Water Quality Performance of Wetlands Receiving NPS Loads

Nitrate Removal Efficiency and Load Reductions Using Targeted Wetland Restorations in the Upper Mississippi River Basin

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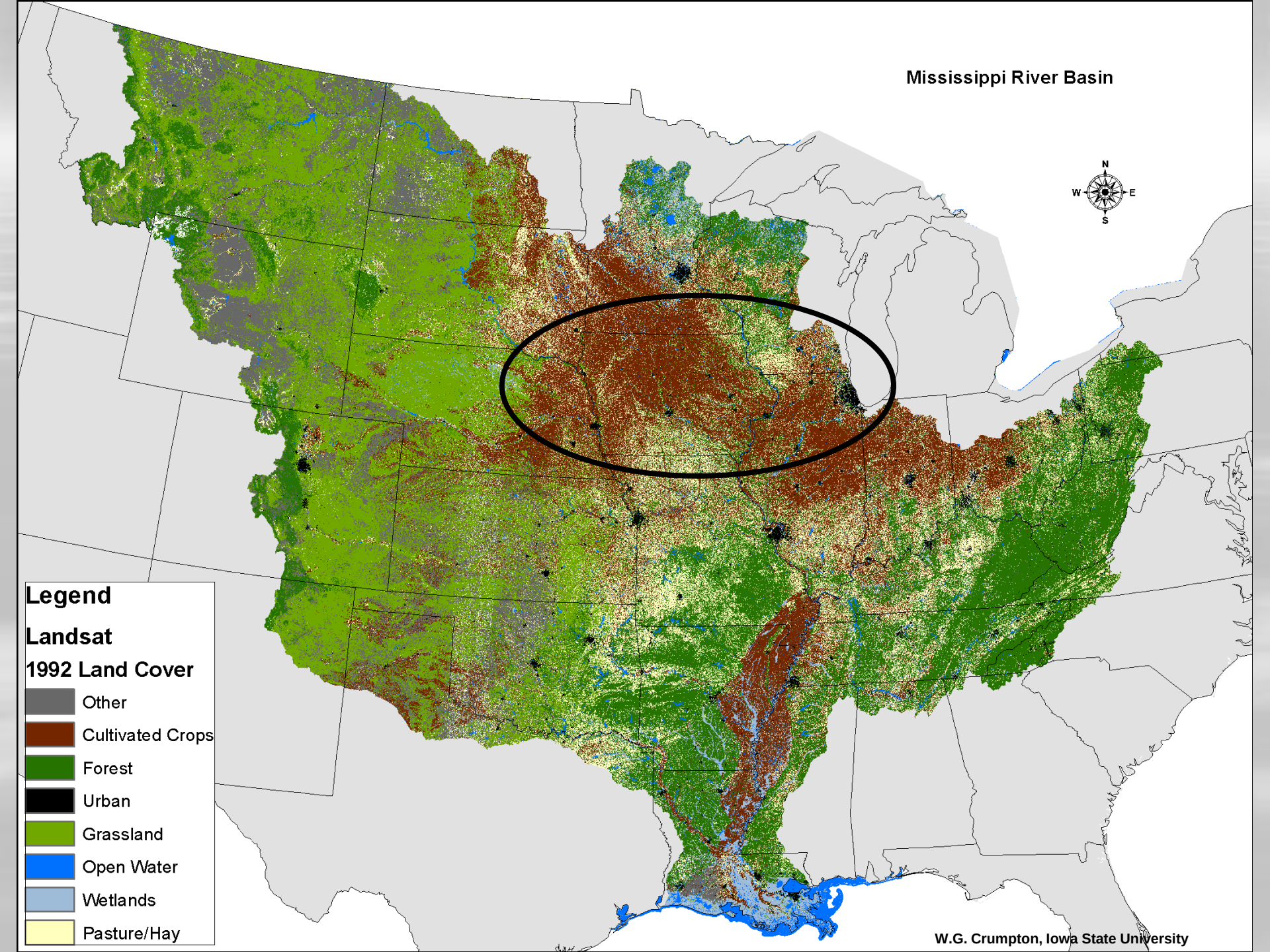
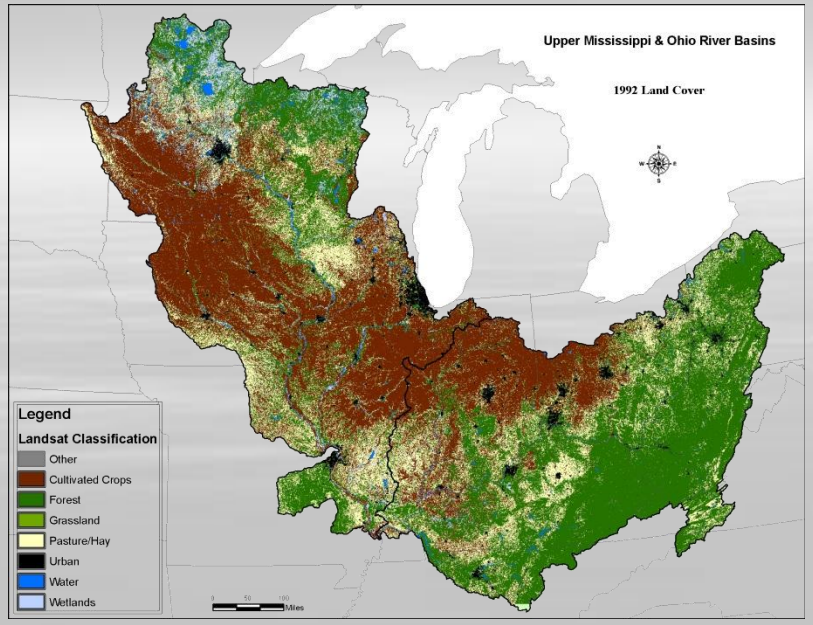

Mississippi River Basin
N
W
E
S
Legend
Landsat
1992 Land Cover
Other
Cultivated Crops
Forest
Urban
Grassland
Open Water
Wetlands
Pasture/Hay
W.G. Crumpton, Iowa State University



Upper Mississippi Basin

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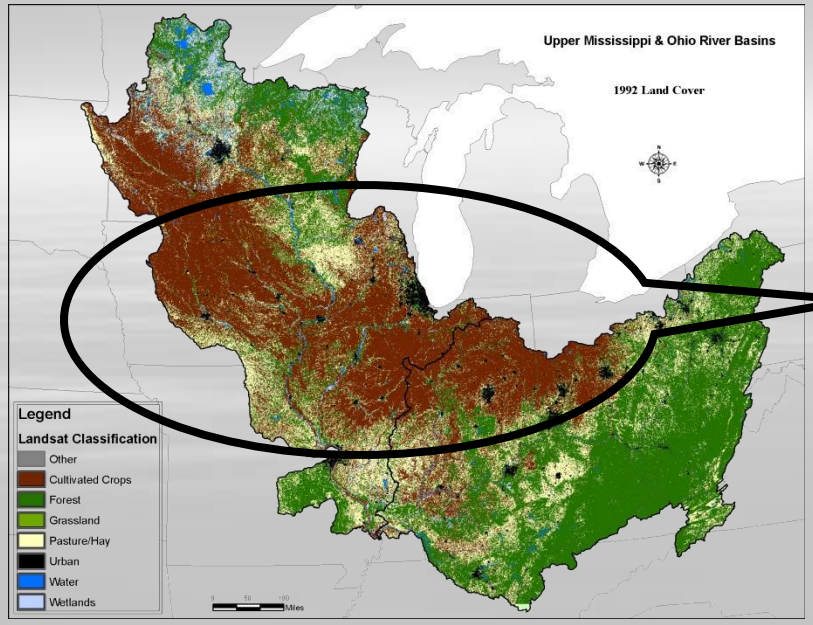
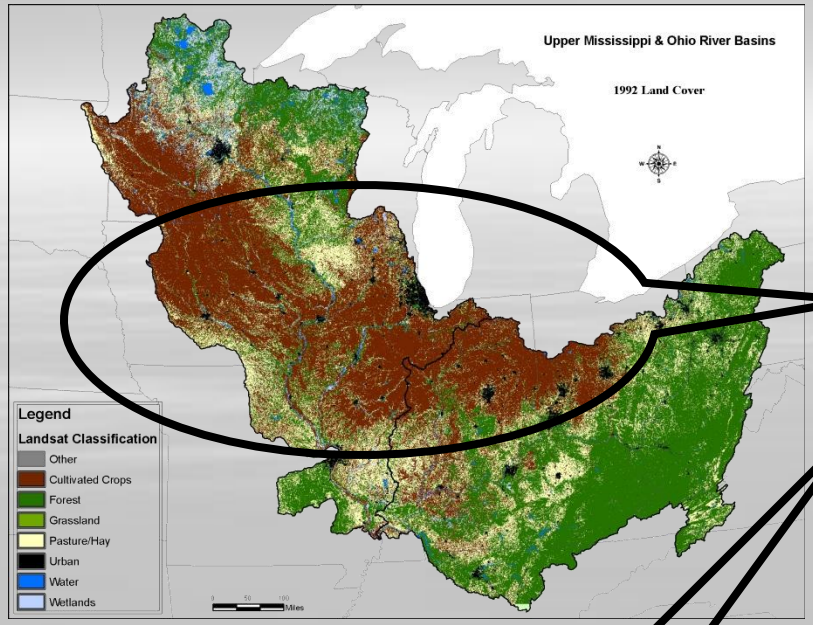
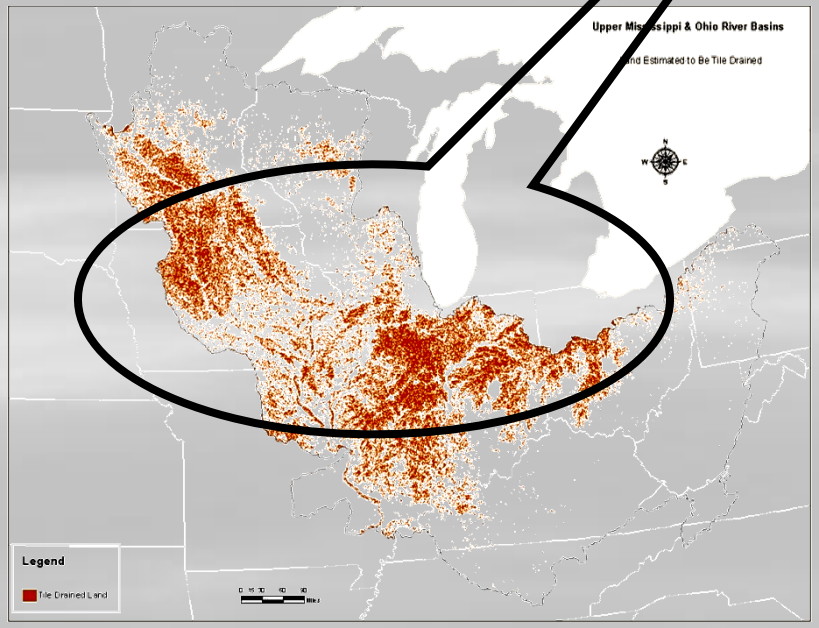


Upper Mississippi Basin is characterized by:

- extensive cultivated cropland





Upper Mississippi Basin is characterized by:

- extensive cultivated cropland
- extensive agricultural drainage

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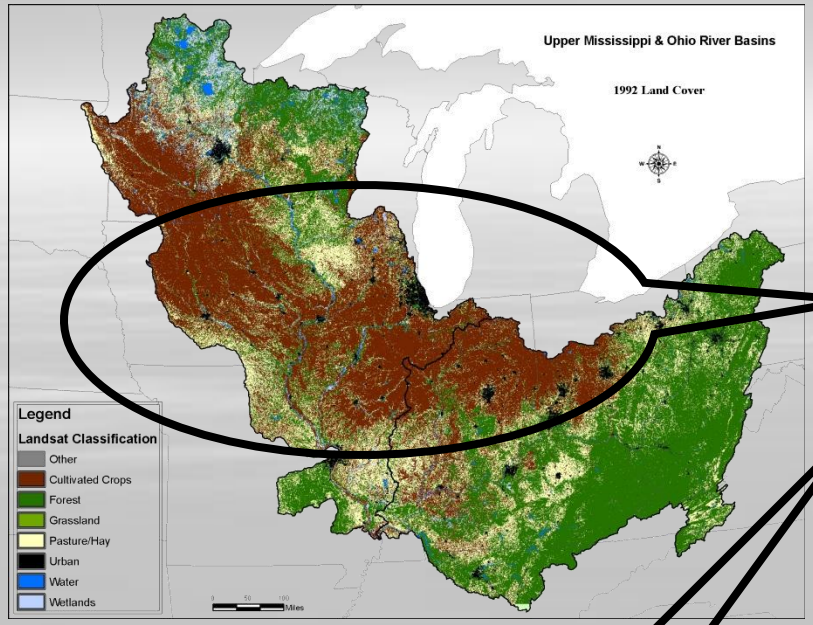
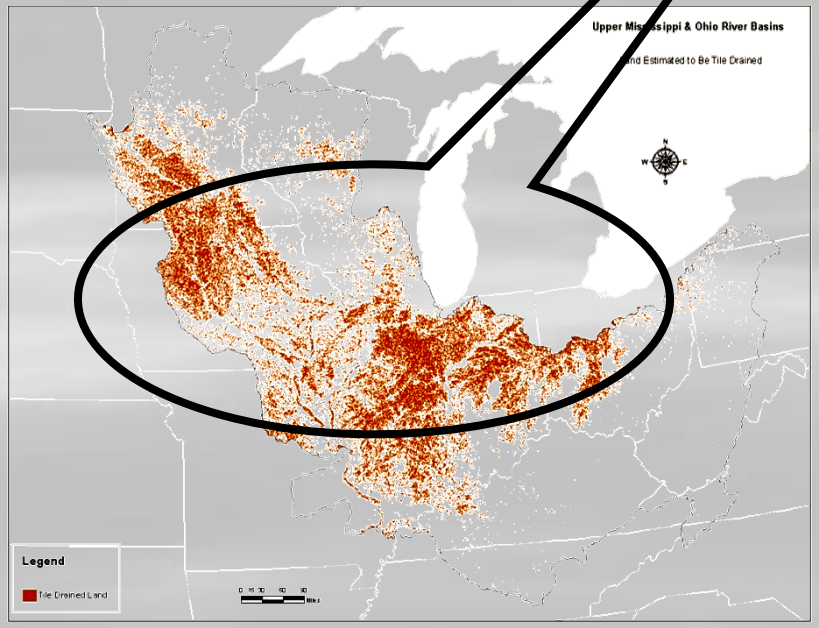
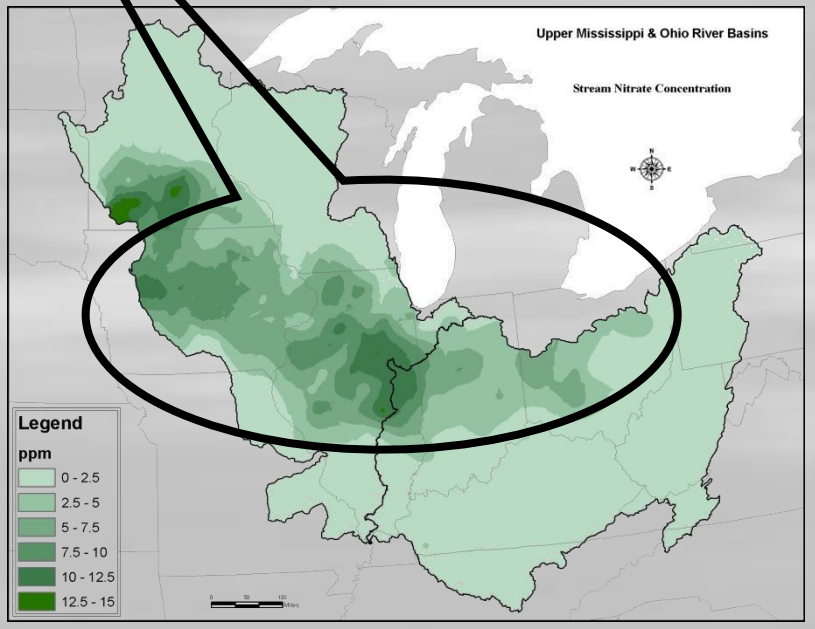
Upper Mississippi Basin is characterized by:

- extensive cultivated cropland
- extensive agricultural drainage
- elevated nitrate concentrations in surface waters







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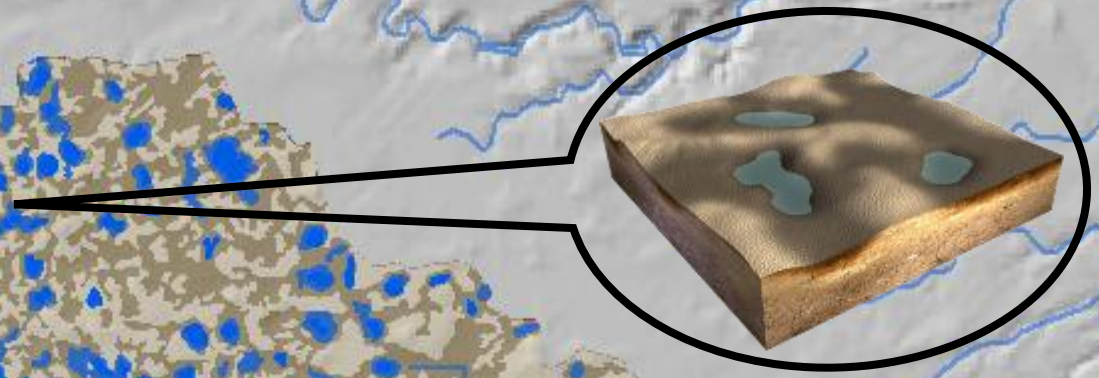
These landscapes were once characterized by extensive wetland systems



Legend

Soils by Landscape Position

- Upland Non-hydric
- Upland Depression
- Upland Swale
- Lowland Drainageway

0 0.5 1 Miles

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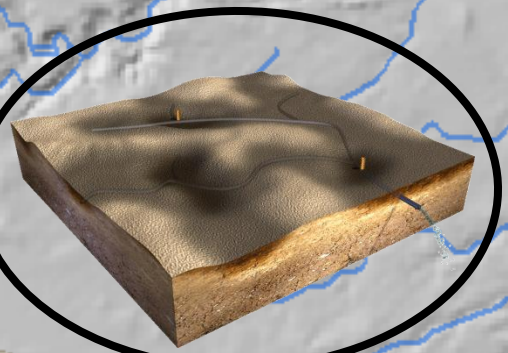
Today these landscapes are characterized by extensive subsurface tile drainage



Legend

Soils by Landscape Position

- Upland Non-hydric
- Upland Depression
- Upland Swale
- Lowland Drainageway
- Tile

0 0.5 1 Miles

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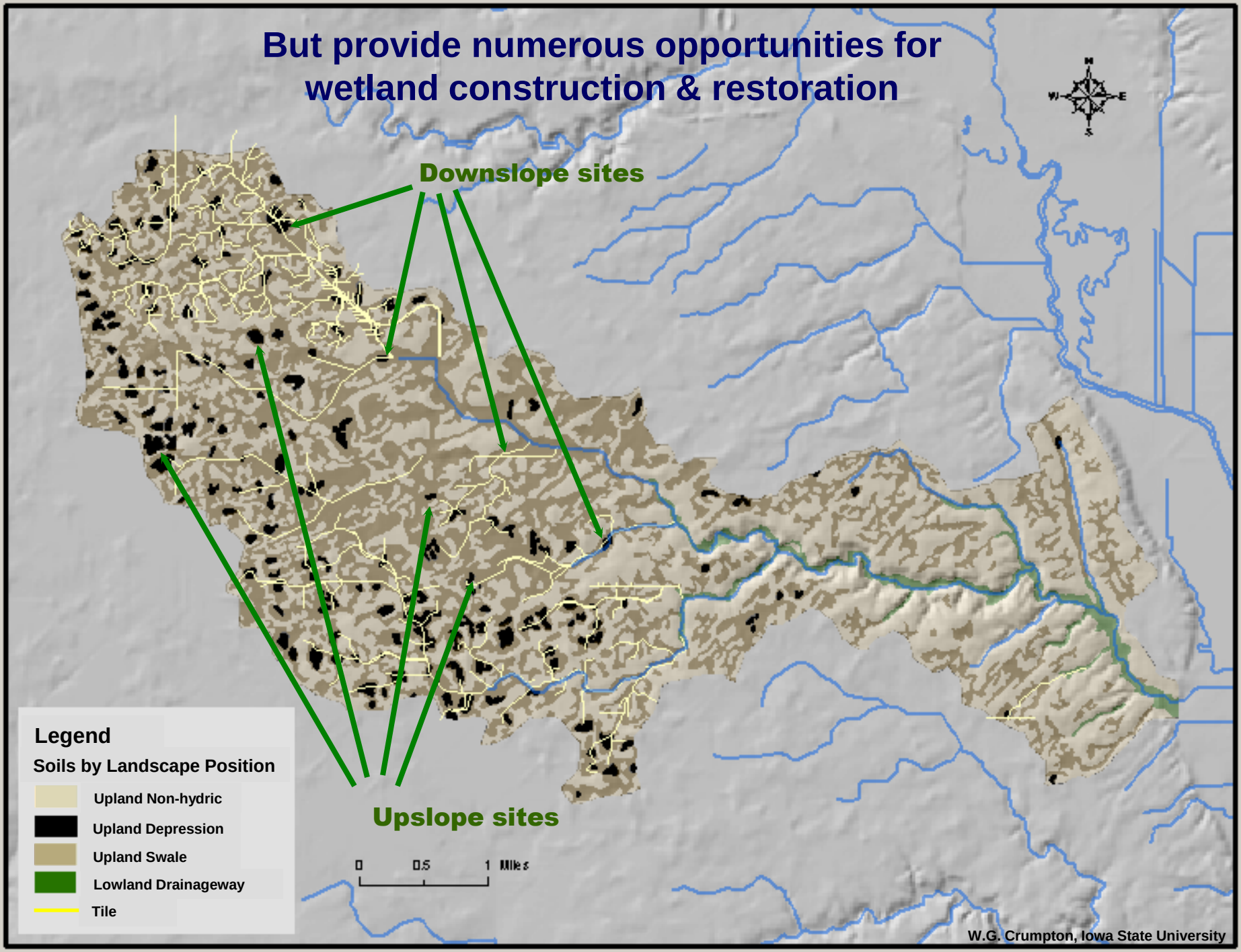
But provide numerous opportunities for wetland construction & restoration



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Restoring Wetlands as N Sinks in Agricultural Watersheds

- N transformation and transport in agricultural landscapes
- N transformation in wetlands receiving NPS loads
- N removal performance of wetlands receiving NPS loads
- Targeting wetland restorations to reduce NPS N loads

