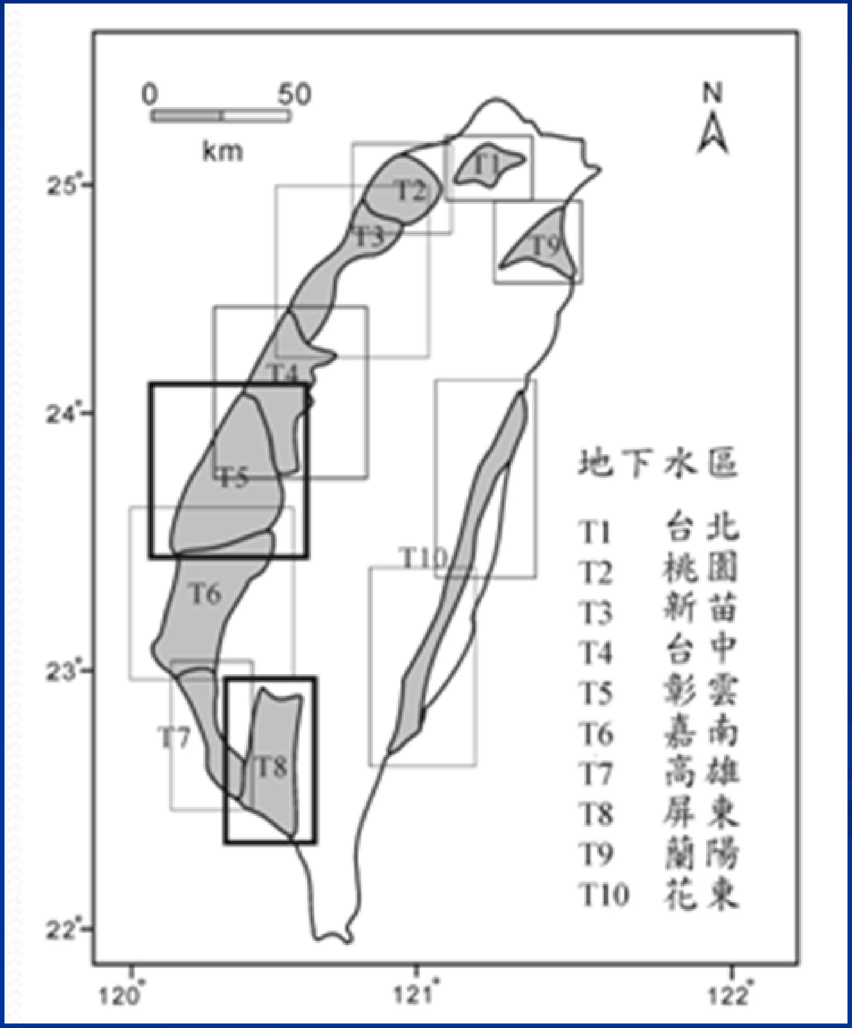
冲積扇之河床入滲

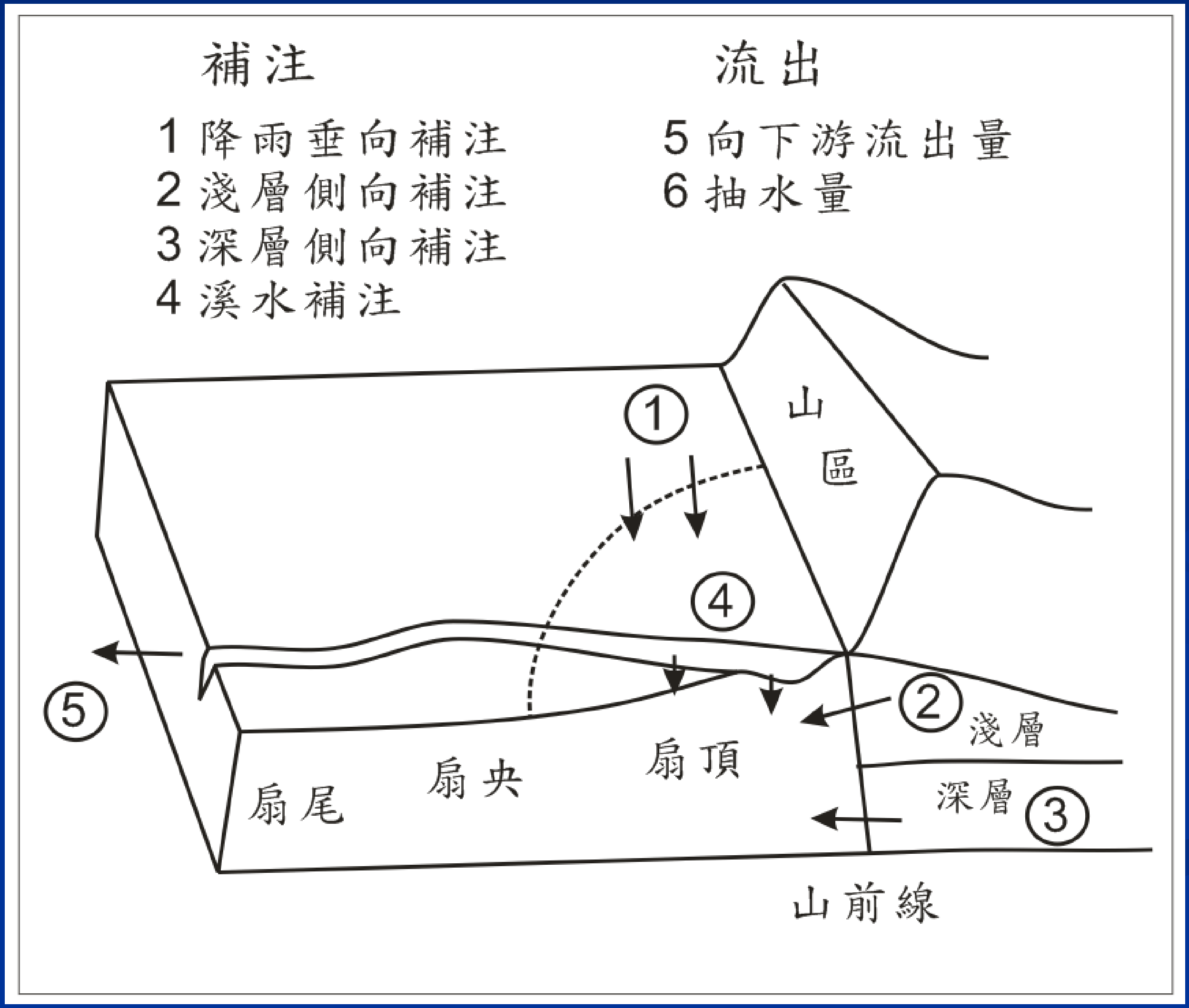
陳文福
嘉南藥理大學
觀光系及溫泉研究所

台灣的水資源

- 地面水 2/3
- 地下水 1/3
- 沖積扇礫石層含水層 7/10



冲積扇地下水收支



補注
流出
1 降雨垂向補注
2 淺層側向補注
3 深層側向補注
4 溪水補注
5 向下游流出量
6 抽水量
1
山
區
4
2
淺層
5
扇頂
扇央
扇尾
深層
3
山前線

河川與地下水交換有多少？
入滲或是出滲？
河床阻塞的影響？
豐水季與枯水季的量？
不同河流的差異（河水含砂量）的影響？

The Impact of Floods on Infiltration Rates in a Disconnected Stream

Wenfu Chen (Chia Nan University),
Chihchao Huang, Minhsiang Chang (CGS),
