The functionality of green storm water infrastructure (GSI) in suburban Maryland watersheds evaluated using stable isotopes ($\delta^{15}N$, $\delta^{18}O$, $\Delta^{17}O$) of nitrate

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What is GSI and why is it important?

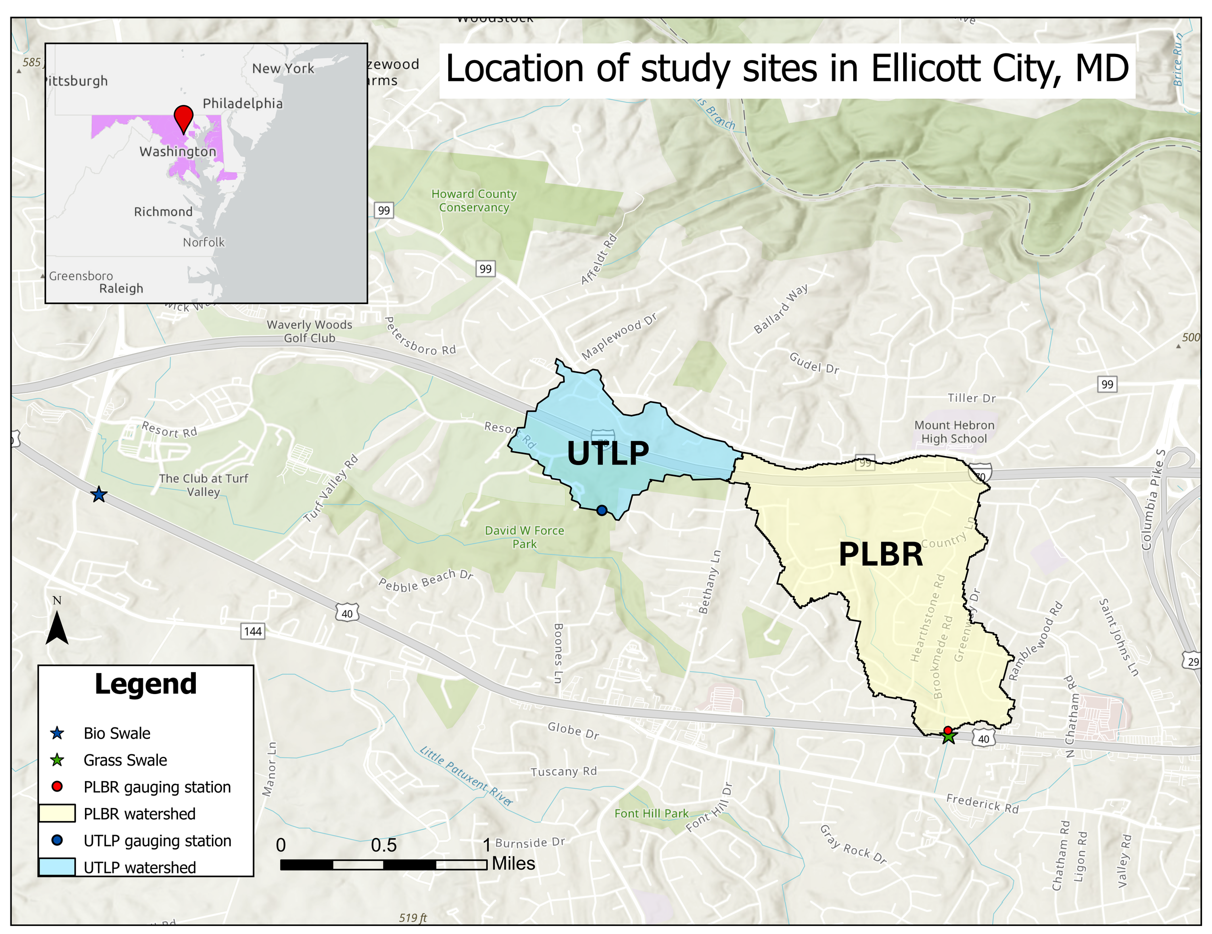
- Urbanization and suburbanization is rapidly occurring and can contribute to a host of negative environmental consequences, including the rapid routing of stormwater through impervious infrastructure which can cause flooding and excess nutrient loading into water bodies.
- Green stormwater infrastructure (GSI) is designed to promote temporary storage of water through enhanced soil infiltration and potentially mitigate the associated negative impacts on receiving waters and downstream ecosystems.
- Better understanding is needed regarding the effectiveness of GSI at improving water quality by promoting physical and biogeochemical processes that retain and/or remove nitrogen during varied hydrological conditions especially during stormflows.

$\Delta^{17}O$: A novel tracer of NO_3^- sources

- The stable isotope composition of NO_3^- is a powerful tool for distinguishing NO_3^- sources and inferring N cycling processes.
- $\Delta^{17}O$ is a conservative tracer that can be used to accurately quantify atmospheric vs. terrestrial NO_3^- sources.

