Chesapeake Bay Program

Science. Restoration. Partnership.

Sanitary Sewer Exfiltration

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Agenda

- Background
- Implications to the Chesapeake Bay
- Goals of the Wastewater Treatment Workgroup
- Plans and preliminary model inputs
- Schedule

- Humans convert food to wastewater

- And we depend on sanitary infrastructure to contain and treat this nitrogen source

Bernhardt et al.: *Urban Impacts on Surface Water Nitrogen Loading*

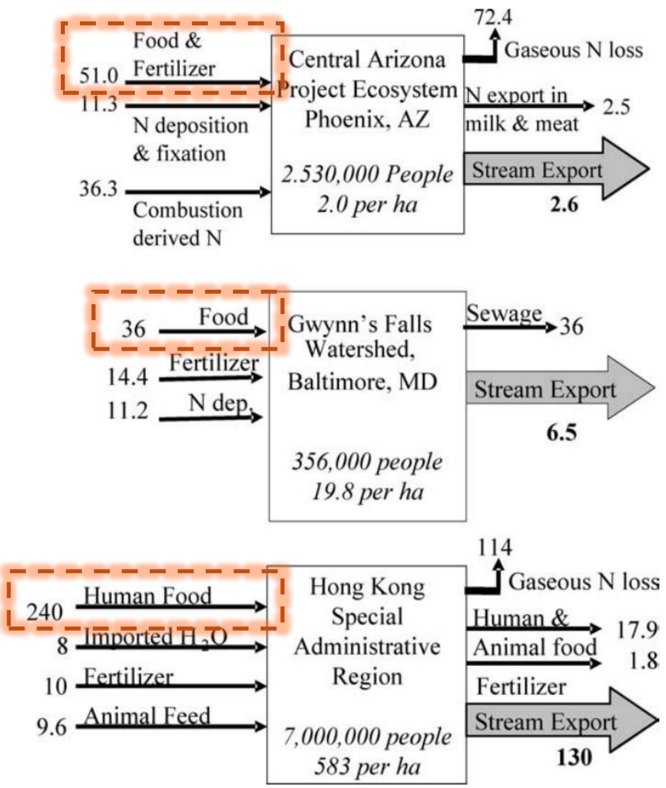
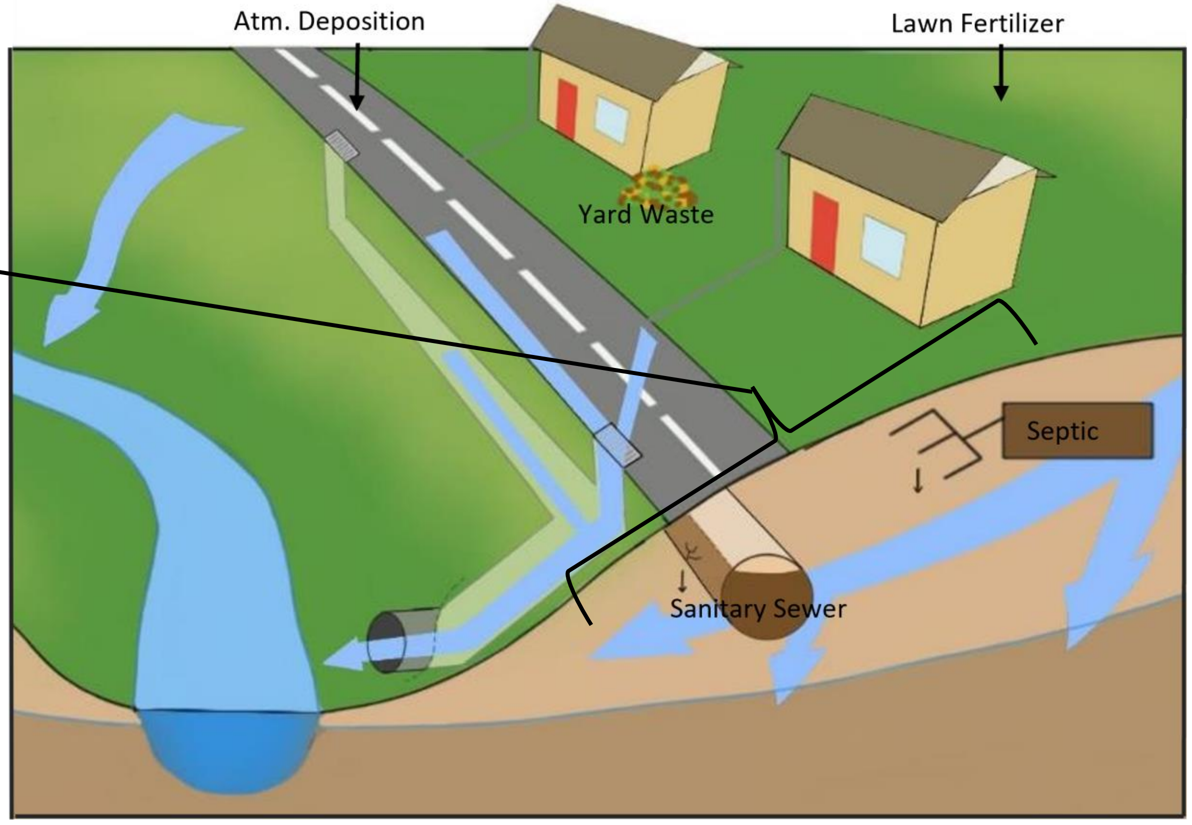


