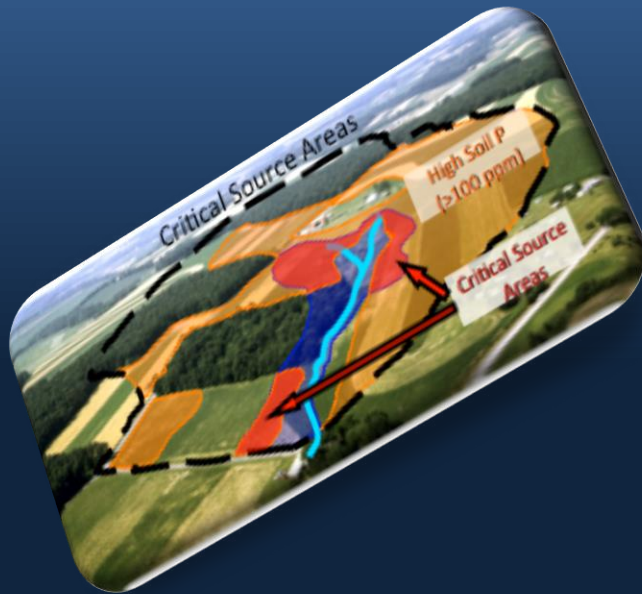


Drainage and legacy P

Global concerns, local problems



Pete Kleinman

USDA Agricultural Research Service
State College, PA 16802

Phosphorus in drainage water

Subsurface transport is ubiquitous

Tile drainage

Tiles create “hydrologic connection”