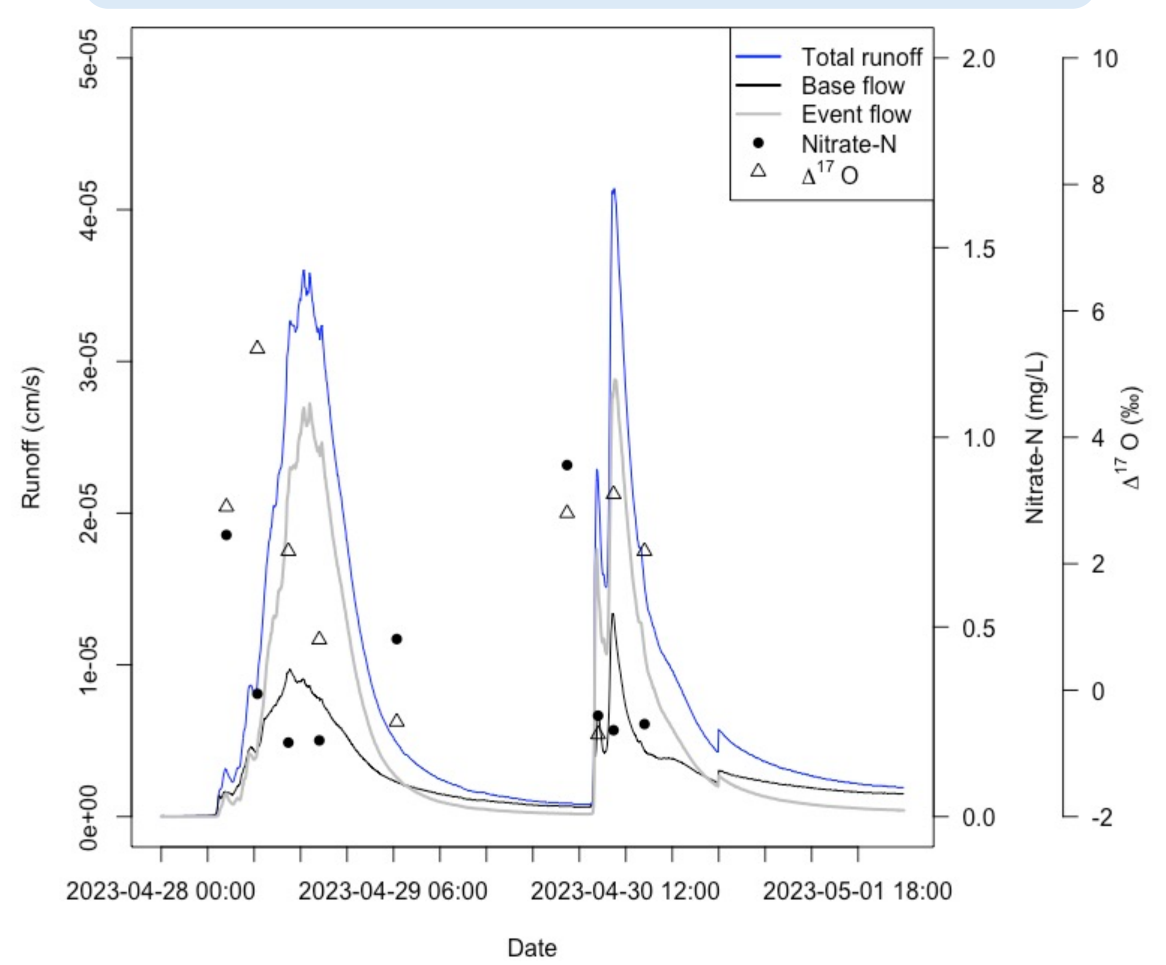
$\Delta^{17}O$ Terrestrial NO_3^- ≈ 0 ‰

$\Delta^{17}O$ Atmospheric NO_3^- > 0 ‰



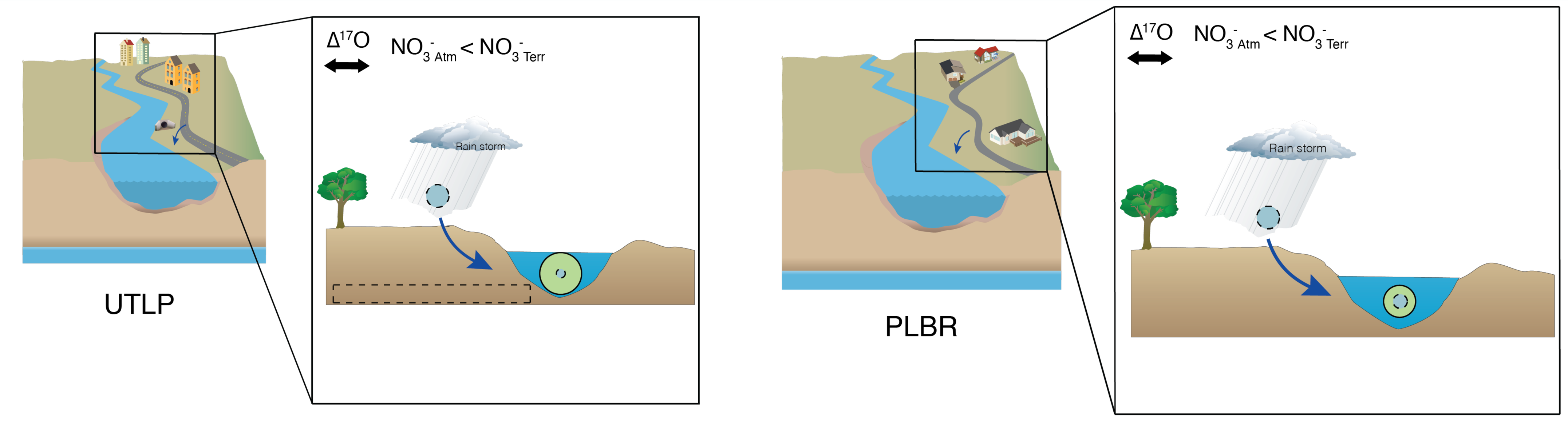
- UTLP watershed (left) has undergone complete GSI implementation as of October 1, 2023, and the PLBR watershed (right) has traditional stormwater management.
- Watersheds are gauged to measure water quantity and quality results, funded by Chesapeake Bay Trust (CBT).

Methods



