

Riparian, stream and floodplain restoration in urban watersheds: the experience from the Baltimore Ecosystem study

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Cary Institute of Ecosystem Studies

With contributions from the scientists and support staff of the Baltimore Ecosystem Study (LTER)



OUTLINE:

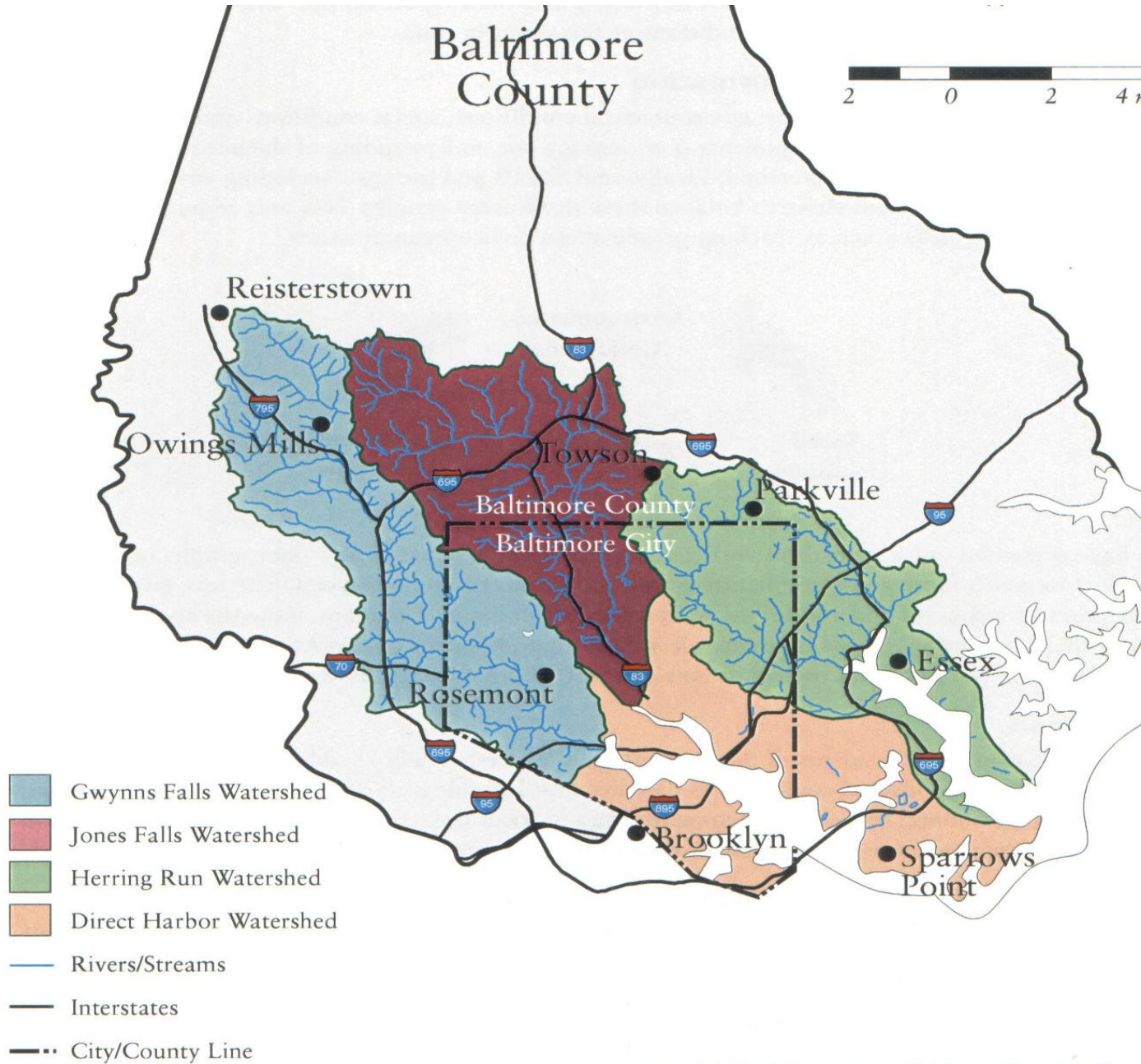
- Introduction to Baltimore Ecosystem Study (BES).
- Long-term data shows the challenge of legacies
- Stream and riparian restoration:
 - Stormwater detention basins
 - Minebank Run
- Deep urban restoration:
 - Baltimore City consent decree
 - Water quality and restoration in decaying neighborhoods
- Socio-ecological dynamics

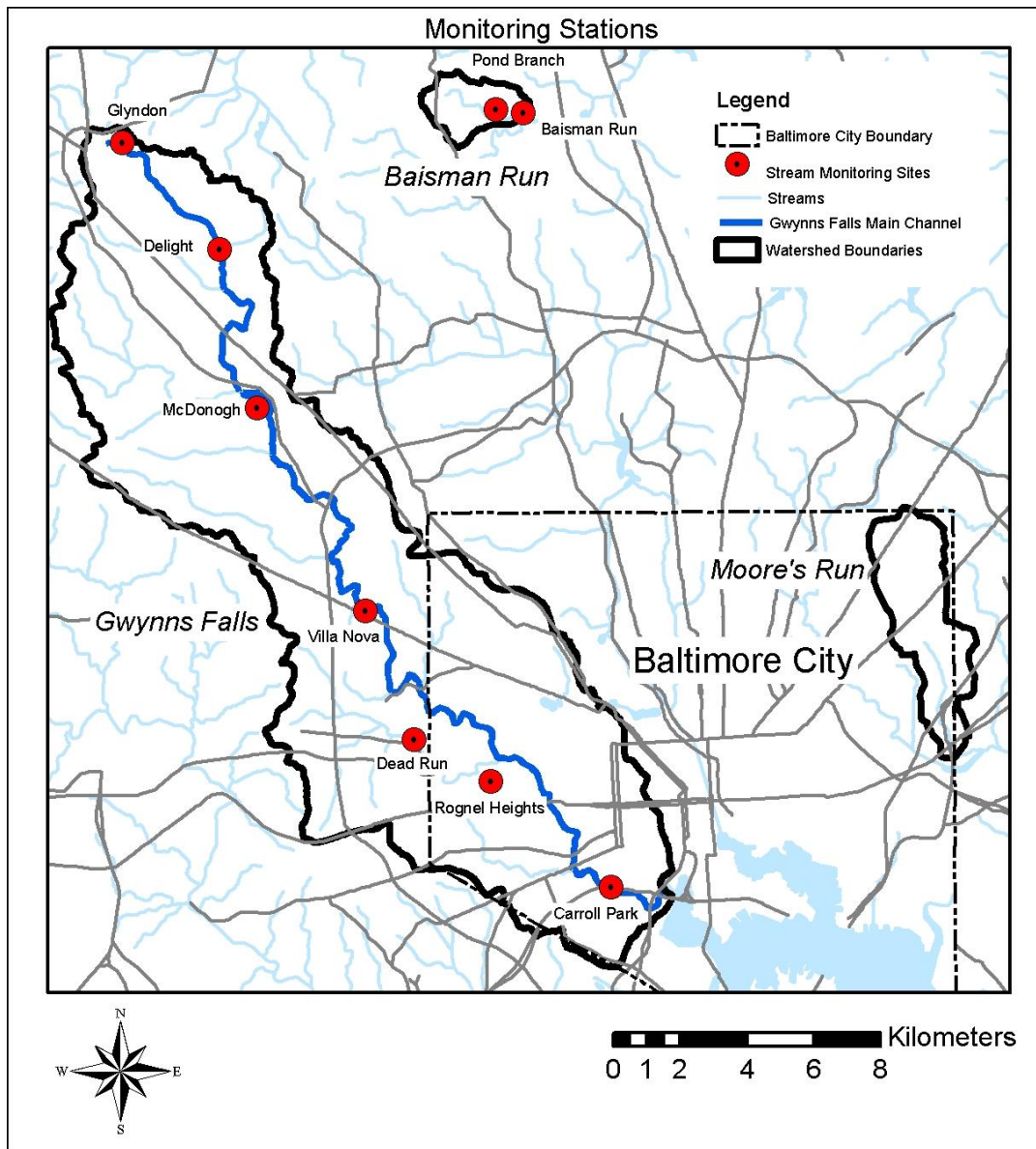
BALTIMORE ECOSYSTEM STUDY

- Component of the NSF LTER network.
- Collaborative effort: Cary Institute, USFS, UNC, USGS, UMBC, UMD, UVM, JHU, PPF, UMO, UCD.
- Components include:
 - Watershed studies
 - Internal dynamics (soils, vegetation, hydrology)
 - Modeling and spatial analysis
 - Social science
 - Historical analysis
 - Education/outreach/understanding

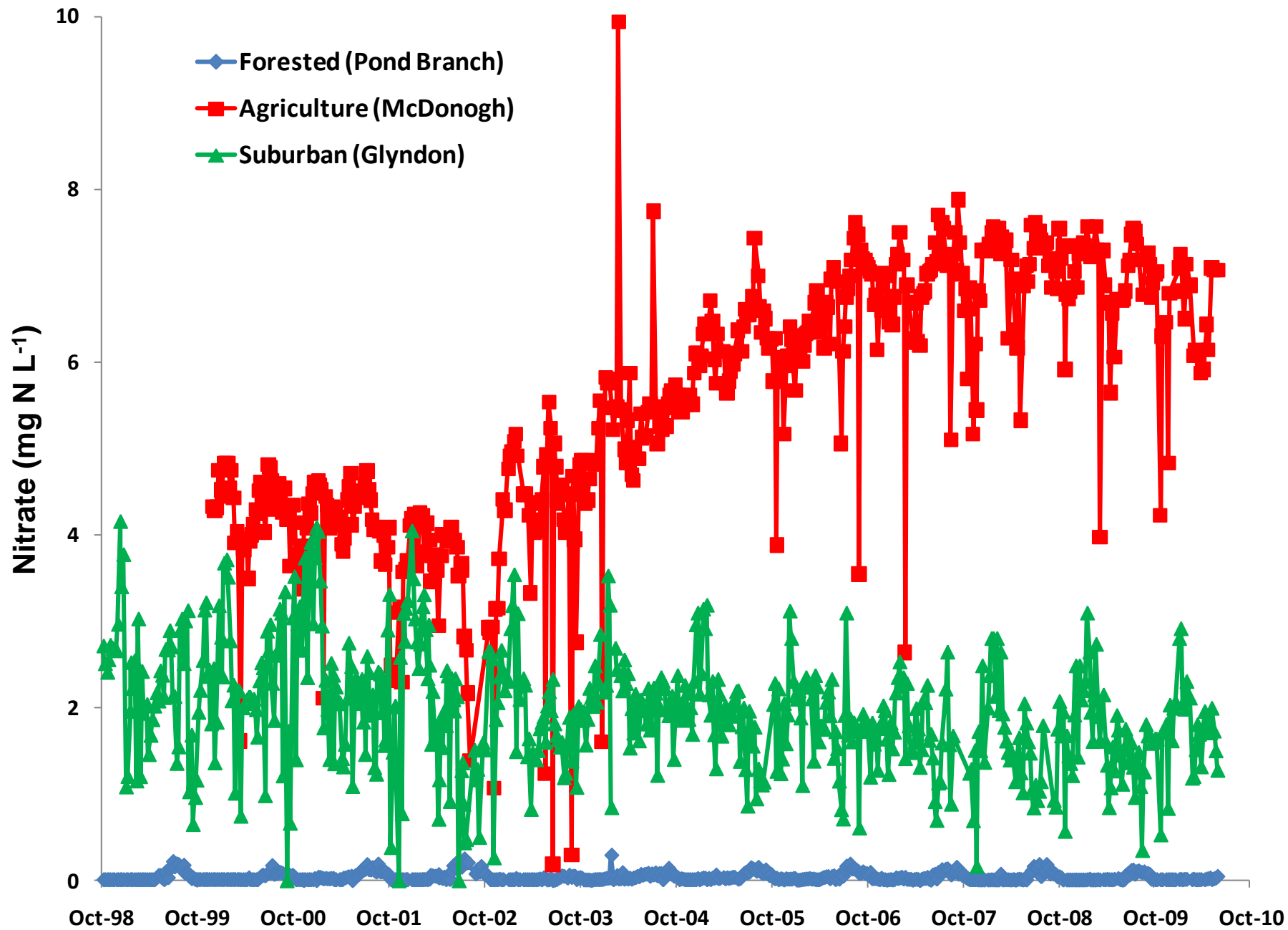
BES and the Chesapeake Bay:

- Provide data on the “urban signal:”
 - Long-term data
 - Publicly available: <http://beslter.org>
- Research on urban watershed processes:
 - Instream
 - Riparian
 - Upland:
 - Forests
 - Lawns
 - Septics
- Coupled socio-ecological approach





Sources: Mike McGuire, UMBC (above) and Guy Hager, Parks & People Foundation (right).



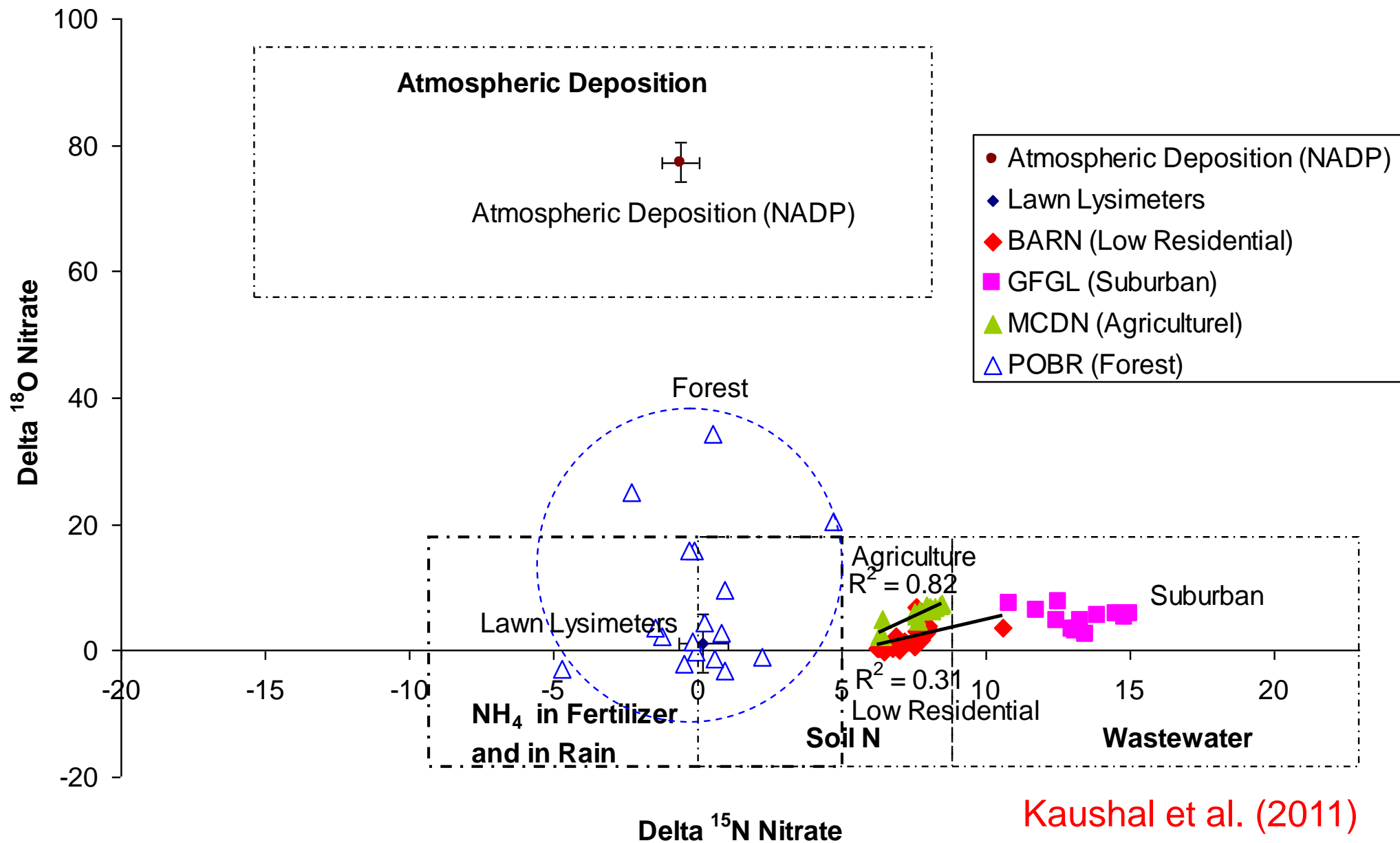
Source: Groffman et al. (2004)

