International Symposium on Erosion and Landscape Evolution (ISELE)
ISELE Paper Number 11062

Scale and Land Use Effects on Simple Relationships between Flow Velocity and Discharge Rate from Watersheds on the Loess Plateau of China

Presenter : Tingwu Lei
E-mail : tingwu@ms.iswc.ac.cn
Co-authors : Shumei Zhou
David Nigel Warrington
Date : 09/21/2011

State Key Laboratory of Soil Erosion and
Dryland Farming on the Loess Plateau,
Institute of Soil and Water Conservation, CAS and MWR

Soil and water loss on the Loess Plateau

Loess Plateau

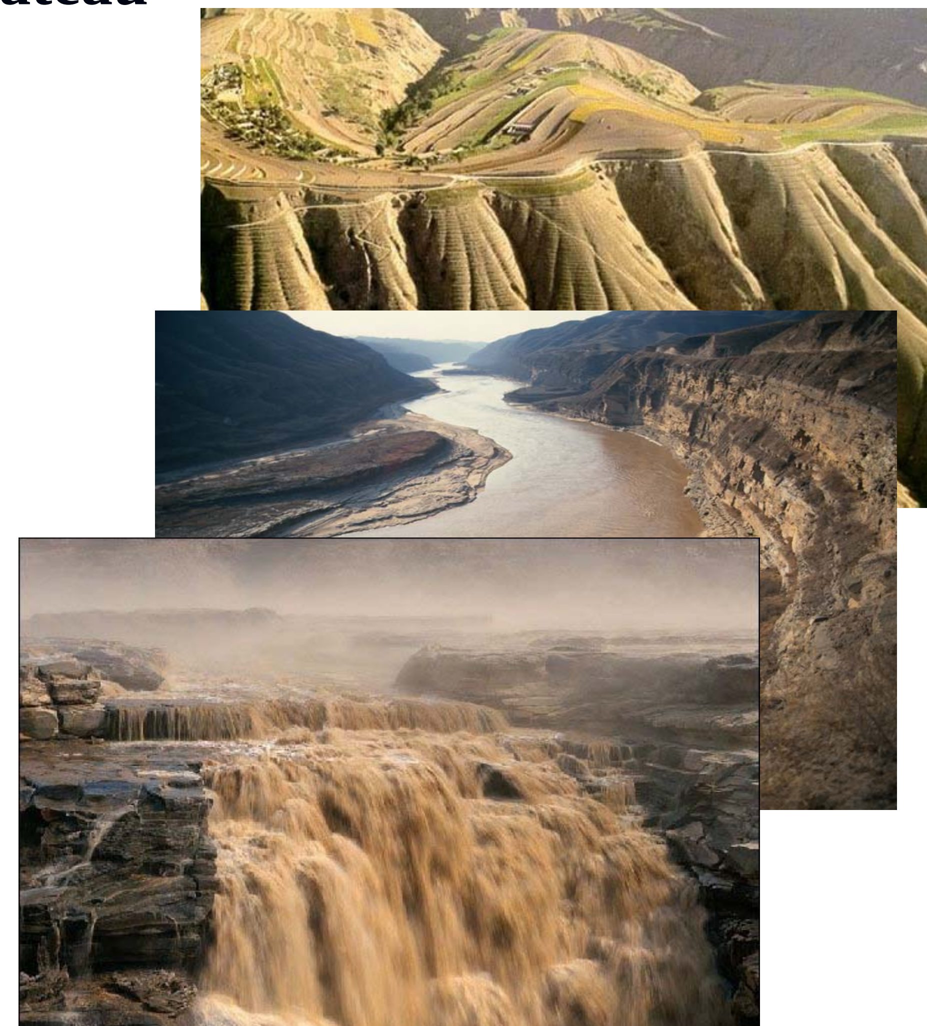
640 000 km^2

Soil and water loss area

450 000 km^2 (> 70%)

Mean annual suspended sediment load

2000-2004: 1.5 ton/year (From Des Walling)



