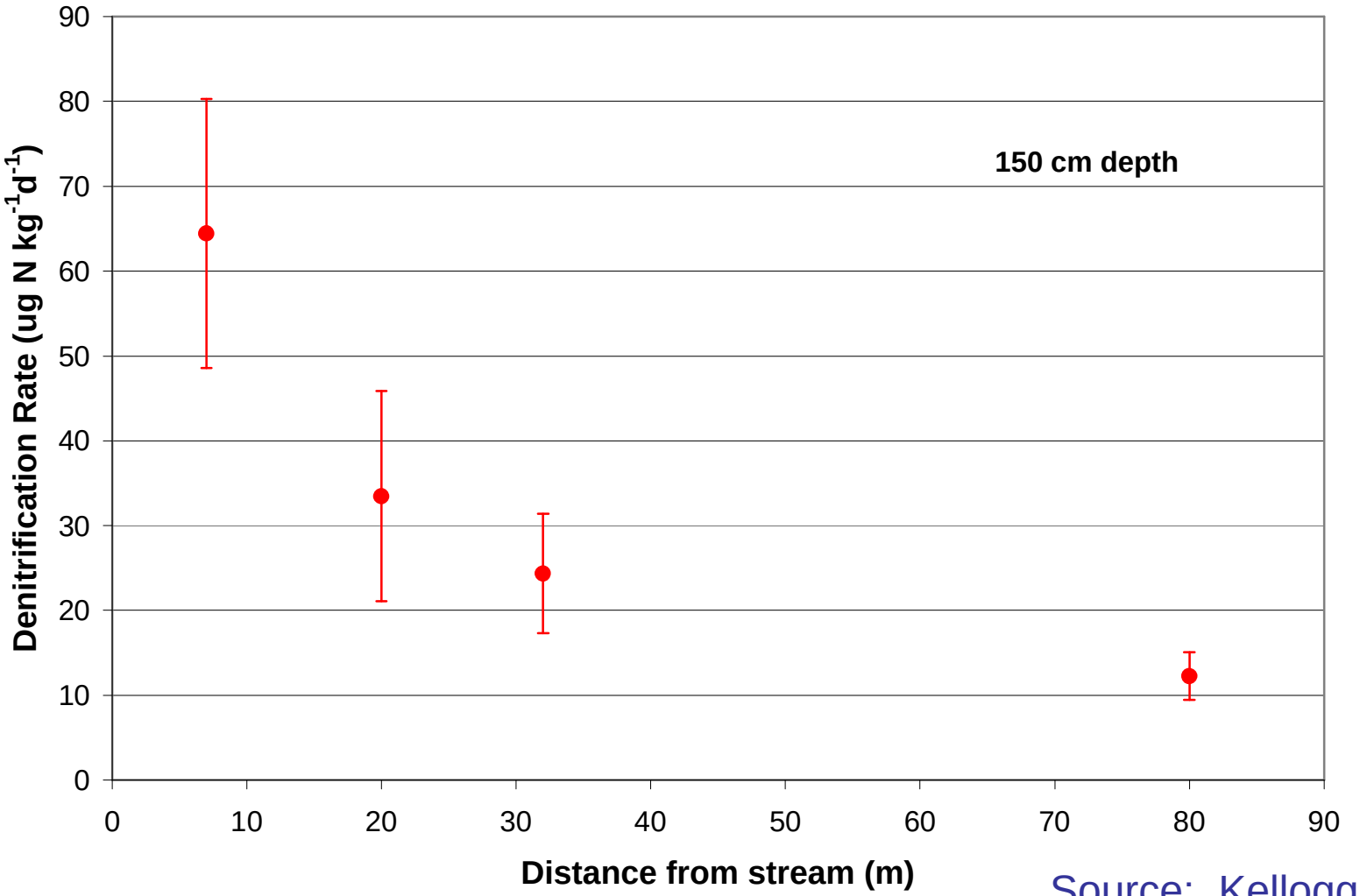


Push-Pull Method

1. Pump groundwater.
2. Amend with $^{15}NO_3$, Br^-, SF_6.
3. Lower DO to ambient levels with inert gas.
4. Push into well.
5. Incubate.
6. Pull from well.
7. Analyze for $^{15}N_2$, $^{15}N_2O$, $^{15}NO_3$, Br^-, SF_6

Source: Addy et al. 2002

Riparian groundwater denitrification rates decline sharply with distance from the stream. Evidence for a "hydrologic edge"?



