



**Sixth Framework  
Programme**

**(2002-2006)**

## **Research in support of the EU Water Initiative**

« Twinning European/Third countries river basins »

**Assessing Flood****Water**  
**Recharge of Alluvial**  
**Aquifers**  
**in Dryland**  
**Environments**

**Title:** Floodwater Recharge of Alluvial Aquifers in Dryland Environments

**Instrument:** Specific Targeted Research or Innovation Project, FP6

**Total Cost:** 2.605.295 €

**EC Contribution:** 1.700.000 €

**Duration:** 42 months

**Start Date:** 1/07/2004

**Consortium:** 12 partners from 7 countries

**Project Coordinator:** Consejo Superior de Investigaciones Científicas-CSIC (Spain)

- 0.8 cm/h
- 

**Paleohydrology  
Geomorphology**

Paleoflood  
Reconstruction

**Vadose Zone  
Hydrology**

TDR Recharge  
Monitoring

*Sustainable Use of  
Flood Recharge in  
Alluvial Aquifers of  
Dryland Environment*

**Hydrology  
Hydraulic Modeling**

Flood Routing  
and Infiltration Model

**Groundwater &  
Isotope Hydrology**

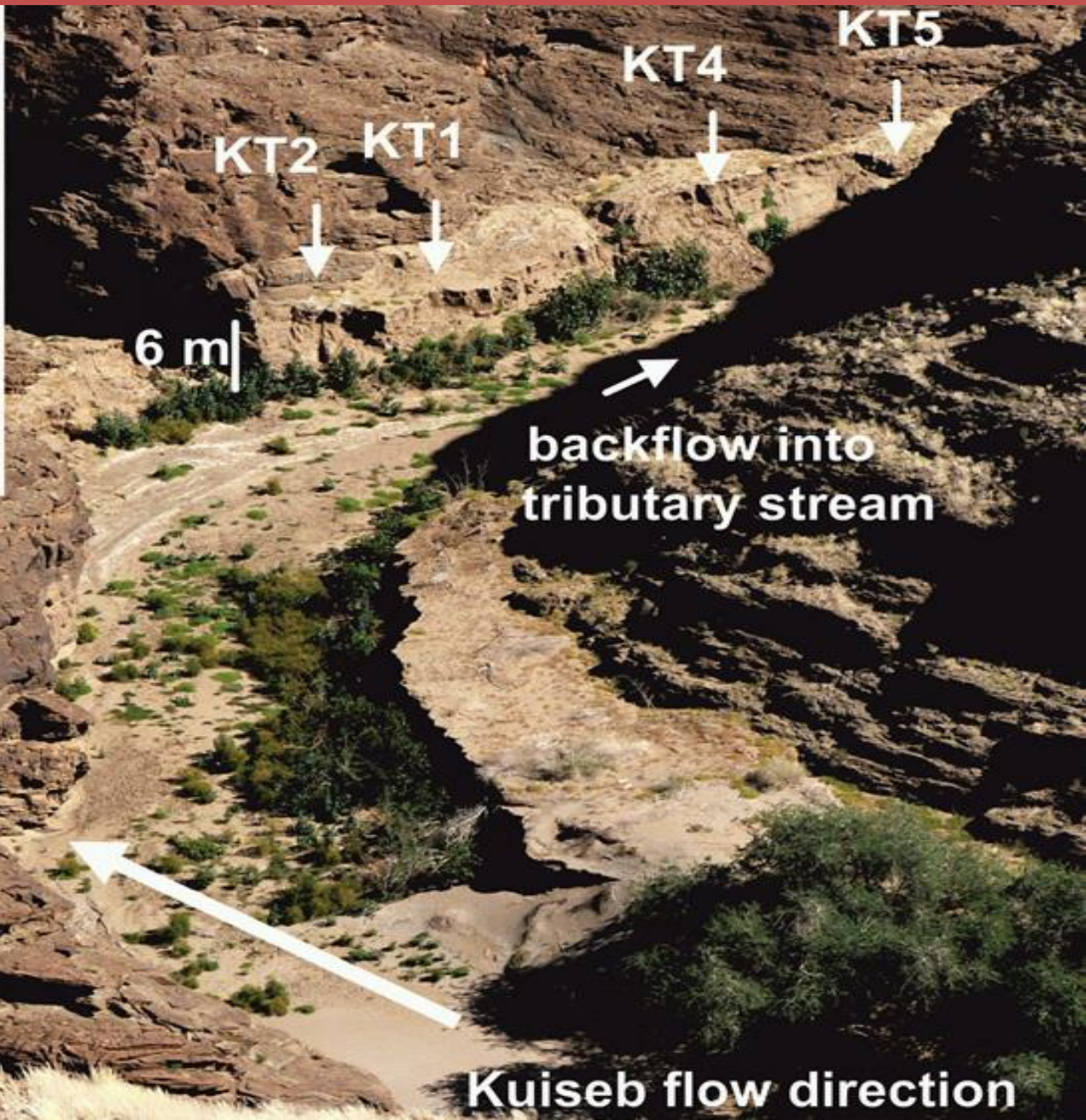
Residence Time  
Flood Origin (Isotopes)