Figure 2. Compiled mass balance estimates for three cities (data in kg N ha^{-1} y^{-1}) arranged in order of increasing population density. Data for Phoenix from Baker *et al.* 2001, for Baltimore from Groffman *et al.* 2004, and for Hong-Kong from Warren-Rhodes and Koenig 2001. Note the discrepancies between the types of fluxes measured in each study.

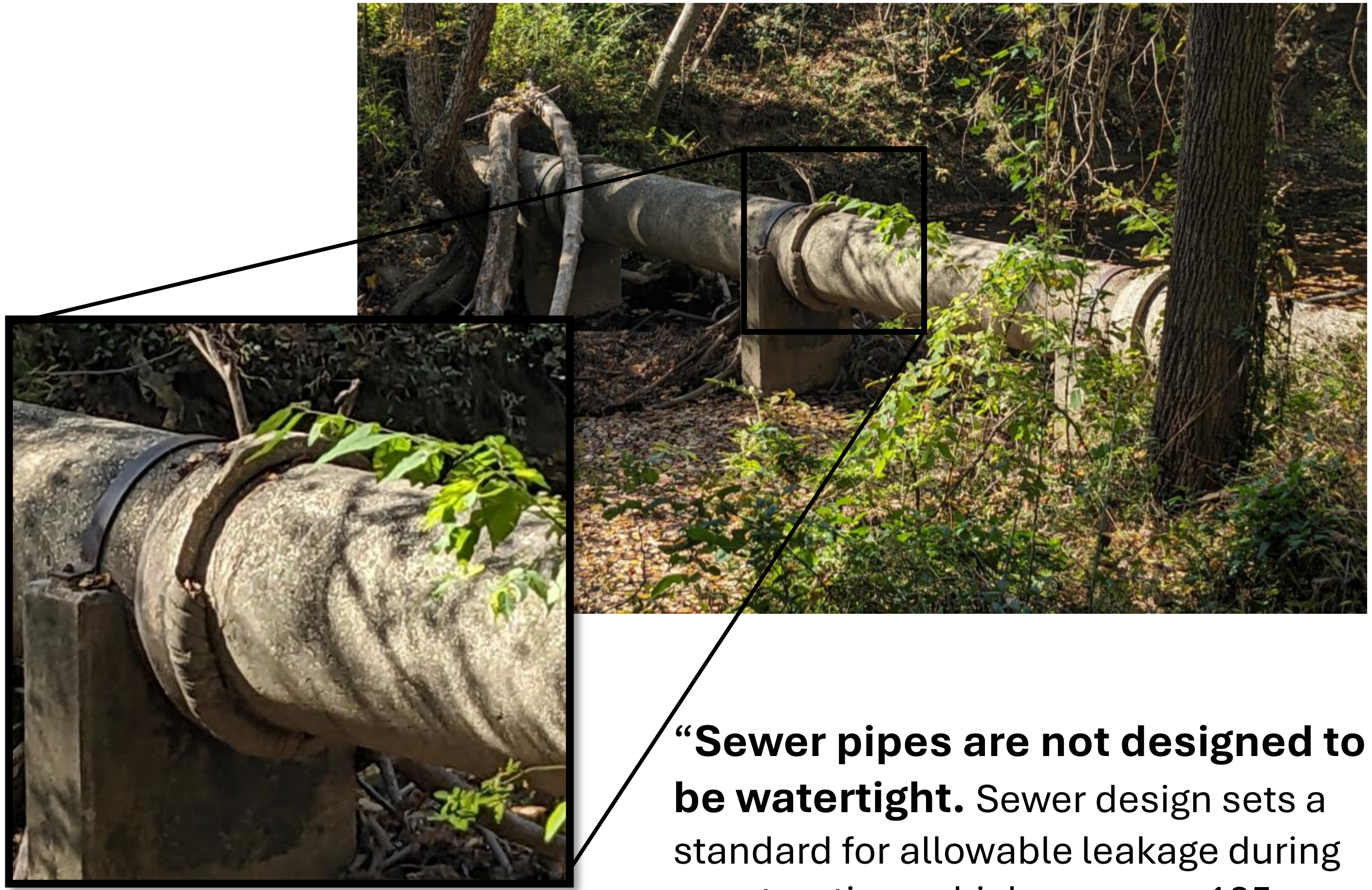


Bernhardt, E. S., Band, L. E., Walsh, C. J., & Berke, P. E. (2008). Understanding, managing, and minimizing urban impacts on surface water nitrogen loading. *Annals of the New York Academy of Sciences*, *1134*, 61–96.

Baker, L. A., Hope, D., Xu, Y., Edmonds, J., & Lauver, L. (2001). Nitrogen balance for the Central Arizona-Phoenix (CAP) ecosystem. *Ecosystems*, *4*(6), 582–602.

Groffman, P. M., Law, N. L., Belt, K. T., Band, L. E., & Fisher, G. T. (2004). Nitrogen Fluxes and Retention in Urban Watershed Ecosystems. *Ecosystems*, *7*(4), 393–403.

Warren-Rhodes, K. & A. Koenig. (2001). Ecosystem ap- propriation by Hong Kong and its implications for sustainable development. Ecol. Econ. 39: 347–359.