W.G. Crumpton, Iowa State University

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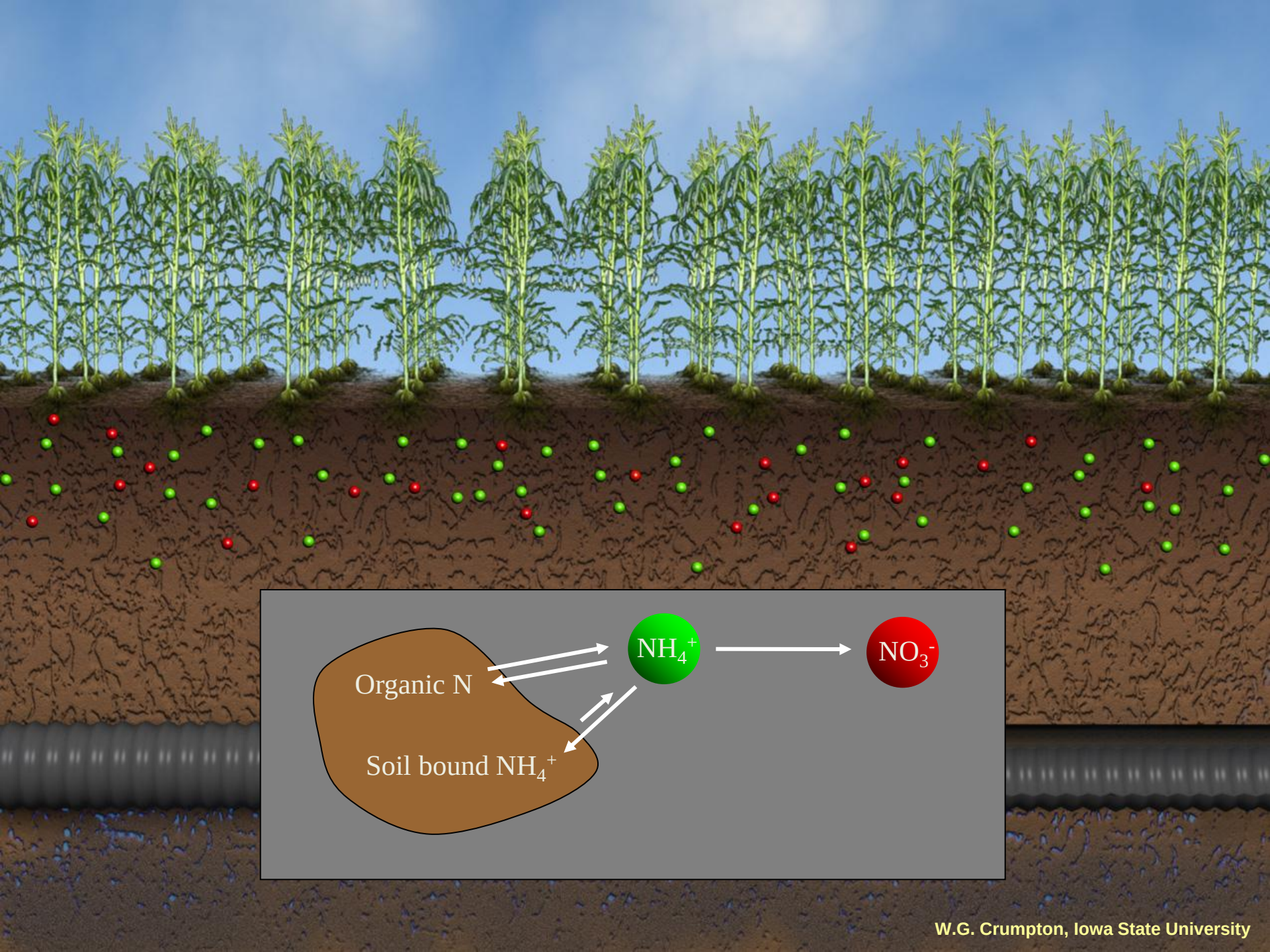
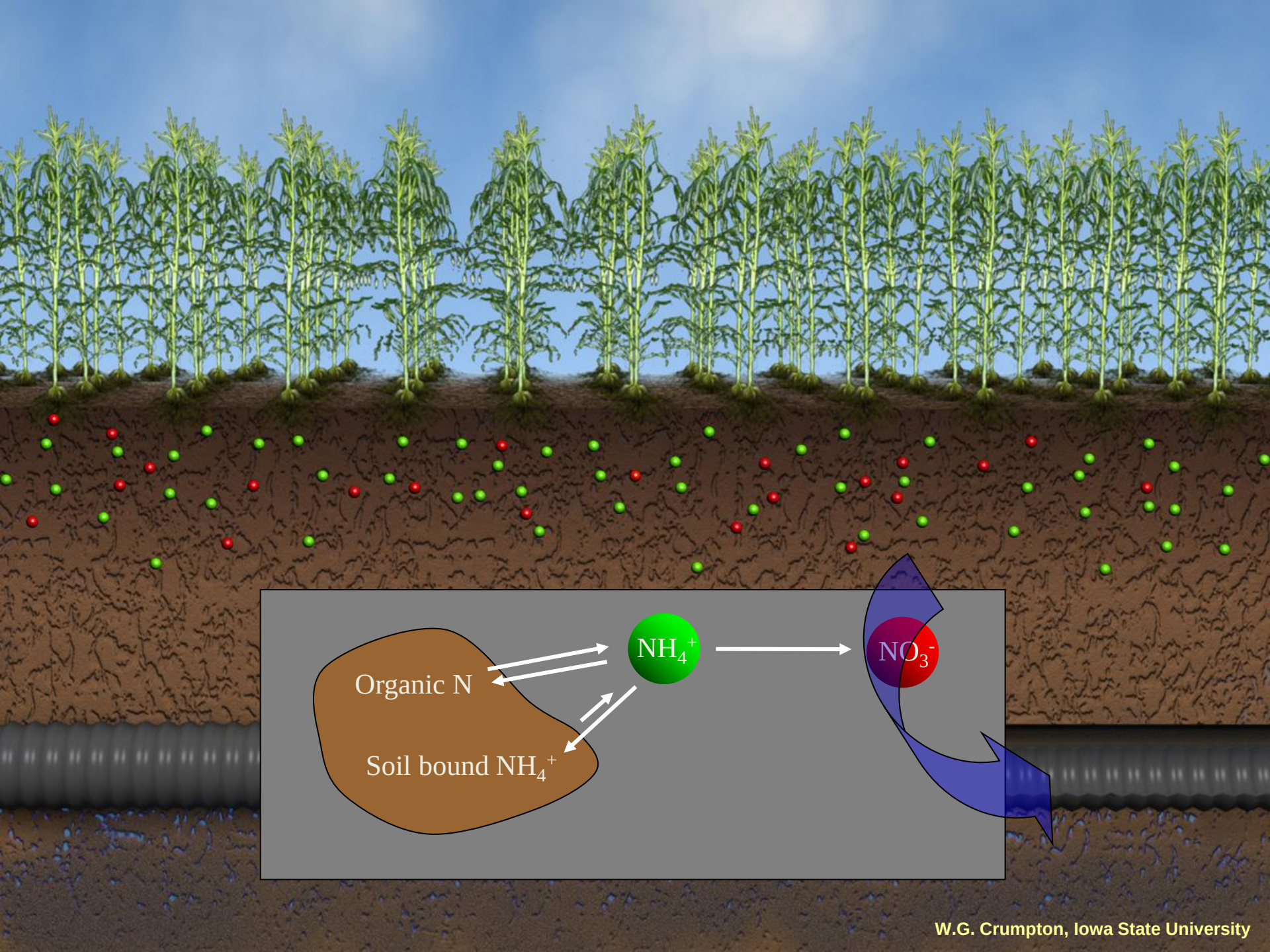
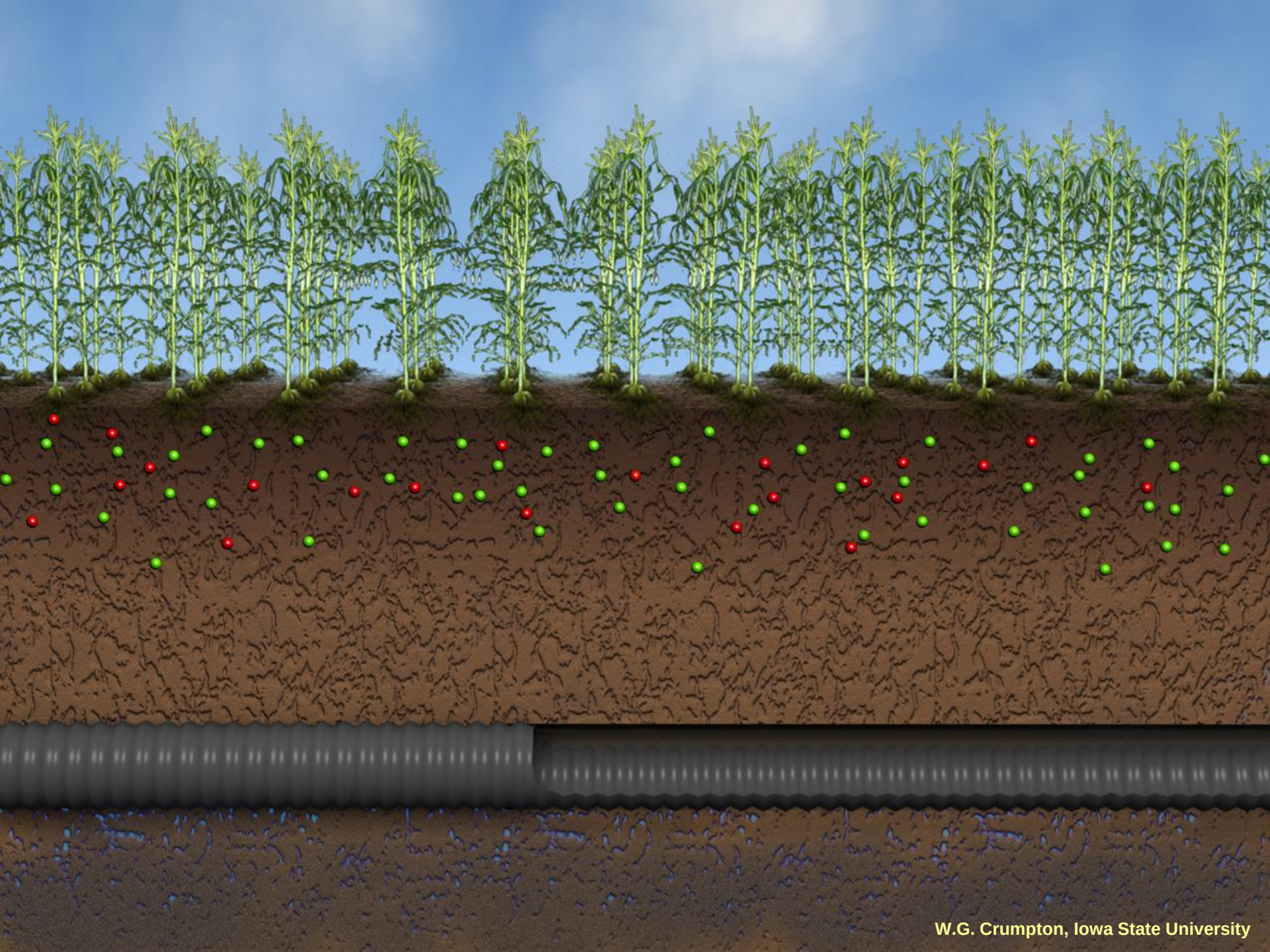
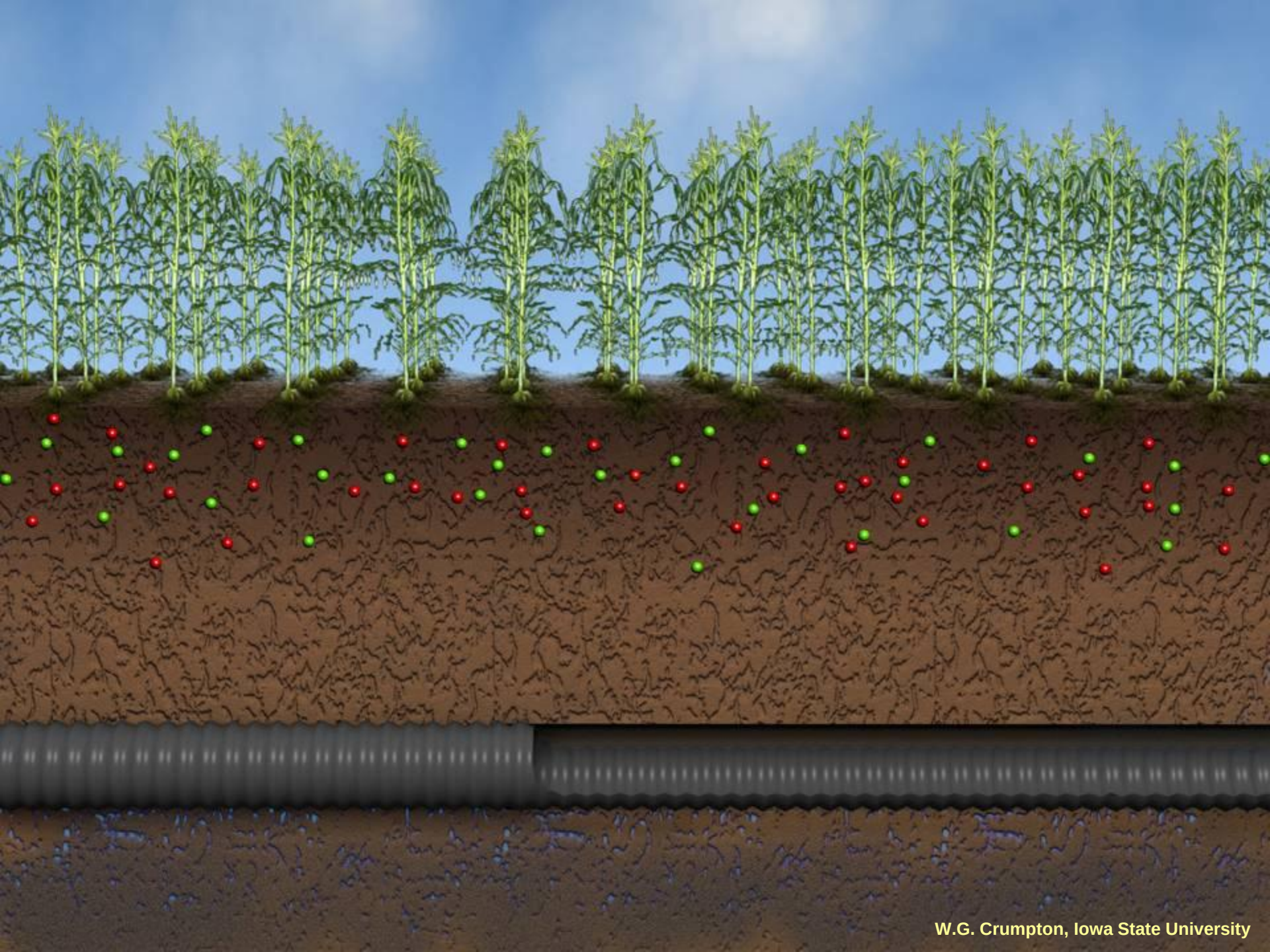


