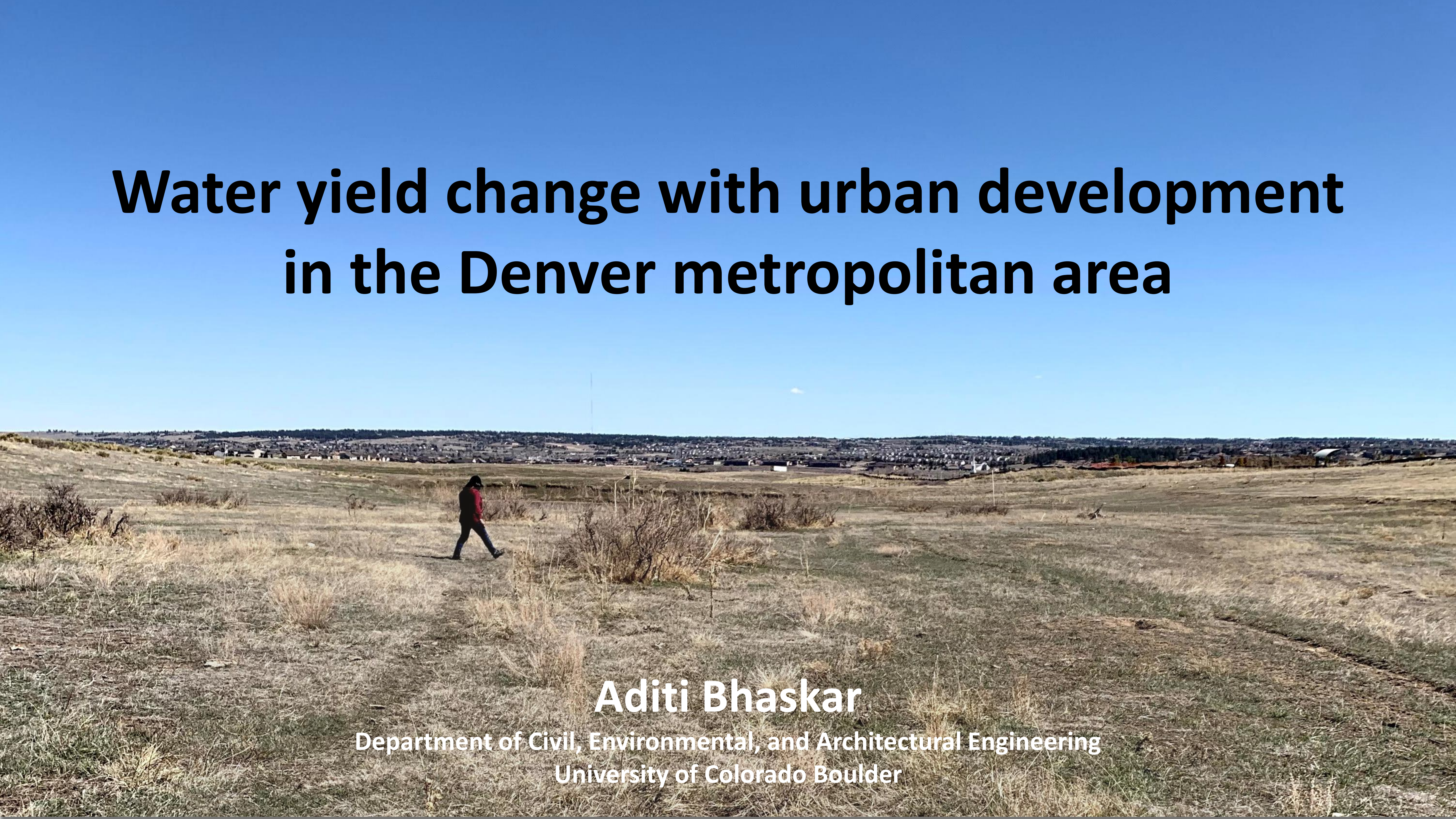


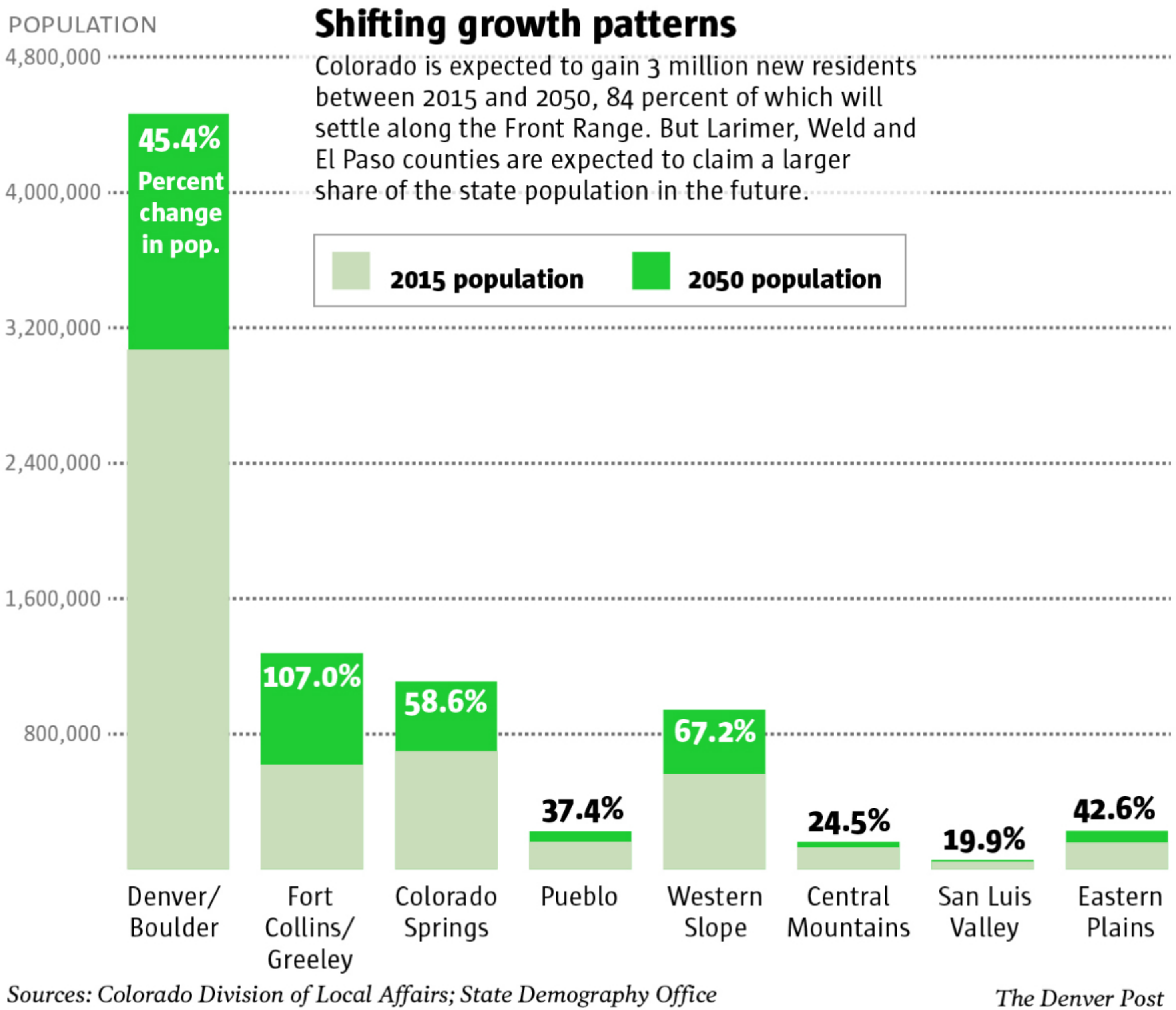
Water yield change with urban development in the Denver metropolitan area

Aditi Bhaskar

Department of Civil, Environmental, and Architectural Engineering

University of Colorado Boulder

Projected growth in Colorado is focused in the Denver area.



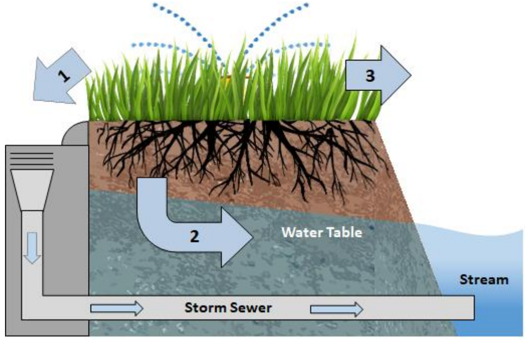
Urbanization changes:

- **Water use**

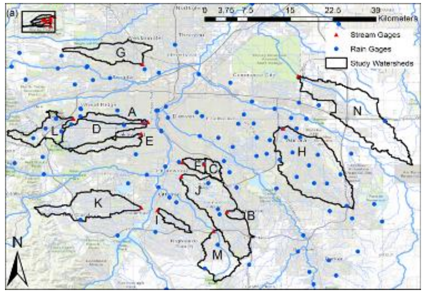
  Nicholas Guthro's presentation next will discuss water use patterns

- **How much flow there is in streams**

The questions addressed today are:



What are the tap water contributions to urban baseflow in the Denver, Colorado area?