Route surface runoff and liquid manure

Especially in soils with good structure

Open ditches

Role of shallow lateral flow

Difficulty in managing legacy P

Even in sloping landscapes

Subsurface transport can be important

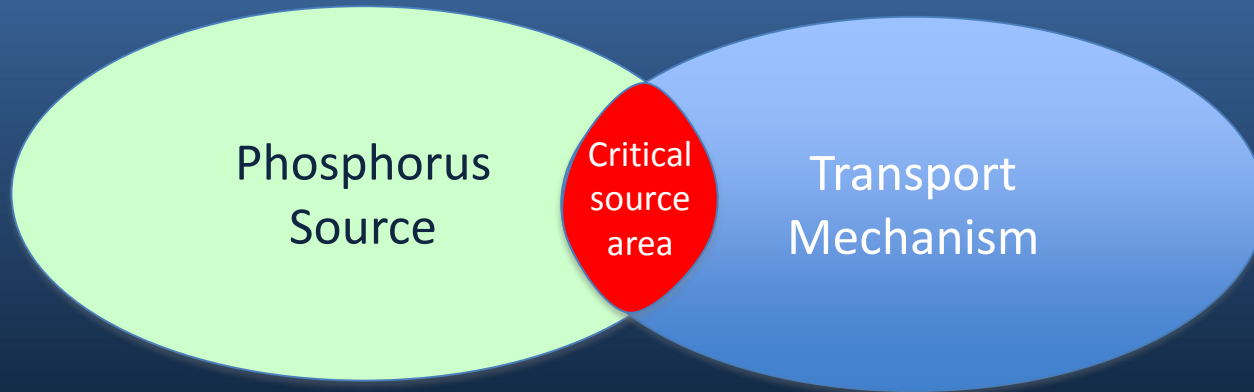
Field drainage – ditches and tiles

lower water tables, faster travel times, increased connectivity

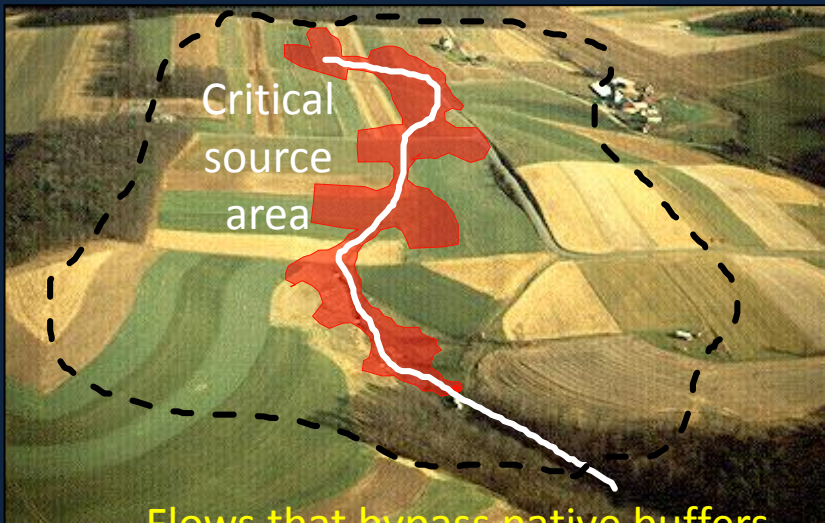


Phosphorus loss from fields

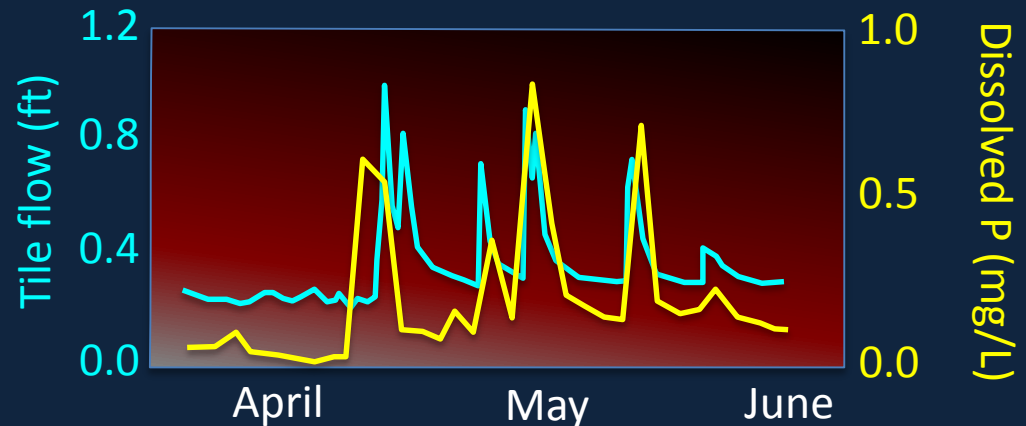
Managing sources and transport pathways



HOT SPOTS



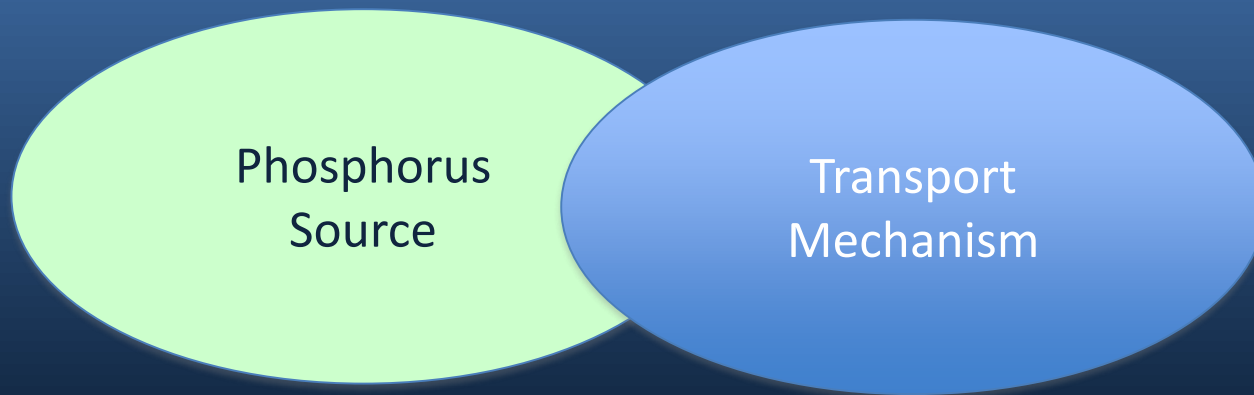
HOT MOMENTS



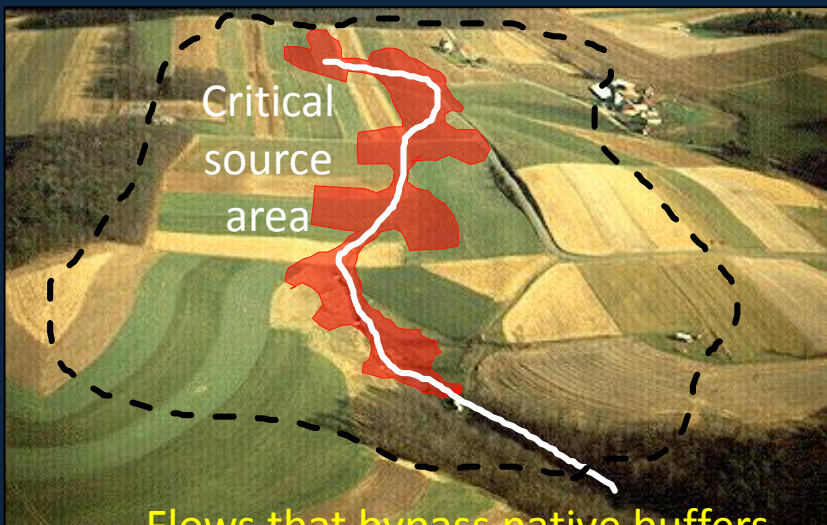
Source: King, USDA-ARS

Phosphorus loss from fields

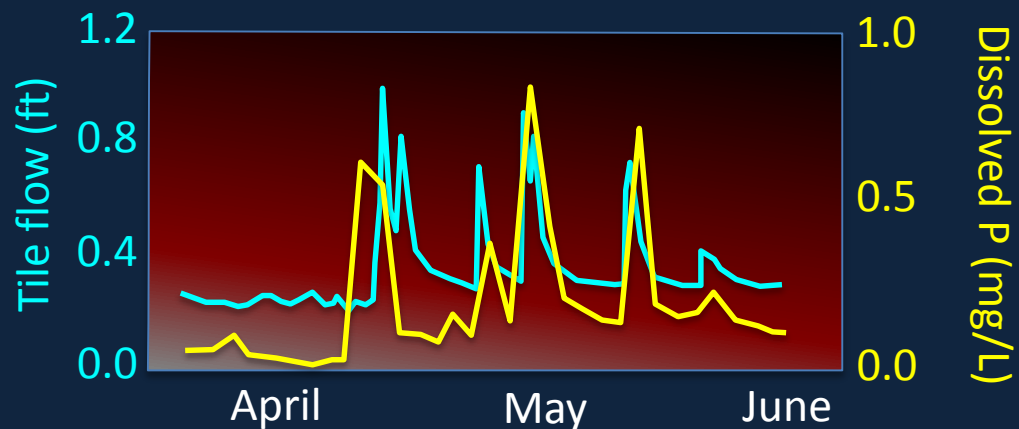
Managing sources and transport pathways



HOT SPOTS



HOT MOMENTS

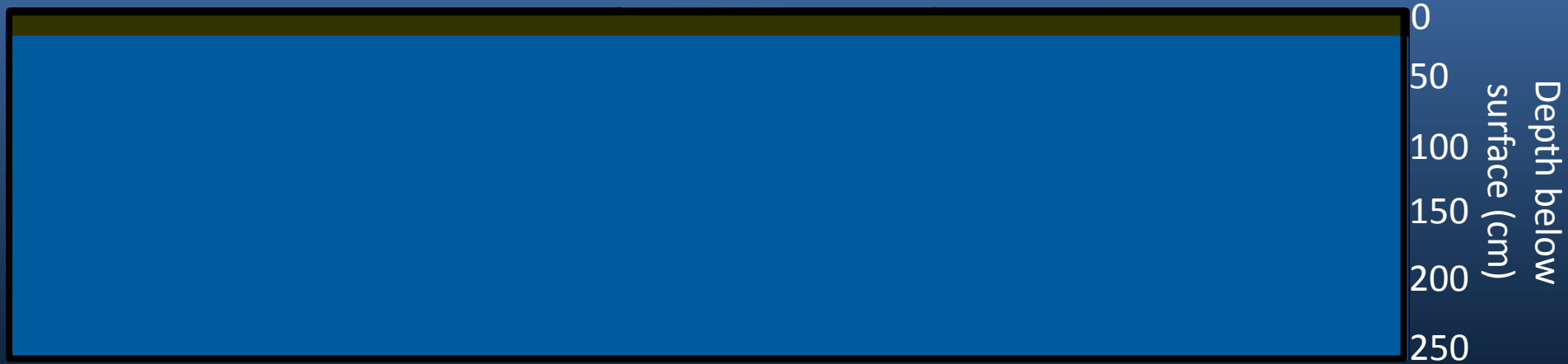


Source: King, USDA-ARS

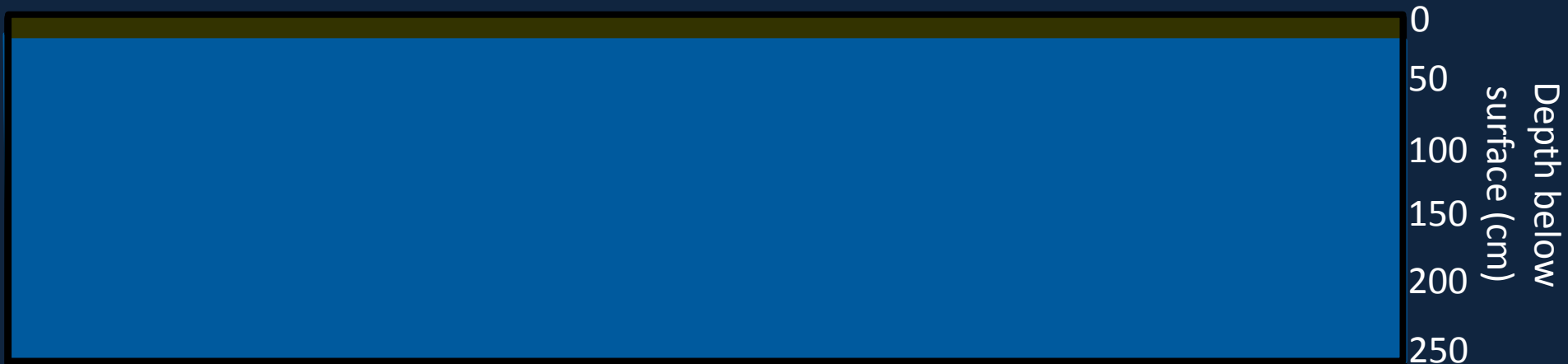
Intensifying artificial drainage

lower water tables, faster travel times, increased connectivity

Ditch drainage

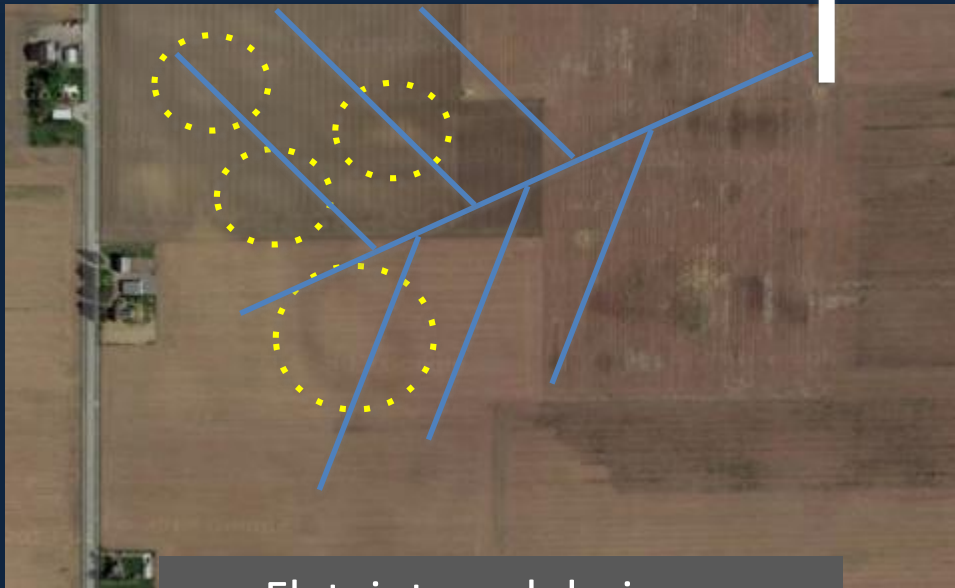
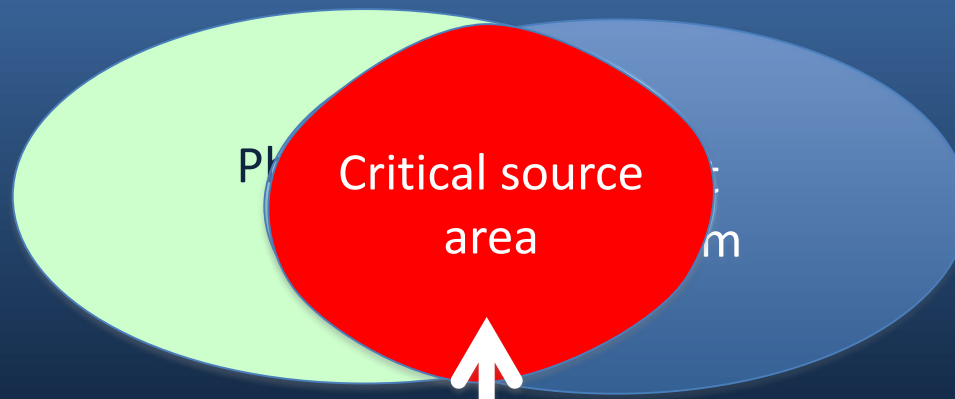


Tile drainage

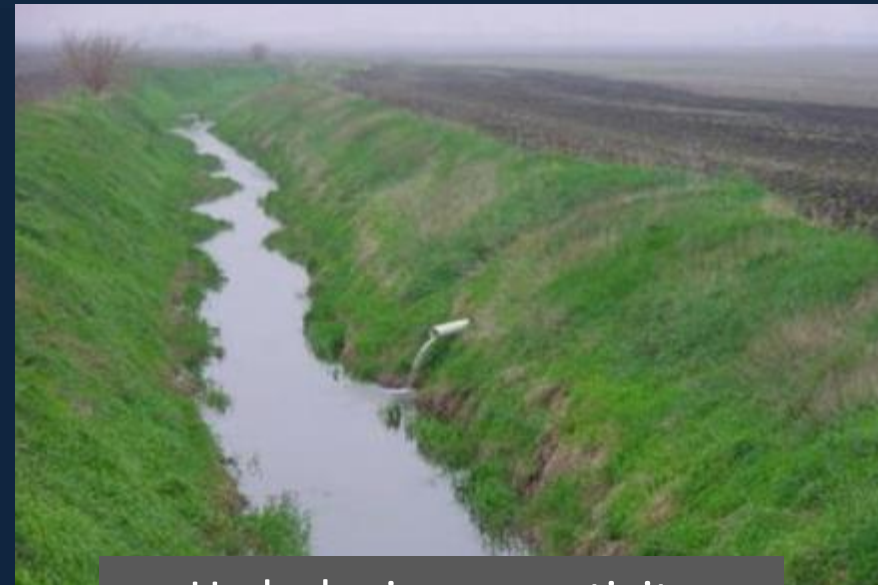


Managing phosphorus loss

Drainage expands critical source areas and "quick flow"



