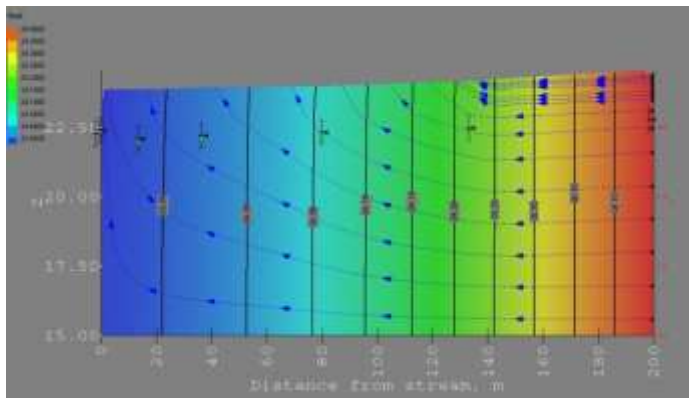


Adaptation to the groundwater module of the Soil and Water Assessment Tool



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Problem statement

Groundwater contaminations

- > drinking water production: human risk
- > pollutant fluxes to surface water: ecological risk

EU AQUAREHAB project aims at:

- **evaluate** and **prioritize** (conventional and additional) water **quality** rehabilitation measures for groundwaters within a geographically delineated management unit :
 - contaminated site
 - body of groundwater (incl. drinking water abstraction areas)
 - subbasin
 - river basin

Important to have proper representation of hydrological and water quality processes and interactions in the groundwater and rip-surface

Review on groundwater in SWAT

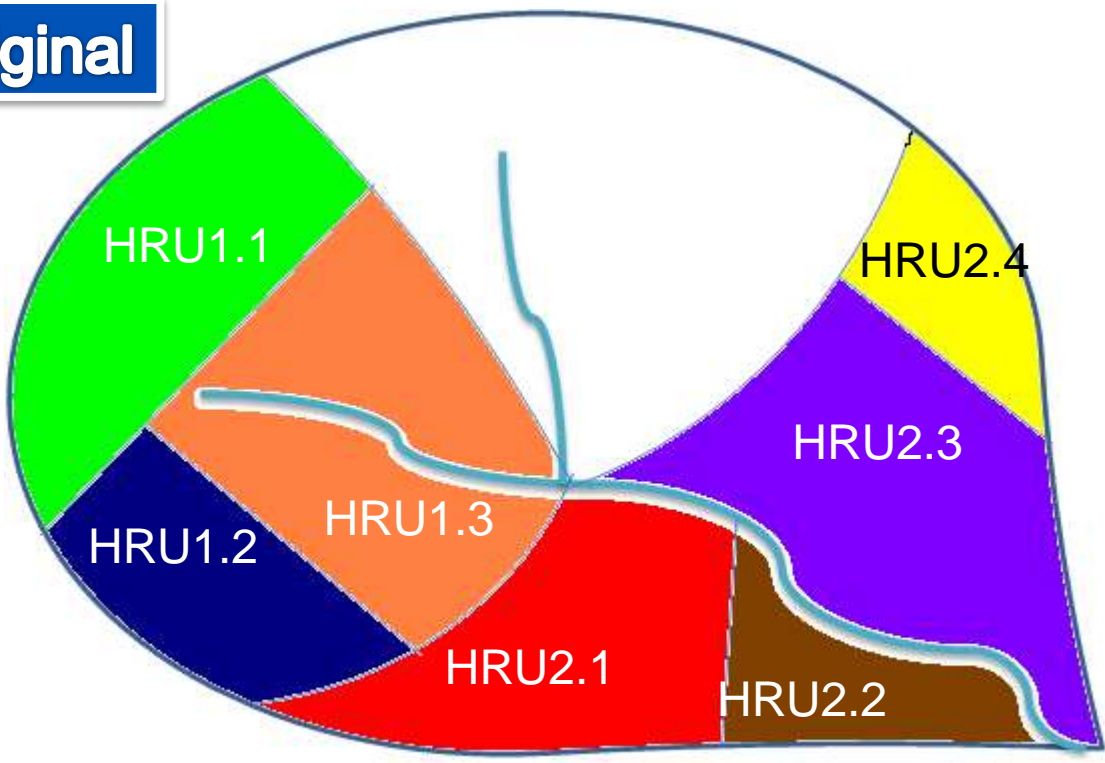
- No representation of groundwater table versus river bed
 - $GWT > RB$ Groundwater recharge
 - $GWT < RB$ River bed infiltration