Pingyu Chang (National Taiwan Ocean U.)
Hsuehyu Lu (National Chung Cheng U.)

Why we study infiltration?

- interactions between groundwater and surface water is important for the effective management of water resources [*Sophocleous*, 2002]
- One of the hot topic:

Dose infiltration increase during a flood event?

Infiltration rates DO increase in floods

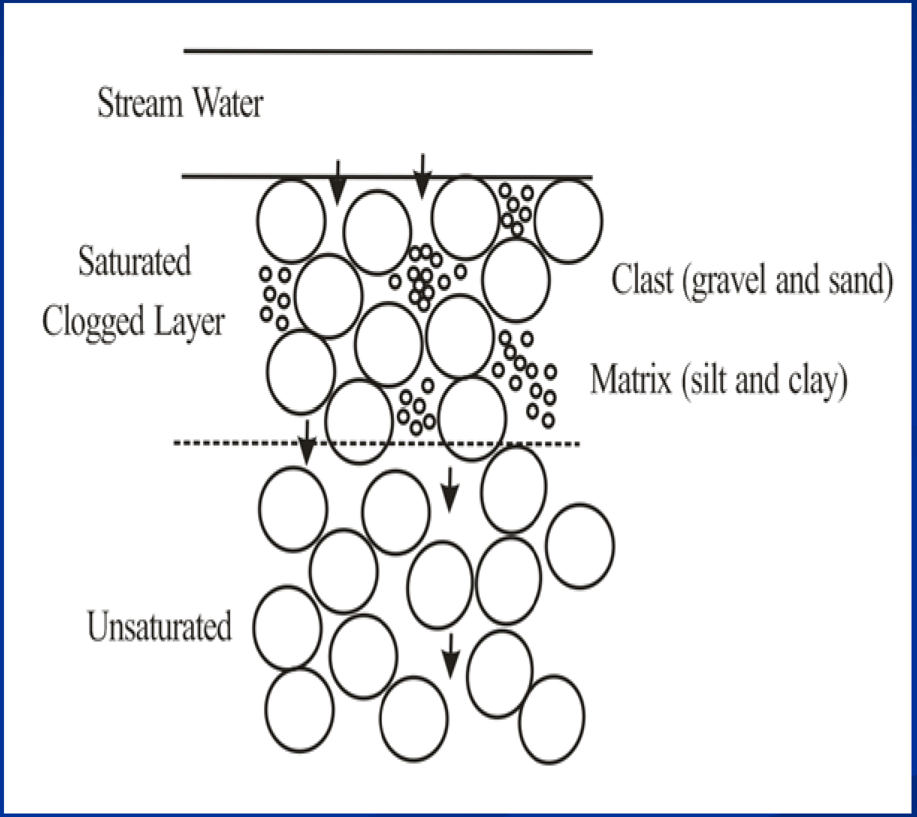
- due to an increase in the stream stage
- the remove of the clogged streambed.

