THE SIXTH INTERNATIONAL SOIL AND WATER ASSESSMENT TOOL, SOUTHEAST AND EAST ASIA CONFERENCE &WORKSHOPS

SWAT modeling of water quality in Prek Thnot catchment

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- Presented by: Mr. CHAN Sakdanuphol: Researcher in Faculty of Agricultural Engineering
- Advisors : Mr. NUT Nareth: Head of Department of Soil and Water Engineering in Faculty of Agricultural Engineering

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Background and Purpose

- Studying the present water quality condition and predicting future water quality is becoming a significant issue to sustain the freshness of the water.

- If the water resource we use is contaminated with various factors that affect the water quality, it will cause health problems to human being and affect the crop growth when we irrigated.

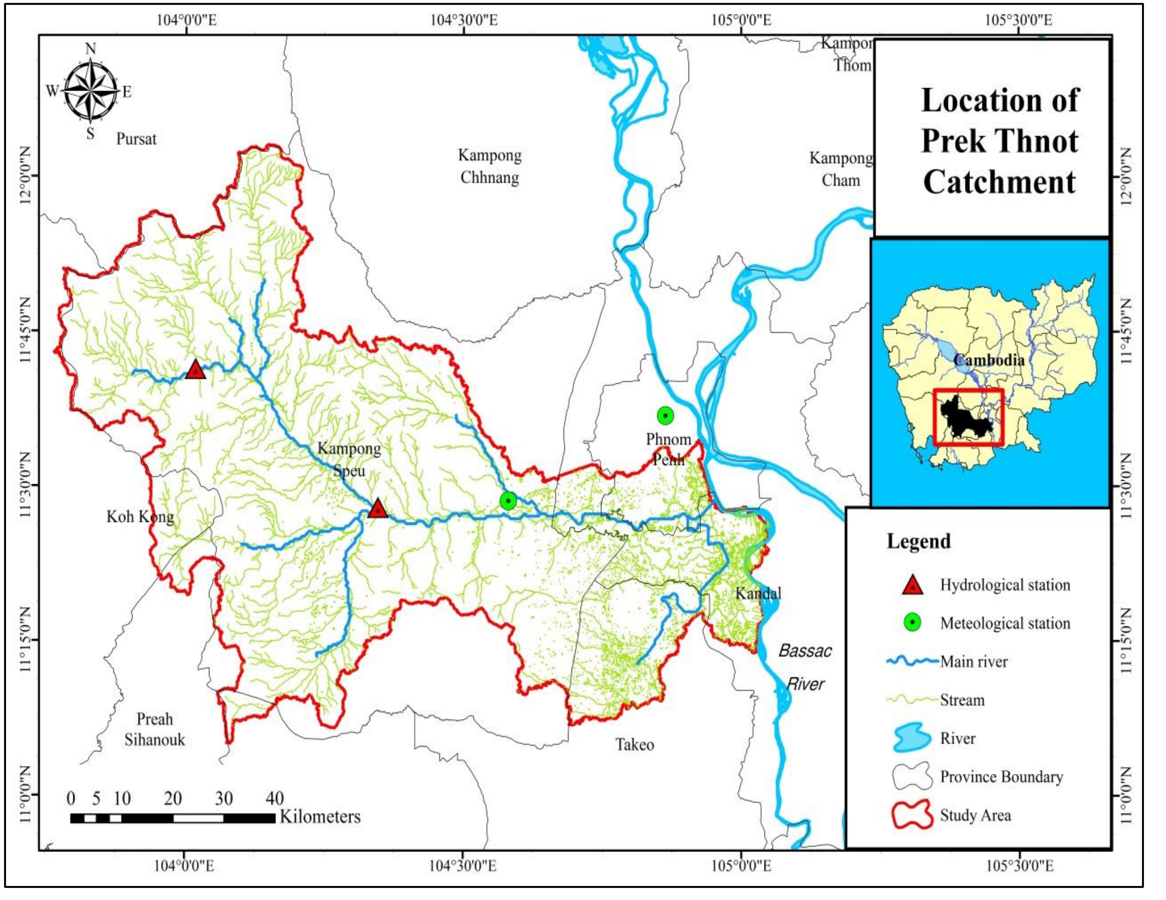
- Prek Thnot catchment is one of the catchments that have a high risk of impairment of its catchment function.

- The purpose of the study was to estimate and assess the streamflow, sediment, total nitrogen (T-N), total phosphorus (T-P), and E-coli in the Prek Thnot catchment.