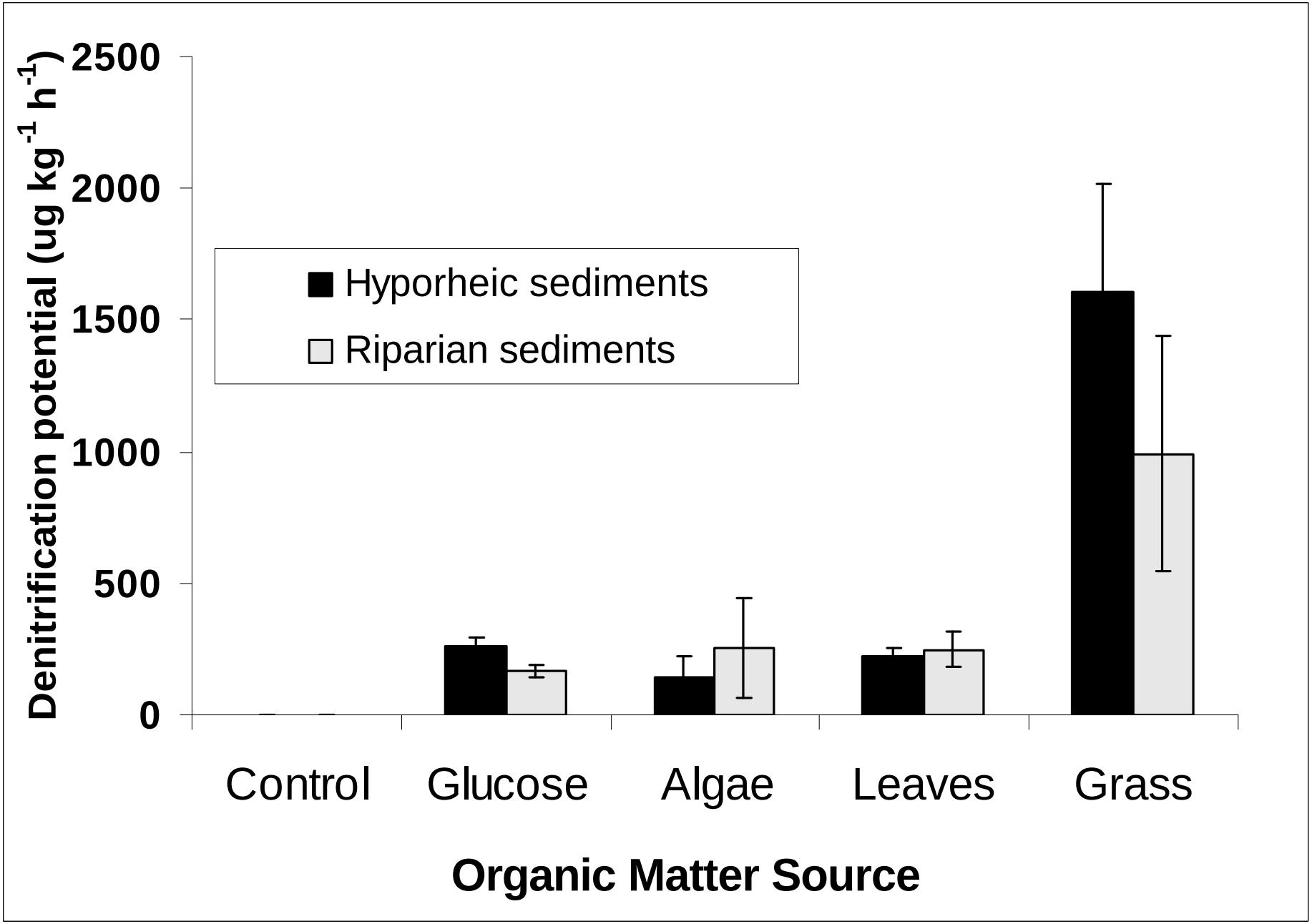
Source: Kellogg et al. 2005

What might create hotspots at the riparian/stream inteface:

- Alluvial carbon deposits?
- Something in the water?

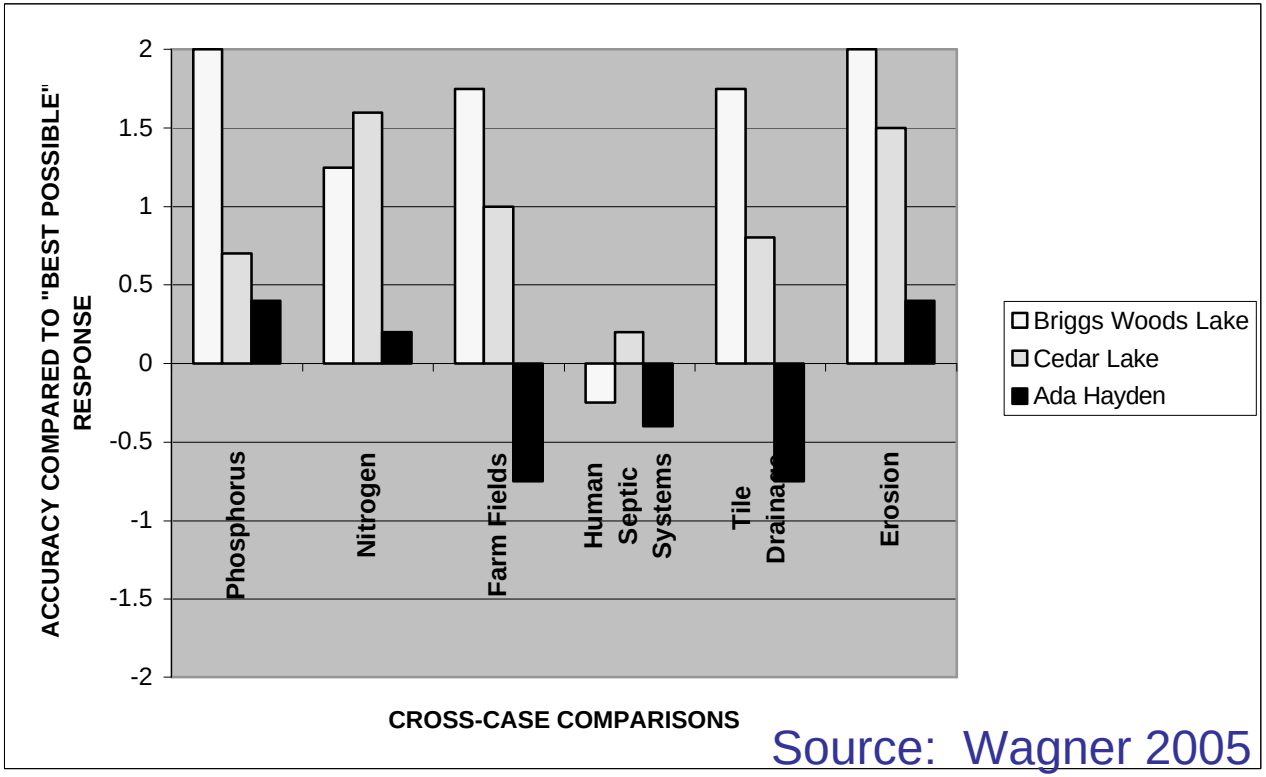
Is there something in the water?