Infiltration rate NO increase

- a new clogging layer will quickly form after an older one has been eroded,
- increase in water depth will compress the clogging layer, making it less permeable during a flood event.

Compression of matrix

- *An increase in stream stage will increase the <u>hydraulic gradient</u> and the <u>downward drag force</u> within the clogged layer, and compresses the matrix of silt and clay [Houston et al., 1999].*



The purpose

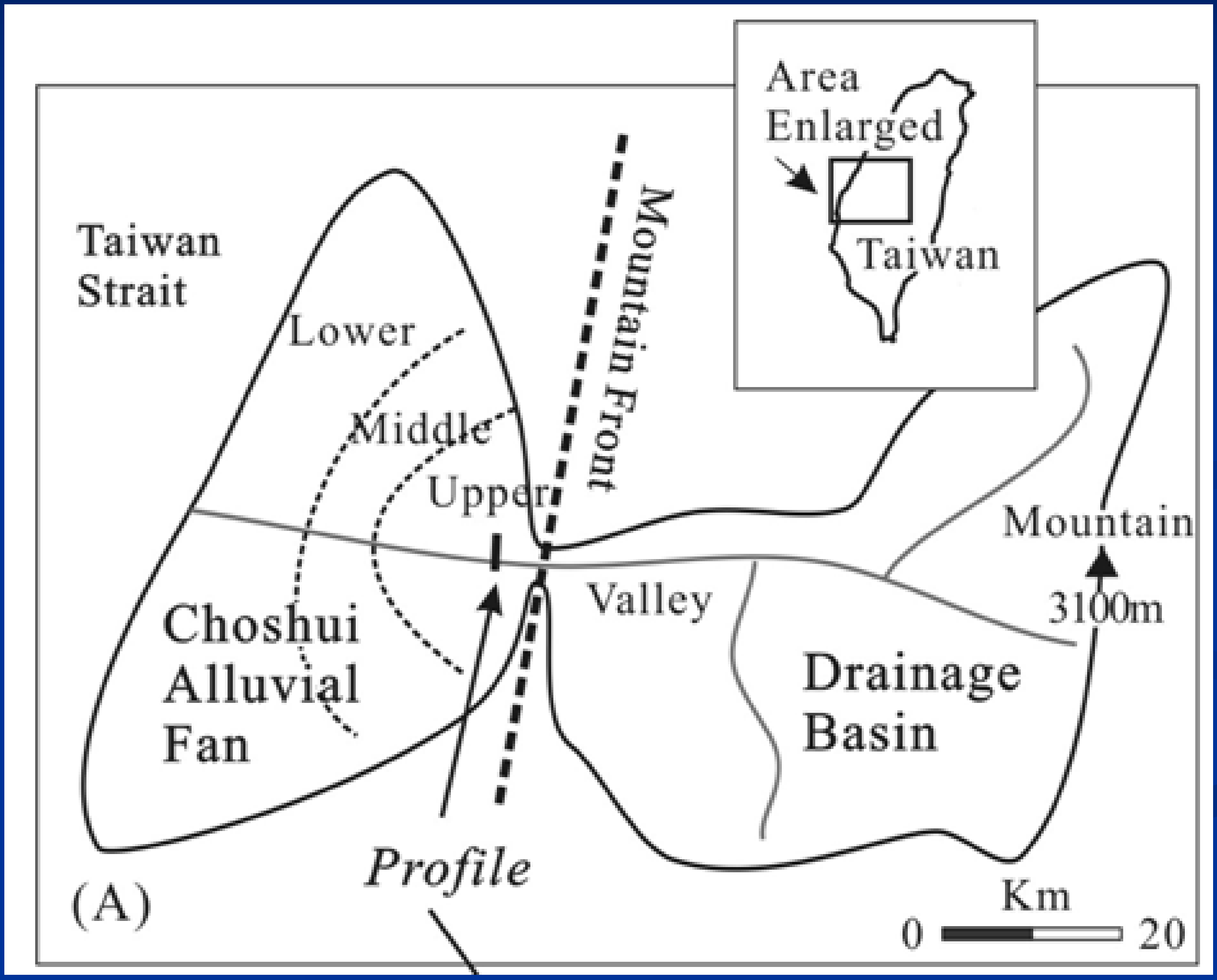
- to understand the impact of floods on infiltration rates within a disconnected stream.
- We use
  - <u>pressure data</u>
  - <u>daily streambed infiltration rates</u> determined from diurnal temperature time series
- over a period of 167 days for five flood events.