Study Area

❖ Prek Thnot Catchment

- ✓ Catchment Area: 6600km²
- ✓ Stream Length: 280km
- ✓ Annual average precipitation: 2117.5mm
- ✓ Annual average temperature: 28°C
- ✓ Forest cover: 47.93% (3169.41km²)
- ✓ Agricultural land: 32.6% (2155.35km²)



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Data acquisition

Data	Type	Period	Description	Source
Digital Elevation Model (DEM)	Raster, 30 m-resolution	2009	Terrain elevation	www.usgs.gov
Cambodia boundary map	Shapefile	2014	Province and district map	www.opendevelopmentcambodia.net
Stream and river map	Shapefile	2010	Vector polyline data	www.opendevelopmentcambodia.net
Soil type map	Shapefile	2002	C.D Crocker 1962	MAFF
Land use map	Shapefile	2002	Land use classification	MAFF
Meteorological data	Daily	1995 – 2016	Observed daily rainfall at three stations: Pochentong, Kampong Speu, and Pursat Wind speed, humidity and solar radiation at Pursat and Kampong Speu station	DOM of MOWRAW www.globalweather.tamu.edu
Stream flow	Daily, Monthly	2000 – 2004 2010	Observed stream flow at Peam Khley Station	DHRW of MOWRAM
Water quality (TSS, T-N, T-P)	Monthly	2010 – 2013 2016	Observed water quality data at Tha Khmao Bridge	DWQM of MOE

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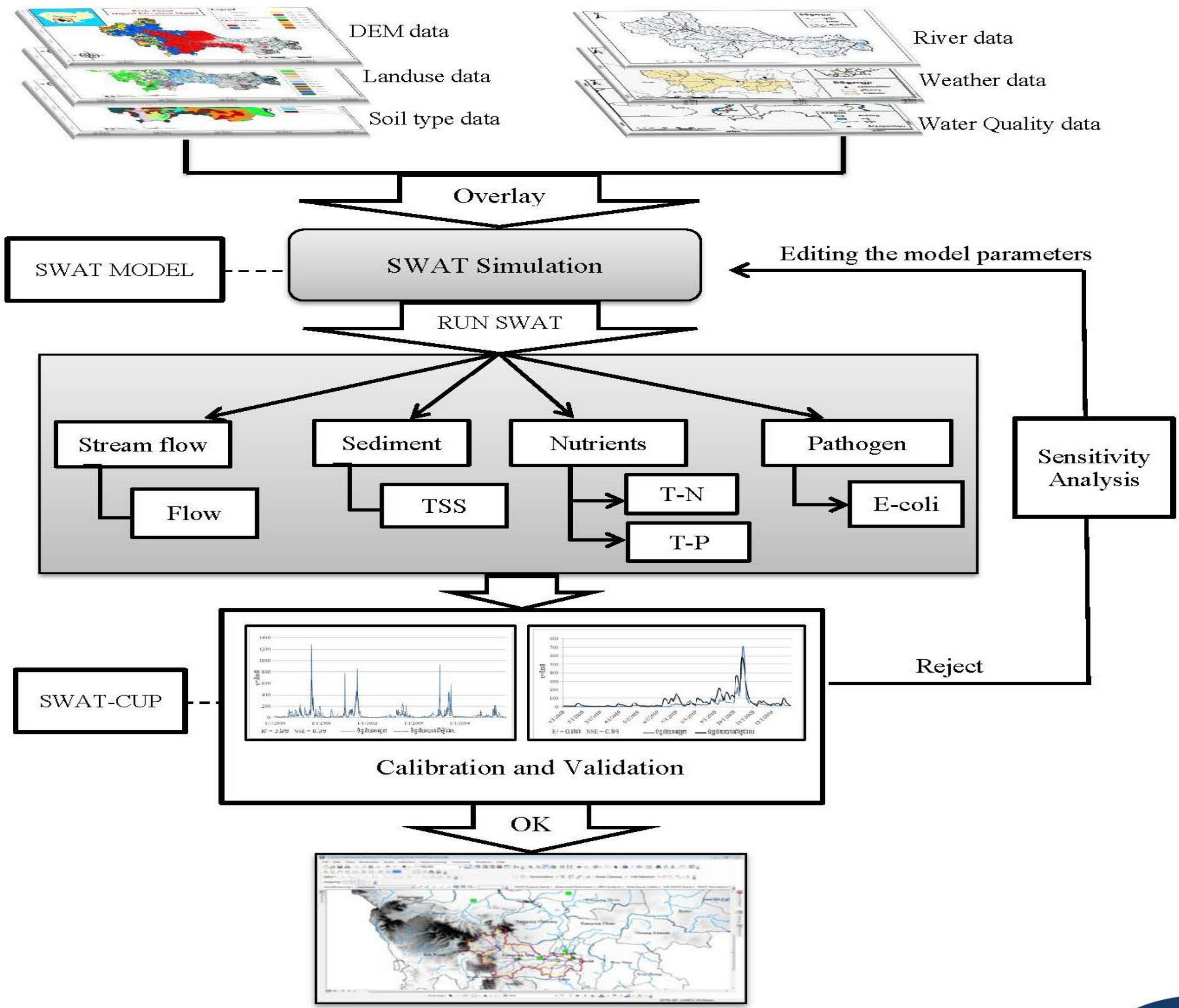
Study Procedure



