Characterizing Groundwater Recharge in the Human Environment: A Case Study

Eawag: Swiss Federal Institute of Aquatic Science and Technology

eawag aquatic research

Robin Weatherl
Supervisor: Prof. Mario Schirmer
Co-author: Maria Henao Salgado, Msc.

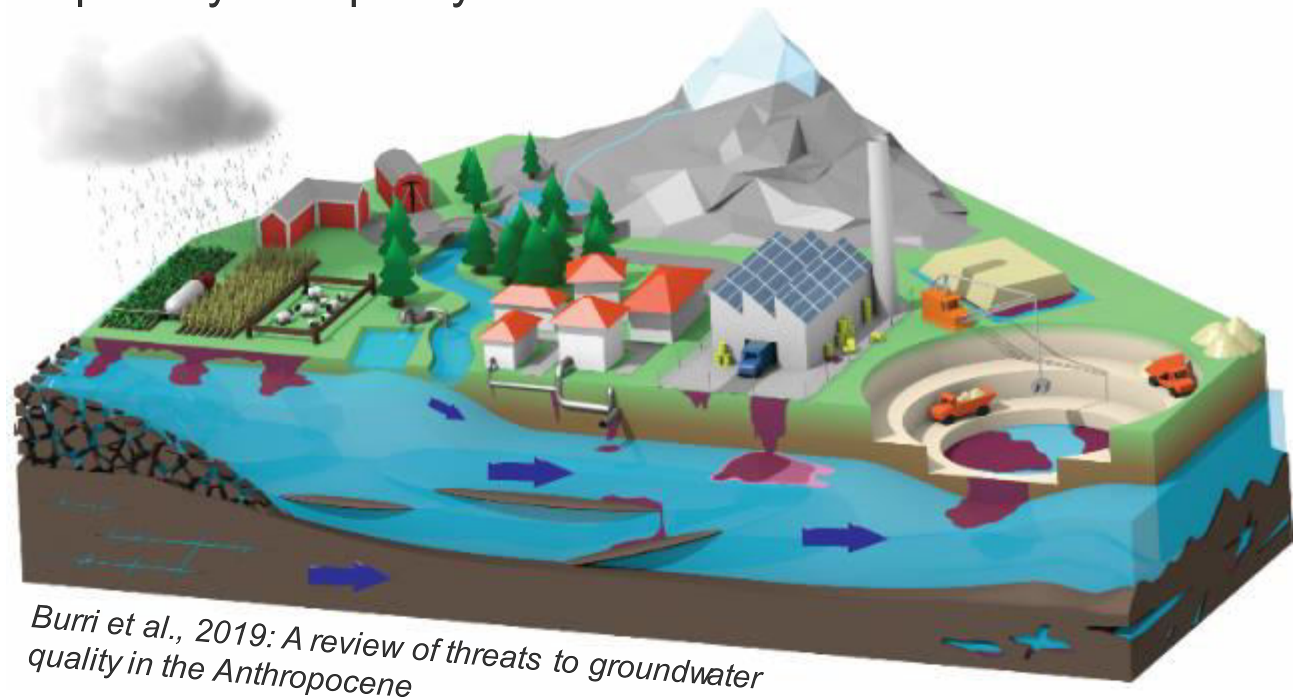
unine UNIVERSITÉ DE NEUCHÂTEL

Liège, Belgium
September 9, 2019

Introduction: Groundwater Recharge

eawag
aquatic research

- Groundwater recharge is one of the least understood components of the water cycle
- Human land development has created additional complexity to groundwater recharge dynamics !
- The rate, timing, and location of recharge are consequential for resulting groundwater quantity and quality



Burri et al., 2019: A review of threats to groundwater quality in the Anthropocene

unine
UNIVERSITÉ DE NEUCHÂTEL

Objectives and Methods

eawag
aquatic research

Global Objective: Explore the influence of human land development on groundwater recharge and associated flow pathways

