Phosphorus retention in a bioretention cell: Insights from process-based modelling

Bowen Zhou[1], Mahyar Shafii[1], Chris Parsons[2], Elodie Passeport[3], Fereidoun Rezanezhad[1], Ariel Lisogorsky[1], Philippe Van Cappellen[1]
[1]Ecohydrology Research Group, University of Waterloo, ON, Canada; [2]Environment and Climate Change Canada, ON, Canada;
Department of Civil and Mineral Engineering & Department of Chemical Engineering and Applied Chemistry, University of Toronto, ON, Canada
Email: b59zhou@uwaterloo.ca

Background & Objectives

- Phosphorus (P) exports from urban stormwater runoff → increases eutrophication risks.
- Bioretention cells (BRCs, Figure 1) is a low impact development (LID) stormwater management technology to enhance runoff infiltration → purported to reduce runoff P export.
- Understanding of P retention mechanisms in BRCs is limited.

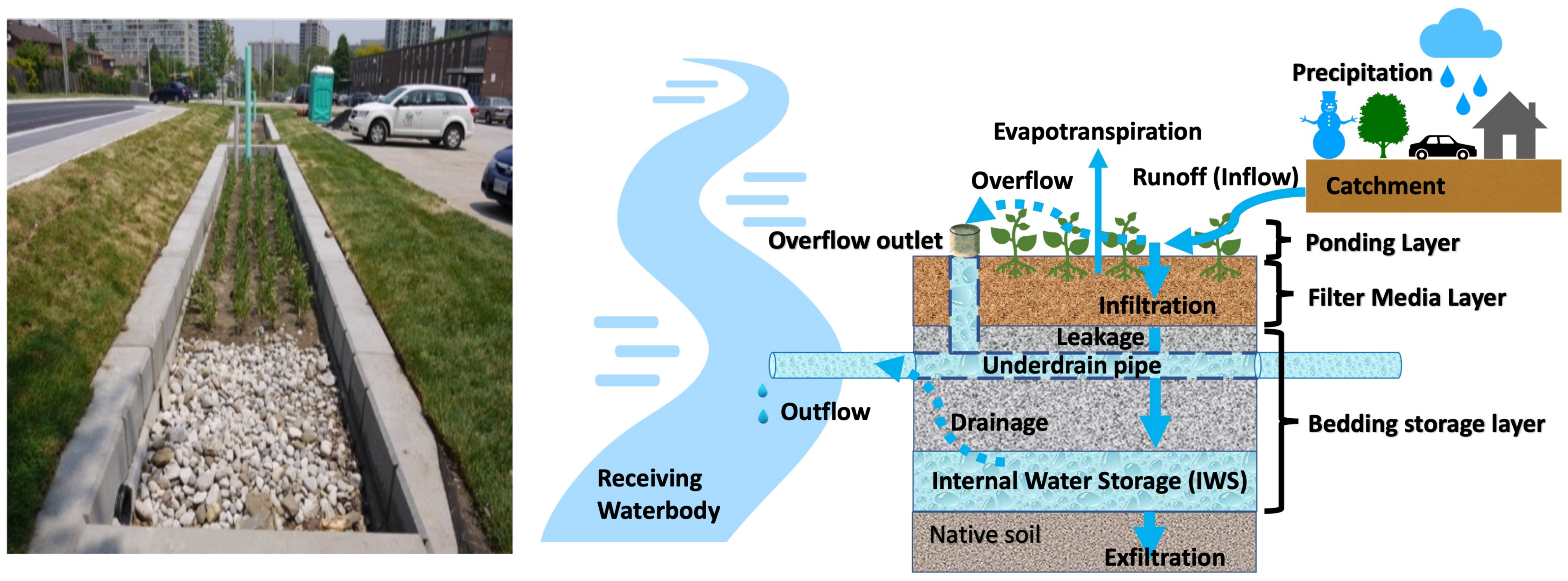

Figure 1. Left: Photo of BRC considered in this study (located in Mississauga, ON, Canada). **Right**: Conceptual diagram of the hydrology of the BRC.