SWAT Hydrological Model

- SWAT is a free software and a physical hydrologic quality model developed by United States Department of Agriculture-Agricultural Research Service (USDA-ARS) (Arnold et al.,1998).
- No matter what type of problem studied with SWAT, water balance is the driving force behind everything that happens in the watersheds.
- The hydrologic cycle as simulated by SWAT is based on the water balance equation (Neithsch et al., 2009)

$$SW_t = SW_0 + \sum_{i=1}^{t} \left(R_i - Q_{surf} - ET_i - w_{seep} - Q_{gw}\right)$$

SW_t = The final soil water content (mm H_2O)
SW_0 = The initial soil water content on day i (mm H_2O)
t = The time (days)
R_i = The amount of precipitation on day i (mm H_2O)
Q_{surf} = The amount of surface runoff on day i (mm H_2O)
ET_i = The amount of evapotranspiration on day i (mm H_2O)
w_{seep} = The amount of water entering the vadose zone from the soil profile on day i (mm H_2O)
Q_{gw} = The amount of return flow on day i (mm H_2O).

Model sensitivity analysis

- In this research the sensitivity analysis was performed for:
  - Stream flow
  - Sediment (TSS)
  - Total nitrogen (T-N)
  - Total phosphorus (T-P)
- However, due to non-availability of observed E-coli data, we only run the model with the default value to present the estimation of E-coli concentration.
- The rank of the most sensitive parameters is depended on the P-value.
- P-value provides information on significance of sensitivity; parameter having value close to zero has higher significance.

Model sensitivity analysis

- Stream flow

Parameter	Definition	Default range	P-value	Fitted value
v__CH_K2	Effective hydraulic conductivity in the main channel alluvium (mm/h)	0–500	0.00	5.12
v__LAT_TTIME	Lateral flow travel time (days)	0–180	0.00	1.70
v__CH_K1	Effective hydraulic conductivity in the tributary channel alluvium (mm/h)	0–300	0.00	23.95
v__DDRAIN_BSN	Depth to subsurface drain (mm)	0–1200	0.002	1200
v__GW_REVAP	Groundwater "revap" coefficient	0.02–0.2	0.038	0.052
v__CANMX	Maximum canopy storage (mm)	0–100	0.045	1.42
v__CH_N1	Manning's "n" value for the main tributary channel	0.01–30	0.05	0.49
v__MSK_X	A weighting factor	0–0.3	0.052	0.3
v__GW_DELAY	Groundwater delay (days)	0–500	0.07	398.05
v__CH_N2	Manning's "n" value for the main channel	-0.01–0.3	0.082	0.27
v__ALPHA_BF	Baseflow alpha factor	0–1	0.084	0.13

- Sediment (TSS)

Parameter	Definition	Default range	P-value	Fitted value
v__LAT_SED	Sediment concentration in lateral flow and groundwater flow (mg/l)	0–5000	0.00	788.65
v__CH_COV1	Channel erodibility factor	0–0.6	0.00	0.24
r__SLSUBBSN	Average slope length (m)	10–150	0.042	-0.049
v__RSDCO	Residue decomposition coefficient	0.02–0.1	0.17	0.02
v__HRU_SLP	Average slope steepness (mm-1)		0.26	-0.12

Model sensitivity analysis

- Total Nitrogen (T-N)

Parameter	Definition	Default range	P-value	Fitted value
v__LAT_ORGN	Organic nitrogen in the base flow (mg N /L)	0–200	0.00	5
v__BC1	Rate constant for biological oxidation of ammonium-nitrogen to nitrite-nitrogen in the reach at 20°C (day-1)	0.1–1	0.00	0.88
v__ERORGN	Organic nitrogen enrichment ratio	0–5	0.028	1.42
v__BC3	Rate constant for hydrolysis of organic nitrogen to ammonium-nitrogen in the reach at 20°C (day-1)	0.2–0.4	0.049	0.343
v__N_UPDIS	Nitrogen uptake distribution parameter	0–100	0.1	60.5
v__CH_ONCO	Organic nitrogen concentration in the channel (mg N /L)	0–100	0.11	27.5

