SWAT 2015
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A Heavy Metal Module Coupled in SWAT Model and Its Application in Liuyang River Upstream Basin in China

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1. Introduction

Heavy metal pollution

1. Introduction

Significance:

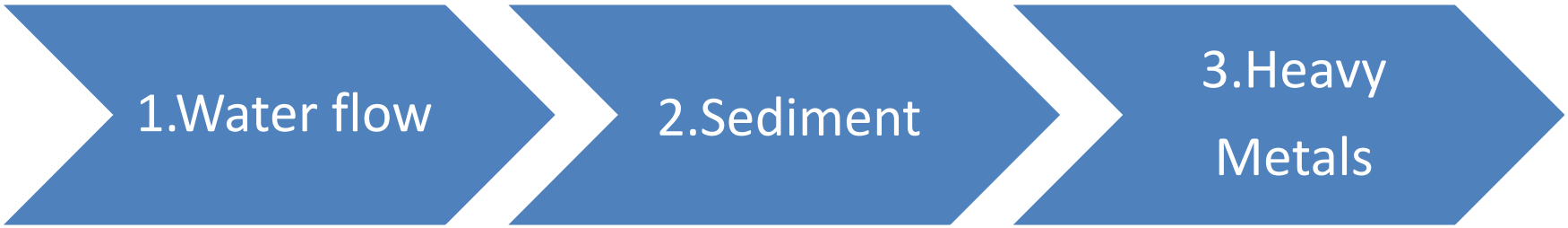
- Heavy metal pollution----A Global environmental problem
- Heavy metal pollution----Impact aquatic ecosystems and human health
- Mining area----Main pollution sources

Challenge:

- Obvious differences among heavy metals
- The speciation of heavy metal in soil is affected by many reactions.
- Involving various environmental factors
- ……

1. Introduction

Obviously, heavy metal pollution has both point and non-point source loading, so we need a hydrologic model to provide the required hydrological and sediment variables in order to provide the driving forces of the heavy metal module.



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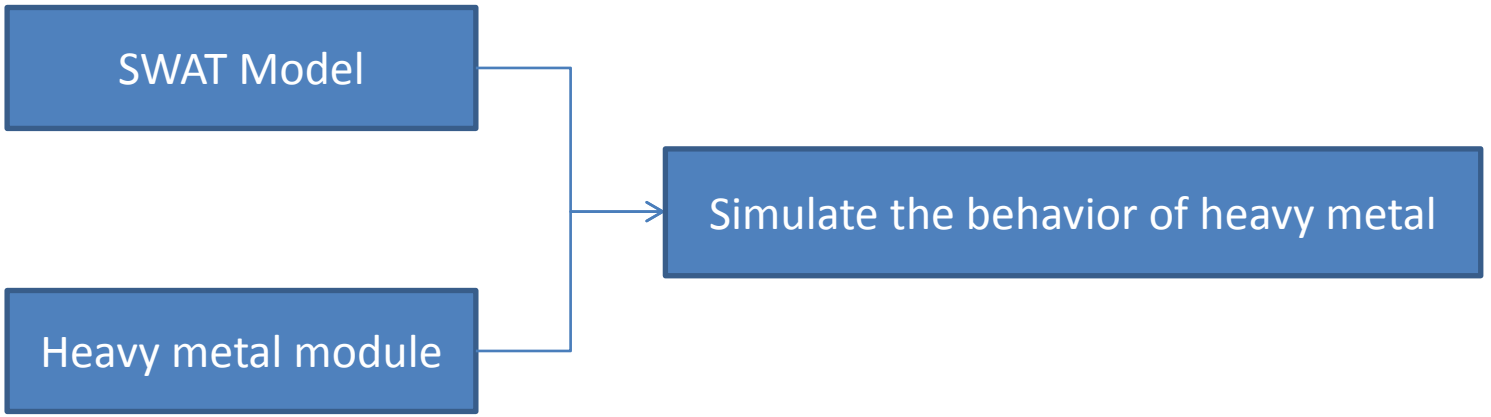
2. Heavy Metal module Coupled into SWAT