- 6-8 samples per event, from each watershed (UTLP and PLBR) were analyzed for 13 storms.
- The denitrifier method was used to measure stable oxygen and nitrogen isotopes of nitrate in storm water and precipitation.
- Samples were analyzed using the Thermo GasBench II interfaced with a Thermo Delta V Plus continuous flow isotope-ratio mass spectrometer.

How does GSI modulate the export of different sources of nitrate?



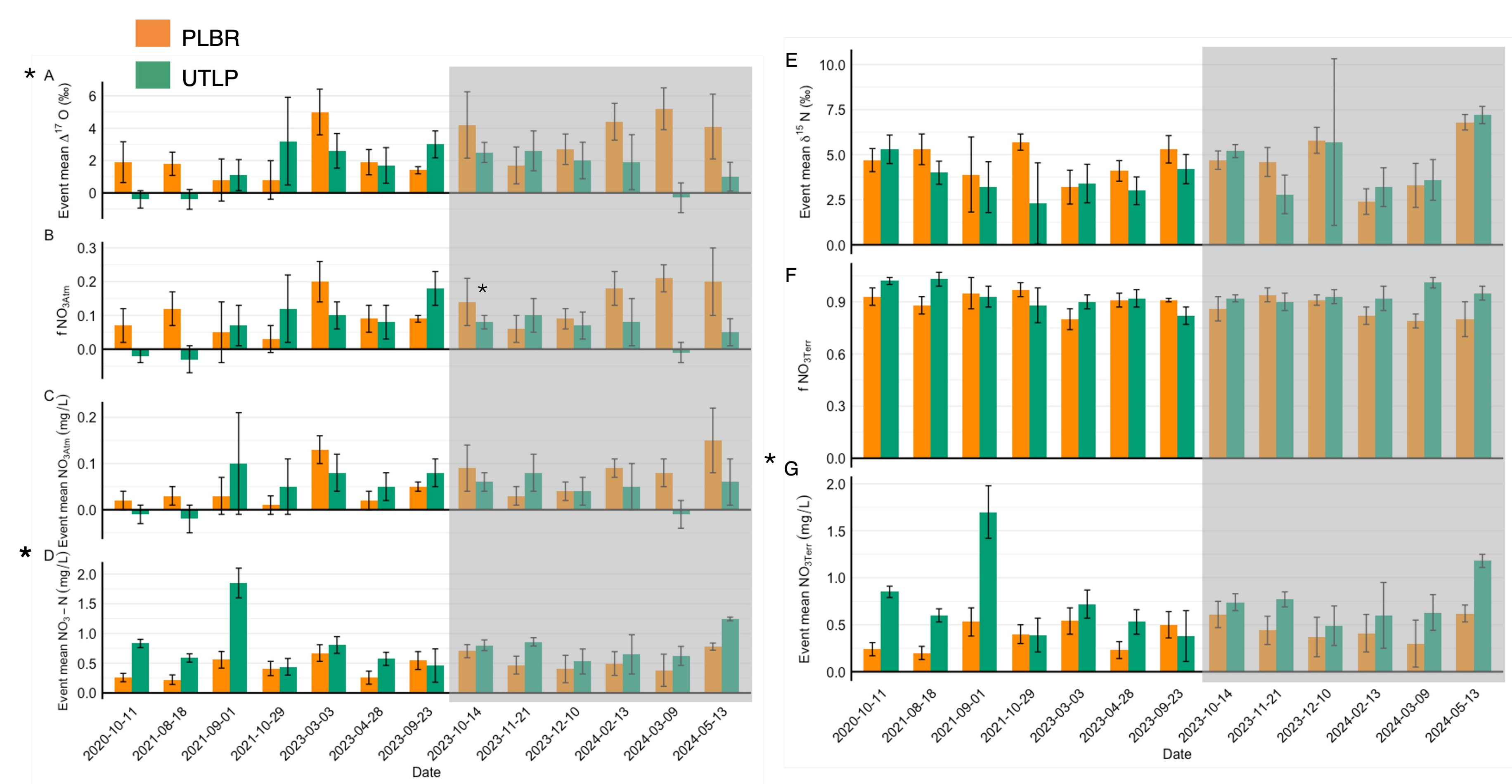
Terrestrial NO_3^- — Stormwater Flow Path

