SWAT+ Current Developments

SWAT Modeling Team

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SWAT+
SOIL & WATER ASSESSMENT TOOL

New, completely restructured version (Bieger et al., 2017)

- Groundwater
- Salt , Carbon, Pesticides
- Plant Growth and Management
- Water Allocation
- Manure Allocation
- SWIFT – Scenario Watershed Integrated Forecasting Tool
- Carbon and Salt
- Documentation

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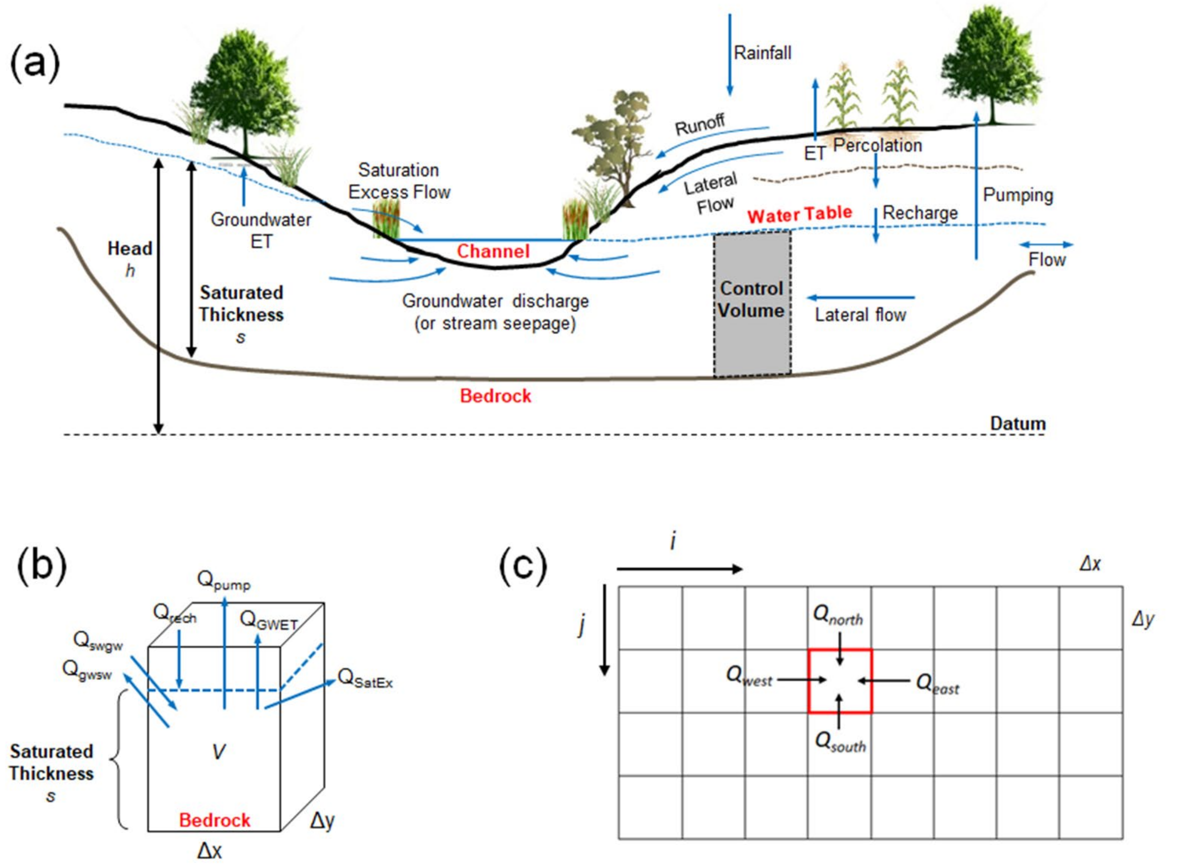
Groundwater Model

GWFLOW – Ryan Bailey

- Physically-based spatially-distributed groundwater flow module called *gwflow*
- Groundwater head and storage are solved using a water balance equation for each grid cell.
- Adds 2-3X to run times
- Interface and global data are available

Ryan T Bailey, Katrin Bieger, Jeffrey G Arnold, David D Bosch
"A new physically-based spatially-distributed groundwater flow module for SWAT+"



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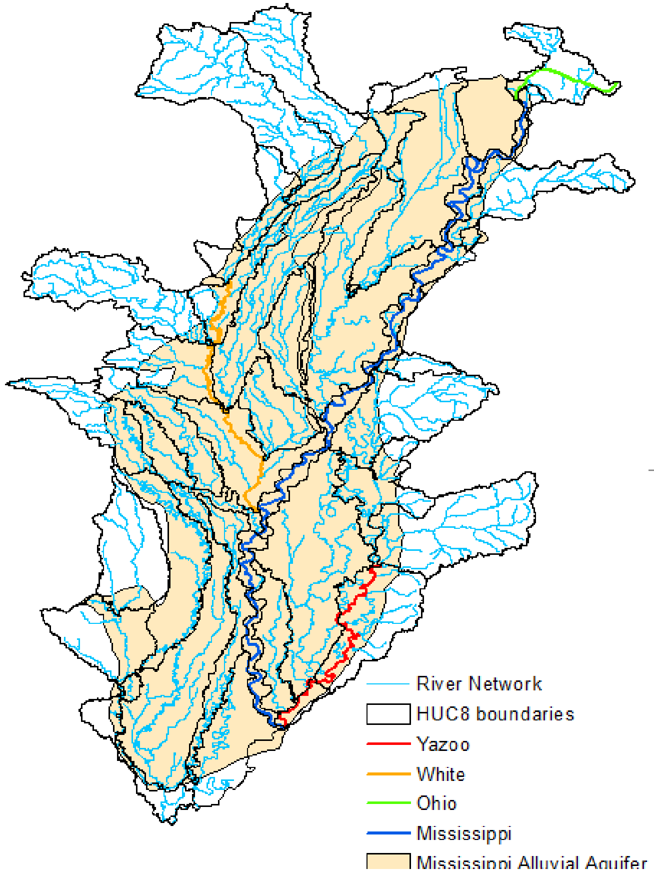
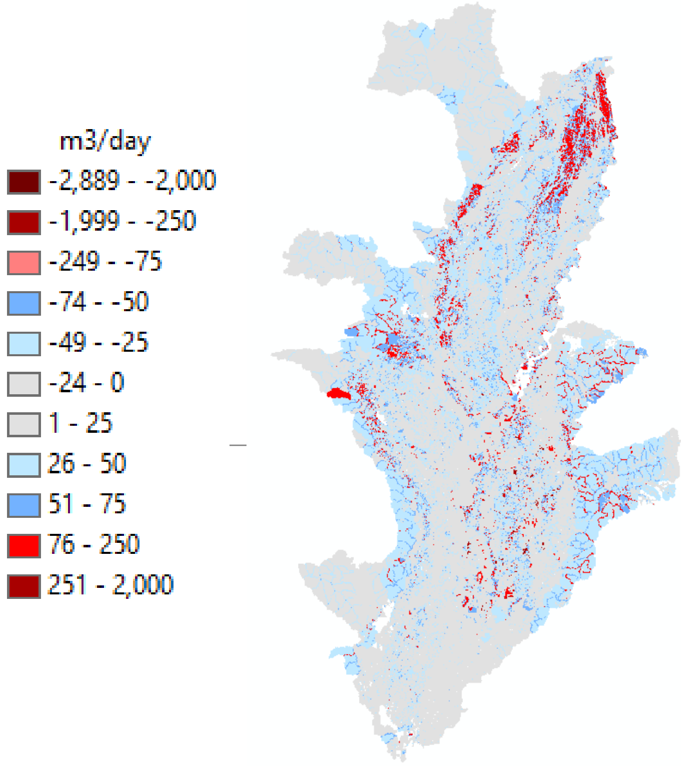
Example with National Agroecosystem Model

