Towards a process-oriented HRU-concept in SWAT: Catchment-related control on baseflow and storage of landscape units in medium to large river basins.

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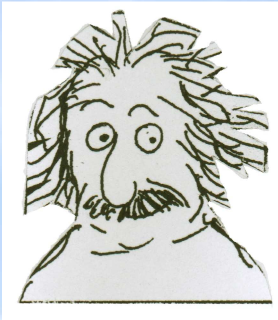
Landscape units and storage:

- What are the main controlling factors for baseflow and storage?
- Different terrain units and landscape types show different hydrological characteristics (suitable land use and management systems!)
- Degree of complexity depends on landscape heterogeneity and scales
- Description of the hydrological connections (topology) in models is complex (HRUs) ➡ SWAT

Procedure:



- Differentiation between valley floor, hill slope and ridge top

- Relating the landscape positions to terrain-based metrics, climate and hydrological analysis

- Linkage of the resulting units

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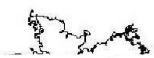
Study areas

- Example: Saale river basin and subbasins



Nr.	Stream flow gauge	Altitude [m a.s.l.]	Basin area [km²]	Average awc*	Mean annual precip* [mm/a]	Land use distribution [% of basin area]				Mean stream flow [m³/s]	Tot. runoff [mm/a]**
						arable	pasture	forest	urban		
1	Calbe-G.	53	23719	0,227	625	64.0	3.7	23.1	11.9	121.10	161.01
2	Bernburg	55	19639	0,225	636	60.9	3.6	22.3	11.5	98.80	158.65
3	Halle-Tr.	69	17979	0,224	645	59.8	3.6	23.4	11.4	98.10	172.07
4	Naumburg.	98	11449	0,222	661	56.7	4.7	29.1	8.7	70.05	192.95
5	Saaleck	115	5040	0,218	727	46.6	6.3	38.5	8.0	40.32	252.29
6	Camburg-S.	119	3977	0,218	744	42.8	7.5	41.8	7.2	31.89	252.87
7	Rothenstein	151	3357	0,218	765	41.3	8.6	42.6	6.5	29.32	275.44
8	Rudolstadt	190	2678	0,218	806	38.2	10.7	43.5	6.5	26.77	315.24
9	Saalfeld-R.	203	2120	0,220	789	41.1	13.0	38.3	6.2	20.56	305.84
10	Kaulsdorf	231	1665	0,220	781	43.5	15.9	33.5	5.6	15.98	302.67
11	Eichicht	235	1665	0,220	781	43.5	15.9	33.5	5.6	16.16	306.08
12	Burgk	339	1249	0,212	817	40.4	21.5	31.0	6.3	12.23	308.80
13	Blankenstein	411	1013	0,210	833	39.1	26.7	27.5	6.6	11.08	344.93
14	Hof	467	521	0,206	827	28.7	33.3	30.4	7.3	5.33	322.62
15	Oberkotzau	484	232	0,223	875	17.8	46.1	30.9	5.2	2.68	364.30
16	Weissdorf	489	47	0,223	795	18.4	55.9	19.1	5.3	0.71	476.39

*area-weighted values (AWC available soil water capacity mm H_2O/mm Soil), **area-weighted values, calculated from stream flow data

- Excellent data base from joint project

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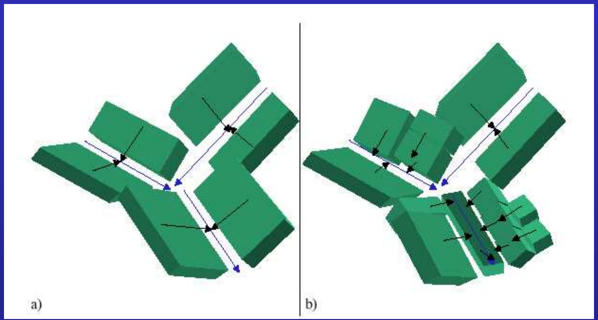
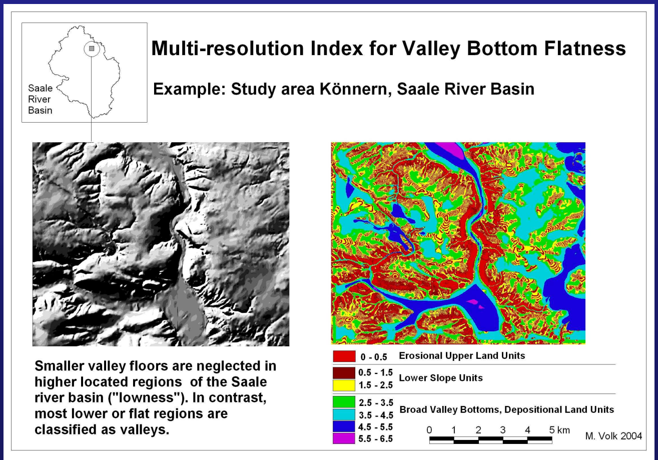
Overview: Existing concepts for HRUs and other „process units“