W.G. Crumpton, Iowa State University

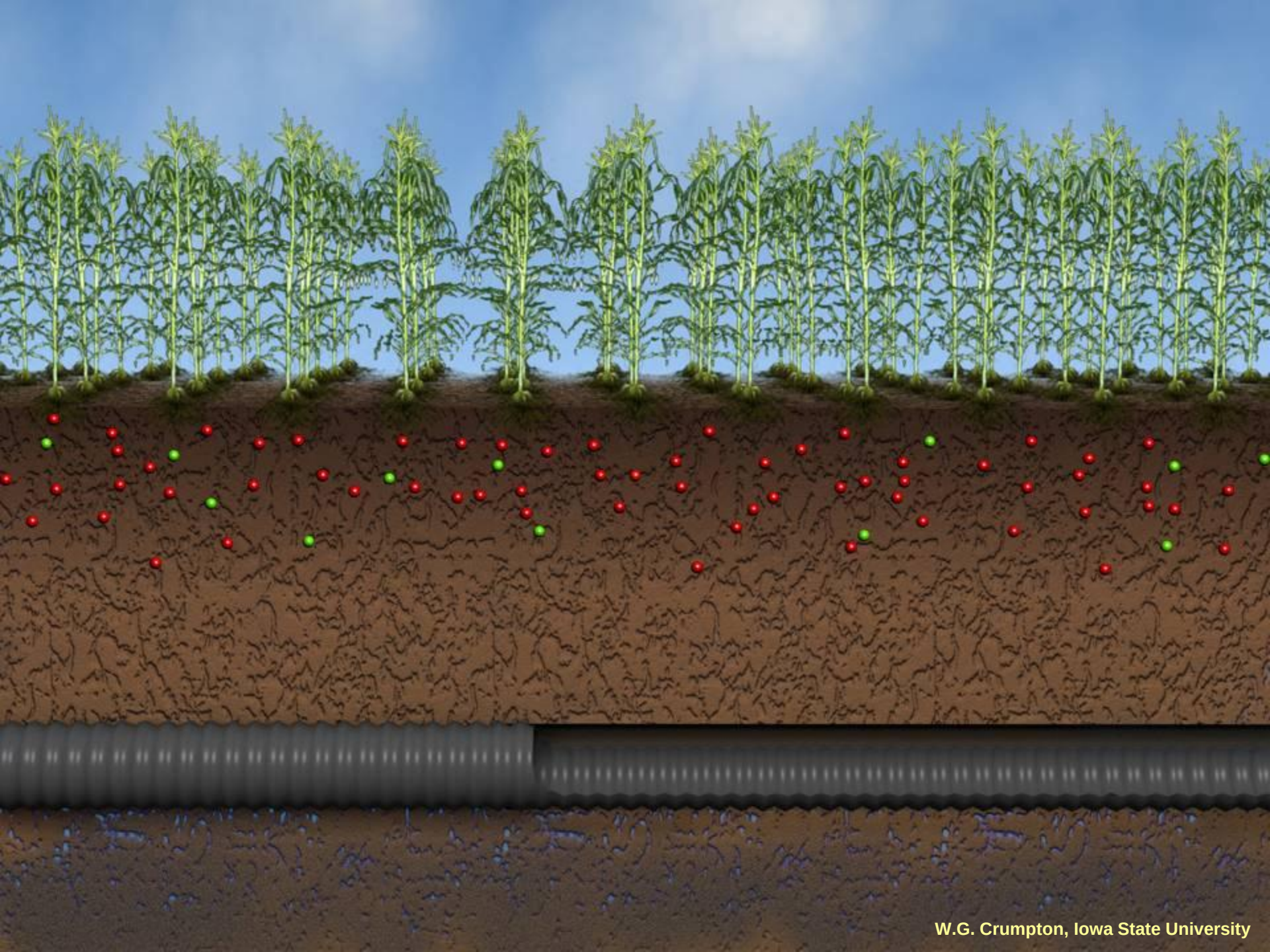


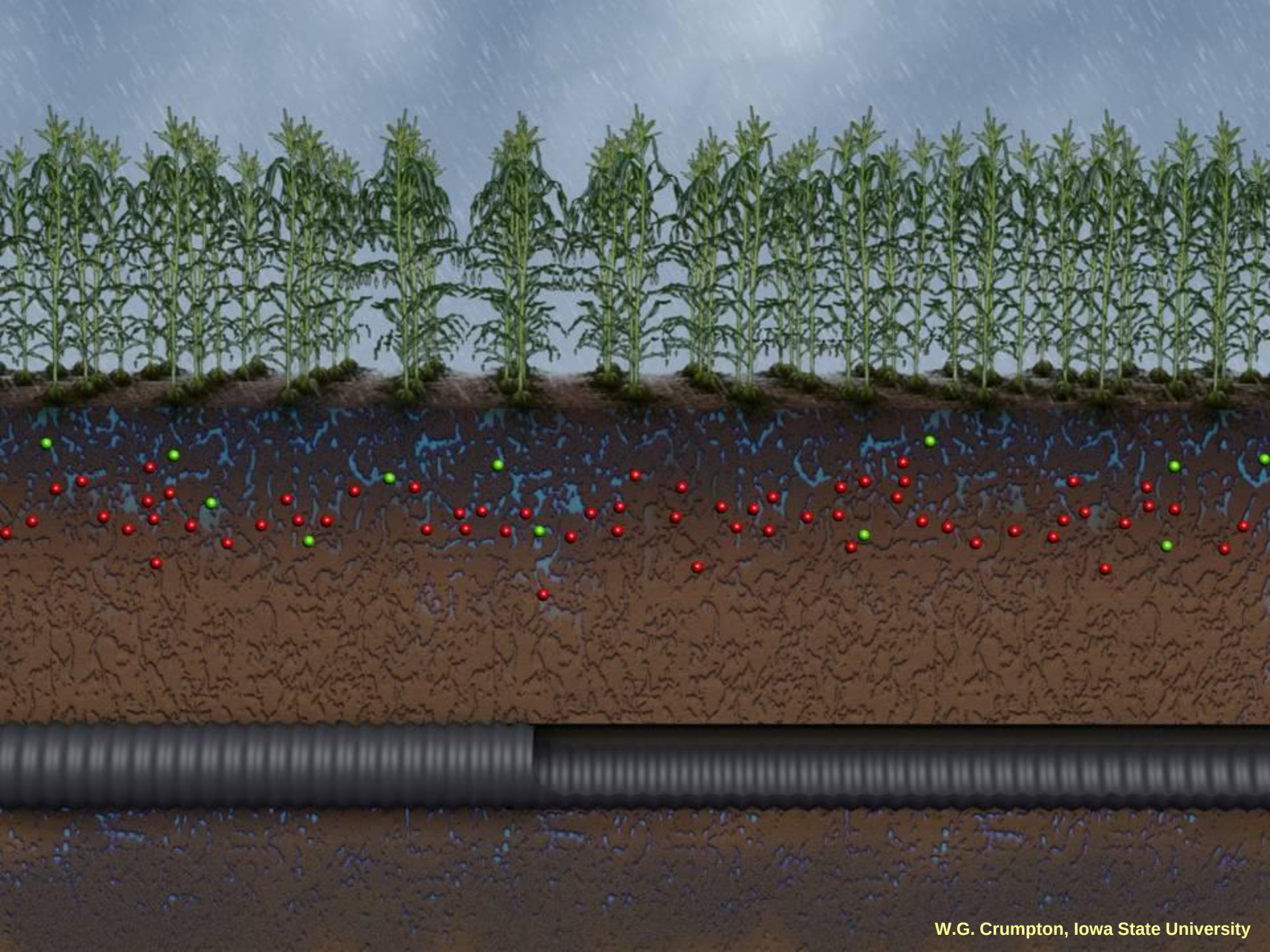
W.G. Crumpton, Iowa State University


W.G. Crumpton, Iowa State University

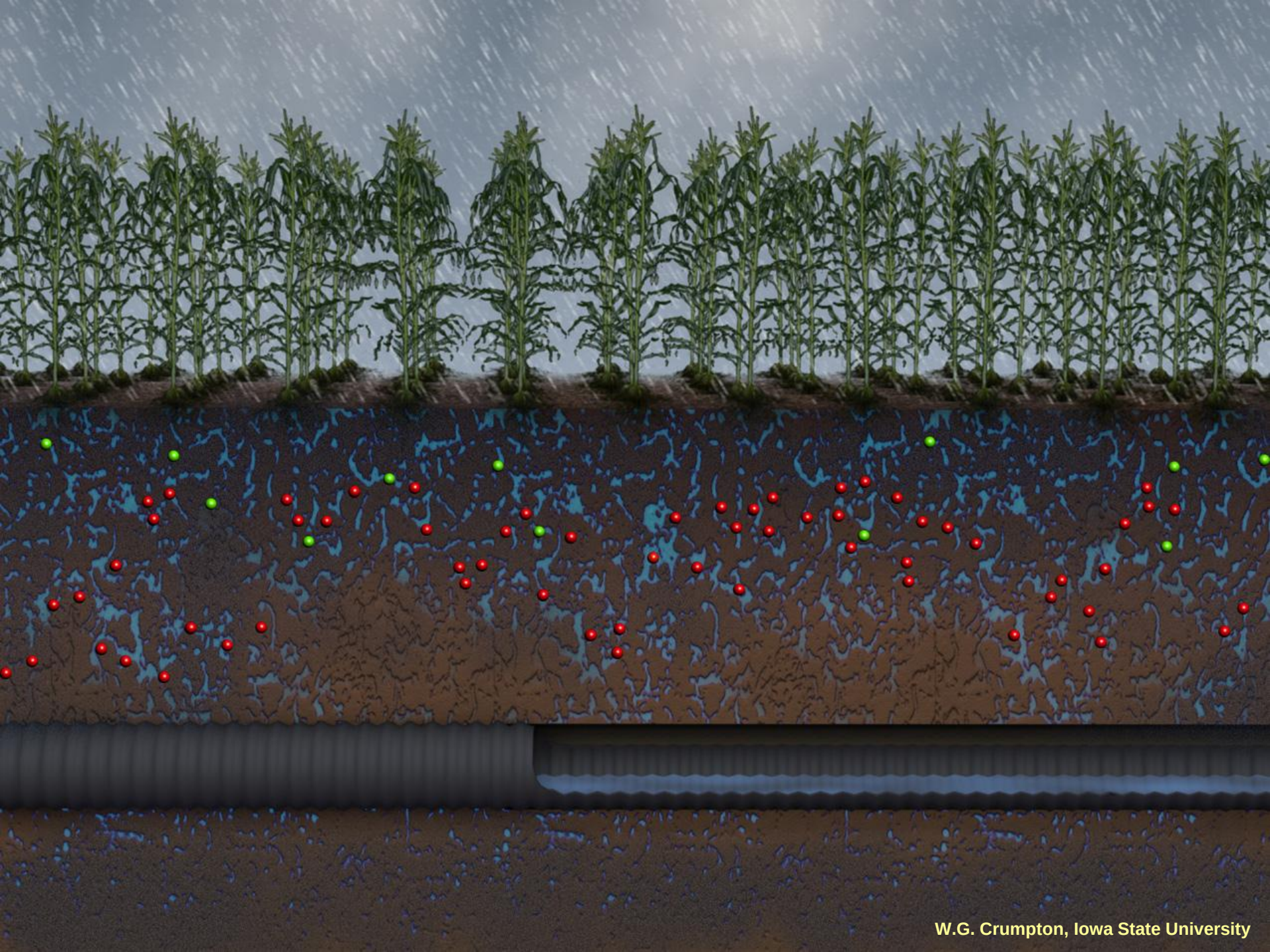


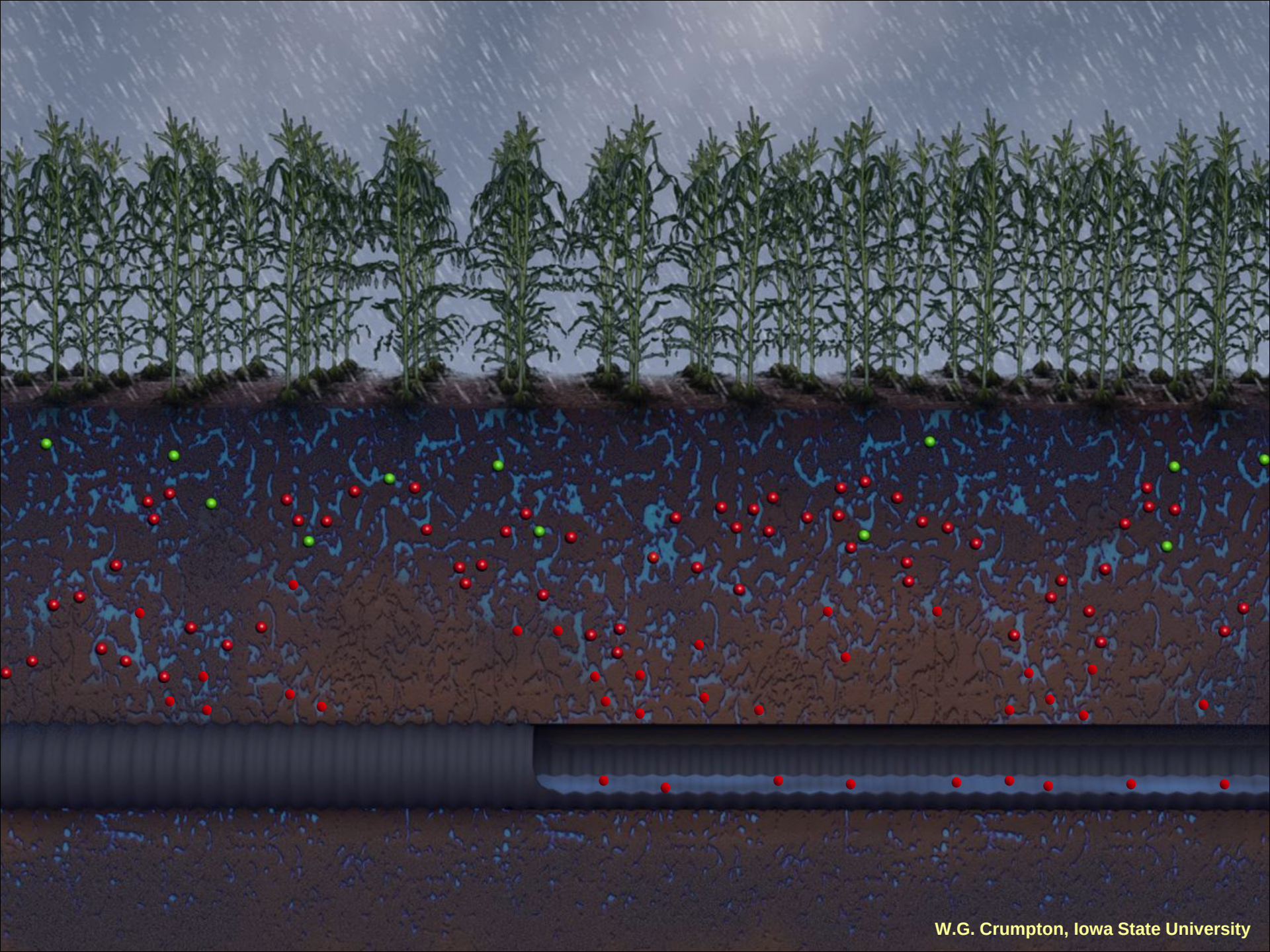
W.G. Crumpton, Iowa State University


W.G. Crumpton, Iowa State University



W.G. Crumpton, Iowa State University

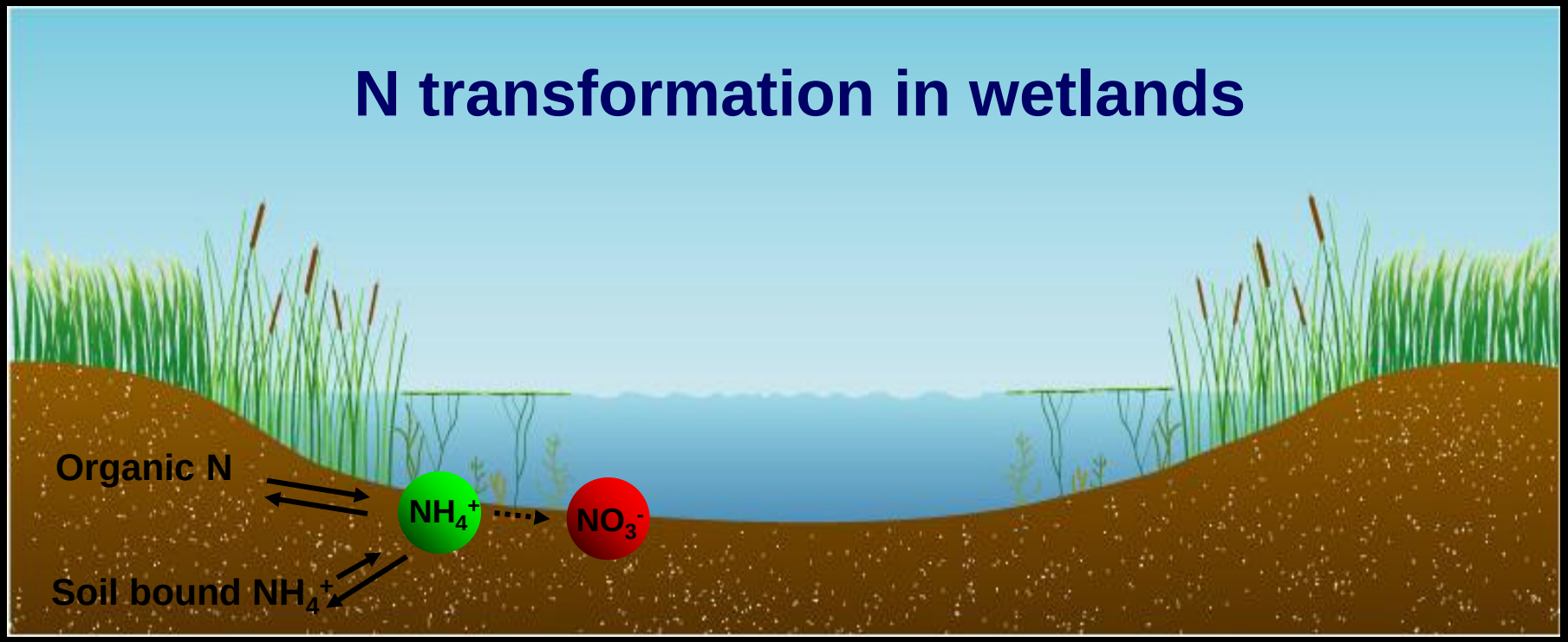

W.G. Crumpton, Iowa State University


W.G. Crumpton, Iowa State University

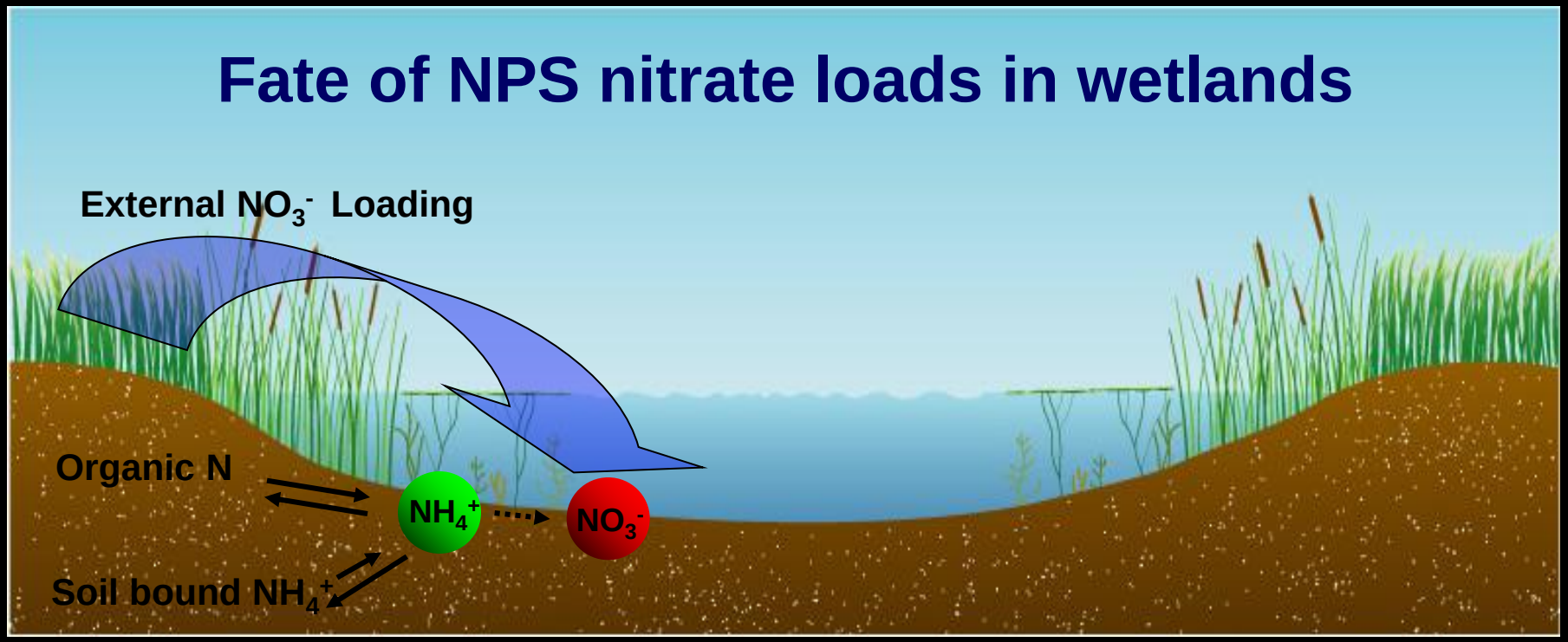
Restoring Wetlands as N Sinks in Agricultural Watersheds

- N transformation and transport in agricultural landscapes
- **N transformation in wetlands receiving NPS loads**
- N removal performance of wetlands receiving NPS loads
- Targeting wetland restorations to reduce NPS N loads

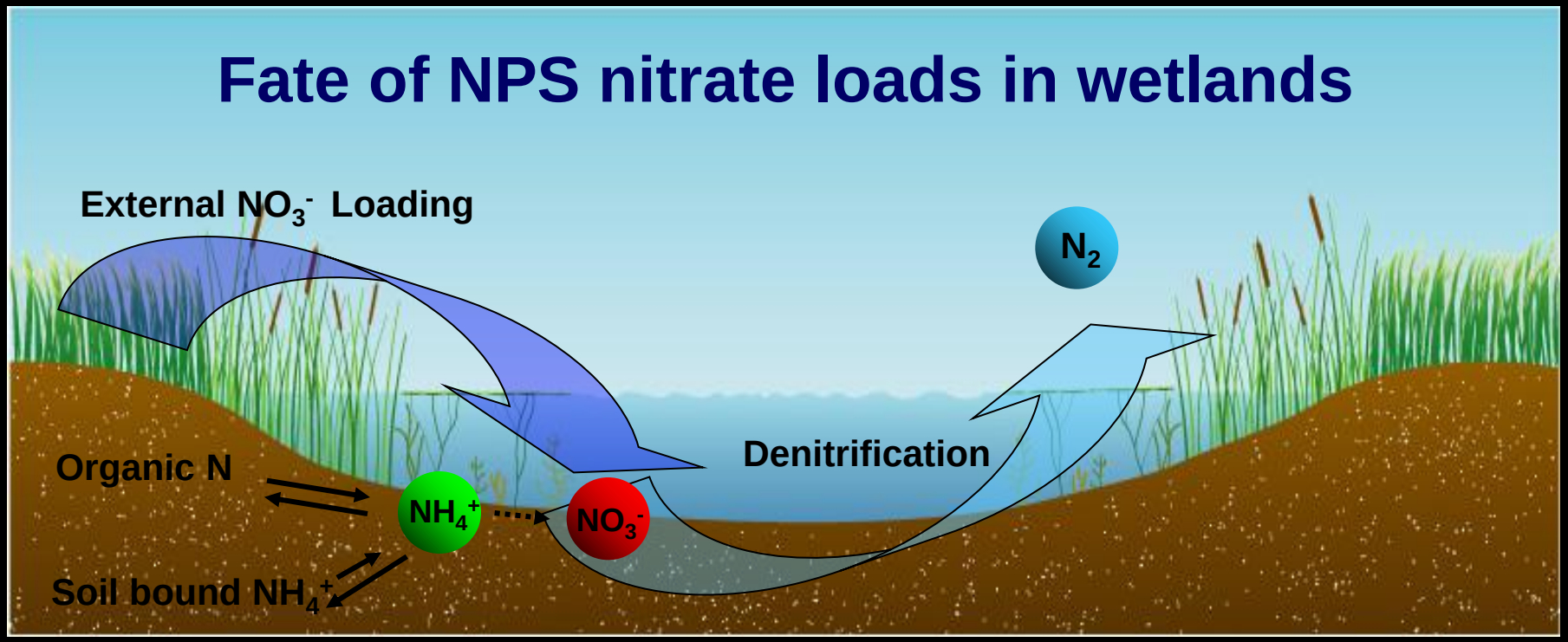
N transformation in wetlands



Fate of NPS nitrate loads in wetlands



Fate of NPS nitrate loads in wetlands



Primary Factors controlling NPS nitrate loss in wetlands

- Bioactive surface area
- Organic carbon supply
- Nitrate transport rate
- Temperature
- Dissolved oxygen
- Nitrate concentration and residence time

Primary Factors controlling NPS nitrate loss in wetlands

- Bioactive surface area
- Organic carbon supply
- Nitrate transport rate
- Temperature
- Dissolved oxygen

Influence of Vegetation Dynamics

- Nitrate concentration and residence time

Primary Factors controlling NPS nitrate loss in wetlands

- Bioactive surface area
- Organic carbon supply
- Nitrate transport rate
- Temperature
- Dissolved oxygen
- Nitrate concentration and residence time

Influence of hydraulic and nitrate loading rates

Restoring Wetlands as N Sinks in Agricultural Watersheds

- N transformation and transport in agricultural landscapes
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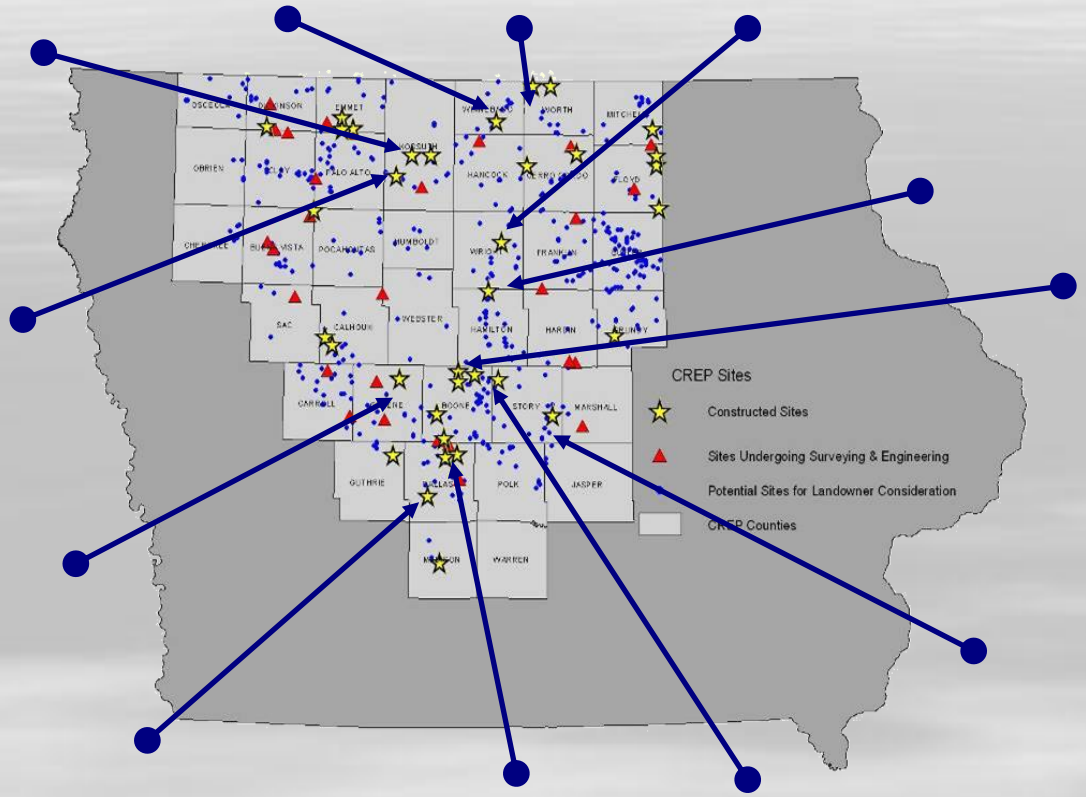
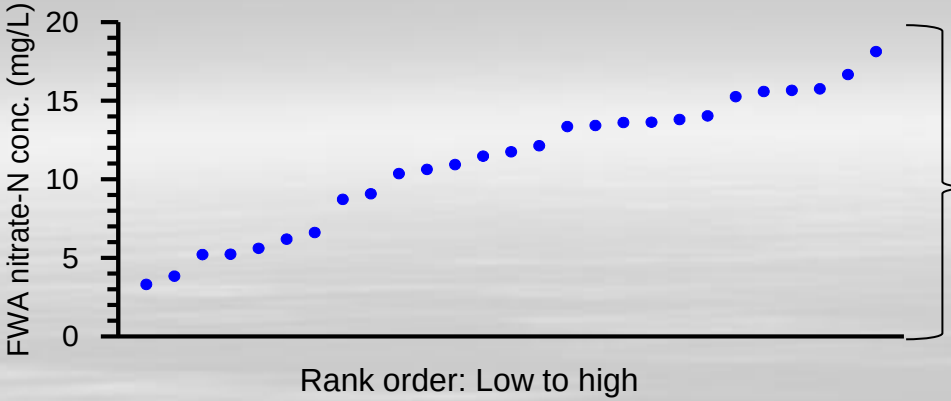
- **N removal performance of wetlands receiving NPS loads**
- Targeting wetland restorations to reduce NPS N loads