Our data did not support the theory that floods linearly increase the infiltration rate.

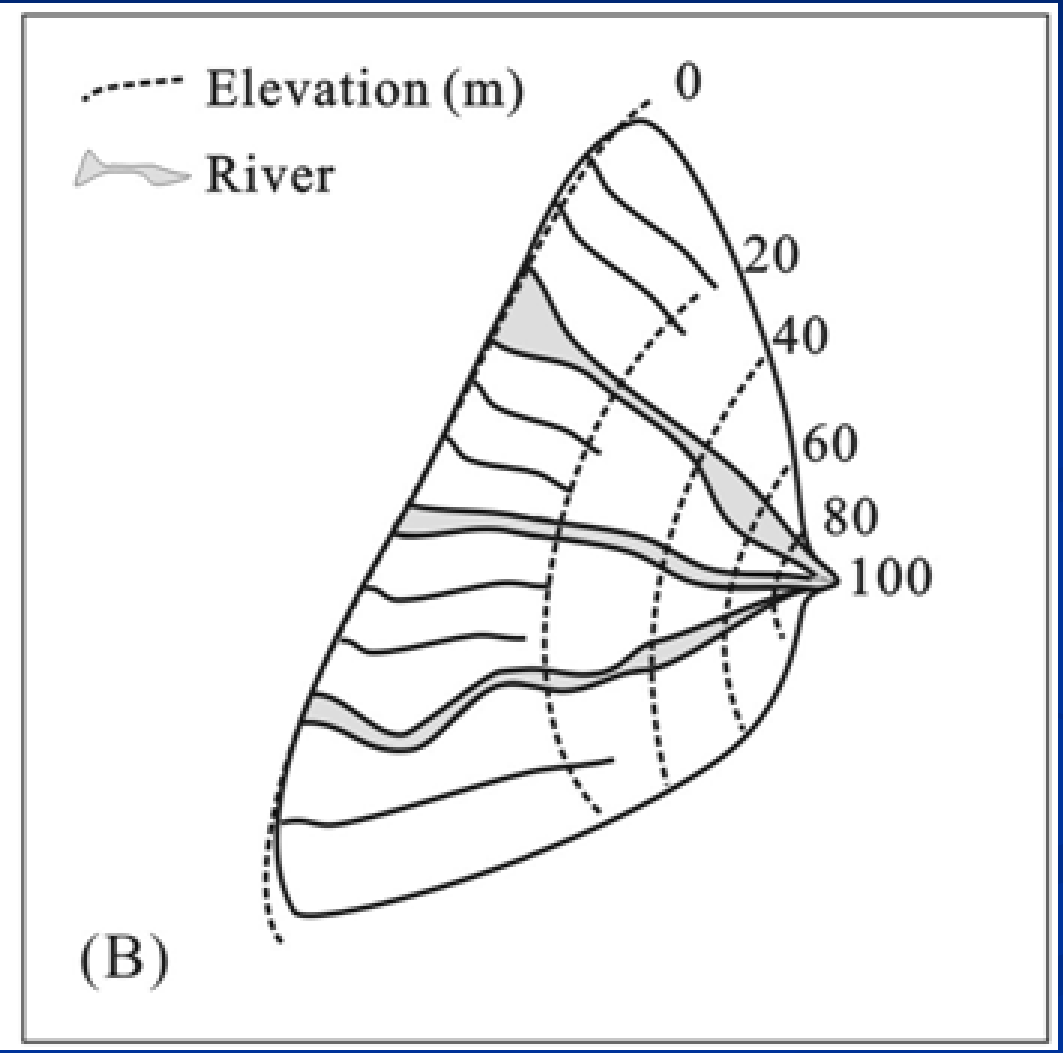
- the streambed was clogged very quickly with a large load of suspended particles
- compaction of the clogged layer
- infiltration rates were also low during the flooding season.

