Microbial Water Quality Simulation Using Agricultural Policy Environmental eXtender (APEX)

Oct 23, 2025

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Microbial module development

Key microbial processes on land and in water bodies

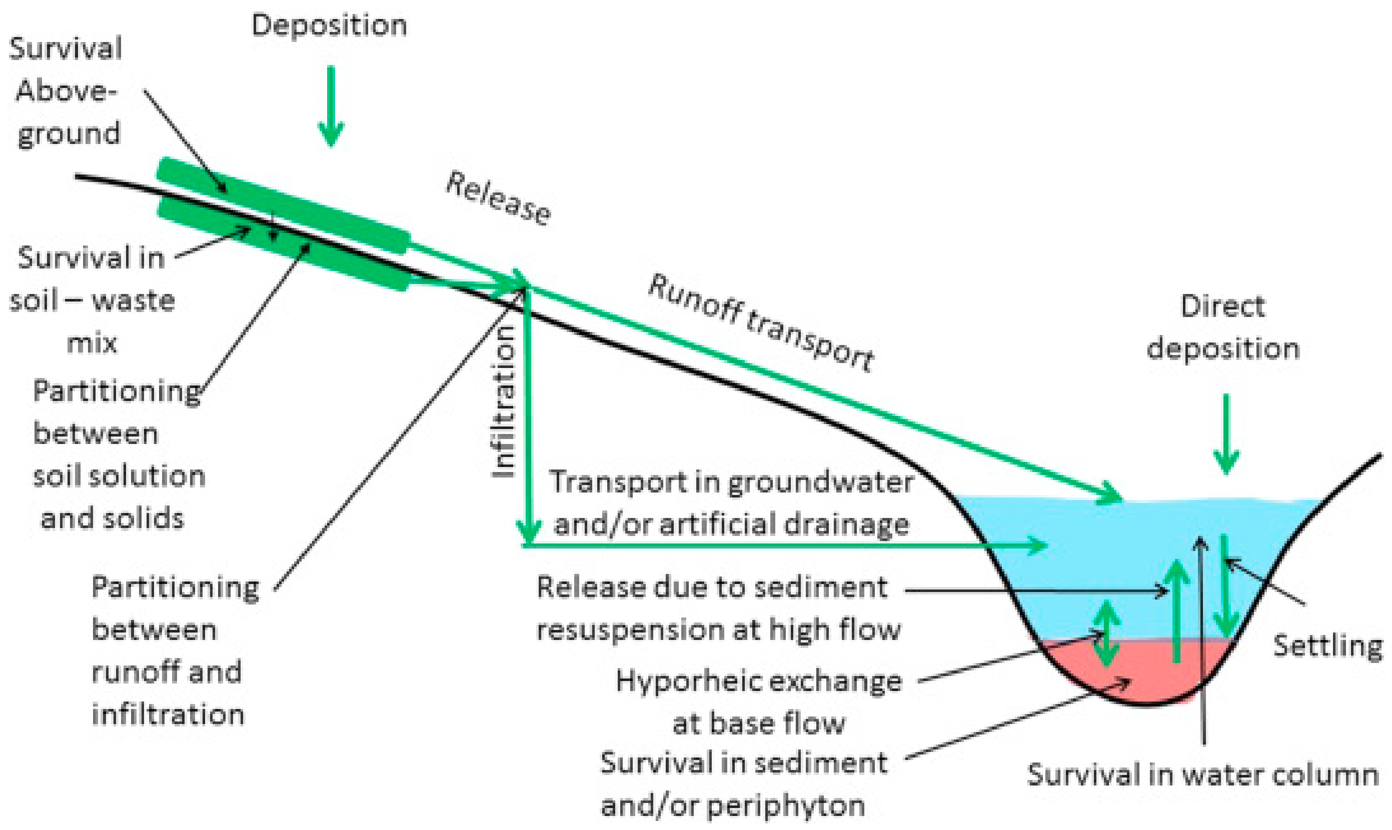

Fig. 1 Key microbial fate and transport on land and in water bodies

1) Animal waste (manure) deposition
2) Die-off on soil
3) Release with runoff
4) Die-off in water
5) Resuspension during high/low flow periods
6) Settling