Nitrogen and oxygen isotopes can identify nitrate sources in streams:

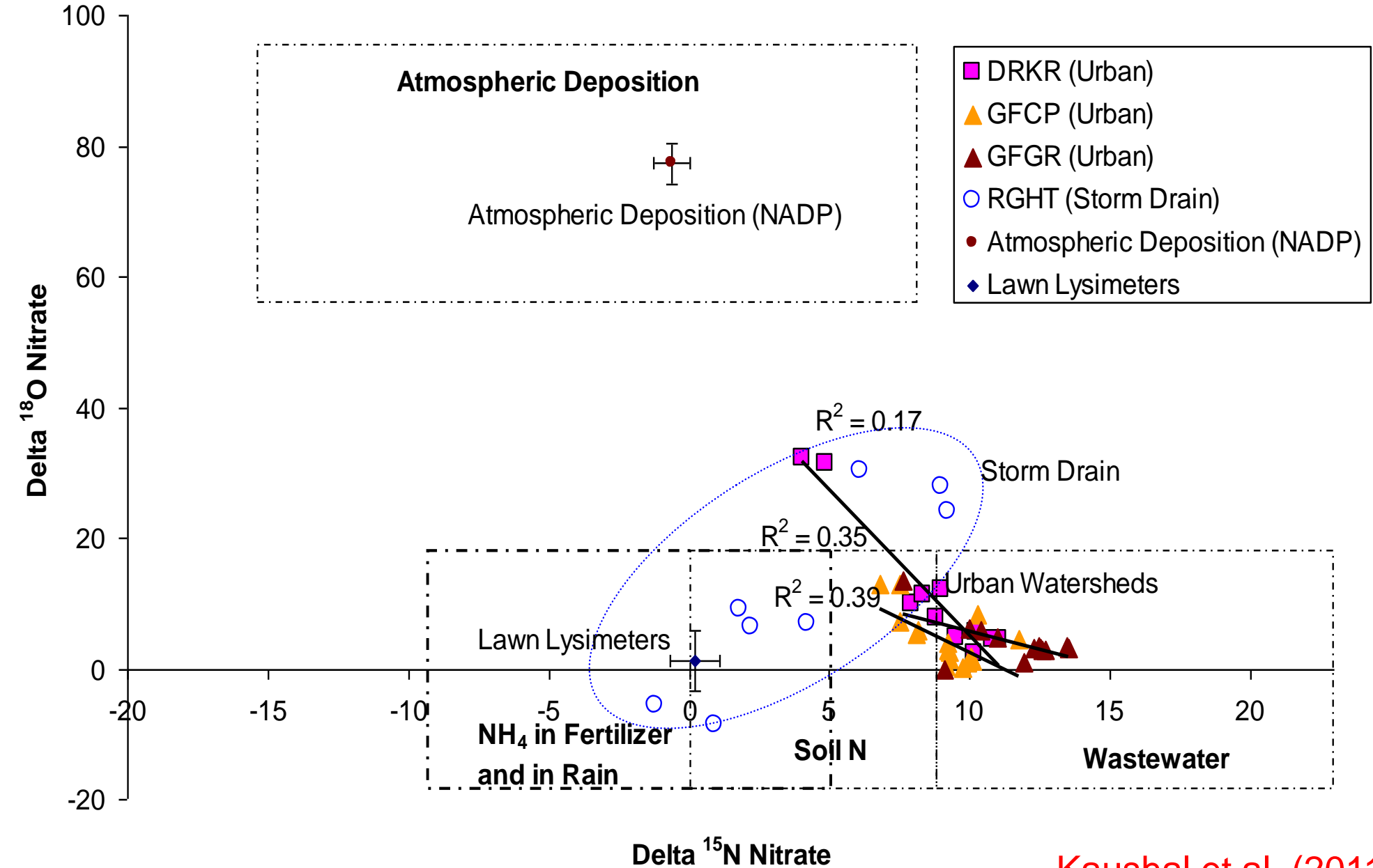


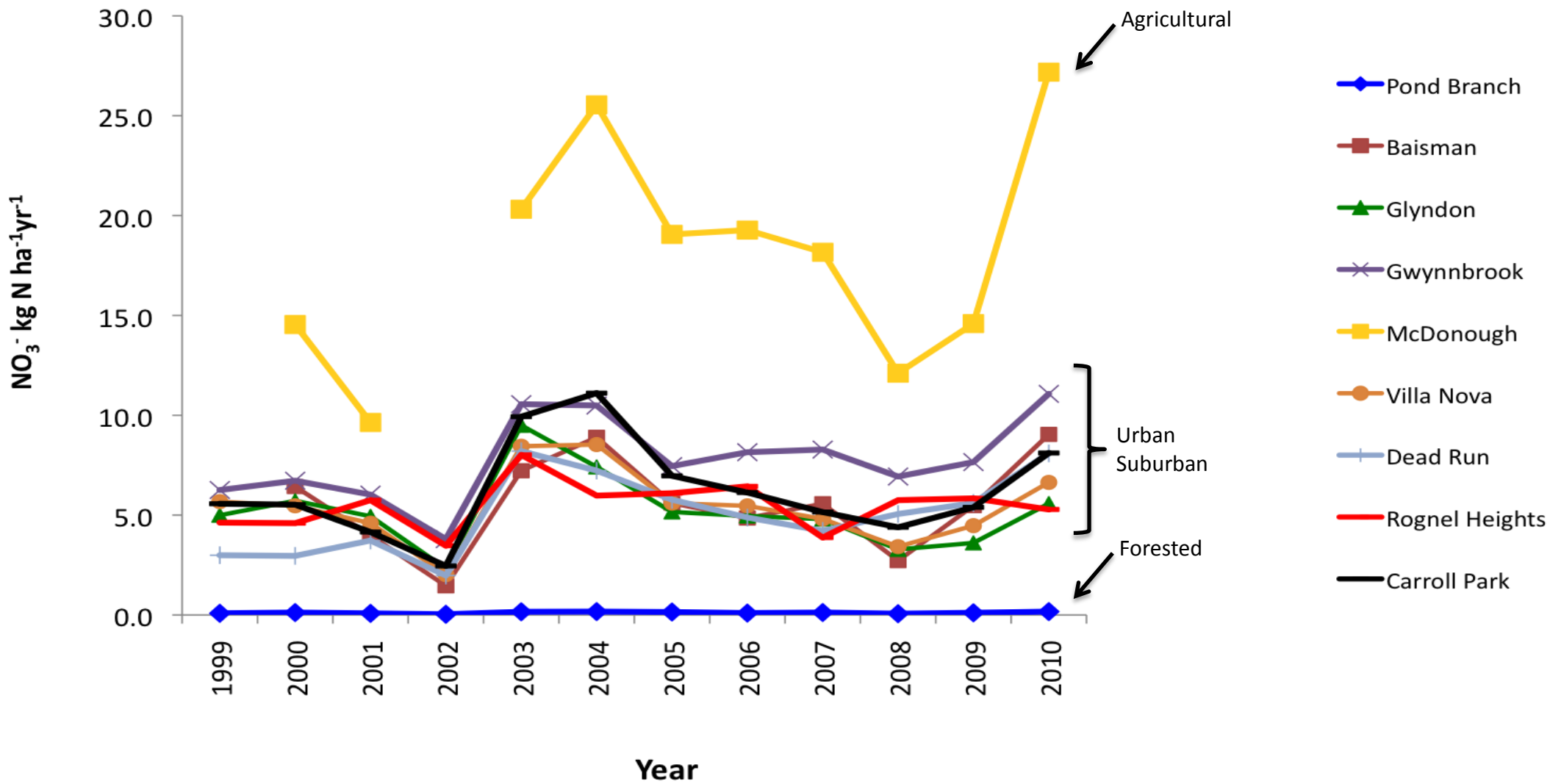
- **Atmospheric Sources:** Delta ^{15}N of nitrate decreases while delta ^{18}O increases.
- **Fertilizer:** Delta ^{15}N of nitrate is low and ^{18}O remains low.
- **Wastewater:** Delta ^{15}N of nitrate is +10 to 20, and delta ^{18}O remains low.
- **Denitrification:** Delta ^{15}N of nitrate increases while delta ^{18}O increases.

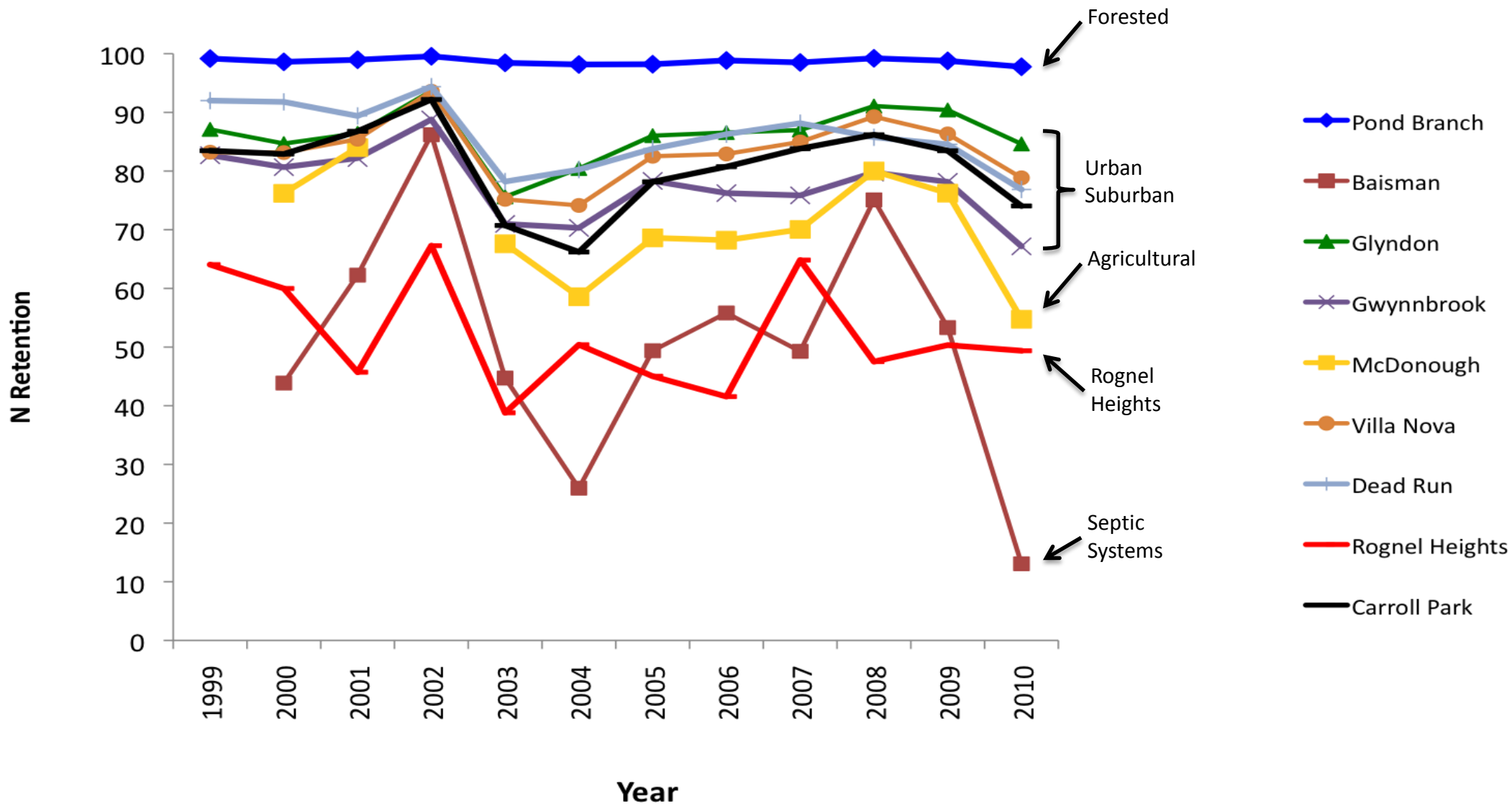
Nitrate sources in forest, agricultural and suburban watersheds:



Nitrate sources in urban watersheds:



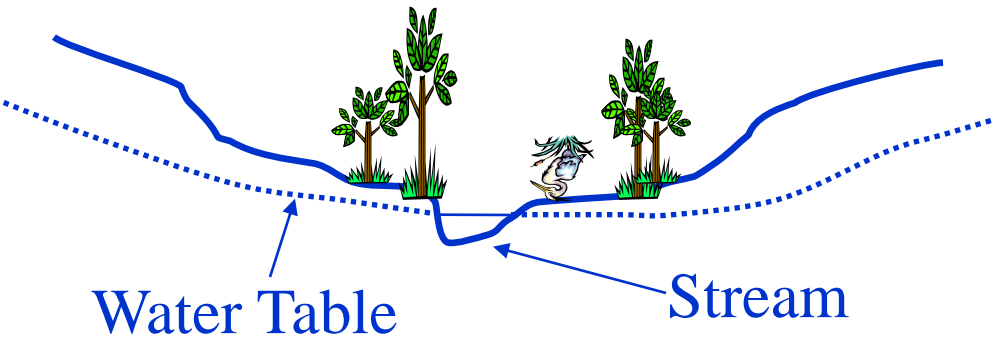




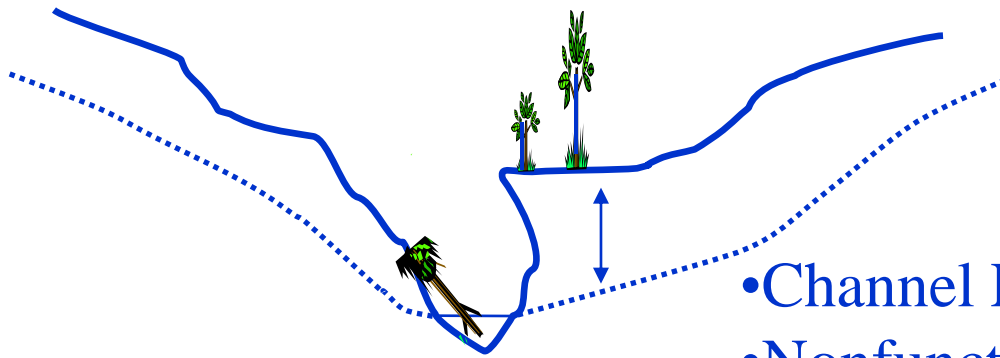
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 - What is the potential for management and restoration to improve the environmental performance of urban ecosystems?