Flow velocity

Direct measurement

Tracers or floating objects

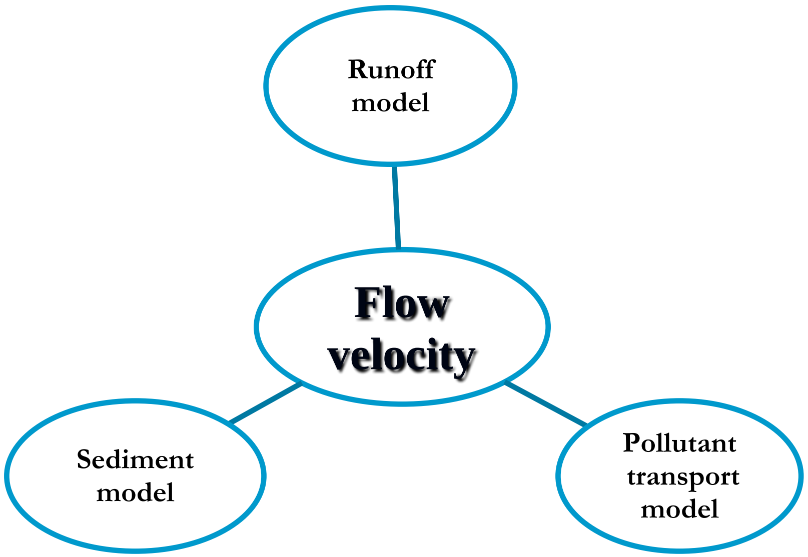
Photogrammetry

Laser–Doppler velocity-profile sensor

Models

The hydraulic theory---***Power function***

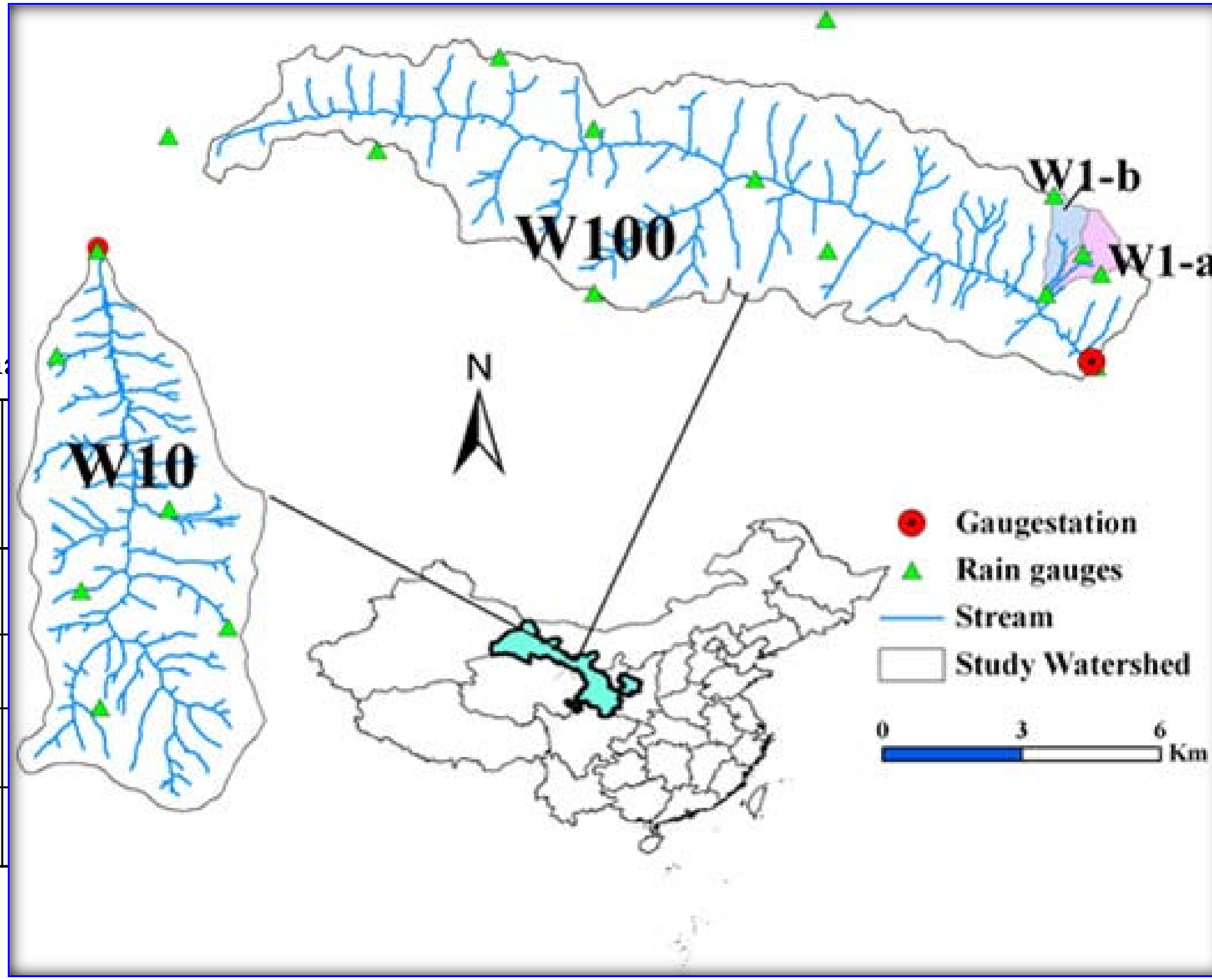
....