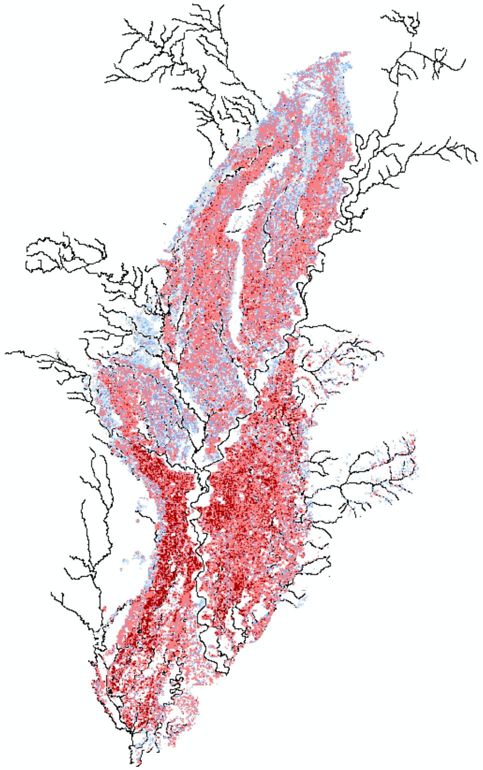
Mississippi Alluvial Plain
(intense groundwater irrigation)



Recharge



Pumping



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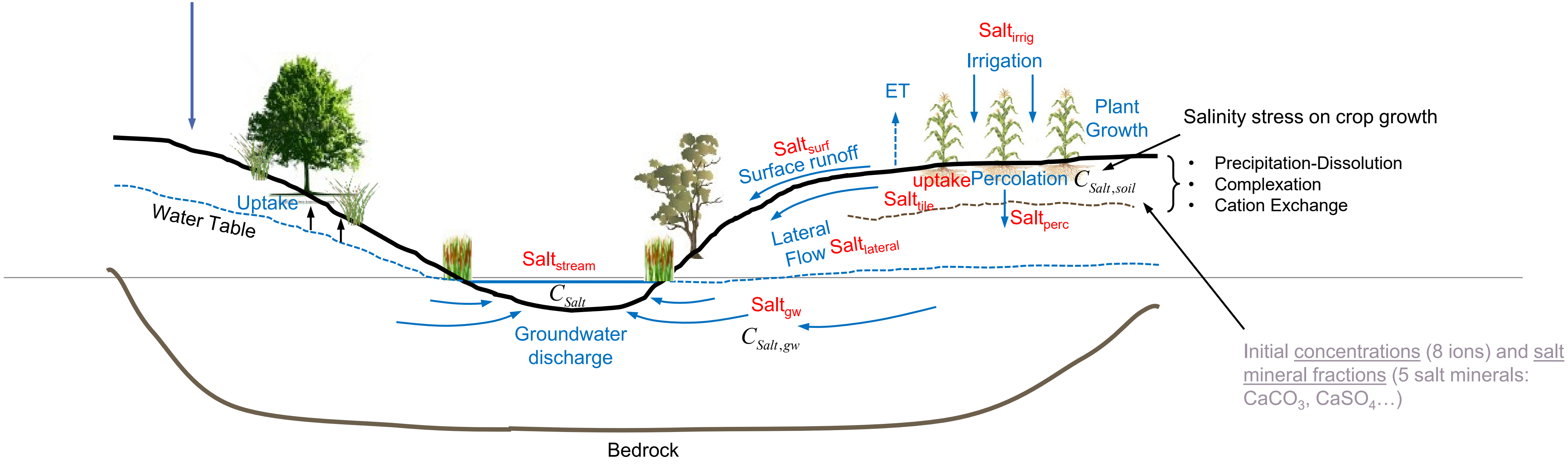
Watershed Salt Transport

External Loadings

1. **Atmospheric Deposition** (rainfall)
2. **Road Salt** (winter weather)
3. **Point Sources** (e.g. WWTP, industry)