Methods

1. Design and install a **groundwater monitoring network** at the site of investigation
2. Quantify the **annual change in groundwater storage**, accounting for changes in variables including evapotranspiration and **surface runoff**
3. Explore the use of **chemical and isotopic tracers** to identify anthropogenic recharge sources and associated processes
4. Combine physical and chemical data to improve the local **conceptual groundwater model** that accounts for artificial influences

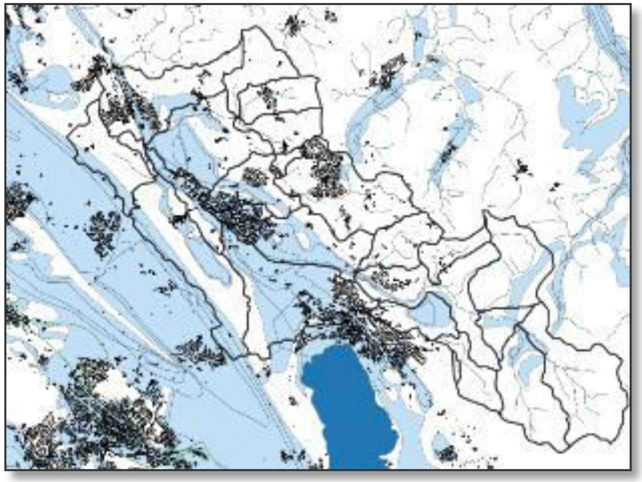
unine
UNIVERSITÉ DE NEUCHÂTEL

Case Study: Fehraltorf and the Kempttal Aquifer

eawag aquatic research

Catchment Characteristics

- **Altitude**: 500 – 900 masl
- **Size**: 35 km^2
- **Climate**: average yearly rainfall of 1300 mm
- **Aquifer geology**: shallow, glacio-fluvial sediments; significant spatial heterogeneity



Land Use Characteristics

- **Population**: approx. 6300
- **Land Use**:
  - 53% Agriculture
  - 19% Urban
  - 26% Forest
  - 2% Industrial
- **Municipal water supply:** 80% sourced from local aquifer

unine UNIVERSITÉ DE NEUCHÂTEL

Estimating Groundwater Recharge

Method	Input	Notes
Water Balance (WB)	Precipitation, evapotranspiration, surface runoff	Accounts for soil type, vegetation type, and permeability
HBV light model	Precipitation, evapotranspiration, surface discharge	Accounts for river discharge, snowmelt, soil moisture, and groundwater levels

- **Evapotranspiration and runoff terms are large sources of uncertainty!**
  - Difficult to quantify in the natural environment
  - Changes due to land development bring added complexity

- HBV light model uses measured river discharge in place of estimated surface runoff – removing one uncertain variable from the traditional water balance

A Closer Look: Surface Runoff

eawag
aquatic research

- **Surface runoff** defined as water that runs off the land surface in response to a storm event, AKA:
  - ‘’Storm water runoff’’
  - ‘’Overland flow’’
- Soil compaction and impervious surfaces lead to increased runoff
- Acts as a carrier for chemicals from surface, soils, and atmosphere
- Stimulates ‘’combined sewer overflow’’ (CSO) in urban areas, creating a pathway of untreated sewer water into groundwater and surface water