Objectives:

- Advance predictive understanding of long-term P retention mechanisms in BRC;
- Develop a model that predicts long-term P accumulation in and export from BRC;
- Identify main P sinks and key processes for P retention in BRC

Methodology

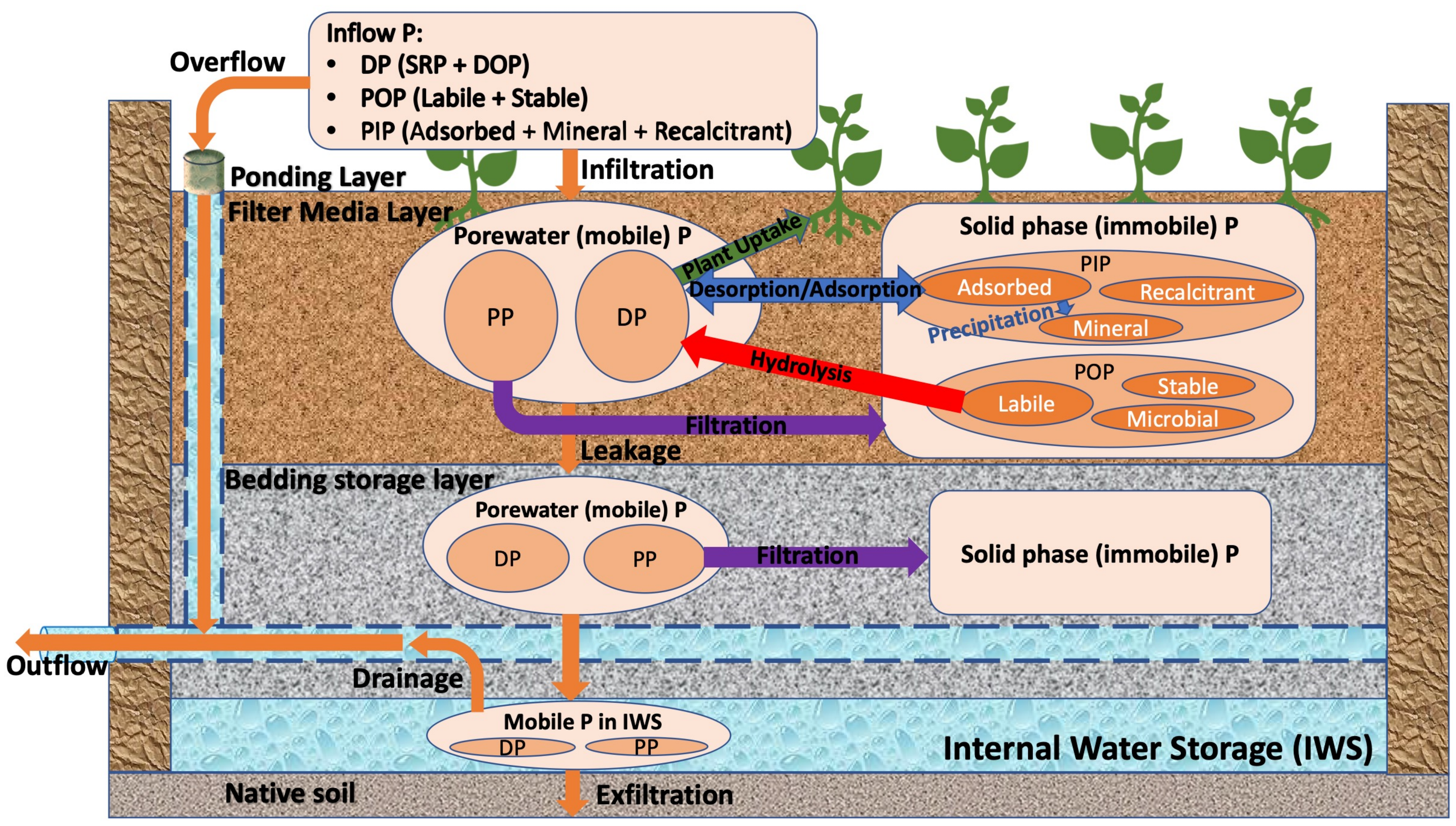

Figure 2. Conceptual diagram of P biogeochemistry in the BRC.

Data availability:

1. Outflow water quantity and quality (2012–2018);
2. Filter media TP concentrations (2013, 2014, 2016, and 2019);
3. P speciation depth distribution from sequential chemical extractions performed on core samples (2019).