- Leaves
- Algae
- Grass


Denitrification potential (ug kg-1 h-1)
2500
2000
1500
1000
500
0
Hyporheic sediments
Riparian sediments
Control
Glucose
Algae
Leaves
Grass
Organic Matter Source

The Social Science Angle:

- Extension, education and outreach can improve perceptions and knowledge of “sources”:
  - But what do people know about sinks?
  - Do we (physical, biological, social scientists and land managers) understand how “farm scale” sink activities translate to the landscape or watershed scale?



Source: Wagner 2005

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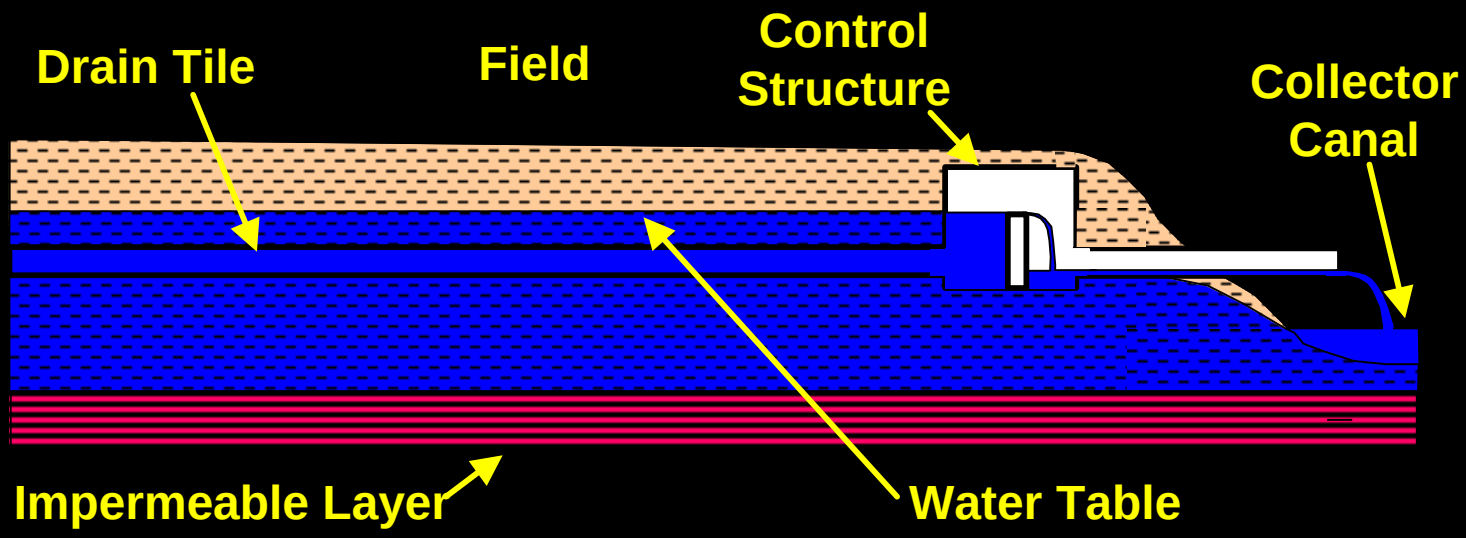
Summary and Conclusions:

- Some promising technology, especially high technology solutions for drained areas.