Microbial module development

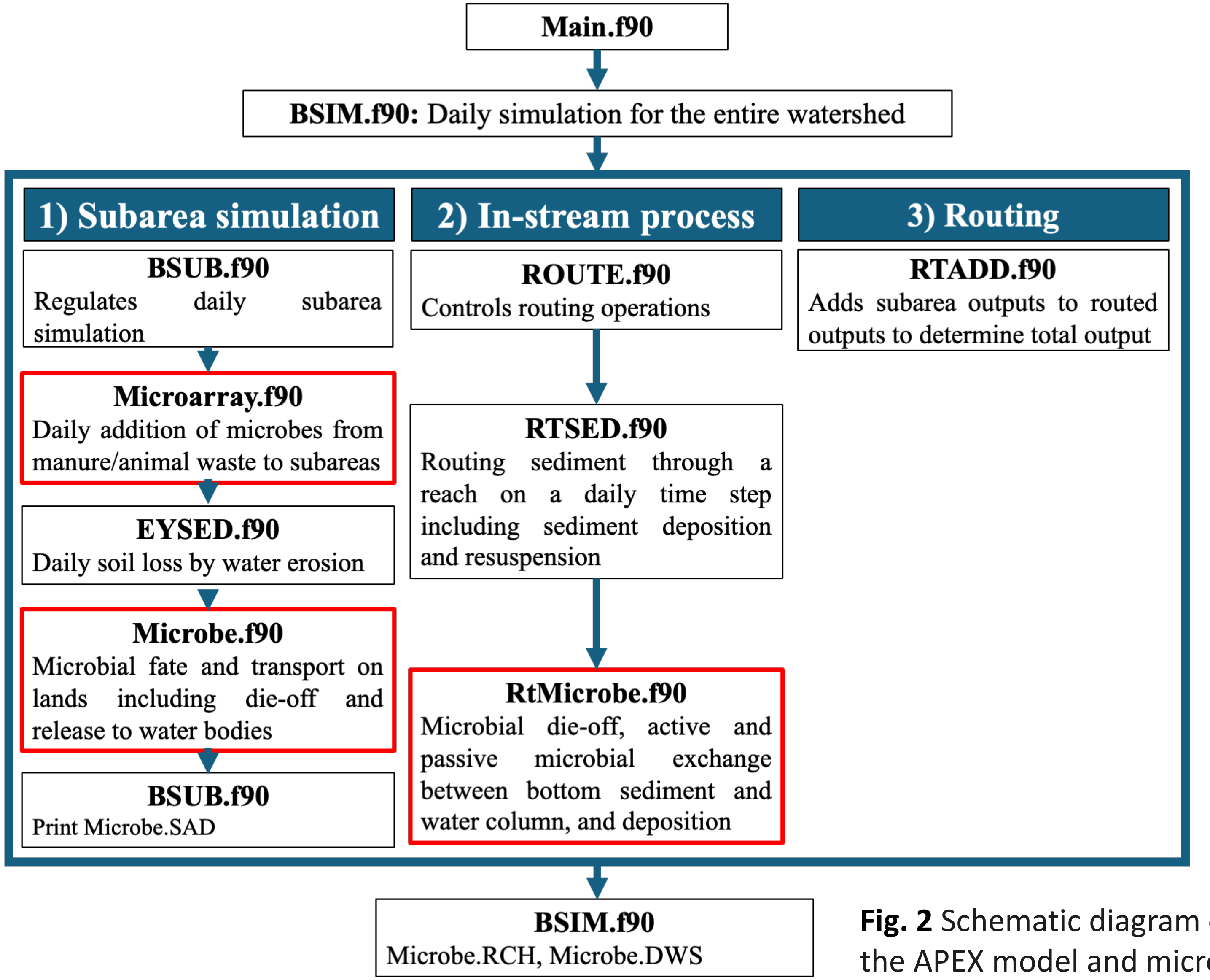

Fig. 2 Schematic diagram of linkage of the APEX model and microbial module

Main subroutines for microbial module

1) **Microarray.f90**
   Addition of microbes on lands from manure from the APEX model
2) **Microbe.f90**
   Microbial release with runoff to water bodies
3) **RtMicrobe.f90**
   Microbial process in water and bottom sediment including die-off passive and active transport, and deposition

Microbial module development

Applications of APEX-M

Research questions

Management questions

Sub-models for microbial inactivation and release

Can we distinguish between microbial sub-models with the monitoring data?

Sub-model evaluation and selection for simulating generic *E. coli*

1. **Inactivation sub-model comparison**
   - Chick's law
   - Q10-model
   - With vs without lag phase, drastic/gradual decrease
2. **Microbial release models comparison**
   - Exponential model
   - Bradford-Schijven model
   - Vadas-Kleinman-Sharpley model
3. **With vs without active transport between bottom sediments and water column**

Microbial sub-models

Table 1. Models for microbial inactivation and microbial release.

Inactivation sub-model	**Equation**	**Microbial release models**	**Equation**
Chick's law	$N = N_0\, e^{-kt}$ $k = k_r \theta^{T-T_r}$	Exponential (Bicknell et al., 1997)	$\frac{N}{N_0} = 1 - \exp(-k_e W)$
Q_{10} model	$k = k_r Q_{10}^{(T-T_r)/10}$ Q_{10}: temperature coefficient	Bradford-Schijven (Bradford and Schijven, 2002)	$\frac{N}{N_0} = 1 - \frac{1}{(1 + k_p \beta W)^{1/\beta}}$
		Vadas-Kleinman-Sharpley (Vadas et al., 2004)	$\frac{N}{N_0} = AW^n$

N, total count of microorganisms; N_0, initial total count of microorganisms; t, time (days). T: temperature; T_r: reference temperature (often 20 °C), A, k_e, k_p, and n are release parameters; W, rainfall depth

Active transport between bottom sediments and water column

$$\mathrm{N} = r \cdot A \cdot C_M$$

r: the bacteria release factor (ton·m^{-2}·day^{-1})
A: bottom area of the reach (m^2)
C_M : bacteria concentration in the bottom sediment of the pond (CFU·ton^{-1})