- However, due to an increase in the <u>wet perimeter</u> within the stream during flooding periods, the total recharge amount to the aquifer was increased.

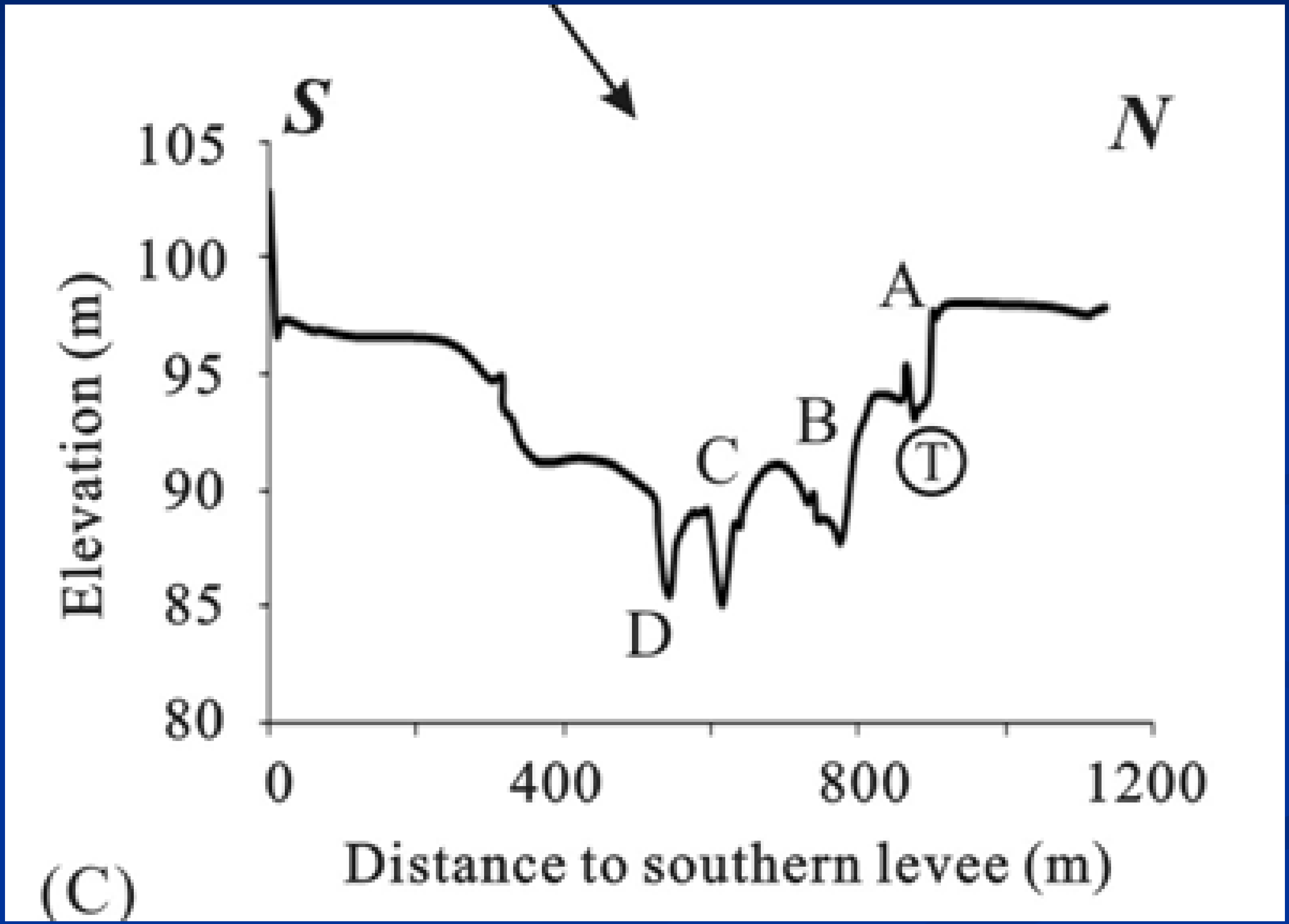
Our study site



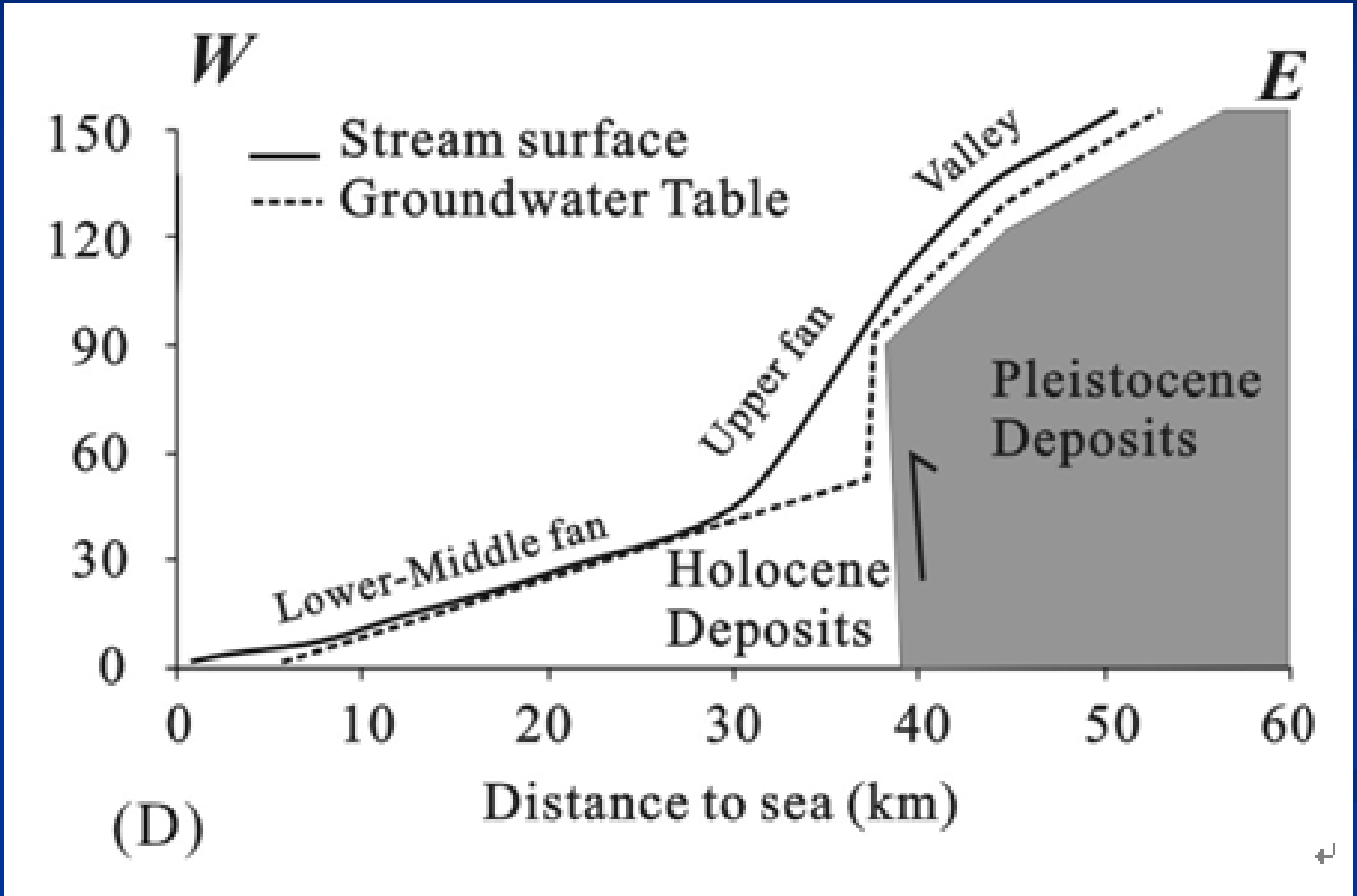
Elevation and river system



River transverse profile N-S



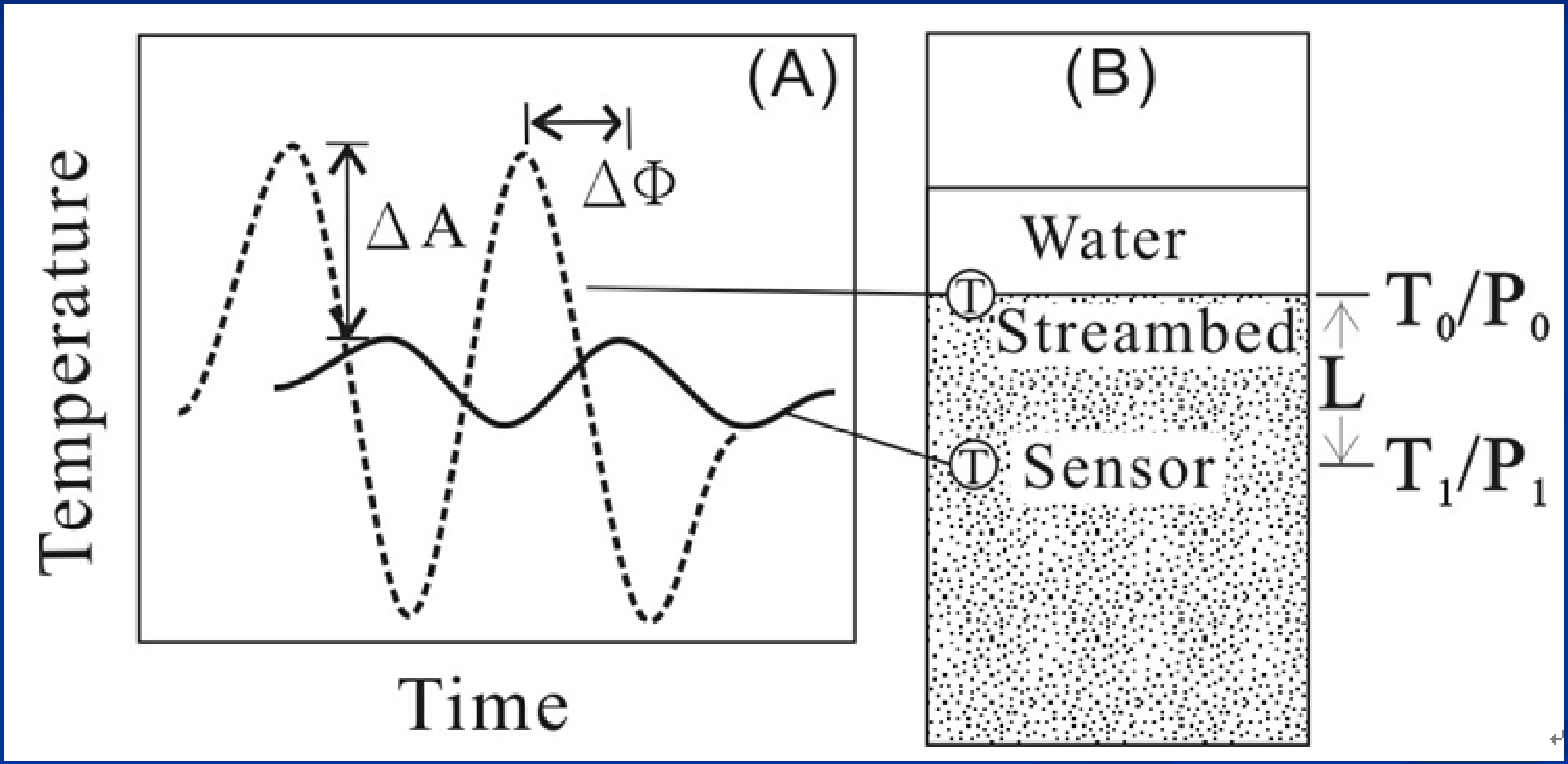
Longitudinal profile E-W



Channel A

Channel B

Two probes in streambed



Schlumberger Mini-Diver

- working range was 0-80°C
- accuracy of ±0.1°C
- resolution of 0.01°C