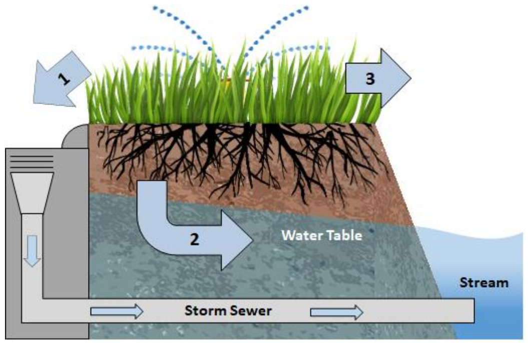


How does the streamflow response to rainfall events change with impervious surface cover in the Denver, Colorado area?

I want to acknowledge here that historical population changes have come at a dire cost.

The land that this research focuses on is located on Nunt'zi (Ute), Hinono'eino' (Arapaho), and Tsistsistas (Cheyenne) traditional homelands.

The questions addressed today are:



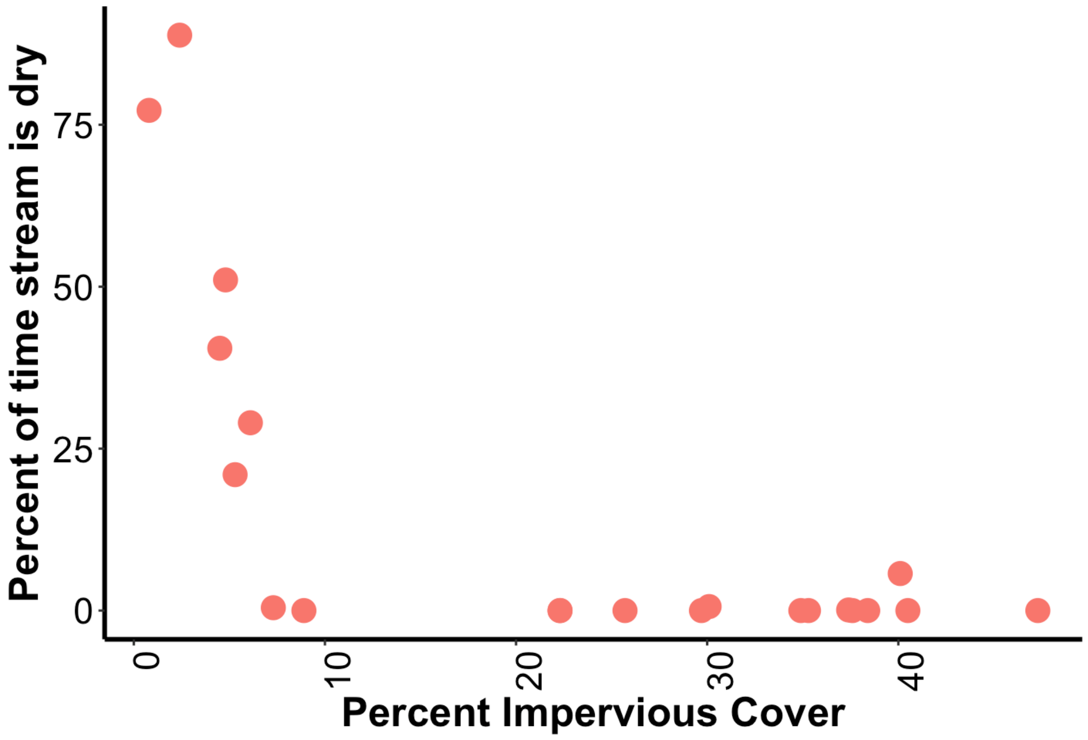
What are the tap water contributions to urban baseflow in the Denver, Colorado area?

Noelle Fillo
2020 CSU MS Graduate
Now at WEST Consultants, Phoenix

Fillo, Bhaskar, and Jefferson (2021) Water Resources Research

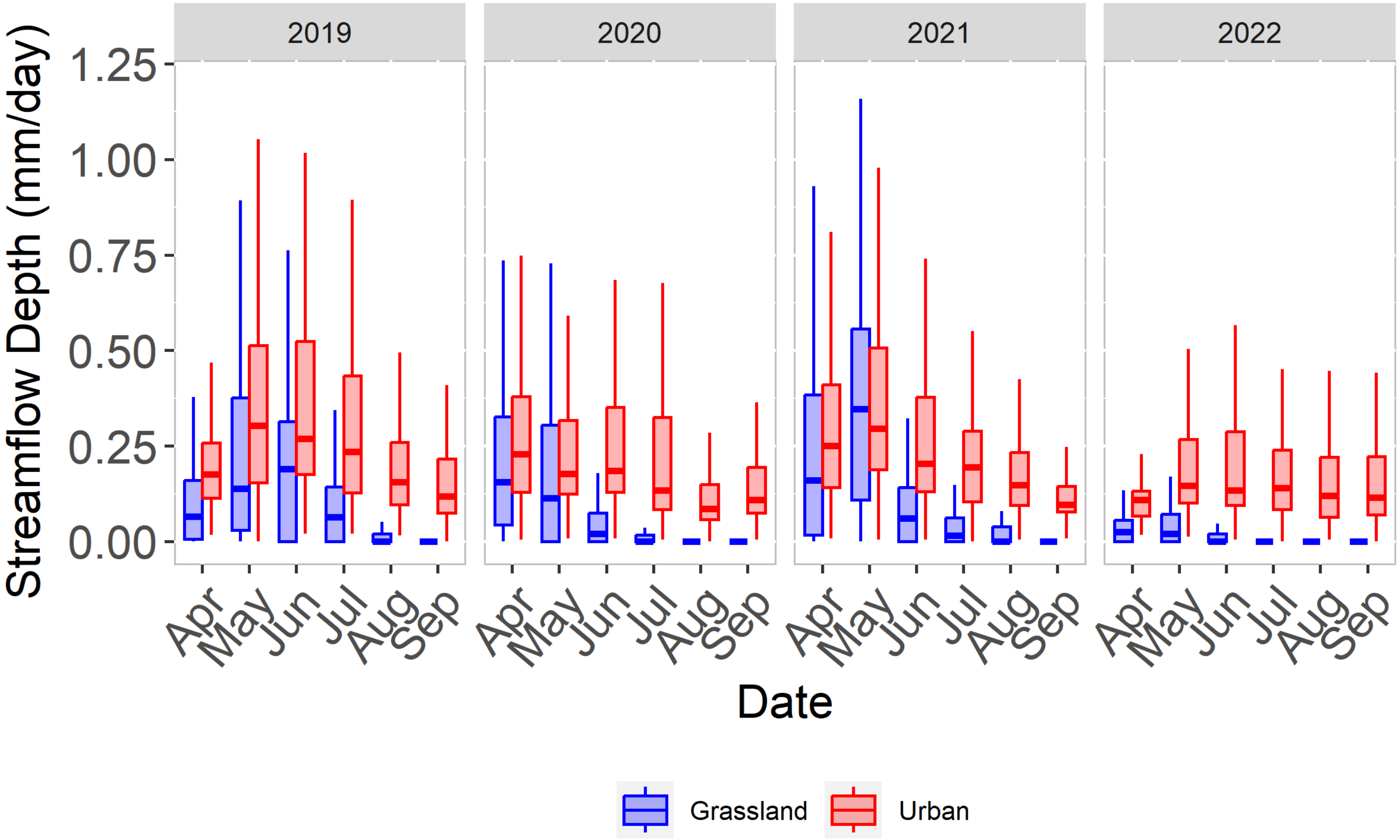
Abdullah Al Fatta
PhD student at CSU

Urban watersheds flowed more often.



Based on analysis of 5-to-15 minute streamflow, limited to April to September, 2013-2020.

Urban streams had more streamflow.