In SWAT both processes can happen simultaneously

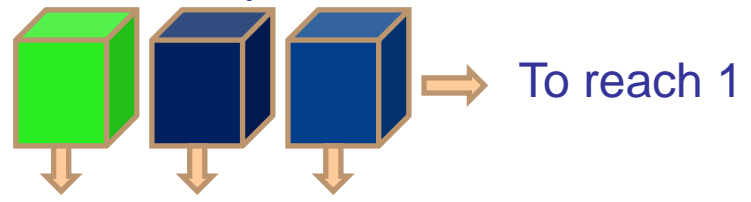
- No routing of the shallow aquifer between HRU/sub-basins
- Often unrealistic mass balances are obtained “black holes”
 - Eg. Large increase of storage in shallow aquifer, especially when $gwqmin \sim 1000$ mm
 - Unrealistic large groundwater losses to $rchr_deep = loss$
 - Unrealistic evapotranspiration ($revap=loss$)
- Water quality processes in riparian zone are not represented

Proposed modification

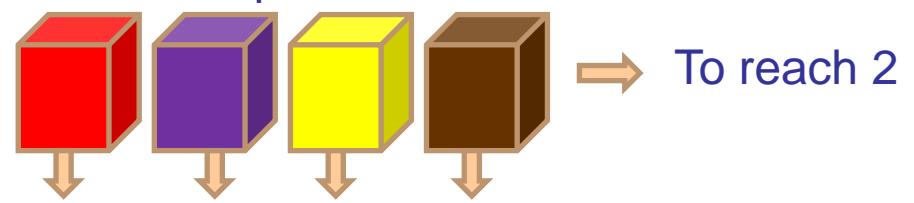
- Modification A: 2 new groundwater bodies
 - Riparian zone
 - Deeper aquifer
 - Routing of deeper aquifer across subbasins
- Modification B: linking shallow aquifer to soil profile
 - When shallow groundwater table $>$ maximum
 - For Revap values (in stead of loss)