Reactive transport modelling:

1. Coupled simulations of hydrologic (Figure 1) and P transformation (Figure 2) processes inside the BRC;
2. P fate and transport in filter media simulated with a 1-D advection-dispersion-reaction model;
3. Model calibrated with field-based data series;
4. Mass balance and sensitivity analyses identify the main P sinks and critical processes that control reduction of P in surface runoff.

Results

P export:.

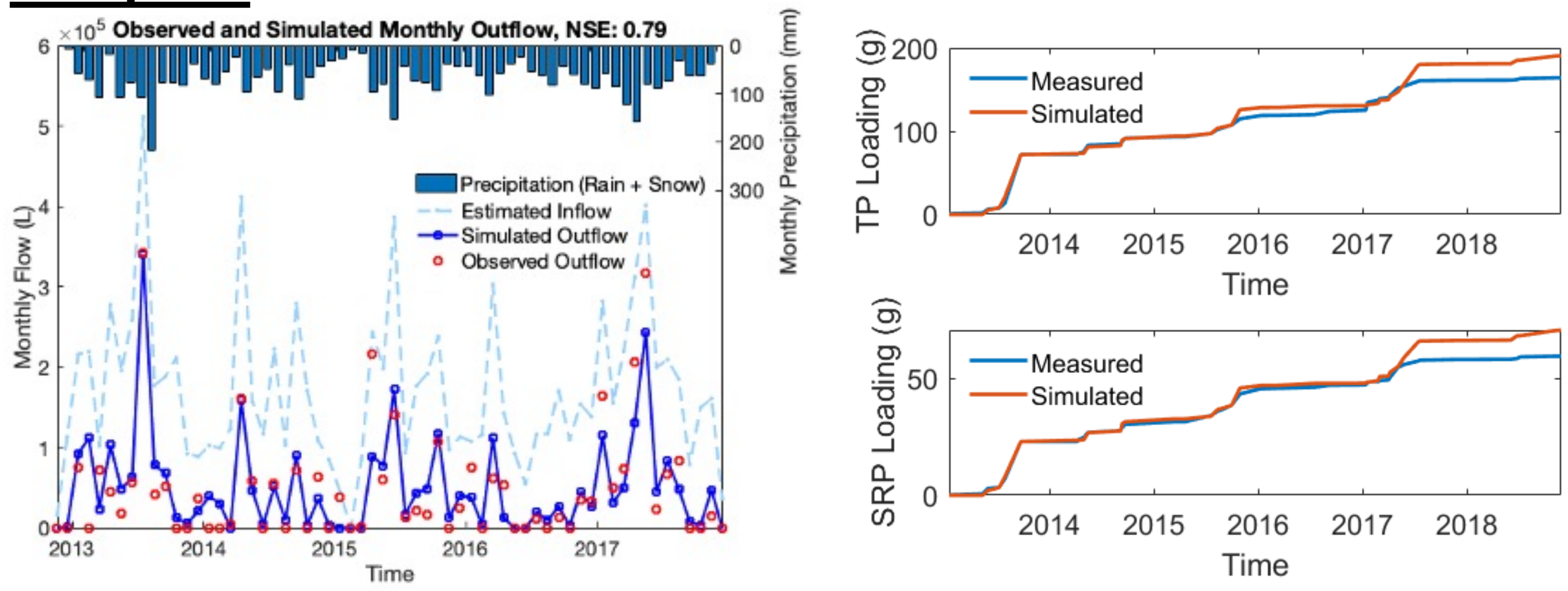

Figure 3. Modeled versus measured monthly water in/outflow volumes (left) and cumulative outflow P loads (right) for the period during which the outflow volumes plus the concentrations of total P (TP) and soluble reactive P (SRP) were monitored.

P accumulation in BRC filter media:.