Salt = SO_4, Ca, Mg, Na, K, Cl, CO_3, HCO_3

Also: salt mass and concentration in reservoirs/ponds/wetlands

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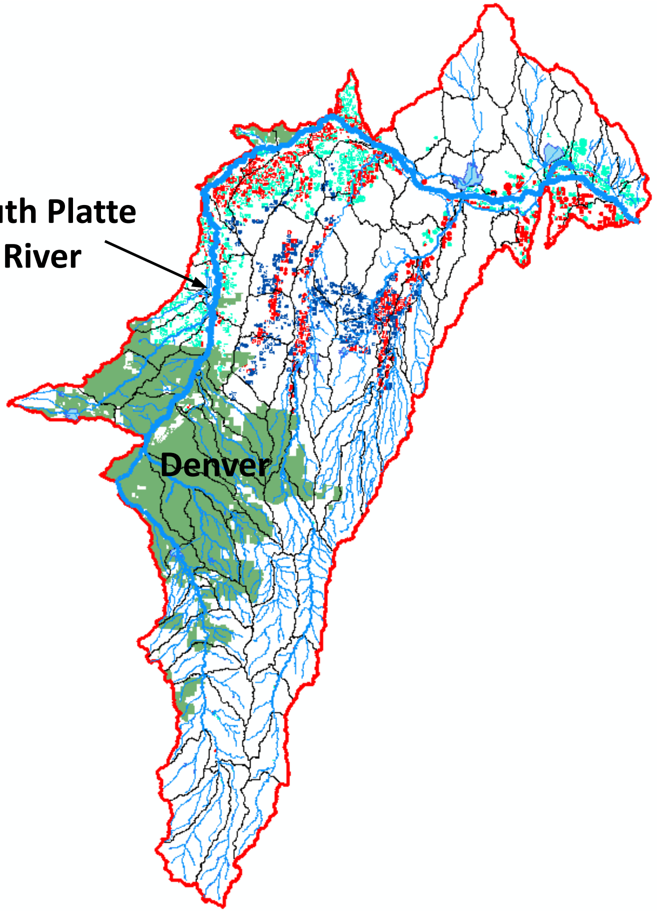
Example with National Agroecosystem Model

Middle South Platte – Cherry Creek
(HUC8 10190003)

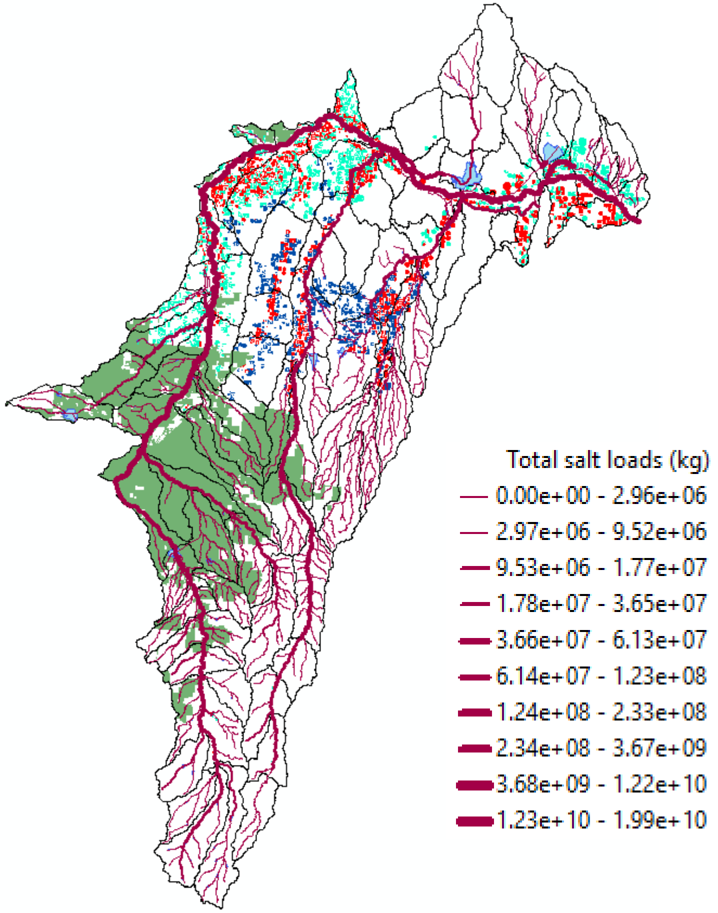


Salinity Module

Account for:
- Salt minerals in soil profile
- Salt in aquifer
- Salt in rainwater
- Salt in applied road salt (winter)
- Salt in WWTP effluent (Denver)
- Salt in tributary inflows

Track salt mass and concentration in each spatial object:
- HRU soil profile
- Aquifer
- Reservoir / wetland
- Channel
- Routing Units