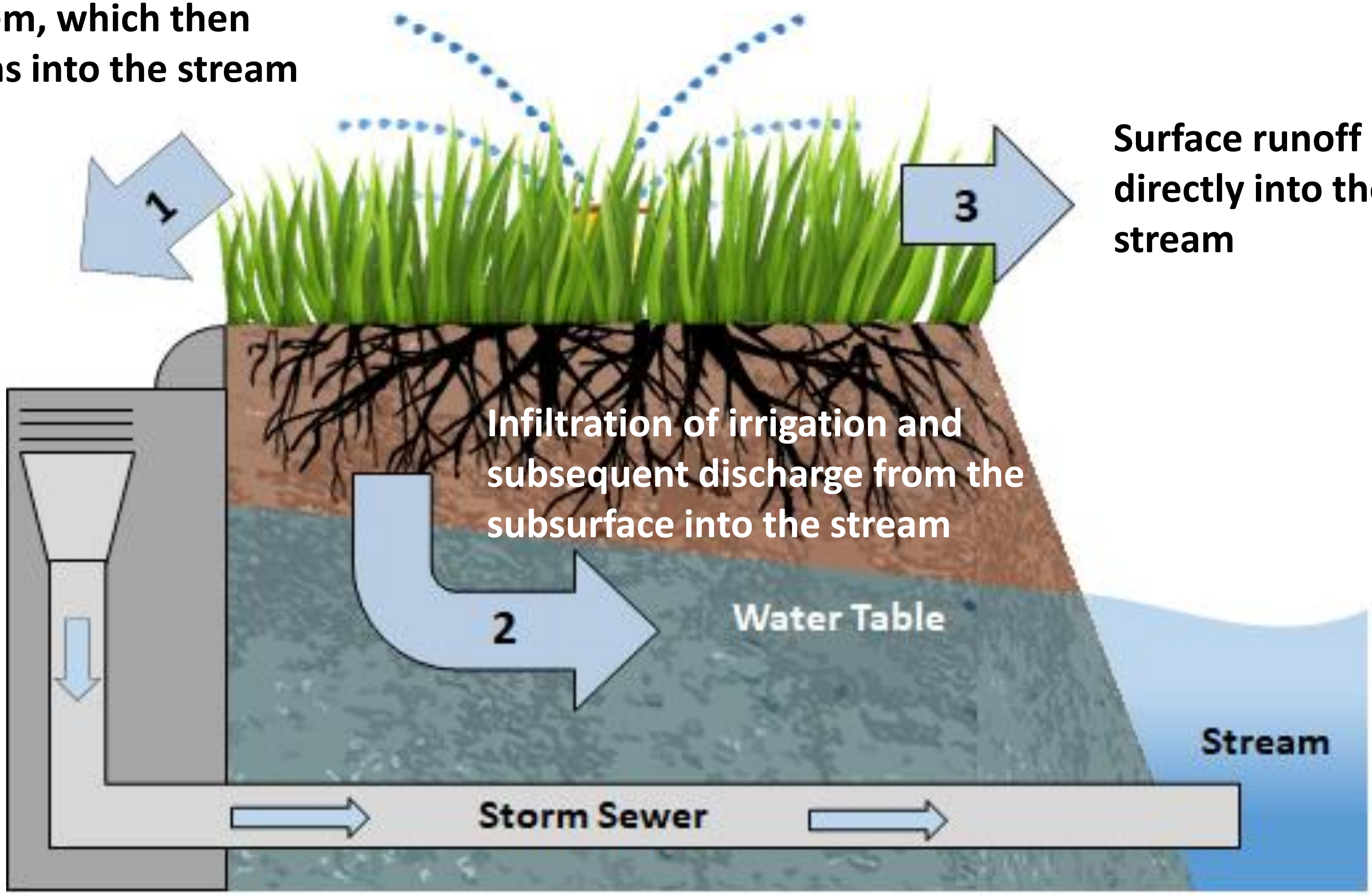


Al Fatta, Bhaskar, et al. (in prep)

Lawn irrigation return flows (LIRFs) can increase baseflow.

Surface runoff into the storm sewer system, which then drains into the stream

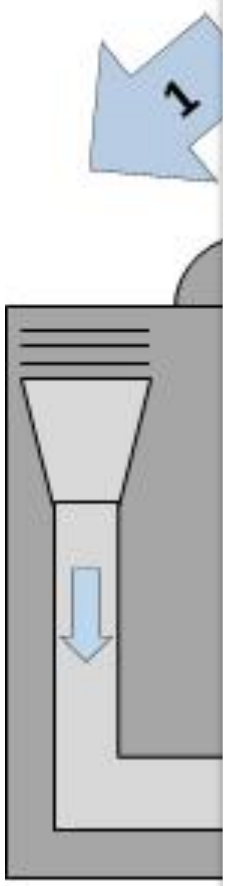
Surface runoff directly into the stream

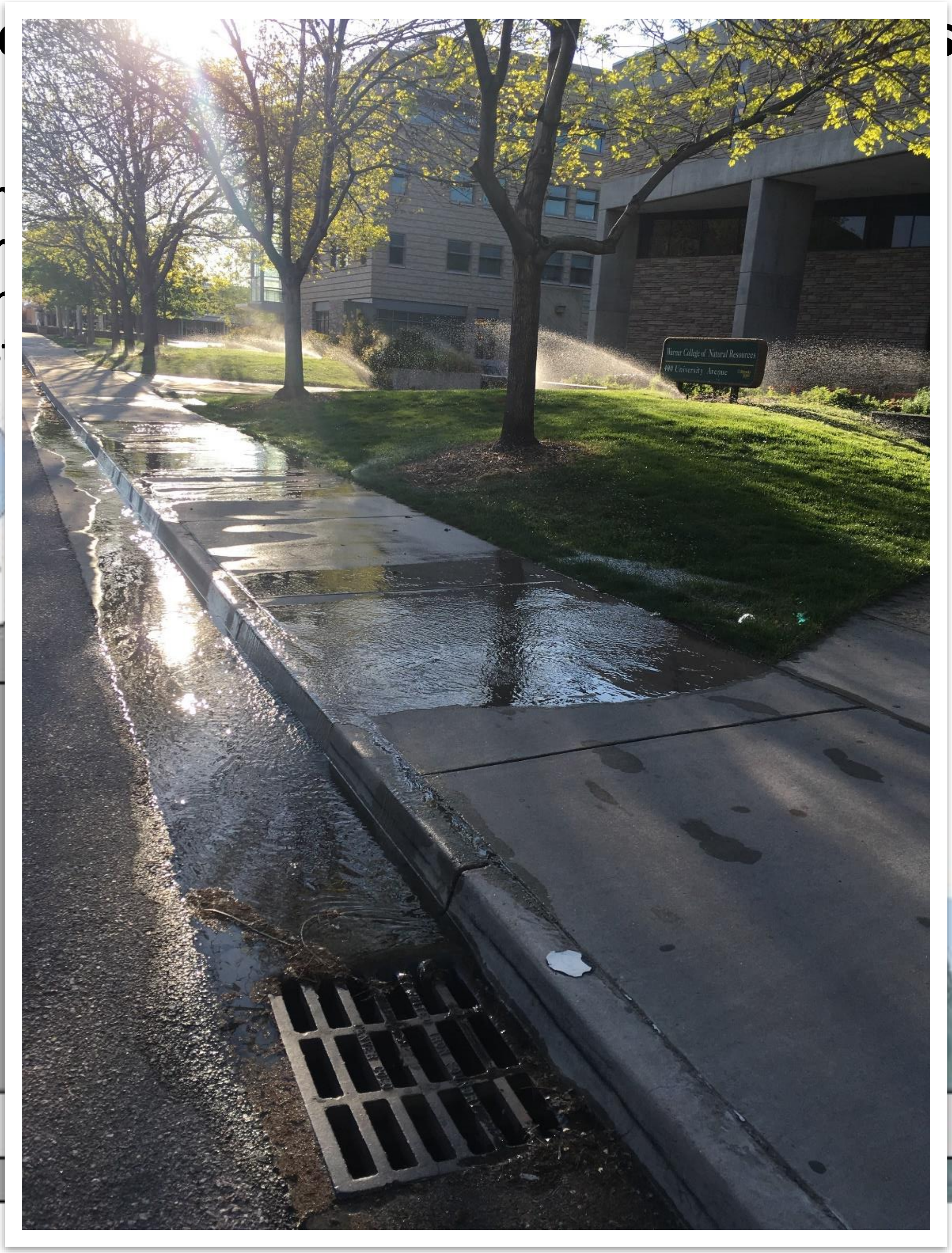


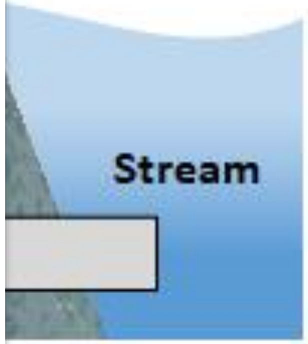
Lawn irrigati se baseflow.