Differences between inactivation sub-models

E. coli inactivation patterns: single stage and multiple stages

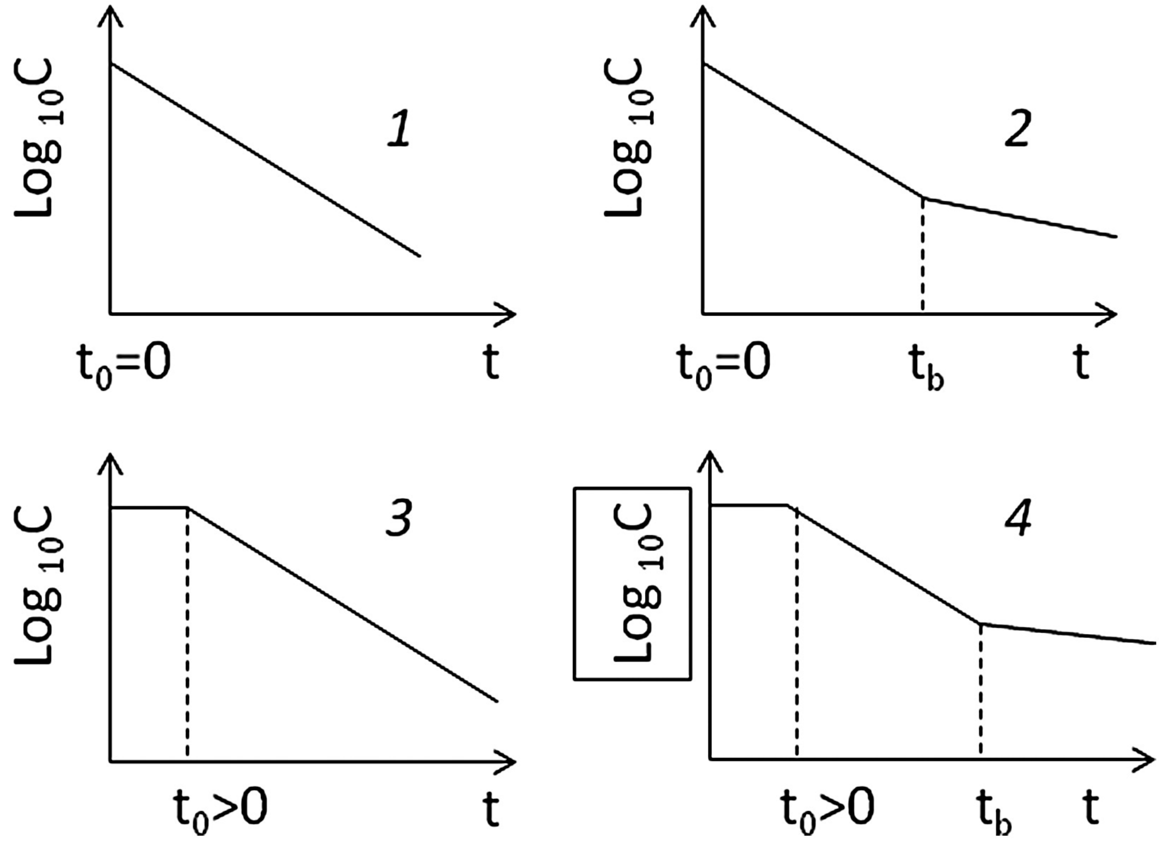

Fig. 3. Patterns found in data on *E. coli* inactivation in waters (Blaustein et al., 2013)