Check results for salt mass balance
Test model for in-river salt loads



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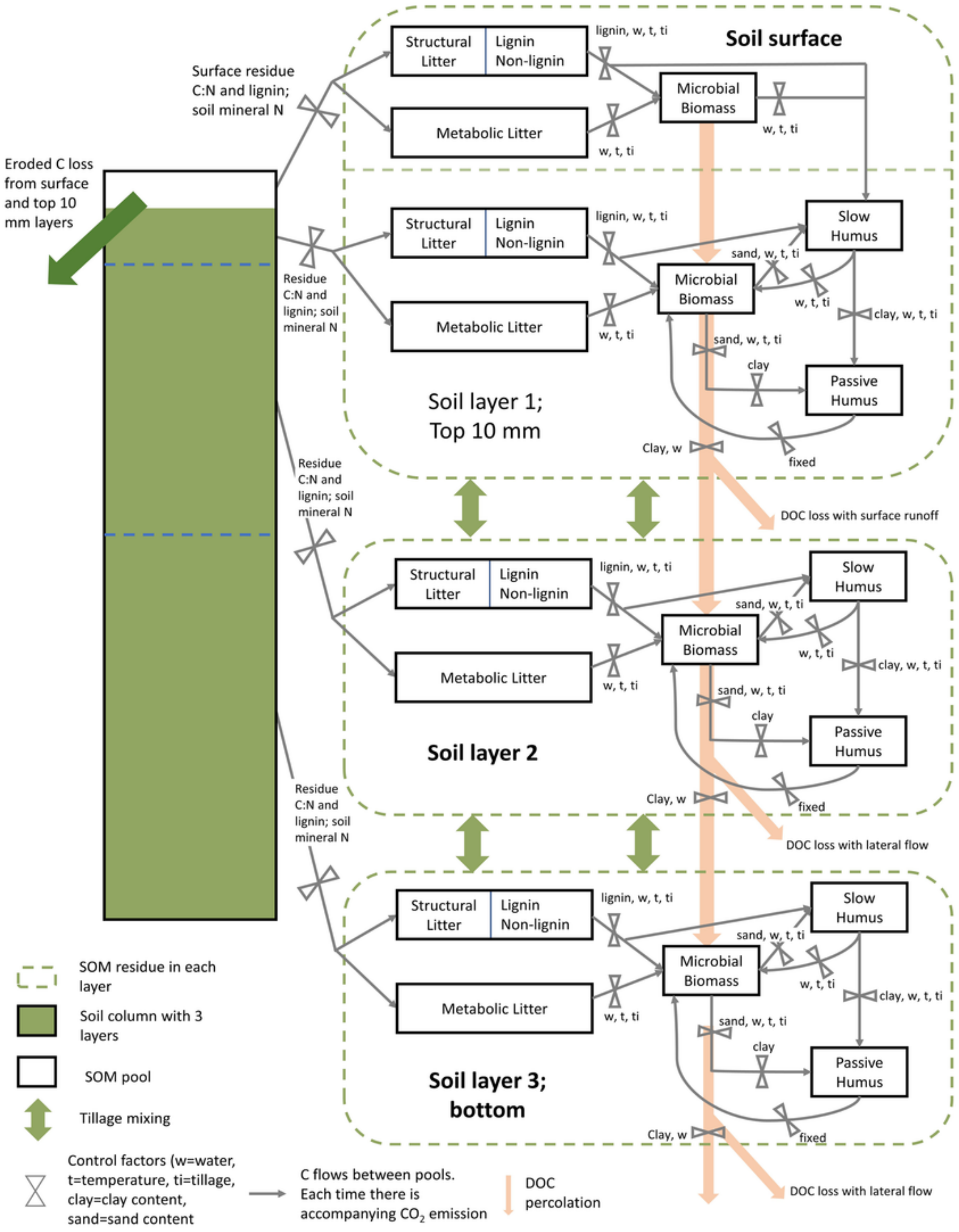
Carbon Model

SWAT-C

- Xuesong Zhang USDA-ARS has developed and is supporting SWAT-C
- Plans to incorporate into SWAT+. Organic object will make cleaner code – require modifications from SWAT
- Soil carbon budget and sequestration.
- Plant growth and management impacts
- Transport in channels and reservoirs



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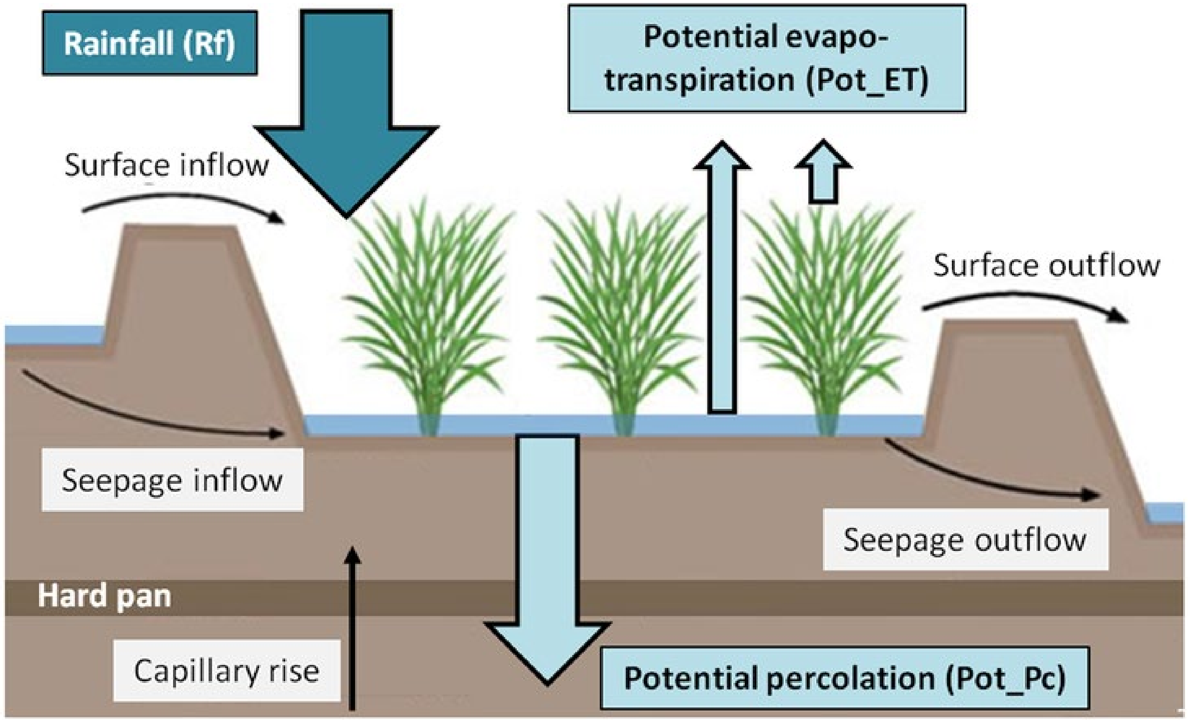
Pesticide Model

- Hendrik - complete fate and transport, updated database, daughter compounds, more complete output files
- Hendrik is currently adding plant uptake
- Rice paddy application

Rice Paddy Management

Rice Paddy

- Jaehak/Phil and international team
- Management – puddling, transplanting, nutrient and pesticide applications
- Dynamic changing of weir height
- Integrating with Water Allocation model