Natural Channel



Channel with Incision Due to Increased Runoff



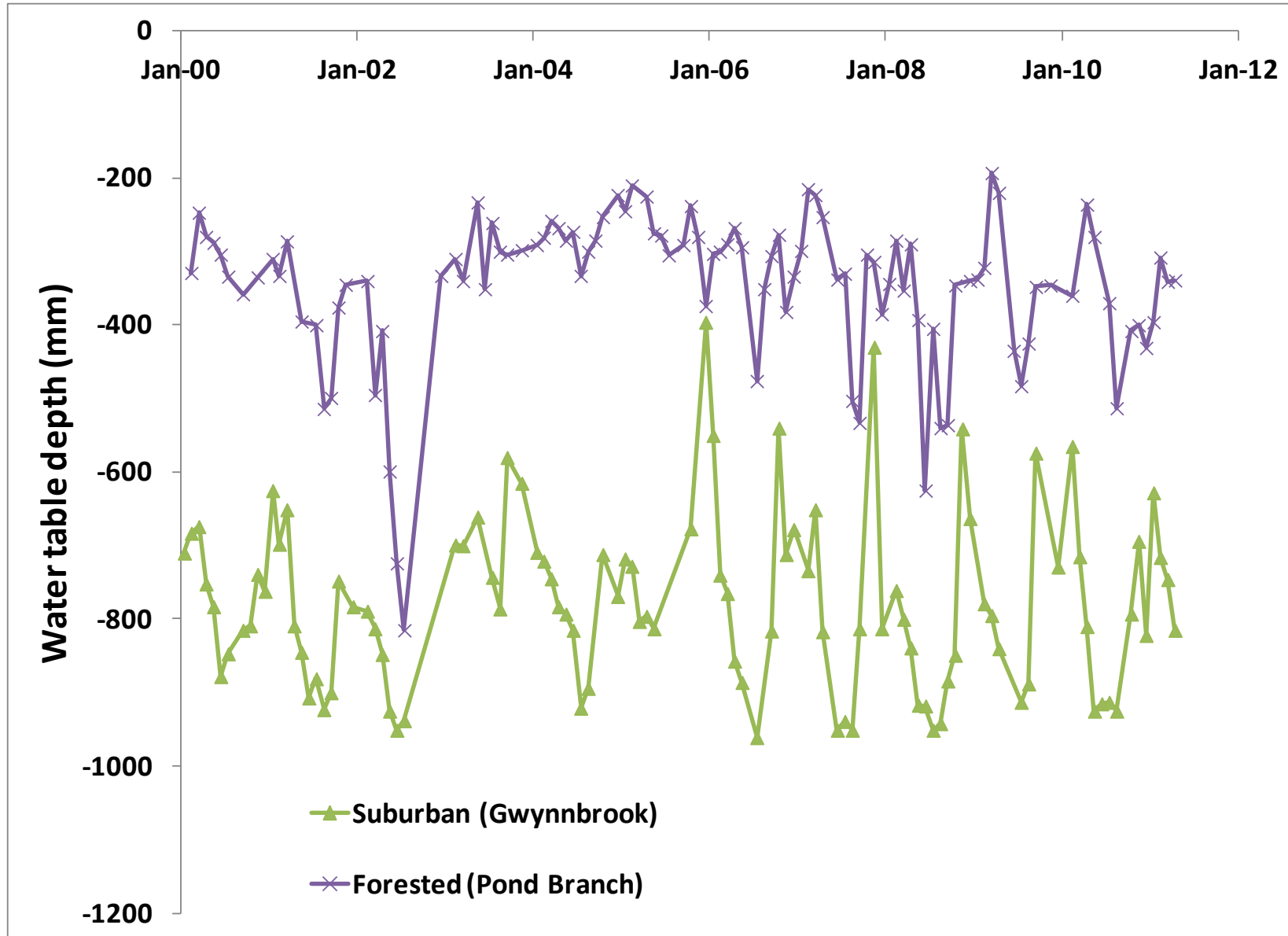
- Channel Erosion
- Nonfunctional Floodplain
- Dry Riparian Soils

- Urban stream syndrome:
 - High storm flows.
 - Incised channels.
 - Drier riparian zones with lower water tables.

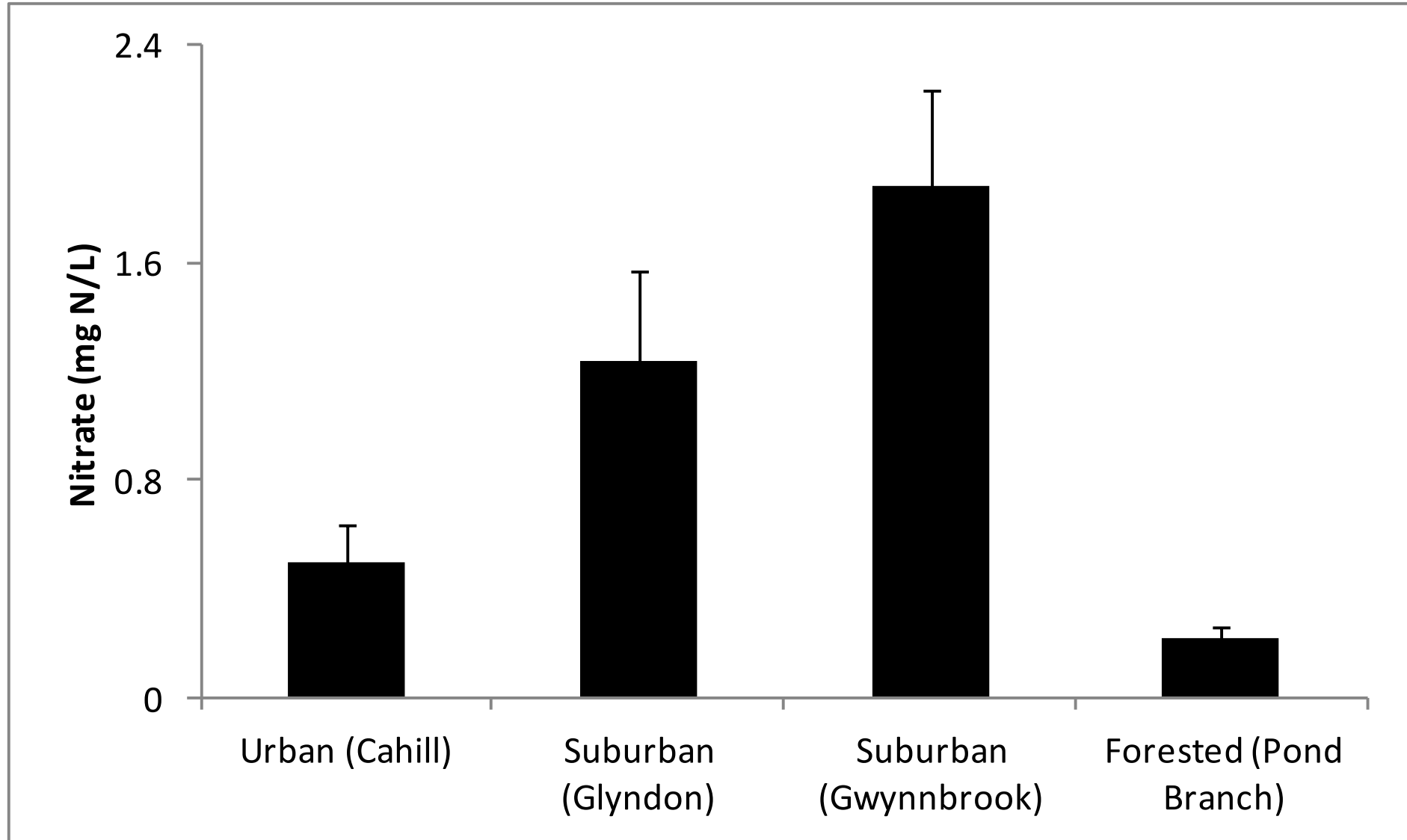
Urban stream syndrome:



Urban stream syndrome results in drier soils and lower water table in riparian zone:



Urban stream syndrome results in higher groundwater nitrate in riparian zone:



Denitrification



- Anaerobic
- Heterotrophic (requires organic C)
- Expect high rates in wetland soils.
- Key component of the water quality maintenance function of wetlands.
- N_2O is a greenhouse gas.

Are detention basins the new riparian zone?



- Stormwater structures (detention basins) are engineered to mitigate impact of impervious surfaces on stream discharge.
- Their impact on nutrients (especially nitrogen) is unclear.

Can you find the detention basins in this suburban landscape?

1/2 mile x 3/4 mile area



Source: Neil Bettez

Can you find the detention basins in this suburban landscape?

1/2 mile x 3/4 mile area



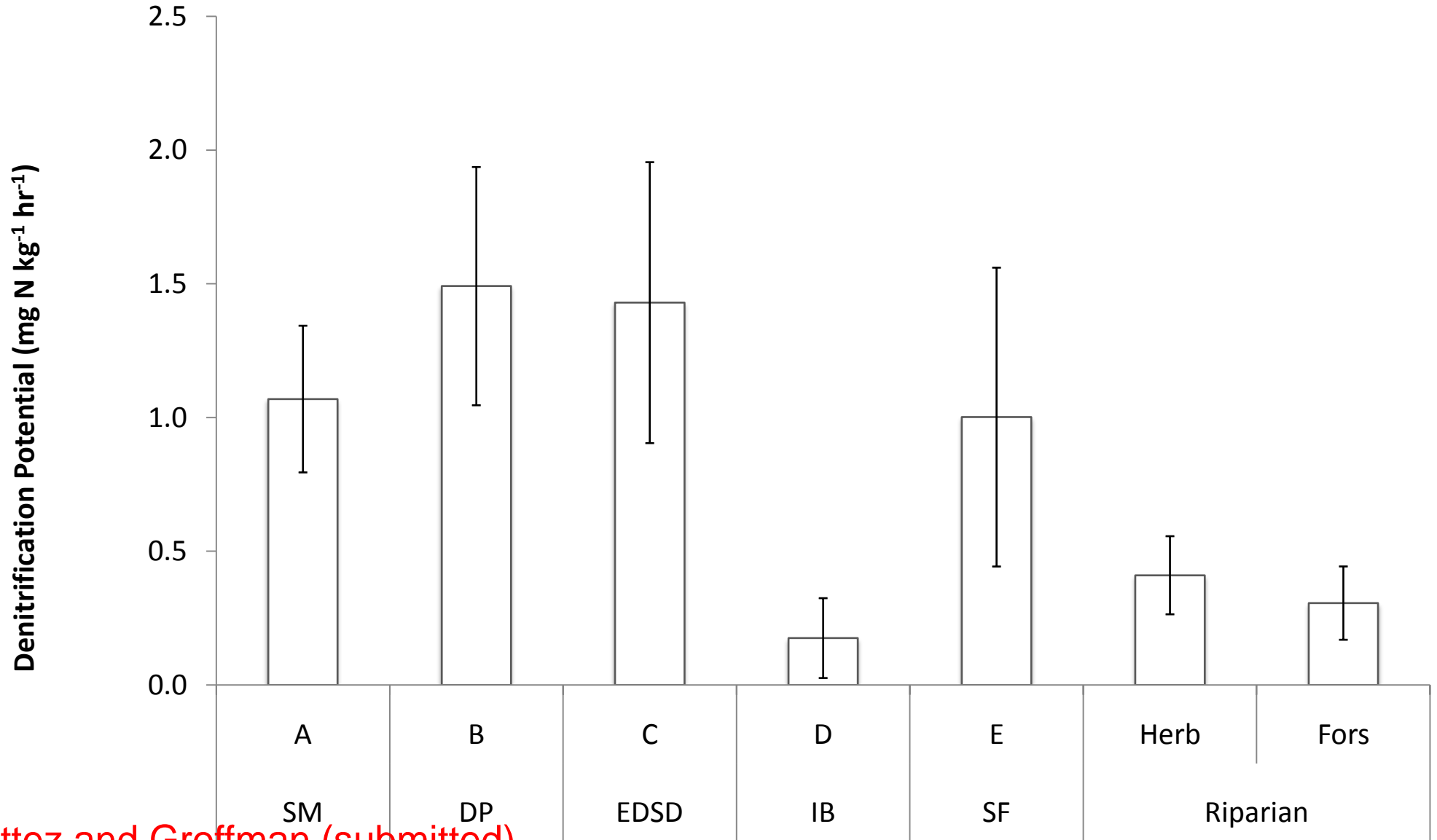
Source: Neil Bettez

Denitrification Enzyme Assay (DEA):

- Denitrification is the anaerobic conversion of nitrate (reactive N) to N_2 gas (unreactive N).
- DEA is a short-term assay that measures potential denitrification by removing factors (oxygen, nitrate, and carbon) that limit denitrification.



DEA higher in detention basins than in natural riparian zones:



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Urban stream syndrome:



Minebank Run project:

- EPA, National Risk Management Research Lab, Ada. Paul Mayer, lead investigator.
 - Project Design, Hydrologic Models, Biogeochemistry
- Baltimore County, Dept Environmental Protection
 - Restoration
- USGS, Water Resources Division, Baltimore
 - Geology, Geomorphology, Geochemistry, Sediments
- Cary Institute of Ecosystem Studies
 - Denitrification
- Maryland Dept. of Natural Resources
 - Biotic Surveys (fish and aquatic invertebrates)

Minebank Run Study Area



Well
Transects

The traditional solution . . .