Surface runoff ir
the storm sewer
system, which th
drains into the st

Surface runoff directly into the stream







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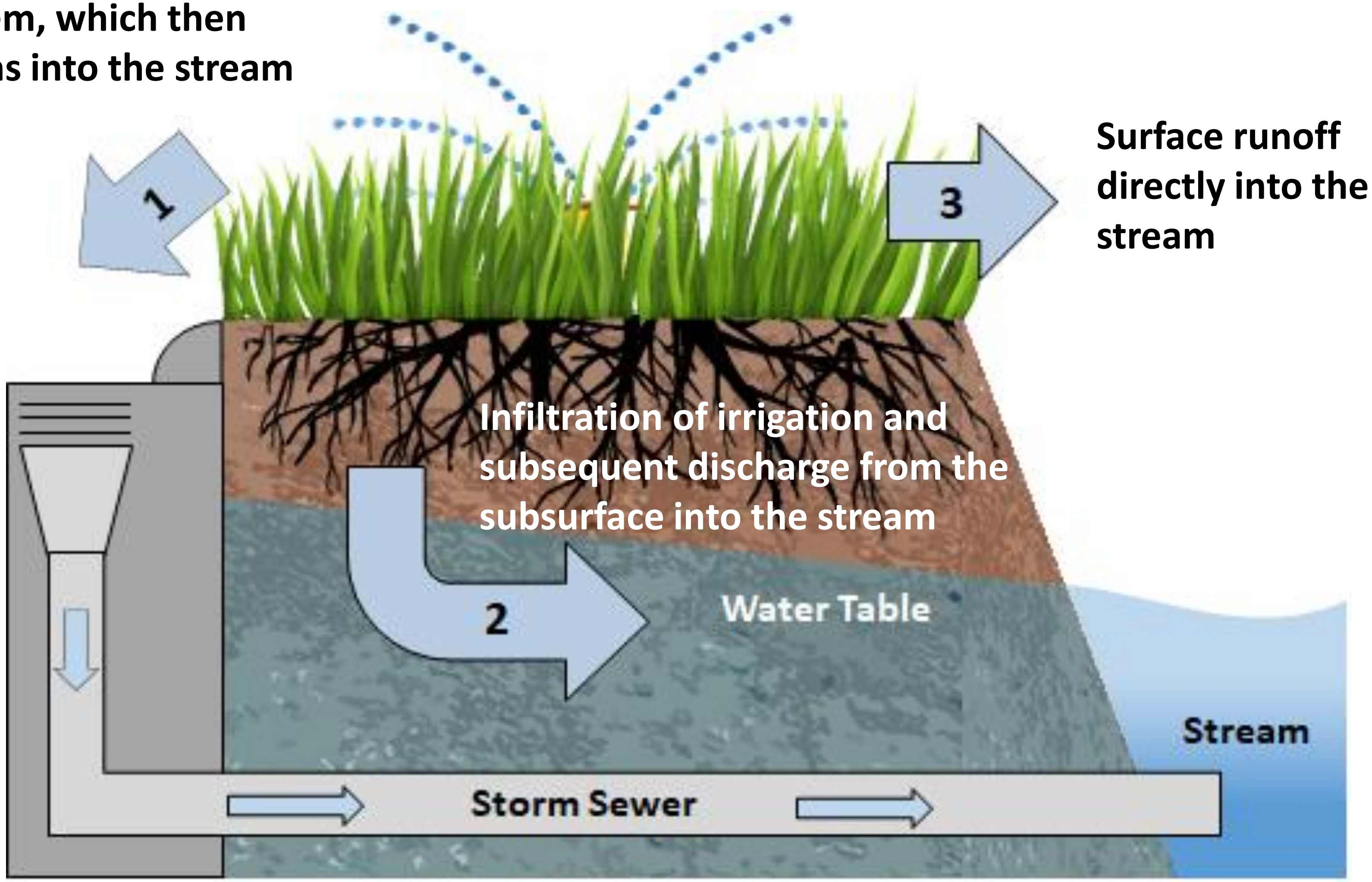
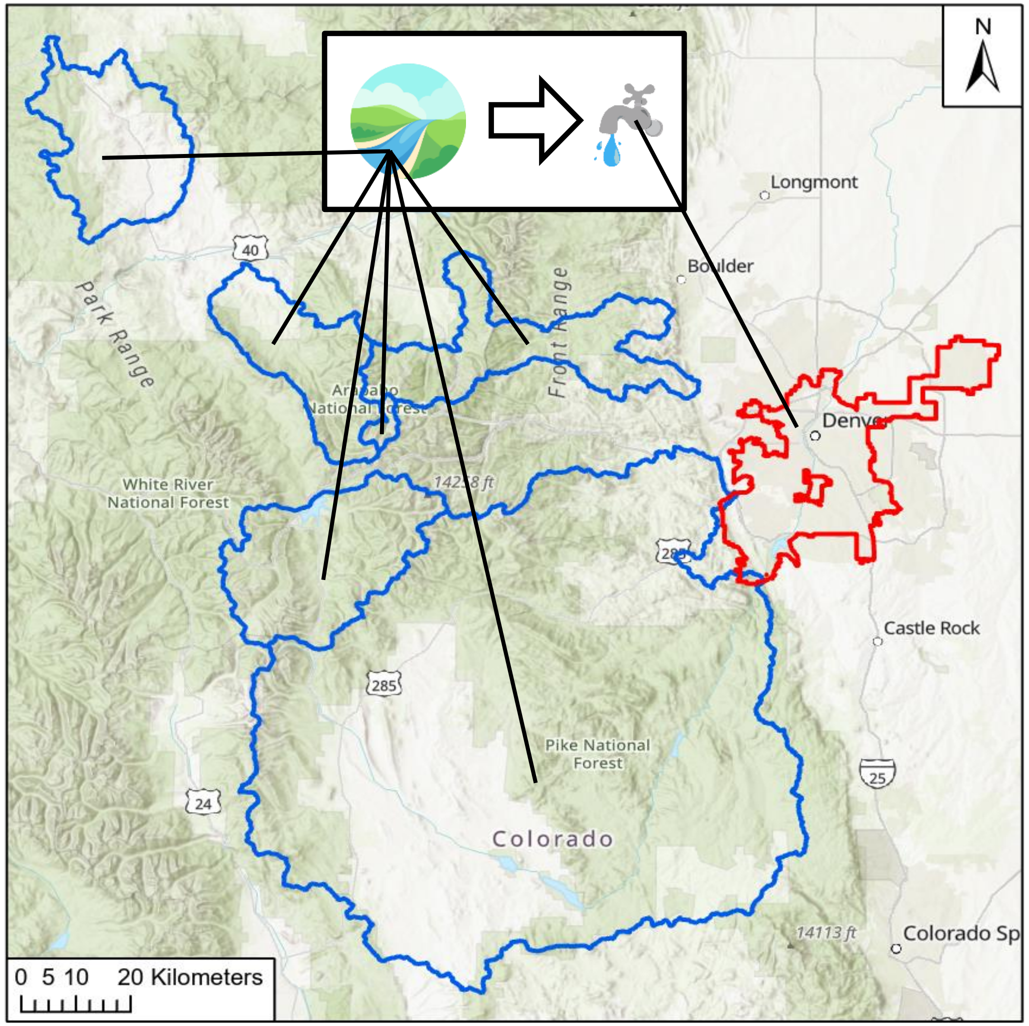


Denver's tap water is imported from higher elevations and is isotopically distinct from locally-derived water.

Surface Water in the Rocky Mountains

Mean Elevation: 2622 m – 3556 m above sea level

δ^2H [‰]



Denver Water Collection Areas
Denver Water Service Area

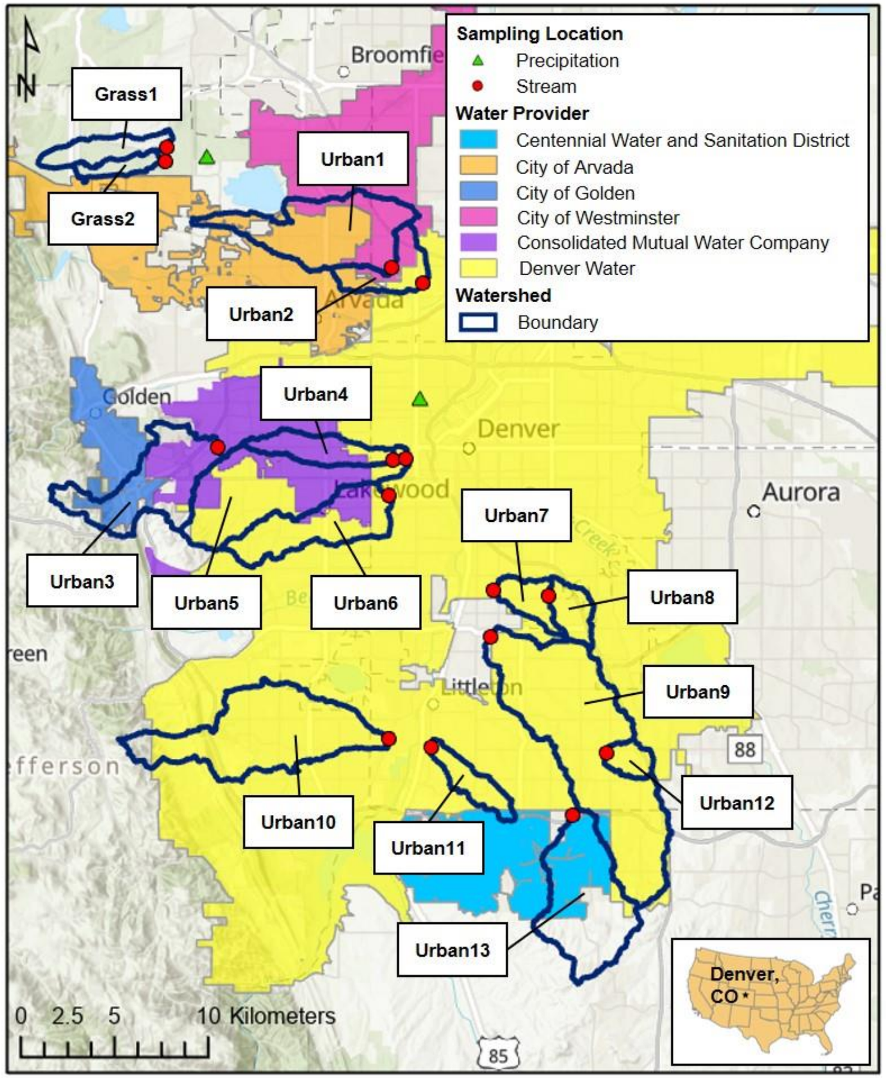
Surface Water in the Denver Metropolitan Area