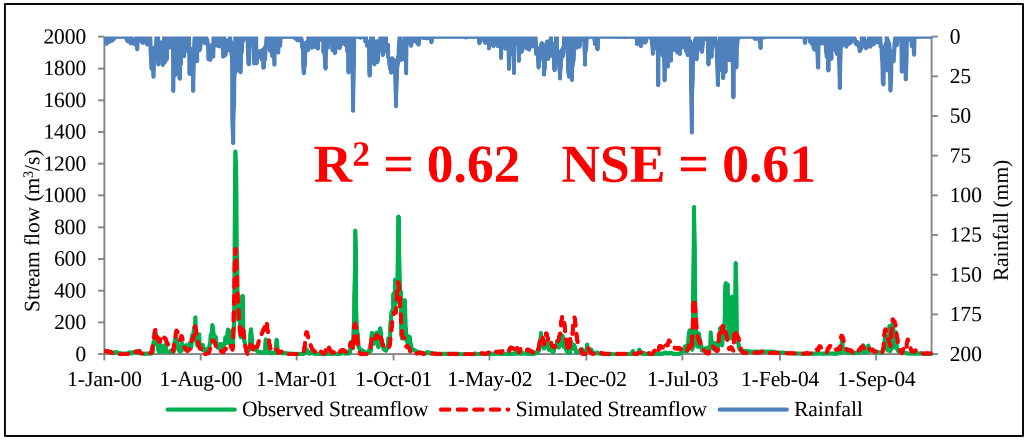
- Total Phosphorus (T-P)

Parameter	Definition	Default range	P-value	Fitted value
v__BC4	Rate constant for mineralization of organic phosphorus to dissolved phosphorus in the reach at 20°C (day-1)	0.01–0.7	0.00	0.034
v__GWSOLP	Soluble phosphorus concentration in groundwater loading (mg P /L)	0–1000	0.00	305
v__PHOSKD	Phosphorus percolation coefficient	100–200	0.006	194.5
v__RS2	Benthic (sediment) source rate for dissolved phosphorus in the reach at 20°C (mg/m2/day)	0.001–0.1	0.01	0.097
v__PPERCO	Phosphorus soil partitioning coefficient	10–17.5	0.02	0.052
v__RS5	Organic phosphorus settling rate in the reach at 20°C (day-1)	0.001–0.1	0.08	0.1
v__LAT_ORGP	Organic phosphorus in the base flow (mg P /L)	0–200	0.12	193

SWAT Calibration and Validation

- Streamflow

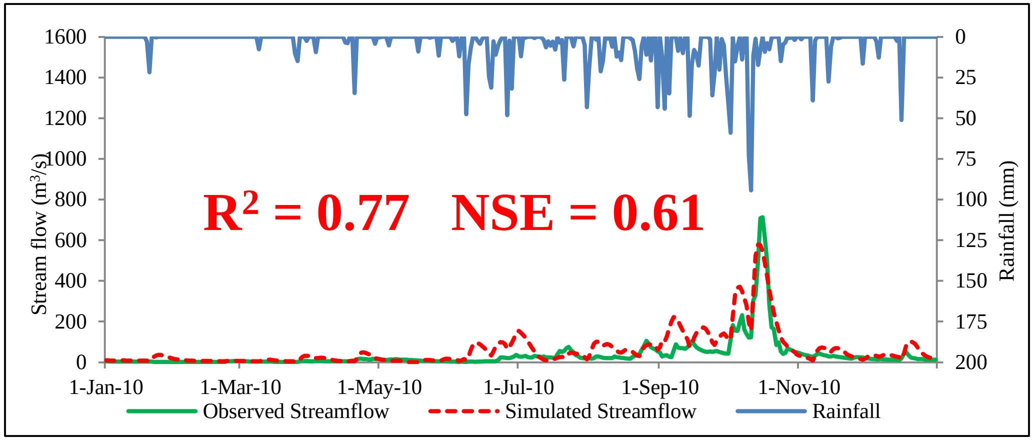
Calibration



Daily Time Series

- Calibration period: 2000–2004
- Additionally, the peak flow was found to be under simulated in model results for the calibration period.

Validation



Daily Time Series

- Validation period: 2010
- Moreover, the peak flow was found to be over slightly different simulated stream flow in the validation period.

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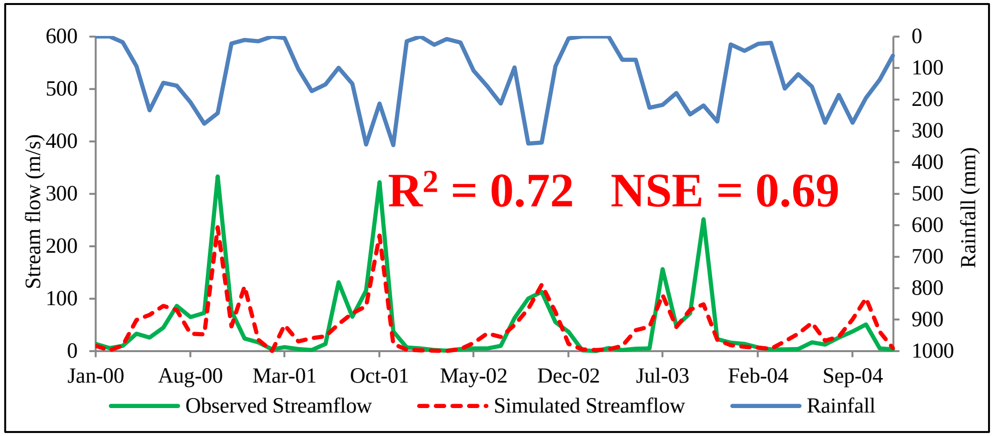
SWAT Calibration and Validation