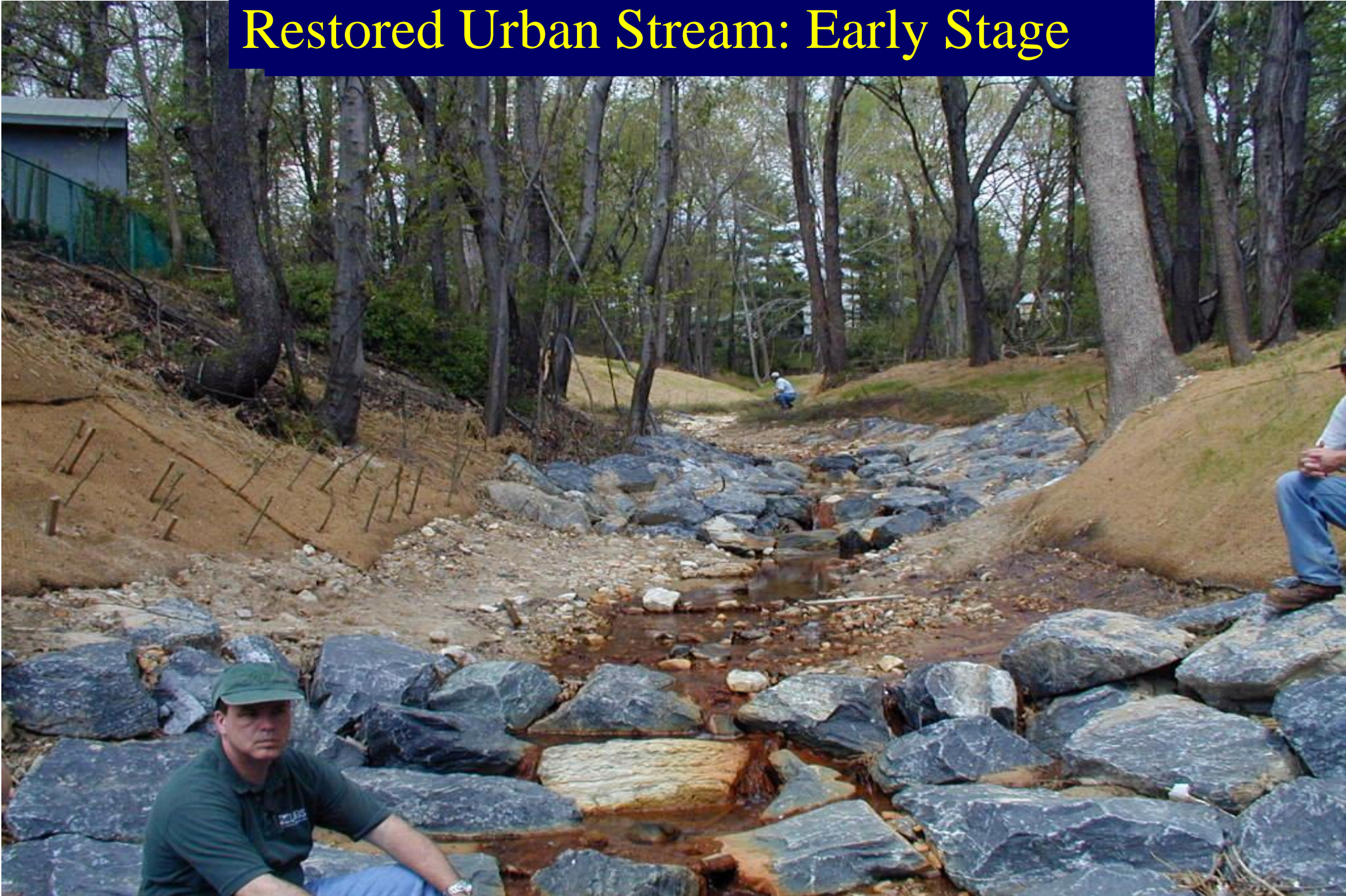


Fig. 3.10 – Stream channelization. Instream modifications, such as uniform cross section and armoring, result in ecological decline.

In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).

By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

Restored Urban Stream: Early Stage



Restored Urban Stream: Developed Stage





Stable, unconnected
floodplain



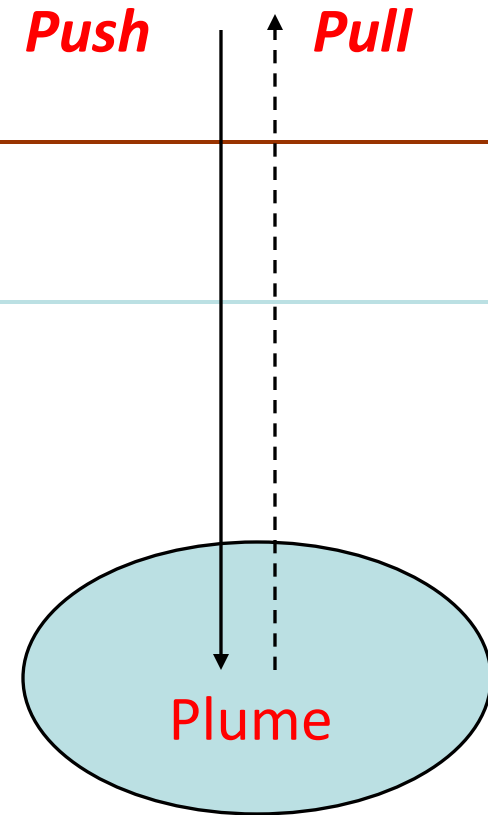
“Connected Floodplain”

Soil Surface

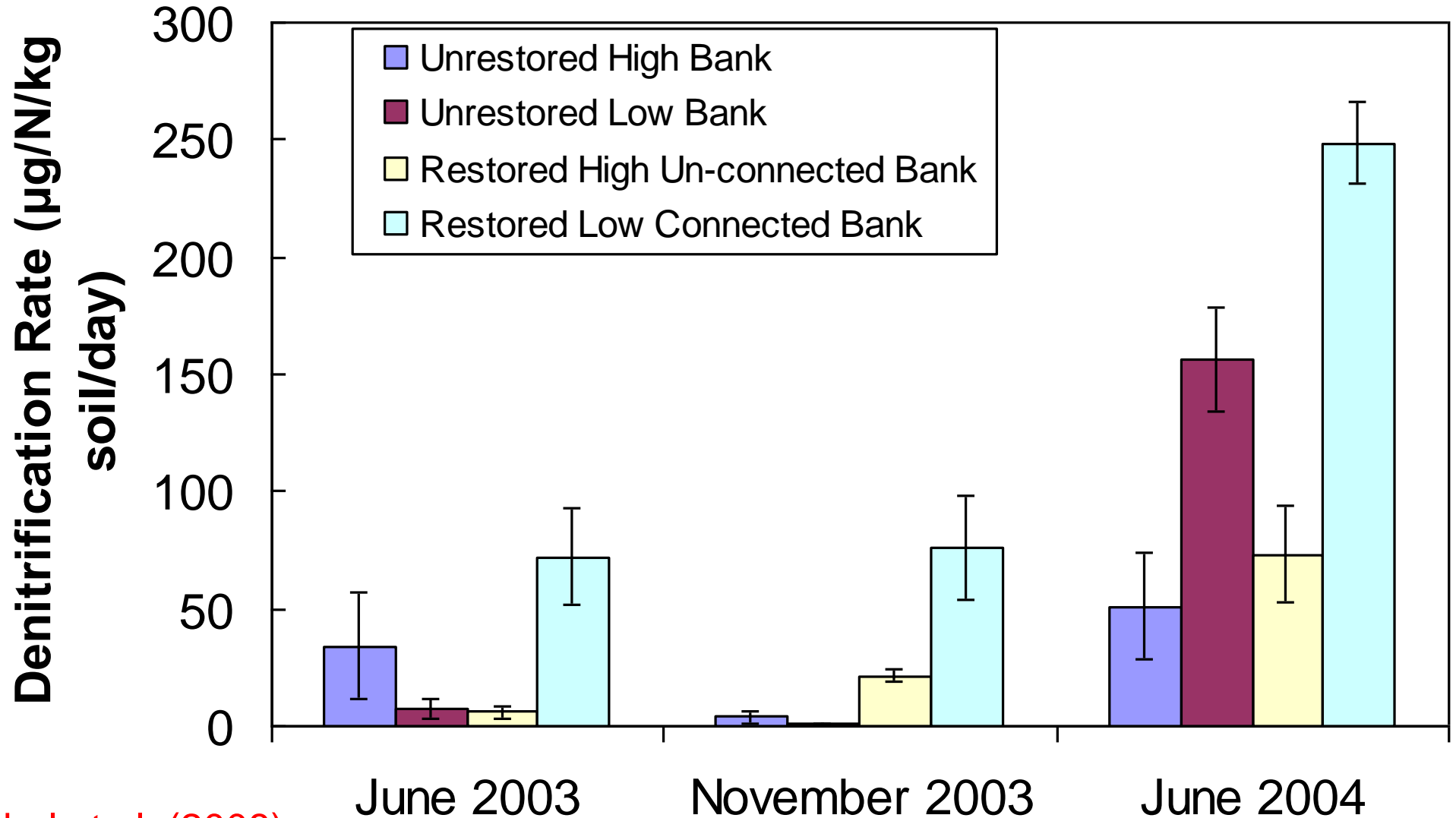
Water Table

Push-Pull Method

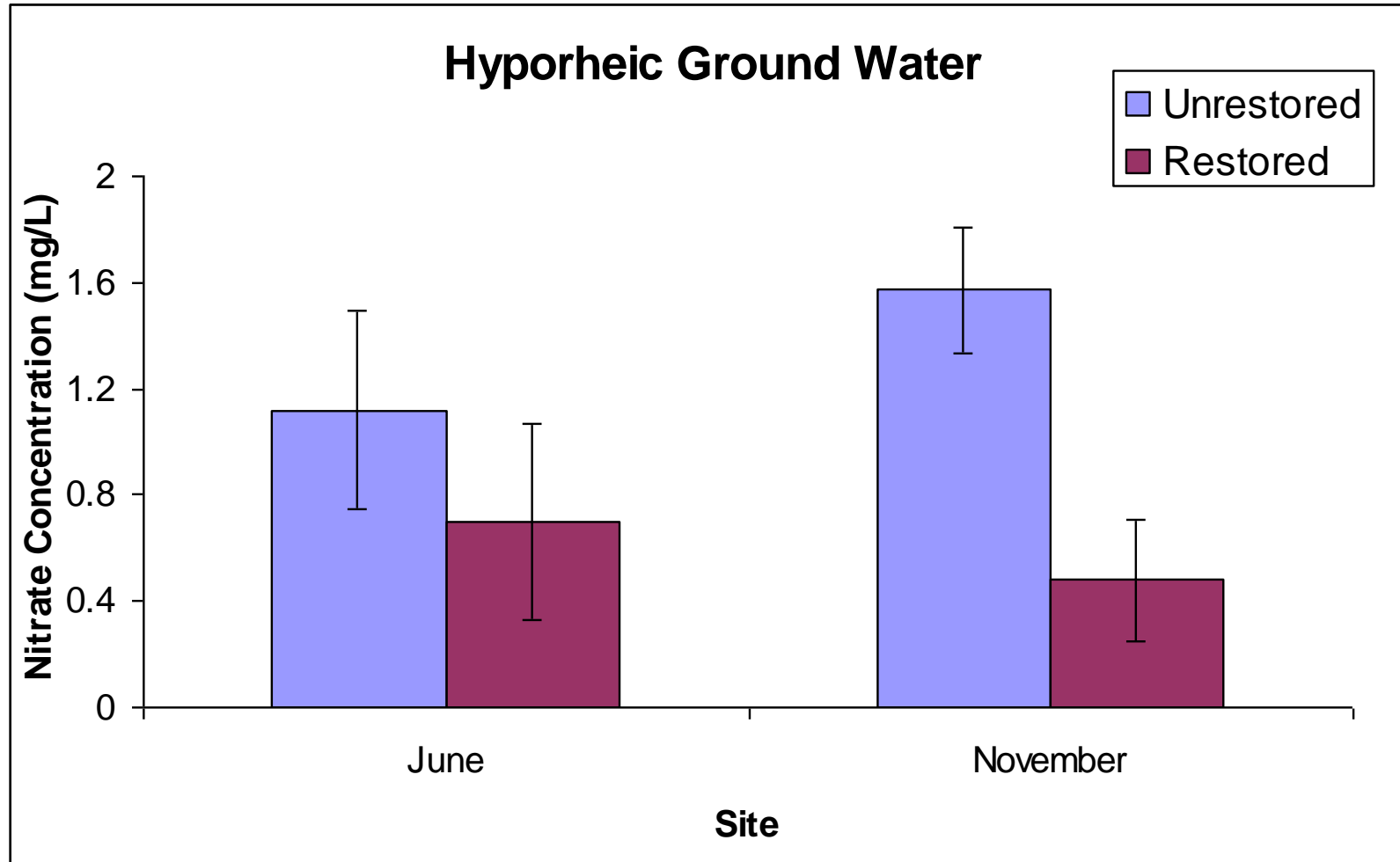
1. Pump ground water
2. Amend with $^{15}\text{NO}_3^-$, Br^- , SF_6
3. Lower DO to ambient levels.
4. Push into mini-piezometer
5. Incubate for 4 hours
6. Pull from mini-piezometer



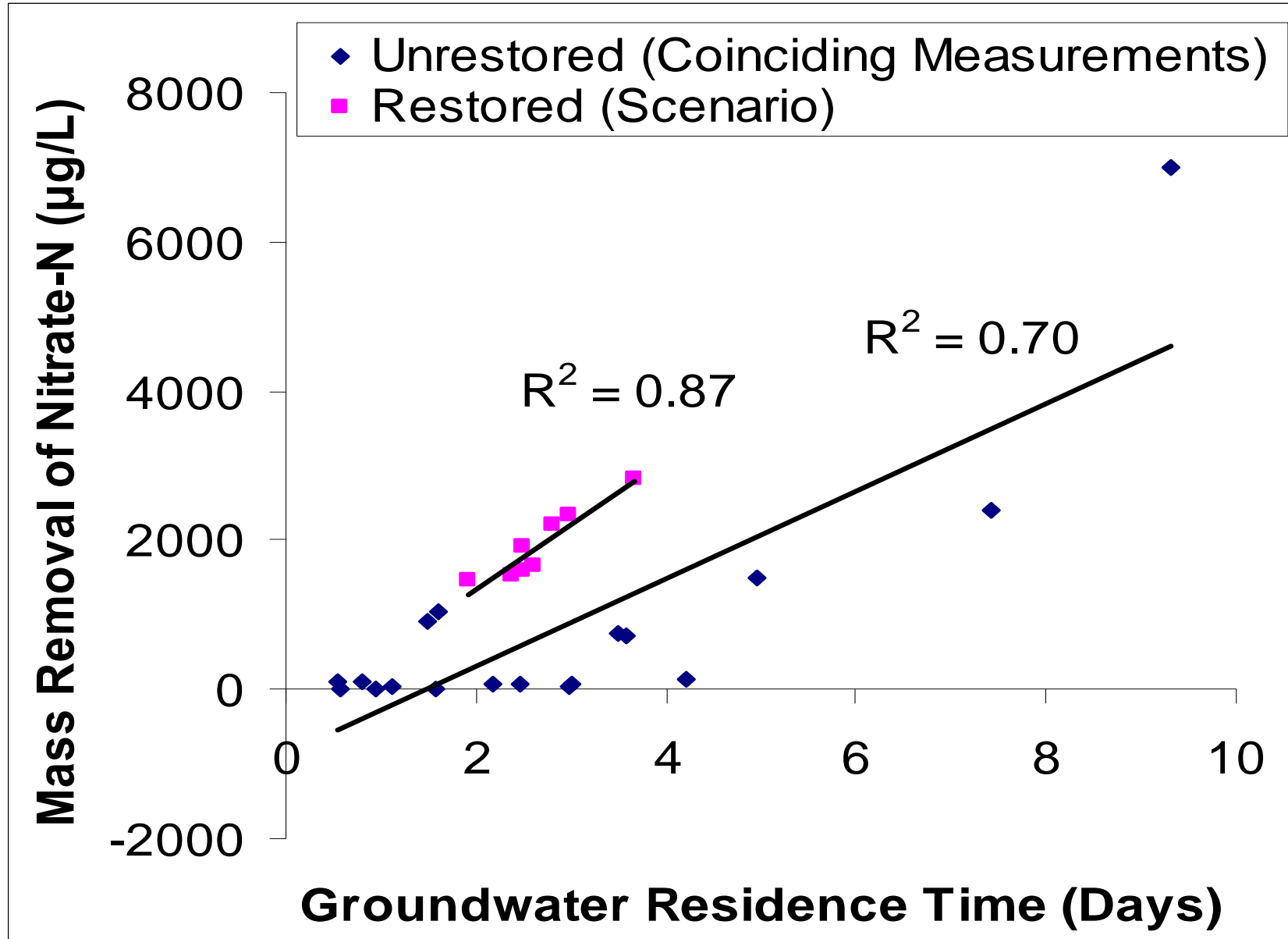
Denitrification higher in restored, connected riparian zones:



Nitrate concentrations lower in restored hyporheic zones:



Nitrate dynamics improved in restored hyporheic zones:



Can stream restoration create denitrification “hotspots” on the floodplain?