Mean Elevation: 1676 m above sea level

δ^2H [‰]

[Leonard Rice Engineers, Inc., "Colorado Water Entities.", 2015]

Our first step to answering our research questions was to characterize the Denver metropolitan area.



Grassland Streams

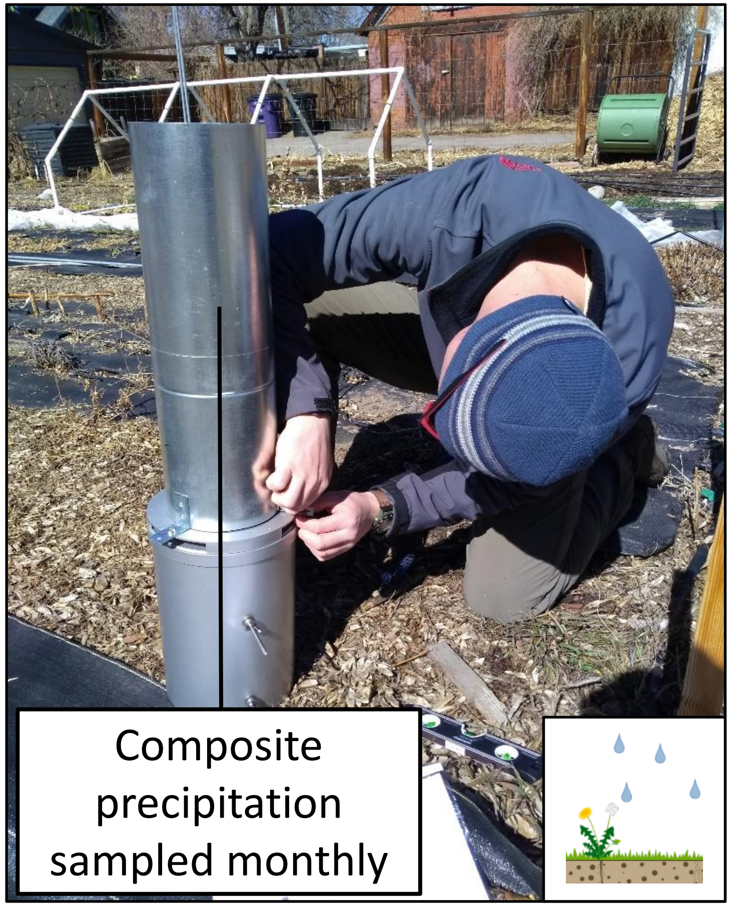
	Area (km²)	Imperviousness (%)
SWOM	3.7	1
WOM	7.5	5

Urban Streams

	Area (km²)	Imperviousness (%)
High	63.3	44
Low	3.9	22

We sampled baseflow, taps, and precipitation in the summers of 2019, 2021, and 2022.

Streams sampled approx. biweekly



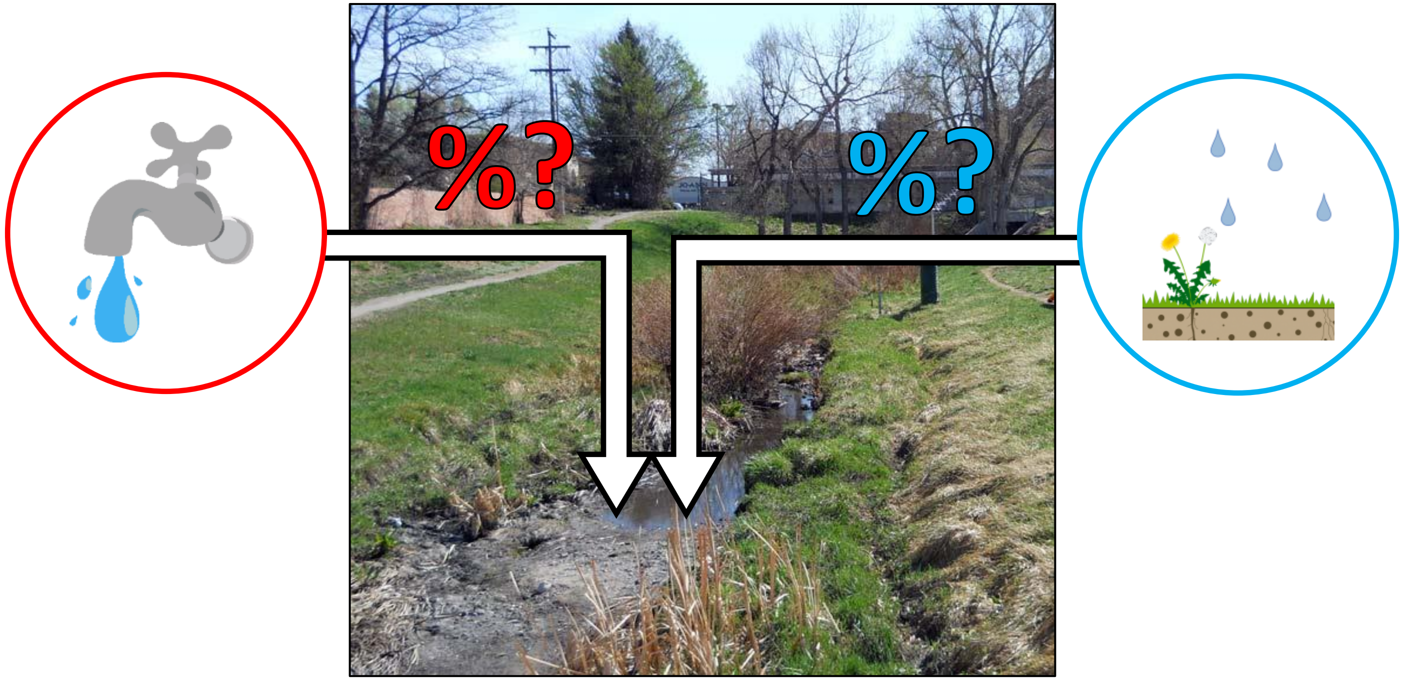
Composite precipitation sampled monthly

Tap samples collected from each water provider in each watershed where baseflow was sampled.