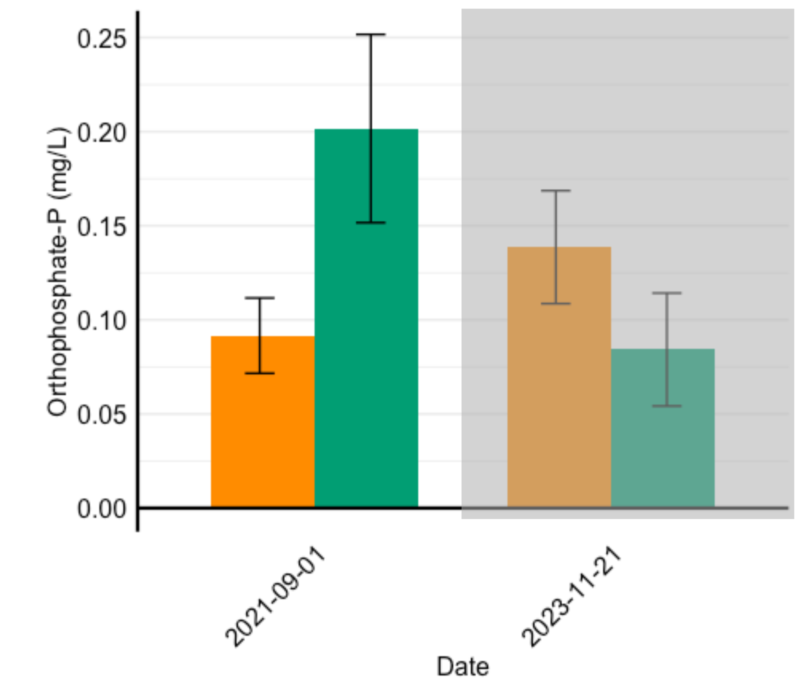
Atmospheric NO_3^- — Underdrain outlet to stream

Total NO_3^- — Green Stormwater Infrastructure Inlet

- At both watersheds $NO_3^-{}_{Atm}$ concentration is less than $NO_3^-{}_{Terr}$.
- There is more total NO_3^- and $NO_3^-{}_{Terr}$ exported at UTLP compared to PLBR.

Flow-weighted event mean variables between watersheds during individual storm events throughout "pre" and "post" periods of GSI implementation at the UTLP watershed.





These fall storm events are hydrologically similar and representative of before and after GSI construction conditions.

Results and Conclusions

- Overall **lower** $\Delta^{17}O$ values and $f\,NO_3^-{}_{Atm}$ at UTLP suggest increased atmospheric nitrate processing (nitrification) in response to GSI at the UTLP watershed (*$p < 0.1$).
- There is a large export of total and terrestrial mean NO_3^- concentrations at the UTLP watershed, indicating that GSI does not reduce, and even increases NO_3^- export through nitrification.
- $\delta^{15}N$ values are relatively low (2.5 -7.5 ‰) suggesting little denitrification is occurring at the watersheds.
- There is a reduction of **orthophosphate-P** export occurring at the UTLP watershed.
- The initial phosphorus content in the bioretention soil and vegetation uptake rates are both mechanisms of orthophosphate-P removal. Soil with high silt and clay composition has increased capacity to absorb phosphorus (Davis et al., 2006).

Next Steps

- Finalize statistical analysis.
- Calculate processing efficiency of atmospheric NO_3^-.
- Calculate loads of atmospheric and terrestrial NO_3^-.
- Understand the ideal design of GSI to promote denitrification and N removal.