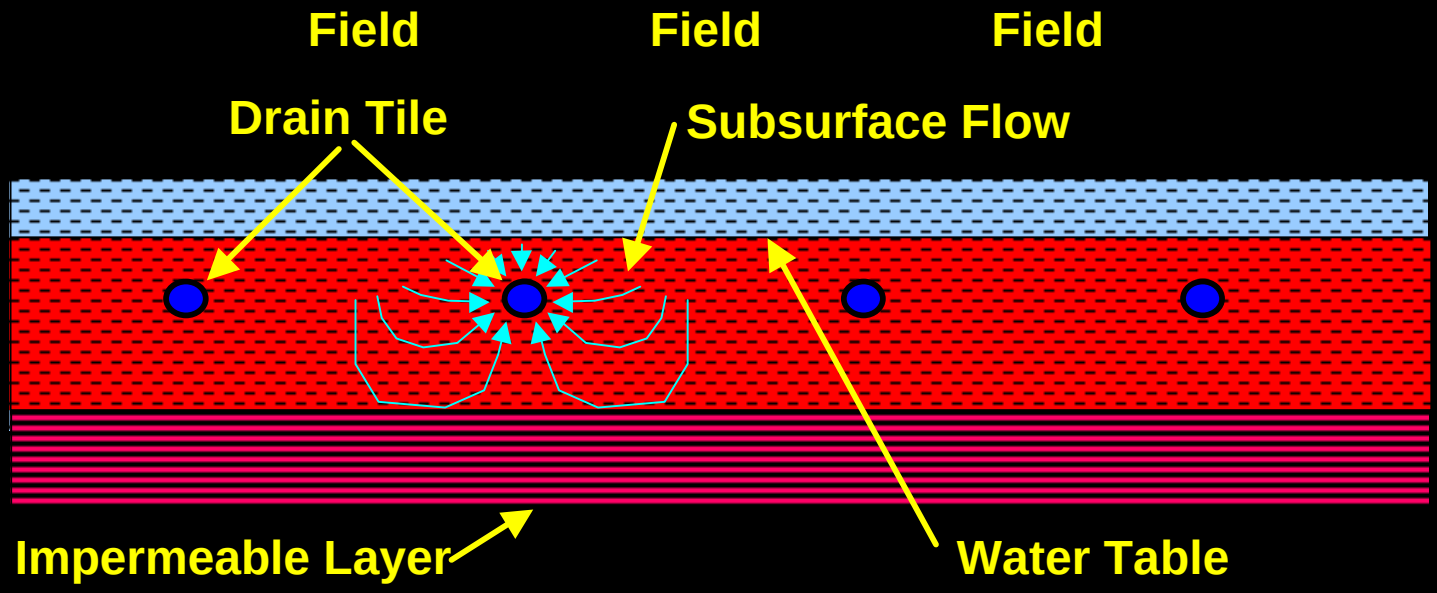
- Some real challenges:
  - Riparian evaluations MUST include assessment of flow paths between the upland, the riparian zone and the stream, and should consider hotspots:
    - Eco-hydrological models and “digital watersheds” are new conceptual and practical tools that should allow us to assess flow paths and hotspots on a routine basis.
  - Does the watershed/landscape approach really work in agricultural areas?

Controlled Subsurface Drainage

Source: T.W. Appelboom, USDA-ARS



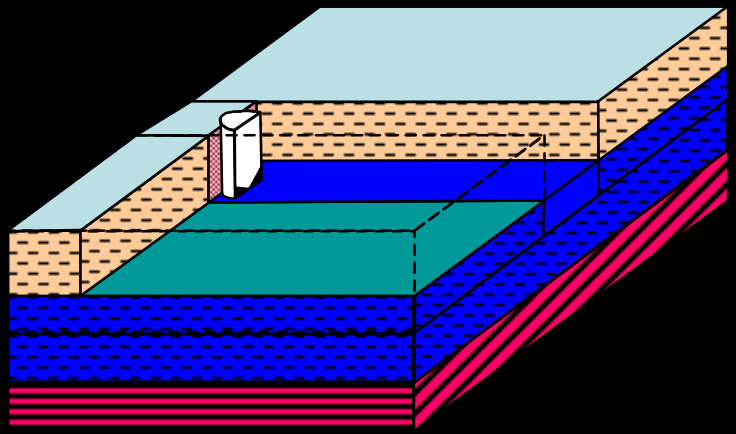
Agri-Drain Corp.

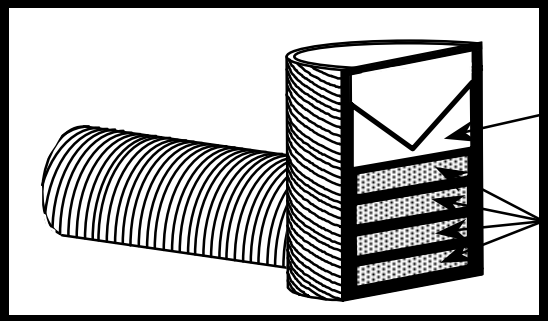


(Sheryl Kunickis, Illinois)