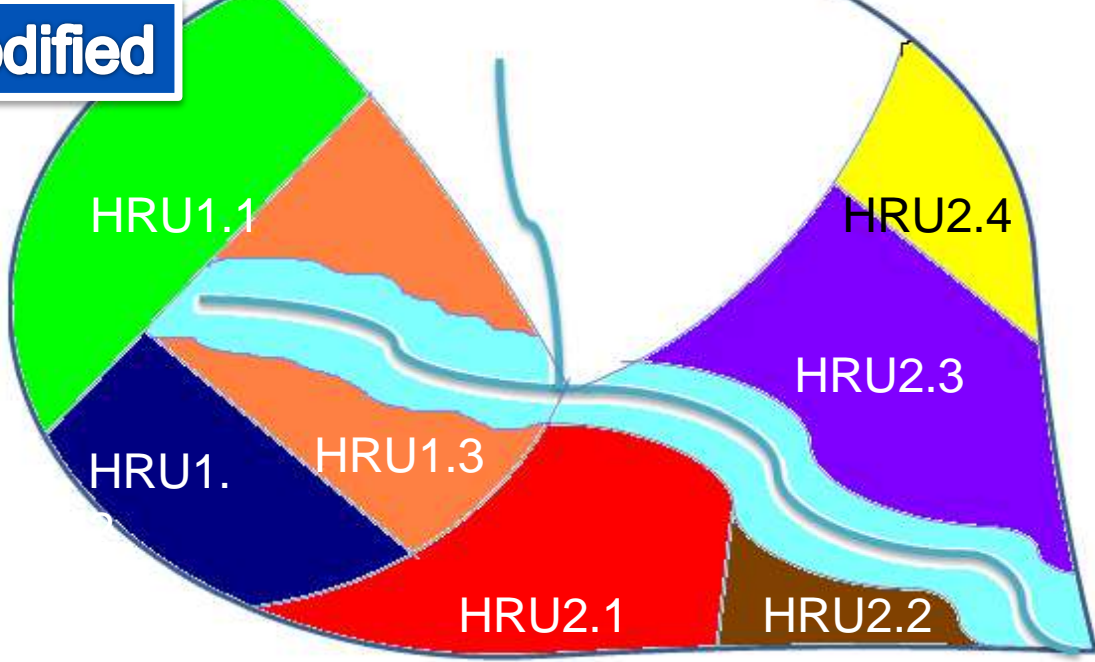
Shallow aquifers subbasin 1



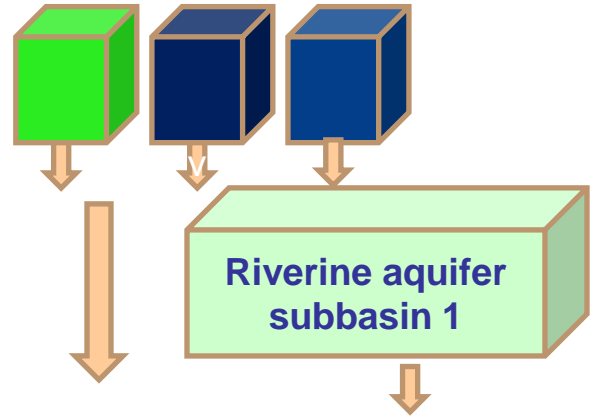
Shallow aquifers subbasin 2



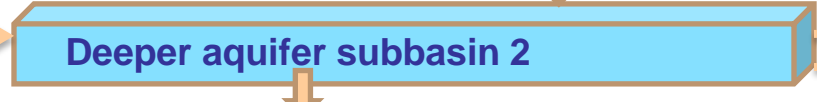
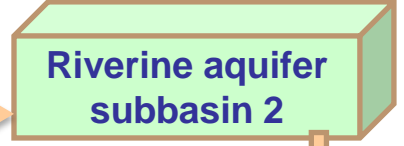
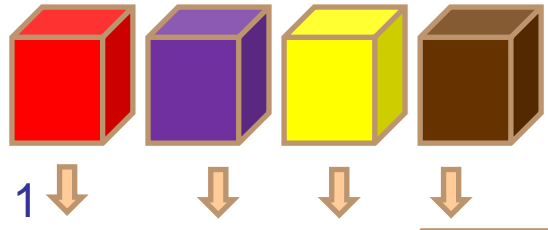
Modified