- Floodplain wetlands can be created deliberately or incidentally during stream and watershed restoration projects.
- These wetlands have the potential to serve as floodplain NO_3^- sinks if:
 - They process a significant amount of water.
 - With significant residence time.
 - With high denitrification.
 - With high plant (algae, macrophyte) uptake.

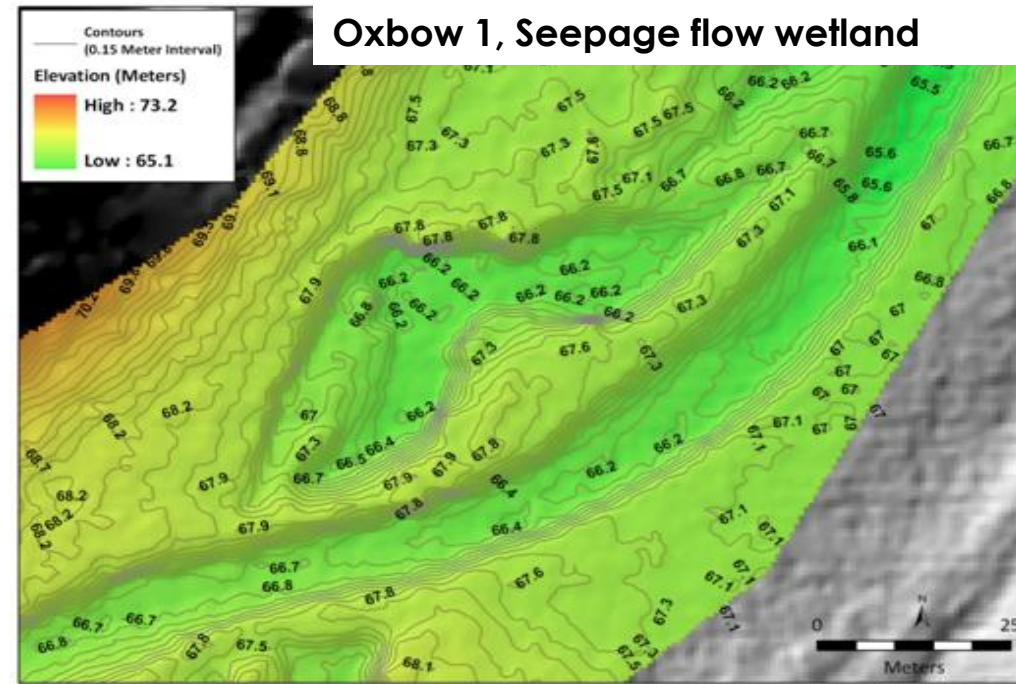


Minebank Run oxbow wetlands:

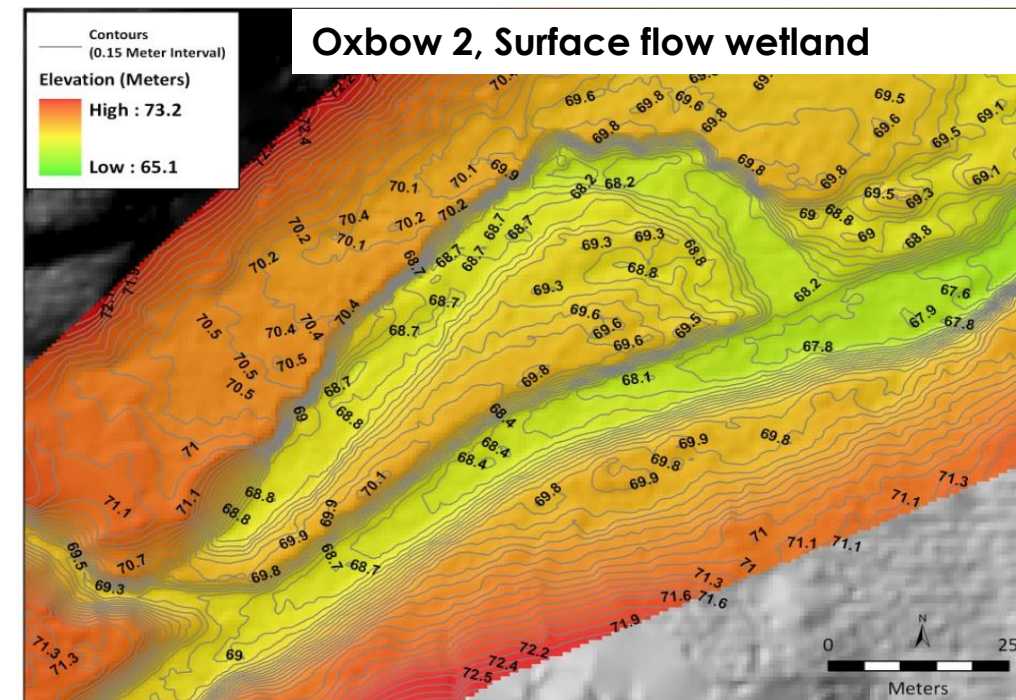
- Created incidentally during stream restoration.
- Vary in nature and extent of connectivity to the stream.
- Extensive measurements of hydrology, denitrification, ^{15}N uptake by plants and algae.

Harrison et al. (2012)

Oxbow 1, Seepage flow wetland



Oxbow 2, Surface flow wetland



Denitrification in urban floodplain wetlands:

- Measured *in-situ* denitrification summer and winter 2008 using the ^{15}N -push pull method.
- Analyzed gas samples for N_2O and N_2

**Constructed storm
water wetlands**



**Oxbow “relict”
wetlands**

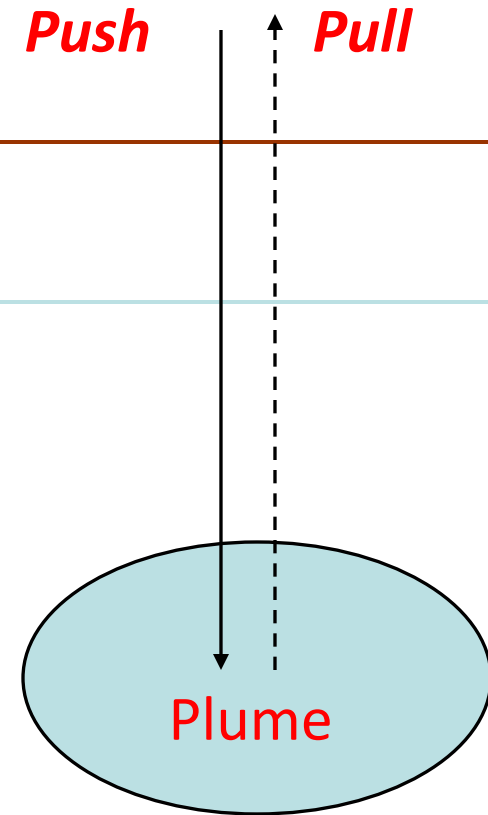


Soil Surface

Water Table

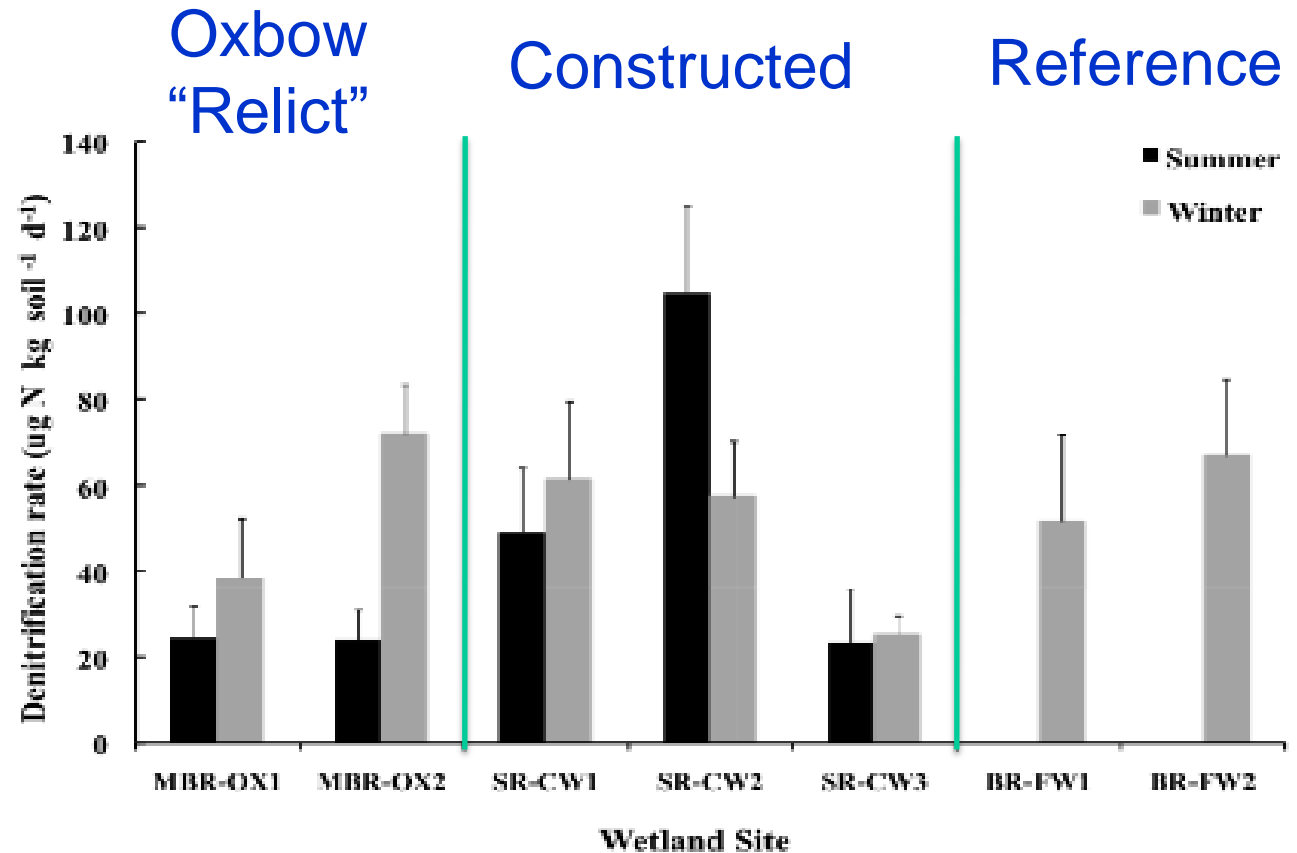
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Denitrification in urban floodplain wetlands:

- Denitrification rates were high – a significant sink for nitrate.
- Rates were higher in winter than in summer.
- Denitrification similar across all wetland types.



OUTLINE:

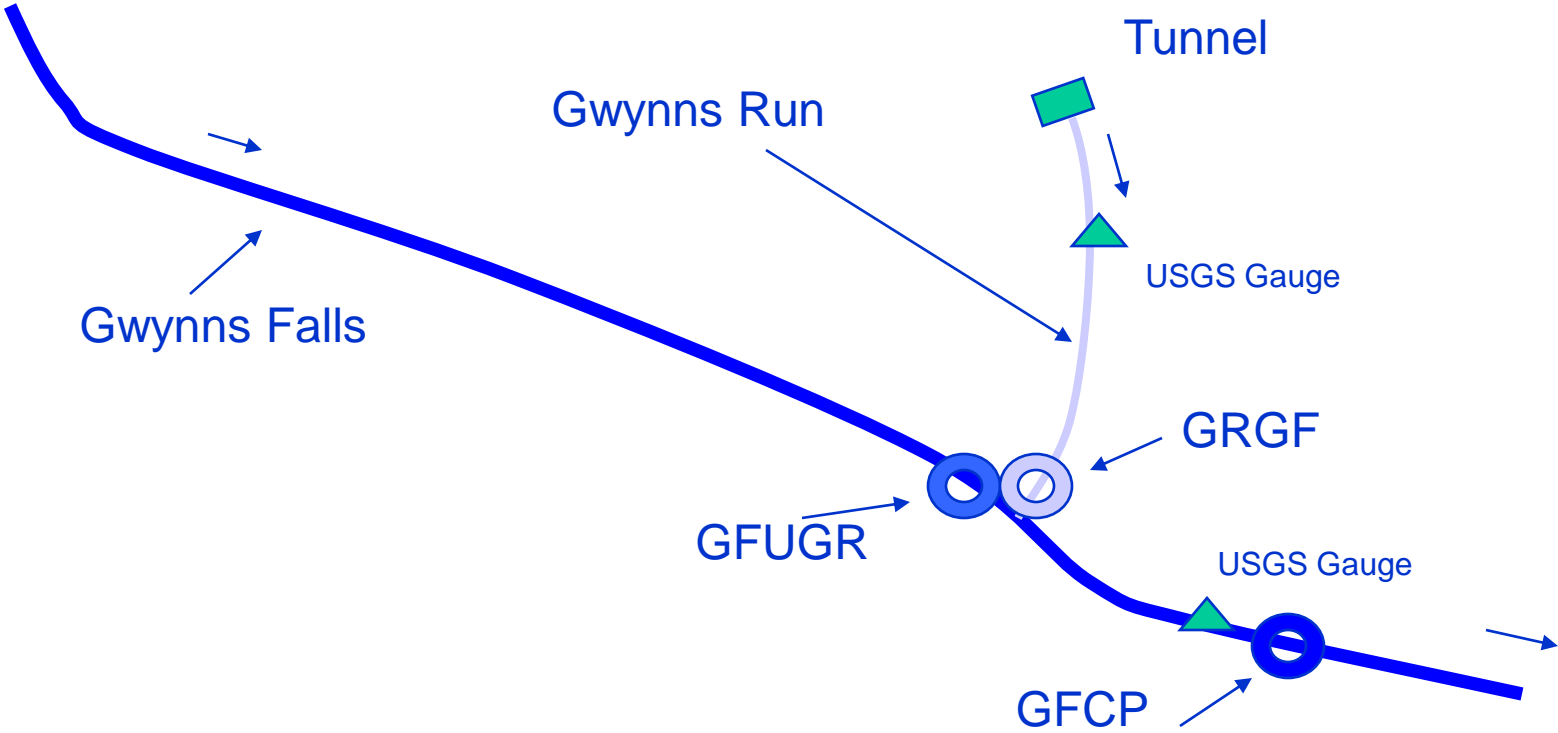
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Consent decree:

- April 2002 agreement to upgrade sanitary sewer infrastructure:
 - \$940 million over 14 years to end chronic discharges of raw sewage into Baltimore streams.
- BES and the consent decree:
 - Some BES long-term sites are/were affected others are not (serve as a reference).
 - Two new treated sites added to the long-term monitoring network : Maidens Choice, Gwynns Run.
 - Provides evaluation of the response at multiple scales.