# Paleoflood Studies in Kuiseb Canyon



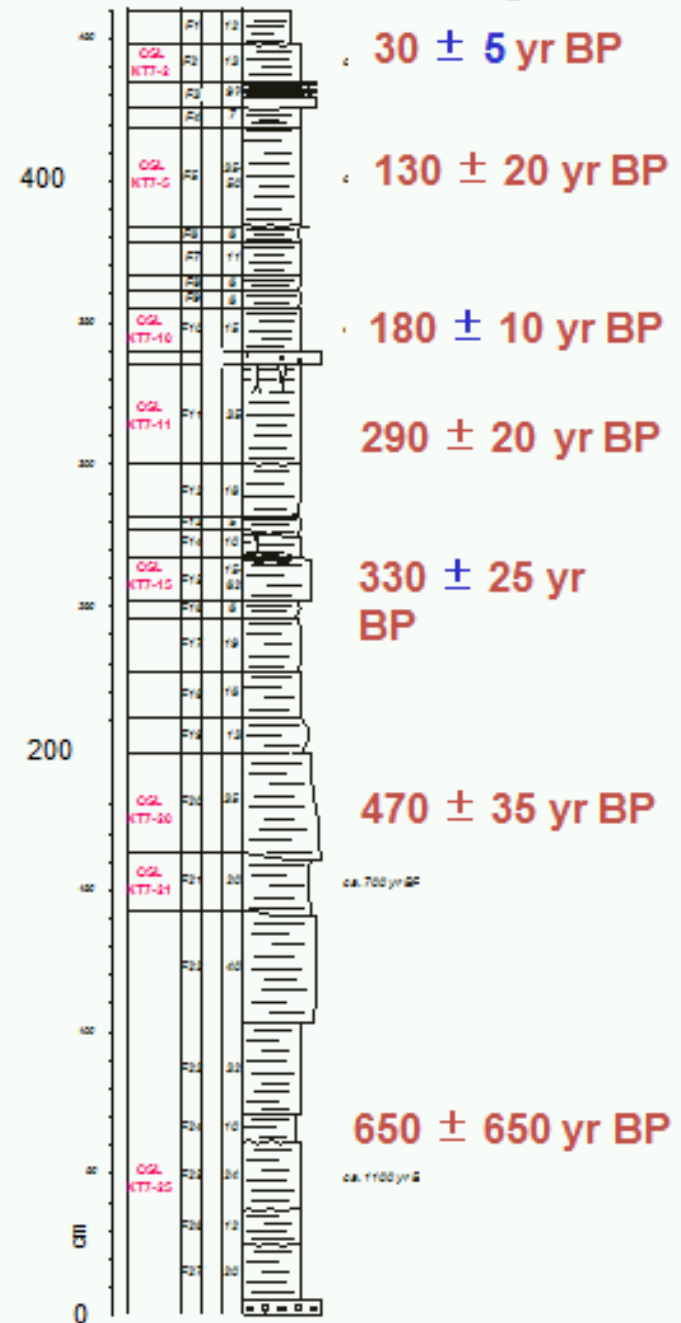
# K400 Slackwater Deposit Paleoflood Archive