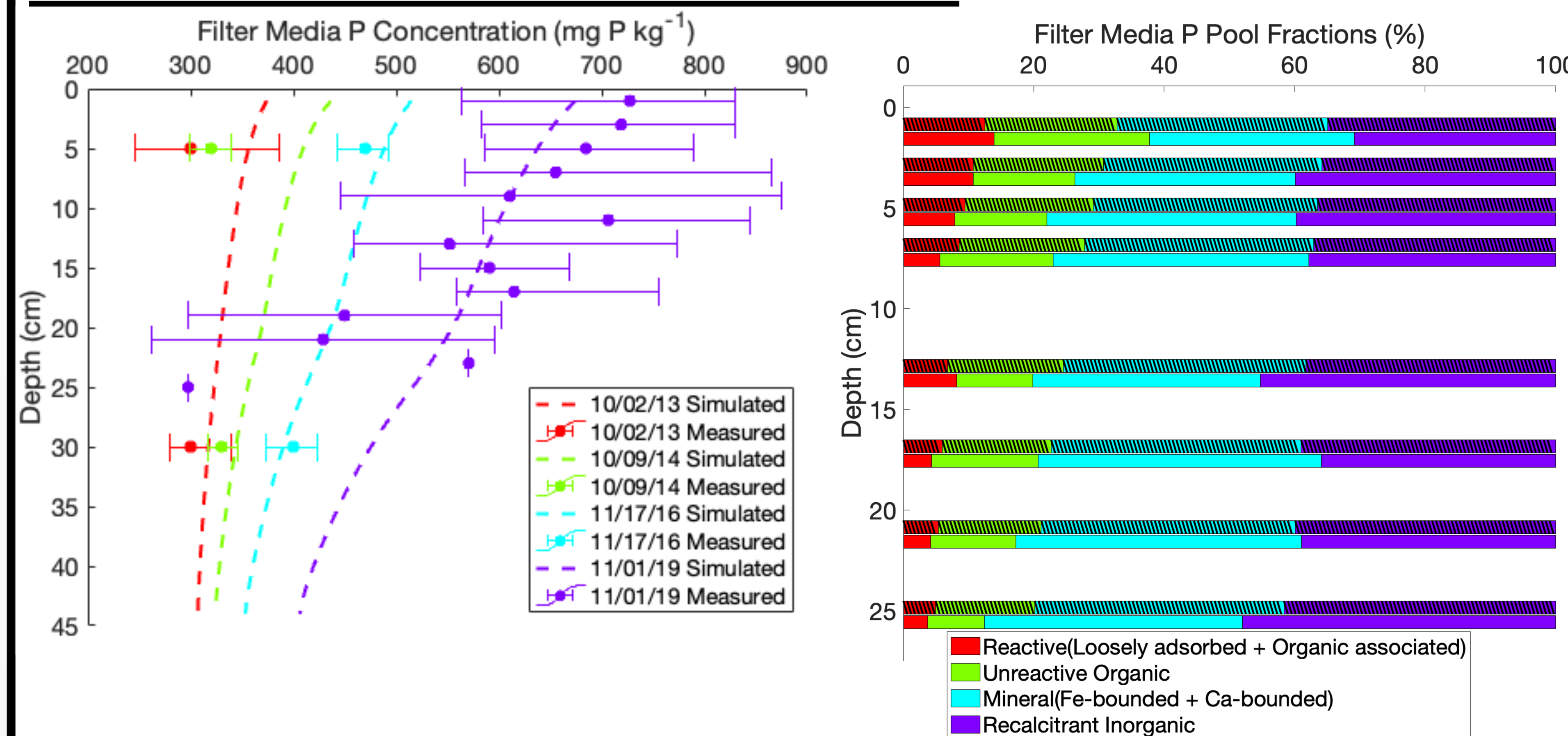

Figure 4. Modeled versus measured concentration depth profiles of (1) TP in cores collected in 4 consecutive years (left), and (2) the distribution of TP over different pools in a core retrieved on November 1st, 2019 (right, for each depth: top bars = modeled, bottom bars = measured).

Water and P mass balances:

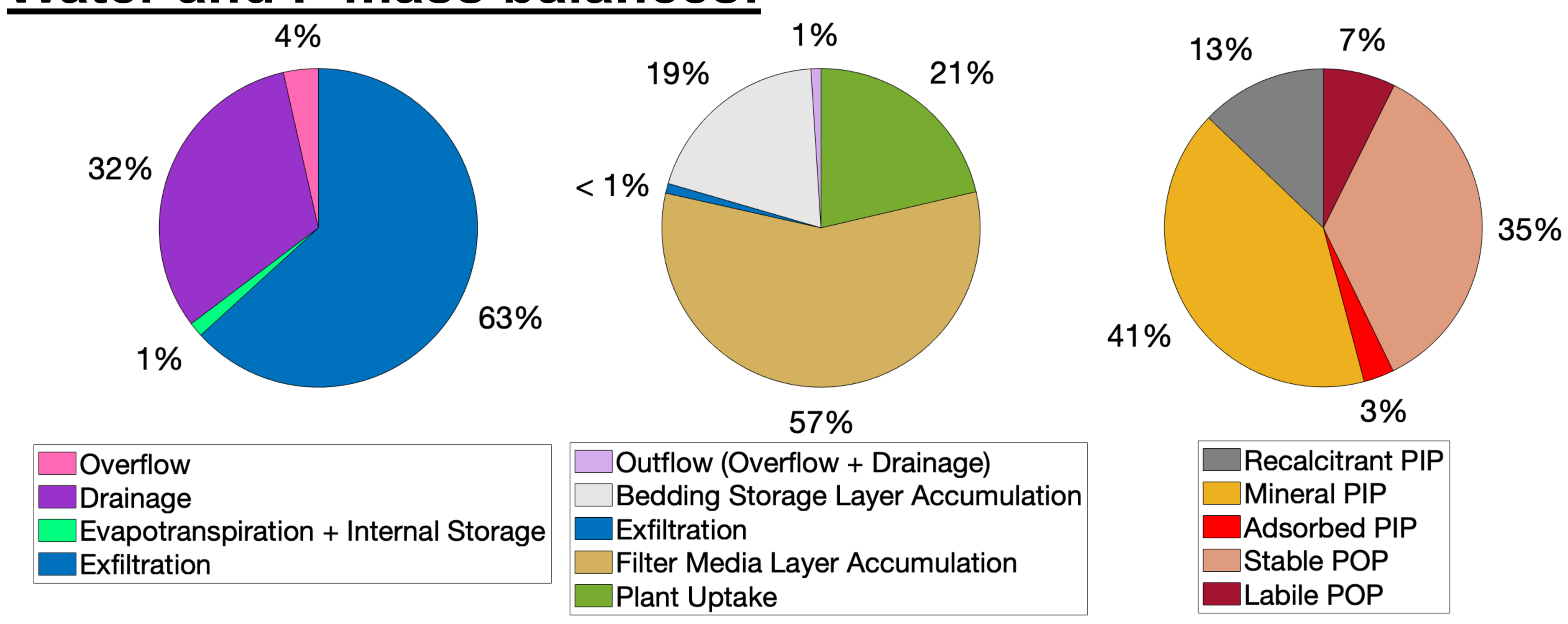

Figure 5. Integrated model-predicted percentages for 2013 to 2019. Including: fate of water inflow to the BRC (left); fate of P entering the BRC (middle); partitioning of P accumulated in the filter media layer over the different pools (right: PIP: particulate inorganic P, POP: particulate organic P.

Conclusions & Acknowledgements

Conclusions:

- Groundwater recharge: principal mechanism reducing BRC outflow;
- Accumulation in filter media layer: dominant mechanism reducing P loads from the BRC (57% reduction over period 2013 – 2019);
- Most (89%) of P accumulated in the filter media layer exists in relatively stable (i.e., unreactive) forms;
- The studied BRC is very efficient at controlling urban P runoff, with no signs of lowering of the retention efficiency after 7 years of operation.

Acknowledgements:

This work was supported by the Managing Urban Eutrophication Risks under Climate Change project under the Global Water Futures (GWF) program funded by the Canada First Research Excellence Fund (CFREF), and by funding from the Natural Sciences and Engineering Research Council of Canada (NSERC) Strategic Partnership Grant (STPGP 521515-18). We thank Credit Valley Conservation (CVC) staff, especially Amanjot Singh and Stephanie Wilson, for sharing data and providing their valuable insights on the monitoring and functioning of the bioretention facility under study. Thanks also to Ecohydrology Research Group members Stephanie Slowinski, Yubraj Bhusal, Alina Arvisais, Marianne Vandergriendt, Dr. Shuhuan Li and Konrad Jens Krogstad for their support in field and lab work.

ecohydrology research group · Canada Excellence Research Chairs · GWF · water institute · Credit Valley Conservation · UNIVERSITY OF WATERLOO