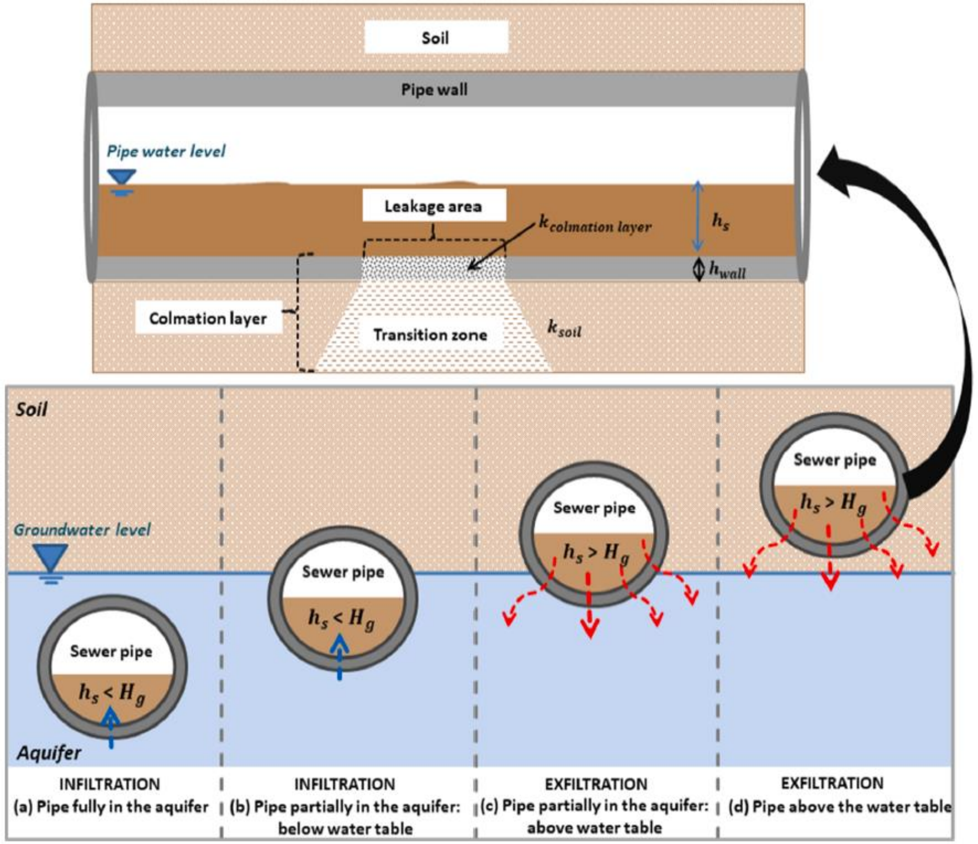


"**Sewer pipes are not designed to be watertight.** Sewer design sets a standard for allowable leakage during construction, which averages 125 gallons per 400 feet of pipe, which is the standard distance between sewer manholes (ASTM, 2009), or about 1,650 gallons per mile of standard sewer pipe."

Chesapeake Bay Program, (2014). "Final Expert Panel Report on Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure"

Net infiltration does not exclude exfiltration

- Net system infiltration does not exclude areas of exfiltration
- Segments may infiltrate in wet periods and exfiltrate in dry periods
- Because WW nutrient concentrations are 2-3 orders or magnitude greater than background, small amounts of exfiltration can represent significant loads



Nguyen, Hong Hanh, Aaron Peche, and Markus Venohr. "Modelling of sewer exfiltration to groundwater in urban wastewater systems: A critical review." *Journal of Hydrology* 596 (2021): 126130.

Why does this matter for the model?

- Proper appropriation of loads
- Improved targeting and crediting of management actions
- Scenario analysis (E.g., remediation, pipe ageing, etc.)

This load is in the bay, the load is in the model, but it is currently misappropriated.

The majority of misappropriation is likely to other urban load sources such as stormwater and lawn fertilizers.

Comparing across studies

Good agreement despite very different methods, regions, and scales.

Study	Exfiltration Vol.	Exfiltrated N	% treated volume
Nguyen and Venohr, 2021	228 gal/day/km	20.8 lb N/year/km	2%