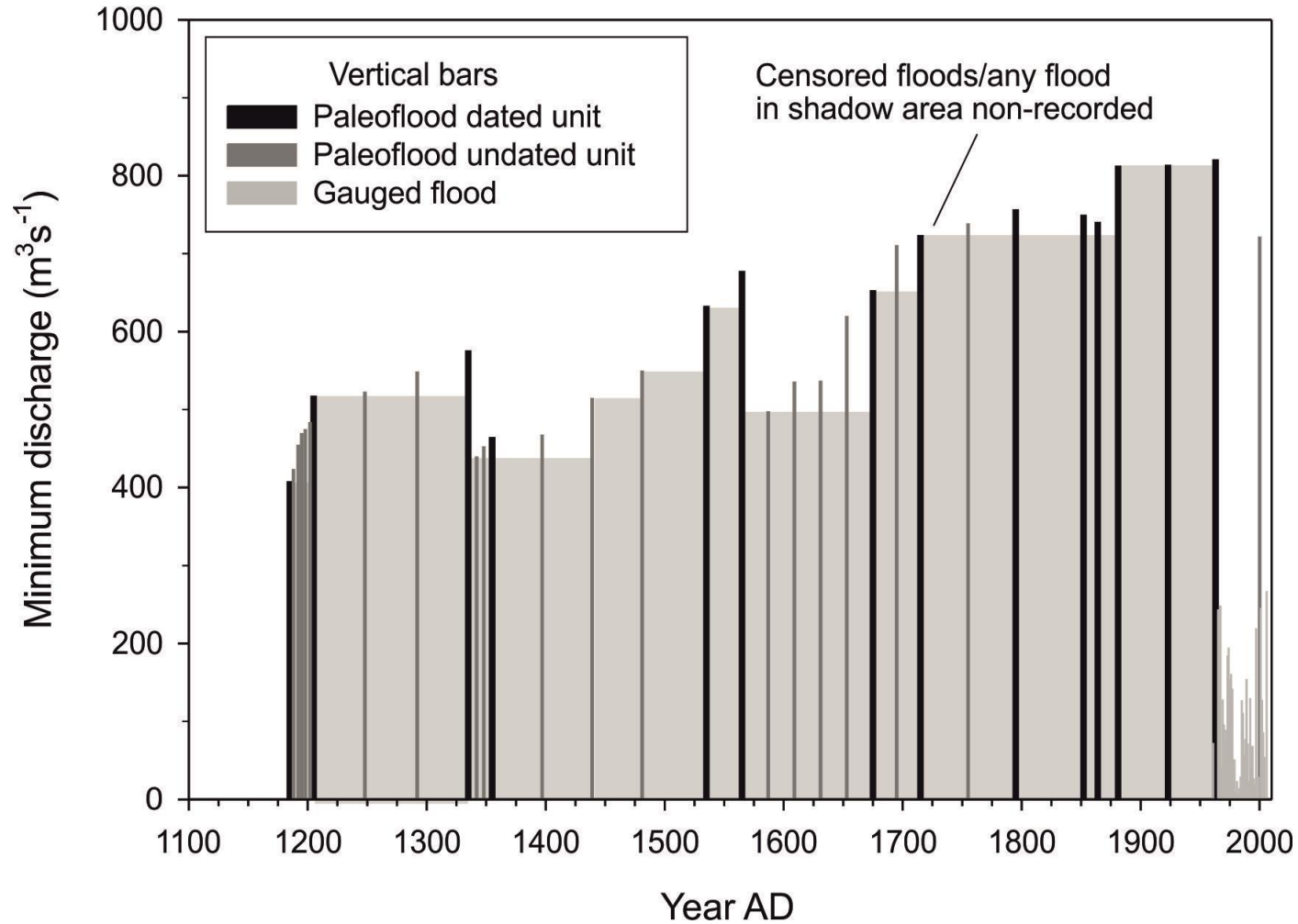
# KT 7

OSL age

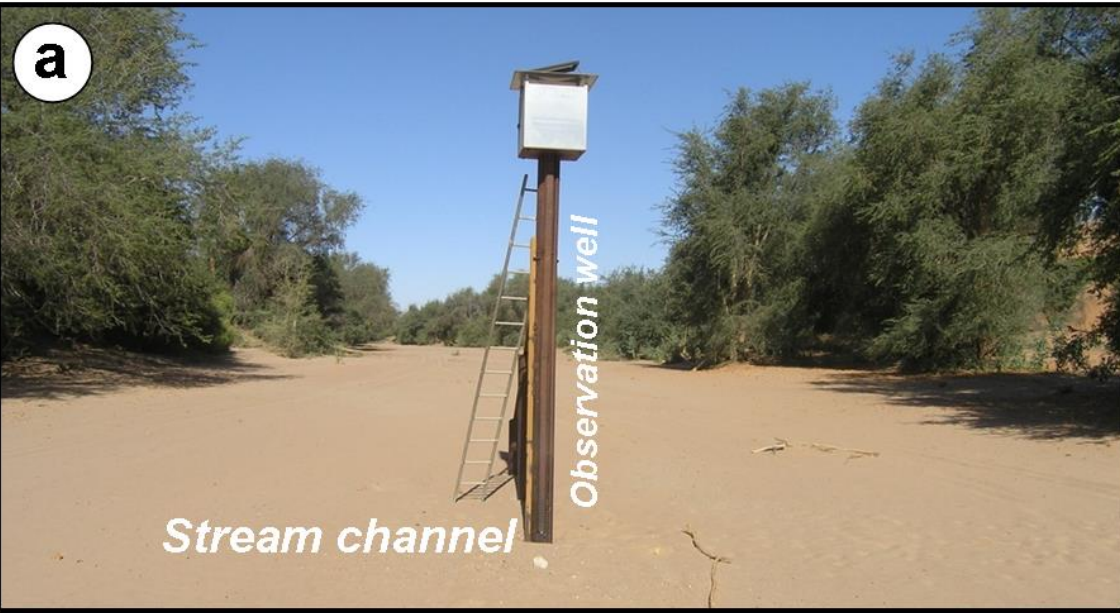


# Hydrometric and Paleoflood Data

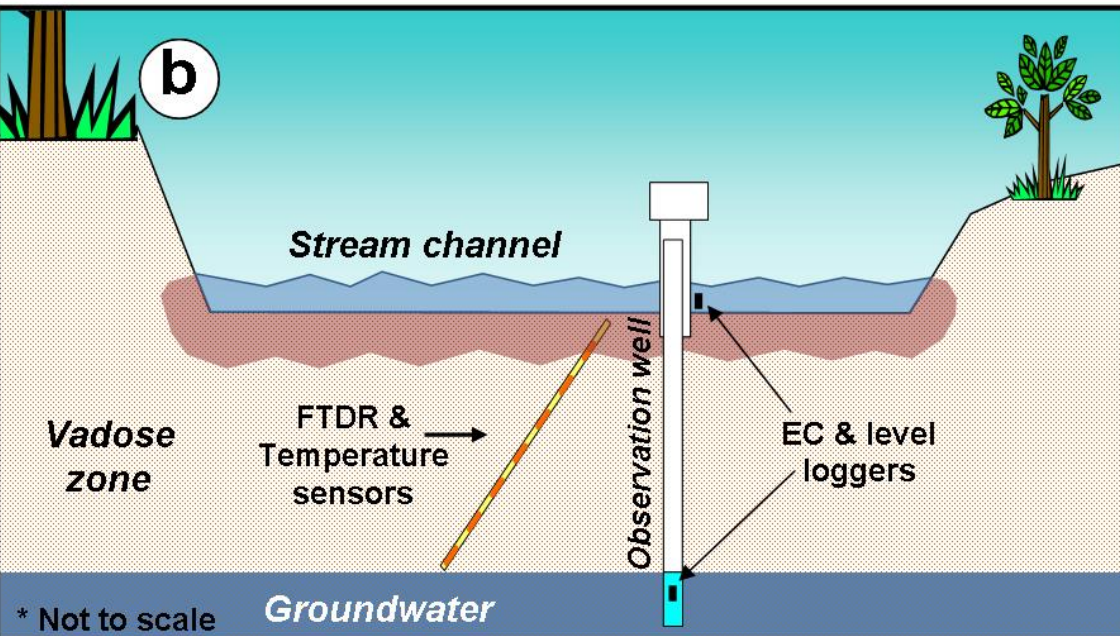
## K-400 Palaeoflood Record



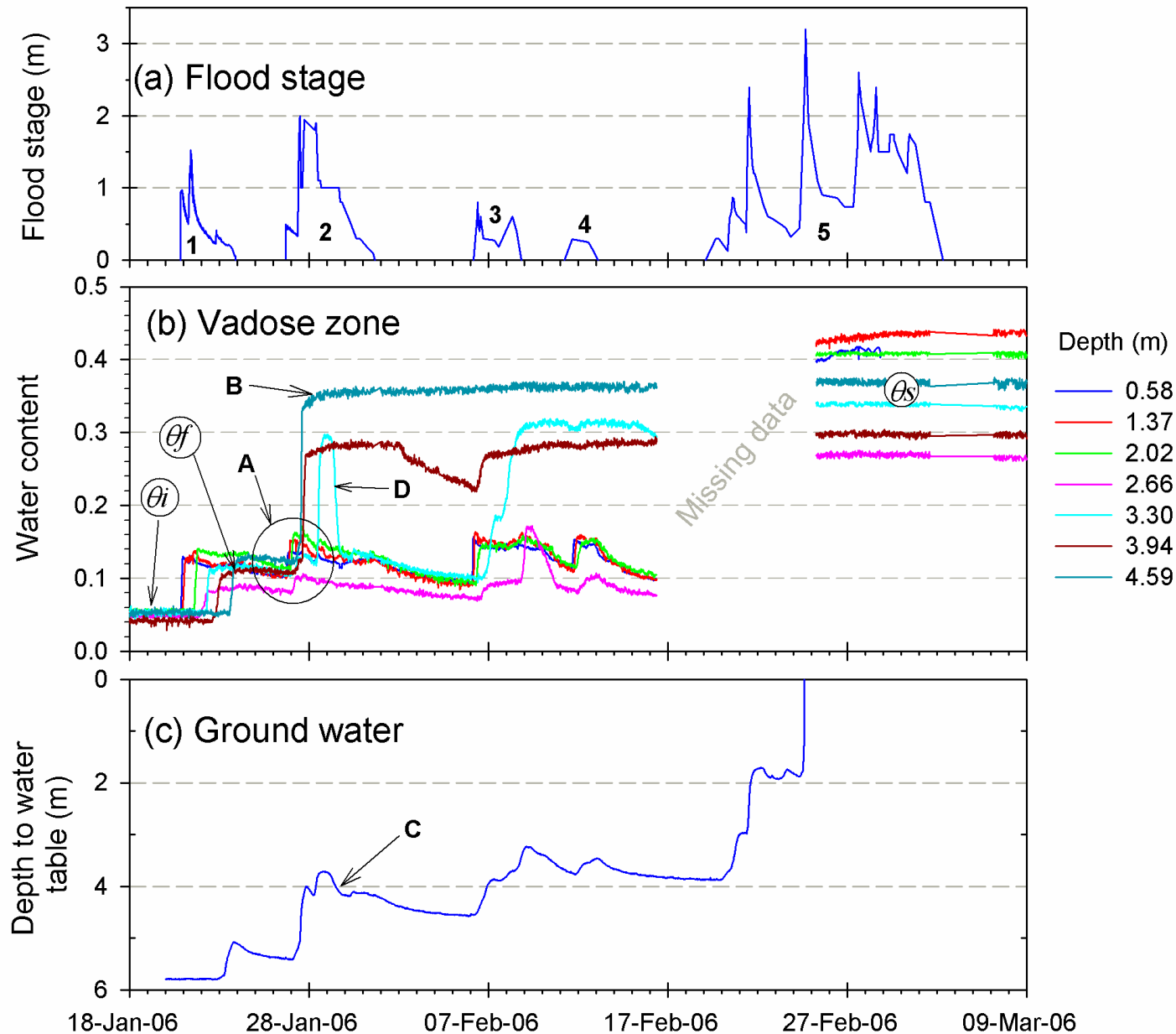
# New Vadose Zone Monitoring System



- Flood stage (piezometers)
- Soil moisture (TDR) at different depths
- Groundwater level of alluvial aquifer
- Continuous measurement and logging
- Systems in Israel, Spain, Namibia, South Africa
- All systems collected data of several flood events



# Groundwater Recharge During Floods



- **Flood wave characteristics: duration, stage**
- **Wetting front movement**
- **Water flux from sensor data**
- **Soil moisture before rise**
- **Groundwater level response**