Controlled Surface Drainage

1 Foot = 0.72 Inch of Rainfall assuming 6% drainable porosity)

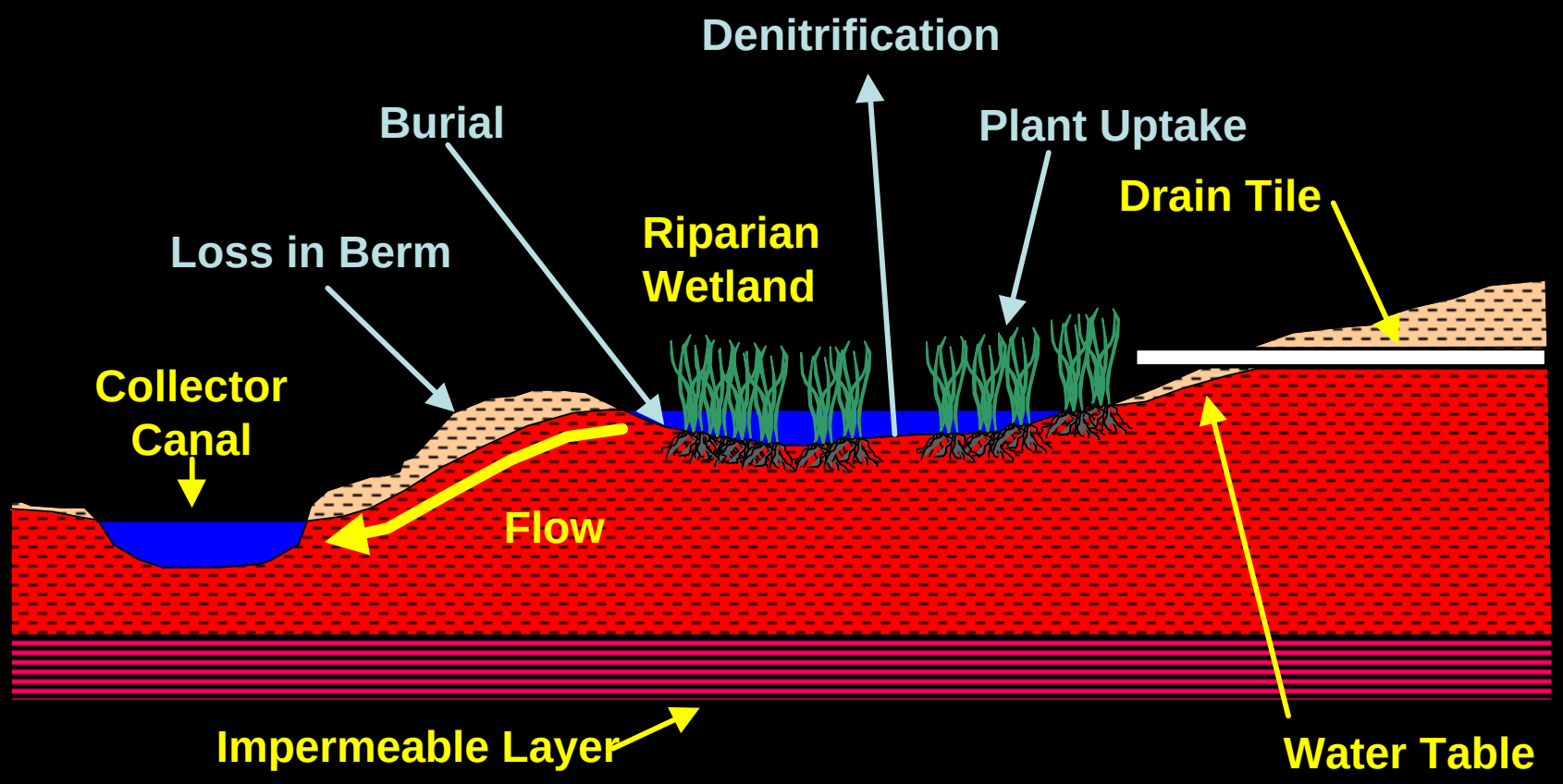




V-Notch Weir Removable Boards