Differences between release sub-models

E. coli release models: exponential, B-S, and VKS

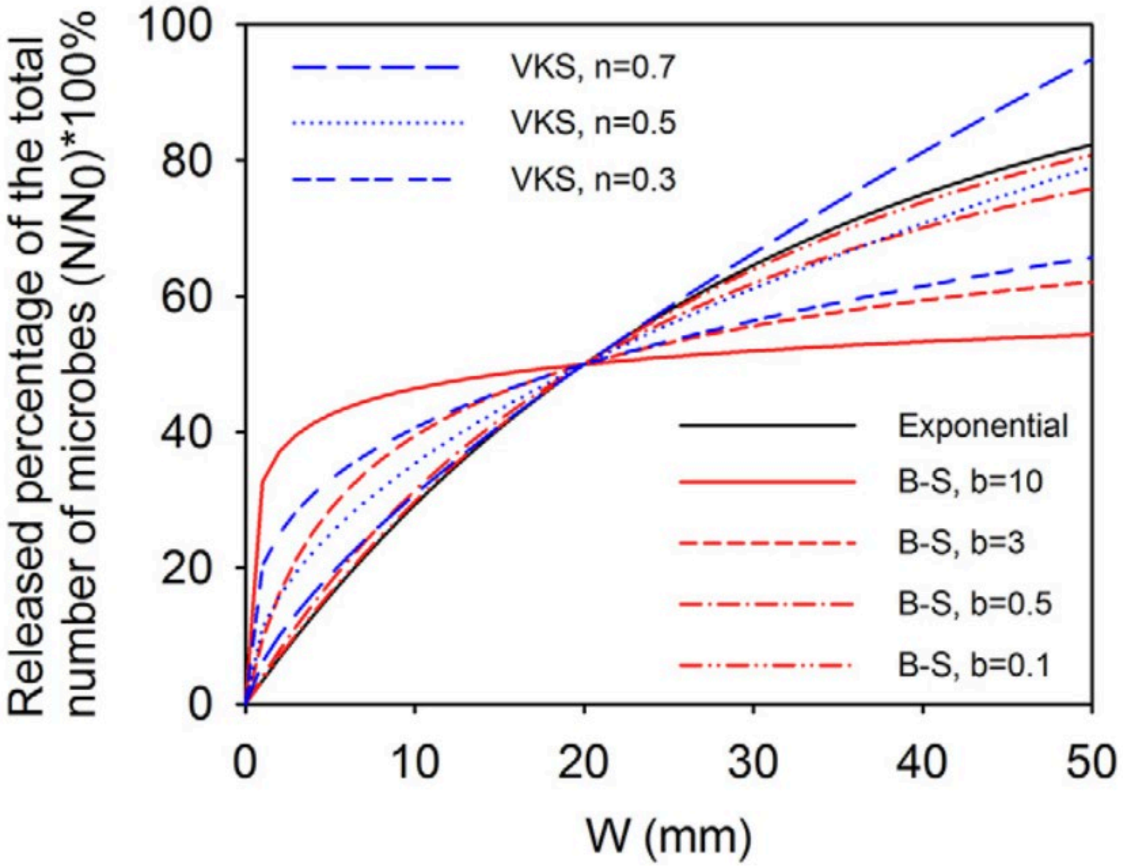

Fig.4. Difference in shapes of release curves simulated with three release models: exponential, Bradford-Schijven (B-S), and Vadas-Kleinman-Sharpley (VKS)

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Do we need to account for additional microbial processes?

Conococheague Creek watershed, PA

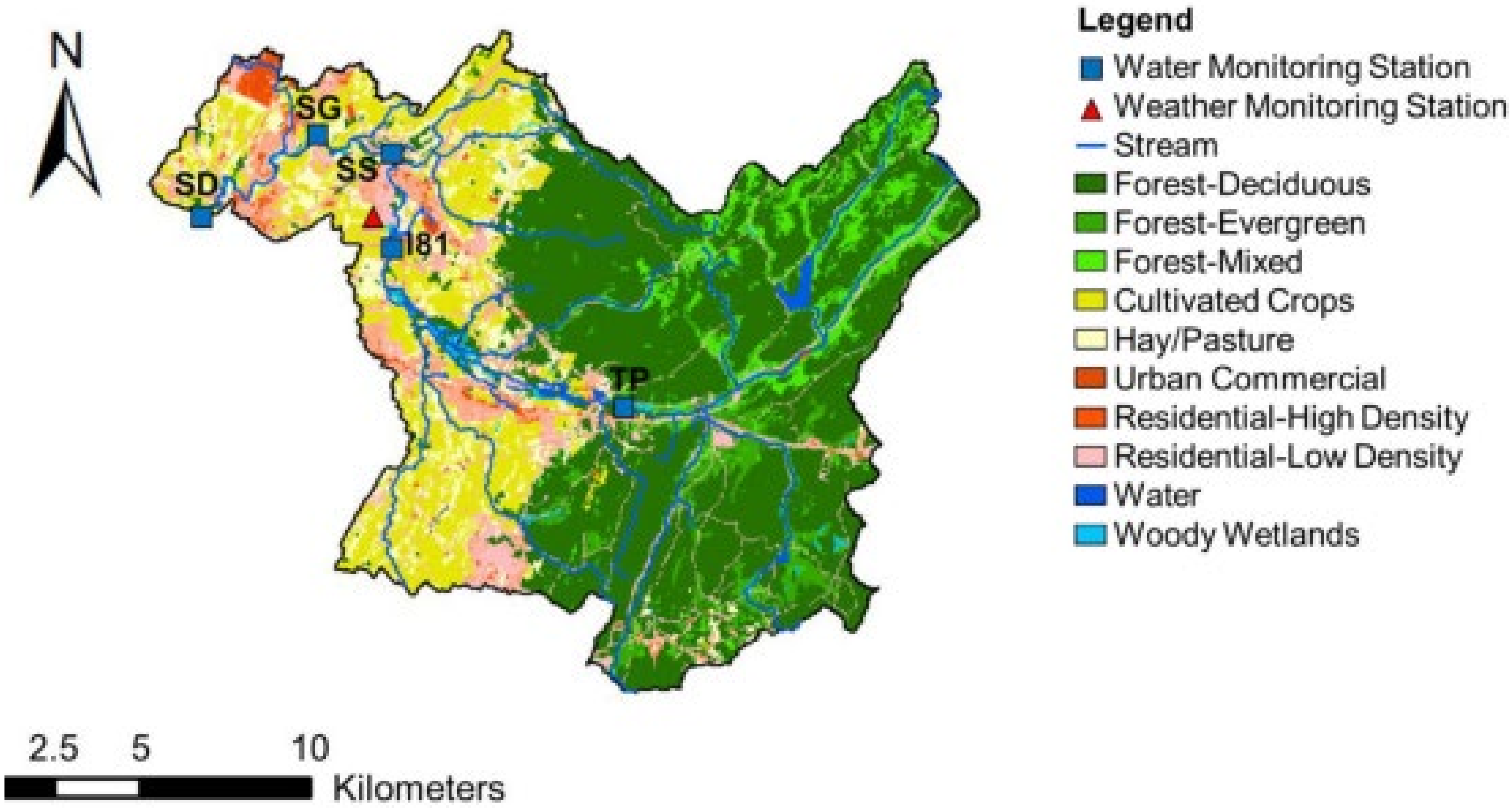


Fig. 5 Land use map of upstream area of the Conococheague Creek watershed and monitoring locations (treatment plant [TP], Interstate 81 [I81], Scotland school [SS], Sycamore Grove [SG], and Silon Dam [SD])