Streamflow

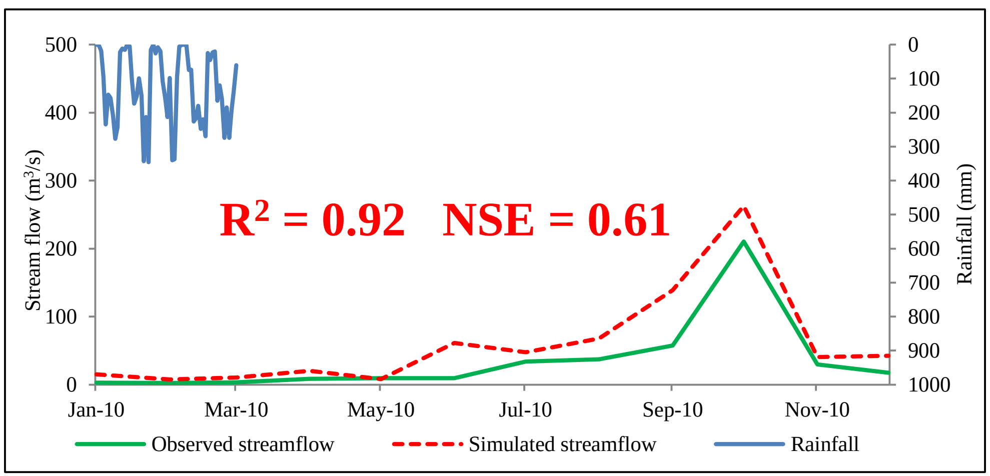
Calibration



Monthly Time Series

- Calibration period: 2000–2004
- The observed and simulated stream flow hydrograph followed the similar pattern, while the simulated peak flows were lower than observed peak flows for the calibration period.

Validation



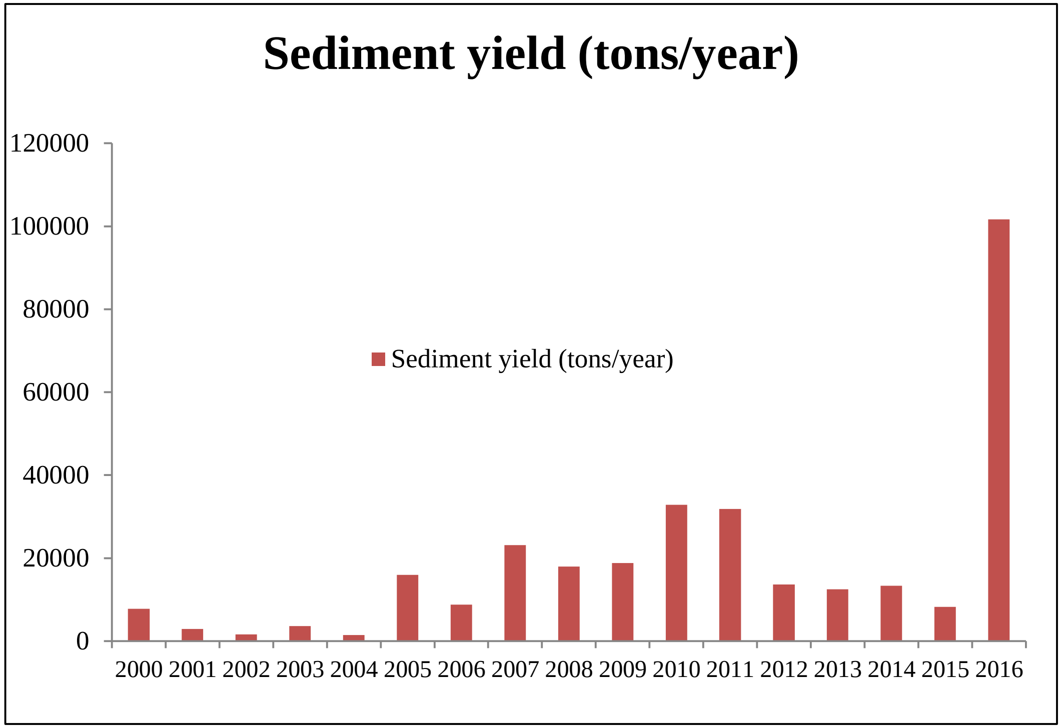
Monthly Time Series

- Validation period: 2010
- the simulated peak flows were higher than observed peak flows for the validation period.