Study Sites

Table 1 General informa

Watershed name	Area (km²)	easuring echnique
W1-a	1.4 **(1)**	uoy
W1-b	1.1 **(1)**	uoy
W10	12.0 **(10)**	uoy
W100	72.8 **(100)**	uoy



Models

Power function (Leopold and Maddock, 1953)

$$V = k\,Q^{m}$$

V is the mean flow velocity, m s^{-1};

Q is the discharge rate, m^3 s^{-1};

k is the flow velocity when Q equals 1;

m is the rate of change in flow velocity.

Logarithmic function model

$$V = e\,Ln\,Q + d$$

V is the mean flow velocity, m s^{-1};

Q is the discharge rate, m^3 s^{-1};

d is the flow velocity when Q equals 1;

e is the rate of change in flow velocity.

Study Purposes

※ **To verify the power and logarithmic function models for flow velocity - discharge rate relationships in the study region;**

※ **To investigate the** impact of watershed scale and land use **on the models.**

Data

Table 2 Hydrologic data collected from the four experimental watersheds

Watershed names		W1-a	W1-b	W10	W100
Calibration	Number of years	9	8	6	6
	Number of data pairs	566	593	687	993
	Time span	1987-2002	1987-2002	1998-2003	1998-2003
Validation	Number of years	3	3	3	3
	Number of data pairs	379	220	290	851
	Time span	2003-2006	2003-2006	2004-2006	2004-2006

Model performance: coefficient of determination (**R^2**), the model efficiency (**E**),

Differences between the numerical constants for different watersheds were **ANOVA** and t-test.