Sites for Wetland Performance Monitoring



Wetlands were chosen to ensure a broad range in factors expected to affect N loss rates, including:

- Nitrate concentration
- Hydraulic loading rate
- Nitrate loading rate



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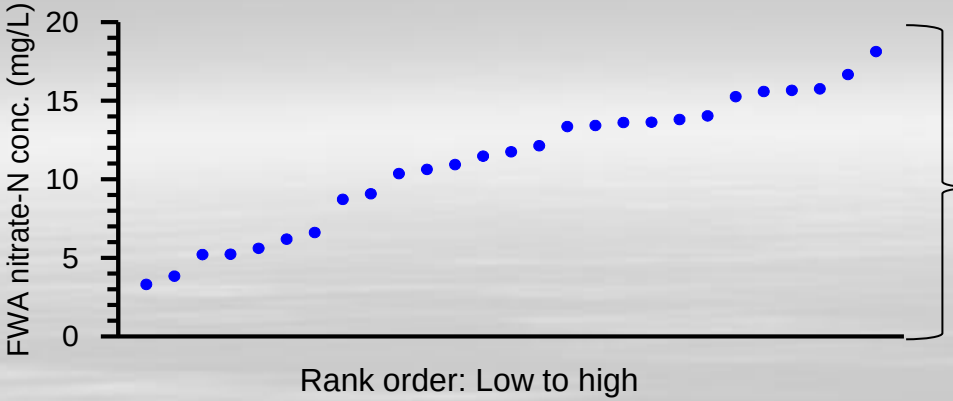
Nitrate concentration

Hydraulic loading rate

Nitrate loading rate



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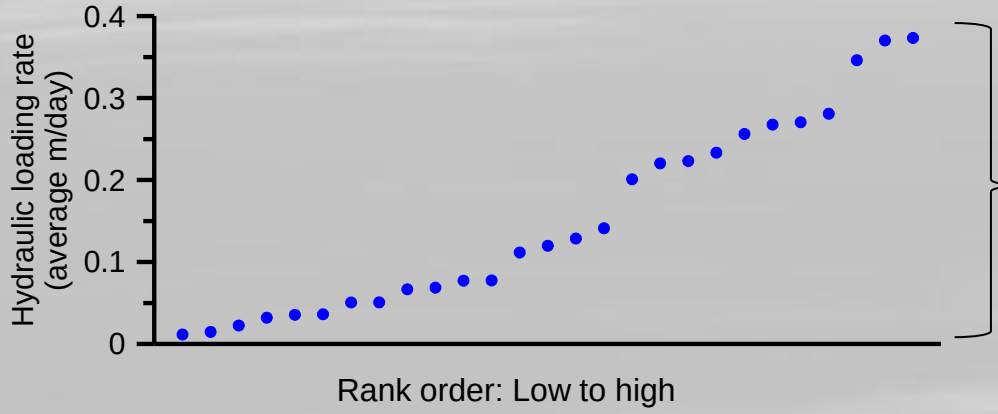
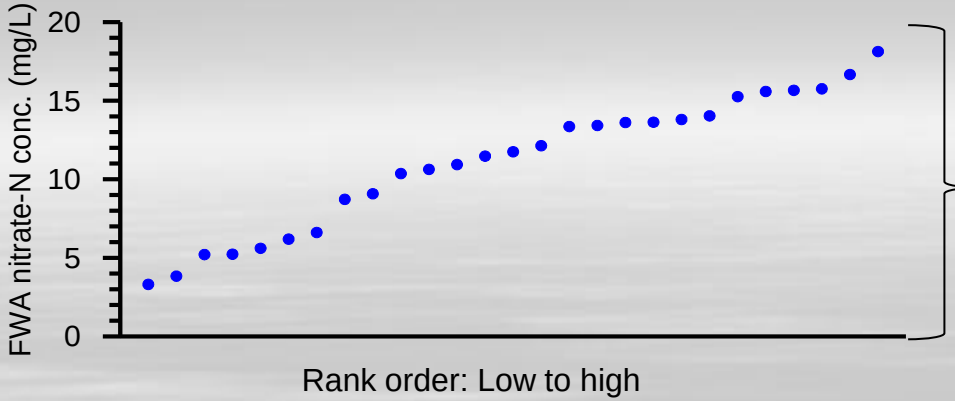


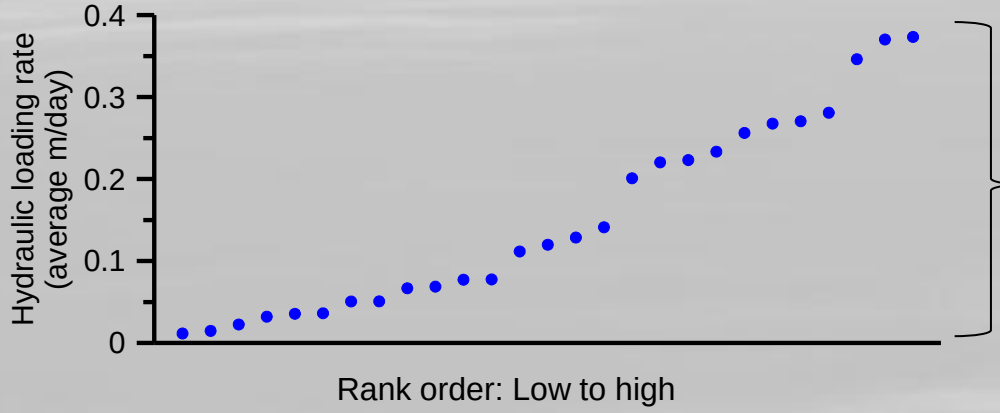
Hydraulic loading rate

Nitrate loading rate

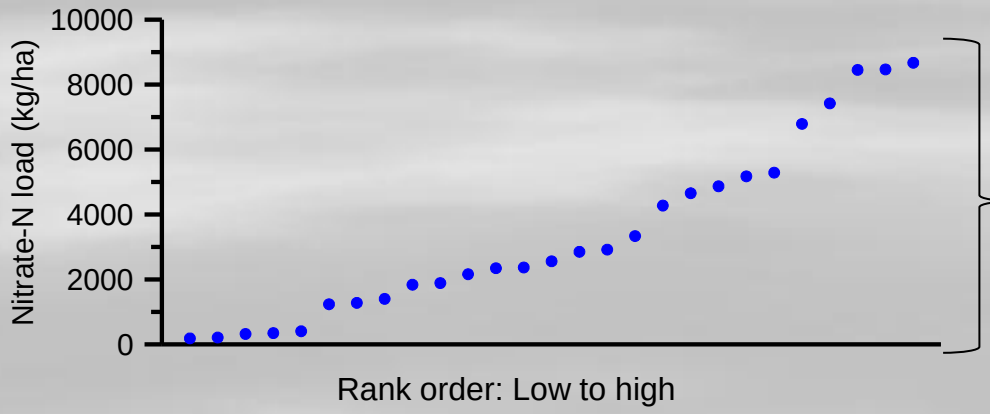
Wetlands were chosen to ensure a broad range in factors expected to affect N loss rates, including:



Nitrate concentration



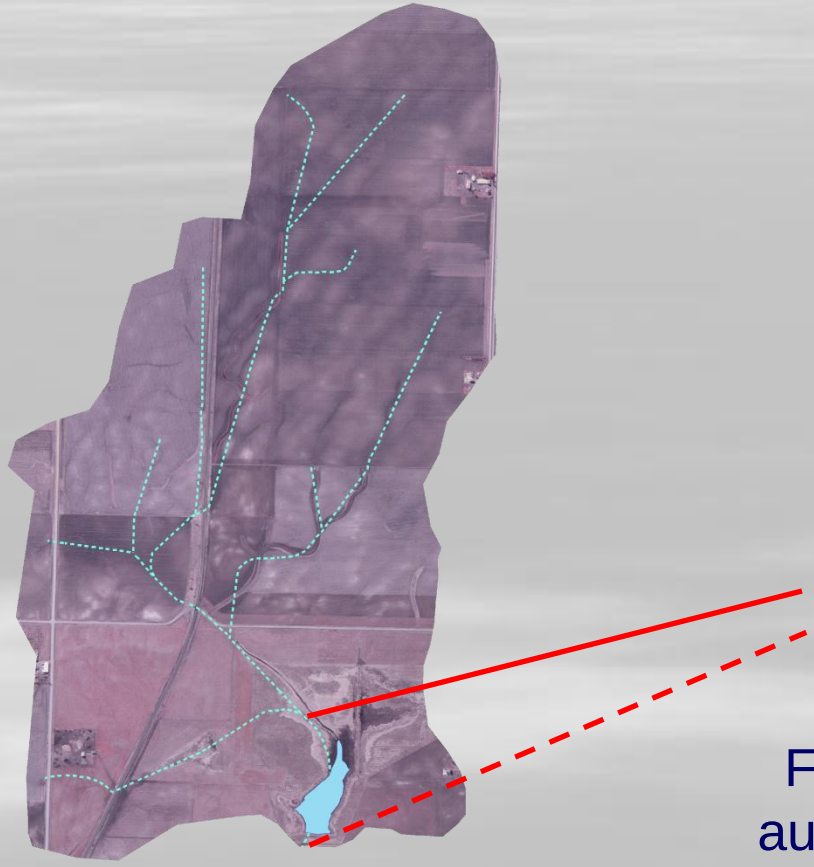
Hydraulic loading rate



Nitrate loading rate

Monitoring of Wetland Performance

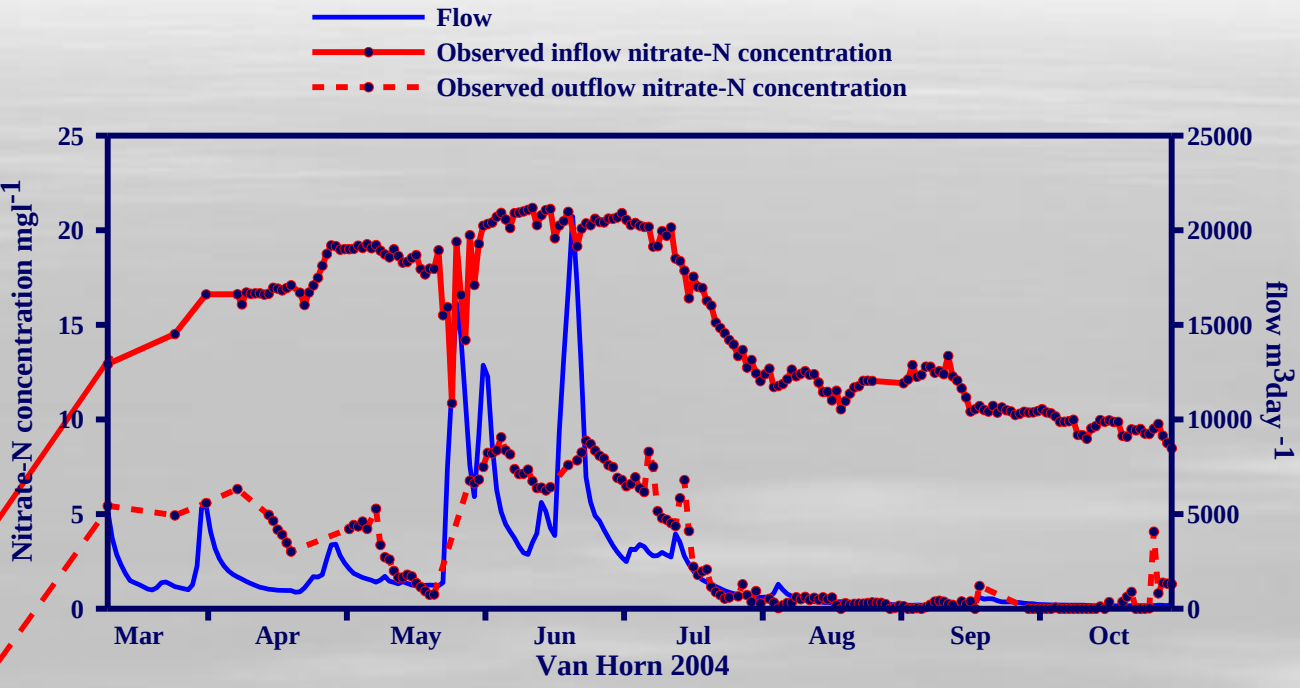
Van Horn Wetland



Field sites instrumented for automated sampling and flow measurement

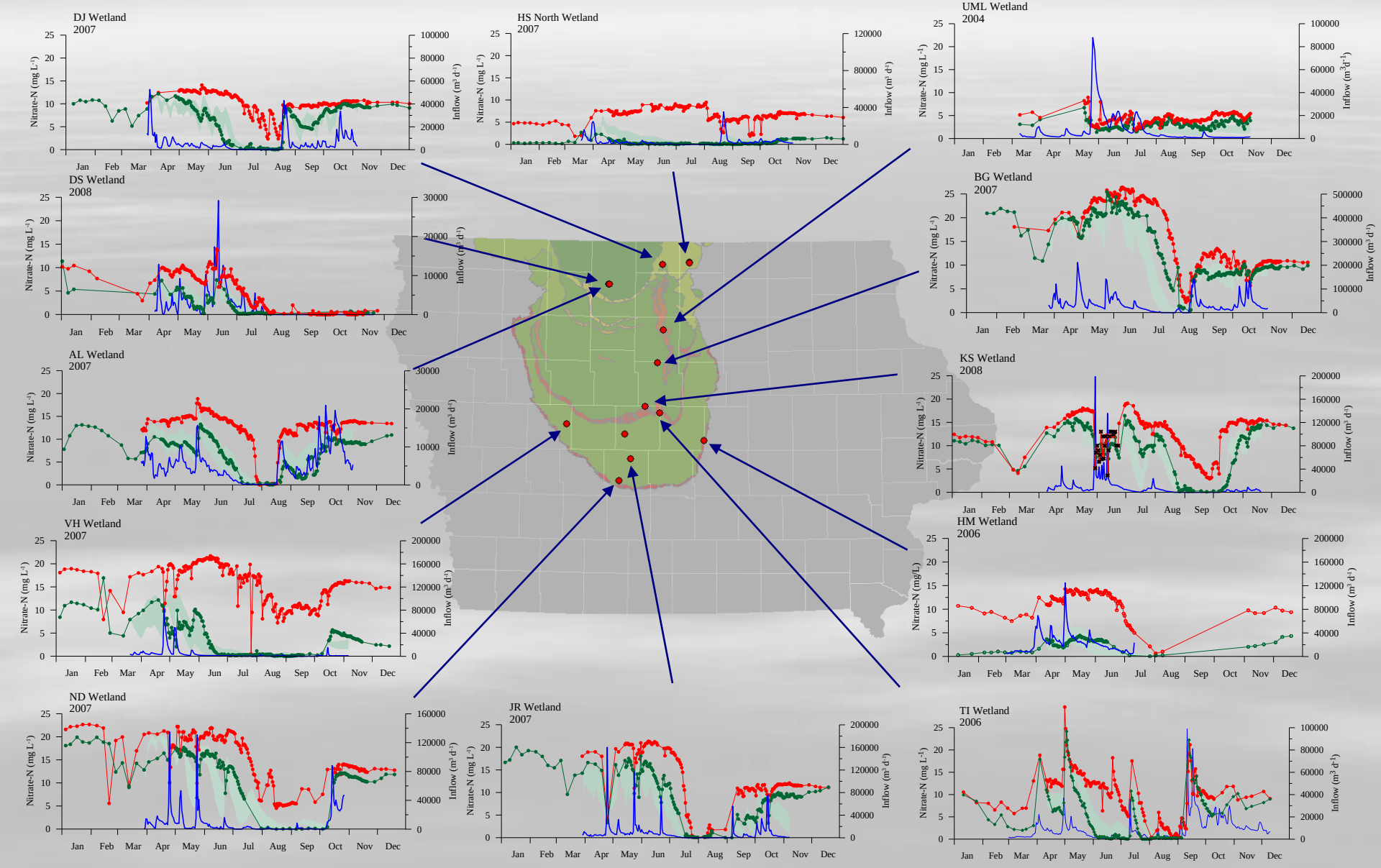
Monitoring of Wetland Performance

Van Horn Wetland



Observed Nitrate concentrations and flow rates for Van Horn Wetland in 2004

Examples from 2007 to 2009 monitoring



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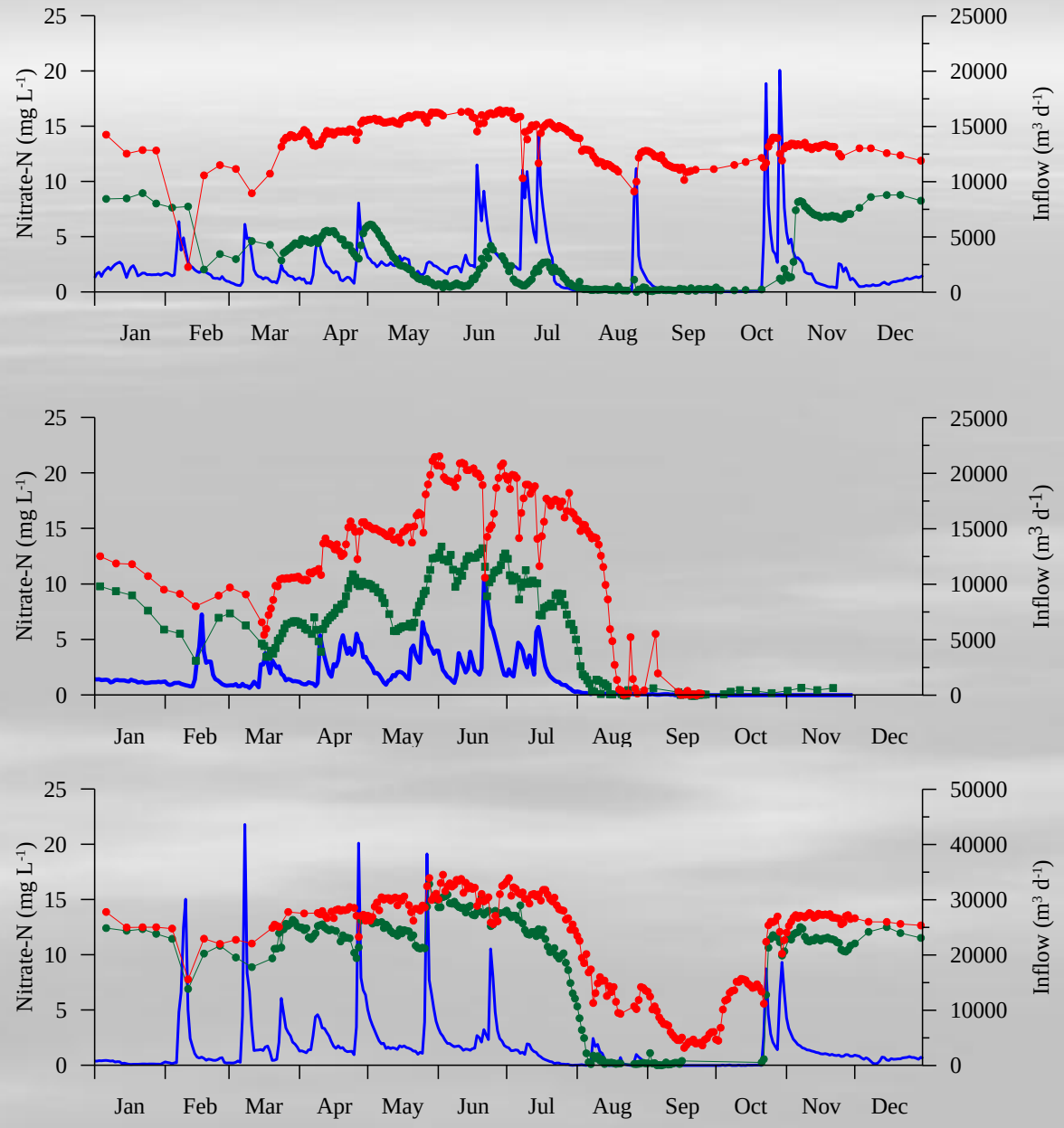
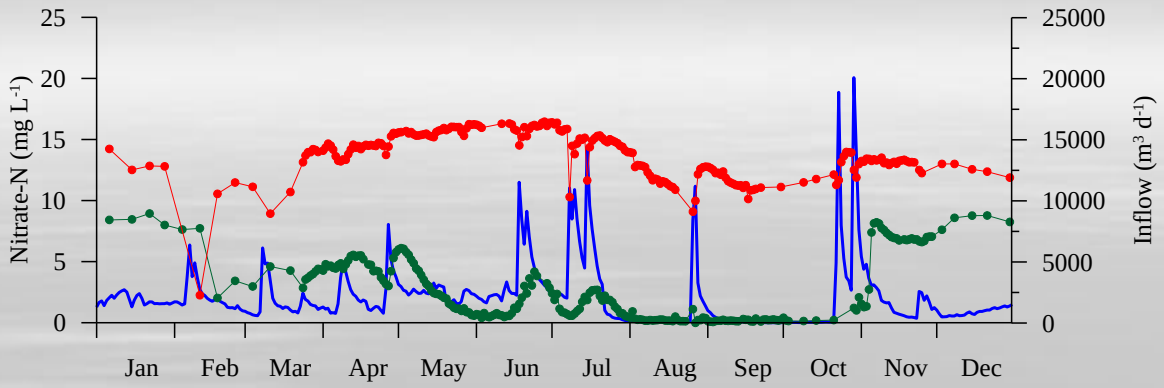
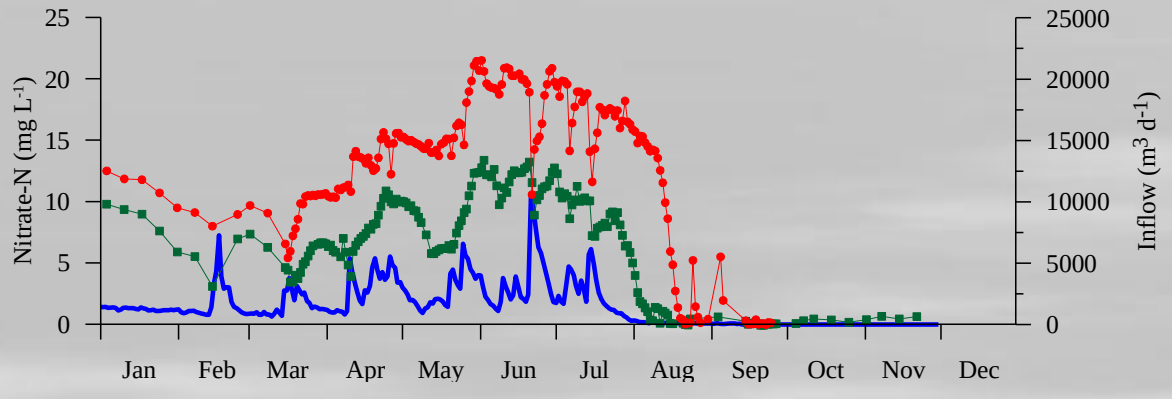
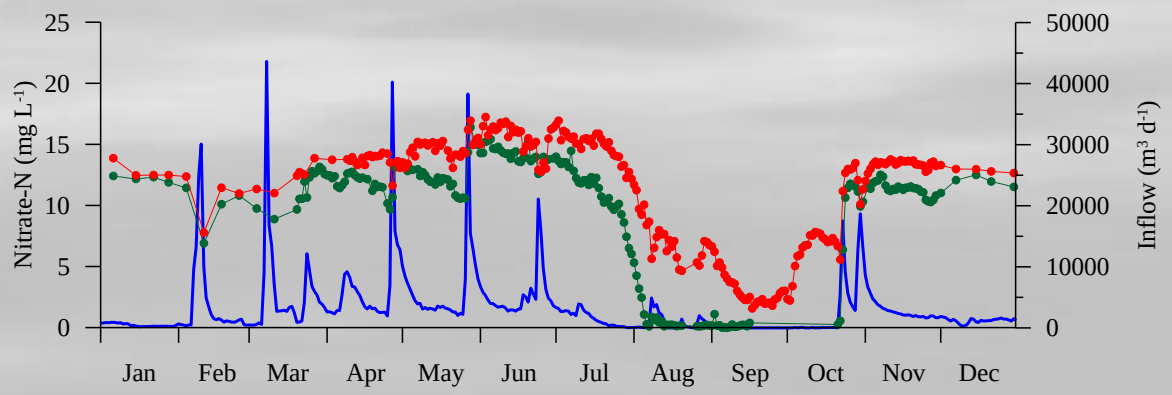