- working range for pressure up to 10 mH2O
- accuracy of ± 0.01 mH2O
- a resolution of 0.002 mH2O
- 9 cm length and 2.2 cm in diameter.

1-D heat transfer eq.

$$(\kappa/\rho C)(\partial^2 T/\partial Z^2) - q(\rho_w C_w/\rho C)(\partial T/\partial Z) = \partial T/\partial t$$

- heat conduction
- $\varkappa$ thermal conductivity
- ϱ density
- C specific heat
- T temperature
- Z depth

- advection term
- q infiltration rate
- ϱ_w water density
- C_w water specific heat

Computer Codes

- Finite different

Therm_Diffusivity.exe for thermal diffusivity

River_Infil_Velocity.exe for infiltration rate

The Verification of Our Program

Data Sources	Thermal Diffusivity (m^2/s)		Low Boundary Temperature (°C)	
	From References	Our Program	From References	Our Program
Tsai et al., 2008	6.23×10^{-7}	6.51×10^{-7}	25.5	25.8
Munz et al., 2010	11.9×10^{-7}	14.5×10^{-7}	---	21.19
	Percolation Velocity (m/s)			
Ronan et al., 1998	1.38×10^{-5}	1.89×10^{-5}	12-13	12.5
Keery et al., 2007	$2.9\text{-}6.4\times10^{-6}$	6.79×10^{-6}	---	6.0
Silliman et al.,1995	$8.3\text{-}83\times10^{-7}$	7.91×10^{-7}	---	20.0