Results

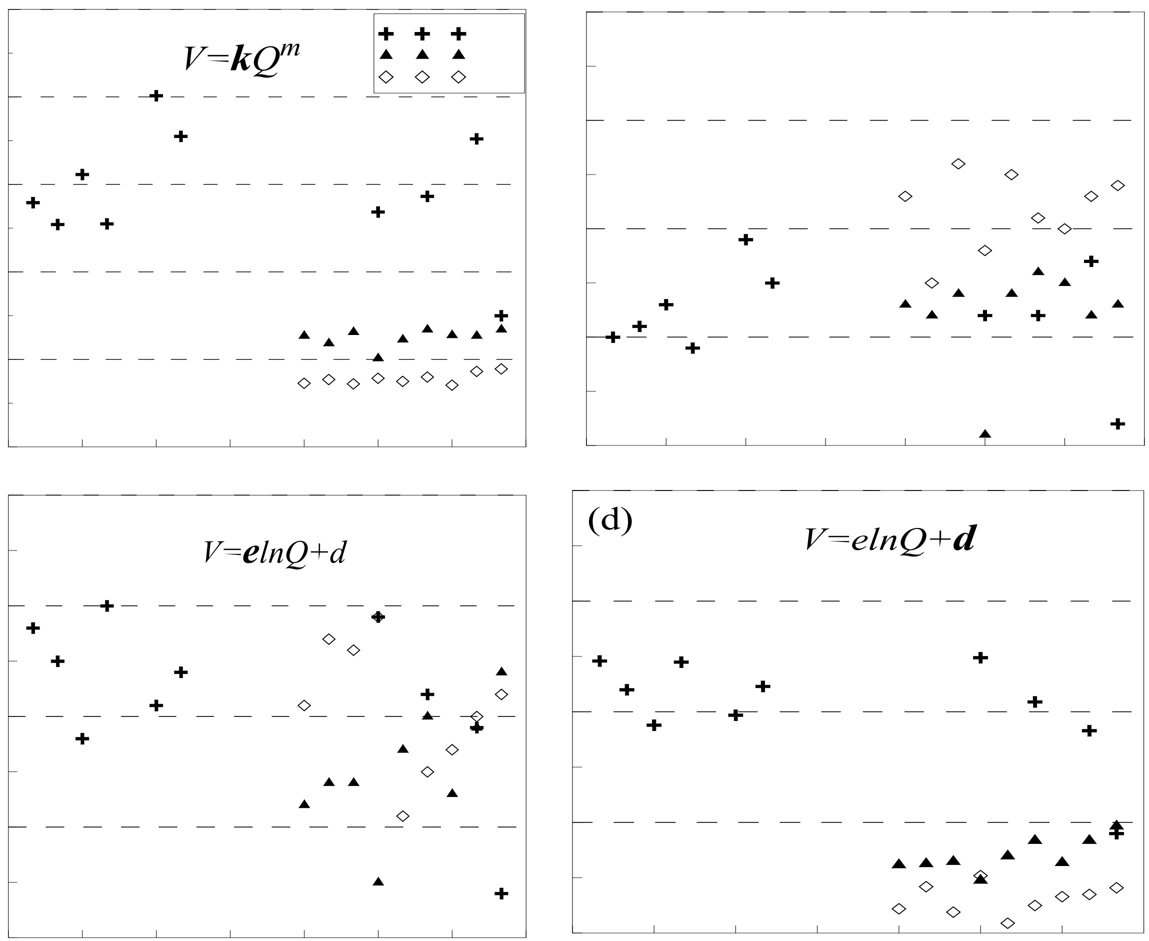
Model adaptability

Table 3 Frequency distribution of the coefficients of determination (R^2)

Watershed names	Function models	<0.5	0.5-0.7	0.7-0.8	0.8-0.9	0.9-1	>0.7 (%)
W1-a	Power	0	1	1	4	1	86
	Logarithmic	0	0	2	2	3	100
W1-b	Power	2	3	1	2	1	44
	Logarithmic	3	2	1	1	2	44
W10	Power	1	0	0	3	2	83
	Logarithmic	1	0	0	4	1	83
W100	Power	0	0	0	2	4	100
	Logarithmic	0	0	0	5	1	100

Results

Scale effect



Distribution of numeric constants of different sized watersheds: W1-a (1 km^2); W10 (10 km^2); W100 (100 km^2).