Shallow aquifers subbasin 1

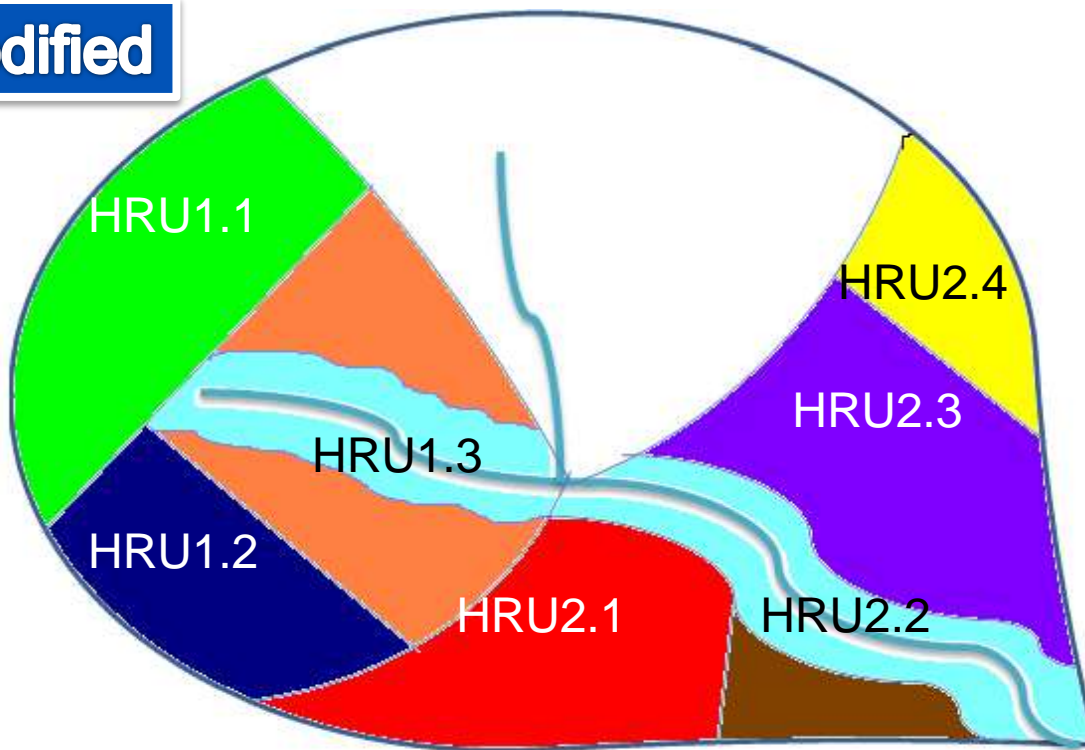


Shallow aquifers subbasin 2

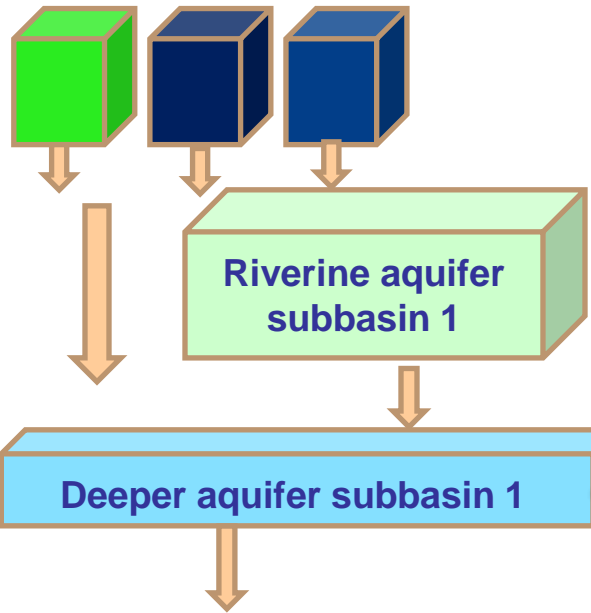


To reach 1

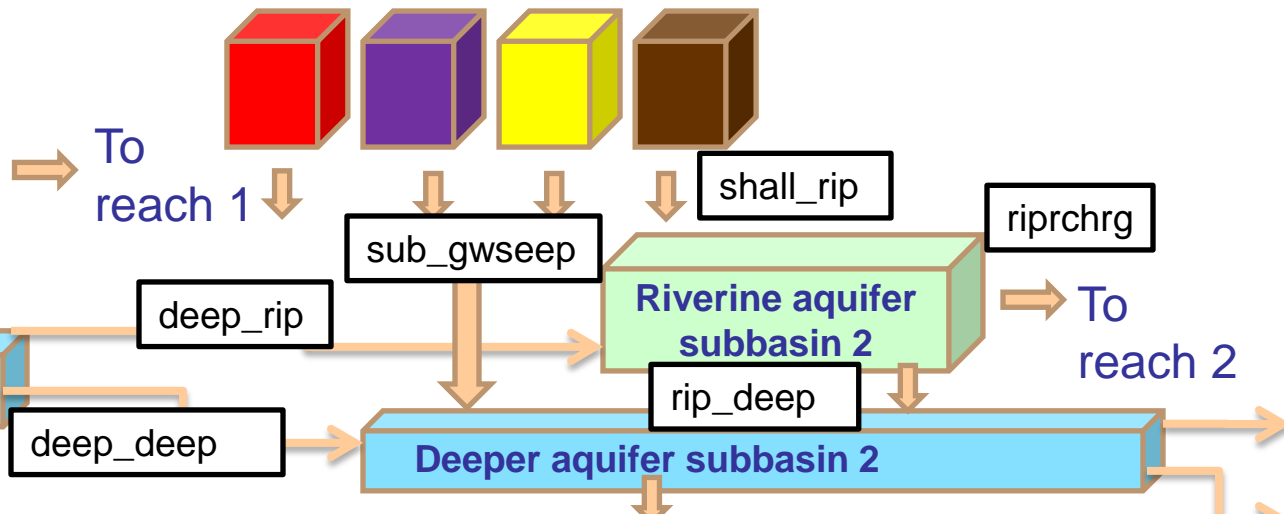
To reach 2



Shallow aquifers subbasin 1



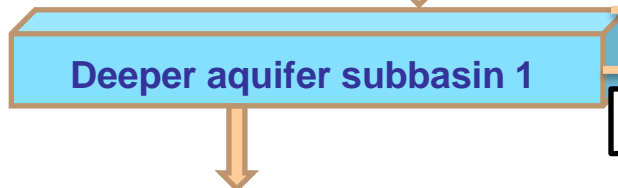
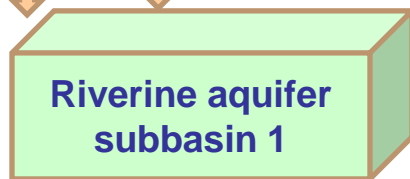
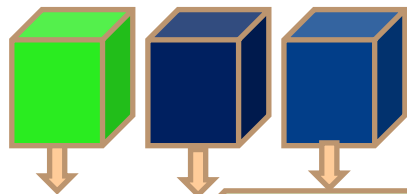
Shallow aquifers subbasin 2