Nitrate-N (mg L-1)
Inflow (m3 d-1)
0
5
10
15
20
25
0
5000
10000
15000
20000
25000
0
10000
20000
30000
40000
50000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Residence time

Longer







Shorter

Residence time

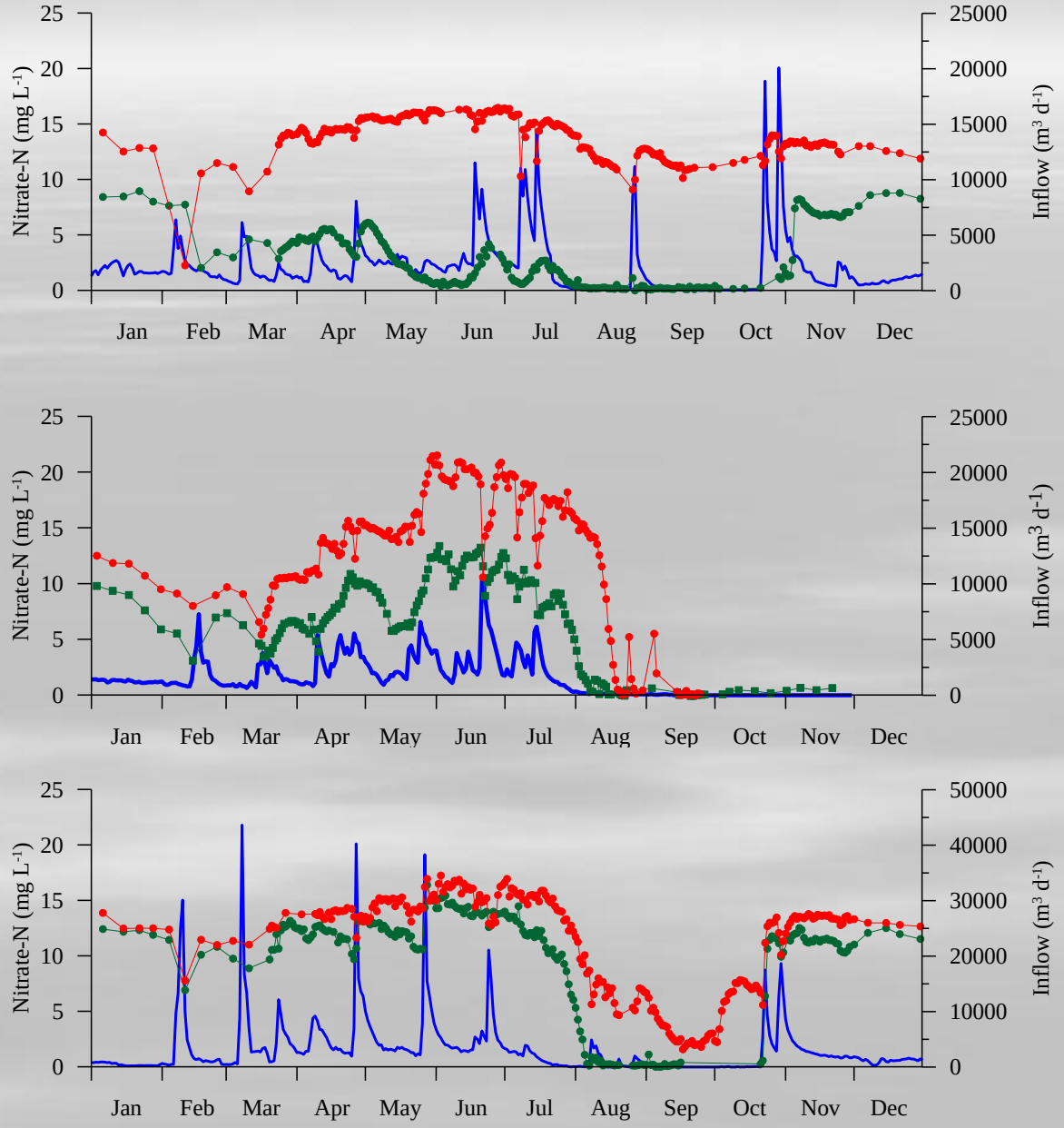
Longer

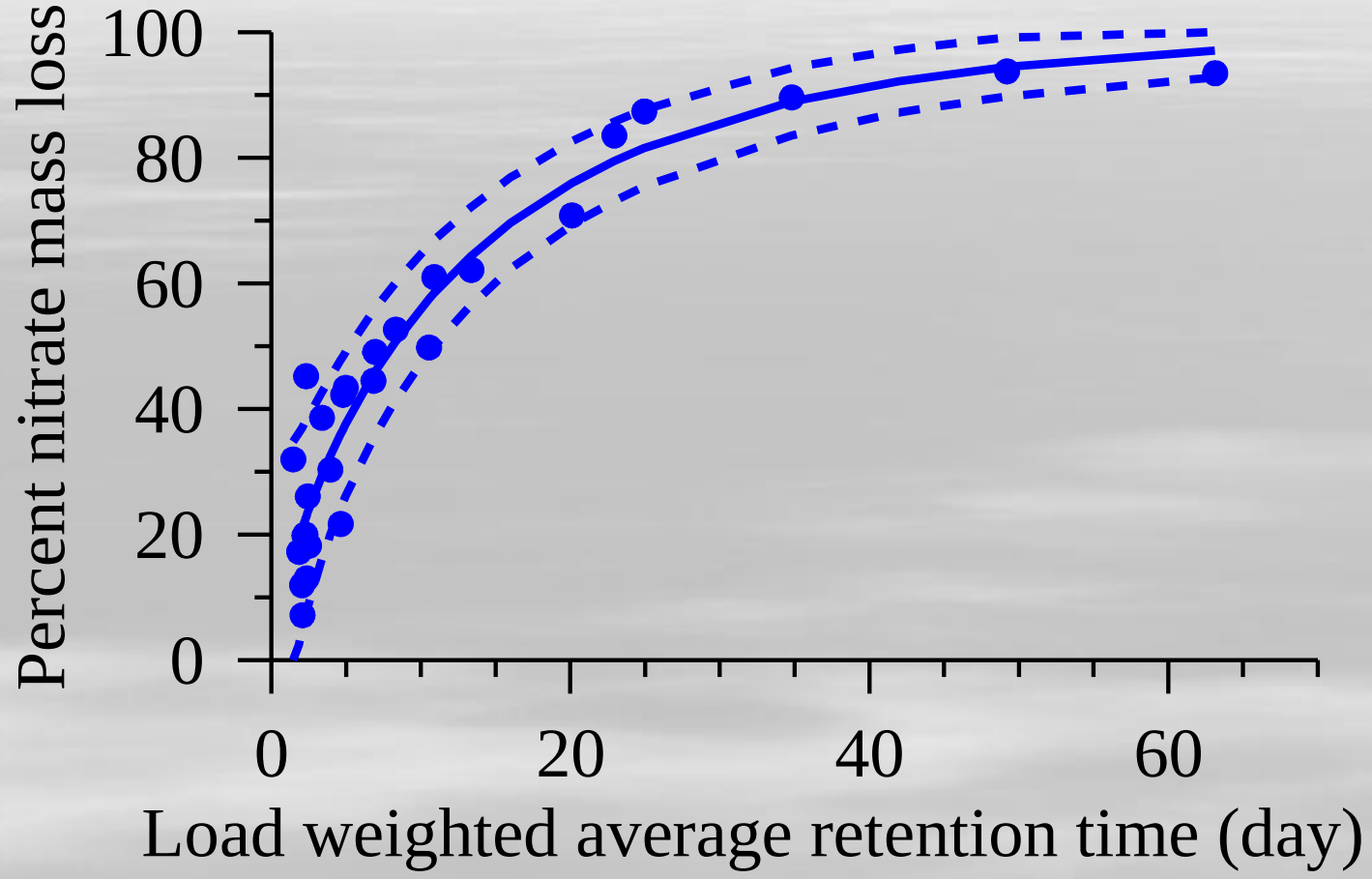
Shorter

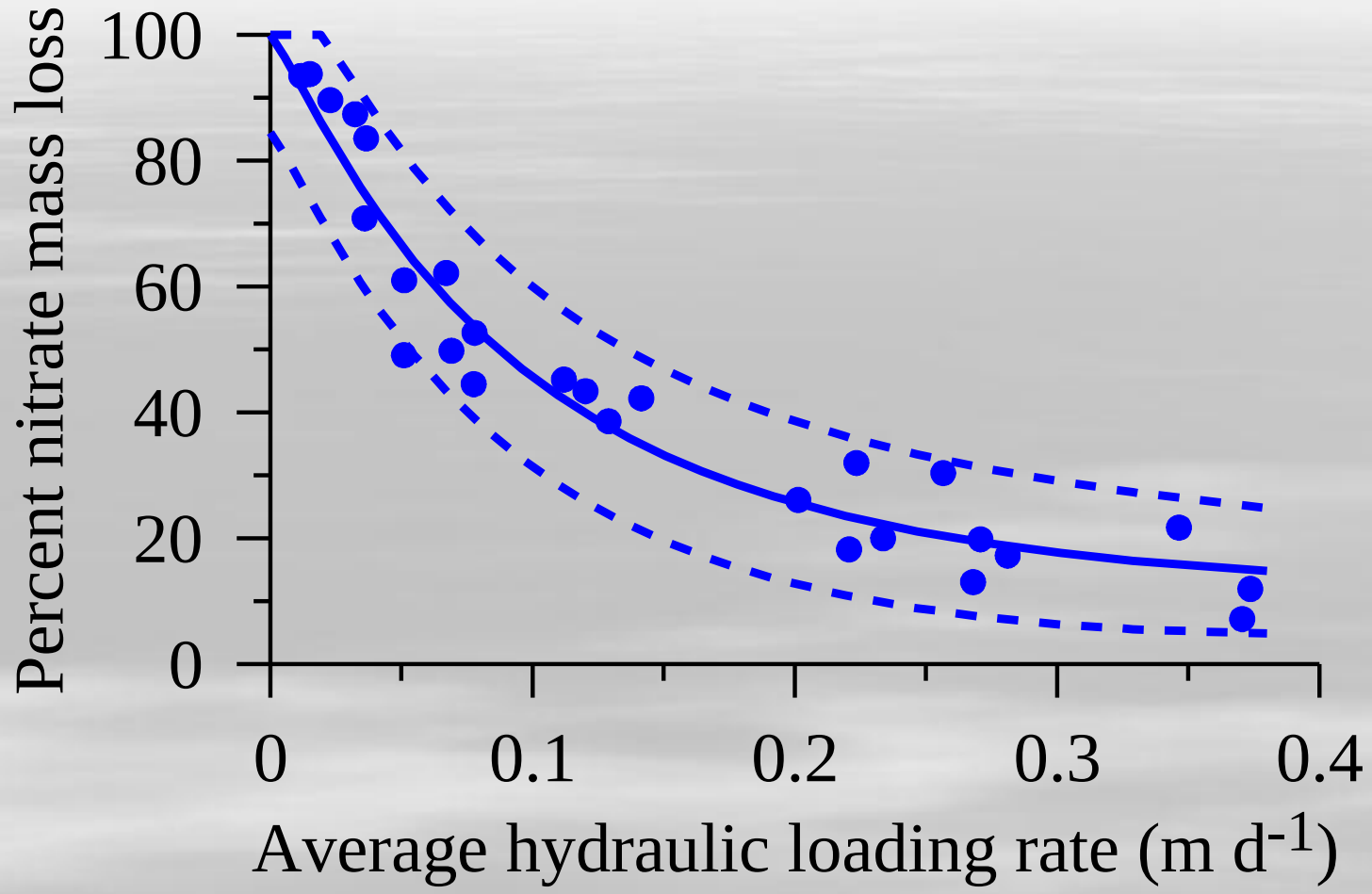
Hydraulic Loading Rate

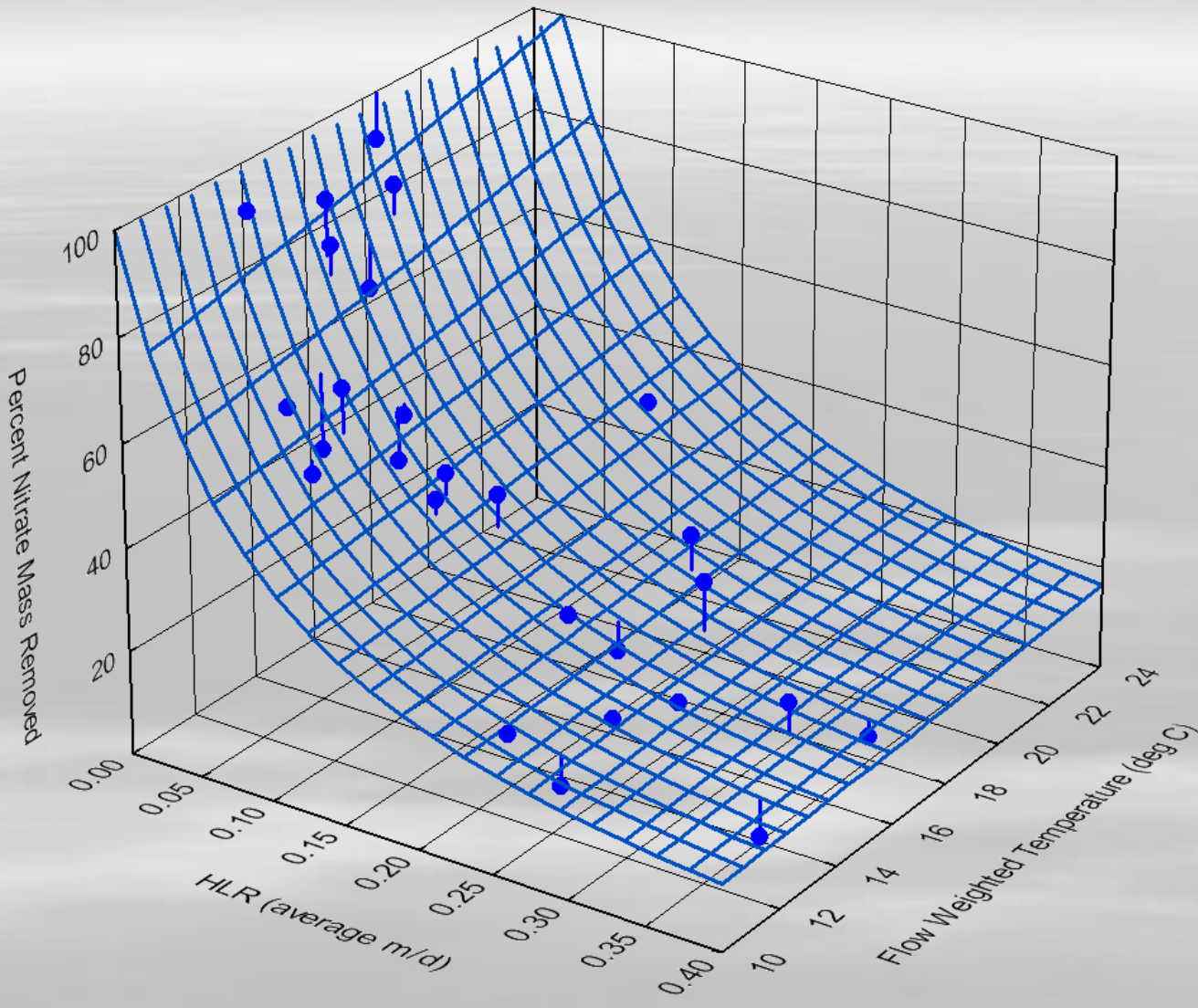
Lower

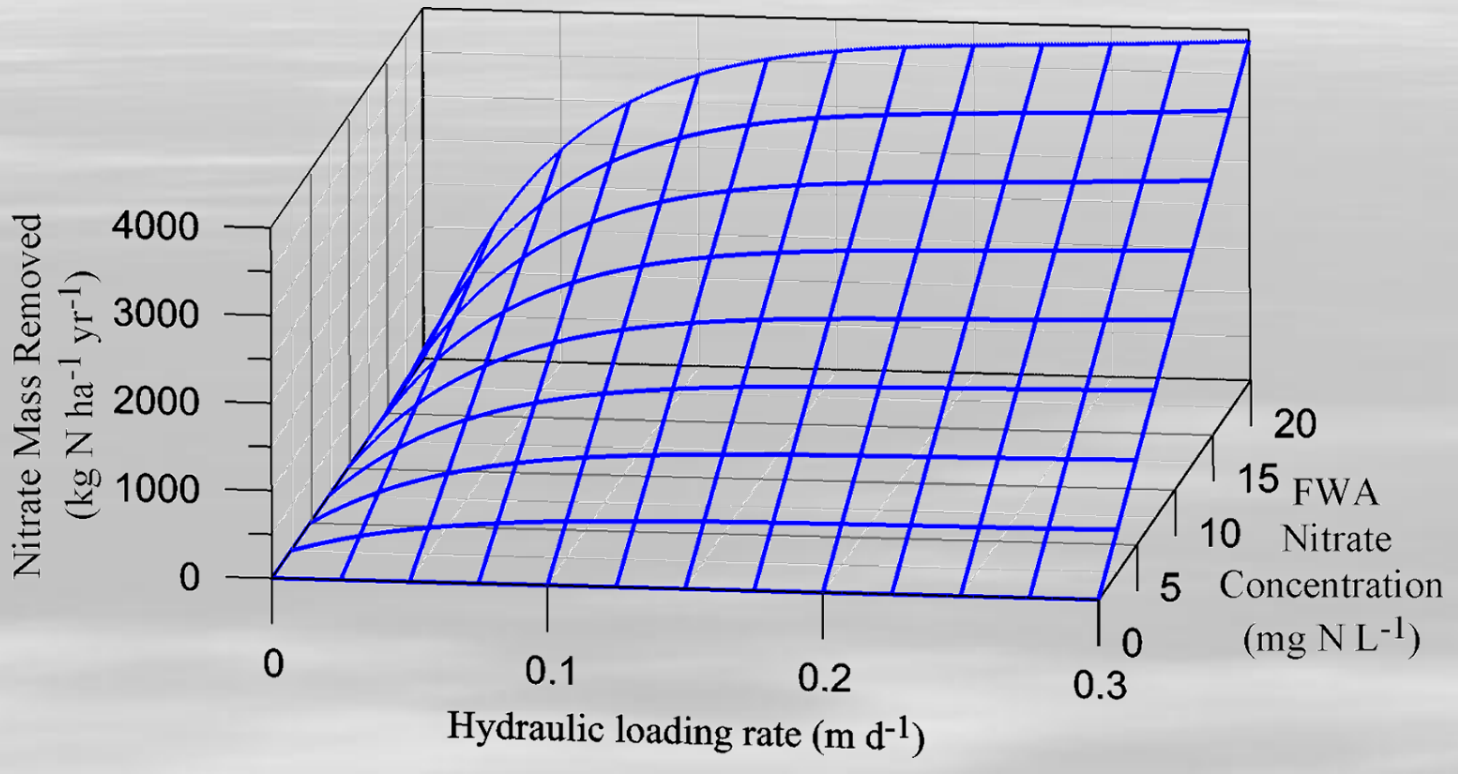
Greater

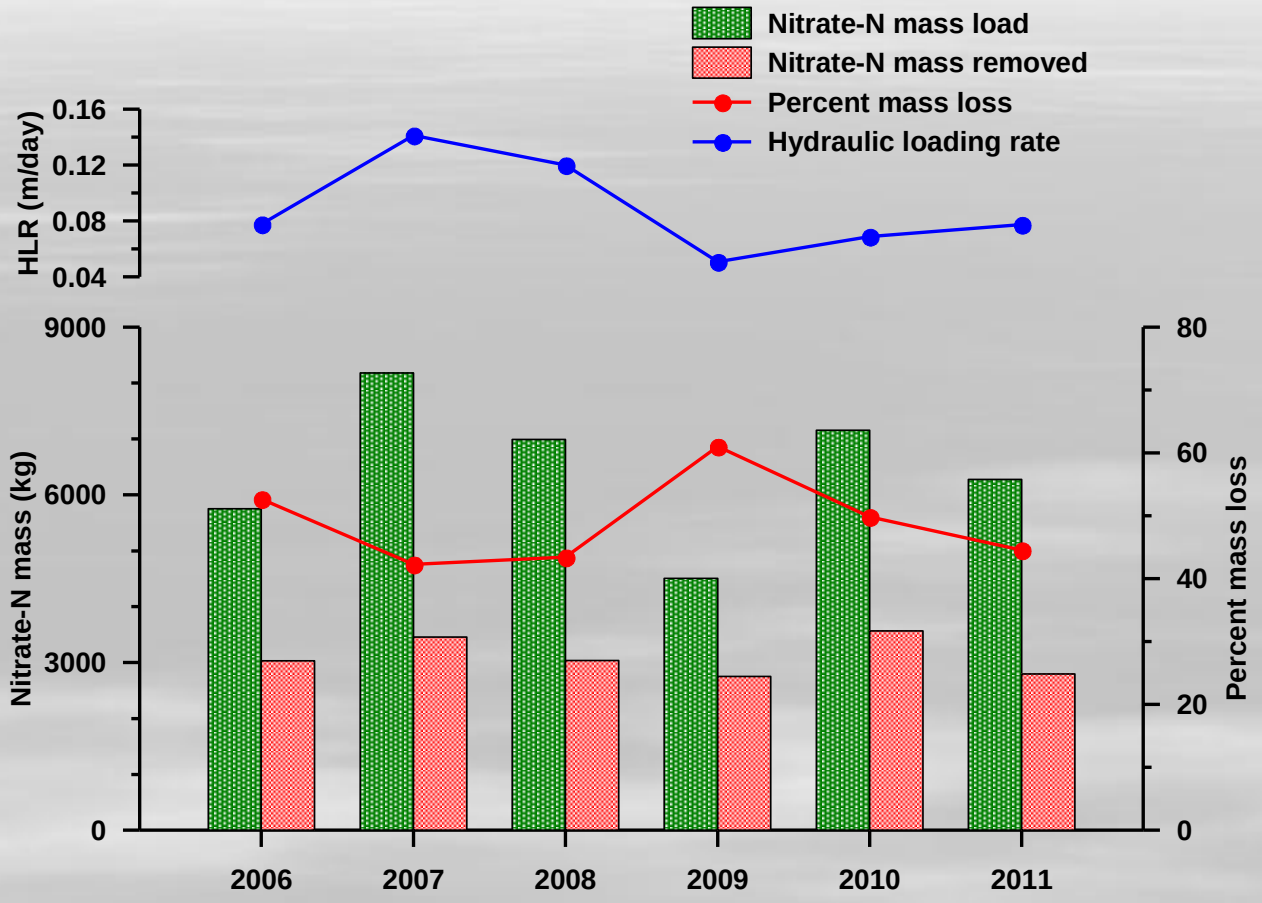



Percent nitrate mass loss
100
80
60
40
20
0
0
20
40
60
Load weighted average retention time (day)