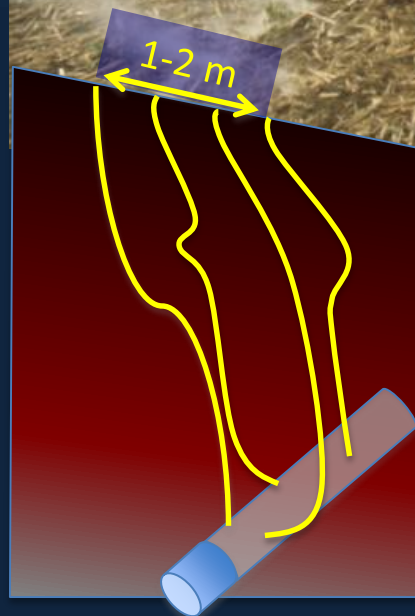
Flat, internal drainage



Hydrologic connectivity

Tile drains route surface runoff

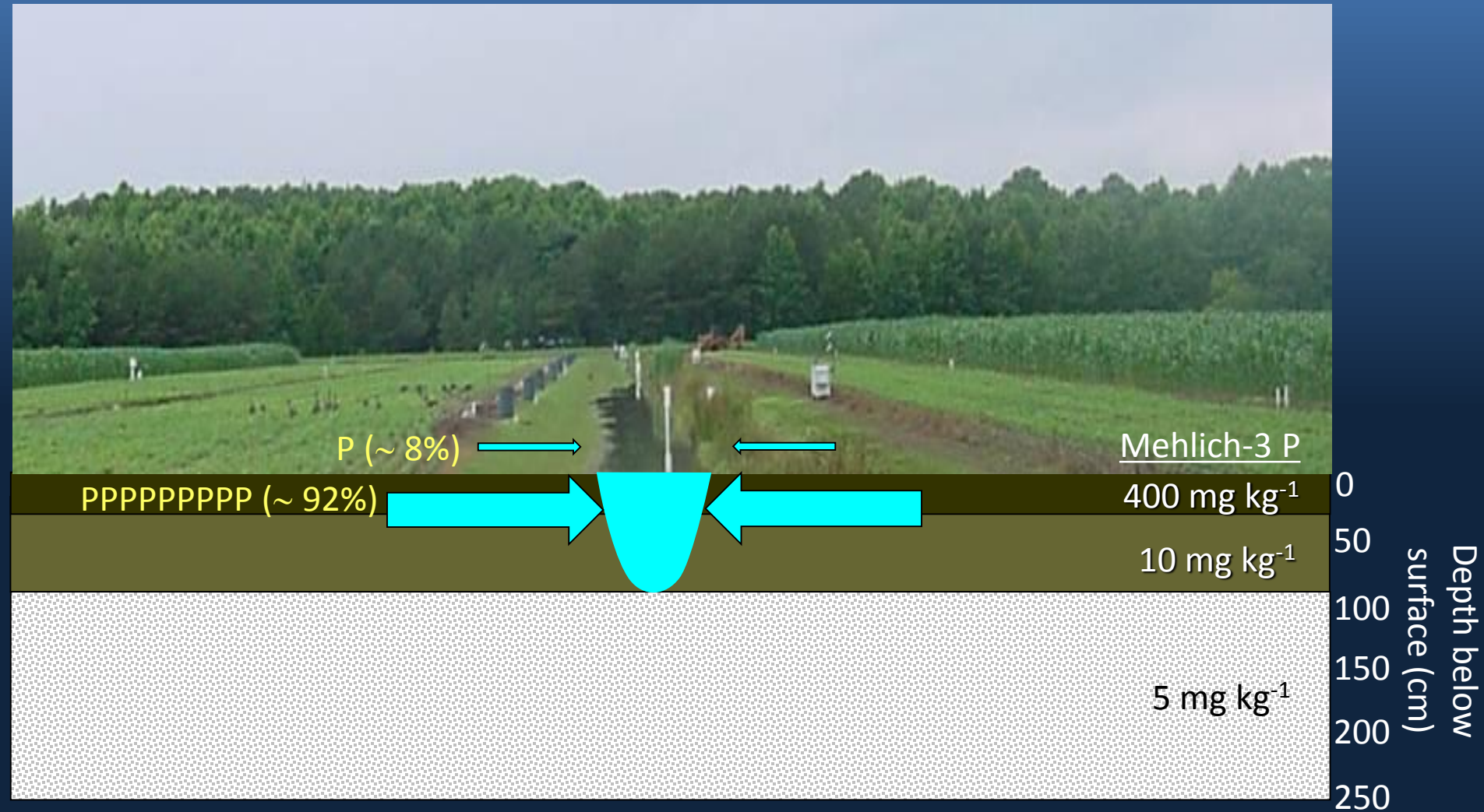
Via macropores



HOT
SPOT

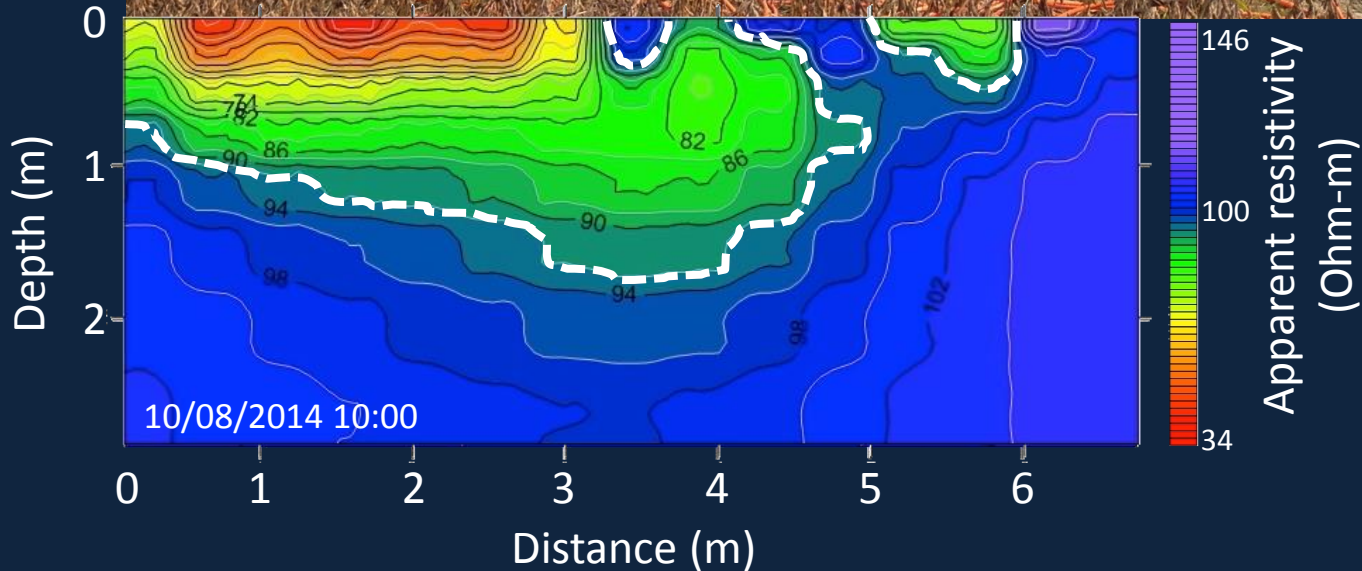
Soil P transfers to drainage ditches

Shallow groundwater is the primary pathway



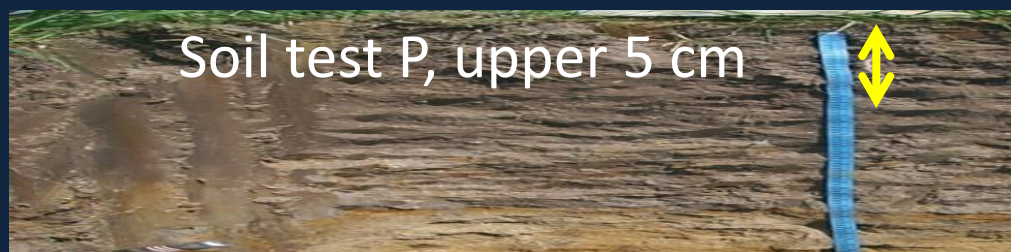
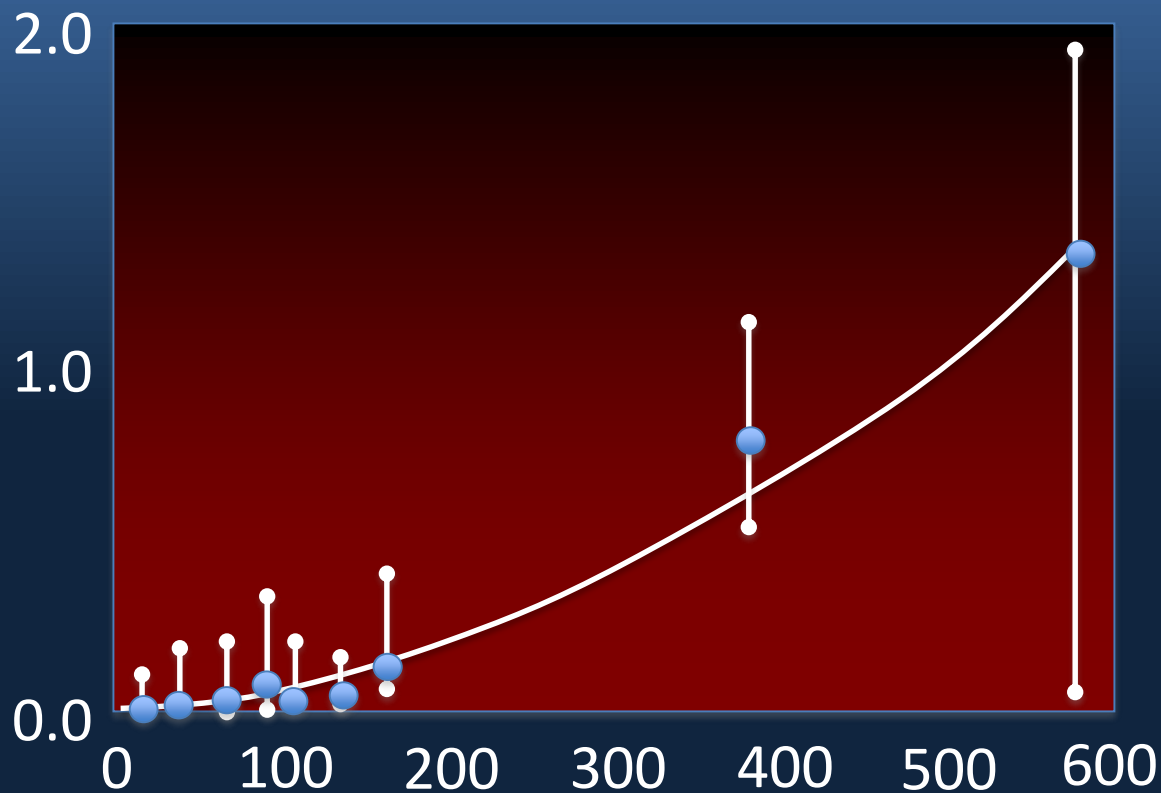
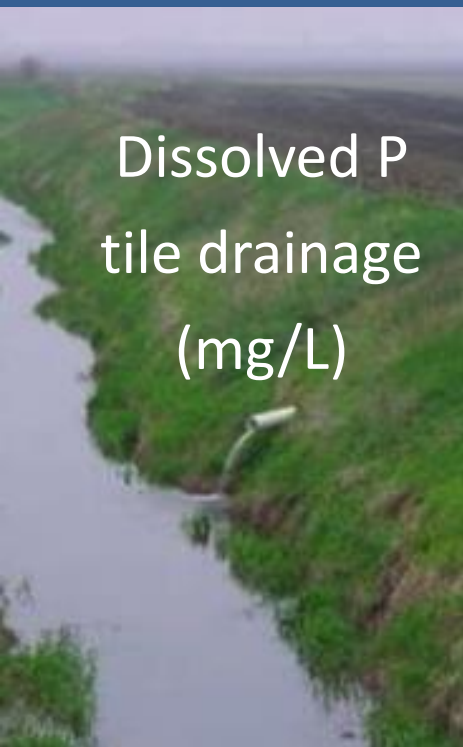
Shallow subsurface flow pathways

Applying tracers with electrical resistivity imaging



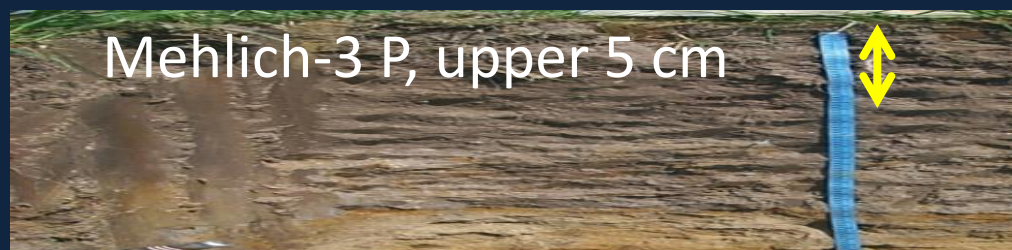
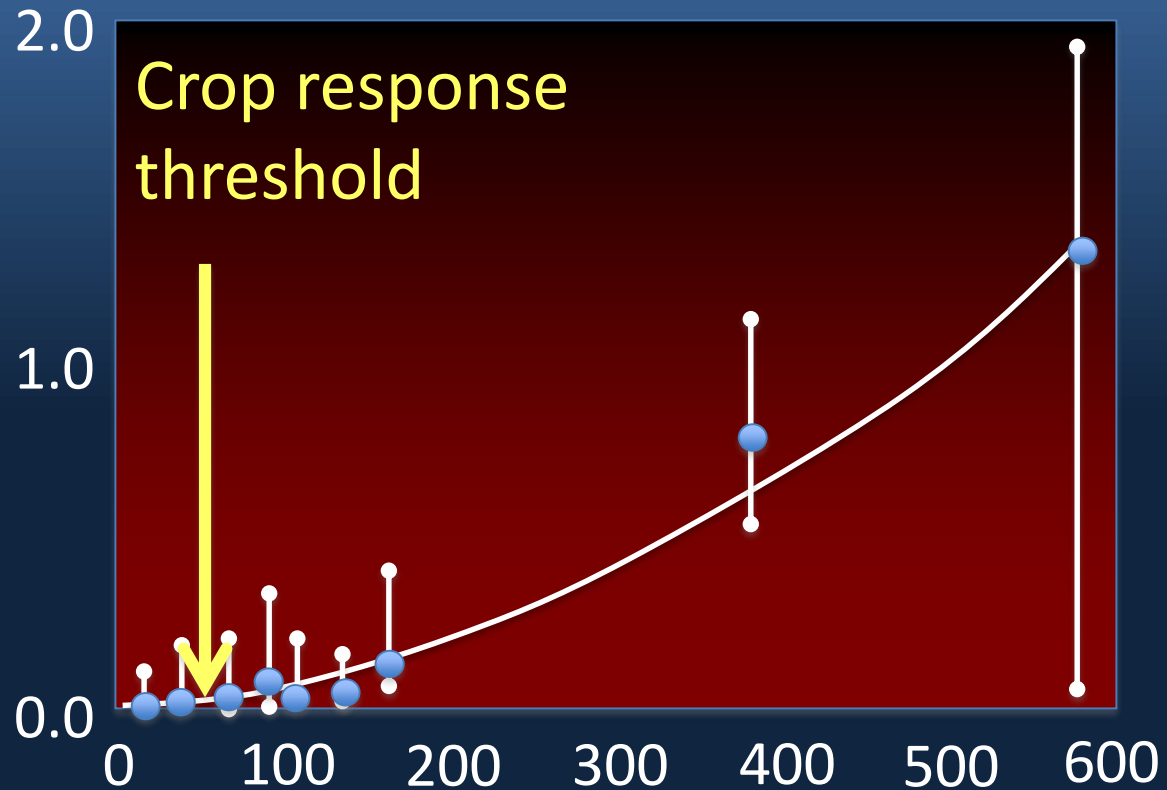
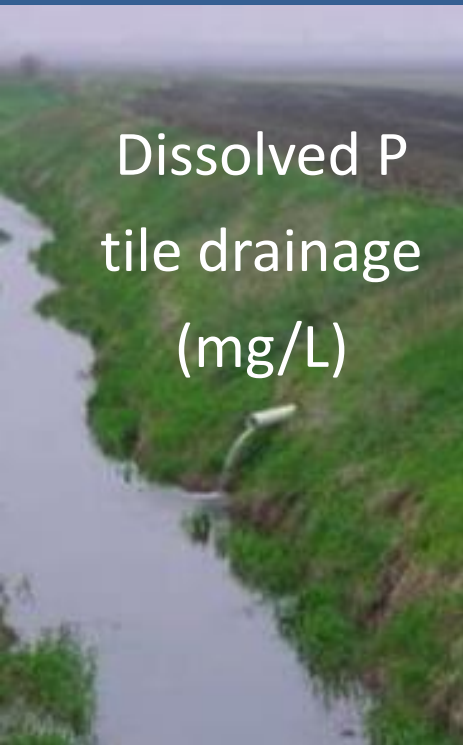
Drainage and subsurface P loss