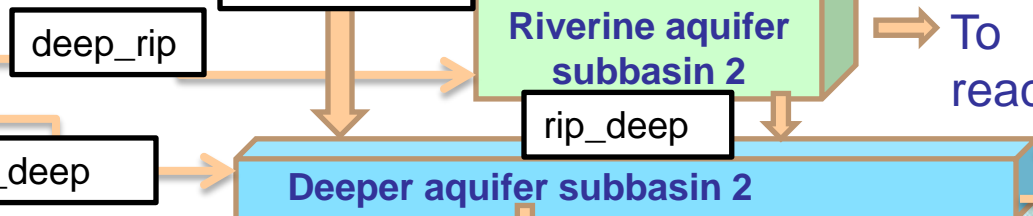
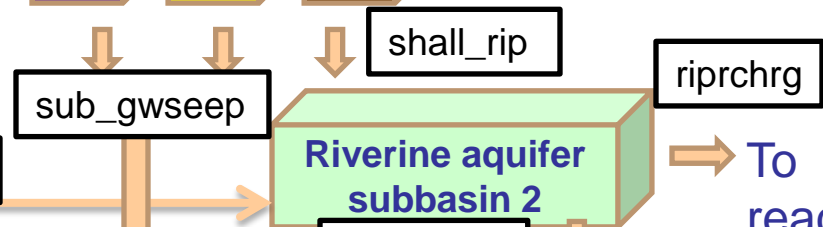
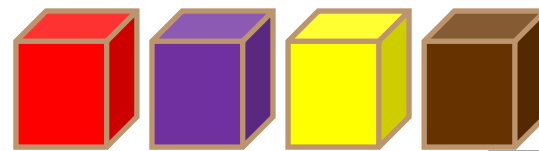
New parameters

- α_{deep} : baseflow alpha factor for deeper aquifer
- α_{rip} : baseflow alpha factor for riparian aquifer
- $f_{\text{deep_deep}}$: fraction of deeper aquifer outflow that goes to deep aquifer
- $f_{\text{deep_rip}}$: fraction of deeper aquifer outflow that goes to riparian zone
- $f_{\text{deep_loss}}$: fraction of deeper aquifer outflow that goes to deep aquifer (losses)