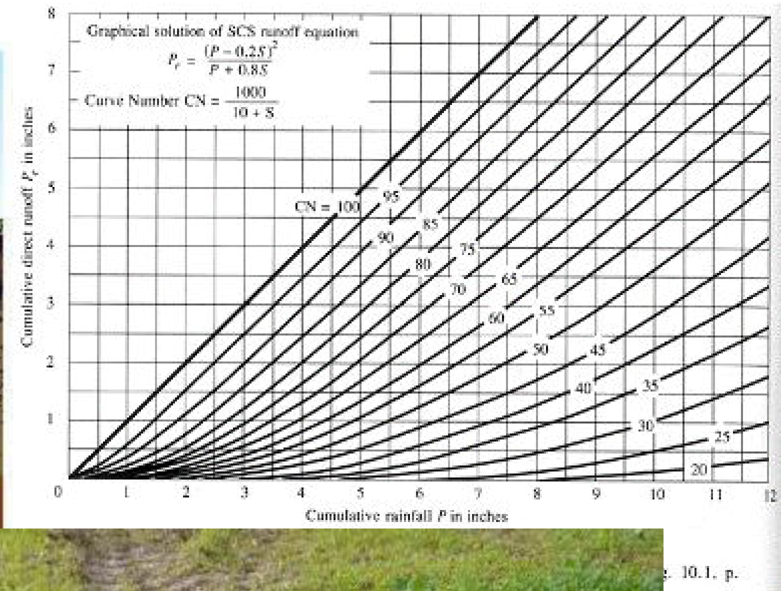
Source: Wikimedia Commons

unine
UNIVERSITÉ DE NEUCHÂTEL

eawag aquatic research

Curve Number (CN) Method

- Direct runoff from rainfall excess estimated from the empirically determined **curve number**
- **Determined via soil types, land use, and hydrologic condition**
- The curve number is constructed from the watershed's conceptual model *–cannot be used to directly assess the accuracy of the conceptual model!*