Many parallels with surface runoff

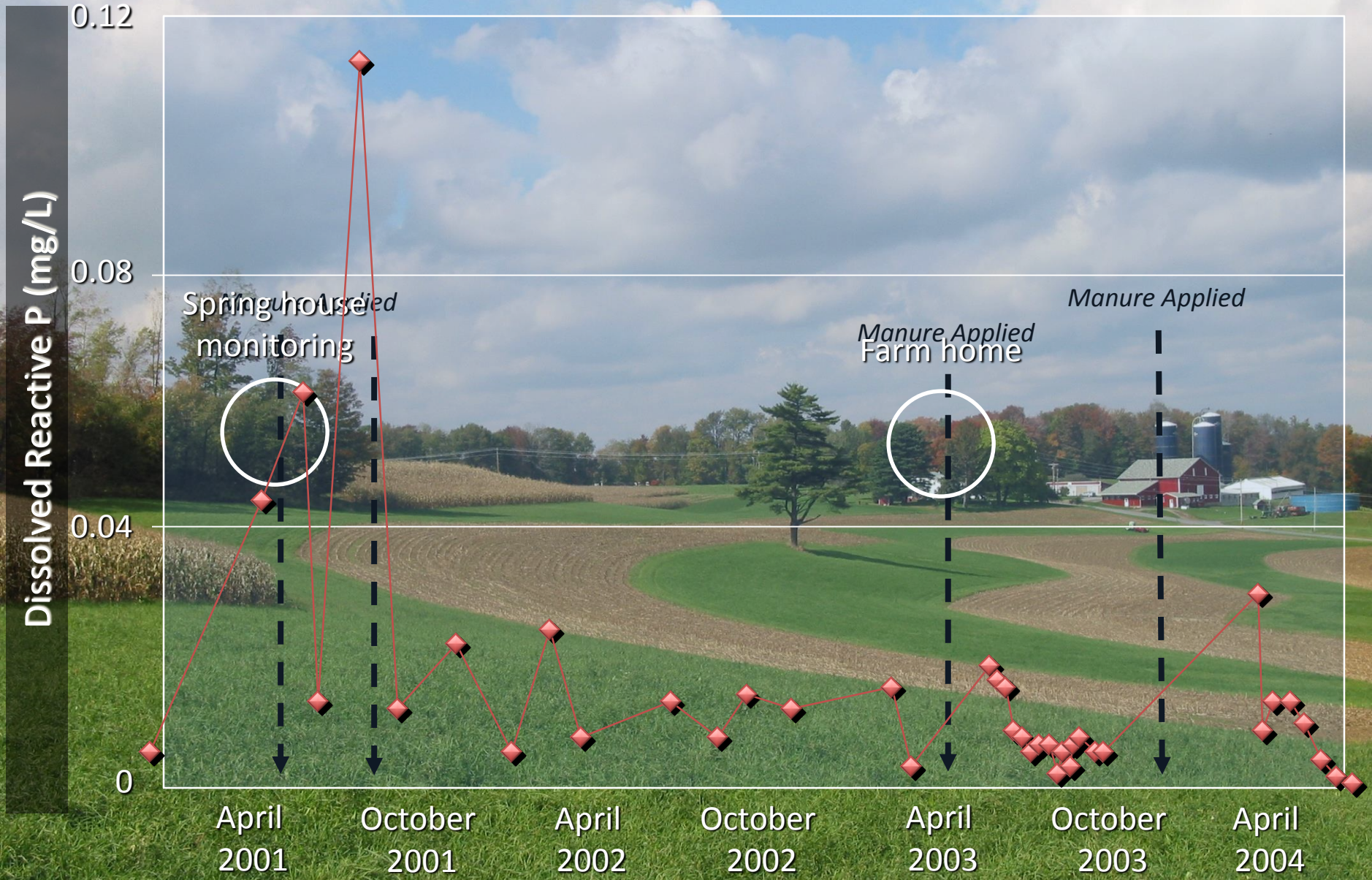


Drainage and soil P

Follow your land grant university recommendations



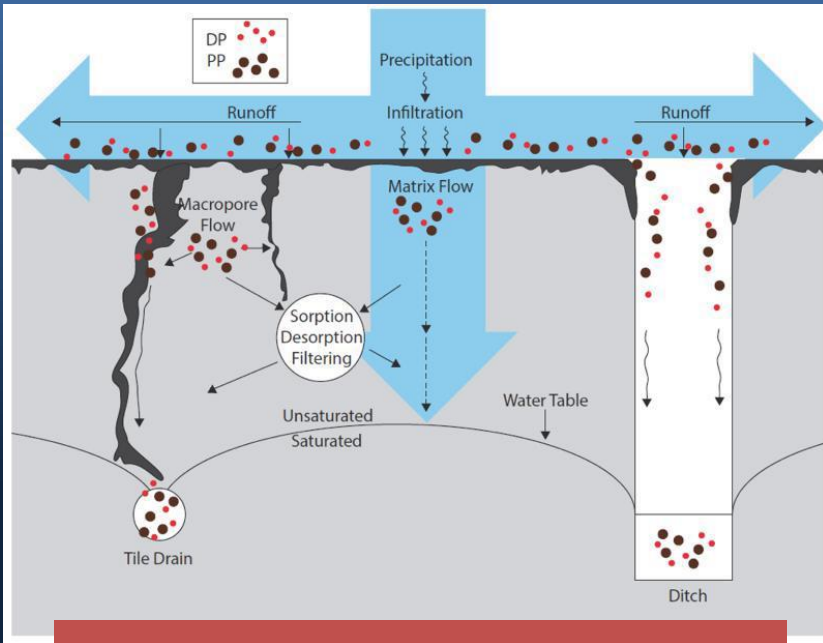
Groundwater P after manure application



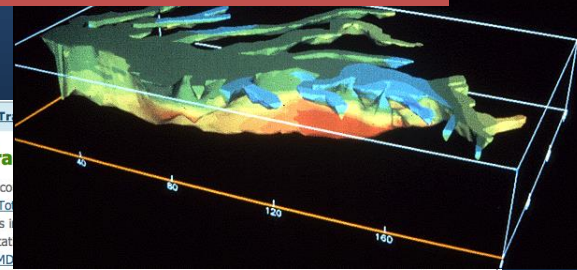
No model gets P in drainage water right

Journal of Environmental Quality, 2015

The Bay Model is not alone. Hopefully version 6.0 will address this.



Idealized model proposed by Radcliffe et al. (2015) after their conclusion



Overview Agriculture TMDL Tr

Chesapeake Bay TMDL Tracking and Accounting

The Chesapeake Bay TMDL Tracking and Accounting System is a public web portal for tracking progress in implementing the Bay Total Maximum Daily Load (TMDL) program. The system tracks the Watershed Model Phase 5.3.0 and tracks the progress of the various jurisdictions' Phase II Watershed Implementation Plans (WIPs) about BayTAS and the terminology of the TMDL program. For more questions about the Bay TMDL, please visit the [Bay TMDL website](#).

States Basins Segments Permitted Facilities

Go to: State, zip, address, etc. Go

Streets Imagery

Manokin River--(MANMH)

Total 2025 Planning Target for Phosphorus: **44,924 lbs/year**

Total Phosphorus 2025 Planning Target by Sector:

- Wastewater
- Agriculture
- Regulated

Download Data

60K
40K
20K
0

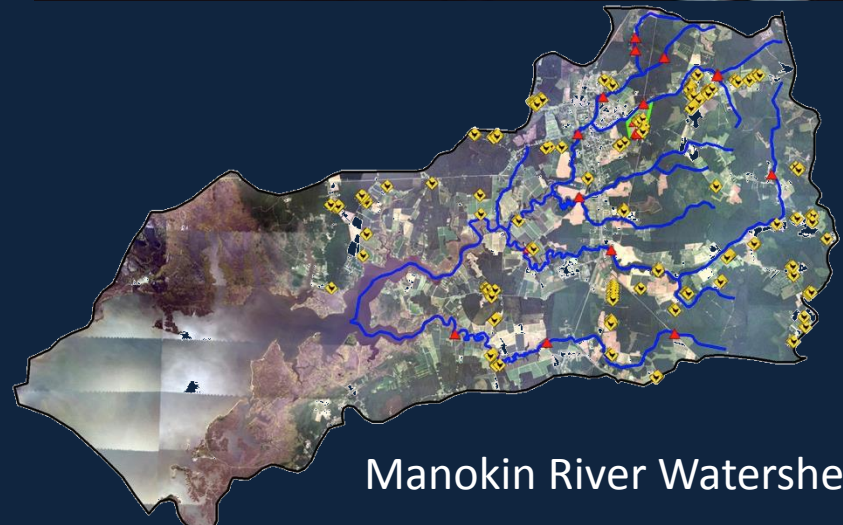
1965 2009 2012 2013 2017 2026

Load Allocation Wasteload Allocation

Loads simulated using 5.3.3 version of Watershed Model and wastewater discharge data reported by Bay Jurisdictions. Progress data updated 3/21/2014.

Legacy P and Artificial Drainage

Delmarva Fresh Chickens:
600 million birds, 800,000 tons
litter



Manokin River Watershed

Legacy P

Intensified and specialized farming systems

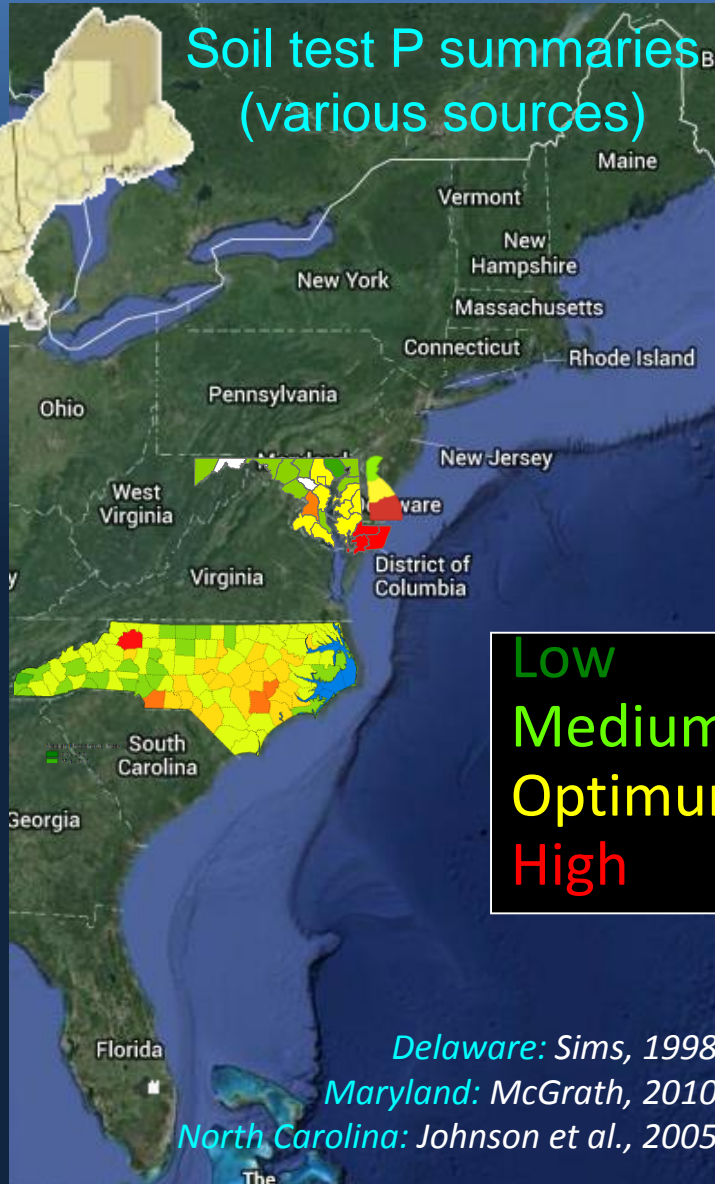
Disconnect between livestock production and soil P fertility objectives

County P balances
(Ag Census)