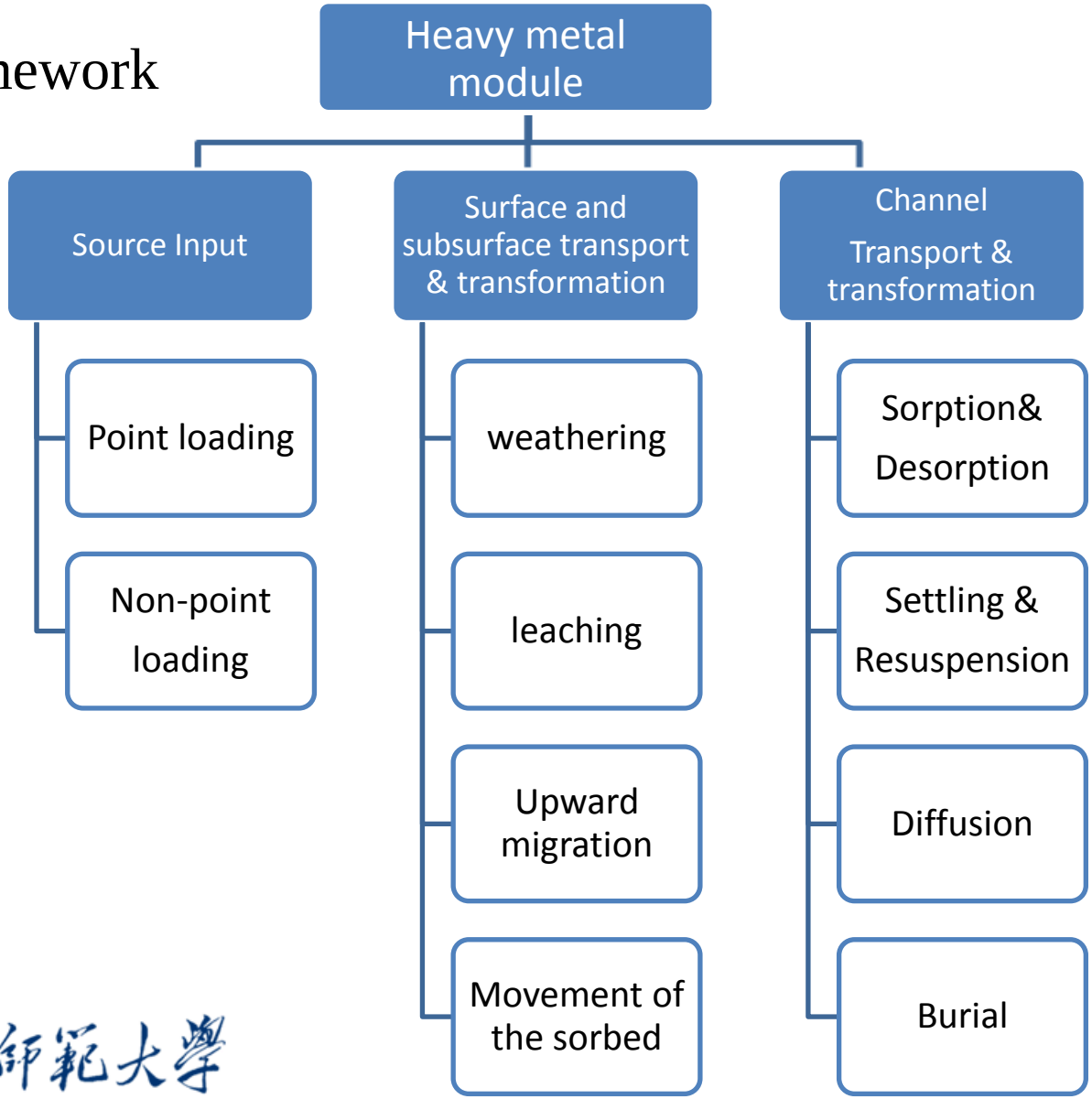
SWAT model

The soil and water Assessment Tool（SWAT）has proven to be an effective tool for nonpoint-source pollution problem. such as nitrogen and phosphorus and pesticide. However, as far as heavy metals is concerned, the SWAT model, by its own version, only allows point source loading inputs, which addresses a small part of heavy metal pollution issues.