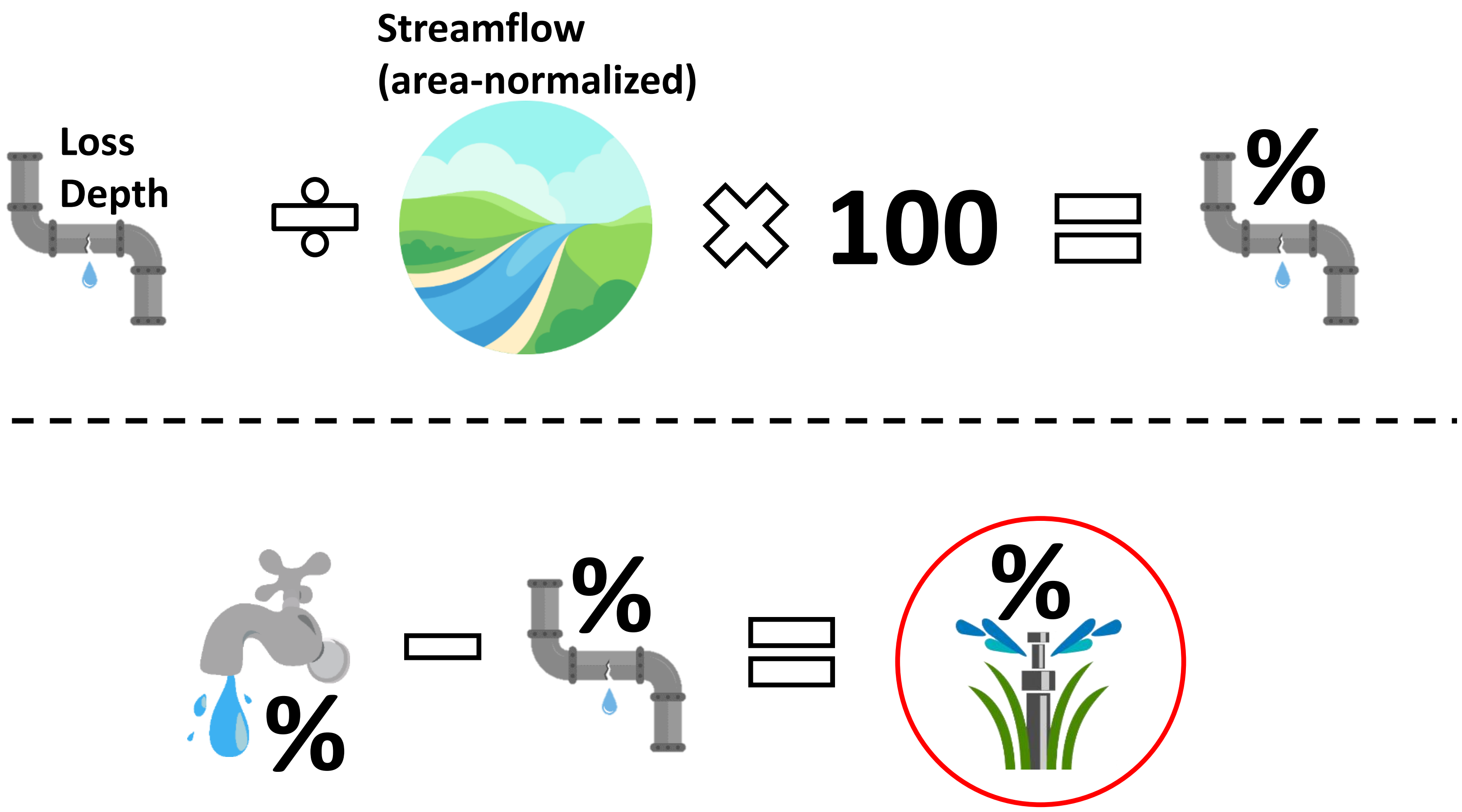
Two end-member mixing analysis was used to solve for tap and precipitation proportions of urban baseflow.

$$\delta_{precipitation} \times \boldsymbol{Proportion_{precipitation}} + \delta_{tap} \times \boldsymbol{Proportion_{tap}} = \delta_{stream} \qquad (3)$$

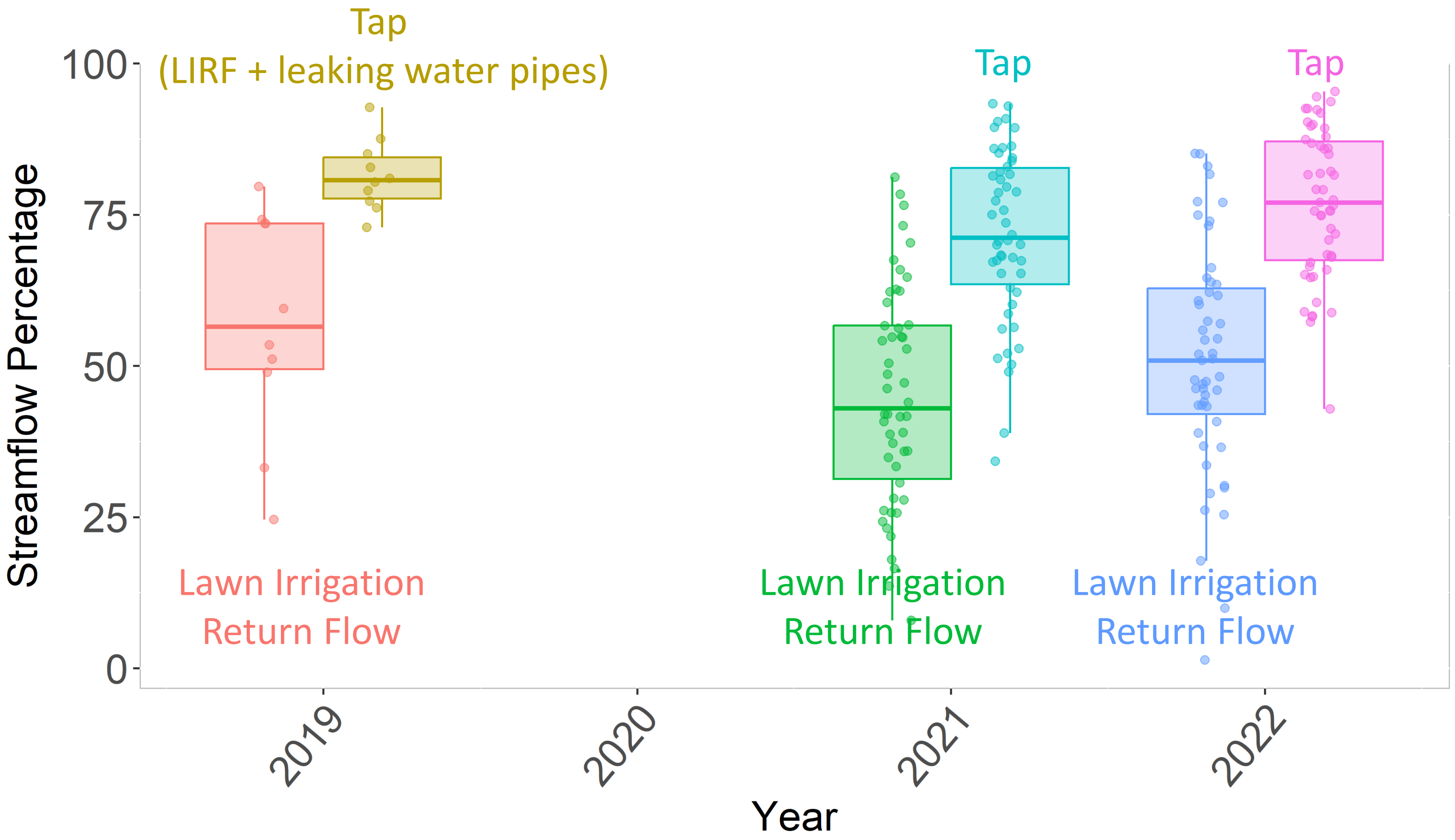
$$\boldsymbol{Proportion_{precipitation}} + \boldsymbol{Proportion_{tap}} = 1 \qquad (4)$$



The LIRF contributions to baseflow were separated implicitly using reported water infrastructure losses.