Three years of monitoring for Conococheague creek watershed, PA

Model evaluation and validation

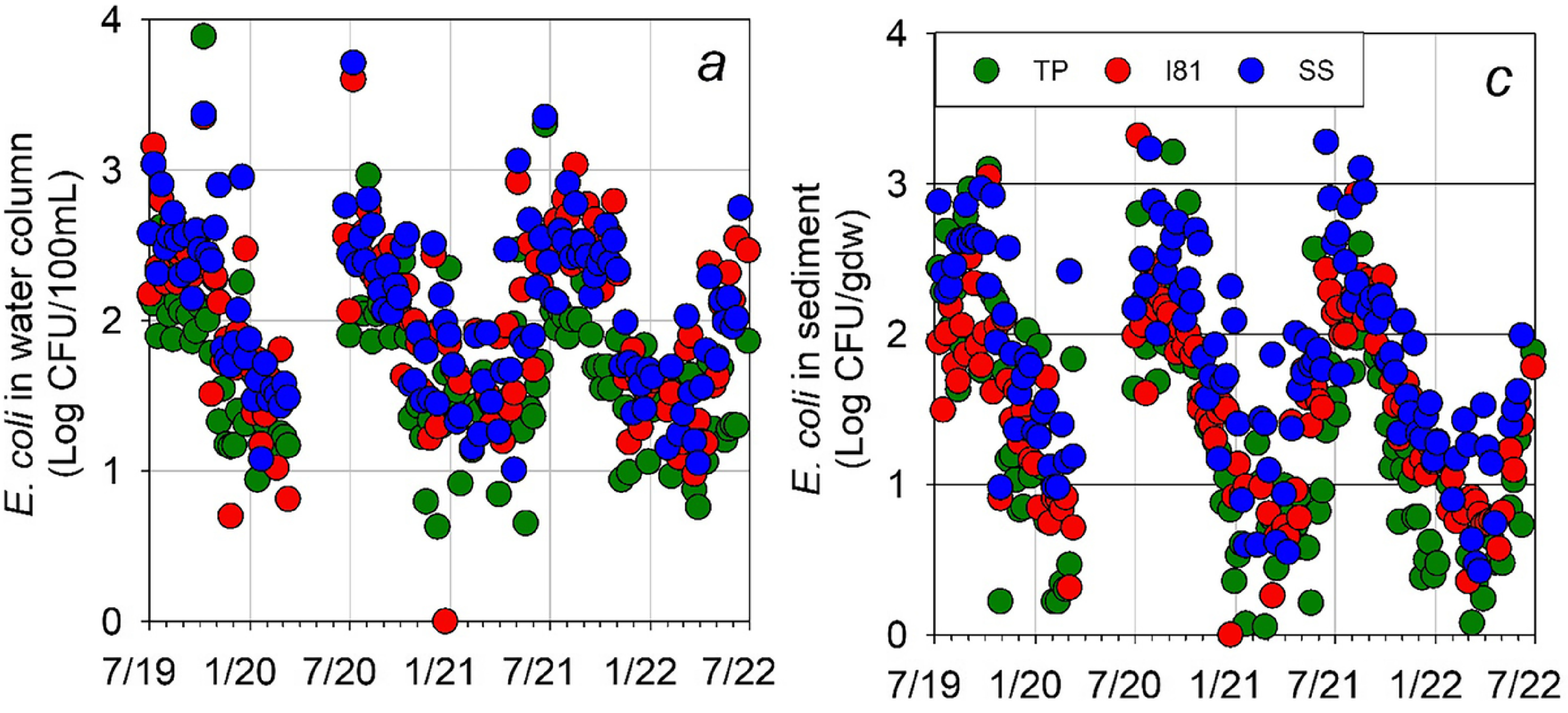
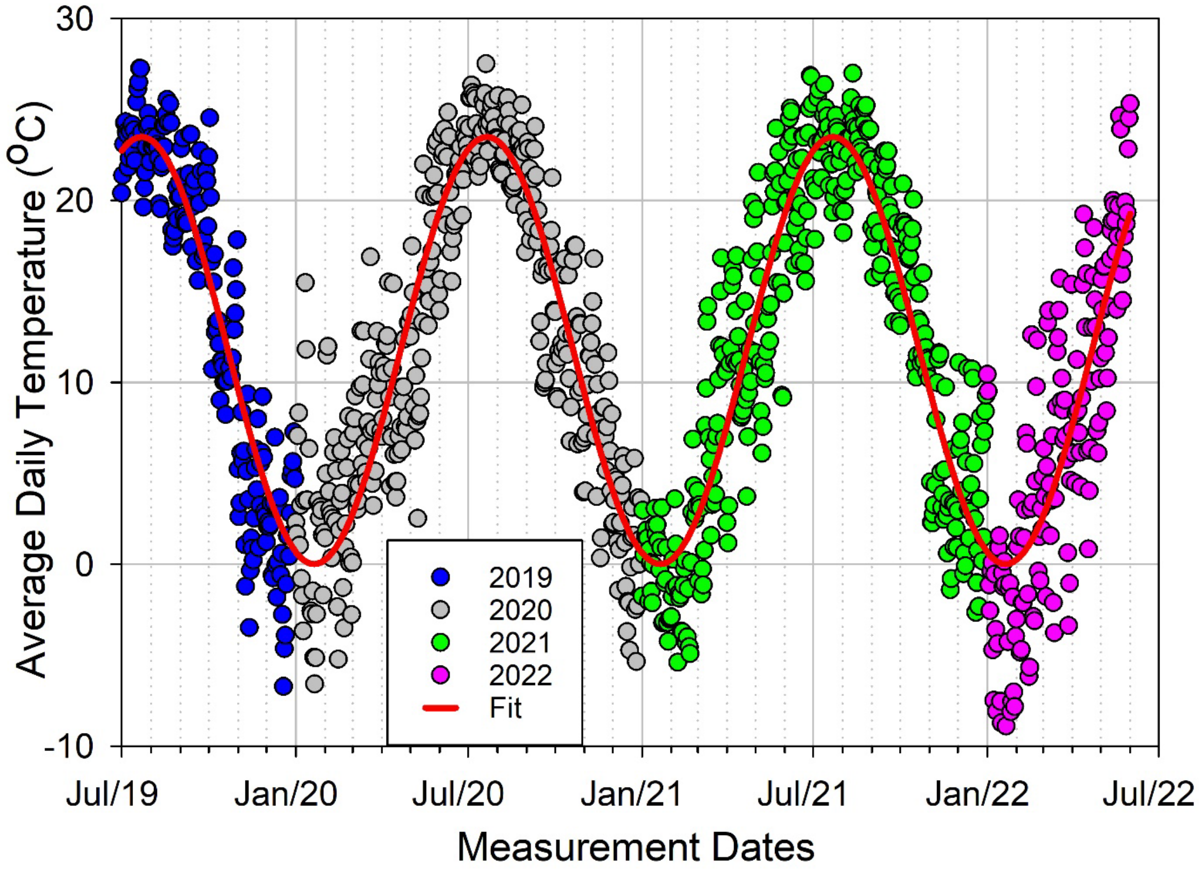
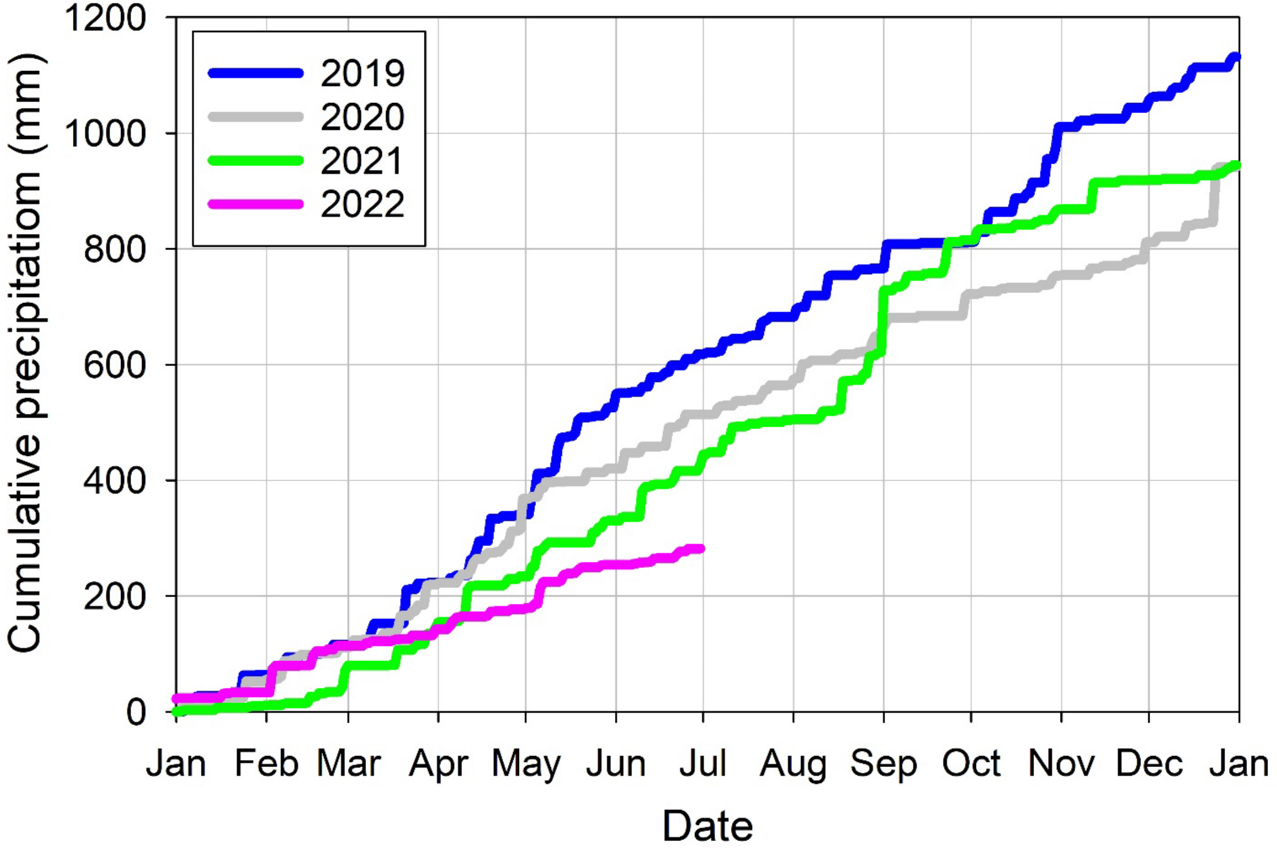