2. Heavy Metal module Coupled into SWAT

Module framework



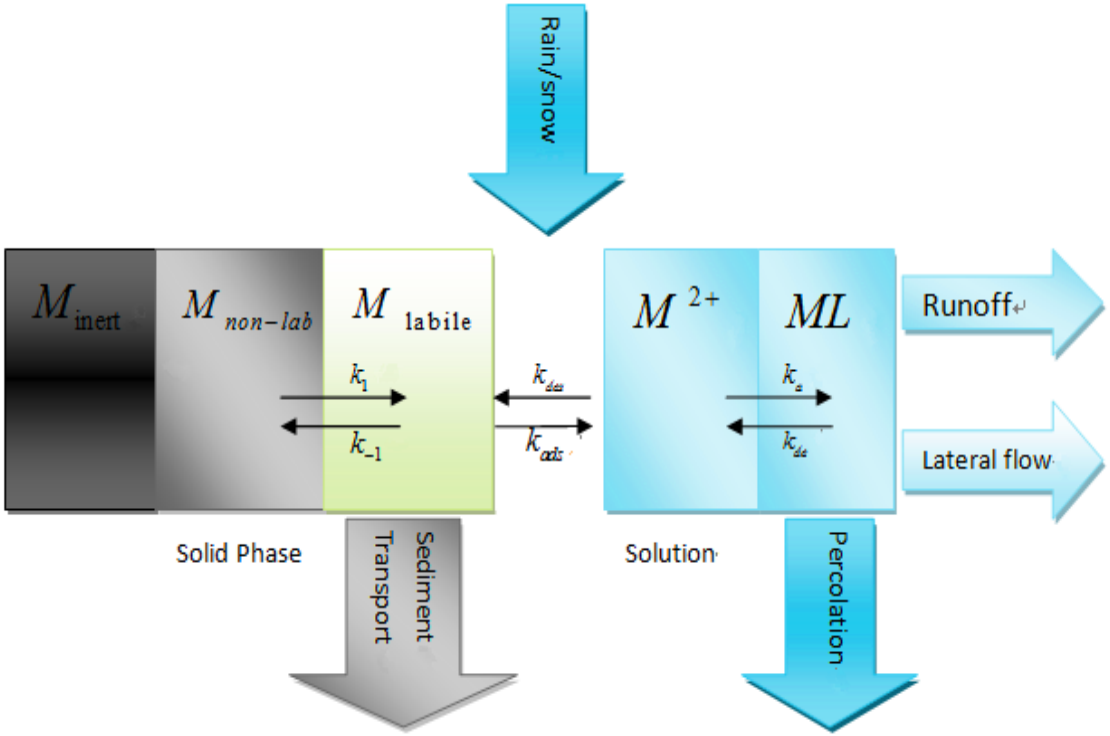
2. Heavy Metal module Coupled into SWAT

Heavy metal in soil

The speciation of heavy metal in soil is affected by many reactions.

solution phase: free ions, complexes with inorganic or organic ligands, or associated with mineral colloids.

soil phase: adsorb on organic matter, oxides, clay minerals or exist in parent minerals.



$$M_n \underset{k_1}{\overset{k_{-1}}{\rightleftharpoons}} M_s$$

$$M_s \underset{k_{ads}}{\overset{k_{des}}{\rightleftharpoons}} [M]$$

$$[M] + \gamma [L] \underset{k_d}{\overset{k_a}{\rightleftharpoons}} [ML_\gamma]$$

M_n is concentration of non-labile metal
M_s is concentration of labile metal
[M] is concentration of ions metal
[L] is concentration of organic matter
$[ML_\gamma]$ is concentration of metal complexes
γ is ligand binding number.

2. Heavy Metal module Coupled into SWAT

Heavy metal in soil

The partition coefficient of heavy metals K_d greatly affects their mobility in soils.

$$K_d = {}^{M_s}\!/\!_{[M]}$$

K_d is different among soil for the same heavy metal because of the different properties of soils such as pH, organic matter, competing ions as H^+ and Ca^{2+} ions. So the risks of metals in soils depend on soil properties and the availability of metals in soil.

2. Heavy Metal module Coupled into SWAT

Key parameter: partition coefficient K_d

$$K_d = M_s / [M]$$

Different K_d in different processes

1. Partition between soil and water
2. Partition between suspended matter and water

Determine the appropriate K_d for various medium

2. Heavy Metal module Coupled into SWAT

Quick equilibrium among metal species

A theoretical analysis has been done to obtain a rule of thumb, that the breakthrough curve can be reasonably well described with the equilibrium assumption if the following condition holds[1]