Source: Wikimedia Commons

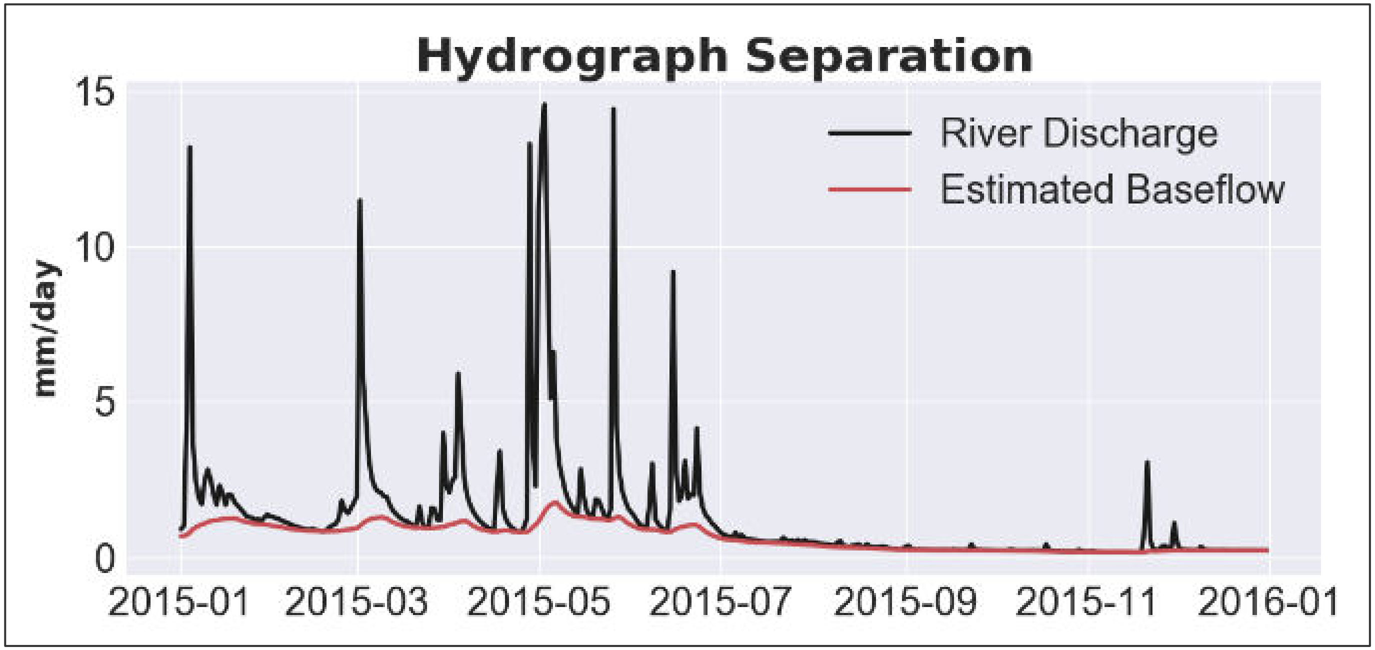
unine UNIVERSITÉ DE NEUCHÂTEL

Surface Runoff

eawag aquatic research

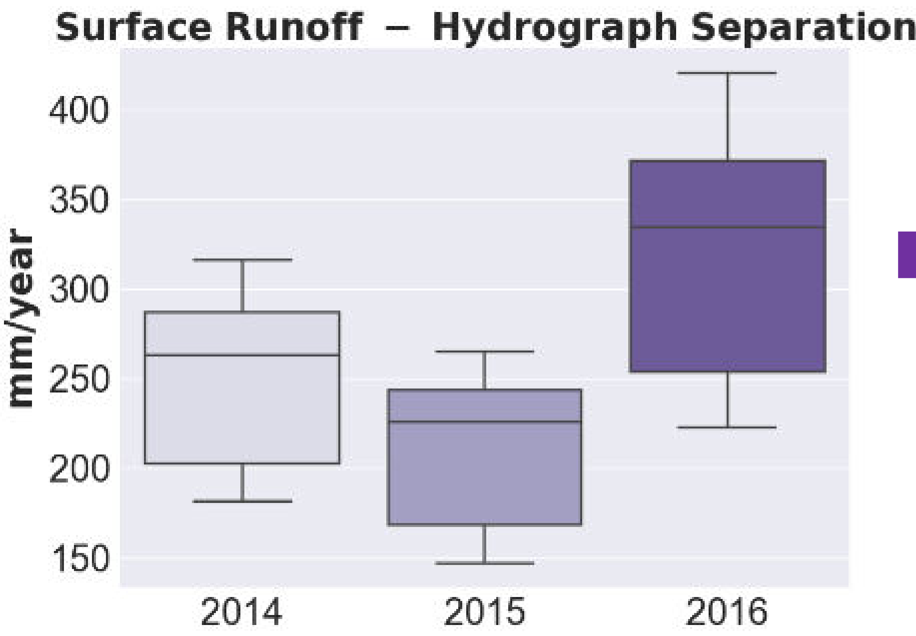
Hydrograph Separation (HS) via Recursive Digital Filter

- Automated technique for separating **baseflow** (groundwater) and **quickflow** (surface runoff) elements of river discharge
- In it's simplest form, only one input required: time series of river discharge
- Quickflow is 'filtered' from the hydrograph, isolating baseflow