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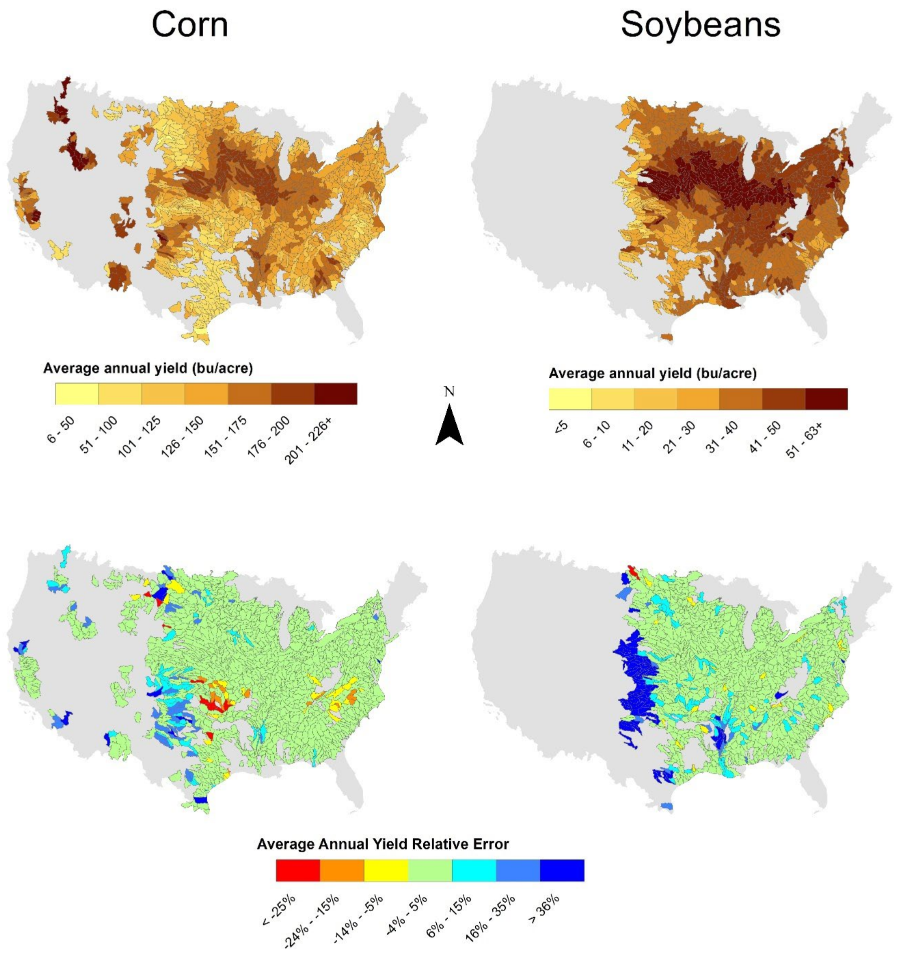
Plant Growth and Management

- Natalja and Temple Team - Crop yield soft calibration – National scale corn and soybeans
- Tassia/Phil - Plant parameters for fruits and vegetables
- Tadesee - Tropical plant growth



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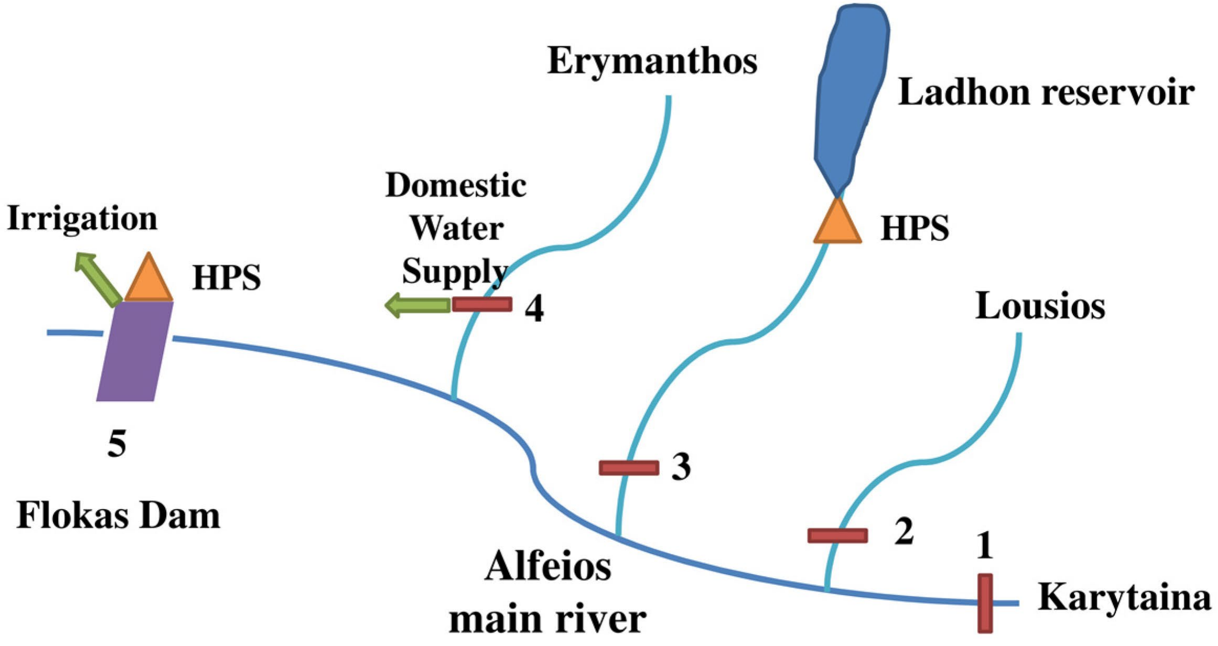
Water Allocation

Source Objects

- Reservoir
- Aquifer
- Channel
- Unlimited source
- No limit on number of objects

Monthly Minimum For Withdrawals

- Reservoir – fraction of principal spillway volume
- Aquifer – water table depth
- Channel – minimum flow
- Unlimited source – no limits