$$\frac{\nu \cdot T_c}{\lambda} < 0.1$$

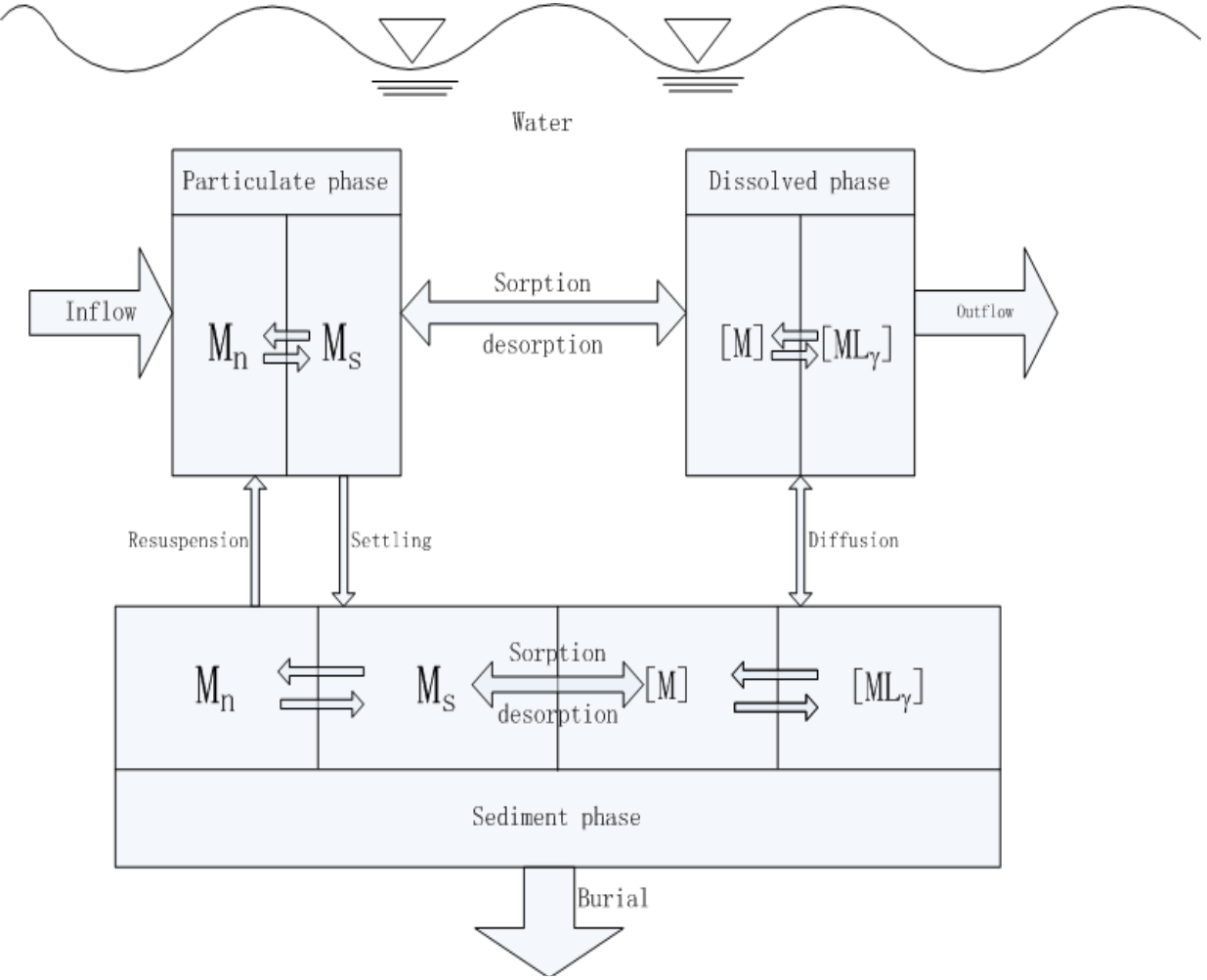
Partitioning reactions are usually faster relative to other environmental processes

υ is the flow velocity of interflow.
T_c is the response time of the reaction.
λ is the dispersivity.

[1].Valocchi, A.J., Validity of the Local Equilibrium Assumption for Modeling Sorbing Solute Transport Through Homogeneous Soils. Water Resources Research, 1985. 21(6): p. 808–820.

2. Heavy Metal module Coupled into SWAT

Heavy metal in the water



Key processes:

Sorption
Desorption
Settling
Resuspension
Diffusion
Burial
……

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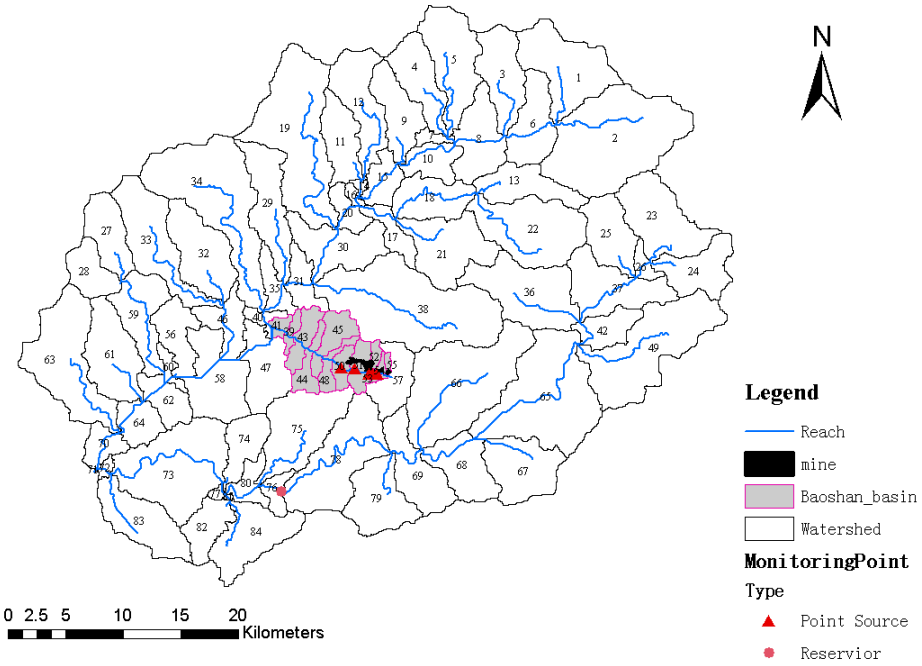
3. Demonstrative Implementation of modified SWAT model

Study area



The Liuyang River Upstream Basin

Location: Hunan province, central china

Area: 1990 Km^2

Precipitation: 1290-1840mm(yearly).