# Recharge During Floods

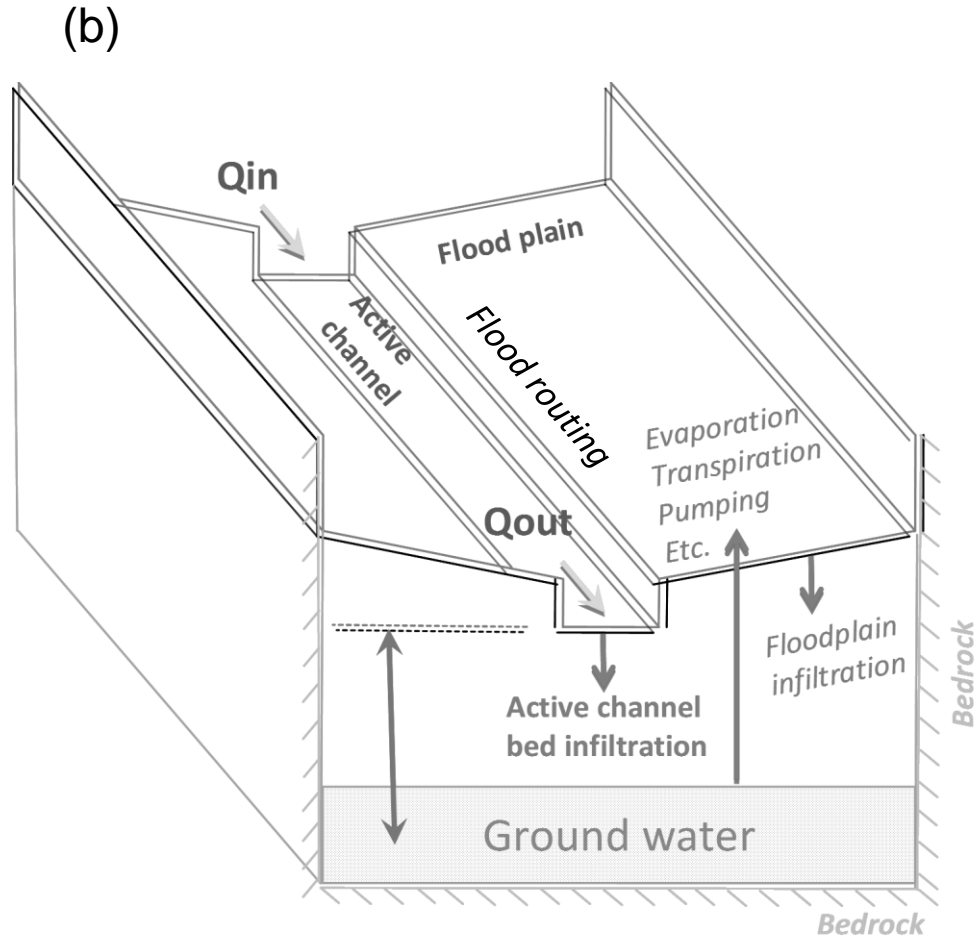
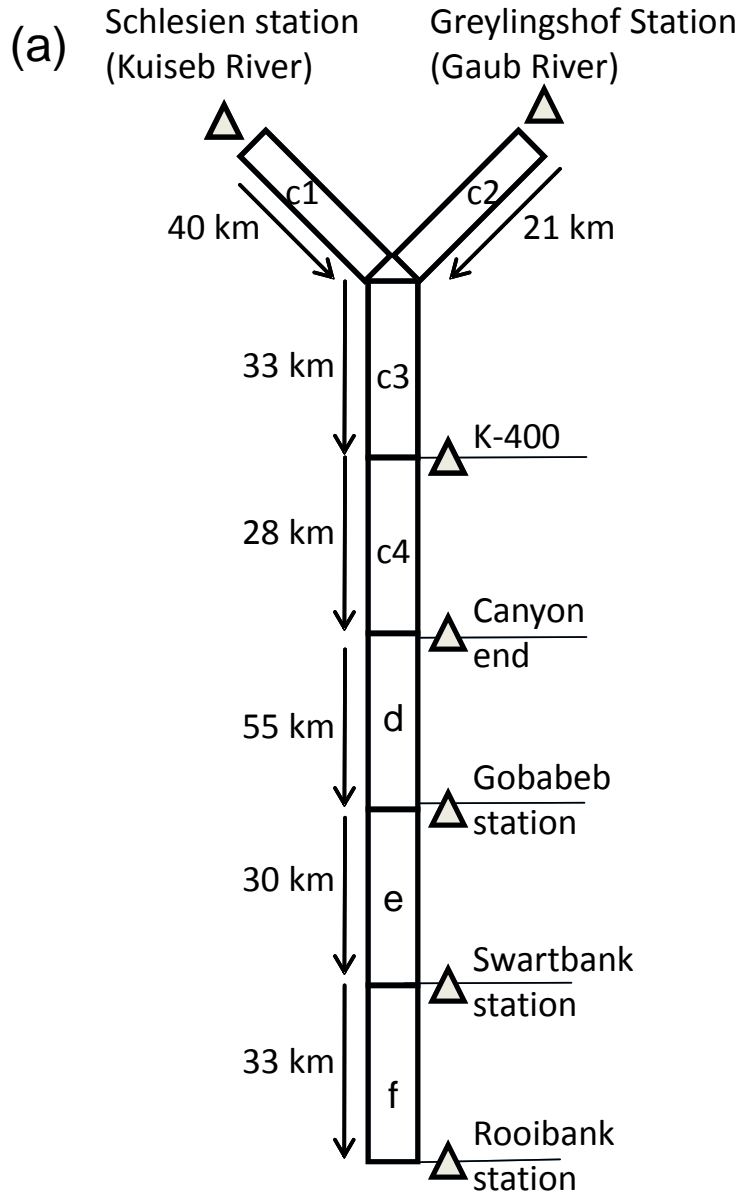
Calculation method	Flux (cm h <sup>-1</sup> )				
	1 <sup>st</sup> flood	2 <sup>nd</sup> flood	3 <sup>rd</sup> flood	4 <sup>th</sup> flood	5 <sup>th</sup> flood
Wetting-front propagation in the vadose zone	1	0.9	1.5	0.7	
Water-table rising rate	1.4	1.38	0.57	0.39	1.05
Increase in ground-water storage	0.71	0.91	0.83		

Recharge rates from two independent measures

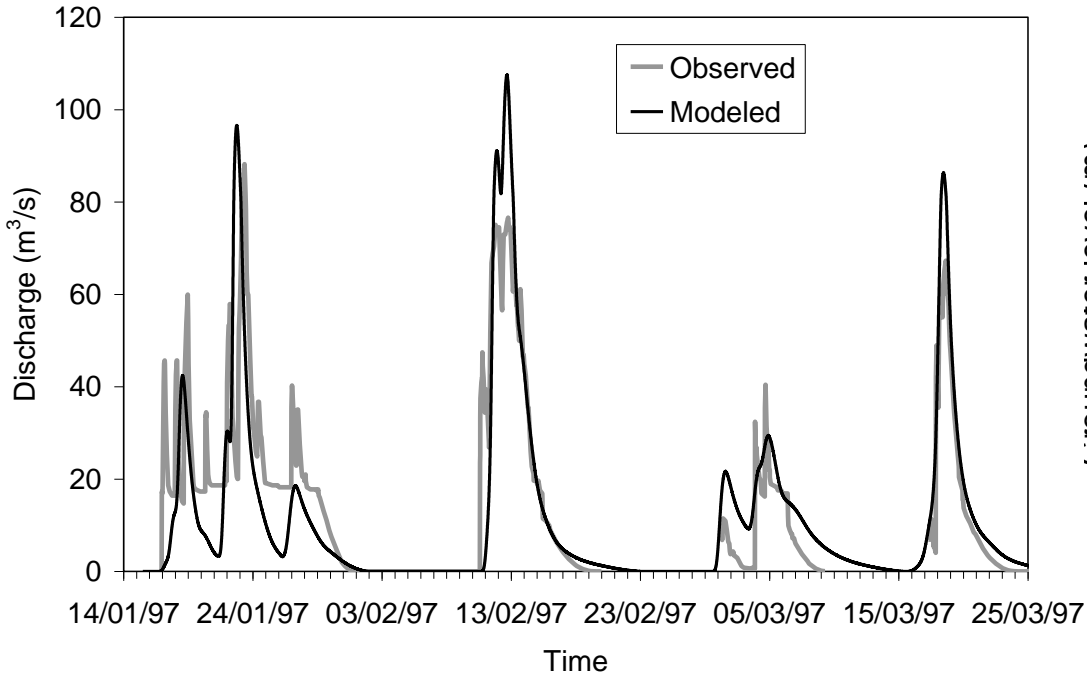
- Wetting front propagation in the unsaturated zone
- Water table rise & increase in ground water storage