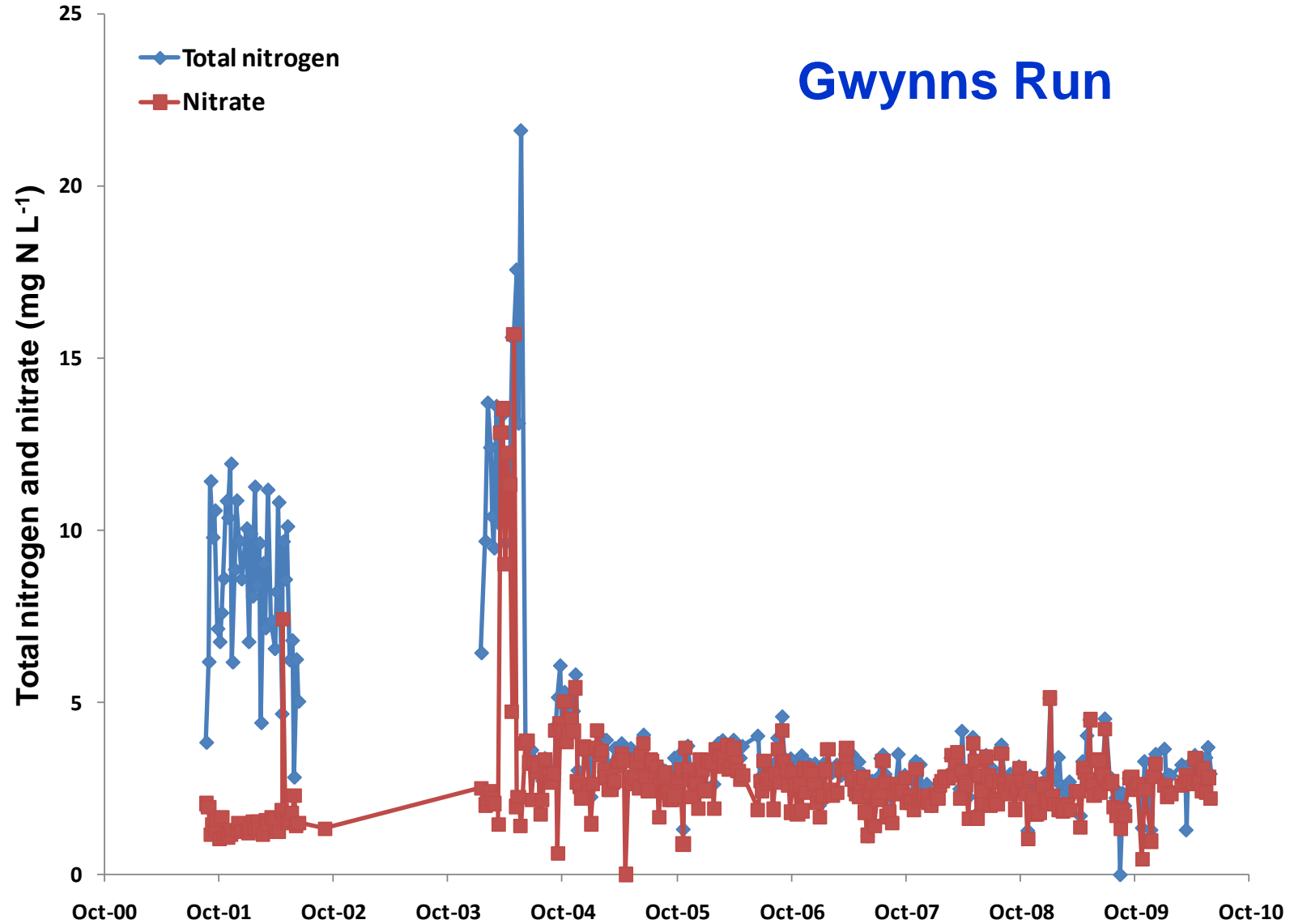
Station Locations(in Carroll Park)

Mid & Upper Watershed GF Stations
(GFVN, GFGB)



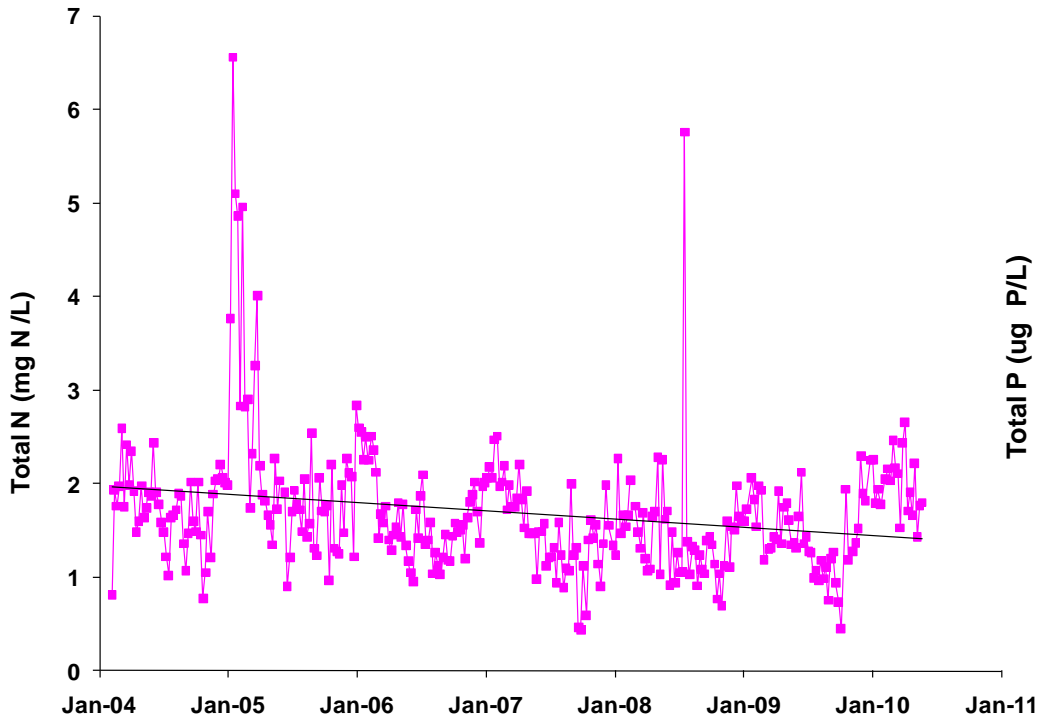
Source: Ken Belt, U.S. Forest Service

Mitigation/repair has definitely had an effect at some sites:

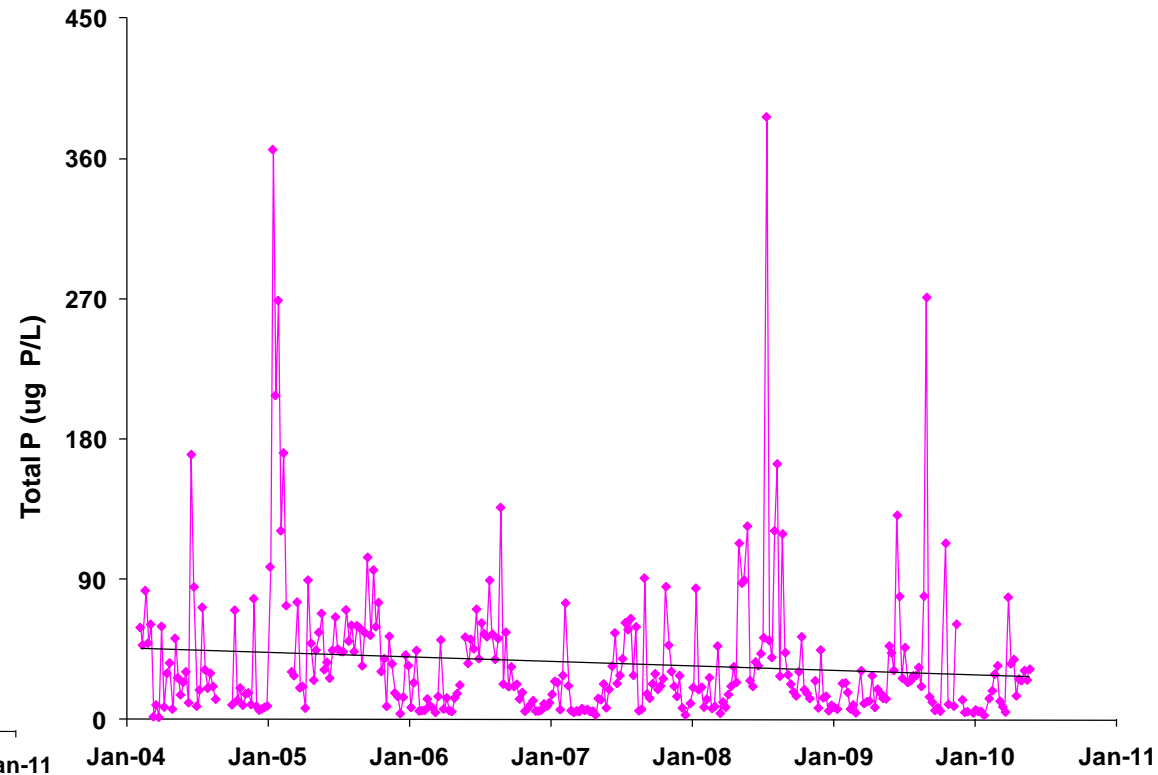


But is harder to see at others (e.g., Maidens Choice):

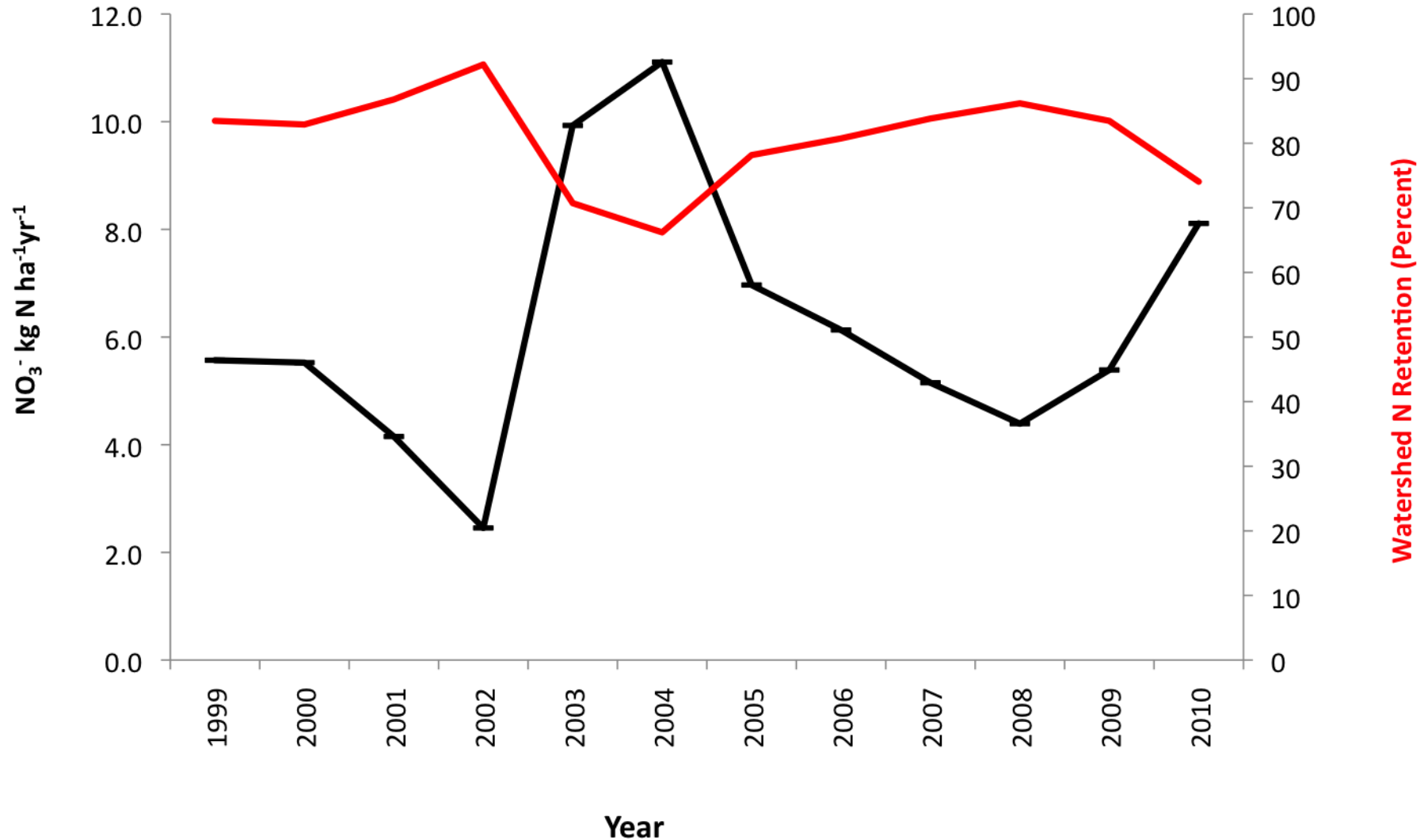
Nitrogen



Phosphorus



Whole watershed performance – is export from the whole Gwynnns Falls changing?



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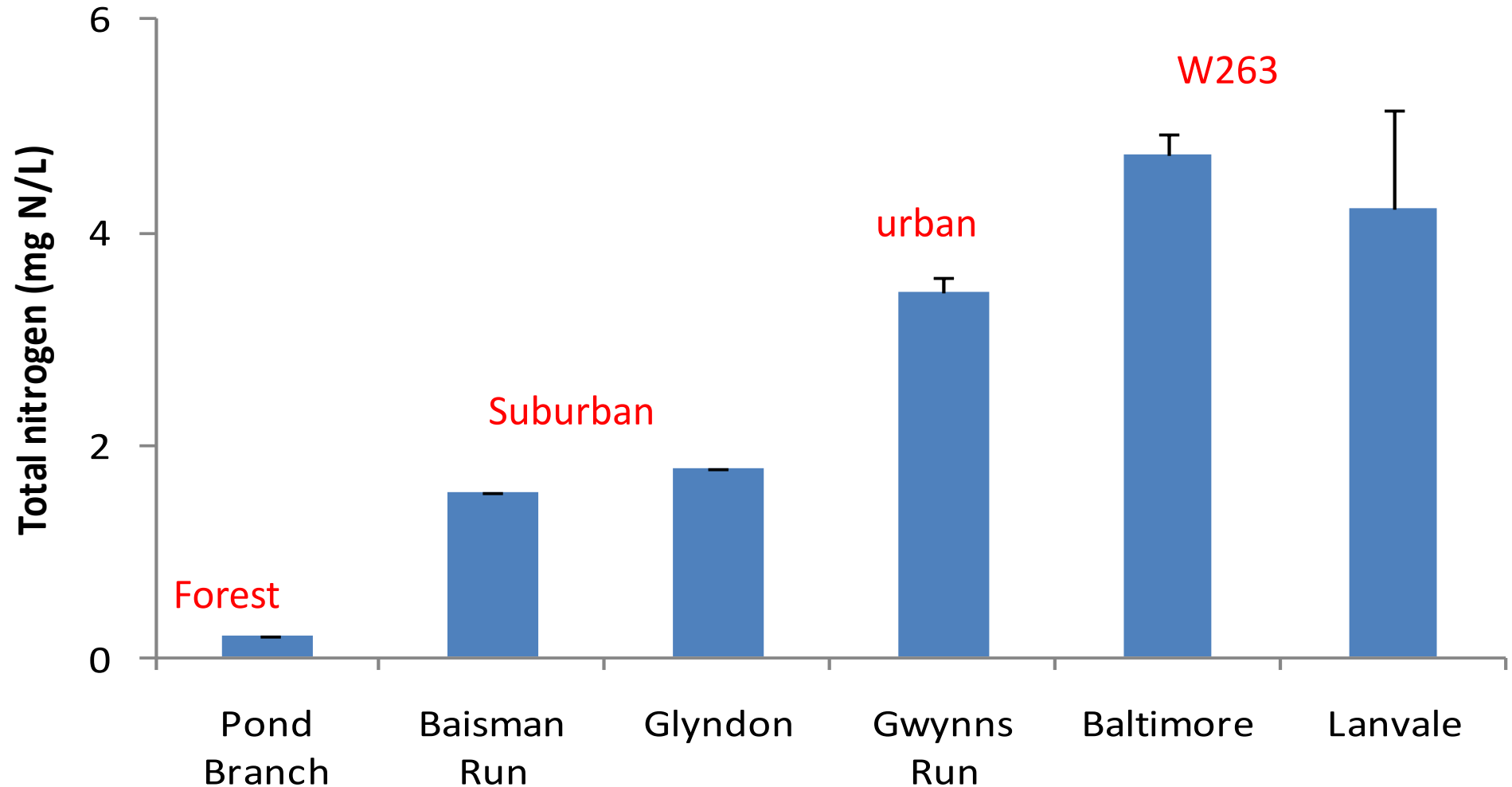
How bad is the water quality in decaying urban neighborhoods?