Results

Scale effect

※ k and d were inversely correlated with watershed size

Values of k and d: W100 >> W10 > W1-a

※ m was positively correlated with watershed size

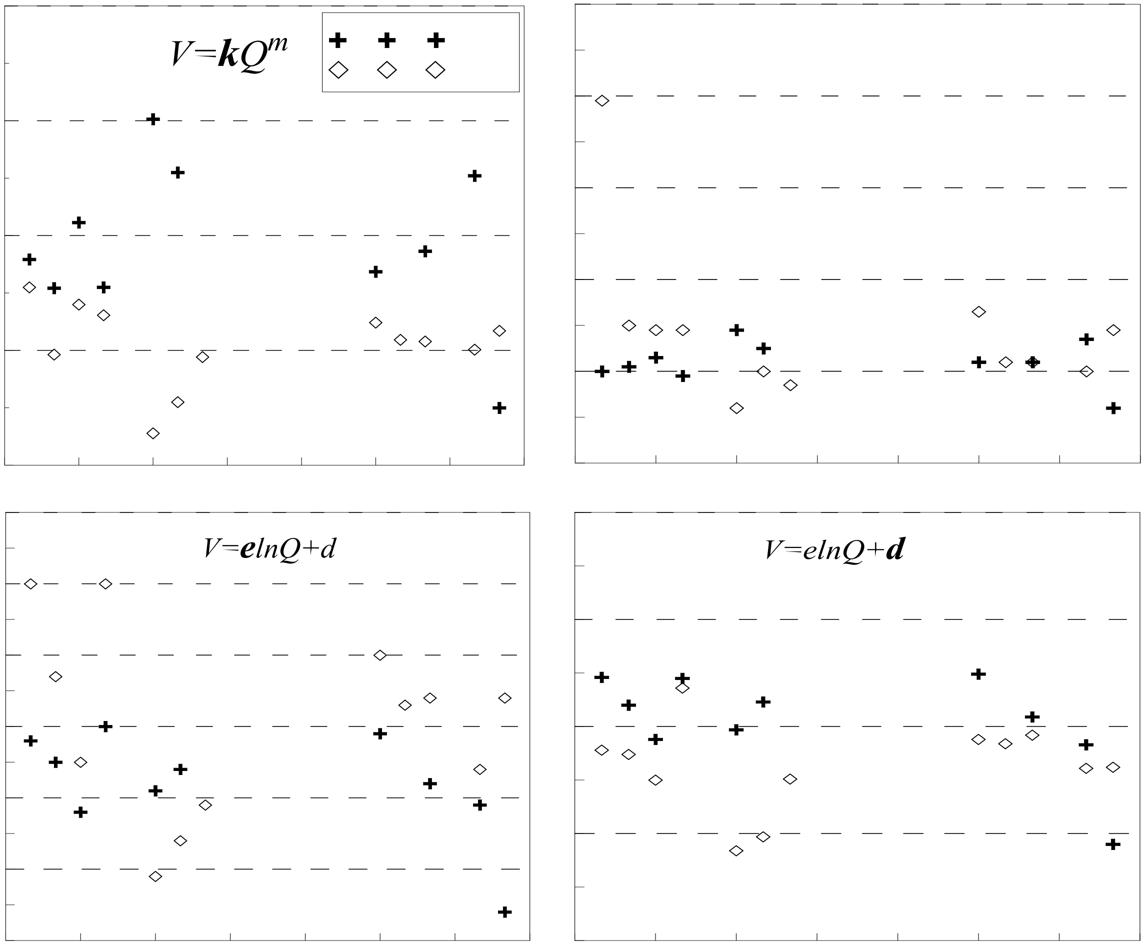
Values of m: W100 >> W10 ≈ W1-a

※ e was not significantly affected by watershed size

Values of e: W100 ≈ W10 ≈ W1-a

Results

Land use effect



Distribution of numeric constants of different watersheds , W1-a, measures implemented; W1-b, measures not implemented.

Results

Land use effect

※ ***k*** and d values were significantly different in watersheds with different land uses;