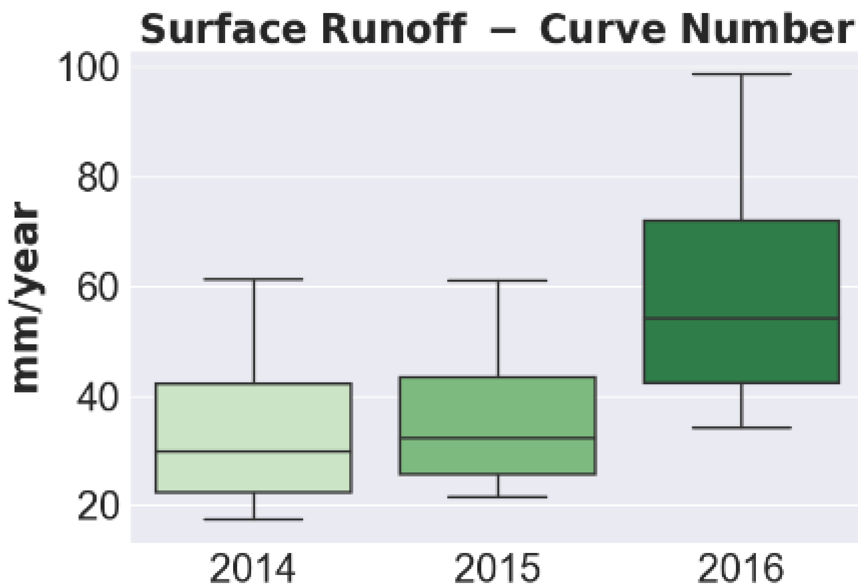


unine UNIVERSITÉ DE NEUCHÂTEL

Annual Estimations of Surface Runoff



Year	Mean	Max	Min
2014	**251**	316	181
2015	**212**	264	146
2016	**322**	420	222



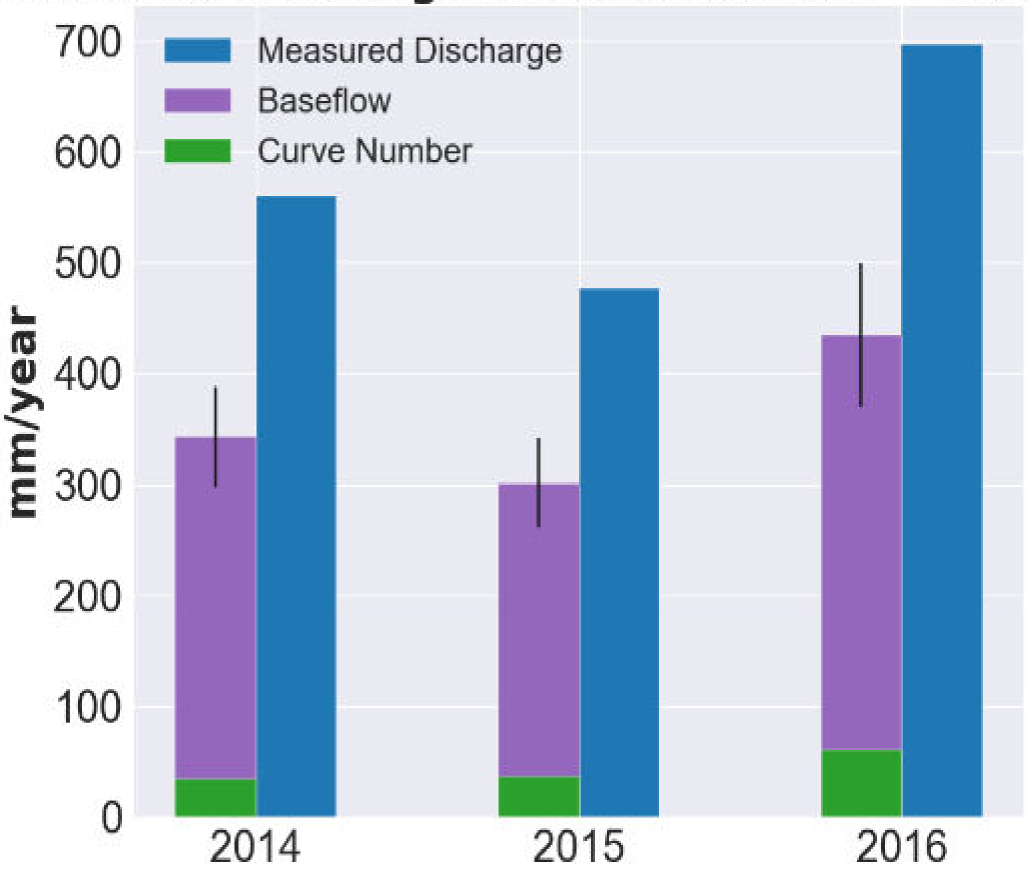
Year	Mean	Max	Min
2014	**34**	61	17
2015	**37**	61	21
2016	**60**	98	34

UNIVERSITÉ DE NEUCHÂTEL

Quickflow =/= Surface Runoff !

eawag aquatic research

Measured Discharge vs Curve Number + Baseflow



- **Curve number** may provide a good approximation of pure surface runoff from storm events
- The **quickflow** element of bivariate hydrograph separation clearly has additional inputs!
  - Need to perform a ***multivariate hydrograph separation***