Maguire et al.: J. Environ. Qual., 2008

Soil test P summaries
(various sources)



Low
Medium
Optimum
High

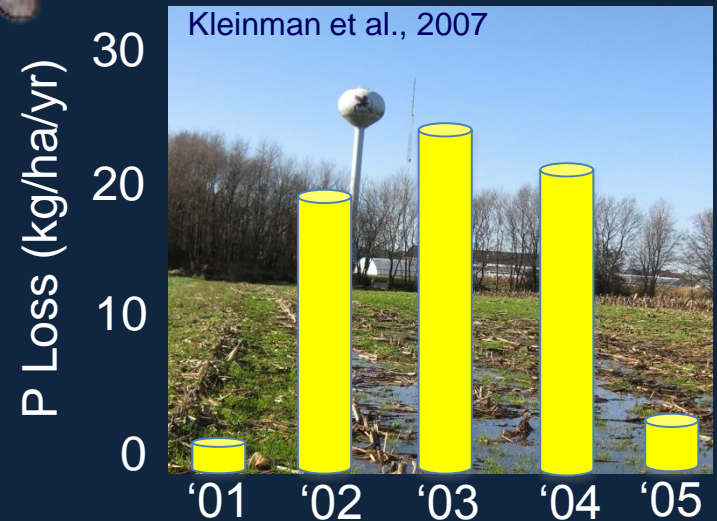
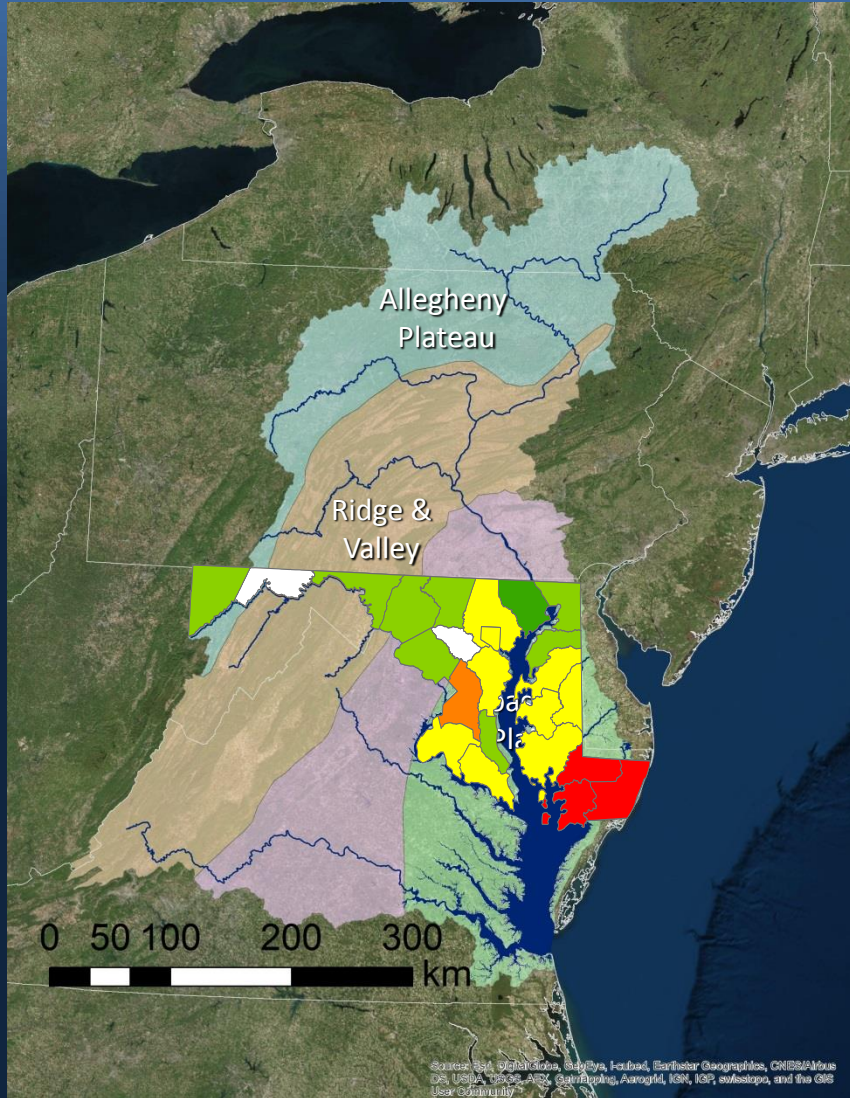
Delaware: Sims, 1998
Maryland: McGrath, 2010
North Carolina: Johnson et al., 2005



Sims et al.: J. Environ. Qual., 1998

Open ditches and legacy P

Manokin River Watershed



Univ. Md. East. Shore Ditches

Drainage ditch monitoring network

Field ditch

1 m deep

2 ha catchment



H Flume on
Field Ditch

Collection ditch

2.5 m deep

17 ha catchment

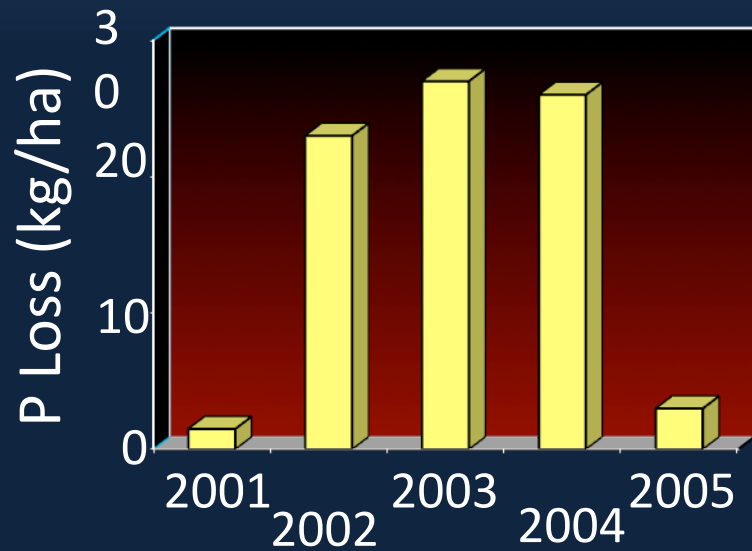
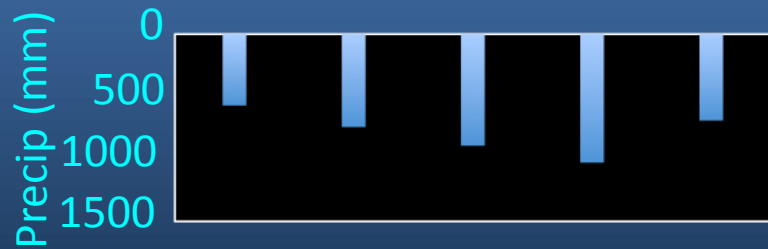


V-Notch Weir on
Public Drainage Association Ditch

Drainage Ditches

Connect legacy P sources with streams

Flashy - drainage fluctuations can be enormous



Kleinman et al., 2007 (J. Soil and Water Conserv.)

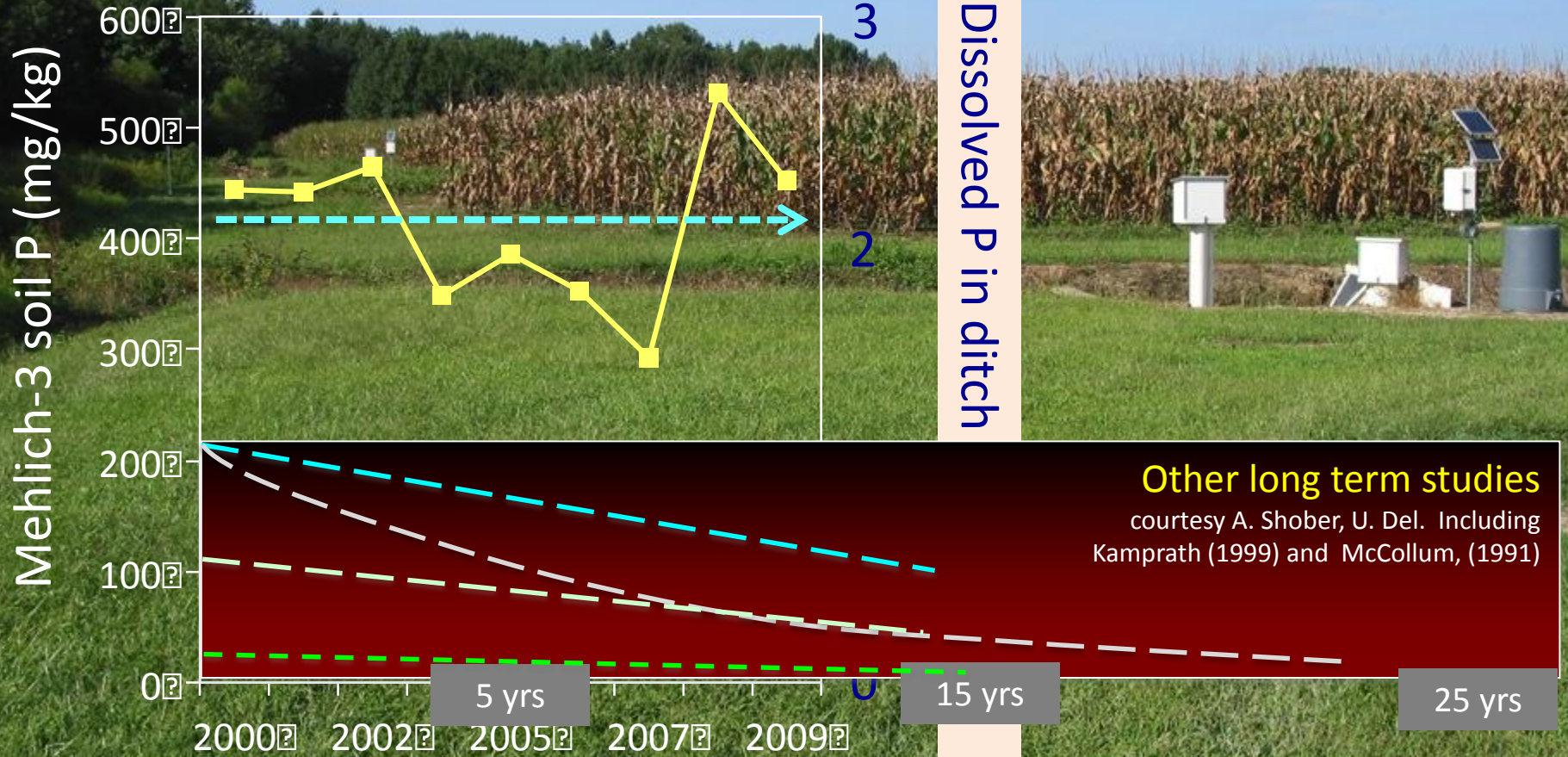
Phosphorus loss in ditch drainage

Greatest risk is in the near-ditch zone (within 5-10 m)