Recharge rates within narrow range: ~ **0.8 cm/h**

# Flood Routing Model



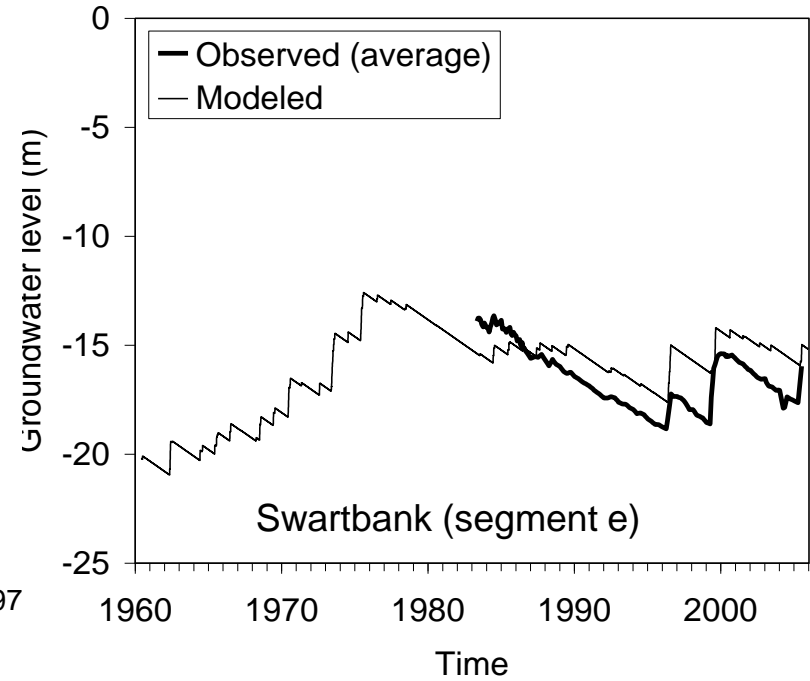
# Flood Routing Model Validation (Surface + Groundwater)