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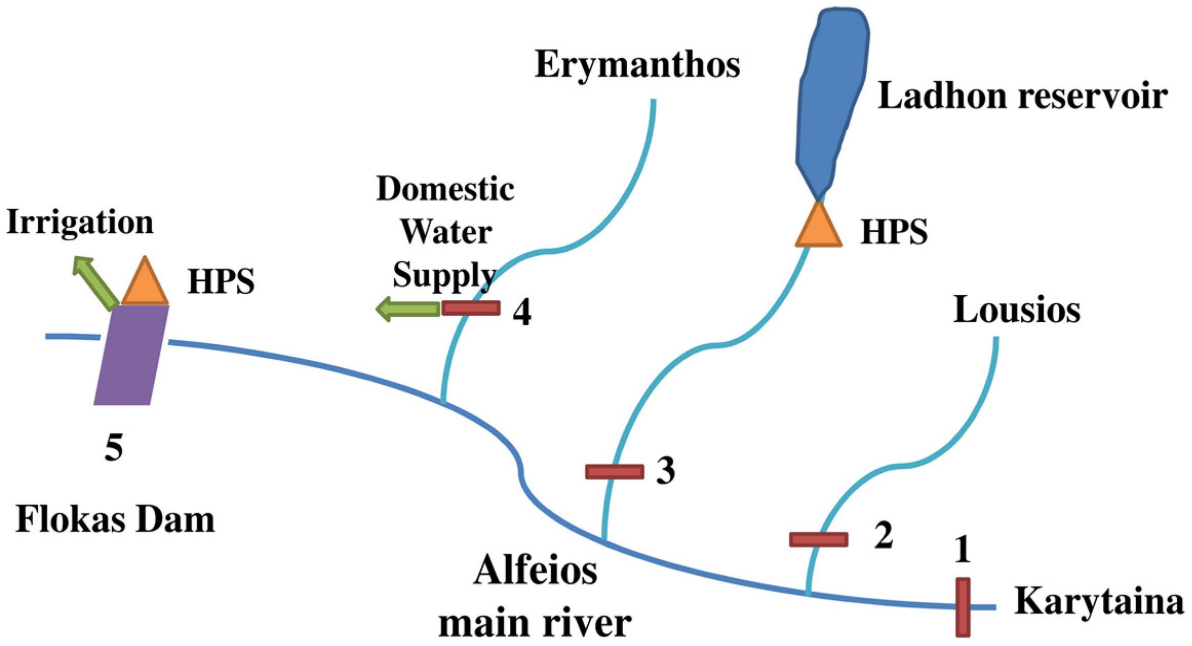
Water Allocation

Demand Objects

- Municipal and Industrial – input constant daily amount or decision table to specify daily withdrawals
- HRUs for irrigation – based on irrigation demand. Triggered by water stress or soil moisture deficit in decision table.

Link to Sources

- Take water from multiple source objects
- Input fraction from each source – 75% gw, 25% res
- Can source compensate if other sources are limiting
- Output withdrawal from each source and when demand was not met



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Urban Water Allocation

Mazdak Arabi and Sybil Sharvelle at Colorado State

Local Water Sources

- ➢Urban Water Demand
- ➢Urban Water Reuse
- ➢Wastewater, Greywater
- ➢Stormwater, Runoff

Monthly Minimum For Withdrawals

- ➢Urban water demand/consumption model
- ➢Integrated land use and water supply planning model. Gray and green stormwater infrastructure model
- ➢Synthetic water distribution network model

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Manure Allocation

Status - Conceptual

- Cibin Raj – Penn State
- Started with Water Allocation module

Source Objects

- Feedlots, Confined Animal Feeding Operations
- Composting centers

Manure Applications

- Use decision tables to condition applications
- Condition on soil phosphorus concentrations
- Condition on distance from source

SWIFT – Simple Watershed Integrated Forecasting Tool

- Export Coefficient – Delivery Ratio Approach
- Uses SWAT+ routing structure – same connect files – same channel and reservoir inputs
- SWIFT run generated by SWAT+ or use output from other models (APEX. SPARROW) or measured data
- Routines for reservoir and channel routing – routes mean flow and uses flow duration curve
- Model with 10,000 hru runs in 10 seconds
- Scenario analysis – approach used in Mississippi River Basin analysis and in Chesapeake Bay Model

SWIFT – Scenario Watershed Integrated Forecasting Tool

HRU Export Coefficients – Average Annual

Runoff mm	Sediment t/ha	Organic N kg/ha	Sediment P kg/ha	Nitrate kg/ha	Soluble P kg/ha	
257.9	0.81	0.41	0.13	11.10	0.8889	Total runoff
71.87	0.00	0.00	0.00	5.64	0.00	Percolate
25.26	0.81	0.41	0.13	1.15	0.8889	Surface runoff
47.47	0.00	0.00	0.00	3.80	0.00	Lateral flow
185.2	0.00	0.00	0.00	6.14	0.00	Tile flow

Output – annual sediment and nutrients

- Landscape loadings – by subbasin and land use
- Channel – bank and bed erosion, flood plain deposition
- Reservoir – inflow/outflow, trapping efficiency