Shallow aquifers subbasin 1



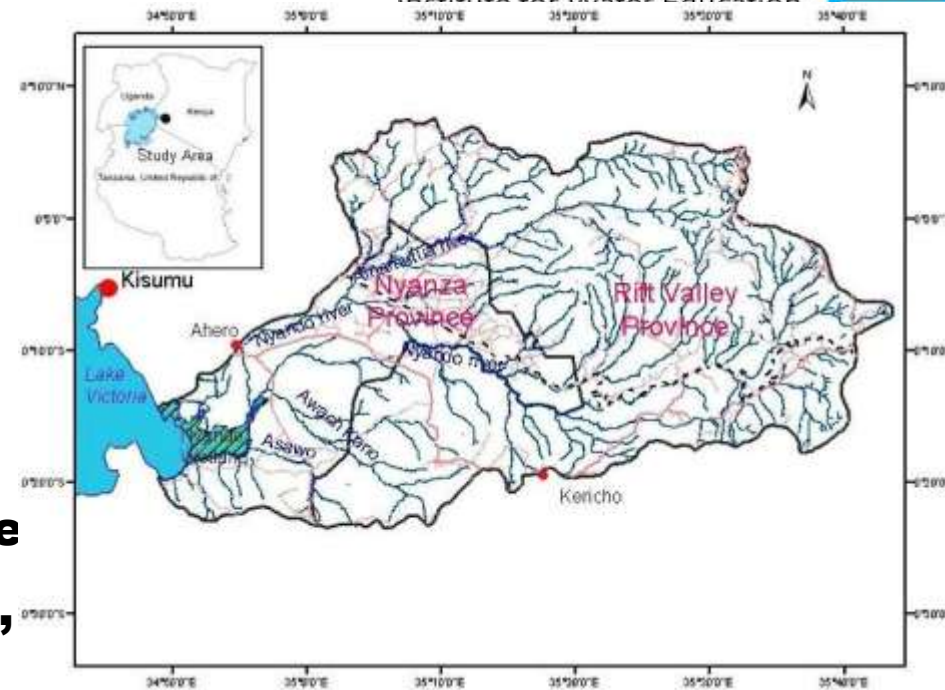
Shallow aquifers subbasin 2



Deep aquifer

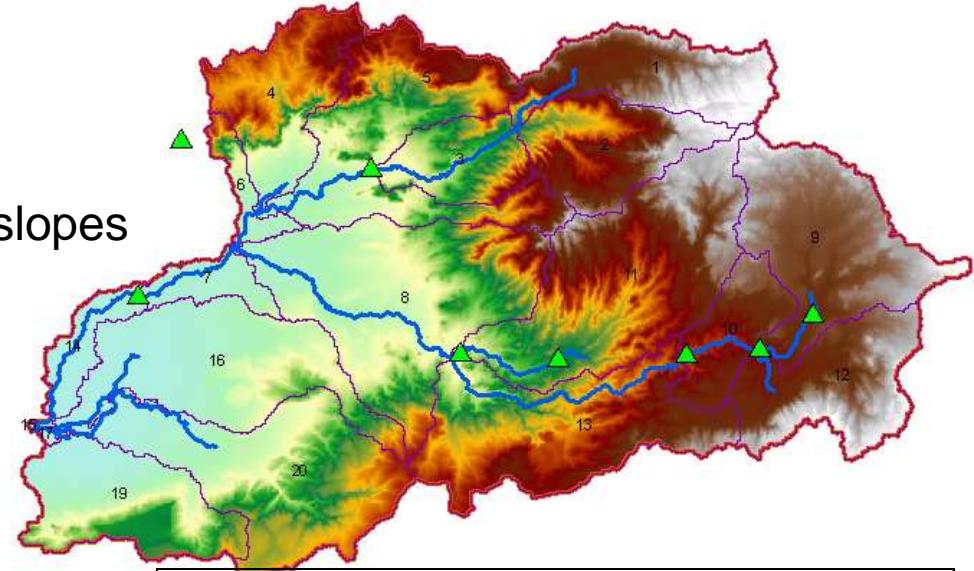
Study Area

- **Western Kenya**
- **Area 3,587 km²**
- **Lies in Nyanza and Rift Valley provinces**
- **Neighbours Lake Victoria to the West, Tinderet hills to the East, Nandi escarpment to the North and Mau escarpment to the Southeast.**
- **Altitude 1000 – 3000 amsl.**
- **Drains to Lake Victoria.**
- **Experiences tropical climate with tri-modal rainfall pattern.**
annual temp. 23 °C, rainfall 1000 – 1600 mm/a

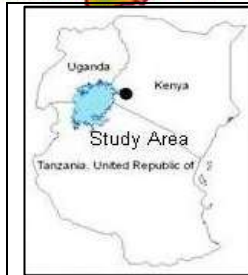
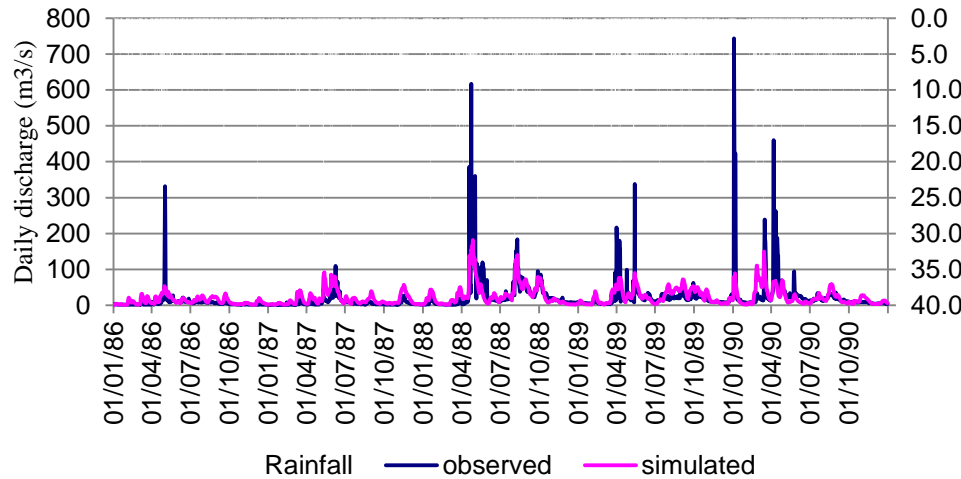


SWAT model application

- 20 sub-basin
- Calibration at 2 outlets
- HRU on the basis of land use, soil and slopes