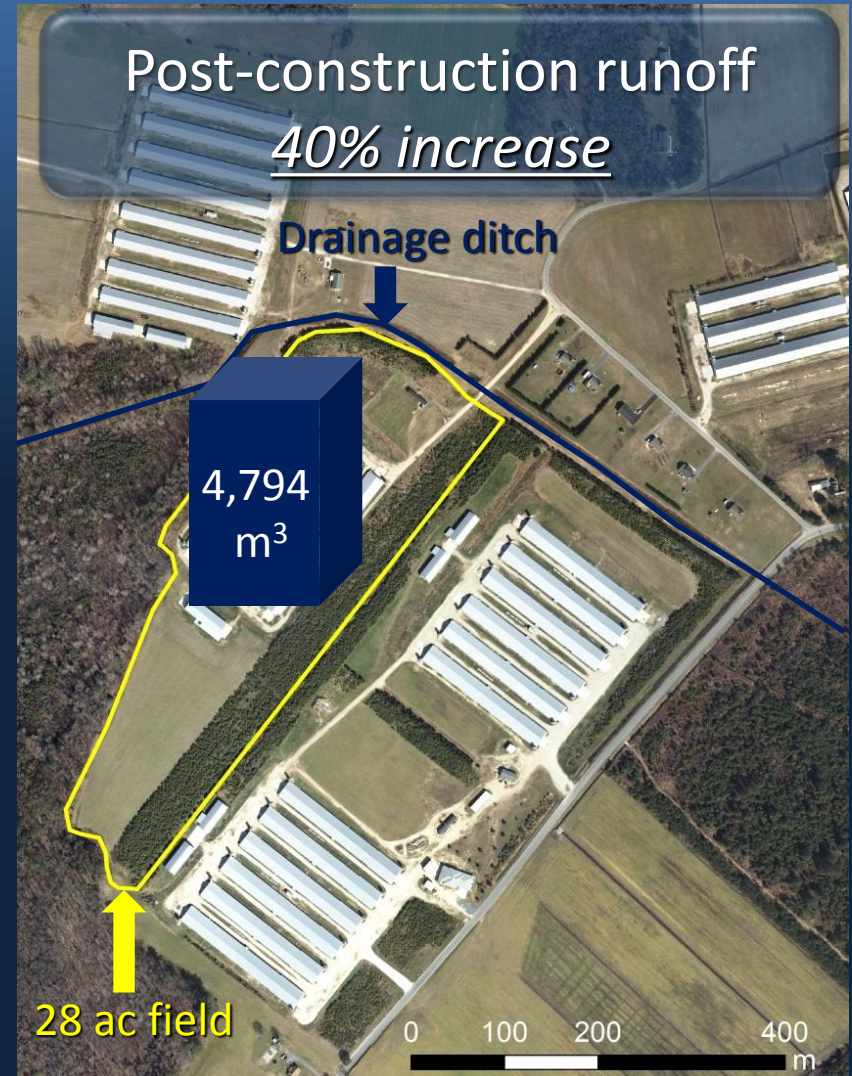
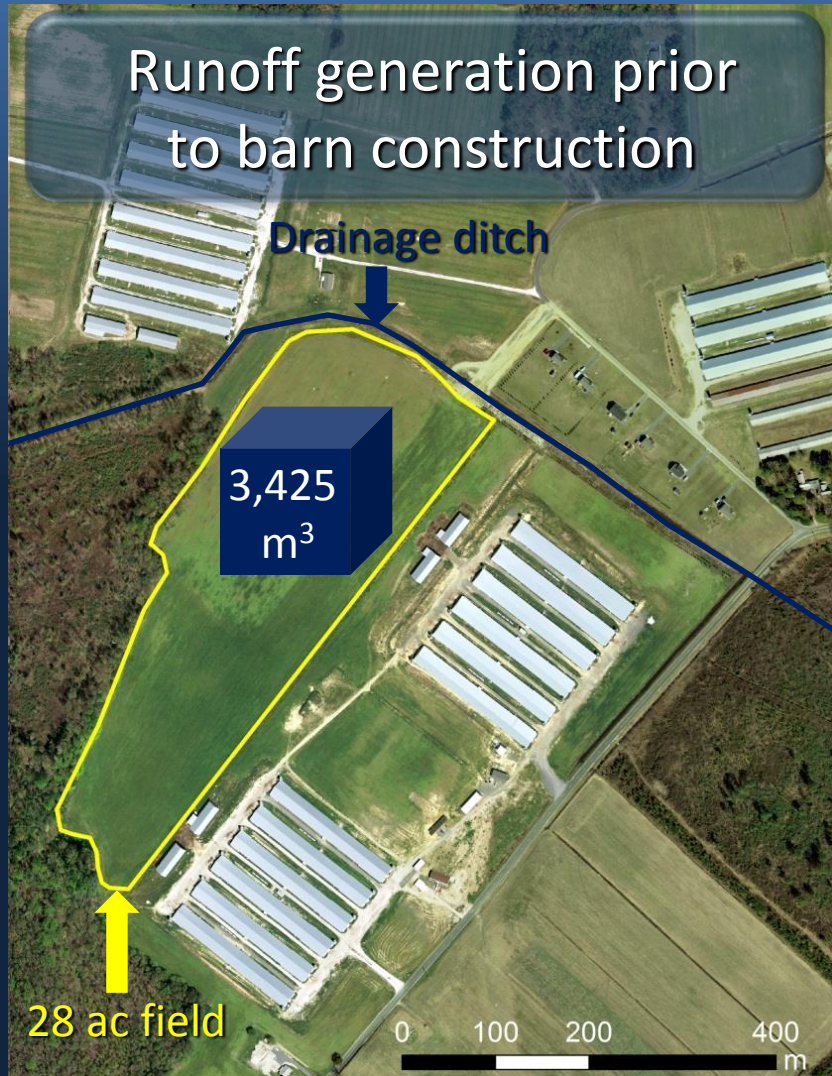
“Mining” legacy P

No change after one decade



The “zero acre” farm

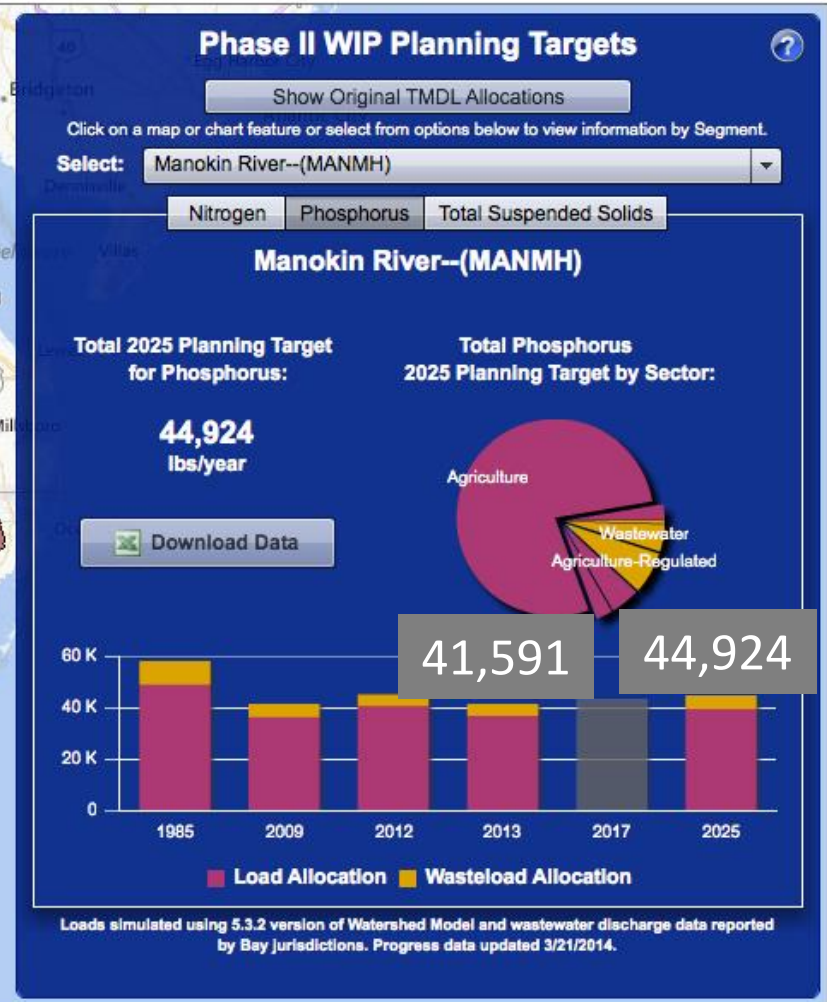
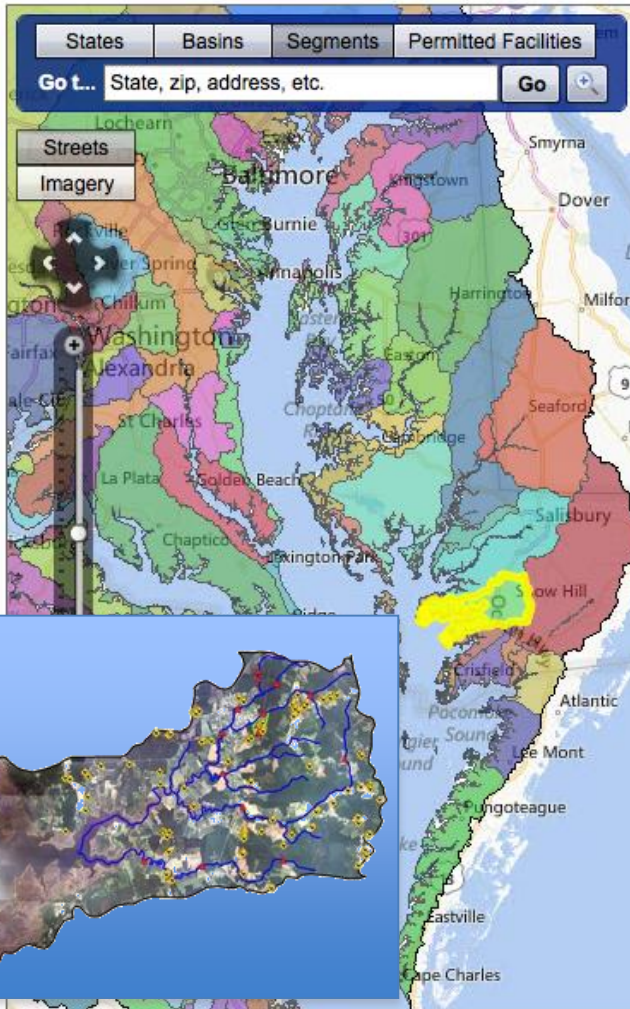
Routing storm water through legacy P sources



Manokin River Modeling and monitoring

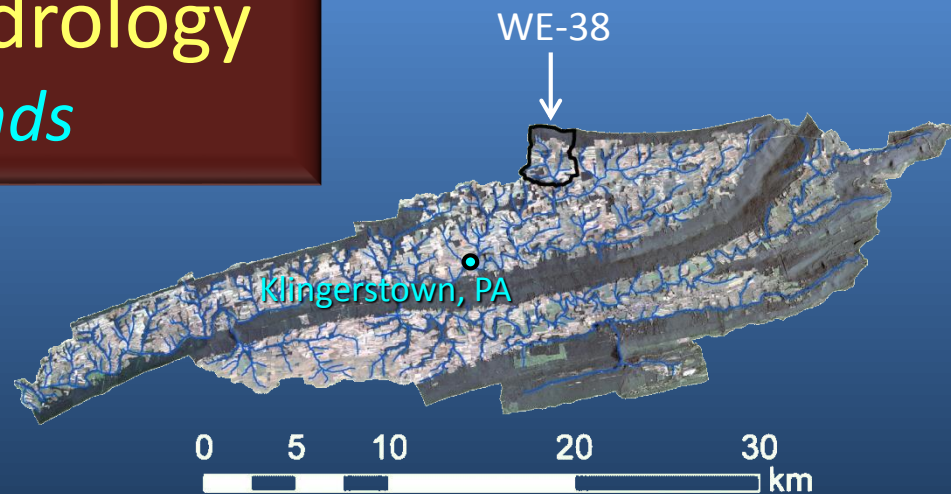
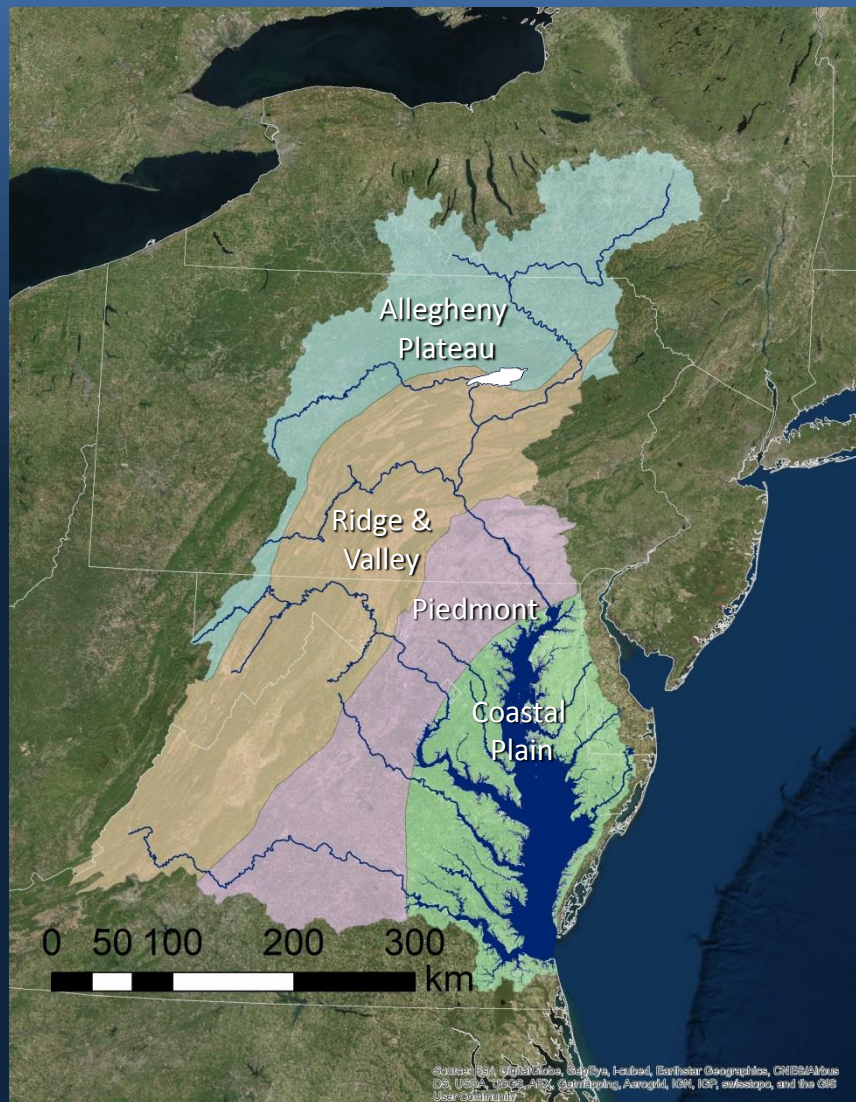
Bay TMDL Tracking and Accounting System