Fig. 6 Time series of *E. coli* concentrations in water column and sediment at TP, I81, and SS in Conococheague Creek Watershed (Pachepsky et al. 2023)





Why did the differences in precipitation not affect the E. coli dynamics?

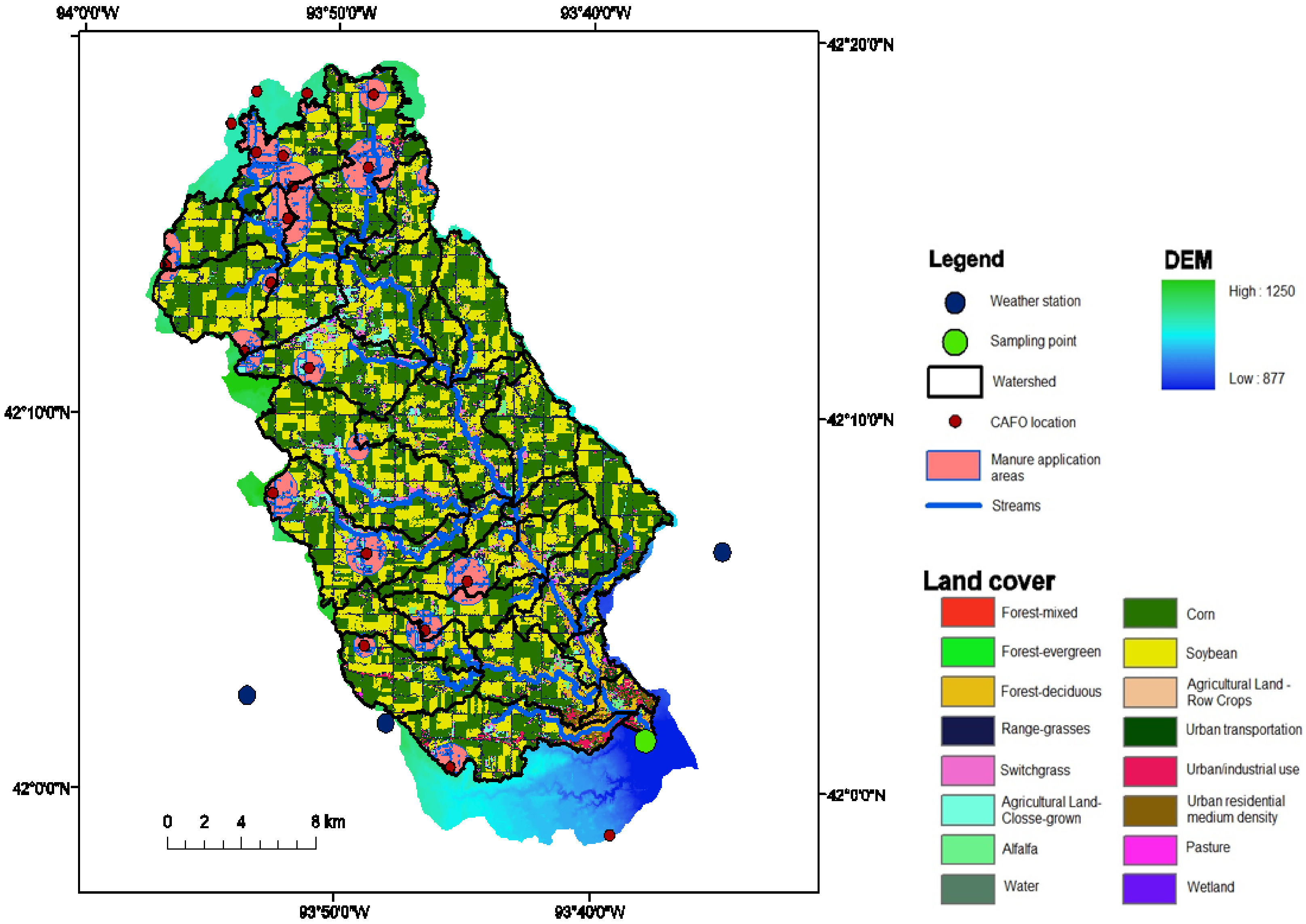


Fig 7. Squaw Creek Watershed; Locations of Weather Stations, Gaging Station, Confined Feeding Operation Units, and Manure Application Areas Are Shown (Pandey et al., 2016).

Microbial module application

How do variations in intra-annual precipitation and temperature affect microbial water quality?