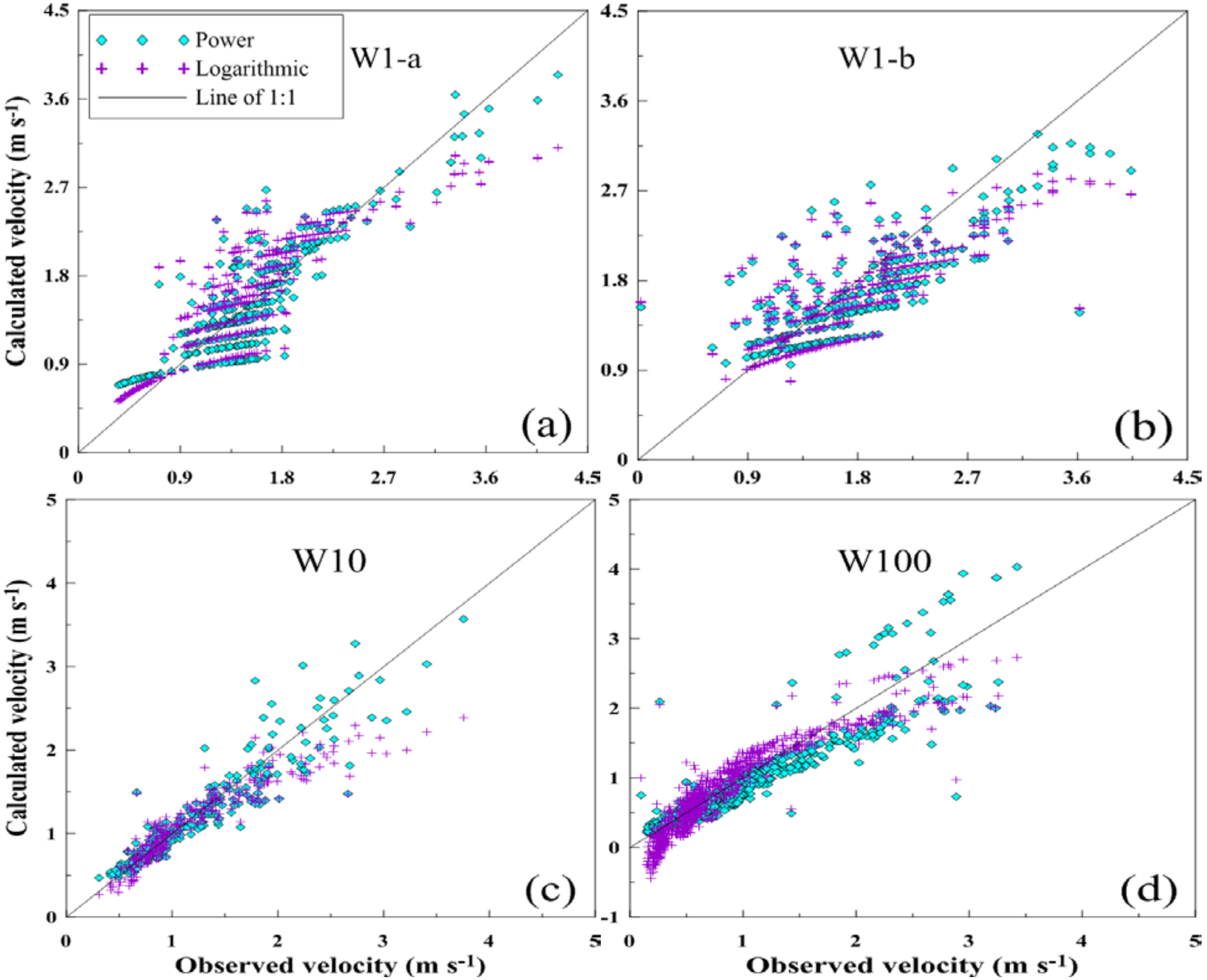
Values of k and d: W1-a ≠ W1-b

※ No significant differences existed between ***m*** and e values in watersheds with different land uses;

Values of m and e: W1-a ≈ W1-b

Results

Validation



Validation results using power and logarithmic function models for the four watersheds: W1-a, W1-b, W10, W100.

Results

Validation

Table 4 Coefficient of determination (R^2) and model efficiency (E) for the experimental watersheds.

Watershed names	Events	Function models	Model	R^2	E
W1-a	566	Power	$V = 3.71Q^{0.21}$	0.83	0.73
		Logarithmic	$V = 0.37\ln Q + 3.35$	0.91	0.62
W1-b	593	Power	$V = 2.84Q^{0.30}$	0.43	0.25
		Logarithmic	$V = 0.49\ln Q + 2.88$	0.74	0.55
W10	687	Power	$V = 1.75Q^{0.23}$	0.79	0.86
		Logarithmic	$V = 0.26\ln Q + 1.73$	0.79	0.82
W100	993	Power	$V = 1.07Q^{0.31}$	0.90	0.84
		Logarithmic	$V = 0.32\ln Q + 1.36$	0.83	0.83

Discussion

※ The flow velocity change was only weakly influenced by watershed size and was not significantly affected by land use;

※ Watershed size inversely impacted the unit discharge flow velocity (***k*** and ***d***), while land use was positively correlated with the unit discharge flow velocity;

※ Both watershed size and land use had an influence on the flow velocity-discharge rate relationship.

Conclusions

※ The models performed at different levels of efficiency for the watersheds;

※ The power function model generally performed better the logarithmic function model;

※ Both watershed size and land use had some impacts on the parameters, especially on the scale factors ***k*** and ***d***;

※ The power function model can be directly used in the experimental watersheds to calculate mean flow velocity as well as providing relevant hydraulic variables for developing hydrologic or sediment yield models.

Thank you!