- W263. Entirely urbanized 435 ha sewershed.
- High impervious surface
- Home to 31,000 people in minority and economically challenged neighborhood.

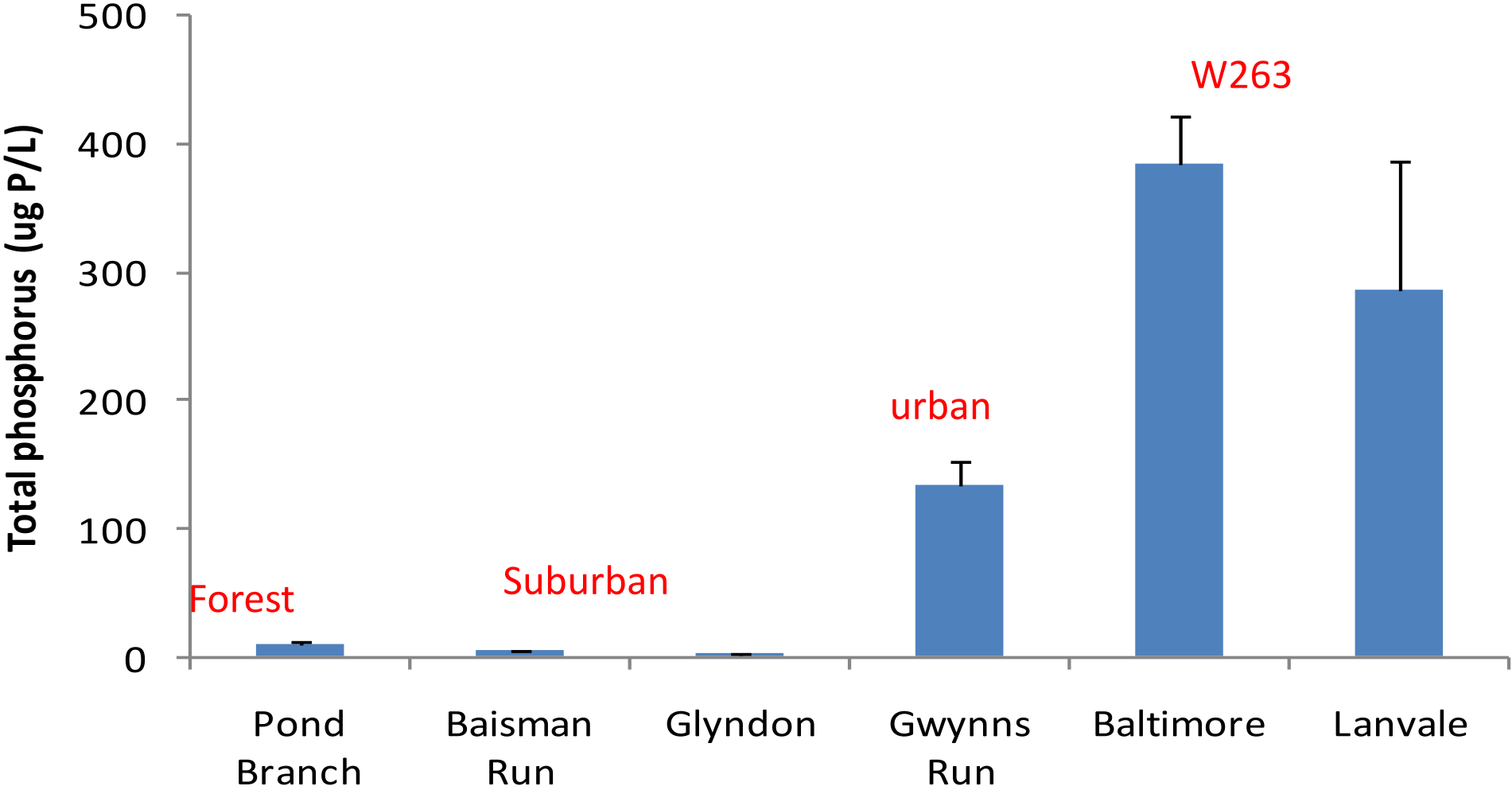


Slide courtesy of Guy Hager, Parks & People

How bad is the water quality in decaying urban neighborhoods?



How bad is the water quality in decaying urban neighborhoods?



WATERSHED 263

- Entirely urbanized with mixed industrial, institutional, and residential land uses.
- High impervious surface (75%) and small area in ground cover (19%) and tree canopy (5.5%).
- Home to 31,000 people in minority and economically challenged neighborhood.
- 11 city neighborhoods in a 935 acre storm water sewershed.
- Significant but dispersed public open space (parks and school) (about 30%) and over 2000 vacant lots.

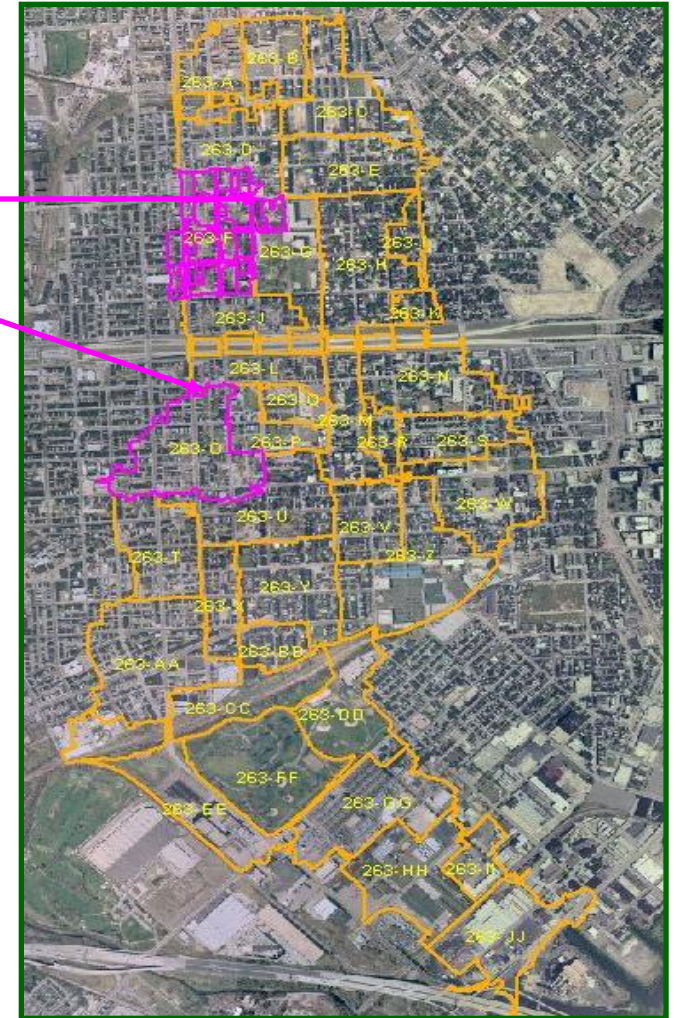


City DPW and BES Set Up A Monitoring, Evaluation and Research Methods

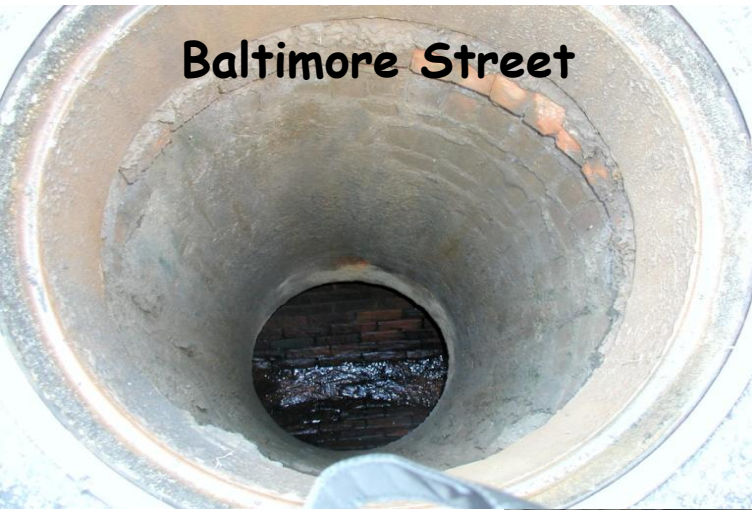
Paired Sub-watersheds

were selected because

- ✓ They are similar in size, percent impervious, and restoration potential.
- ✓ Both were subjects of detailed surveying, modeling and study by project partners.