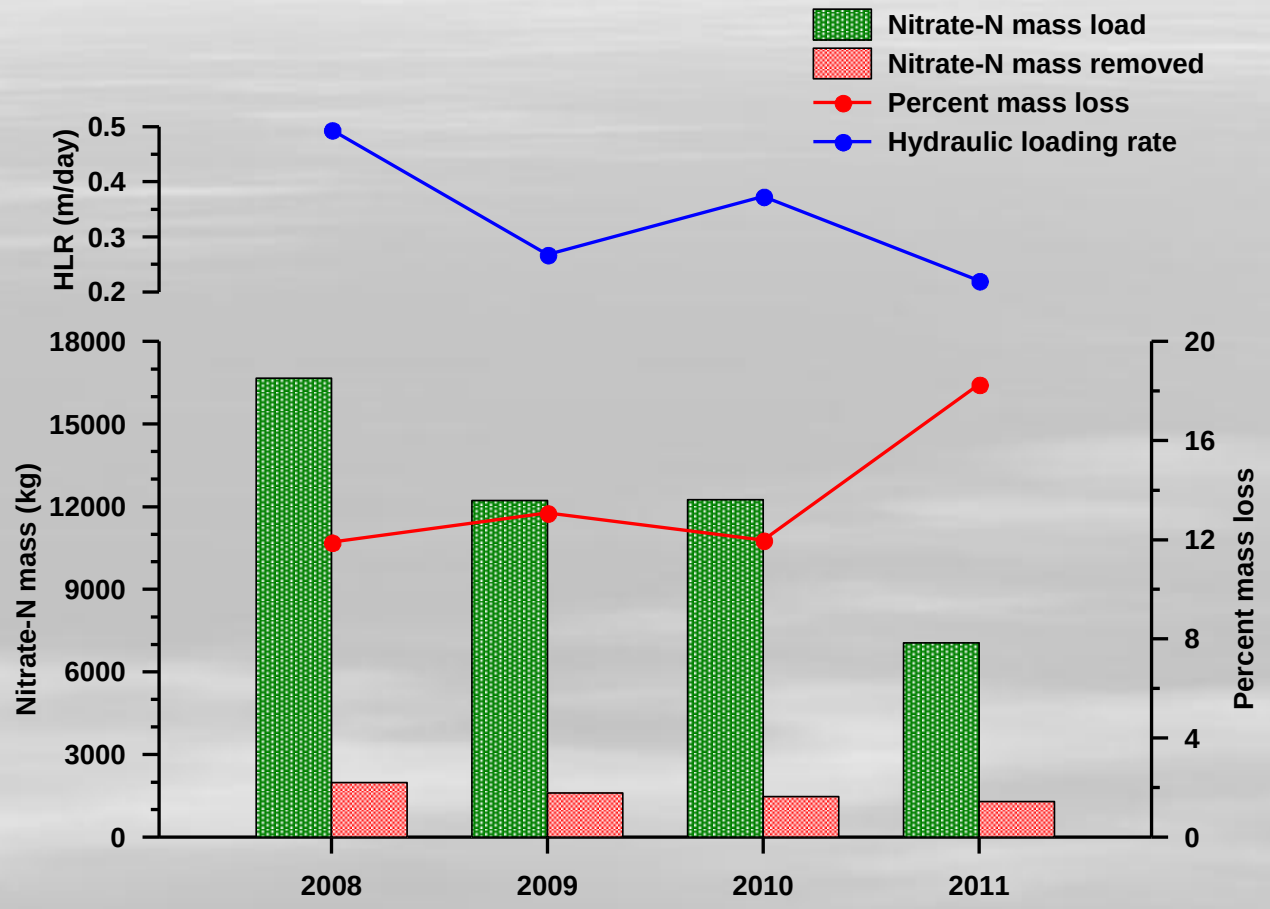

Percent nitrate mass loss
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
Average hydraulic loading rate (m d-1)


Percent Nitrate Mass Removed
100
80
60
40
20
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
HLR (average m/d)
10
12
14
16
18
20
22
24
Flow Weighted Temperature (deg C)


Nitrate Mass Removed
(kg N ha-1 yr-1)
4000
3000
2000
1000
0
0
0.1
0.2
0.3
Hydraulic loading rate (m d-1)
0
5
10
15
20
FWA
Nitrate
Concentration
(mg N L-1)

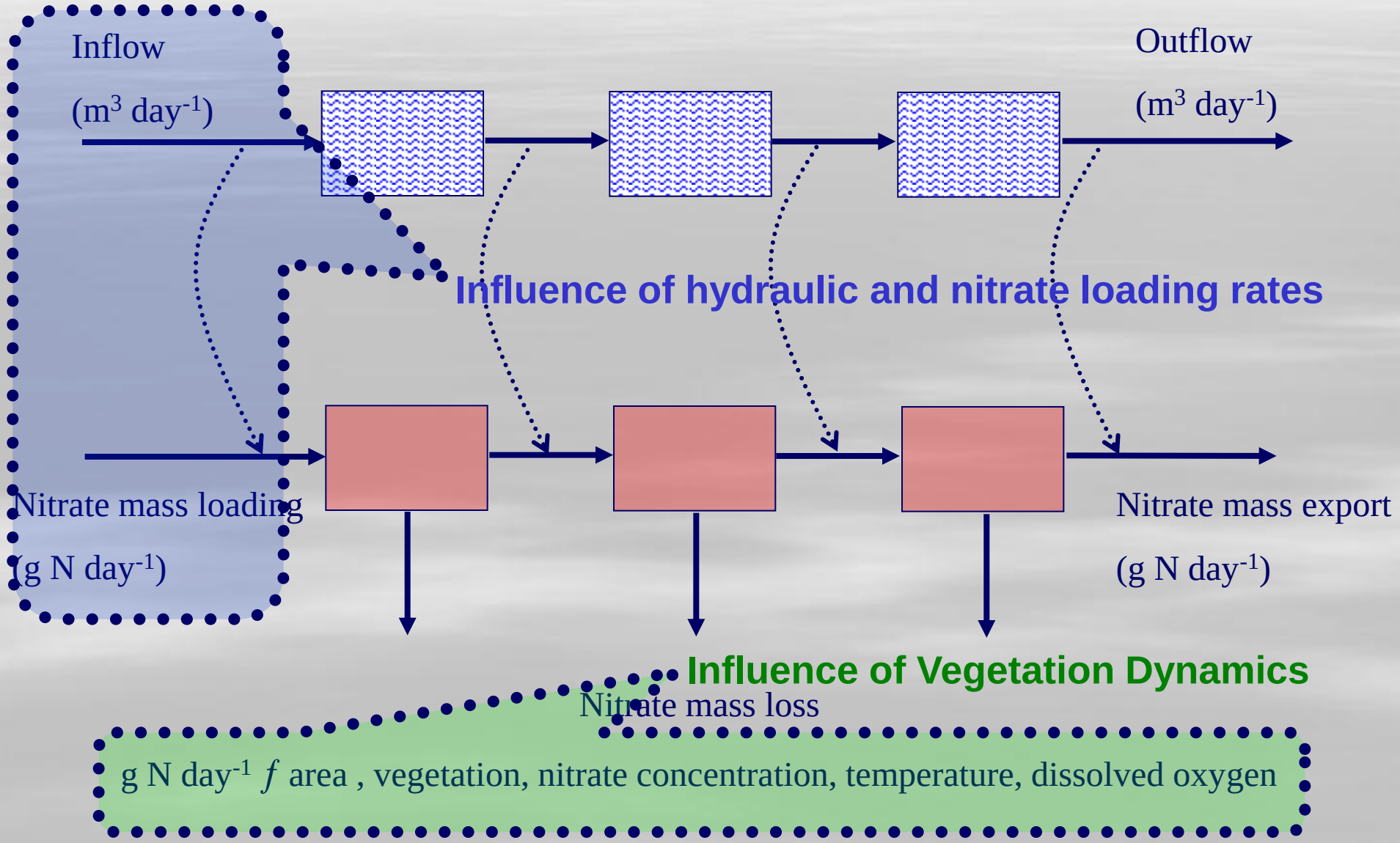


AL wetland (1.07% area ratio)

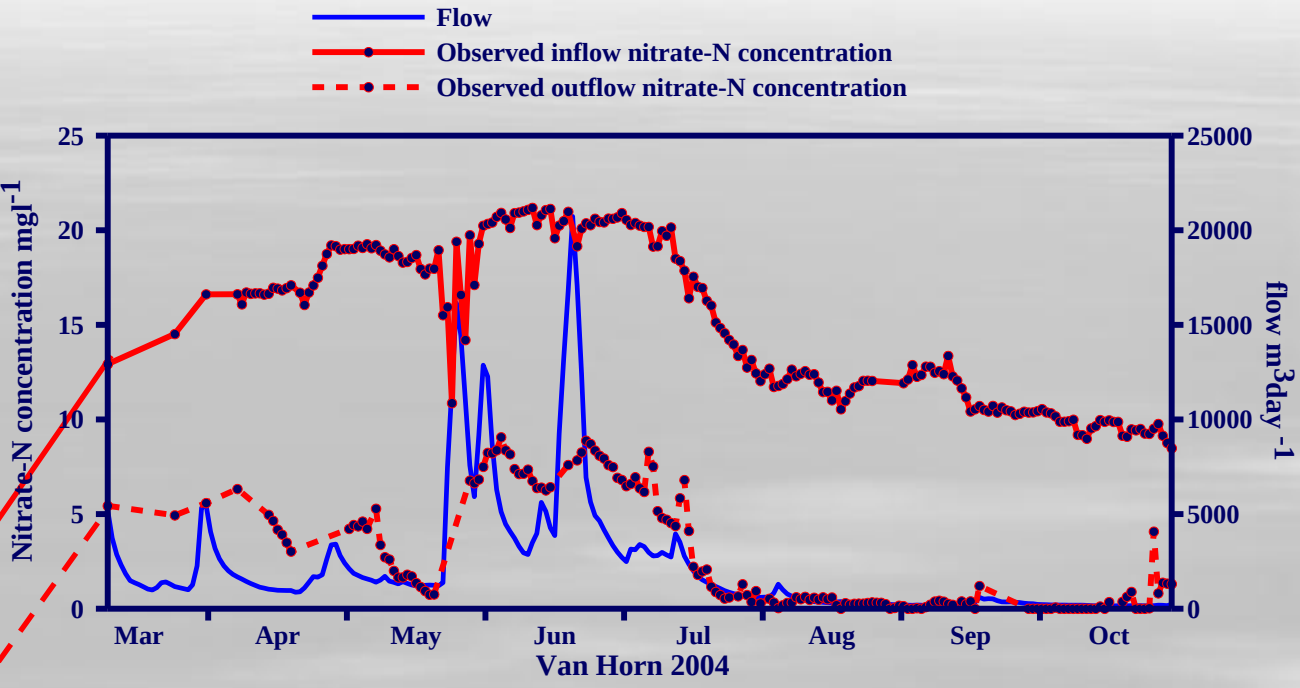


KS wetland (0.48% area ratio)

Dynamic Modeling of Wetland Performance



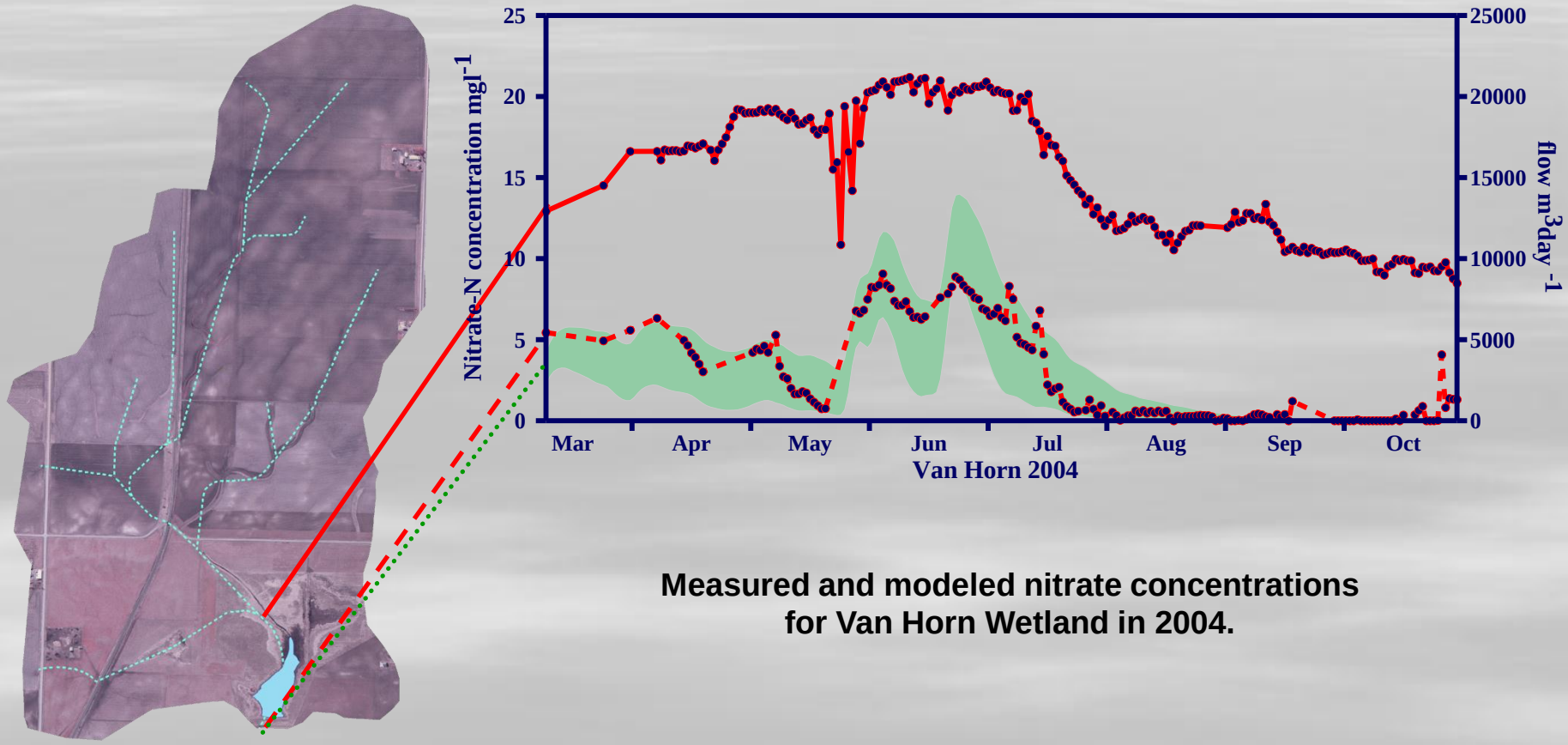
Van Horn Wetland



Observed Nitrate concentrations and flow rates for Van Horn Wetland in 2004

W.G. Crumpton, Iowa State University

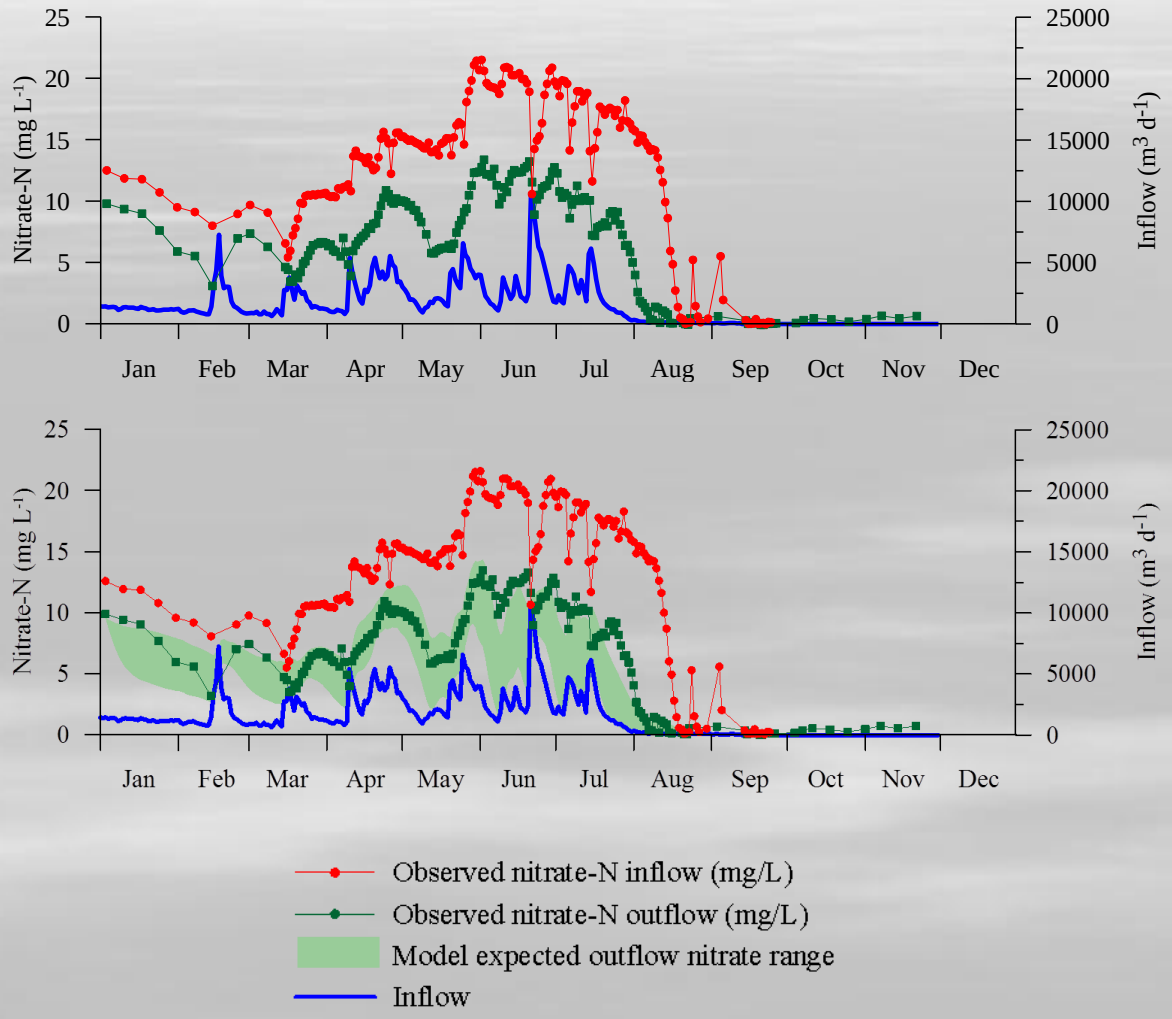
Van Horn Wetland



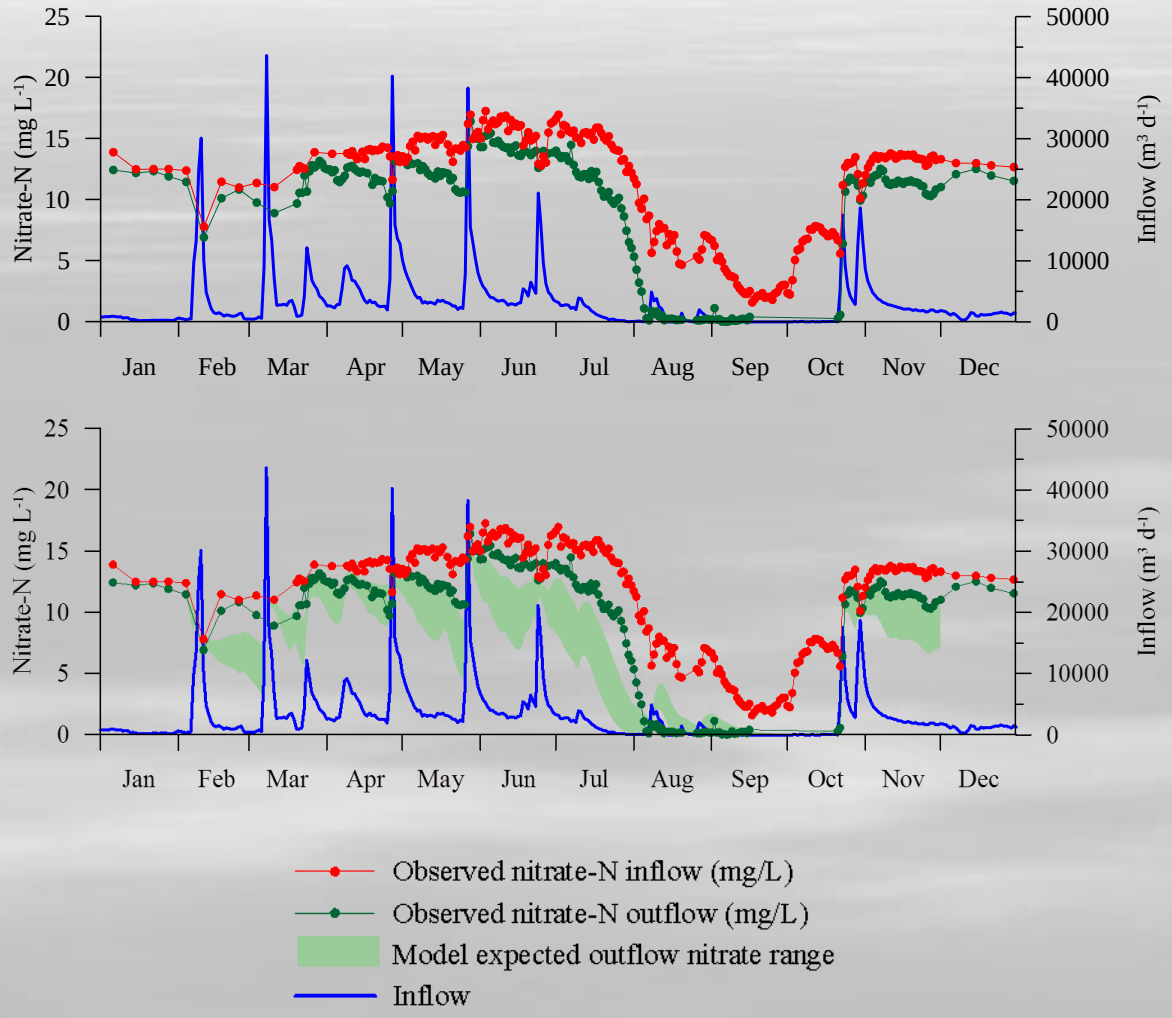
Measured and modeled nitrate concentrations for Van Horn Wetland in 2004.