- Hydrological Similarity Units (HSU), Dynamic Topmodel, (Beven & Freer 2001, Tilch et al., 2002)

- HRU concept by Jena group (PRMS, MMS, OMS; Flügel 1996, Staudenrausch 2001,Bongartz 2002)
  -- *cooperation*



- Multi-resolution Index for Valley Bottom Flatness (MRVBF) (Gallant & Dowling 2003)
  -- *cooperation*



Slope position *(USDA Forest Service 1999)*

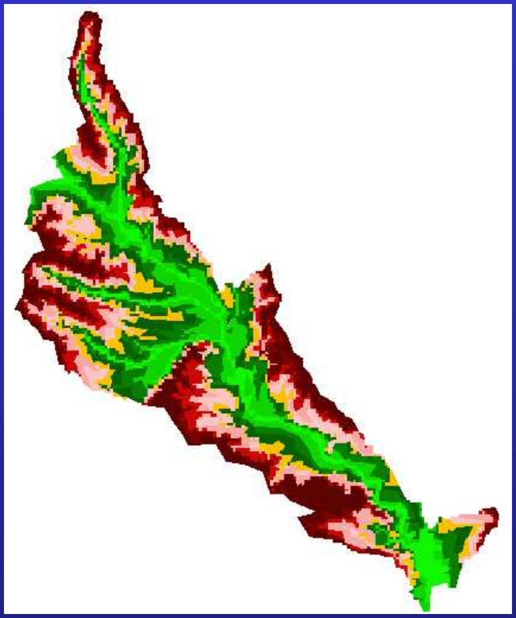
- Valleys and ridgelines are identified via flow accumulation (Grid module in Arc/Info).

- All cells with a downhill flow accumulation greater or equal than the limit for minimum flow accumulation "valley" will be considered as valley floor, and receive a value of 0 in the outgrid.

- The "uphill" flow accumulation at a cell is equal to the number of cells downridge of that cell. It is calculated by multiplying elevation by –1 and then calculating downhill flow accumulation.

Slope position *(USDA Forest Service 1999)*

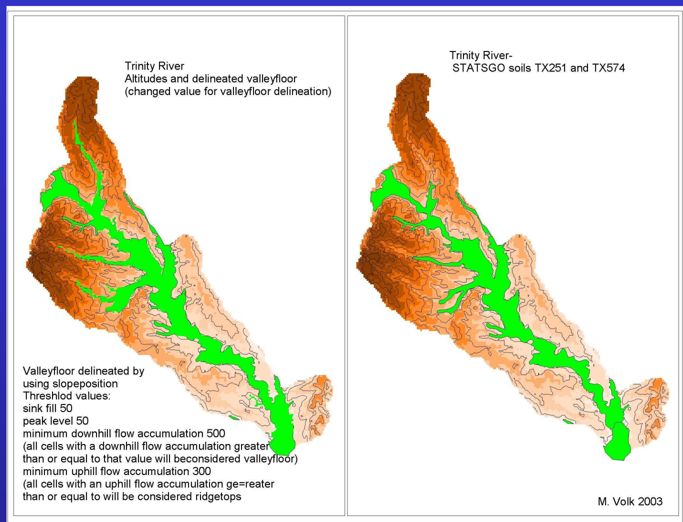
- Slope position is calculated for the cells in the output grid as the elevation of each cell relative to the elevation of the valley the cell flows down to and the ridge it flows up to (vertical distance z).
  This is presented as a ratio, ranging from 0 (valley floor) to 100 (ridge top).