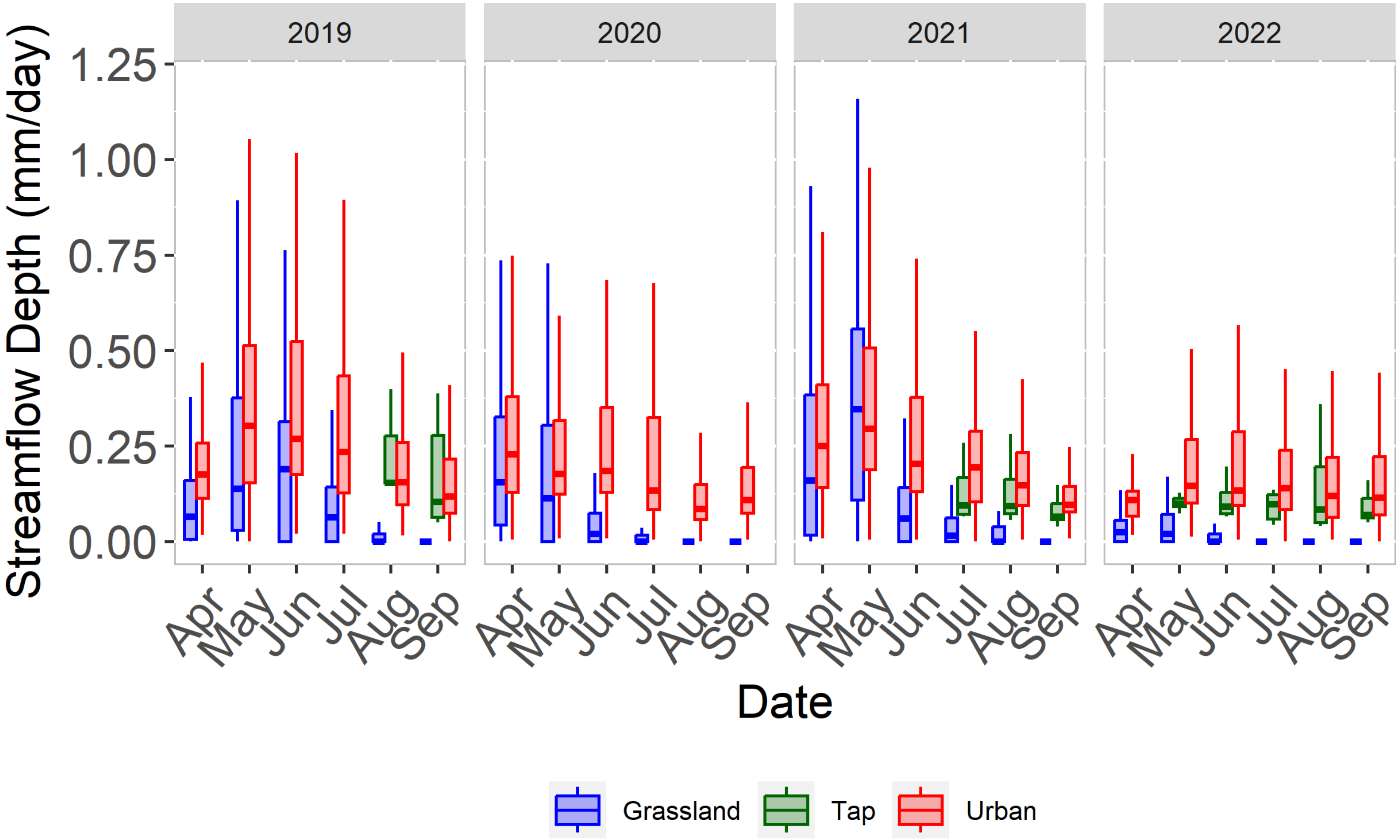


~ ¾ of urban baseflow is from leaking pipes, and
~ ½ of urban baseflow is from lawn irrigation return flow.



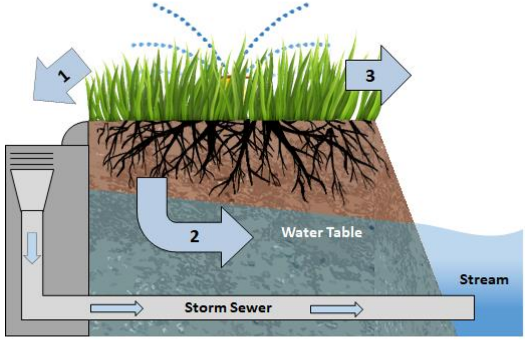
Al Fatta and Bhaskar (in prep)

Tap contributions are a large part of why streamflow is higher in urban streams.

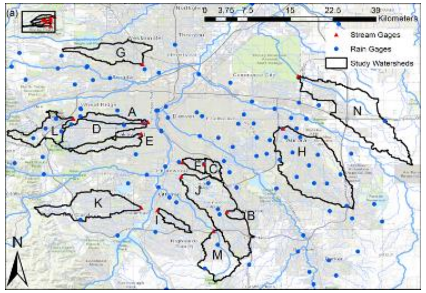


Al Fatta, Bhaskar, et al. (in prep)

The questions addressed today are:



What are the tap water contributions to urban baseflow in the Denver, Colorado area?



How does the streamflow response to rainfall events change with impervious surface cover in the Denver, Colorado area?

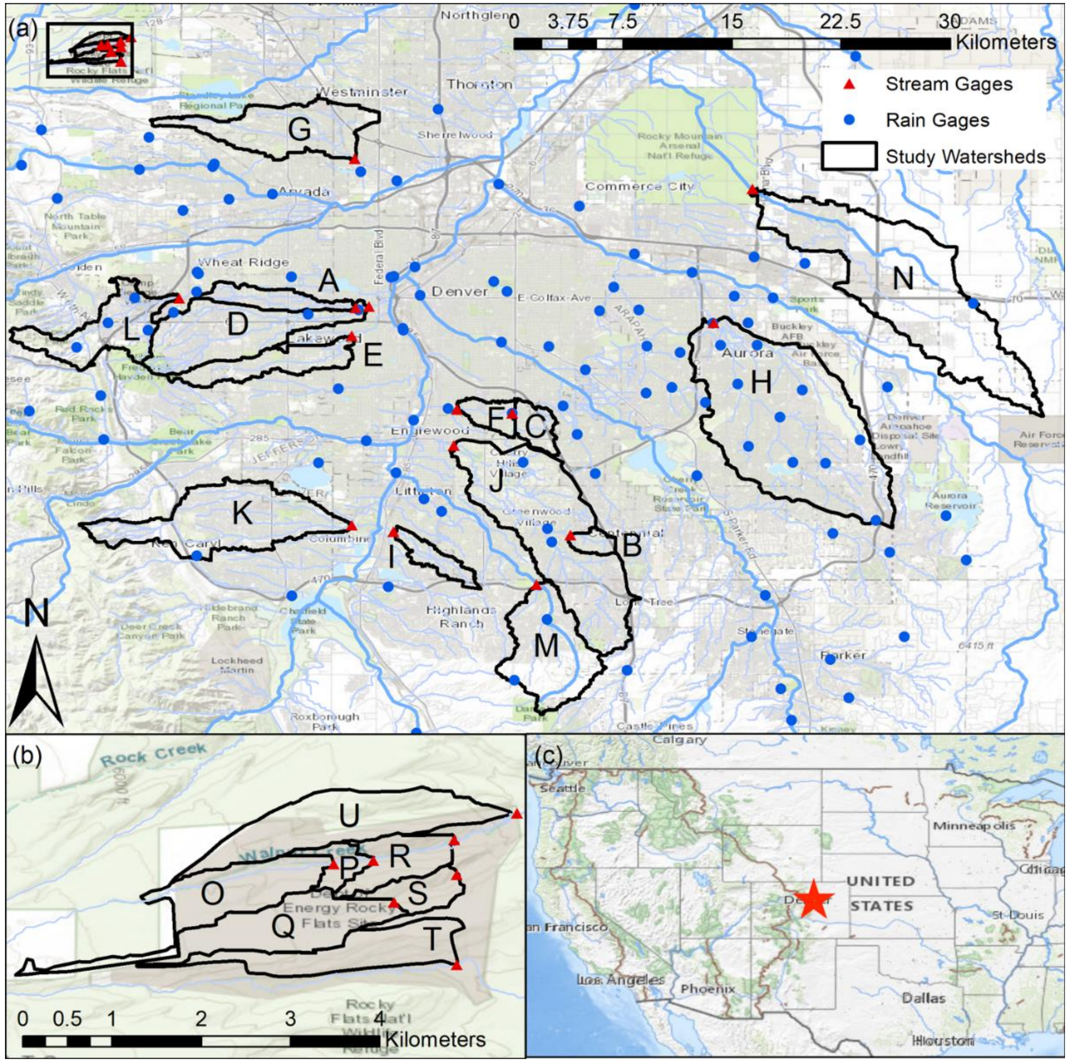
Stacy Wilson

2021 CSU MS Graduate

Now at Wright Water Engineers, Denver

Wilson, Bhaskar, Choat, Kampf, Green, Hopkins (2022), Hydrological Processes

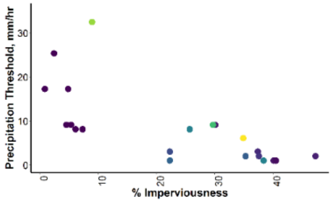
We identified 3,644 paired rainfall-streamflow events using instantaneous streamflow + a semi-automated process.

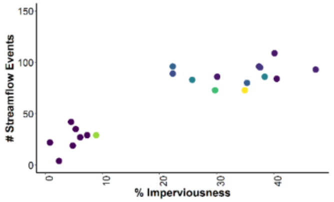


Wilson, Bhaskar, Choat, Kampf, Green, Hopkins (2022), Hydrological Processes

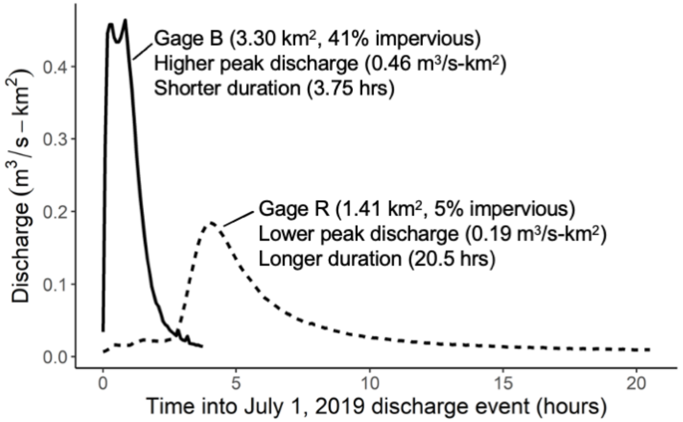
In semi-arid Denver, CO, USA urbanization…

- increased the responsiveness of these watersheds to even small rain events, resulting in more streamflow events occurring in watersheds with more impervious surfaces