W.G. Crumpton, Iowa State University

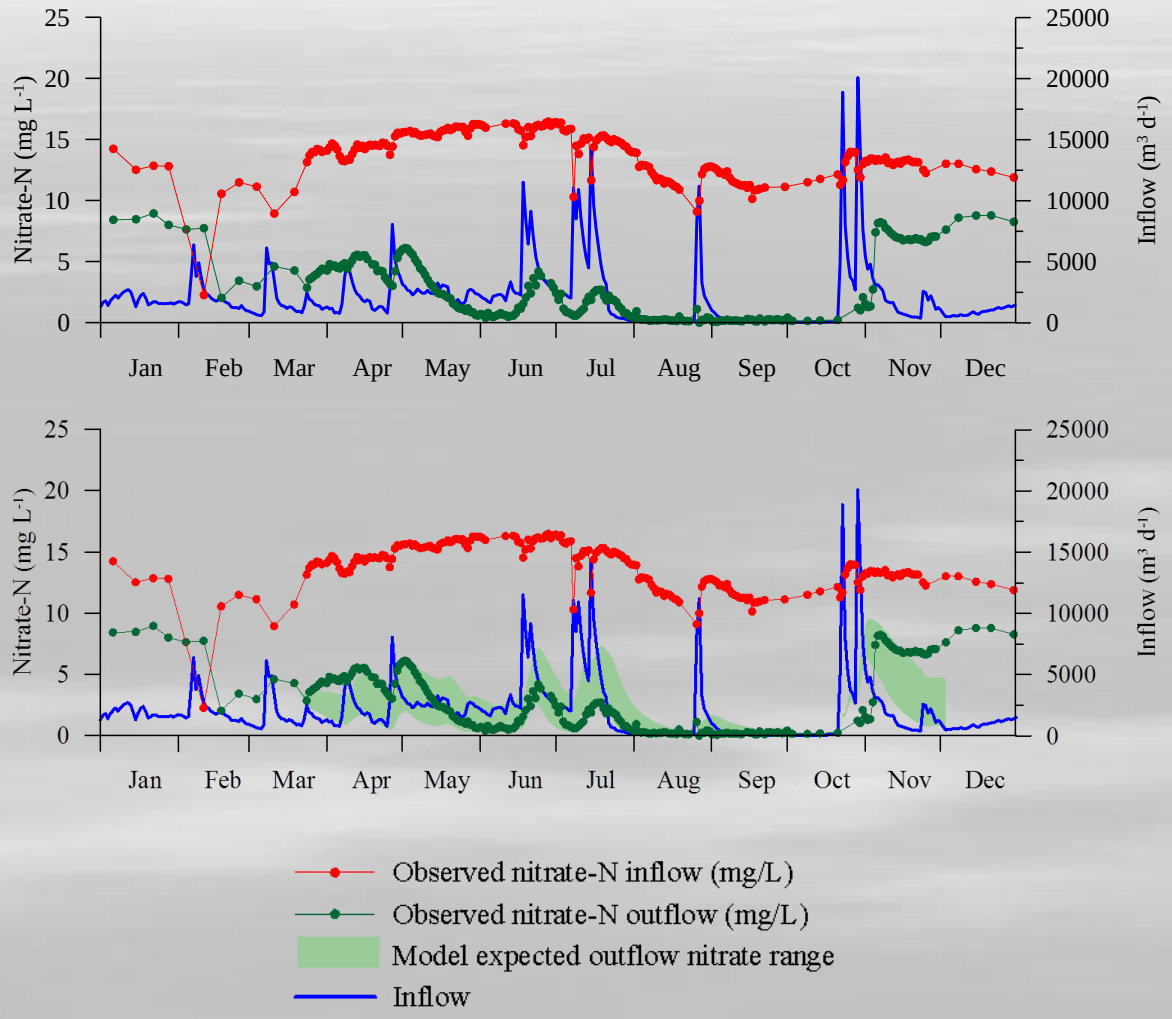
AL 2011


Nitrate-N (mg L-1)
Inflow (m3 d-1)
0
5
10
15
20
25
0
5000
10000
15000
20000
25000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Observed nitrate-N inflow (mg/L)
Observed nitrate-N outflow (mg/L)
Model expected outflow nitrate range
Inflow

KS 2009


Nitrate-N (mg L-1)
Inflow (m3 d-1)
0
5
10
15
20
25
0
10000
20000
30000
40000
50000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Observed nitrate-N inflow (mg/L)
Observed nitrate-N outflow (mg/L)
Model expected outflow nitrate range
Inflow

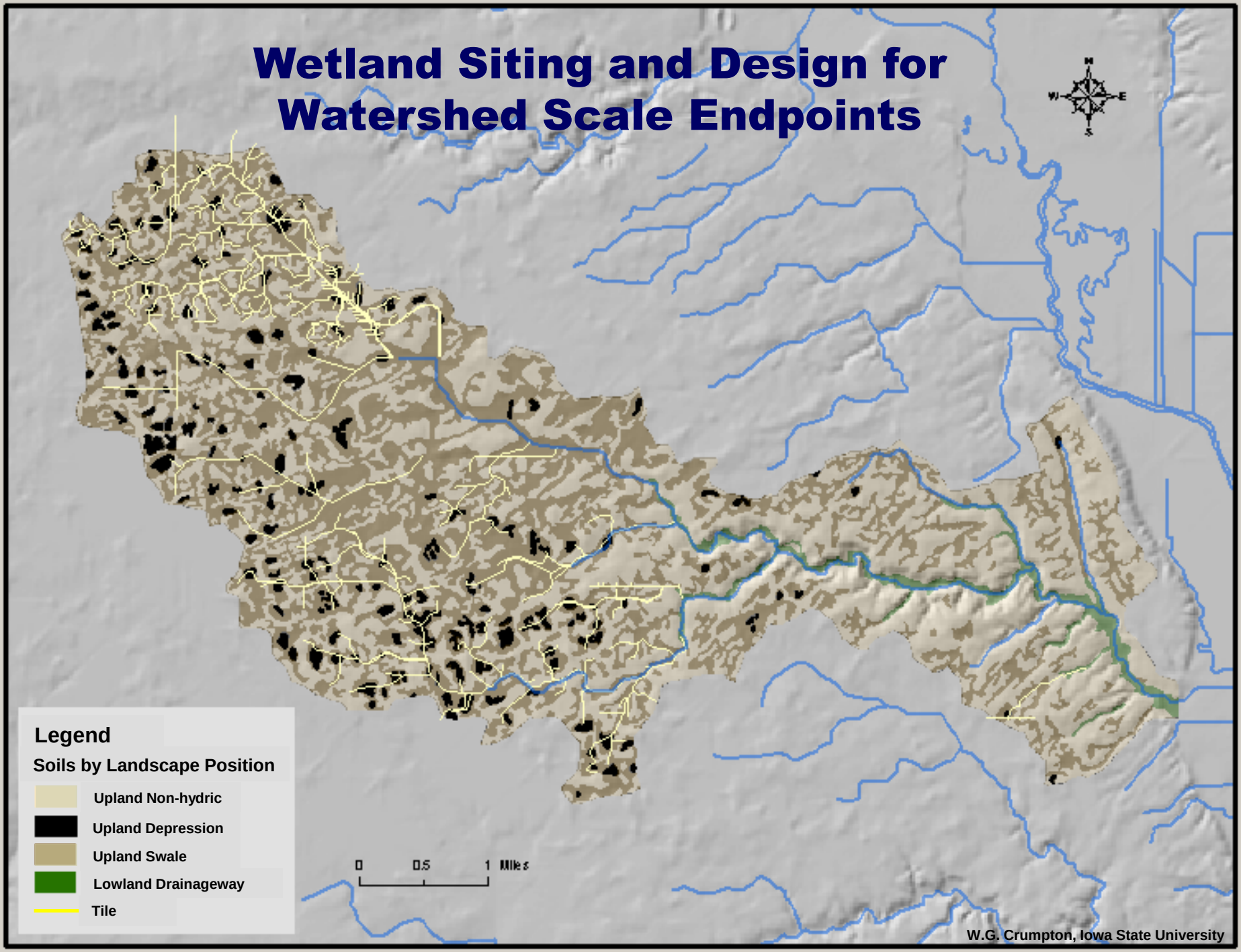
VH 2009


Nitrate-N (mg L-1)
Inflow (m3 d-1)
0
5
10
15
20
25
0
5000
10000
15000
20000
25000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Observed nitrate-N inflow (mg/L)
Observed nitrate-N outflow (mg/L)
Model expected outflow nitrate range
Inflow

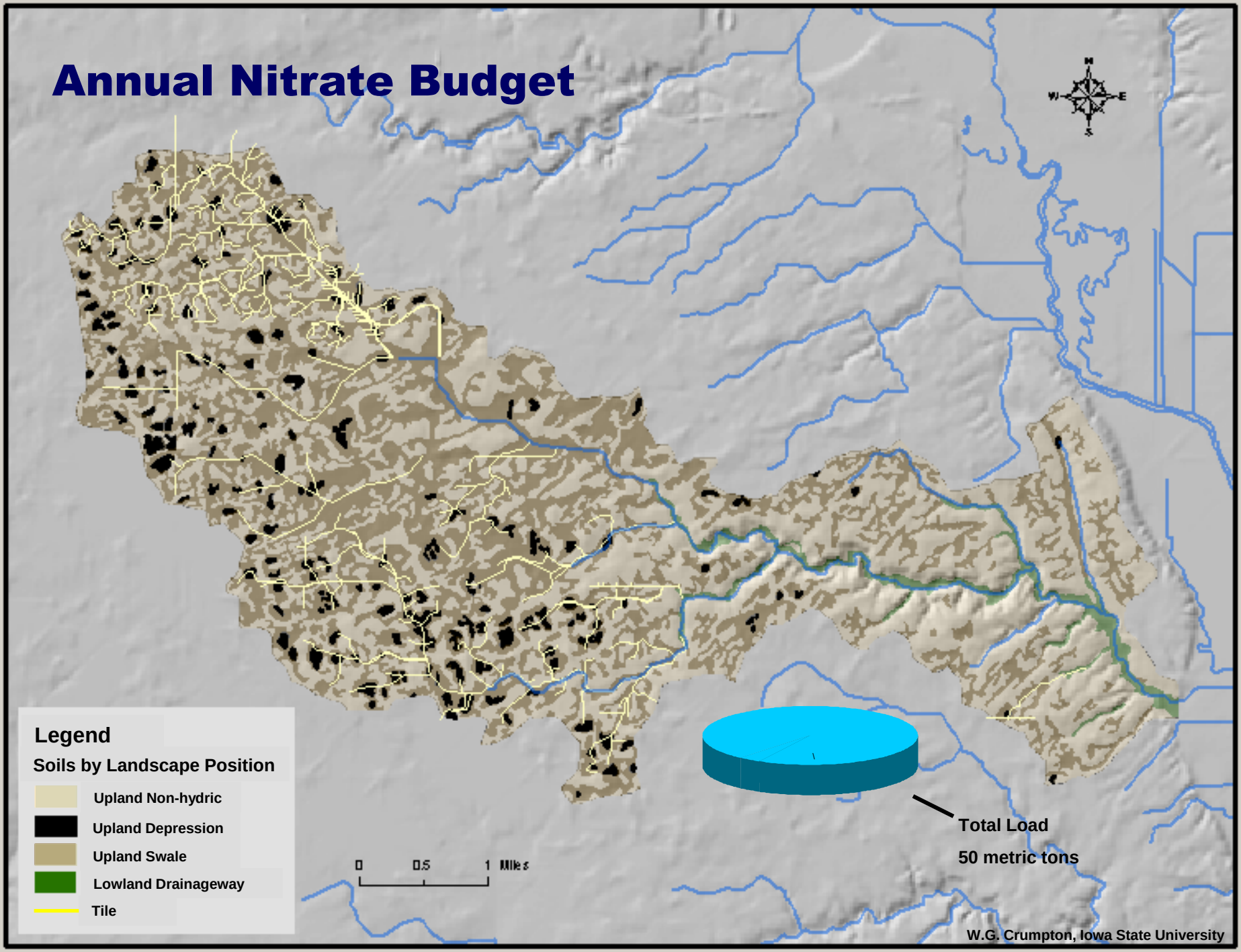
Restoring Wetlands as N Sinks in Agricultural Watersheds

- N transformation and transport in agricultural landscapes
- N transformation in wetlands receiving NPS loads
- N removal performance of wetlands receiving NPS loads
- **Targeting wetland restorations to reduce NPS N loads**

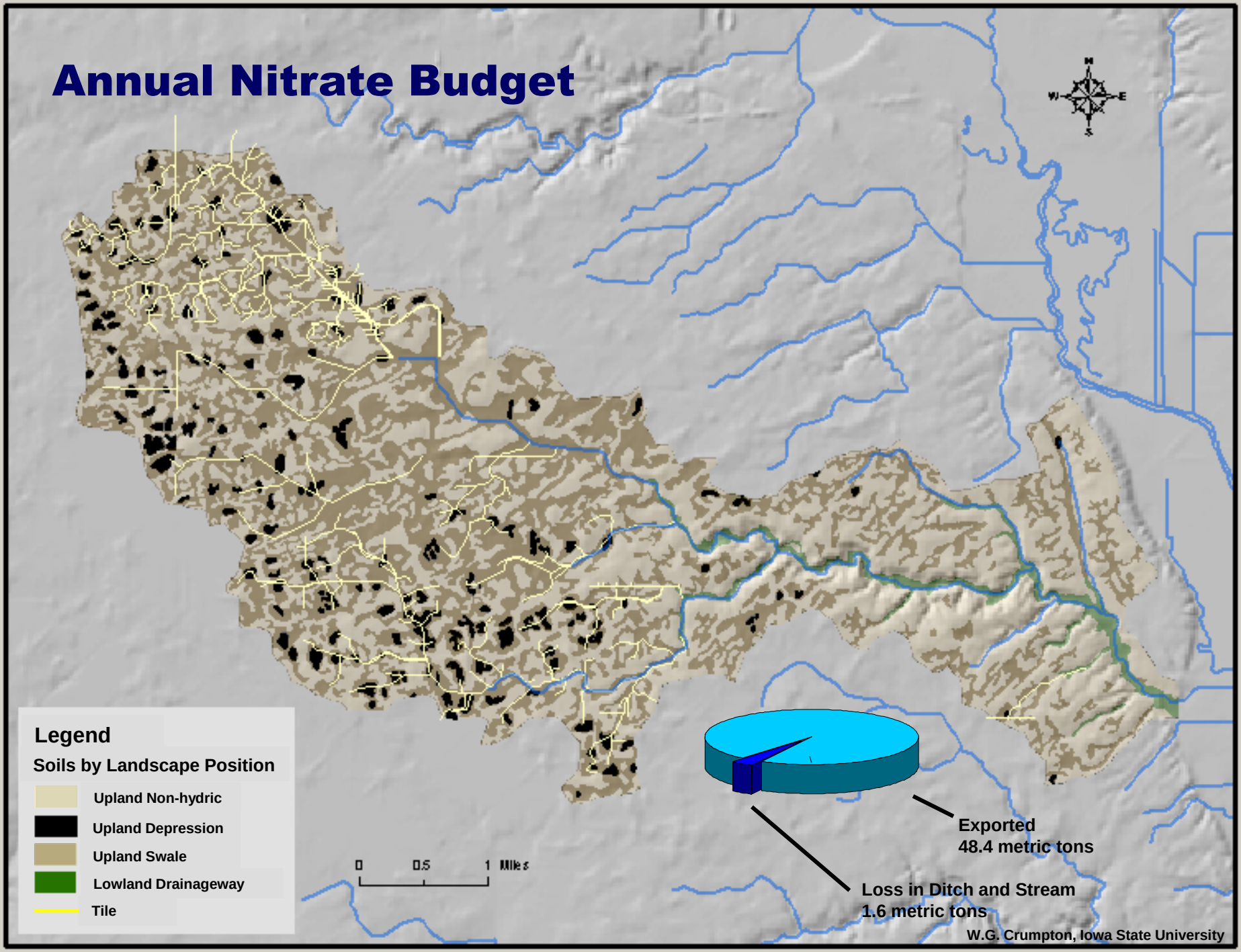
Wetland Siting and Design for Watershed Scale Endpoints