Source: T.W. Appelboom, USDA-ARS

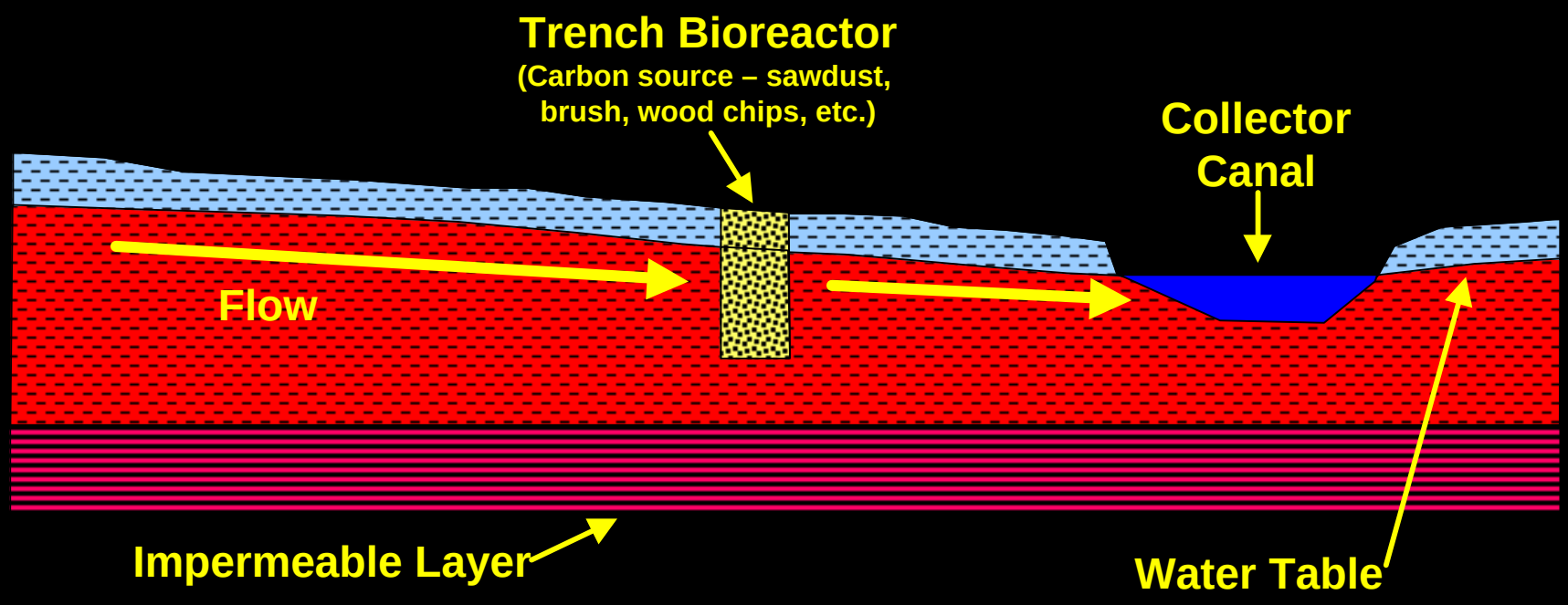
Constructed Wetland



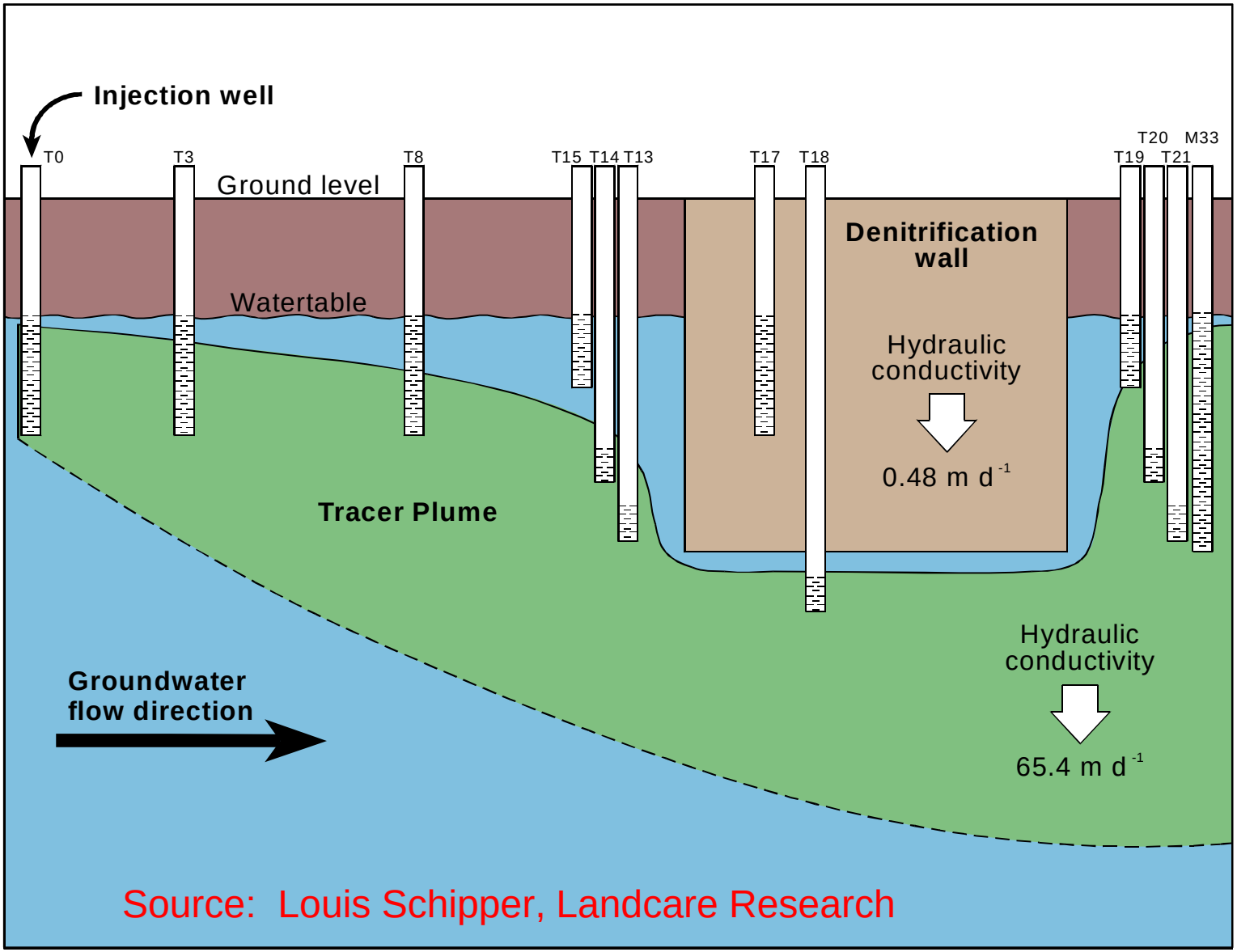
Source: T.W. Appelboom, USDA-ARS