unine UNIVERSITÉ DE NEUCHÂTEL

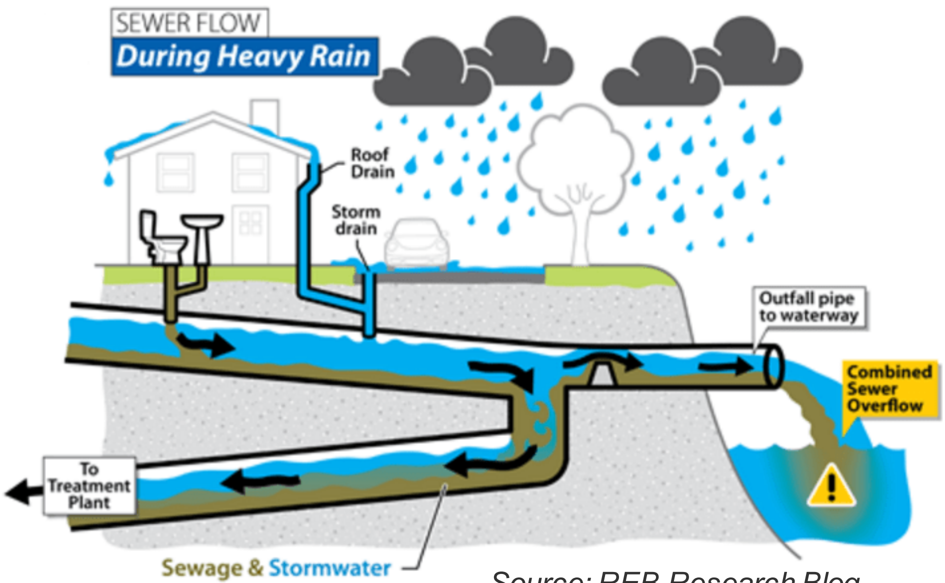
Additional Inputs to River Discharge

eawag aquatic research

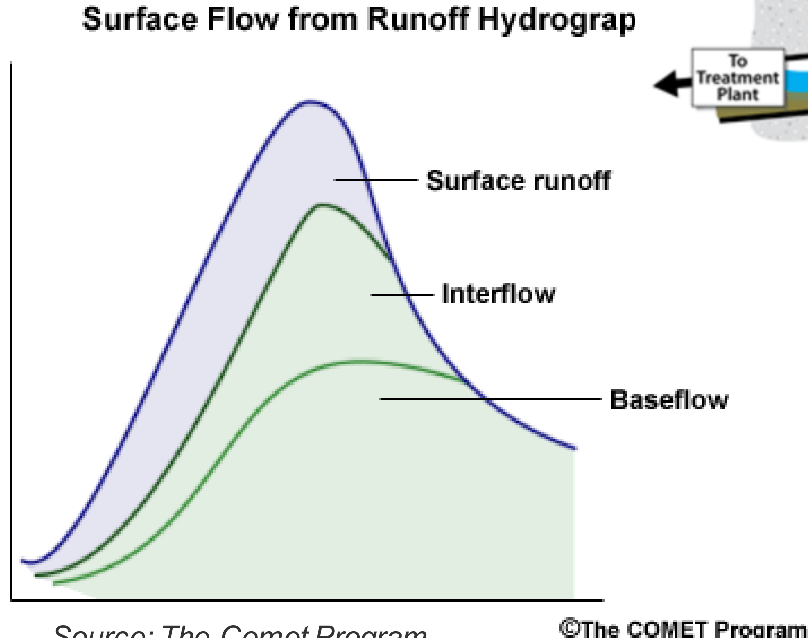
Hydrograph separation – a bivariate model is not enough!

What other elements might be present?

- Soil water
- Sewer water during combined-sewer overflow
- Treated effluent
- … ?