SWAT Calibration and Validation

Sediment Yield

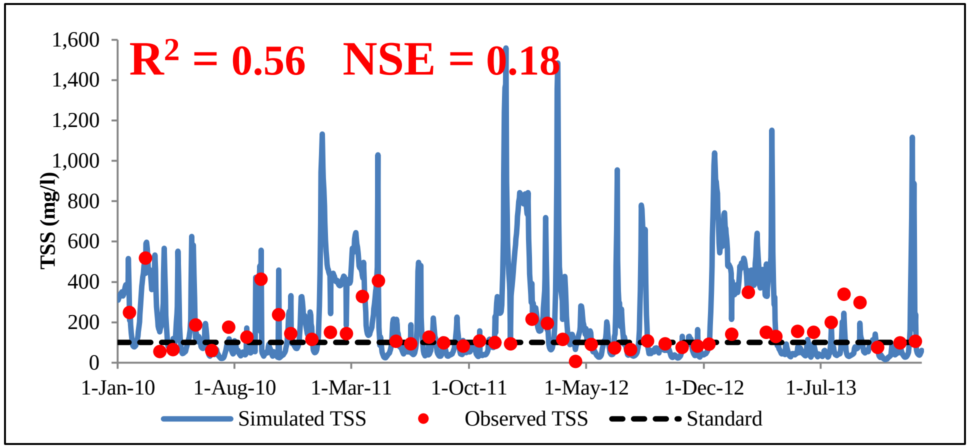
Year	Annual stream flow (m^3/s)	Sediment yield (tons/year)
2000	643.4	7806
2001	490.8	2905
2002	262.8	1589
2003	330.2	3622
2004	244.6	1487
2005	381.3	15993
2006	270.7	8800
2007	358.8	23145
2008	394.1	17938
2009	372.3	18830
2010	608.4	32868
2011	353.1	31838
2012	263.7	13638
2013	299	12521
2014	218.7	13321
2015	209	8242
2016	568	101656



SWAT Calibration and Validation

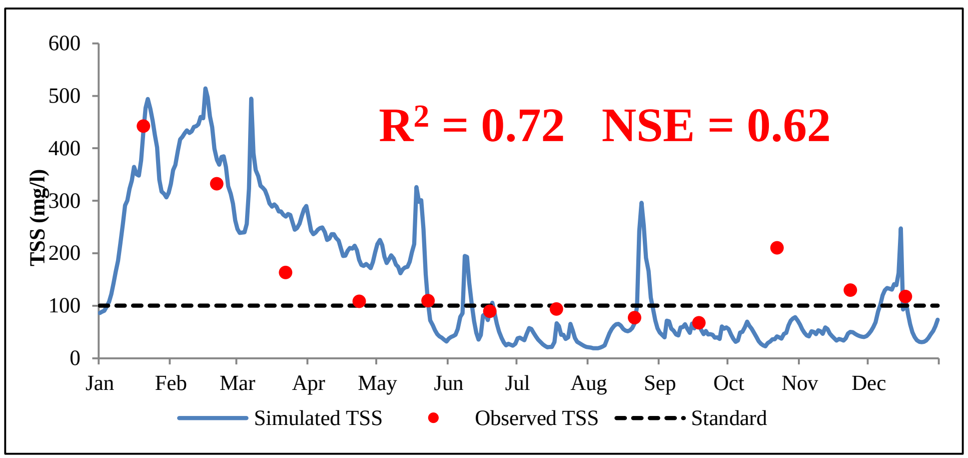
- **Sediment Concentration**

Calibration



- Calibration period: 2010–2013
- The average observed TSS = 157.3 mg/l
- The average simulated TSS = 198.18 mg/l
- The main reason of the high sediment concentration is that the bulk of wastewater from the city center at the outlet of Cheung Aek Lake.

Validation

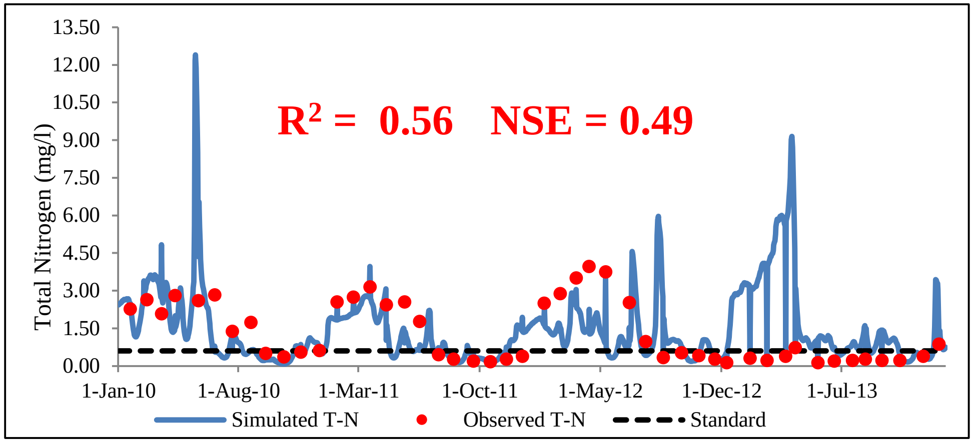


- Validation period: 2016
- The average observed TSS = 162 mg/l
- The average simulated TSS = 137.5 mg/l
- The water river goes absolutely down during the dry season and the strong rainfall carries too much solids and sand including restaurant, household, and construction site residues during the rainy season.