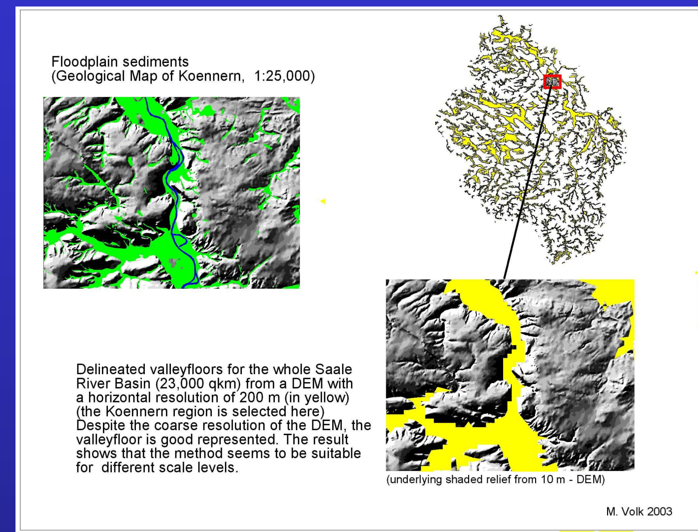
- Method shows good results (better as with object-based program eCognition, using very complex algorithms ☺)
  - problem is to find the “right” threshold
  values for defining valley floor, hill slope and ridge top

Slope position *(USDA Forest Service 1999)* - How to validate?

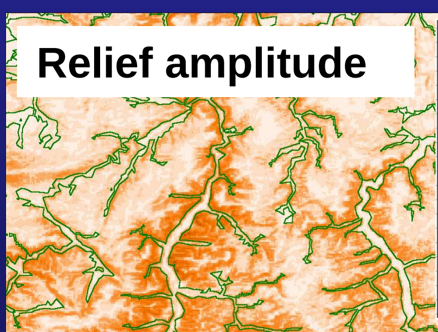
(a) Floodplain sediments and soils

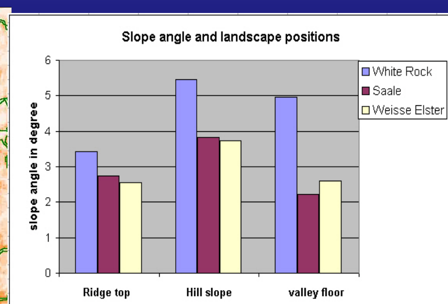


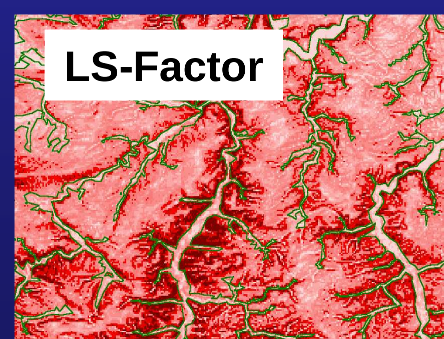
(b) Different scales

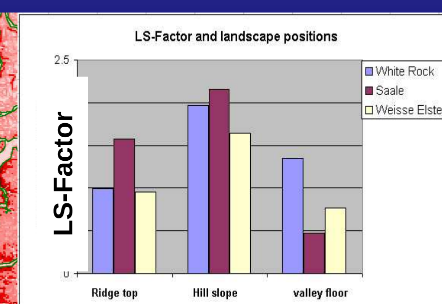


(c) Morphometric parameters



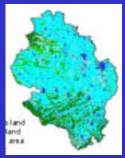


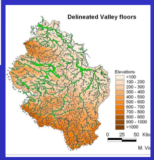


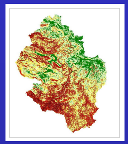


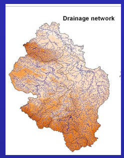
Landscape units, basin characteristics and storage

Dimensionless Indices used for basin characterization (Selection):





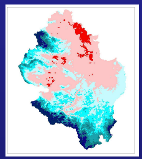




- Basin areas
- Proportion of delineated landscape units
- Average slope angle
- Stream length and drainage density (L/A)
- Hypsometric Integral

$$Int = \frac{Elev_{mean} - Elev_{min}}{Elev_{max} - Elev_{min}}$$

- Climate index (rainfall/PET)