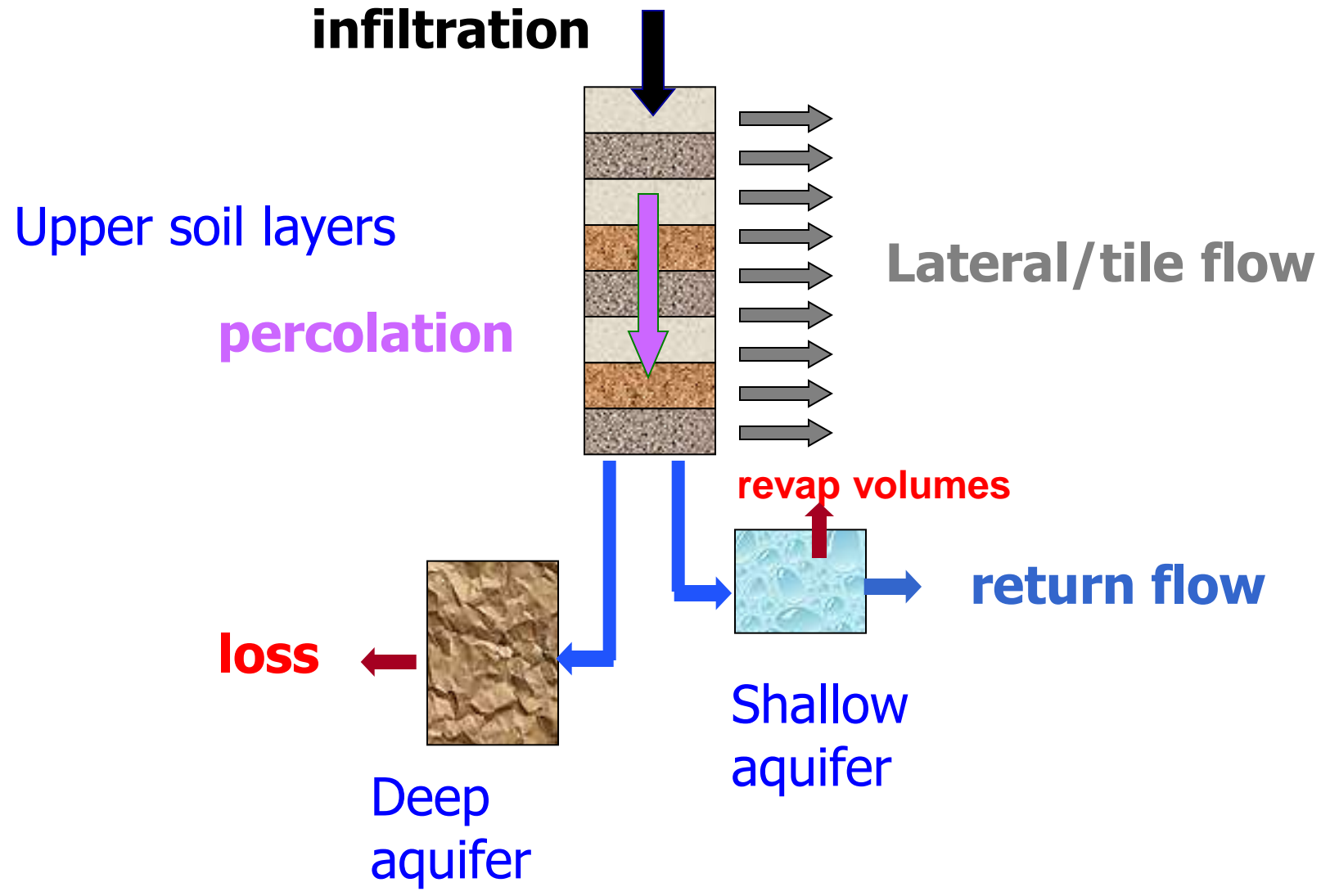
Calibration at 1GD03



Sensitivity analysis results

| | NSE - downstream | PBIAS - downstream | NSE - upstream | PBIAS - upstream |
|--------------------|---------------------|-----------------------|----------------|---------------------|
| alpha_deep | 10 | 10 | 10 | 10 |
| alpha_rip | 1 | 1 | 1 | 1 |
| f_deep_loss | 8 | 8 | 9 | 8 |
| f_deep_deep | 5 | 5 | 6 | 6 |
| Alpha_Bf | 2 | 2 | 2 | 2 |
| Gwqmn | 6 | 7 | 7 | 7 |
| Gw_Delay | 4 | 4 | 3 | 4 |
| Gw_Revap | 3 | 3 | 4 | 3 |
| Revapmn | 9 | 9 | 8 | 9 |
| Rchrg_Dp | 7 | 6 | 5 | 5 |