Hydrology: Daxi river

Xiaoxi river

Baoshan steram (tributary of Daxi River)

Mining area: Qibaoshan mine, 6.5Km^2

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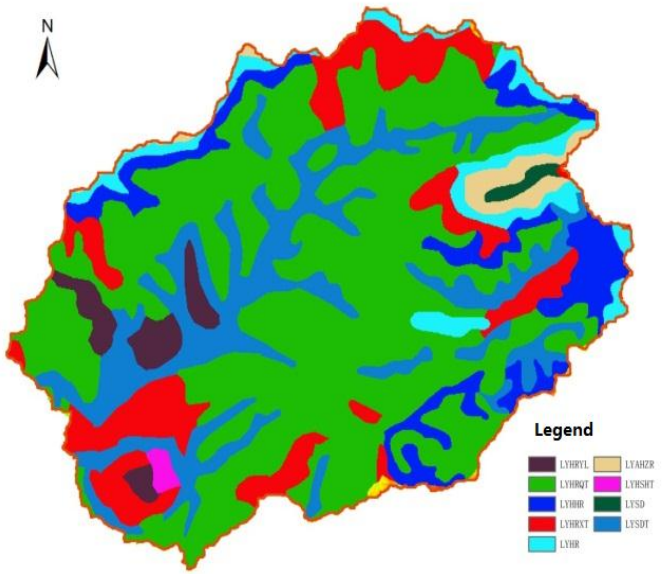
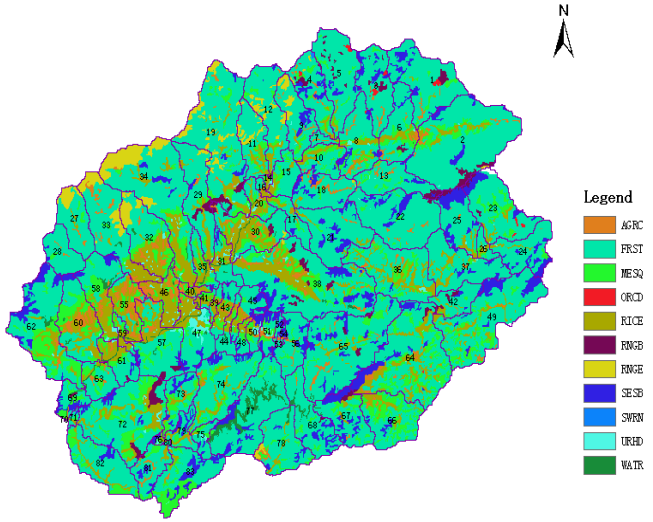
3. Demonstrative Implementation of modified SWAT model

Basic data for SWAT model

Type	Precision/ parameters
Digital elevation model(DEM)	30m
Soil data	1:1000000
Land use data	30m
Weather data	daily
hydrological data	daily
Point source(heavy metal)	/





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3. Demonstrative Implementation of modified SWAT model

Additional data for SWAT model coupled with heavy metal module

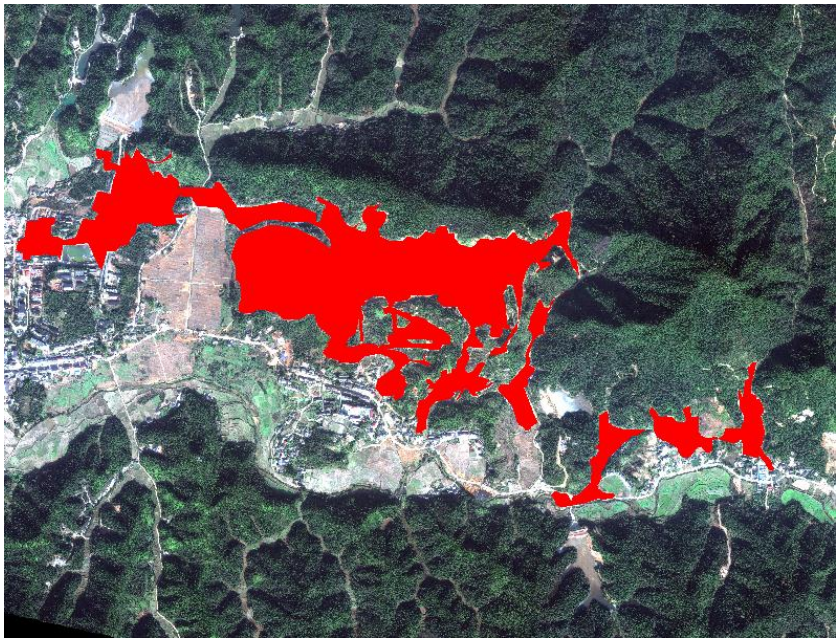
Property data of heavy metal

Parameter	description
Kd	Soil partition coefficient between solid and aqueous phase
kx	Rate constant for conversion of exchangeable species to non-labile in soil
km	Rate constant for conversion of non-labile species to exchangeable in soil
kl	Rate constant for conversion of aqueous ions to metal-ligands in water
kr	Rate constant for conversion of aqueous metal-ligands to ions in water
ku	Rate constant for uptake of aqueous metal by plants
ksol	solubility of heavy metal in water
kwash	Washout efficiency from heavy metal source
gamma	Ligand binding number