- Mean soil AWC
- Baseflow index (bf/strf)

Hydrological analysis

Streamflow data

Area-weighted to basins

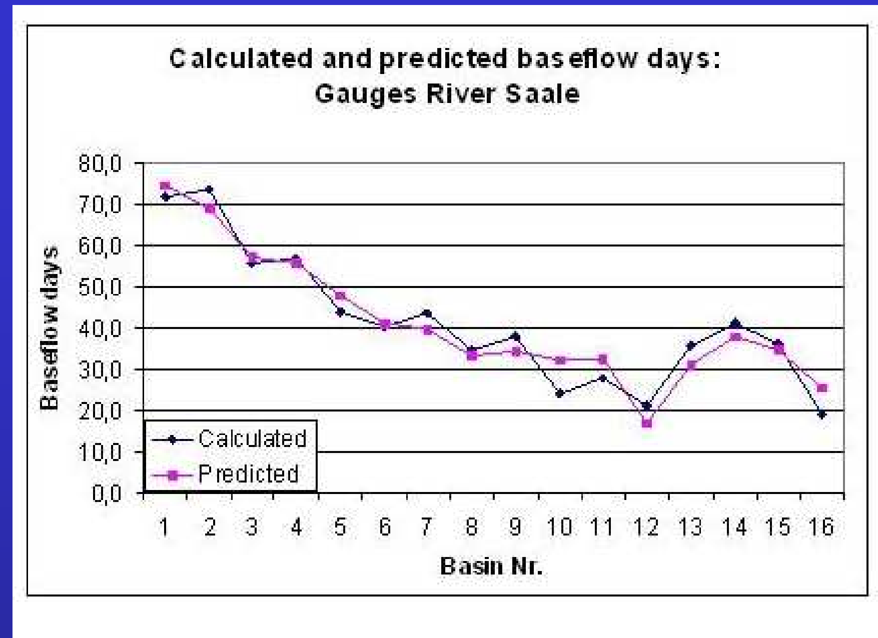
Input for baseflow recession analysis

Baseflow separation and recession analysis

Contribution of baseflow to streamflow

Recession constant "alpha" resp. baseflow days as an indicator for transmissivity and storage.
Low number bfd = rapid drainage and little storage
High number bfd = slow drainage and high storage

First results



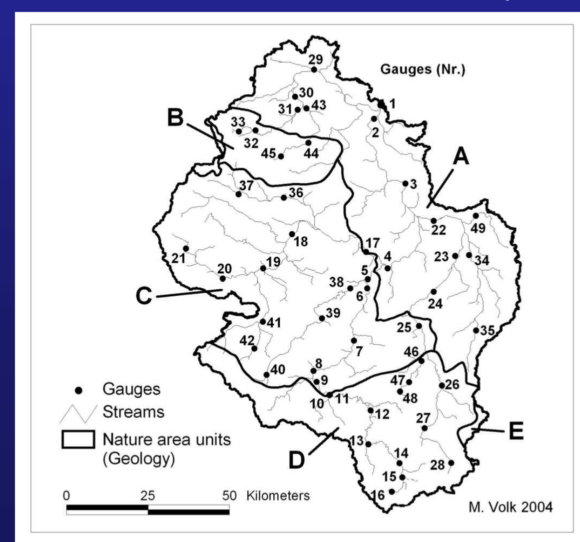
Strongest correlations to:

- **basin size** *(r^2= 0.81)*
- **stream length** *(r^2 = 0.81)*
- **climate index** *(r^2= 0.75)*
- **baseflow index** *(r^2= 0.75)*
- **drainage density** *(r^2= 0.72)*
- **valley floor** *(r^2= 0.59)*