Bioreactors

Source: T.W. Appelboom, USDA-ARS



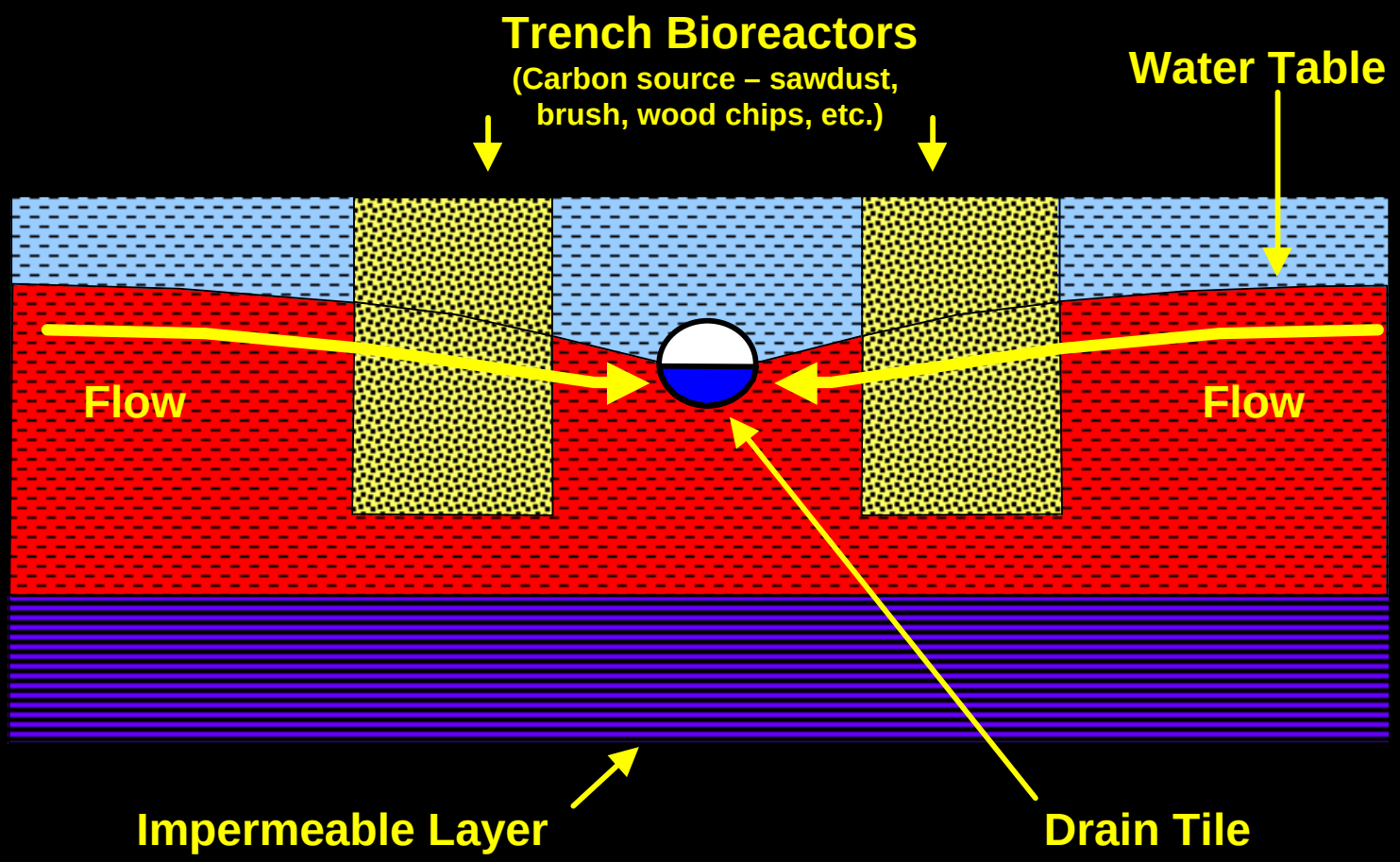
Hydrologic complexities can reduce the effectiveness of trench bioreactors:



Source: Louis Schipper, Landcare Research

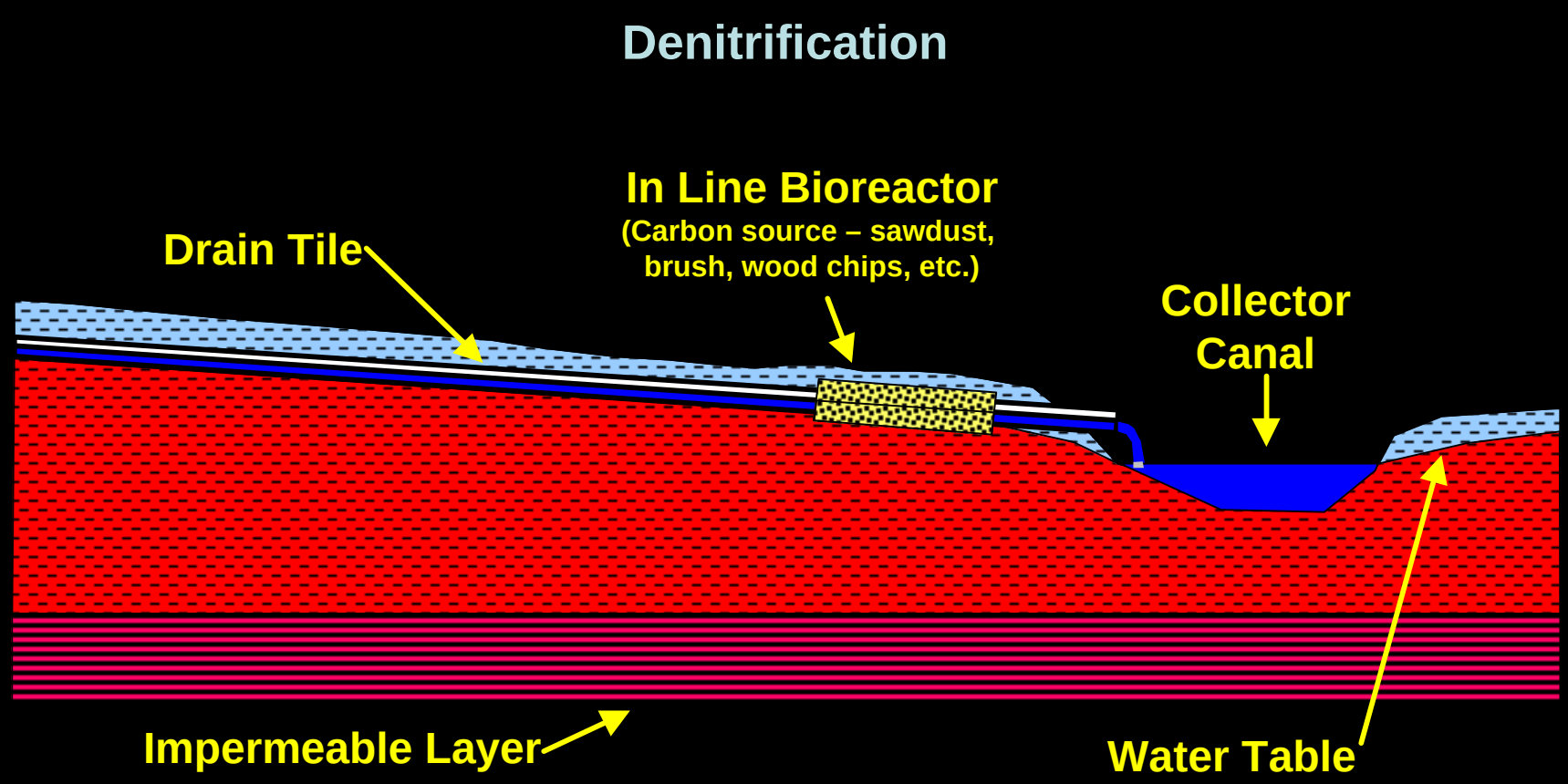
Bioreactors

Source: T.W. Appelboom, USDA-ARS



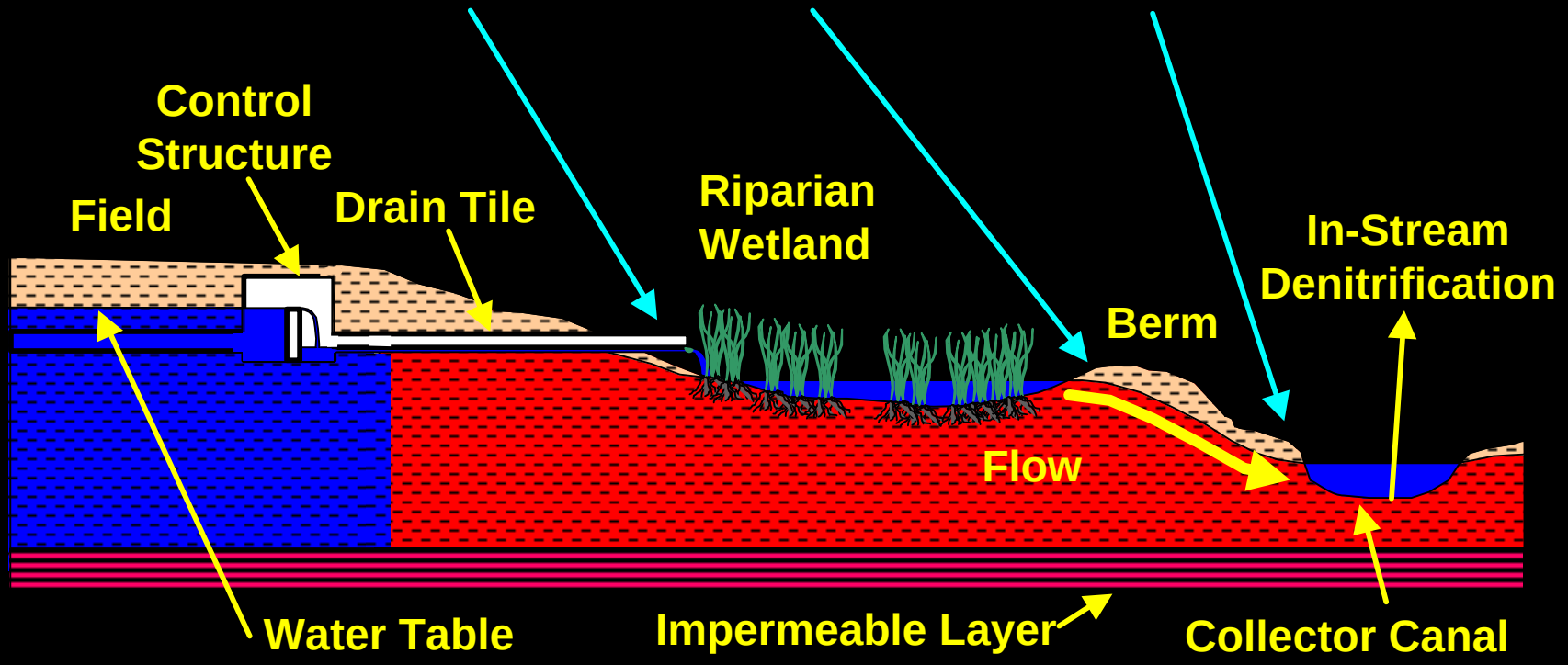
Bioreactors

Source: T.W. Appelboom, USDA-ARS



Combining practices can produce significant nitrogen removal

5 acres	50% flow red.	40% mass red.	18% mass red.	5% mass red.
½ inch/day	133 m^3/day	133 m^3/day	133 m^3/day	133 m^3/day
266 m^3/day	10 mg/L	6 mg/L	4.9 mg/L	4.7 mg/L
10 mg/L	1.33 kg/day	0.79 kg/day	0.65 kg/day	0.63 kg/day
2.66 kg/day				



Overall ➡ 76% reduction in mass
53% reduction in concentration

Source: T.W. Appelboom, USDA-ARS