Parameters of nonpoint-source

Parameter	description
hmlfr	fraction of mine/tailing/piling area in HRU
hmlsrc	heavy metal source after weathering, ready for rain-washing-out.
hmlrock	heavy metal in rock to be weathered
hmlenr	heavy metal enrichment ratio
Solhml_ex	Exchangeable(labile) Metal concentration in 1st layer soil
Solhml_nl	Non-labile Metal concentration in 1st layer soil

3. Demonstrative Implementation of modified SWAT model



recognize the mine/tailing/piling area in the remote sensing image

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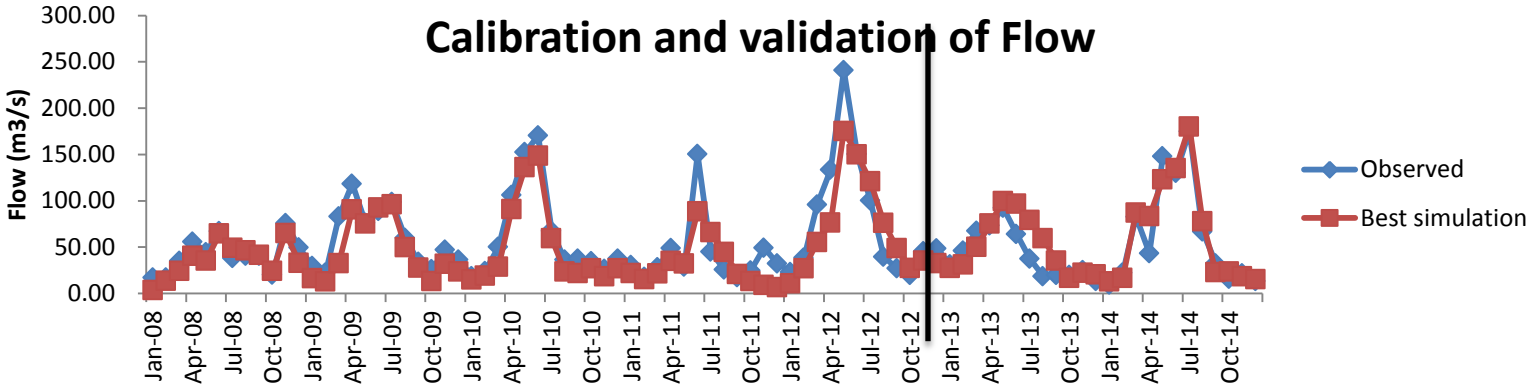
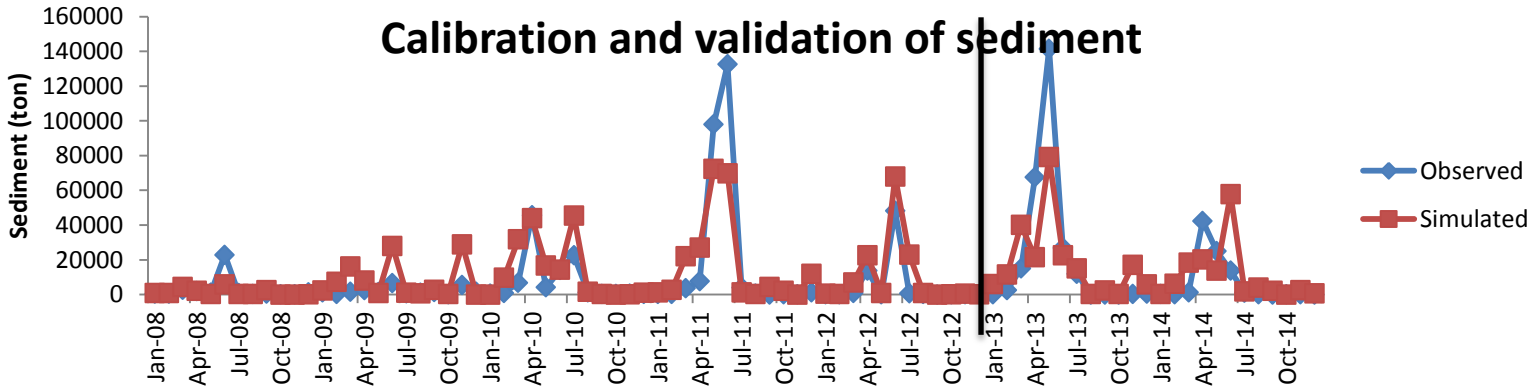
4.Result



	Calibration(2008-2012)		Validation(2013-2014)	
	R2	Ens	R2	Ens
Flow	0.83	0.80	0.85	0.82
Sediment	0.69	0.64	0.63	0.65