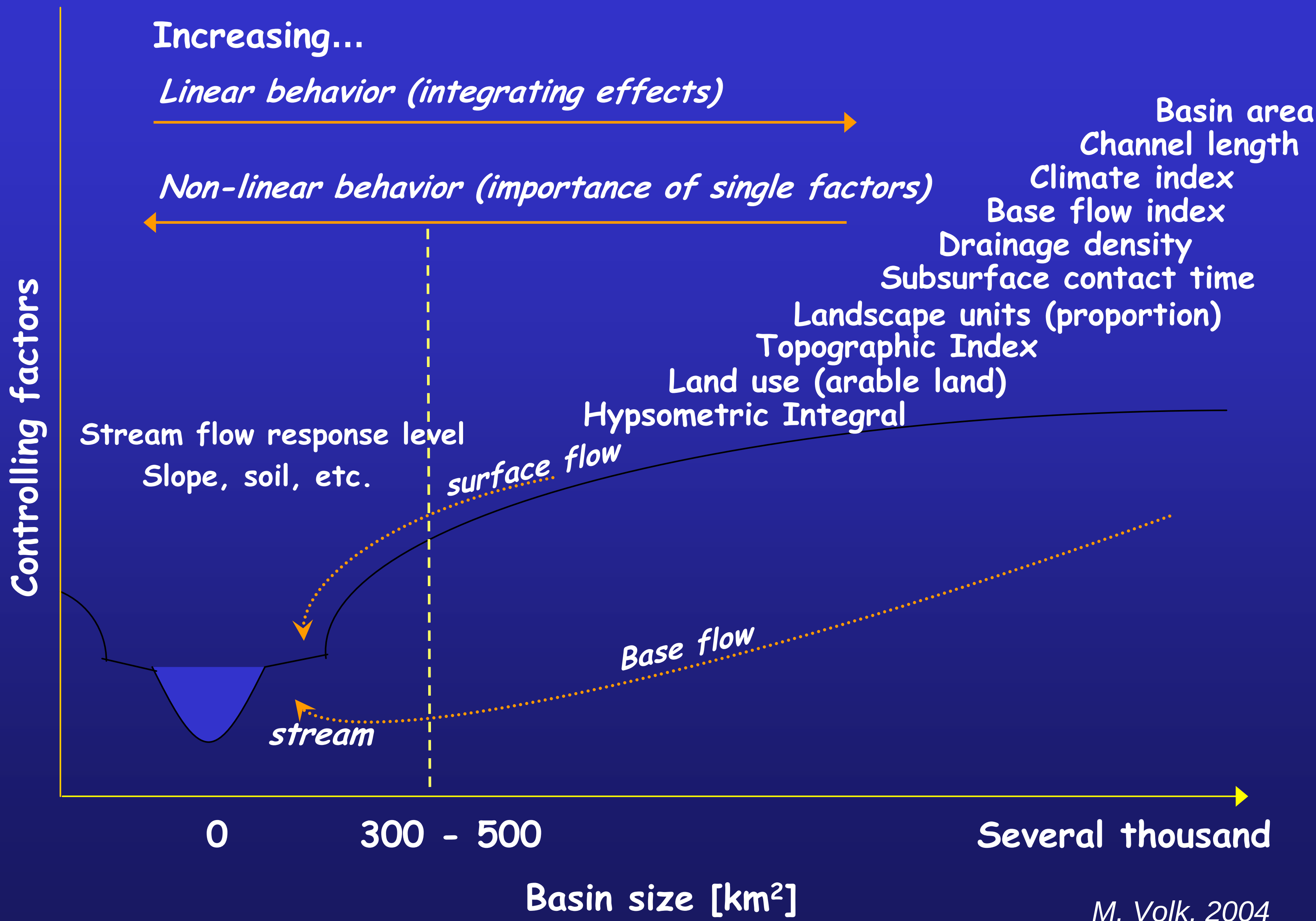
- **Best results for basins >300 km² (more linear behavior)**

- **Results confirmed by testing a macro model on 49 other gauges of the Saale river basin**