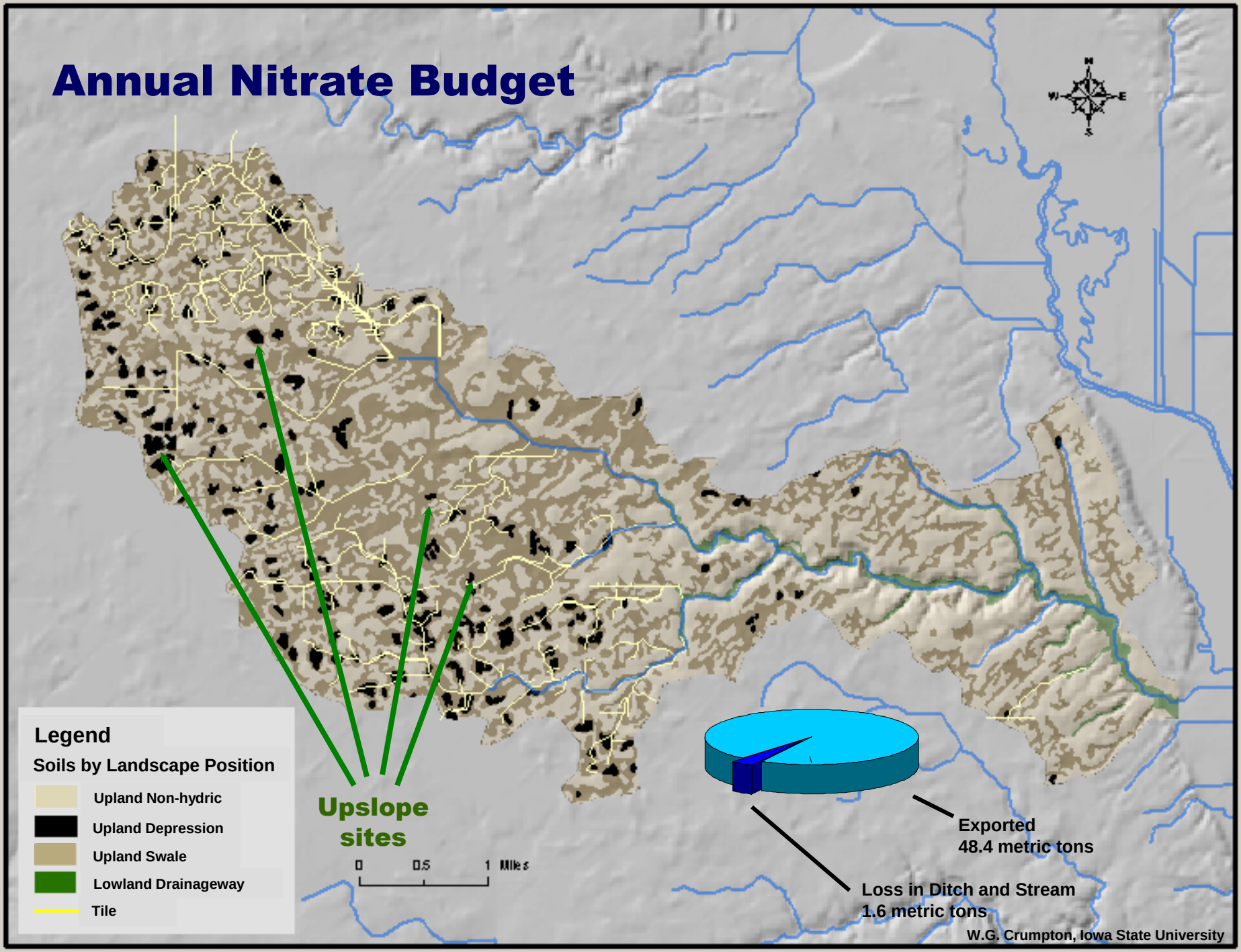
Annual Nitrate Budget



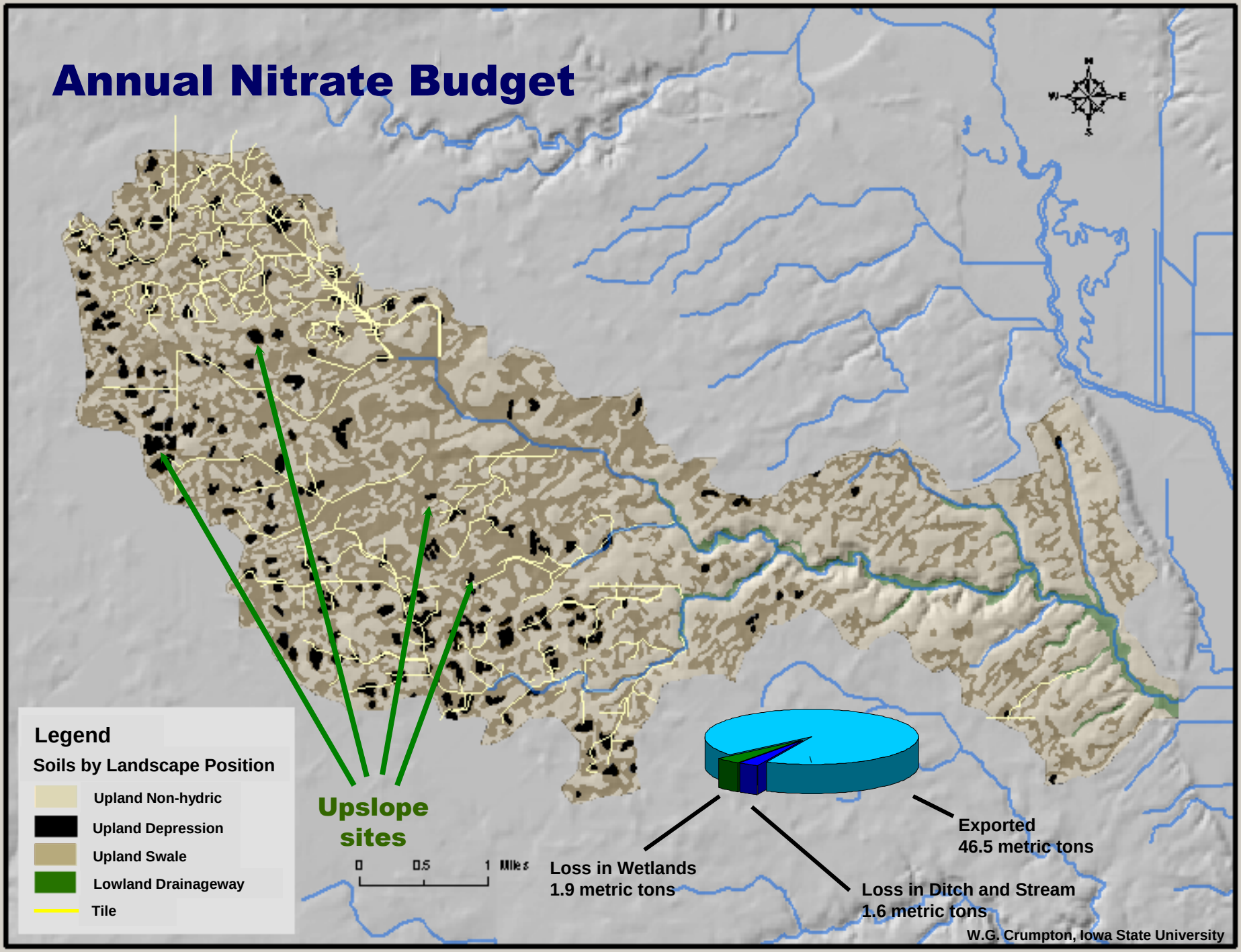
Annual Nitrate Budget

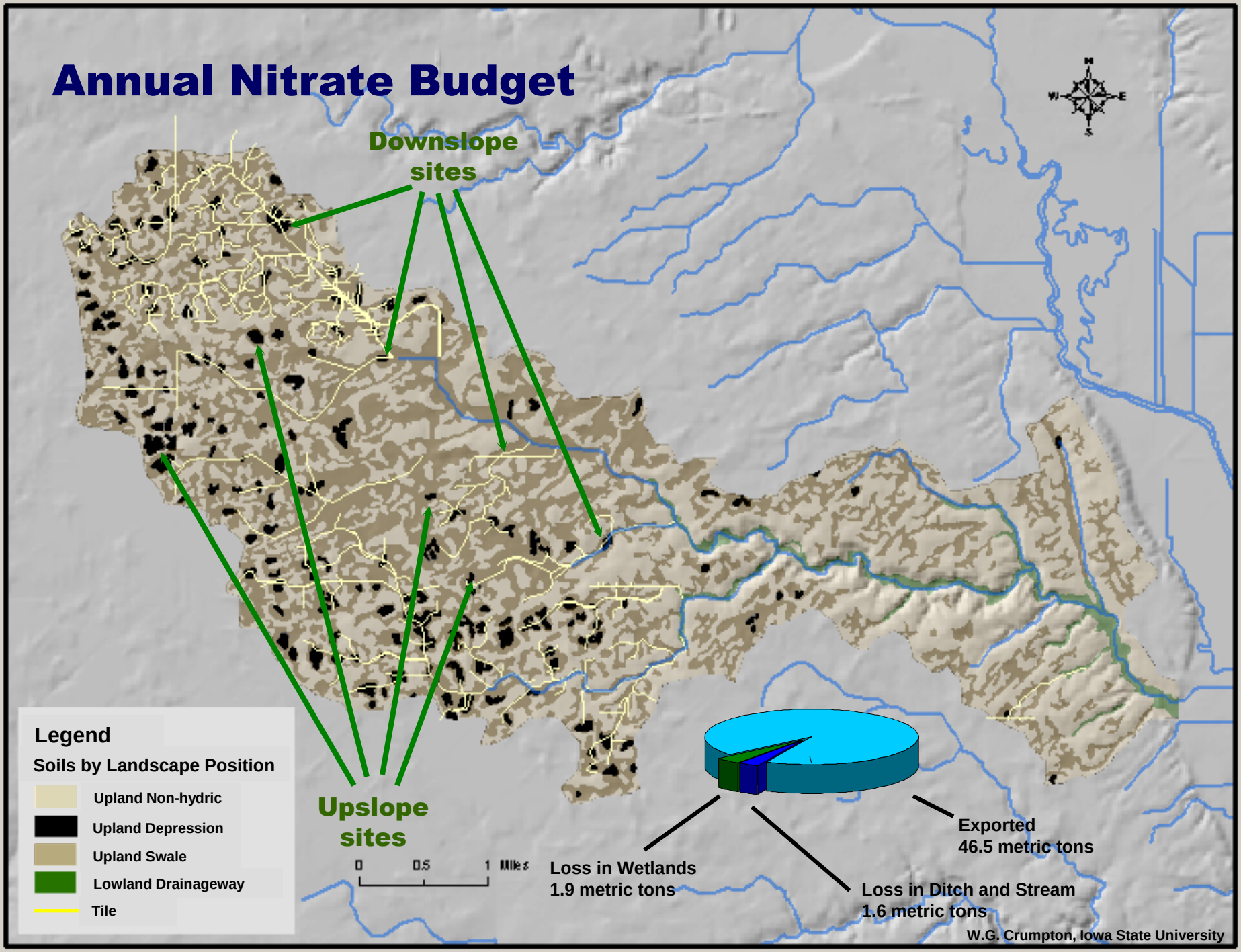


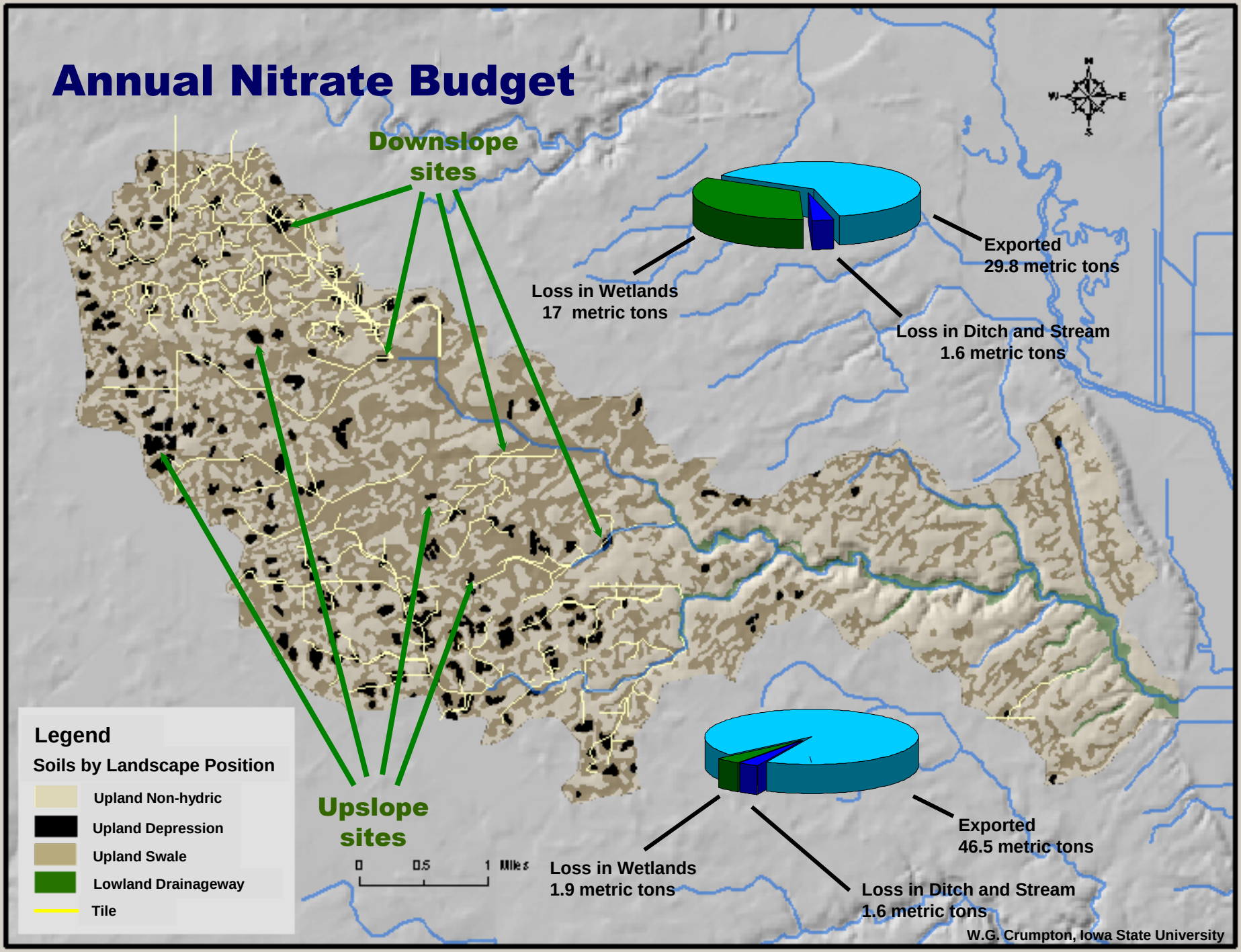
Annual Nitrate Budget



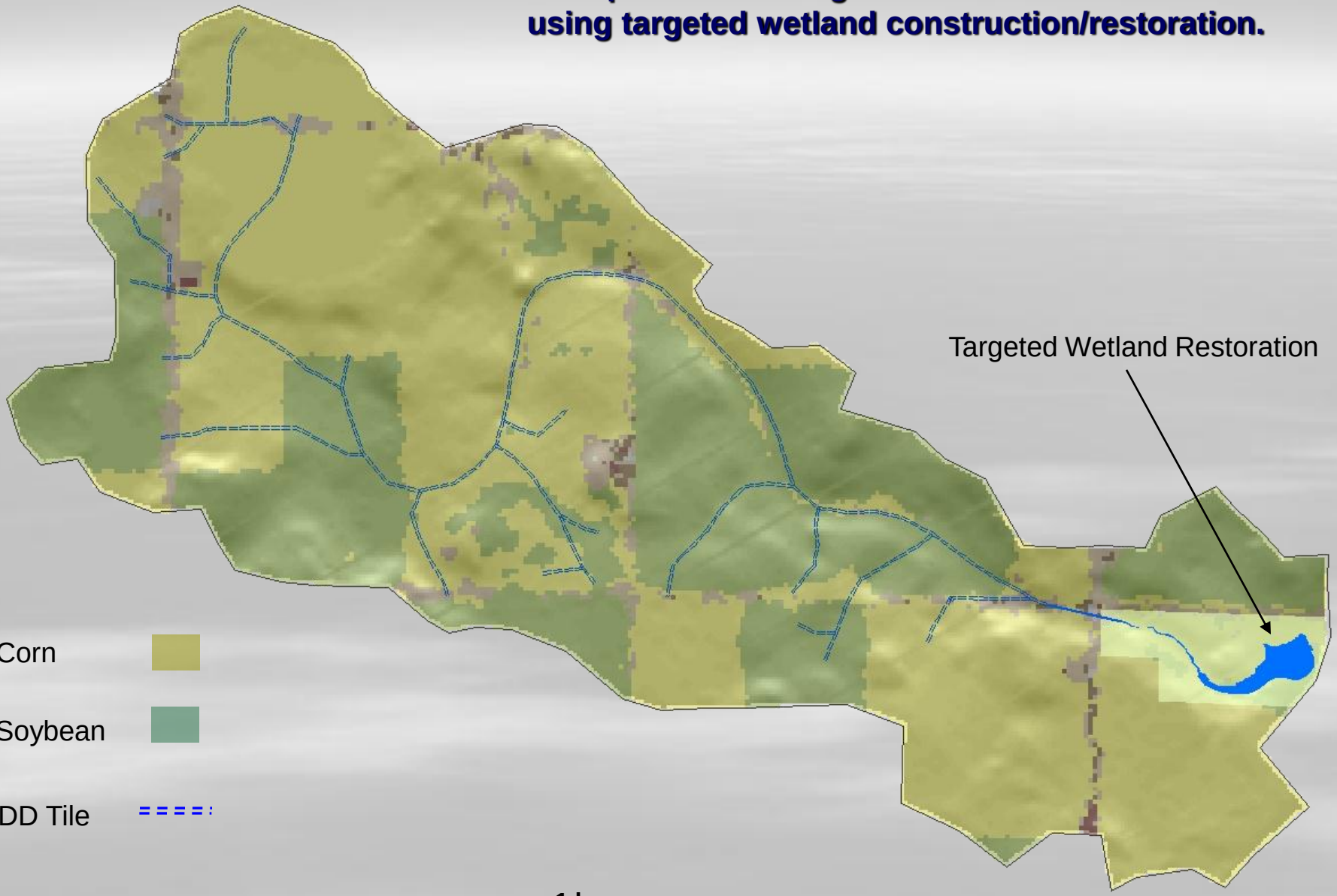
Annual Nitrate Budget




Annual Nitrate Budget
Downslope sites
Upslope sites
Legend
Soils by Landscape Position
Upland Non-hydric
Upland Depression
Upland Swale
Lowland Drainageway
Tile
0
0.5
1 Miles
Loss in Wetlands
1.9 metric tons
Loss in Ditch and Stream
1.6 metric tons
Exported
46.5 metric tons
W.G. Crumpton, Iowa State University


Annual Nitrate Budget
Downslope sites
Upslope sites
Exported 29.8 metric tons
Loss in Wetlands 17 metric tons
Loss in Ditch and Stream 1.6 metric tons
Exported 46.5 metric tons
Loss in Wetlands 1.9 metric tons
Loss in Ditch and Stream 1.6 metric tons
Legend
Soils by Landscape Position
Upland Non-hydric
Upland Depression
Upland Swale
Lowland Drainageway
Tile
0 0.5 1 Miles
W.G. Crumpton, Iowa State University

There is potential for significant NPS N load reductions using targeted wetland construction/restoration.



W.G. Crumpton, Iowa State University

www.IowaCREP.org

IOWA CONSERVATION RESERVE ENHANCEMENT PROGRAM

- Home
- Program Information
- Water quality issues
- Monitoring
- Images
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Overview

The Iowa Conservation Reserve Enhancement Program (CREP) is a joint effort of the Iowa Department of Agriculture and Land Stewardship (IDALS) and the USDA Farm Service Agency in cooperation with local Soil and Water Conservation Districts that provides incentives to landowners to voluntarily restore wetlands targeted for water quality improvement in the heavily tile-drained regions of Iowa.

The goal of the program is to reduce nitrogen loads and movement of other agricultural chemicals from croplands to streams and rivers by targeting wetland restorations to the sweet spots on the landscape that provide the greatest water quality benefits. CREP wetlands are targeted to receive tile drainage by gravity flow, treating the water before it enters downstream waters.

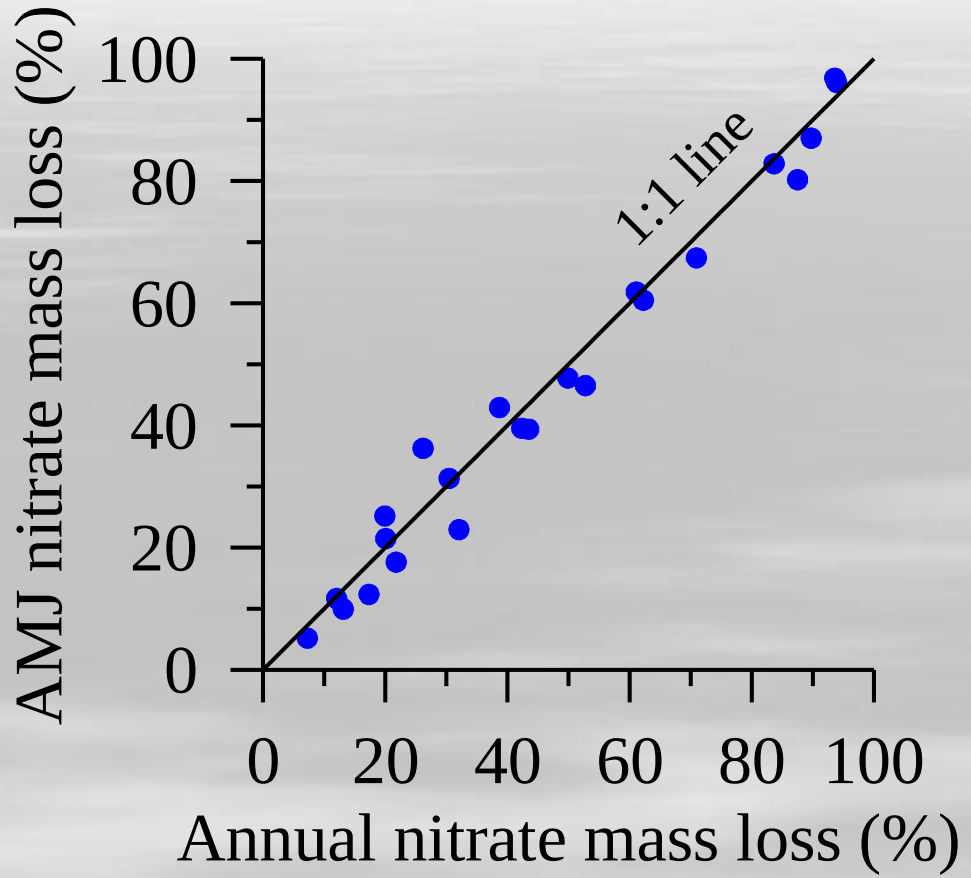
In order to ensure wetlands are targeted to the most advantageous locations, IDALS uses advanced GIS analyses to find locations that are properly sized and situated to maximize water quality benefits. Wetland sizing and targeting criteria is based on nearly two decades of research and monitoring by Iowa State University (ISU).

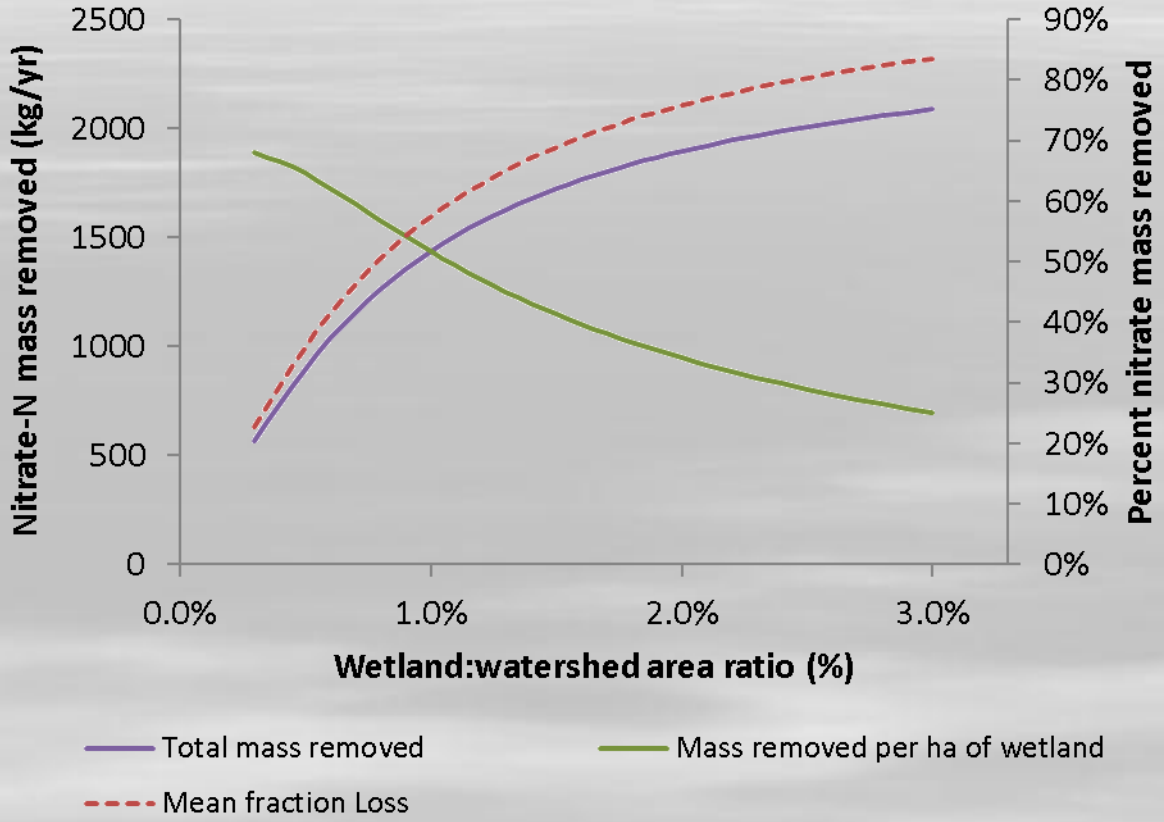
Research and monitoring by ISU shows that CREP wetlands can remove 40-70% of nitrogen loads from cropland drainage waters. Nitrogen reduction is primarily achieved through naturally occurring denitrifying bacteria in wetlands. Through denitrification, bacteria remove nitrate from the water and release it as nitrogen gas into the air as an innocuous end product.

In addition to improving water quality, these wetlands provide high quality wildlife habitat and recreational opportunities. The high quality buffers in conjunction with the shallow wetland habitats of these areas have proven to be a tremendous boon to a multitude of wildlife. CREP wetlands are particularly popular with duck and pheasant hunting enthusiasts and are widely used for these activities. From trumpeter swans to shorebirds and everything in between, these areas have shown that wetland restorations targeted for water quality benefits provide high quality habitat benefits as well.

W.G. Crumpton, Iowa State University

April/May/June Performance





For a 1 km^2 watershed having WY = 0.25 m/yr and FWA nitrate-N concentration of 10 mg/L. This gives a total inflow load of 2500 kg N per year.