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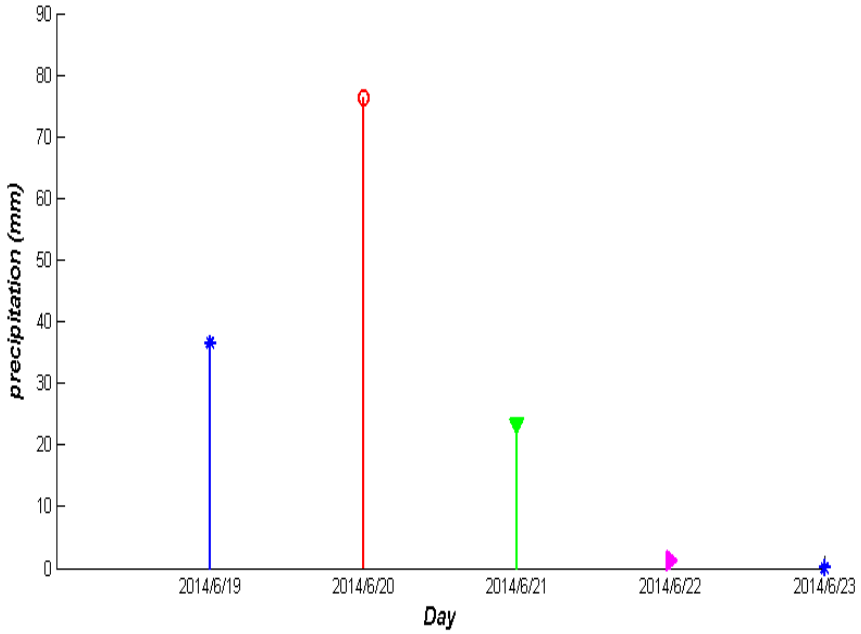
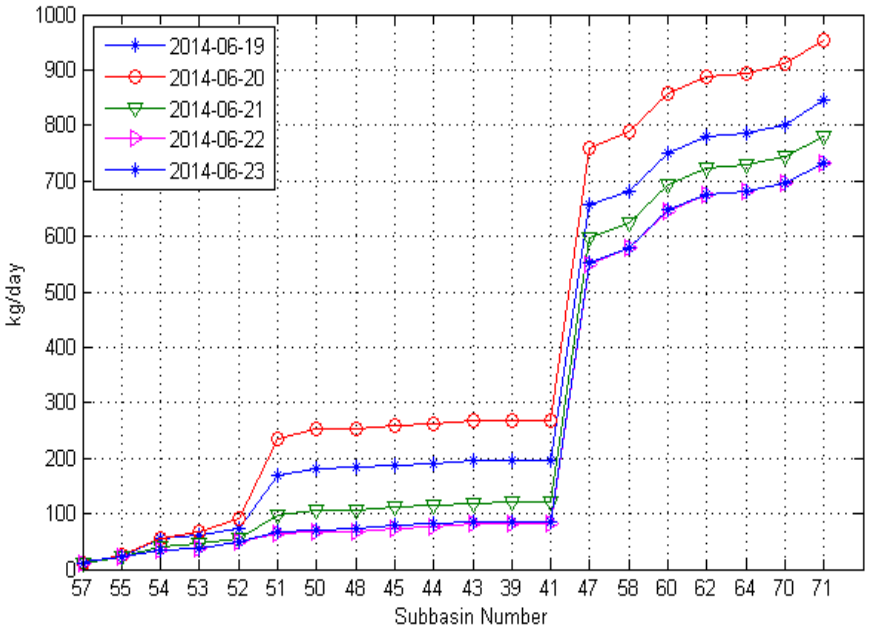
4.Result



Precipitation (Baoshan basin) of the monitoring period



Simulated results (Zn) of monitoring period

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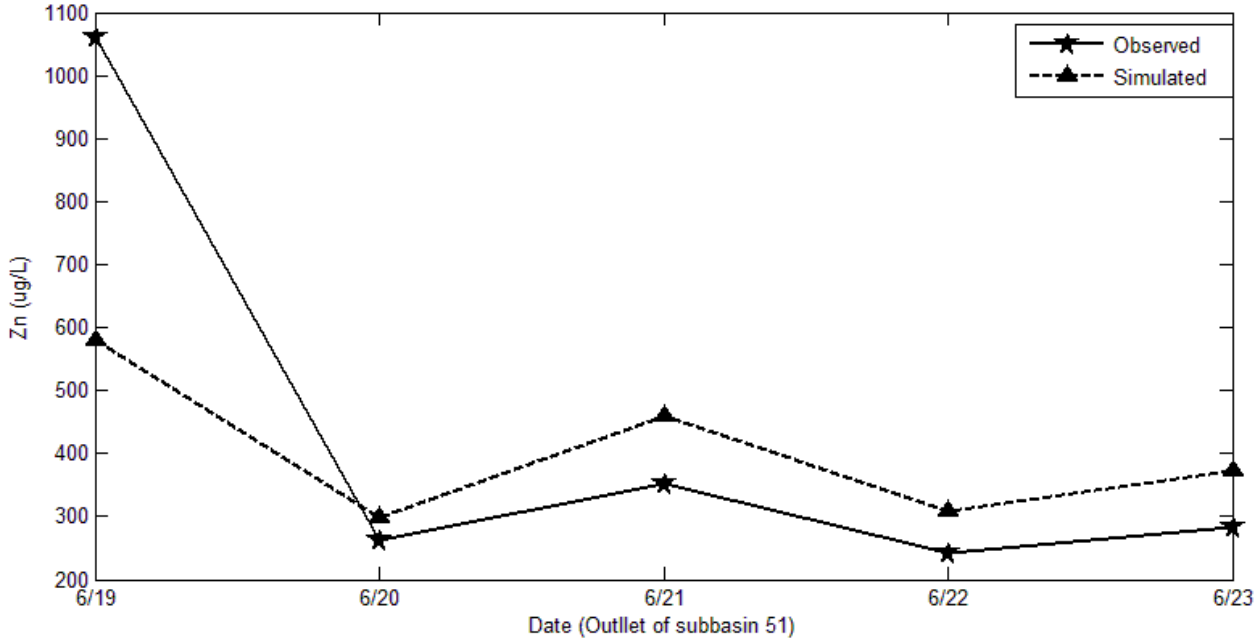
4.Result