- **Further development of the macro model**



Scale- and catchment-related control on storage behavior

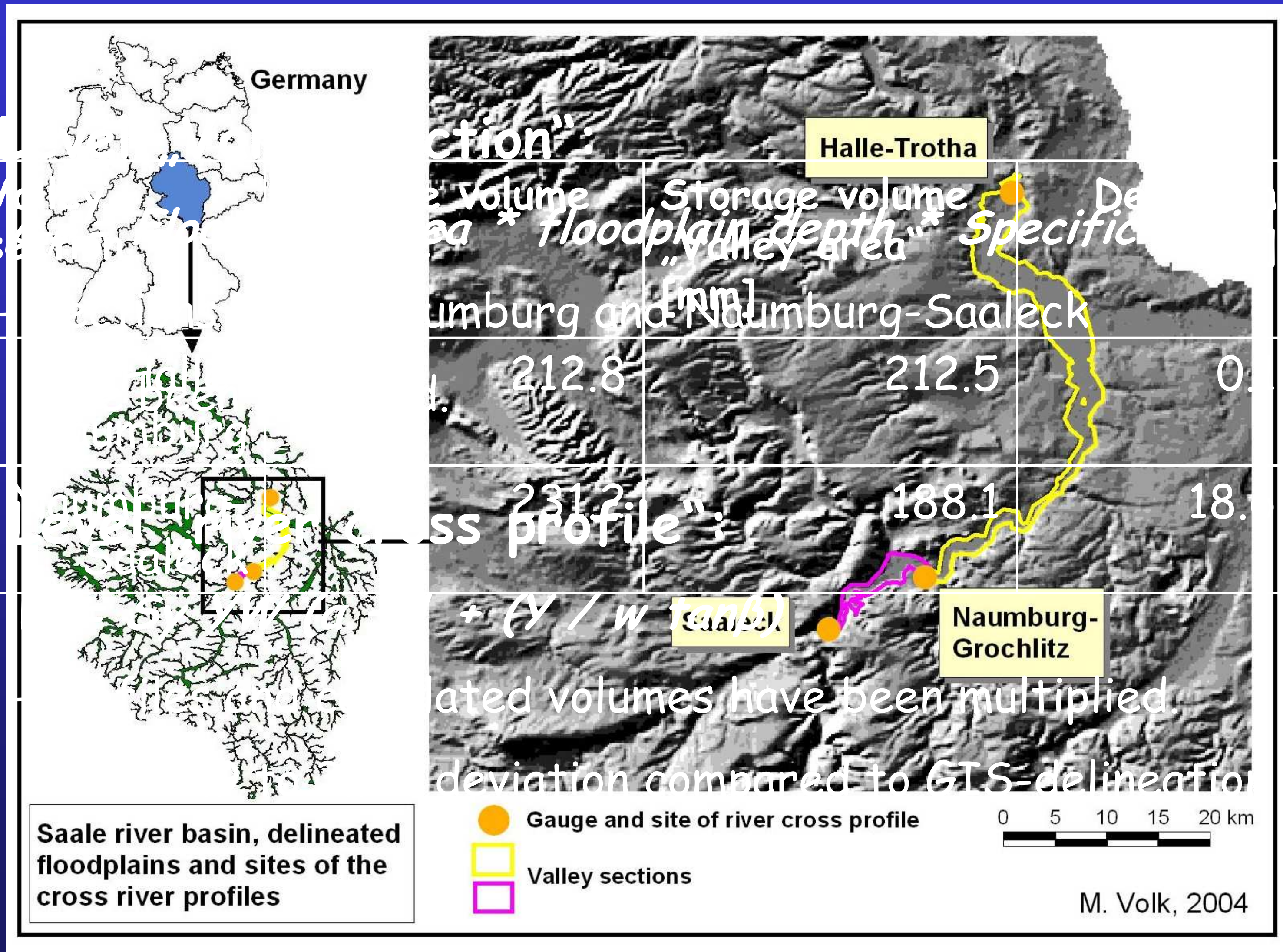


M. Volk, 2004

Next steps (1):

- Storage volume on different scale levels - testing the methods
- River basin level (1): simple approach:
  $V_{FP} = Area_{FP} * Depth_{soil} * Water\ content\ variable$
- River basin level (2):
  Maximum Baseflow (Filter):
  $V_m = Q_0 / a$
- Level valley section / river cross profile: comparison calculation “river basin” / “small-size” (numerical approach)

Level Valley section / river cross profile: Comparison calculation "River basin"/"small-size" (numerical approach)