Subsurface flow



Subsurface flow

Infiltration

Saturation excess flow

-> **surface runoff**

Upper soil layers

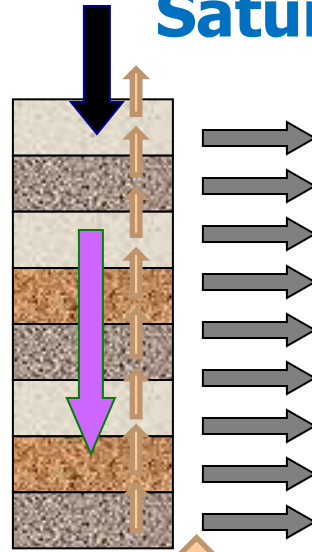
percolation

lateral flow/tile flow

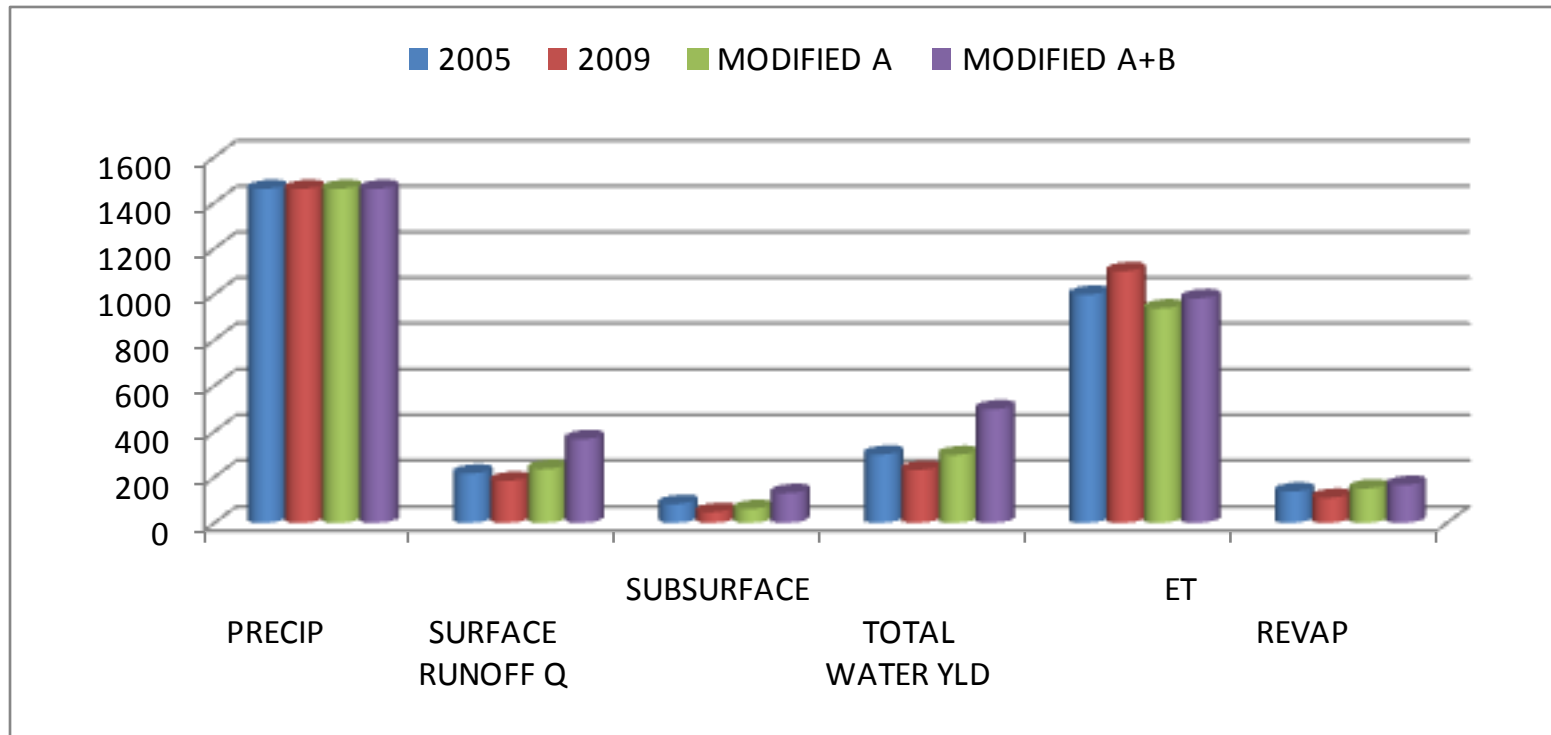
loss ← **Deep aquifer**

High shallow flow -> to soil profile
revap volumes
return flow

Shallow aquifer



Mass balance



Conclusions

Modified groundwater module is presented:

- Reduce risk for inconsistent mass balances
- Allows for saturated excess flow
- Allows for moving groundwater from one subbasin to another
- Allows for the elaboration of a riparian aquifer
 - Better representation of interaction between river-aquifer in riparian zone
 - Better representation of riparian water quality processes