SWAT Calibration and Validation

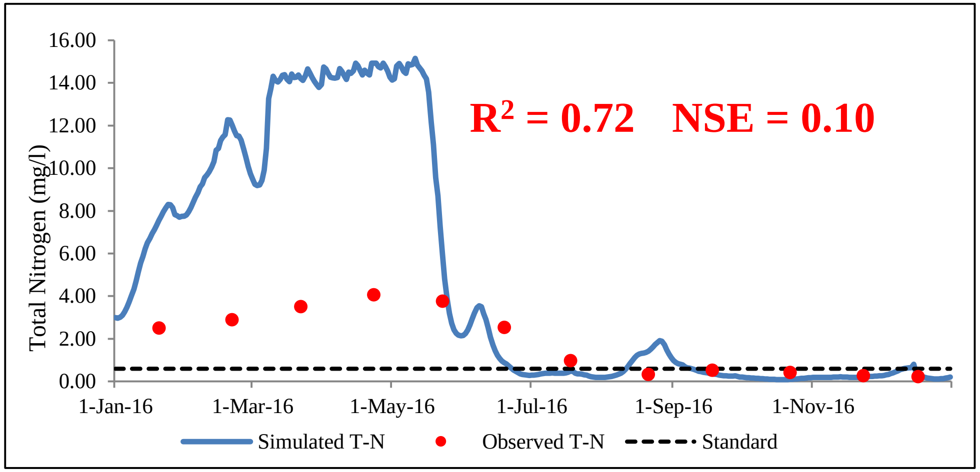
- **Total Nitrogen (T-N)**

Calibration



- Calibration period: 2010–2013
- The average observed T-N = 0.13 mg/l
- The average simulated T-N = 0.13 mg/l
- T-N was over the standard limitation of 0.6 mg/l during the dry season due to the closed location of the outlet at Cheung Aek Lake.

Validation



- Validation period: 2016
- The average observed T-N = 1.84 mg/l
- The average simulated T-N = 5.2 mg/l
- T-N was over the standard limitation of 0.6 mg/l during the dry season due to the wastewater from industries and agricultural practices in the upstream.

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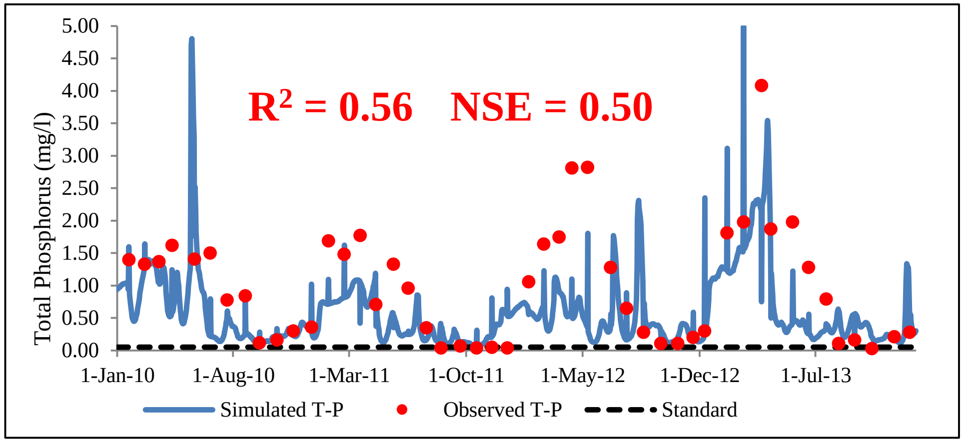
SWAT Calibration and Validation