The Bay TMDL Tracking and Accounting System (BayTAS) was developed to inform EPA, the Bay Jurisdictions, and the public in implementing the [Bay Total Maximum Daily Load \(Bay TMDL\)](#). BayTAS stores the TMDL allocations (based on the Watershed Model Phase 5.3.0 and tracks implementation progress (based on the Watershed Model Phase 5.3.2 and the jurisdictions' Phase II Watershed Implementation Plans (WIPs)). BayTAS data are displayed through the TMDL Tracker. [Learn more about BayTAS](#) and the [terminology of the TMDL](#) in the glossary found in Section 13 of the TMDL. Get answers to [frequently asked questions](#) about the Bay TMDL.



Variable source area hydrology

Chesapeake Bay uplands



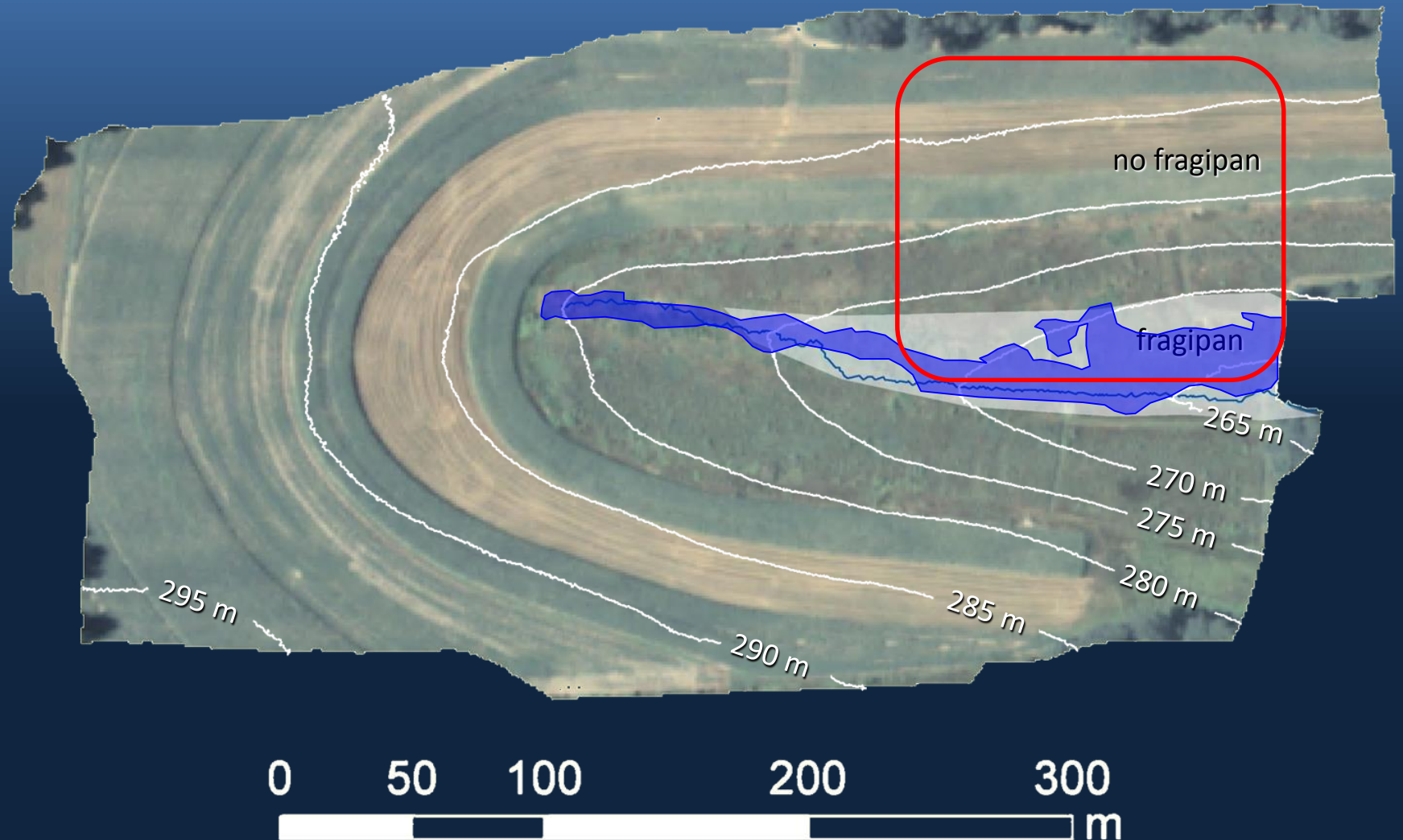
WE-38 Watershed (7.3 km²)

Mattern
(11 ha)