Simulated Vs Observed



The simulated and measured concentration of Zn

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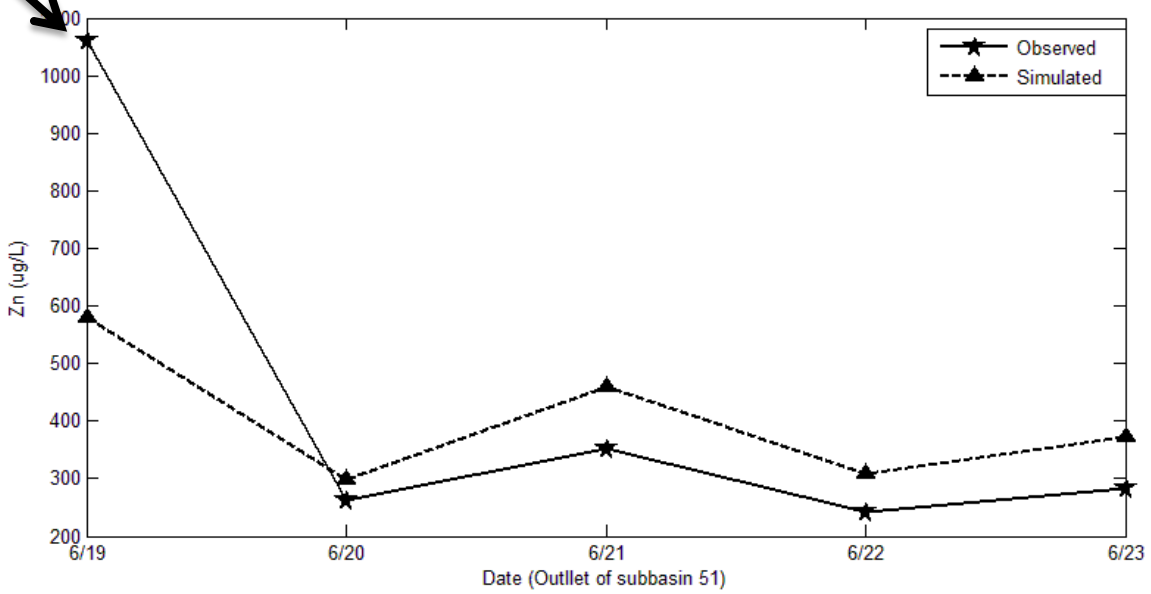
4.Result

A very high concentration： the first rainy day after nearly two weeks drought!



The simulated and measured concentration of Zn

zinc showed clear correlations with hydrology, with peak concentrations during low flows and minimum concentrations during high flows (snowmelt) along with an 'early flush' spike at the beginning of snowmelt[2].

[2]Caruso B S, Cox T J, Runkel R L, et al. Metals fate and transport modelling in streams and watersheds: state of the science and USEPA workshop review[J]. Hydrological Processes, 2008, 22(19):4011–4021.

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5. Conclusion and discussion

- A heavy metal module coupled with SWAT model is established to simulate the Zn daily amount in liuyang river upstream basin.
- This modified model contains the processes of weathering, leaching absorption and so on, which embodies the overall process of source release, migration and transformation of heavy metals.
- The Zn loading is different between the rainy and non-rainy day, The amount of Zn in the rainy day is nearly twice than that of the non-rainy day

5. Conclusion and discussion

On going and future work

- Partitioning between the riverine sediment and its pore water
- The Zn loading is different between the rainy and non-rainy day which indicate that we could focus on the precipitation process.
- More measured data are needed to test and improve the modified model

[2].HYDROLOGICAL PROCESSES *Hydrol. Process.* **22**, 4011–4021 (2008)

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Thank you for your attention !

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