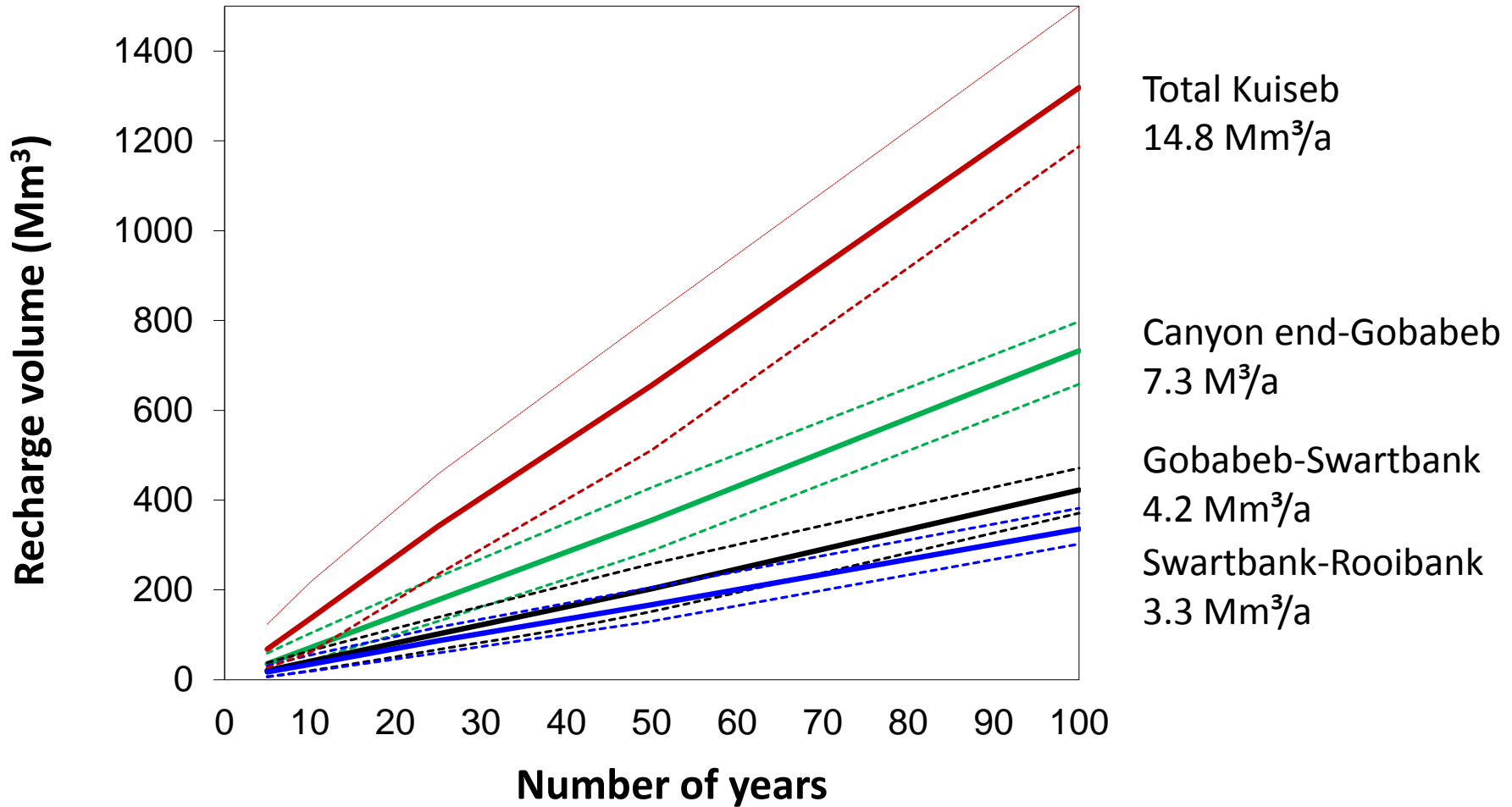
Faulty part



Part used for validation

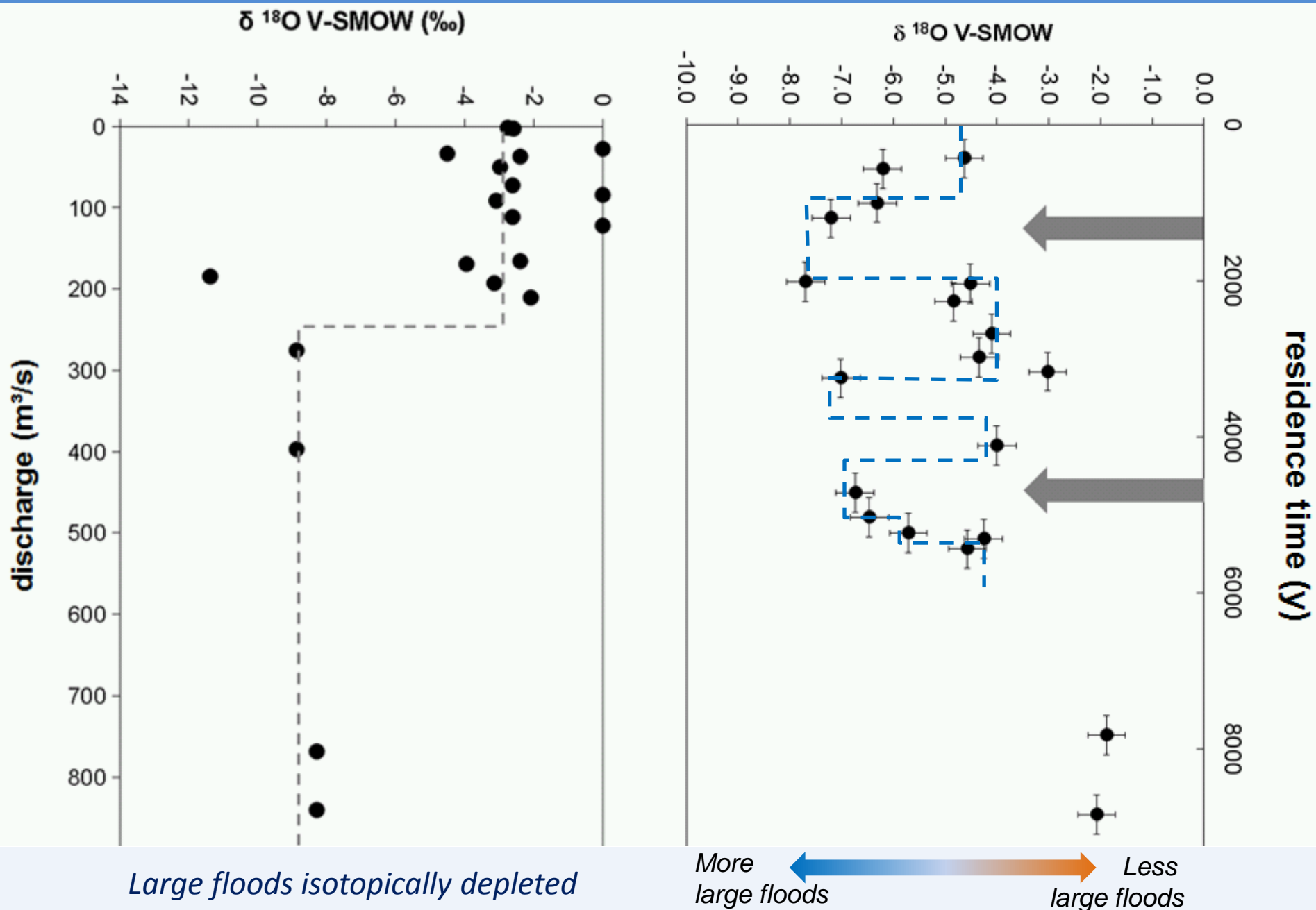


# Centennial Recharge Amount, Recurrence and Intermittance



Groundwater volume, Mm <sup>3</sup>	Average time to replenishments <sup>a</sup> , year	Peak floods m <sup>3</sup> s <sup>-1</sup>	Groundwater storage capacity, Mm <sup>3</sup>	Sustainable aquifer yield, Mm <sup>3</sup>
340–240	3–4	800–1,250	14	7–15