Source: REB Research Blog



Source: The Comet Program

UNIVERSITÉ DE NEUCHÂTEL

Comparing Estimates of Groundwater Recharge

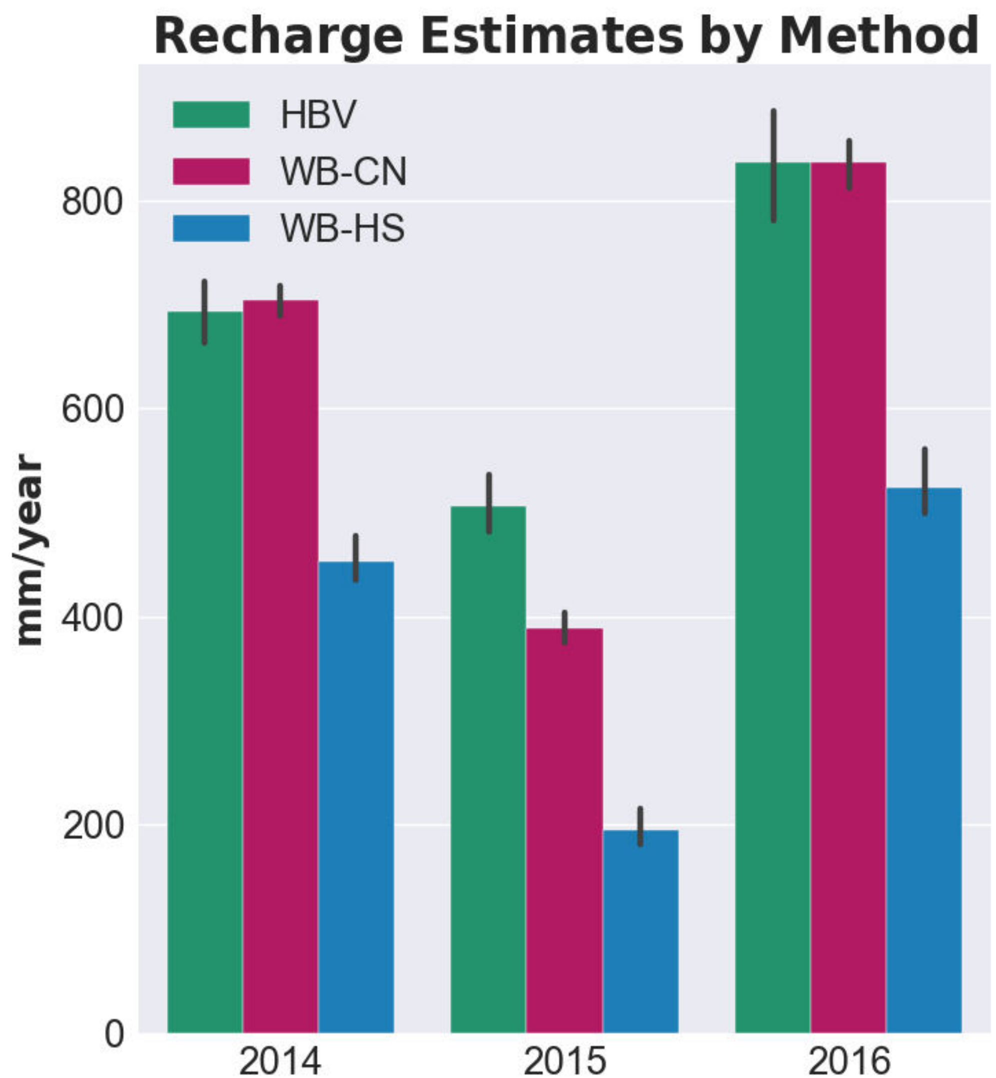
eawag aquatic research

Estimates – Average Values

Year	HBV	CN	HS
2014	705	717	424
2015	515	379	198
2016	863	848	520

Uncertainties

- No method explicitly accounts for interflow!
- **Hydrograph separation** likely overestimates runoff and **underestimates recharge**
- **HBV and CN** assume infiltration = recharge – likely **overestimate recharge**



unine UNIVERSITÉ DE NEUCHÂTEL

Next Steps

Assessing and Improving Groundwater Recharge Estimates

- Improvement in estimates of surface runoff
- Construction of a numerical model to compare with empirical methods

Chemical and Isotope Analyses

- Construct an isotopic mixing model (3+ components) for more precise hydrograph separation
- Mass balance of organic micropollutants to evaluate their utility as a tracer for sources of recharge and flow pathways

Conceptual model

- Combined analysis of independent data: multicomponent statistical analysis to identify correlations and trends

Thank You !