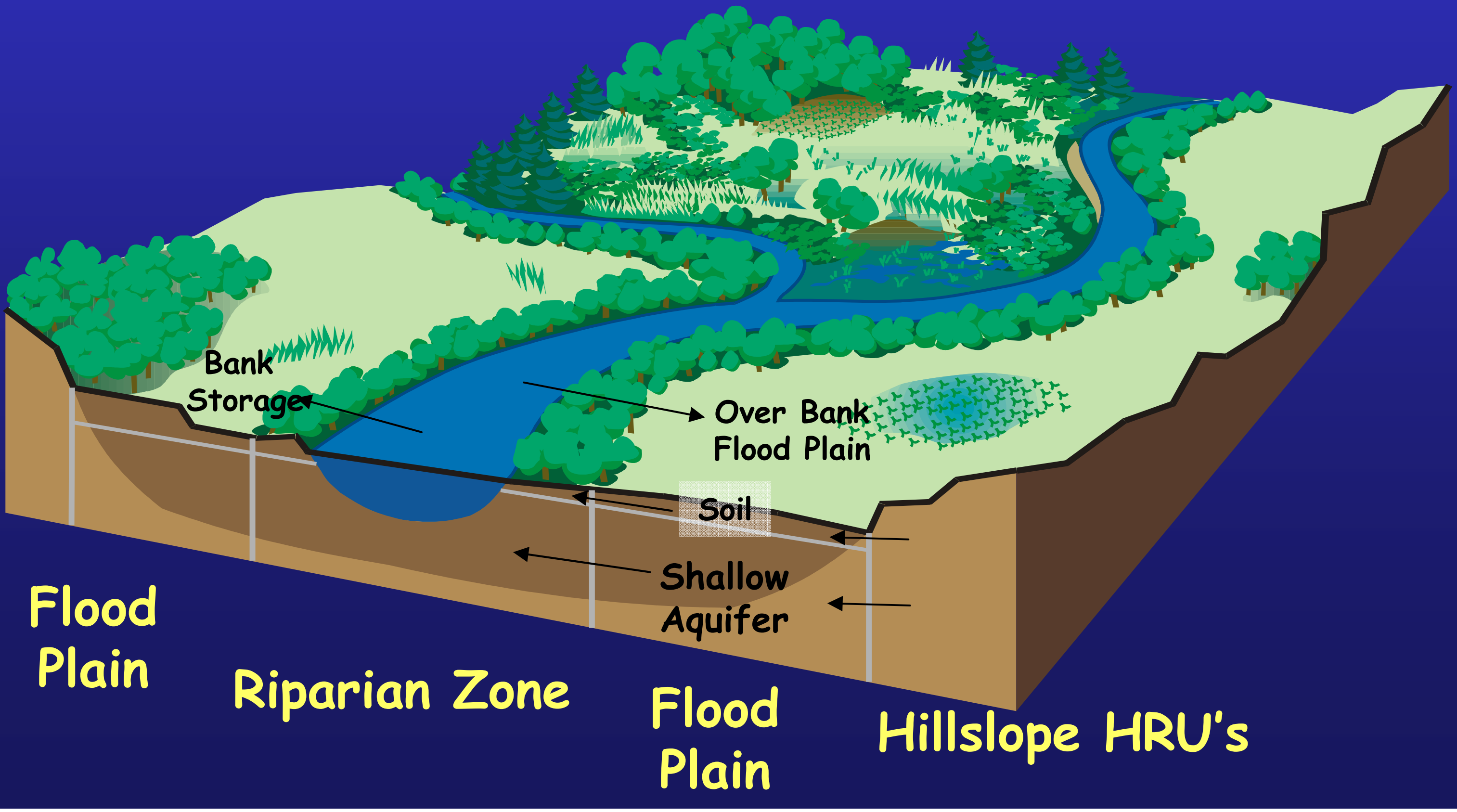
Next steps (2)

- Methods for a rule-based delineation of the units (among others streamorder - valley width)
- Maximum Storage of valley floors
- Comparing and testing the new concept and developments in areas with hydrological instrumentation and/or surveys :
  - Linear vs. non-linear methods (coop. with H. Wittenberg)
  - Tracer experiments (isotopes) to quantify the water flows
  - Existing HRU vs. new concept(s)
- Transforming the application into the Pre-processing tool of AVSWAT

SWAT

SWAT 200X. Current research:

- "Landscape positions"
  (new HRUs: valley-, slope- and ridge top areas)
- Riparian zones (cooperation with other institutes)



Thank you!