Delesantro et al., 2022	365 gal/day/km	33.2 lb N/year/km	2.40%
Steele et al., in review	630 gal/day/km	56.6 lb N/year/km	0.60%
Lerner and Halliday, 1994	246 gal/day/km	22.5 lb N/year/km	
Amik et al., 2000			11.40%
Ellis et al., 2003			5-10%
Wakida and Lerner, 2005			13%
Fenz, 2003			1-5%
Rieckermann et al., 2005			11%
Karpf and Krebs, 2004			2.80%

Notes:
- Values are the mean for each study or study region
- N load may be estimated assuming 30mg/l N in raw WW
- Delesantro et al., 2022: Assuming NO_3^- proportion from WW ~ TN proportion from WW
- Studies estimate exfiltration from pipe, to GW, or to streams
- Studies may estimate treated volume based on total flow or DWF

This suggests that generalizing sanitary sewer exfiltration loads is reasonable.

Potential impacts of SS Exfiltration in the CBW

Conservative estimated contribution to the CBW from literature:

- 665,392 – 2,217,974 lb N/year
- 0.23 - 0.76% of the total N load to the CB
- 1.51 - 6.04% of the WW load to the CB
- 3.28 - 10.93% of the urban load to the CB
- 0.60% – 48.9% of the load from individual urbanized catchments to CBW**
- 13 - 47.5% of the measured load from individual urbanized residential catchments in the NC Piedmont*

Note: Values derived from the mean of studies or study regions (Delesantro et al., 2022; Nguyen and Venohr, 2021)

Assuming 30mg/l N in raw WW

Delesantro et al., 2022: Assuming NO_3^- proportion from WW ~ TN proportion from WW

*Assuming stormflow WW exfiltration loading from mean of Delesantro et al., (in review) urban catchments and baseflow WW exfiltration from Delesantro et al., 2022