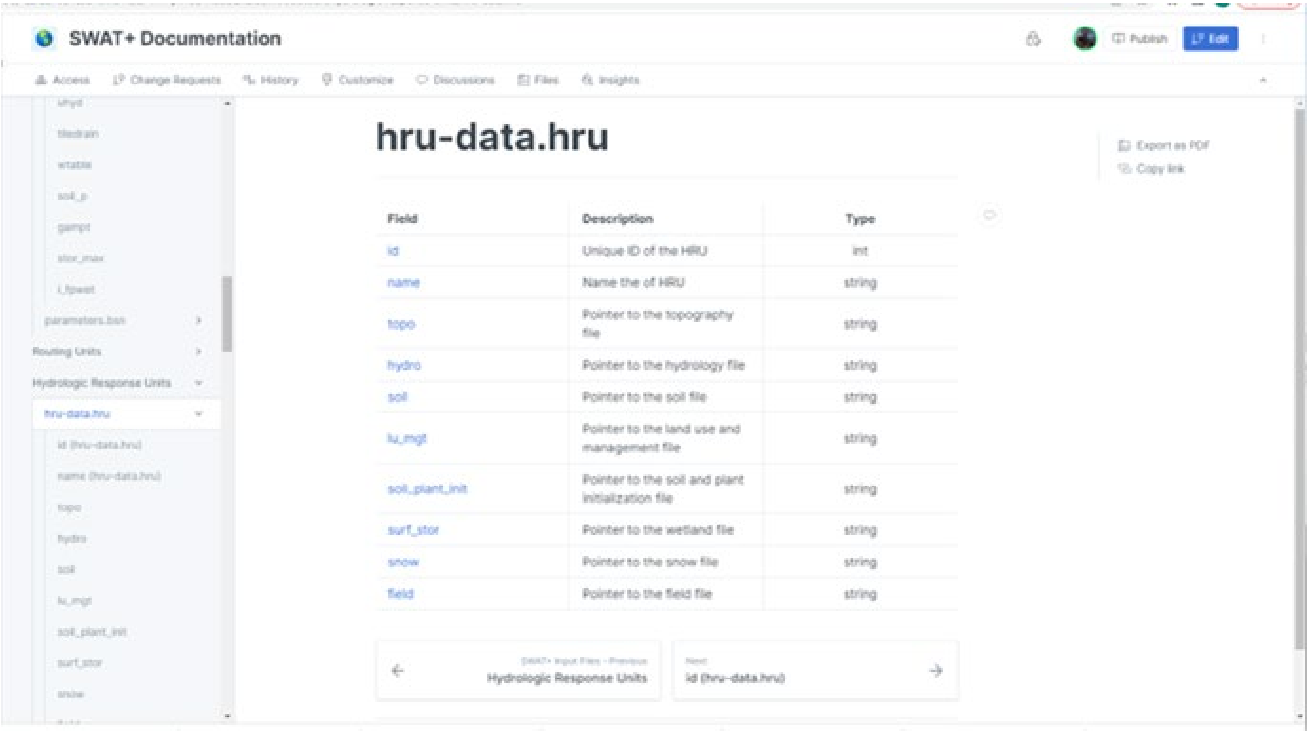
Scenarios

- Climate – annual precipitation and PET
- Land use – complete change (ag -> forest) or BMP efficiency
- Channels – dimensions, flood plain slope, bed/bank material, vegetation
- Reservoir – size, trapping efficiency

Documentation

Git Books

- ➢Katrin has first draft of input/output documentation
- ➢Translated the SWAT2012 theoretical documentation into Git Books
- ➢Integrate theory and i/o and ultimately link code documentation
- ➢Git Books makes it easy for others to contribute



Field	Description	Type
id	Unique ID of the HRU	int
name	Name the of HRU	string
topo	Pointer to the topography file	string
hydro	Pointer to the hydrology file	string
soil	Pointer to the soil file	string
lu_mgt	Pointer to the land use and management file	string
soil_plant_init	Pointer to the soil and plant initialization file	string
surf_stor	Pointer to the wetland file	string
snow	Pointer to the snow file	string
field	Pointer to the field file	string

Thanks – appreciate everyone's efforts

Groundwater Model

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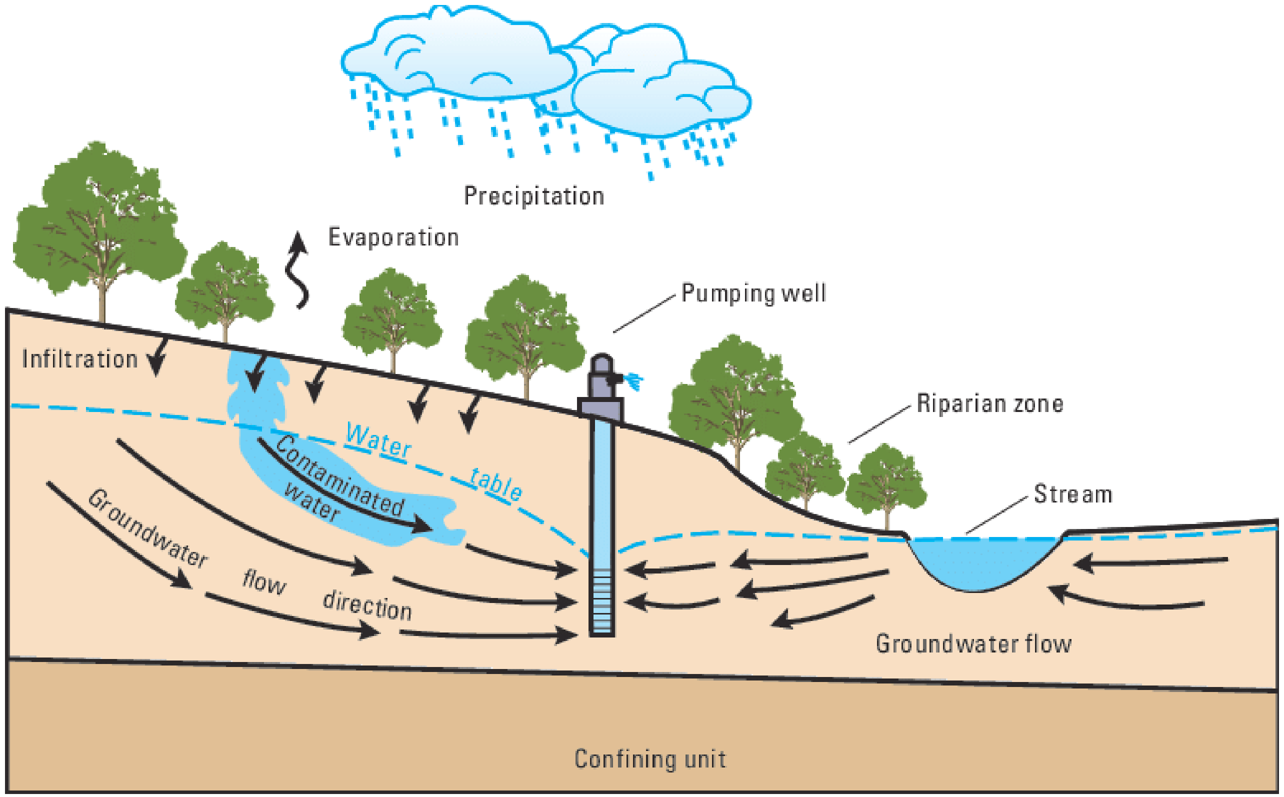
Existing Lag Model