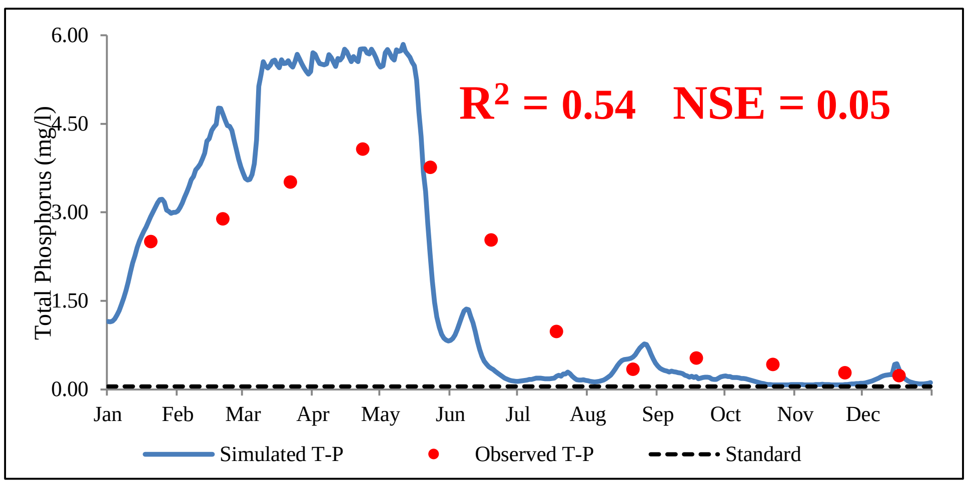
- **Total Phosphorus (T-P)**

Calibration



- Calibration period: 2010–2013
- The average observed T-P = 0.98 mg/l
- The average simulated T-P = 0.88 mg/l
- The high T-P concentration was found to be exceeded the standard limitation of 0.05 mg/l during the dry season.

Validation



- Validation period: 2016
- The average observed T-P = 0.74 mg/l
- The average simulated T-P = 2.03 mg/l

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SWAT Calibration and Validation

E-coli Concentration

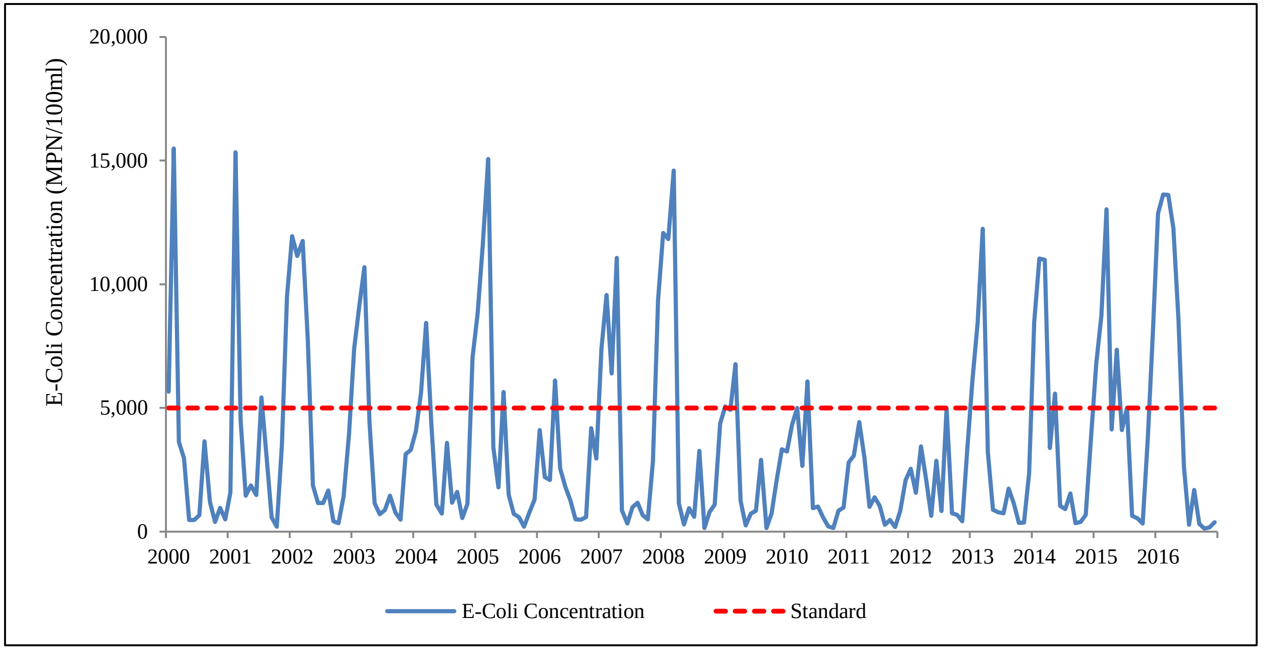
- Due to non-availability of observed E-coli data, we could only run the model with the default value to analyze for the simulated period 2000–2016.

During Dry Season

- E-coli Range = 169.7 – 15490 MPN/100ml
- Average E-coli = 5637.02 MPN/100ml

During Rainy Season

- E-coli Range = 120.7 – 8558 MPN/100ml
- Average E-coli = 1422.19 MPN/100ml



Conclusions

- The results of this research pointed that SWAT model successfully calibrated and validated with the good statistical indicators both in calibration and validation periods.

- Furthermore, the water quality simulation obtained the values are under or equal the standard limitation, but some of them are exceeded the standard limitation.

- We can conclude that the water quality in Prek Thnot catchment is poor or is said to be affecting the health of the consumers, animals and biological life in the river.

- Therefore, the conclusion presented that SWAT model could be applied at Prek Thnot catchment to define the modeling of water quality change and guarantee sustainable development of the water pollution management.