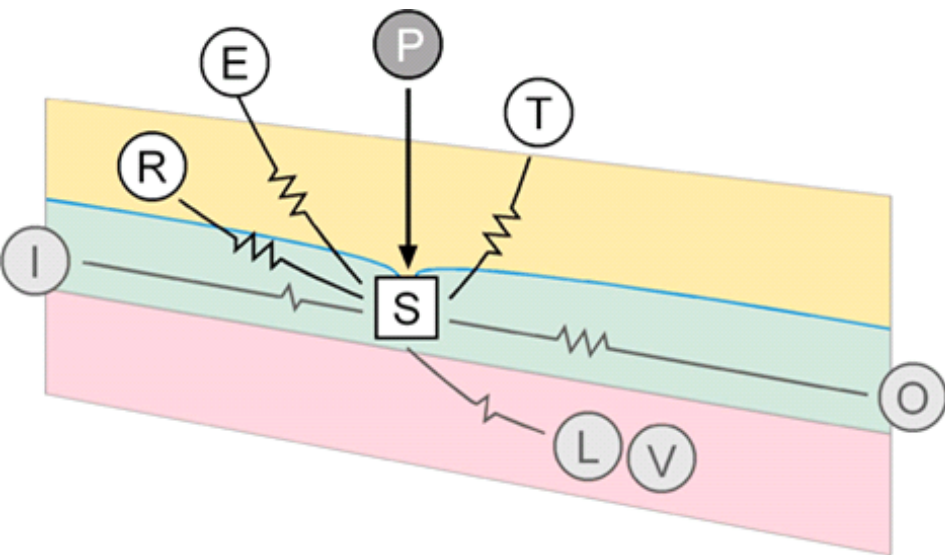
# Groundwater Isotope and Residence Time Studies



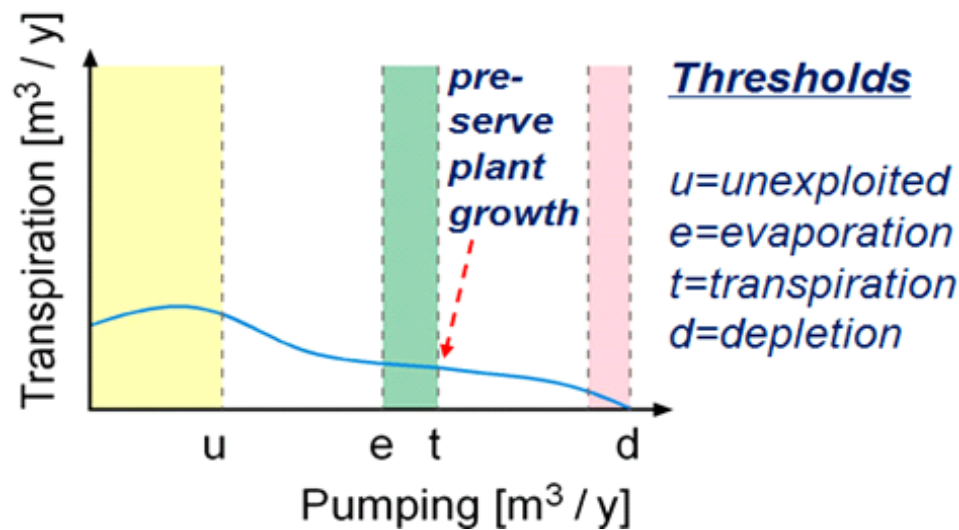
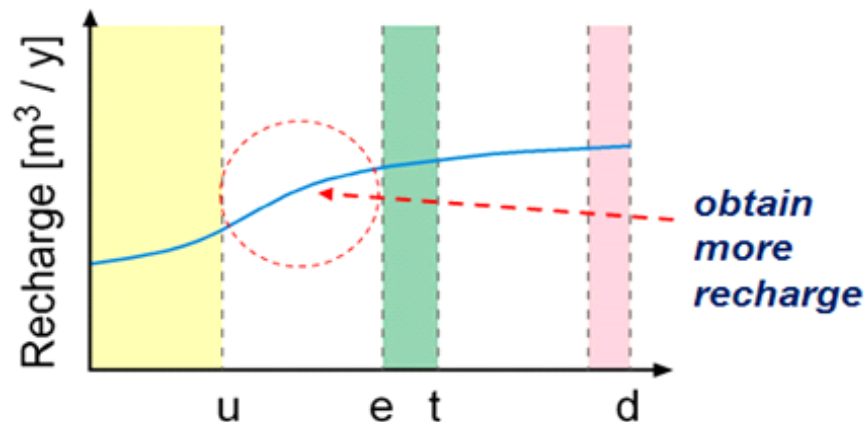
*Large floods isotopically depleted*

More large floods ← → Less large floods

# Adaptive Groundwater Management



Pumping (P) changes transpiration (T), recharge (R), storage (S), lateral in- and outflow (L) and vertical seepage (V).



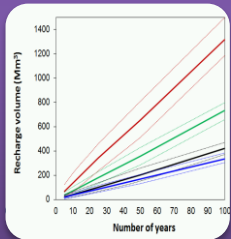
# WADE Conclusions



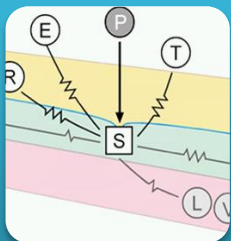
Palaeoflood studies provide excellent record of extreme floods over the last 1000 years, and sensitivity to climate variability.



Recharge processes were monitored and a rate of 0.85 cm/h was measured. Clogging minor in Kuiseb, important in dam (Israel).



A flood routing, infiltration and recharge model was developed and calibrated: Recharge amount, recurrence and intermittance.



Groundwater residence time and isotope studies indicates millennial recharge episodes. Adaptive groundwater management increases yield.

## Waders

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Carole Roberts, DRC  
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Ephrat Morin, Blanca Botero

## Key Publications

Benito et al. (2010), Wat. Res. Man.  
Dahan et al. (2008) Ground Water  
Dahan et al. (2007) J. Hydrol.  
Morin et al. (2009) J. Hydrol.  
Klaus, Külls & Dahan (2008) J. Hydrol.

## Impact

Long Term Flood Recharge Assessment Tool  
Re-assessment of Kuiseb aquifer  
Re-assessment of OMDEL dam  
Strategic Environmental Assessment Namibia  
New Policy on Recharge Dams in Arava  
Patented TDR technology  
Recharge-based Permit System (Swakop)