Lanvale & Baltimore "stream" sampling sites



Baltimore Street



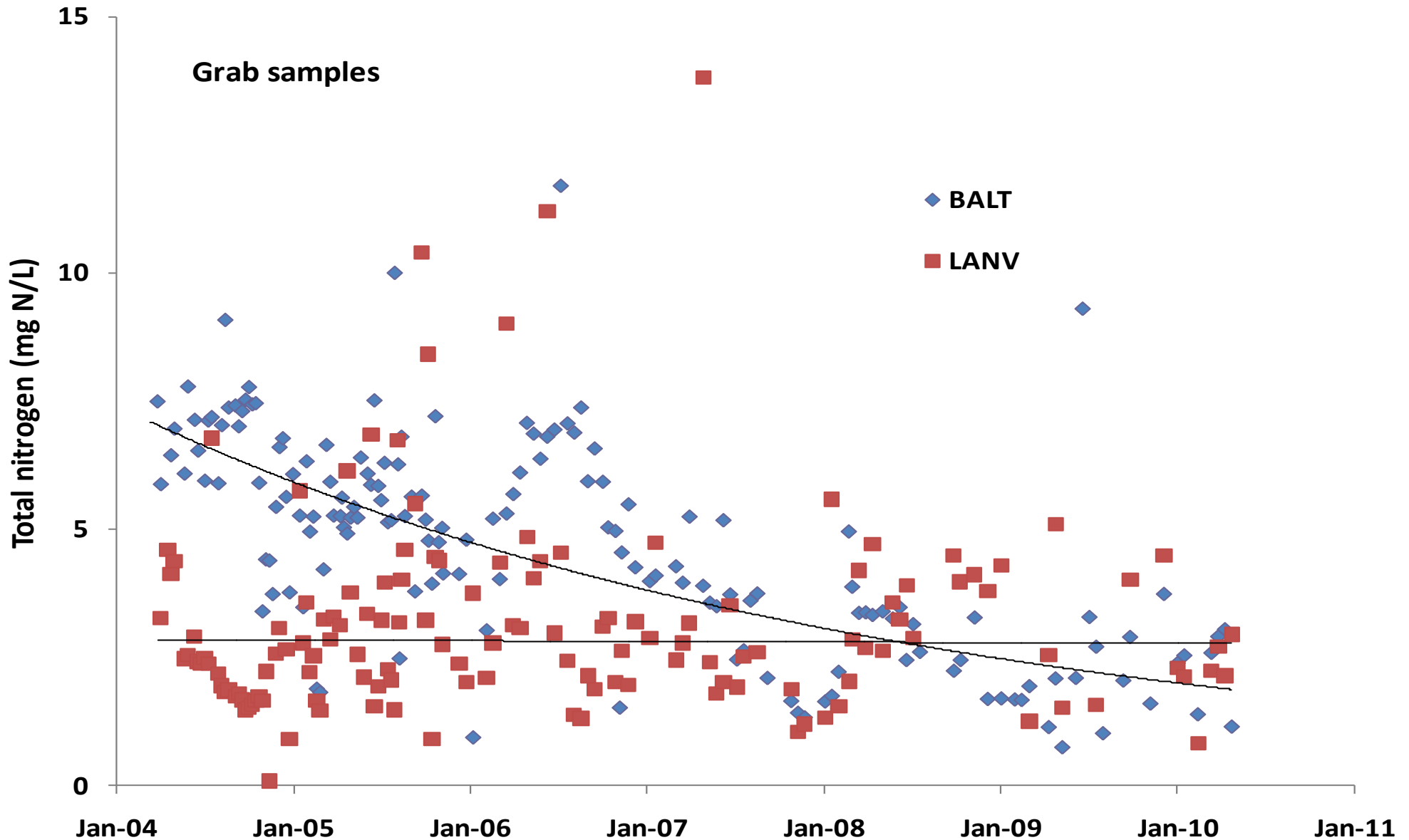
Baltimore Street



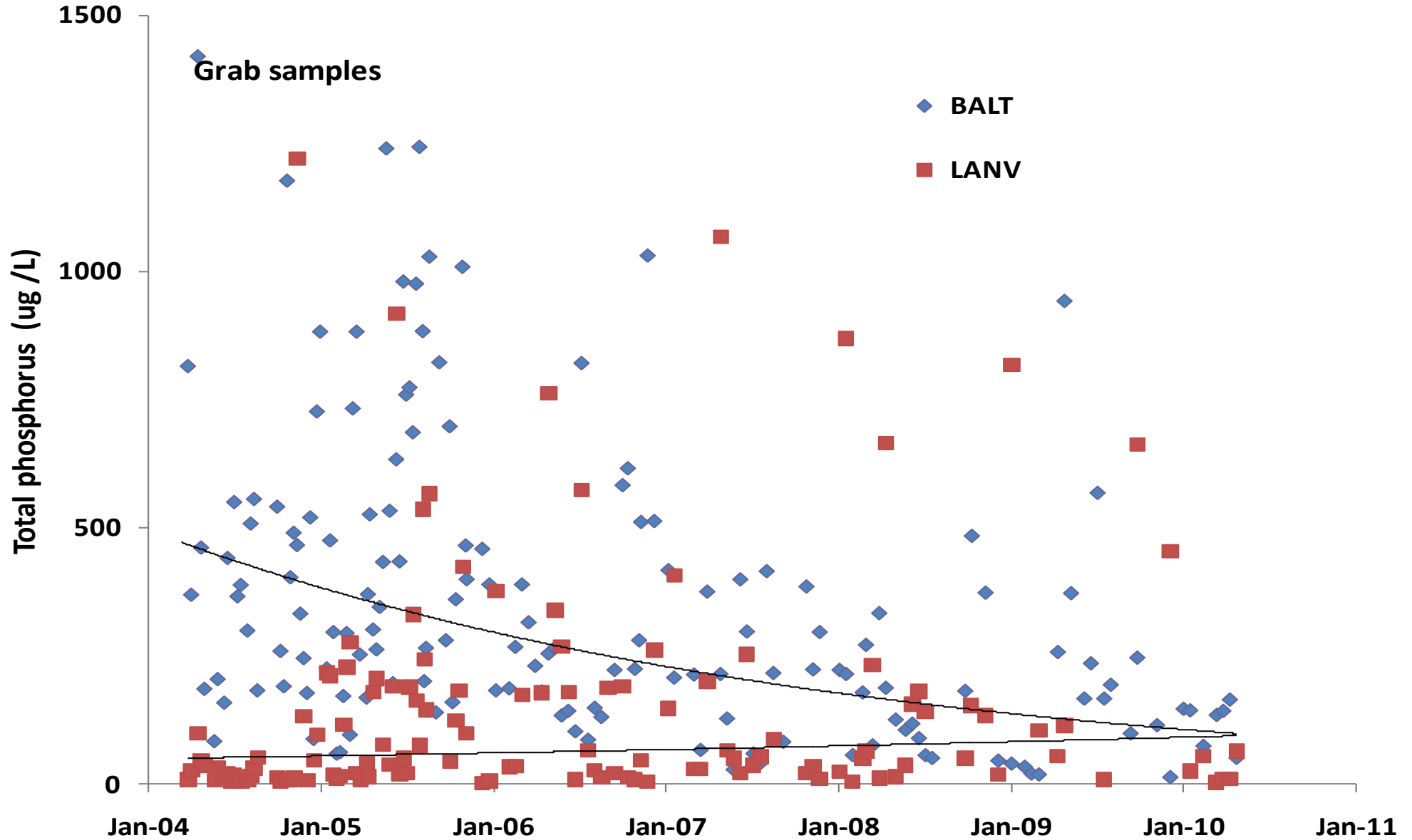
Lanvale Street



Marked declines in total nitrogen in grab samples from the Baltimore subwatershed



Declines in total P in grab samples from the Baltimore subwatershed:

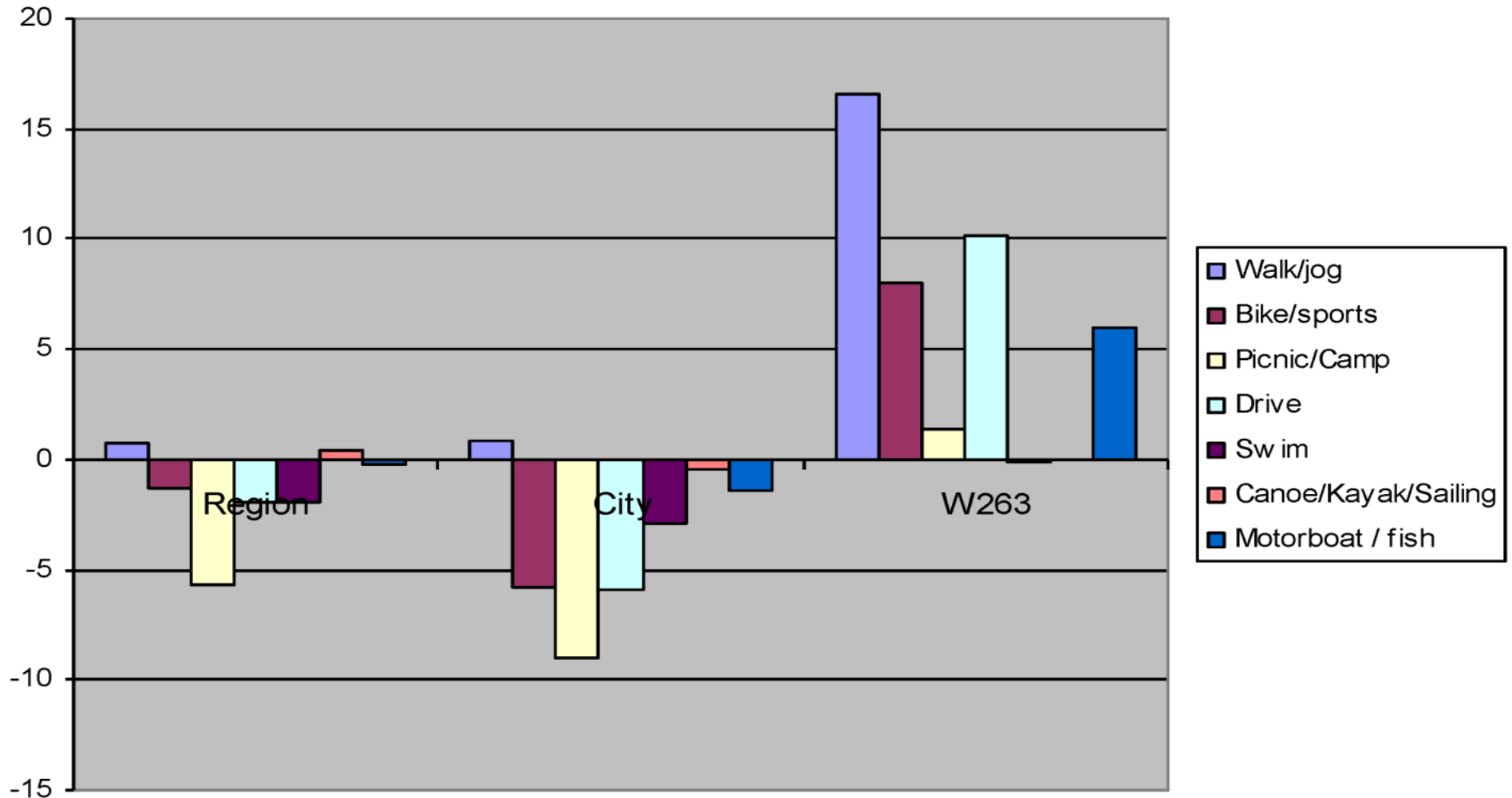


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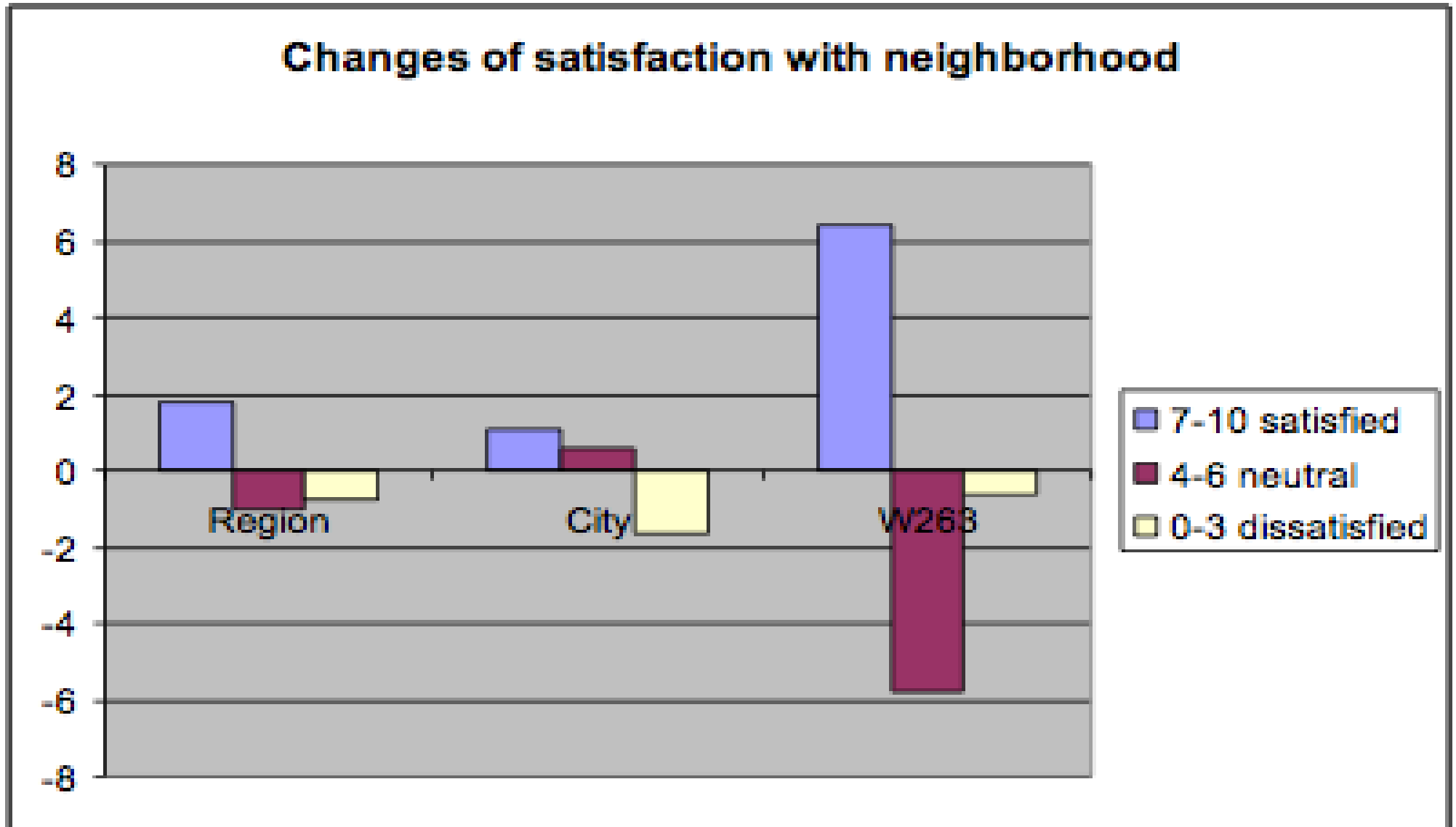
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Recreational Activities

Changes of activities

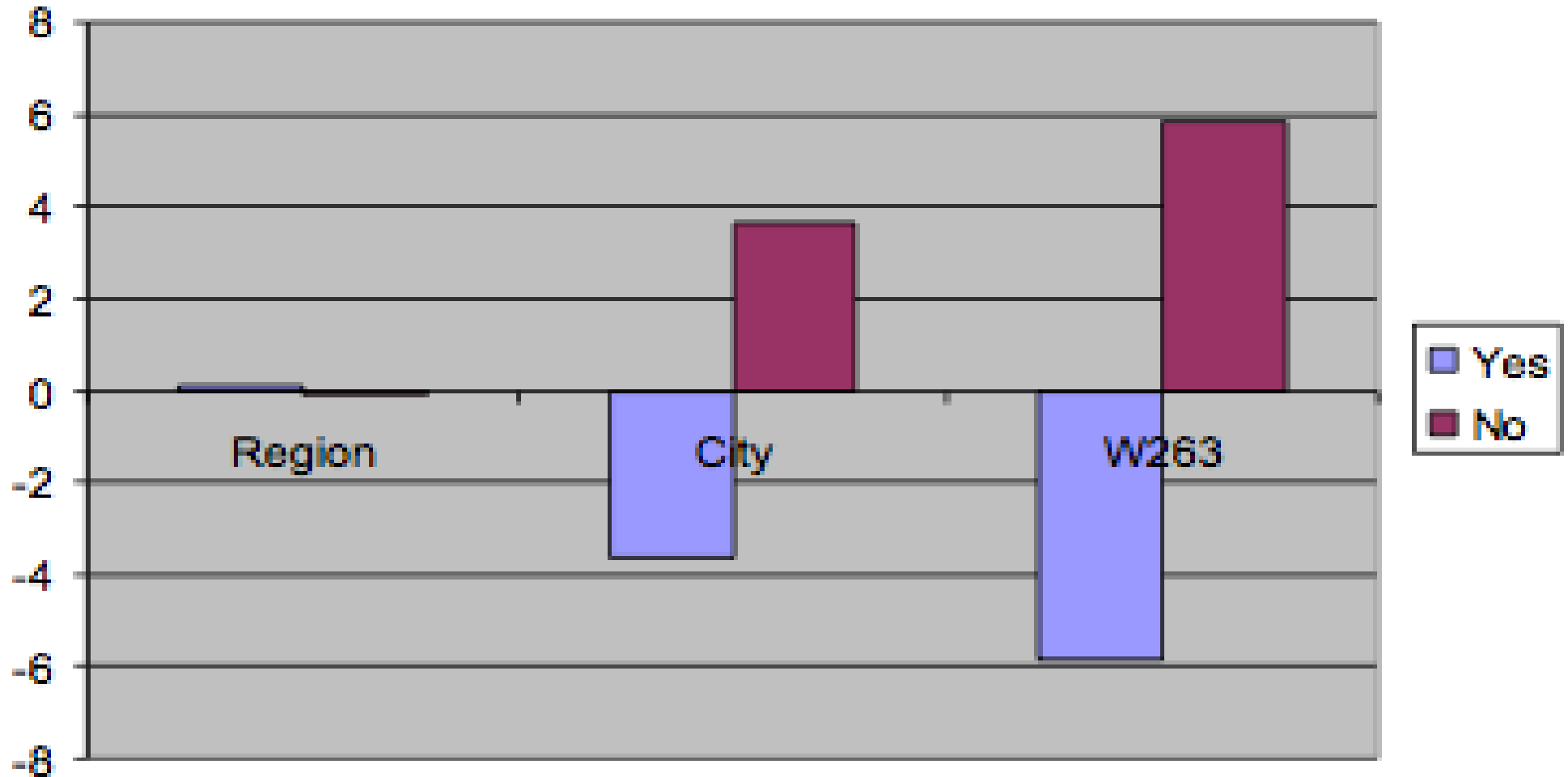


Neighborhood Satisfaction



Neighborhood Desirability

Changes of willingness to move out



Retrofit Construction



Considerations

- Traffic impacts
- Temporary utilities
- Existing underground structures
- Security

Schoolyard Greening

(over 22 acres of asphalt removed so far)

Baltimore City Sustainability Plan has recently set a goal of reducing impervious surface



Stony Run

Heavily urbanized area

- One of the most polluted streams in the city
- Highly developed
 - Impervious surfaces
 - Limited space



Restoration Efforts:



Bulldozing a Creek in Order to Help Save It: City Spending \$10 Million on Disputed Stony Run Job

Posted on: Friday, 18 August 2006, 06:00 CDT

By Tom Pelton, The Baltimore Sun

Aug. 18--In the name of saving the environment, Baltimore is spending more than \$10 million to bulldoze a wooded park and cut down nearly 150 trees for a stream reconstruction project. But some scientists warn that this aggressive method of erosion control is outdated, discredited and destructive.

Results:



CONCLUSIONS:

- Stream, riparian and watershed restoration have the potential to improve urban watershed performance:
 - Stormwater detention basins and other practices.
 - Stream and floodplain restoration.
 - Fixing huge sewer leaks.
- Effects of restoration are *sometimes* to see over short time periods:
 - Multiple factors affect performance.
 - Climate is a strong driver.
 - On the other hand, denitrification function can be established/restored very quickly.
- Social dynamics are important – both positive and negative.