** using full range in exfiltration values reported from Nguyen and Venohr, 2021

WWTWG Considerations

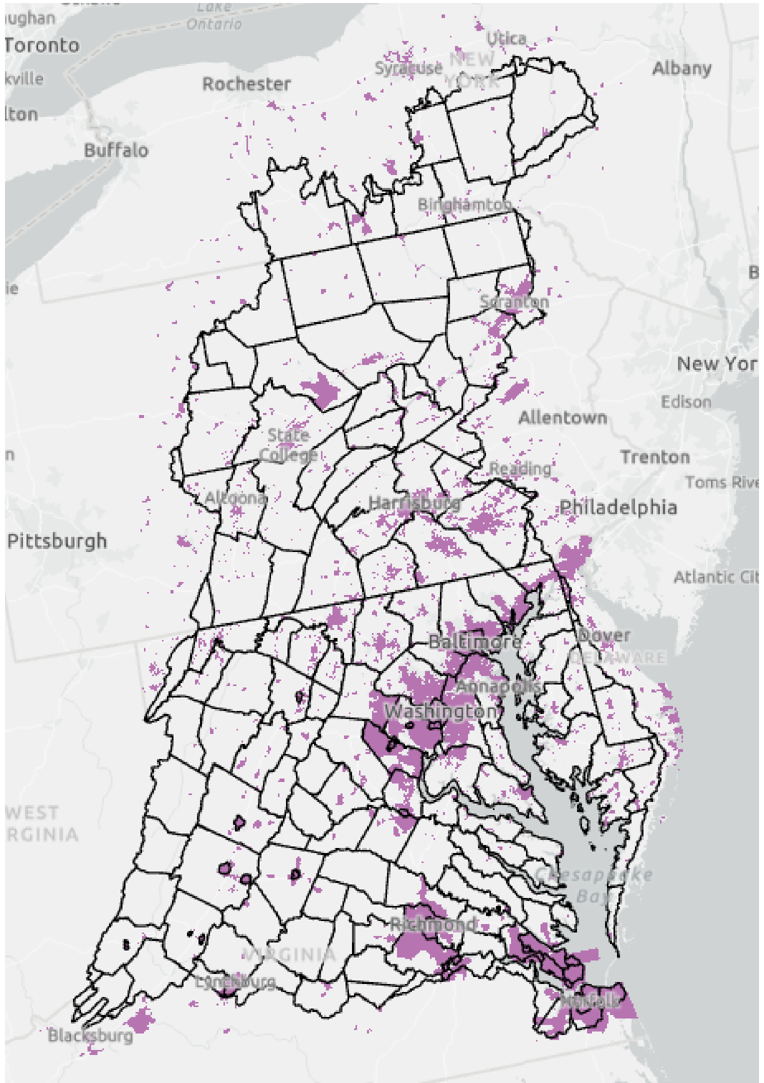
- Acknowledge interest in more accurately attributing the sources of the load.
- Default values risk overestimating loads due to differences in collection systems, surrounding geology, and on-going rehabilitation efforts.
- It’s important that we not overestimate the exfiltration load.

Potential modeling of sanitary sewer exfiltration

- Several options for modeling sanitary sewer exfiltration have been discussed.

Link to previous meeting materials: [Wastewater Treatment Workgroup]

- A sub workgroup is testing and evaluating a preliminary model structure applied at a limited scale.



CBW WWTP Service Boundaries

Preliminary model structure

- A default exfiltration value as a percent of treated volume will be defined by expert judgement and literature
- Spatially exfiltration will be mediated by optional factors identified as drivers of exfiltration by expert judgement and literature.
  - Geologic basin as a metric of water table depth
  - The proportion of the system which is gravity fed
  - The proportion of the system which is new or recently rehabilitated

Exfiltration Vol. = Fraction exfiltration * Annual system treatment volume * Geologic coef. * Fraction gravity line * 1/fraction new or rehabbed

Exfiltrated nutrient mass = Exfiltration Vol. * concentration in raw WW[1]

Workgroup Defined, Required State Provided Input, Optional State Provided Input

[1]Chesapeake Bay Program, (2014). "Final Expert Panel Report on Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure"

Schedule

November	December	January	February	March	April
Testing of preliminary model		Evaluate preliminary results	Refine model	Work group model recommendation	Seek feedback or approval from the WQGIT

Discussion