- Input depth of aquifer and initial depth to groundwater
- Input depth of revap (related to root depth) and depth to sustain flow (related to channel depth). Specific yield becomes sensitive parameter
- Provides physical meaning to the input parameters



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Plant Growth and Management

- Organic Objects to partition plants – and soil and residue
- Partitioning is transparent and allows realistic harvest operations – grain, biomass, root, biomass+root, residue

```
type organic_mass
    real :: m = 0.      !kg/ha      |total object mass
    real :: c = 0.      !kg/ha      |carbon mass
    real :: n = 0.      !kg/ha      |organic nitrogen mass
    real :: p = 0.      !kg/ha      |organic phosphorus mass
end type organic_mass
```

```
type plant_community_mass
    character(len=4) :: name
    type (organic_mass), dimension(:), allocatable :: tot      !kg/ha   |total biomass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: ab_gr    !kg/ha   |above ground biomass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: leaf     !kg/ha   |leaf mass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: stem     !kg/ha   |wood/stalk mass for individual plant in community
    type (organic_mass), dimension(:), allocatable :: root     !kg/ha   |root mass for individual plant in community (by soil layer)
    type (organic_mass), dimension(:), allocatable :: seed     !kg/ha   |seed (grain) mass for individual plant in community
end type plant_community_mass
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```

Decision Tables

Precise, compact way to model complex rule sets and their corresponding actions

CONDITIONS	ALTERNATIVES
ACTIONS	ACTION ENTRIES

Actions

irrigate
reservoir release
fertilize
plant
harvest
tillage
drainage
lu_change
structural practices

Alternatives

< > =

Action Entries

yes no

Conditional Variables

soil_water	soil_p
w_stress	n_applied
month	biomass
jday	cover
hu_plant	lai
hu_base0	vol
year_rot	flow
year_cal	lat
year_seq	long
prob	elev
land_use	day_len
ch_use	plant
n_stress	plant_type
soil_n	

Decision tables

Precise, compact way to model complex rule sets and their corresponding actions

Current Uses in SWAT+

- Land management
- Reservoir release
- Land use updates
- Scenario Analysis

- Land Use updates – land use change, structural practice changes
- Decision tables can be easily maintained and supported

Auto Irrigation Example

Name	Conditions	Alternatives	Actions			
auto_irr	1	1	1			
VAR	OBJ	OB_NUM	LIM_VAR	LIM_OP	LIM_CONST	ALT1
w_stress	hru	0	null	-	0.8	<
ACT_TYP	NAME	OBJ	OB_NUM	TYPE	CONST	OUTCOME
irrigate	stress_0.8	hru	0	sprinkler	25.	y

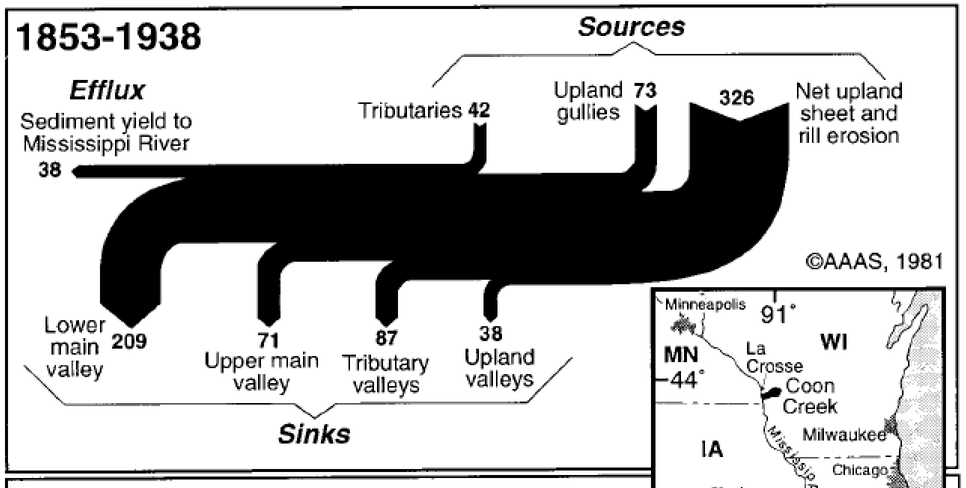
Soft Calibration – Coded in SWAT+

Soft calibration of water balance

- Surface Runoff, Baseflow, Tile Flow, and ET as % of Precip.
- Simple heuristic procedure has been included in SWAT+ with one/two variables for each process. Initial guess at parameter variables and linear interpolation in following runs. Calibrates within 15 simulations.

Soft calibration of crop yields

- Input average annual crop yields by region
- Simple heuristic procedure using hi, bio_e, esco, epco, and lai_potential
- Natalja completed paper on corn and soybean calibration across the US



Elevation Bands

Replaced Elevation Bands

- Input elevation of each object, weather gage, and weather generator station
- Input temperature lapse rate and precipitation lapse rate
- More physically realistic – elevation bands are lumping on top of hru lumping within a subbasin
- Input lapse rates by hru

Simulating Carbon and Pesticides, Salts, Pathogens, and Metals

- Pesticides – Hendrik - complete fate and transport, updated database, daughter compounds, more complete output files
- Salt – Ryan has developed complete fate and transport routines. He is transferring into SWAT+
- Pathogens – SWAT code transferred over to SWAT+, no updating or testing
- Metals – framework in place but no progress on process algorithms
- Carbon – Xuesong Zhang has complete carbon budget in SWAT, haven’t begun transfer into SWAT+

Subdaily Routing

- Green and Ampt with subdaily precipitation or daily precip and unit hydrograph
- Muskingum and Variable Storage Coefficient methods
- Using rating curves – calculated from channel dimensions or input from US HAND database

- Connecting overbank flood with flood plain. Flood plain/channel link file. Structure is there but still a work in progress