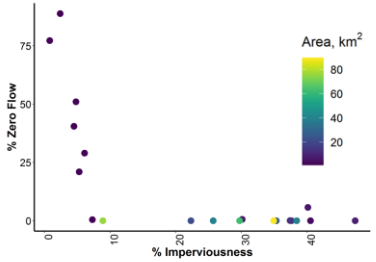




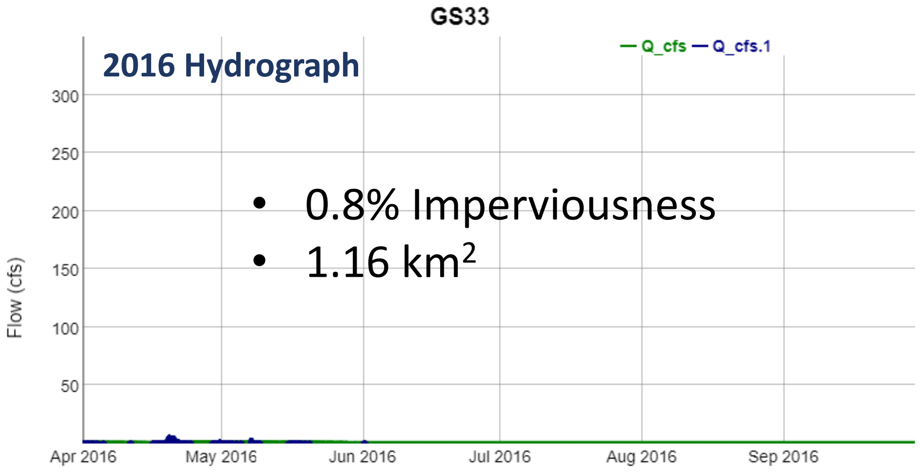
- increased peak streamflow and shortened streamflow event duration

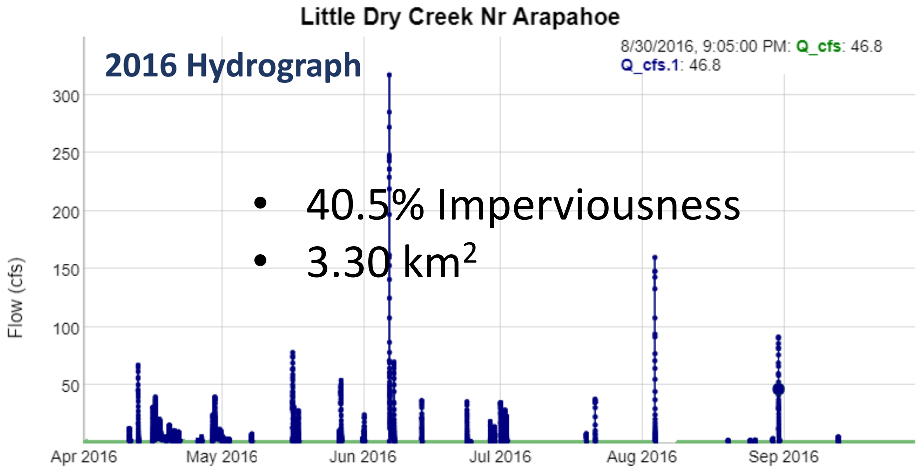


- reduced the time that streams are dry



- does not have a clear effect on total runoff, runoff ratio, or time to peak





How do these changes compare to other studies?

↓ zero flow — Agrees with Phoenix (McPhillips et al., 2019)

↓ precipitation threshold

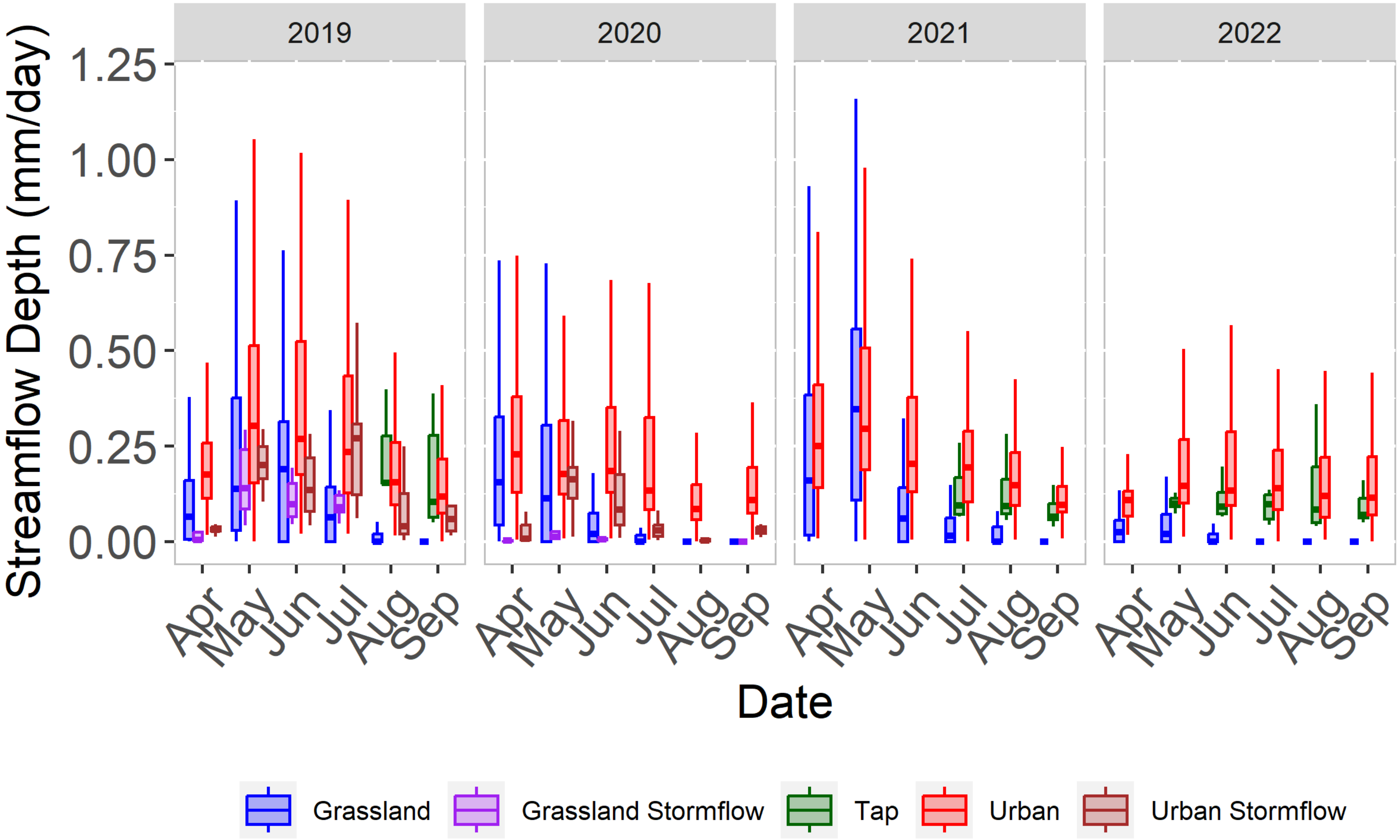
↑ streamflow events — Agrees with Phoenix and Tucson

↑ peak flow

↓ streamflow event duration — Opposite of Tucson (Gallo et al., 2013)

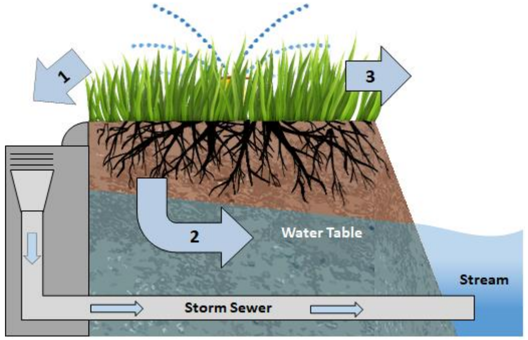
↔ runoff depth, time to peak — Agrees with Tucson (Gallo et al., 2013)

The higher stormflow in urban streams also contributes to higher streamflow.

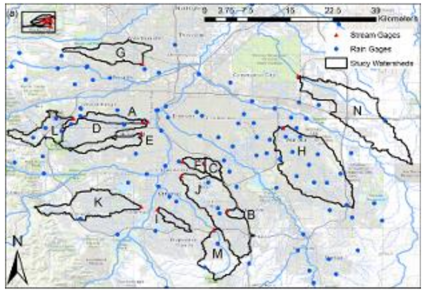


Al Fatta, Bhaskar, et al. (in prep)

In summary:



An isotope mixing analysis estimated that tap water contributed a mean of 80% of urban baseflow on specific days in late summer.



Urbanized watersheds in Denver have higher peak flow and shorter streamflow responses compared to their less developed counterparts.

Ongoing work is looking at:

- How to predict these changes to streamflow based on watershed properties
- Monitoring streamflow in a rangeland watershed as it urbanizes
- How changes to water management such as rainwater harvesting would affect flow and use

Ask Santiago Ramírez Núñez and Junwon Lee about this at their posters this afternoon!

aditi.bhaskar@colorado.edu