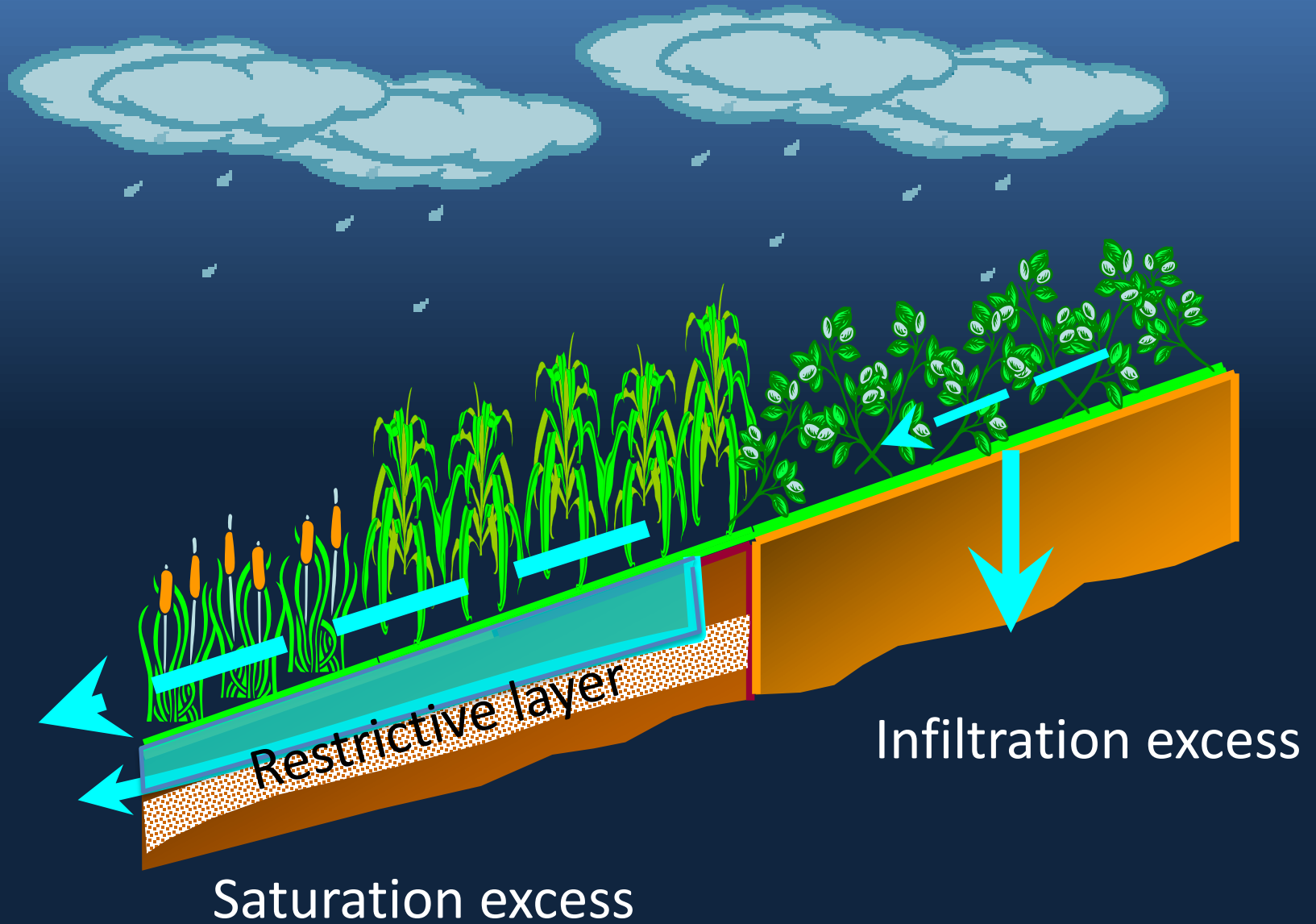
Fragipan soils and zones of saturation

Late October 2003



Surface runoff generation

Saturation vs. Infiltration excess



Fragipan soils enhance surface runoff generation

Infiltration excess
Saturation excess

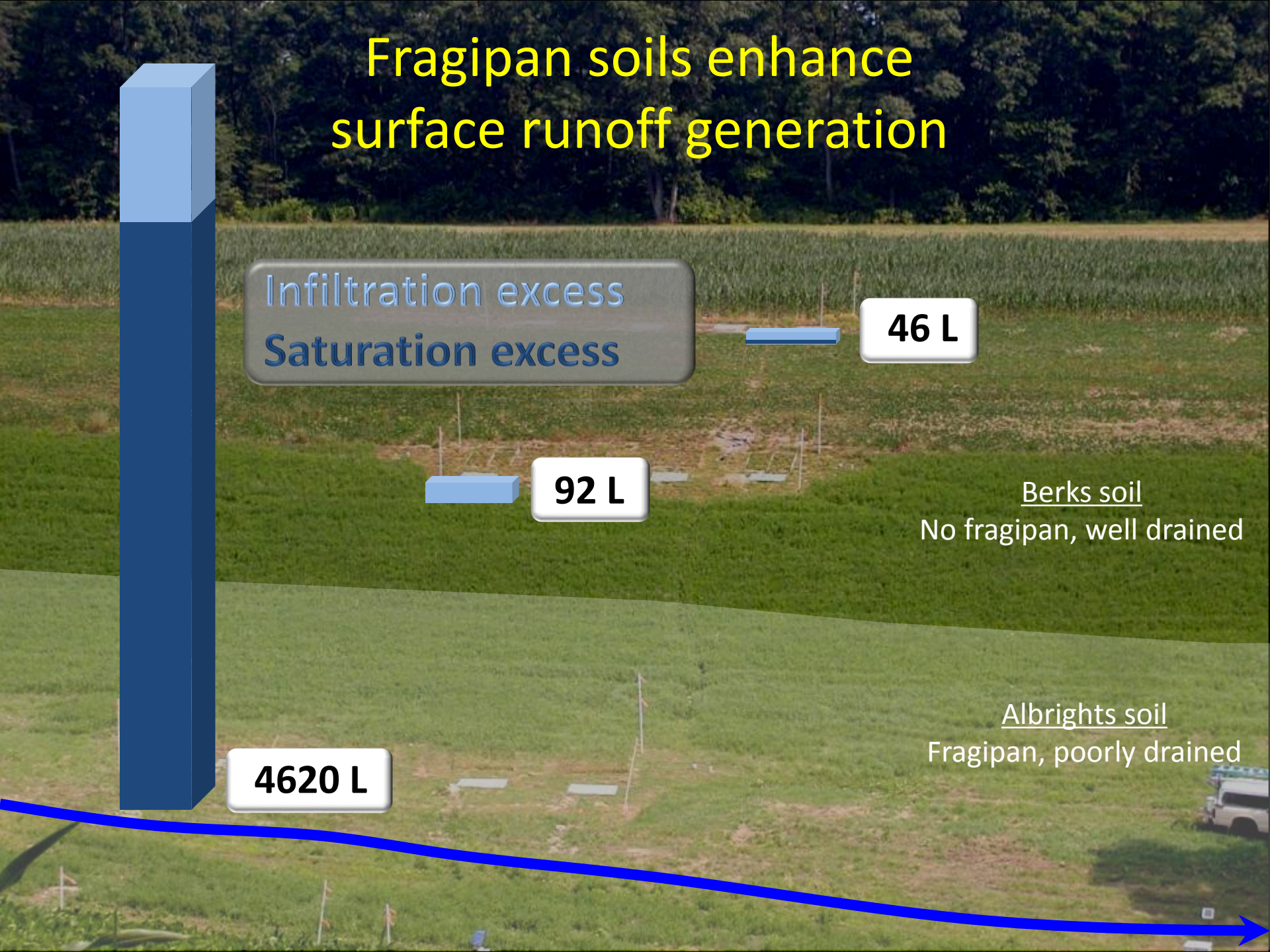
46 L

92 L

4620 L

Berks soil
No fragipan, well drained

Albrights soil
Fragipan, poorly drained



which can lead to large phosphorus (P) losses,
even from modest sources

Total P

6 kg/ha/yr

1 kg/ha/yr

<1 kg/ha/yr

Soil test P
177 mg/kg

Soil test P
144 mg/kg

Soil test P
78 mg/kg

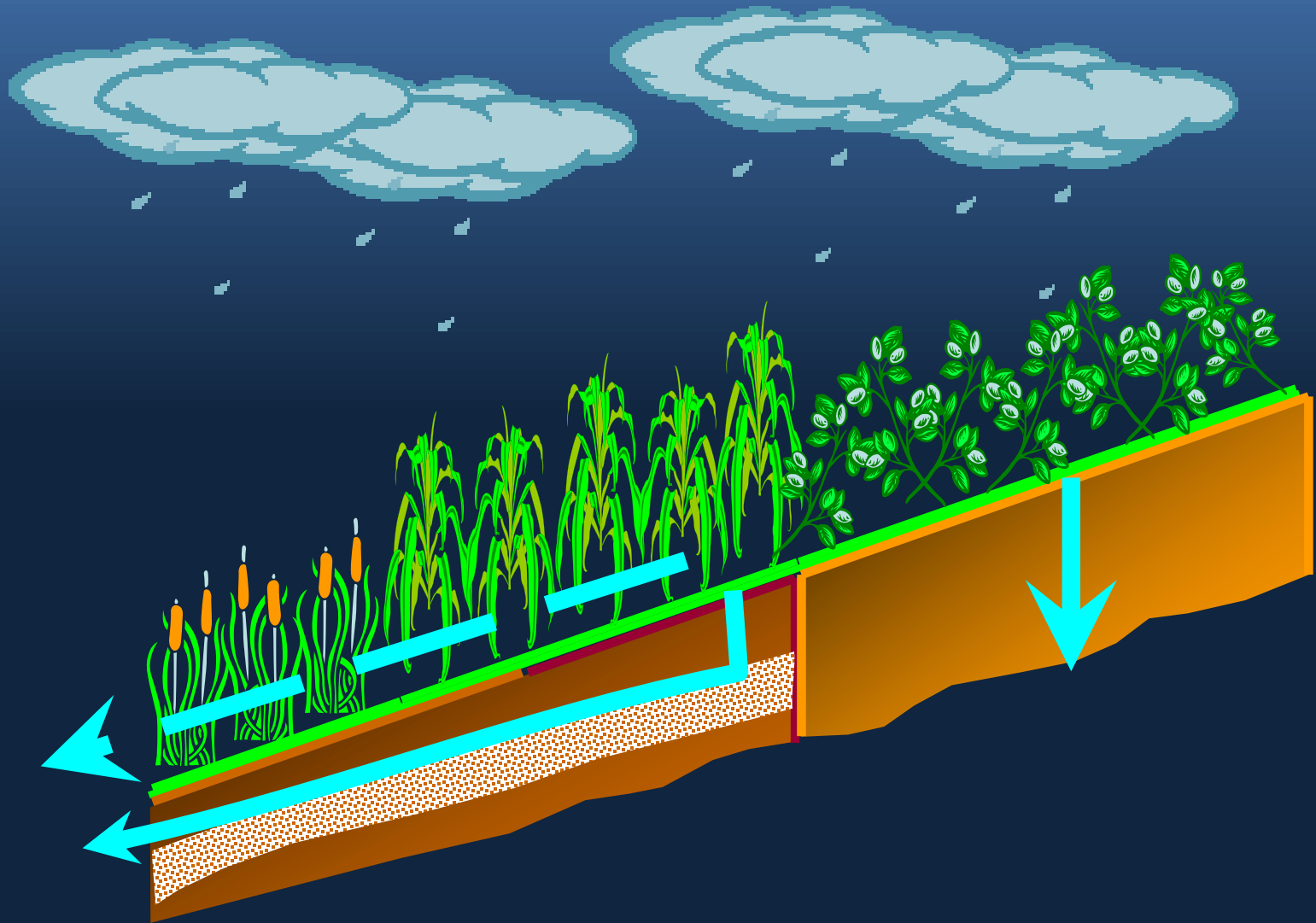
Berks soil
No fragipan, well drained

Albrights soil
Fragipan, poorly drained



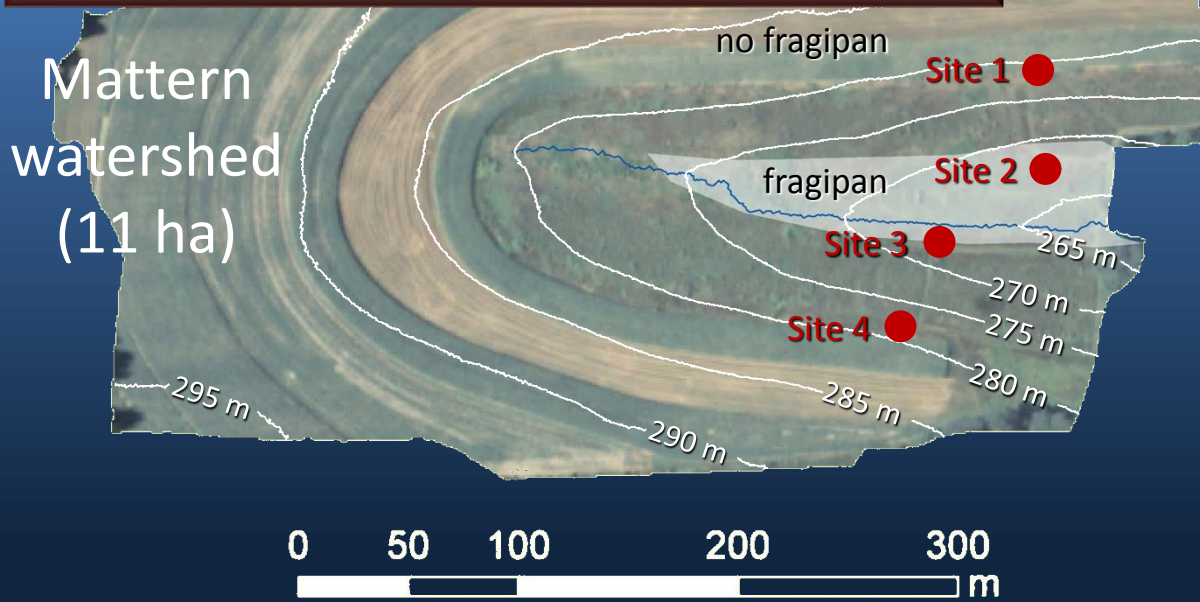
Subsurface P transport in sloping landscapes

An often overlooked pathway



Hillslope monitoring

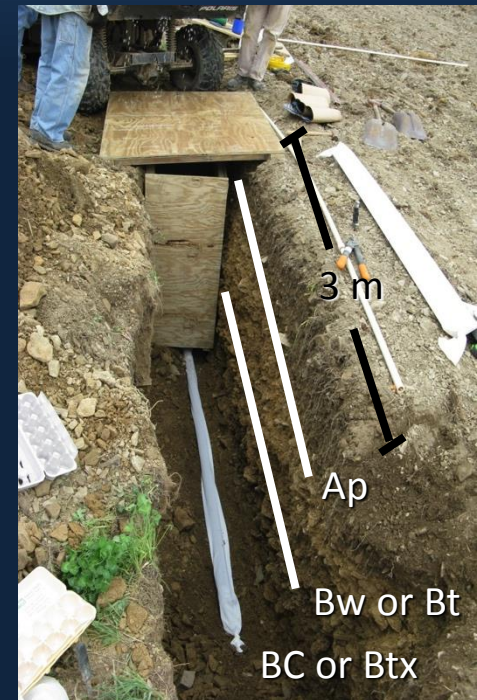
Surface and subsurface flow



Overland flow



Subsurface flow



Average P concentrations (mg/L)

Tropical storm Lee (Sept. 4-10, 2011)

1.2 mg L⁻¹ PP

DP

Site 1 - seepage slope
Soil P = 177 mg kg⁻¹

no fragipan

0.18 mg L⁻¹

fragipan

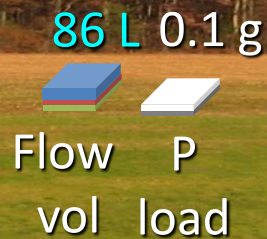
Site 2 - foot slope
Soil P = 72 mg kg⁻¹

P loads (g) – dominated by flow

Tropical storm Lee (Sept. 4-10, 2011)

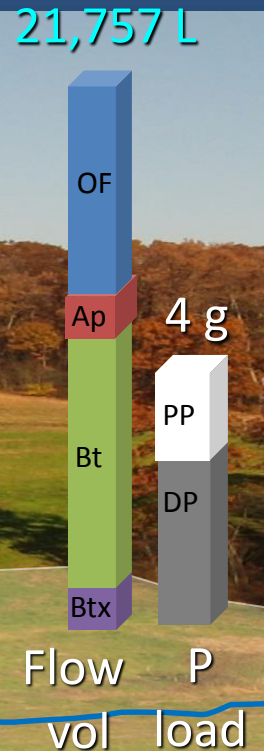
Site 1 - seepage slope
Soil P = 177 mg kg⁻¹

no fragipan



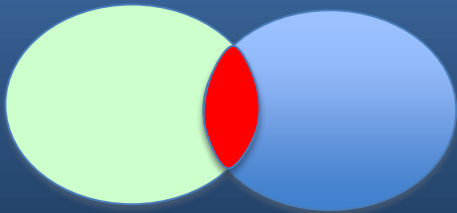
Site 2 - foot slope
Soil P = 72 mg kg⁻¹

fragipan



Management

All of the above, sooner rather than later



Manure management



- Placement* *Close contact with soil minimizes P in drainage water. Applying 1-2 m away from drains avoids bypass. Tillage effects are mixed (especially fine textured soils)*
- Timing* *Avoid periods before storm events and when soils are wet (can't store liquid manures) or dry (and cracked)*
- Rate* *Keep application rates as low as possible*
- Form* *Liquid manures, amendments to reduce P solubility*

peter.kleinman@ars.usda.gov