<u>**Intra-annual weather patterns**</u>

- Rainfall intensity/precipitation/temperature

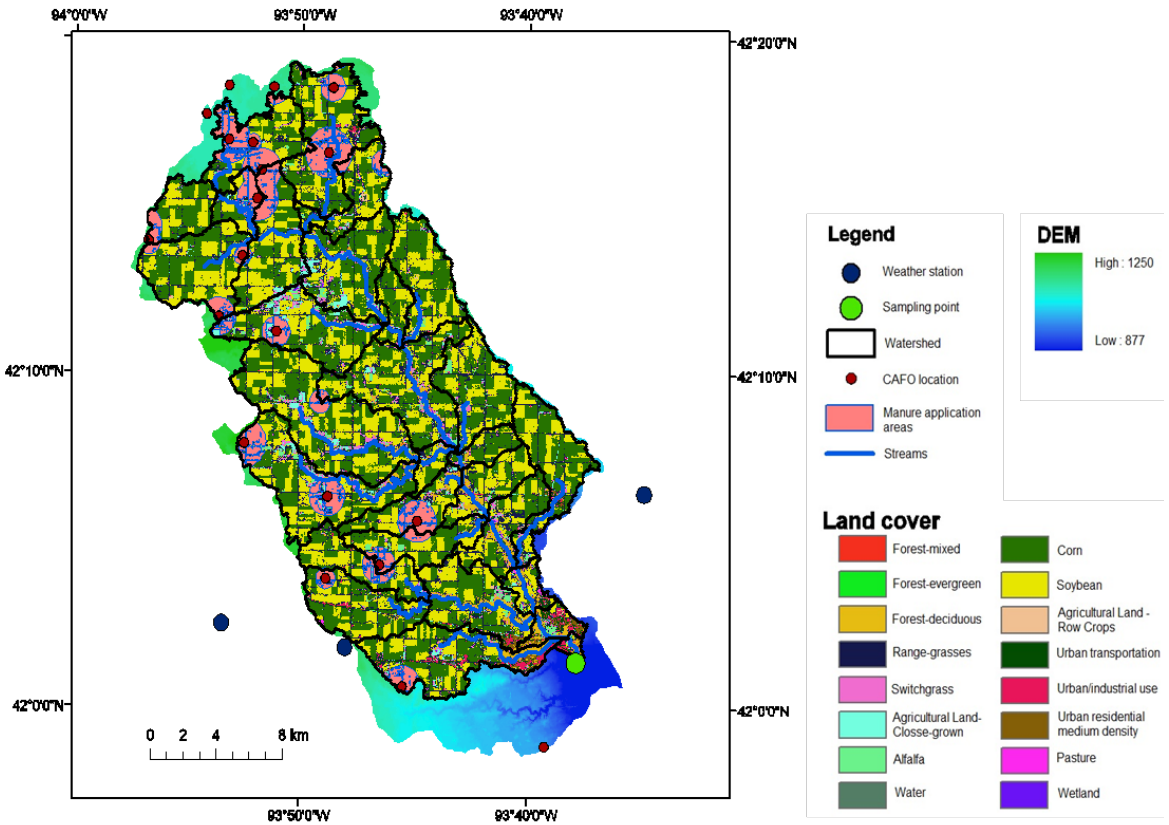
<u>**Possible changes due to changing weather patterns**</u>

1) Release of manure with runoff into streams

2) Baseflow and surface runoff conditions

3) Water volume in streams

4) Microbial die-off on land and in streams



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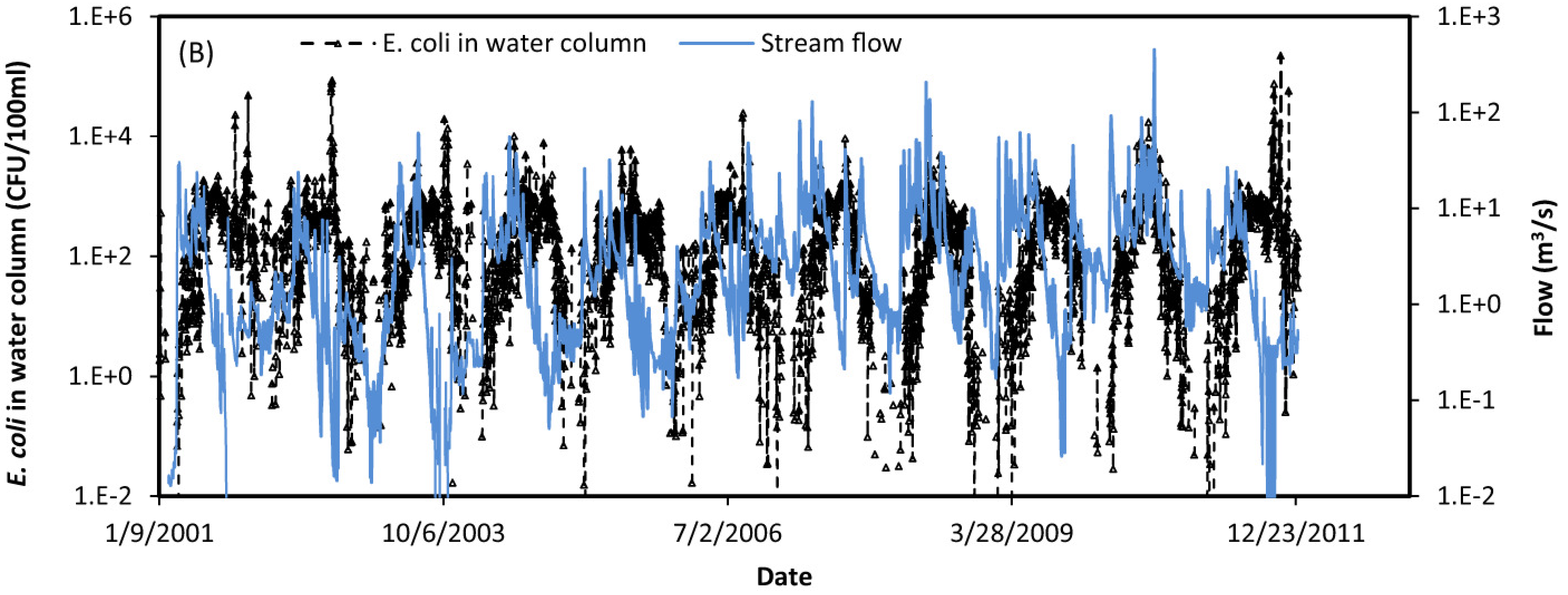

Fig 6. *E. coli* Levels (CFU/100 g) in the water column and stream flow in Squaw Creek Watershed (Pandey et al., 2016).

<u>Intra-annual temperature and precipitation patterns will significantly affect microbial water quality under current watershed management practices.</u>

Thank you!

Soil & Water Assessment Tool SWAT

USDA Agricultural Research Service

University of Maryland 1856 Department of Environmental Science & Technology