---Not available in references

Measured thermal parameters

- thermal diffusivities (saturated) 6.0-7.2×10^{-7} m^2/s
- average 6.6×10^{-7} m^2/s
- thermal conductivity 1.94 W/m°C
- thermal diffusivities (dry) 2.1-2.6×10^{-7} m^2/s
- average 2.3×10^{-7} m^2/s
- thermal conductivity 0.33 W/m°C

1-D heat transfer

Temperature series measured

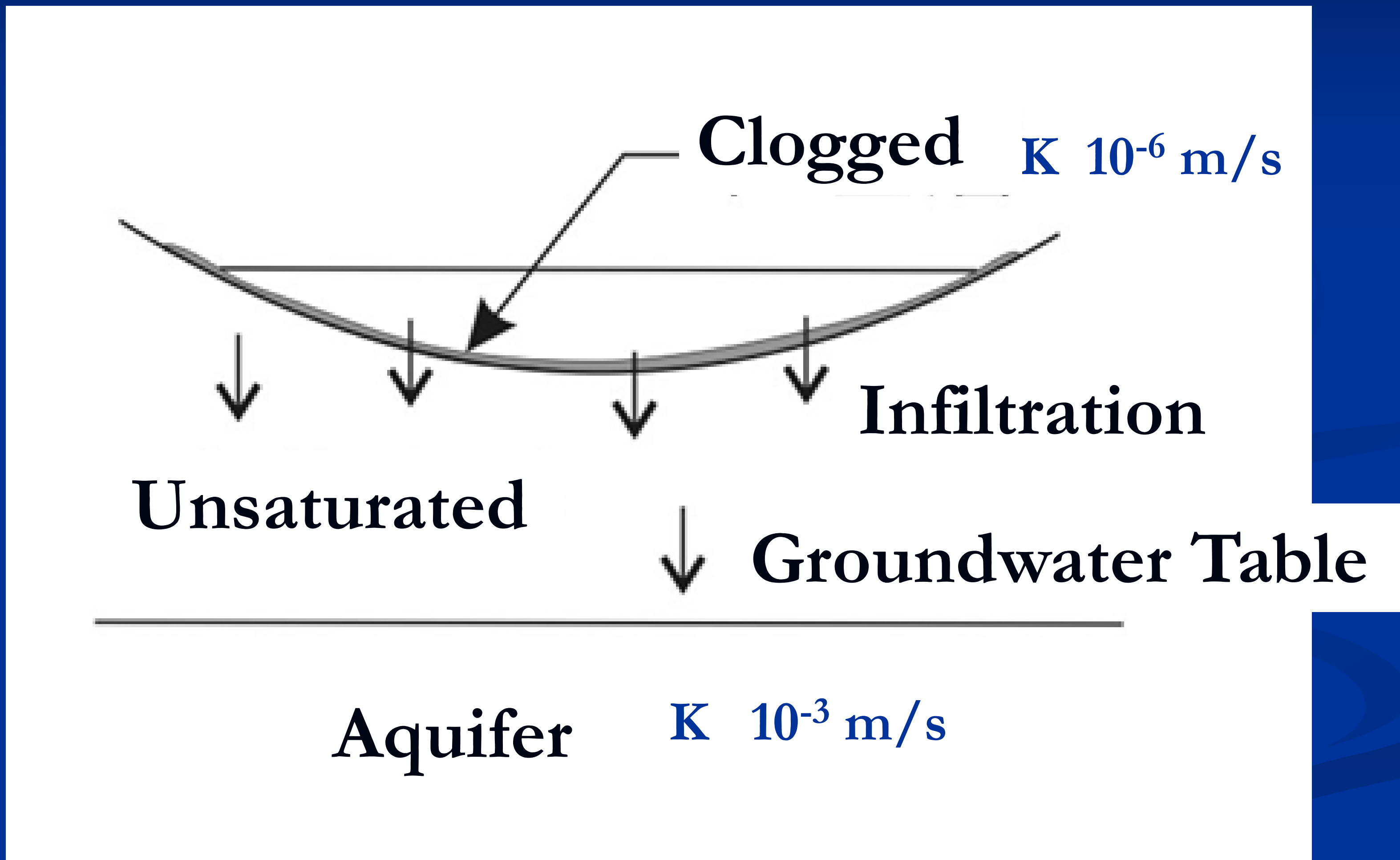
$$(\kappa/\rho C)(\partial^2 T/\partial Z^2) - q(\rho_w C_w/\rho C)(\partial T/\partial Z) = \partial T/\partial t$$

- heat conduction
- $\varkappa$ thermal conductivity
- ϱ density
- C specific heat
- T temperature
- Z depth

- advection term
- q infiltration rate
- ϱ_w water density
- C_w water specific heat

Only q unknown

Disconnected stream



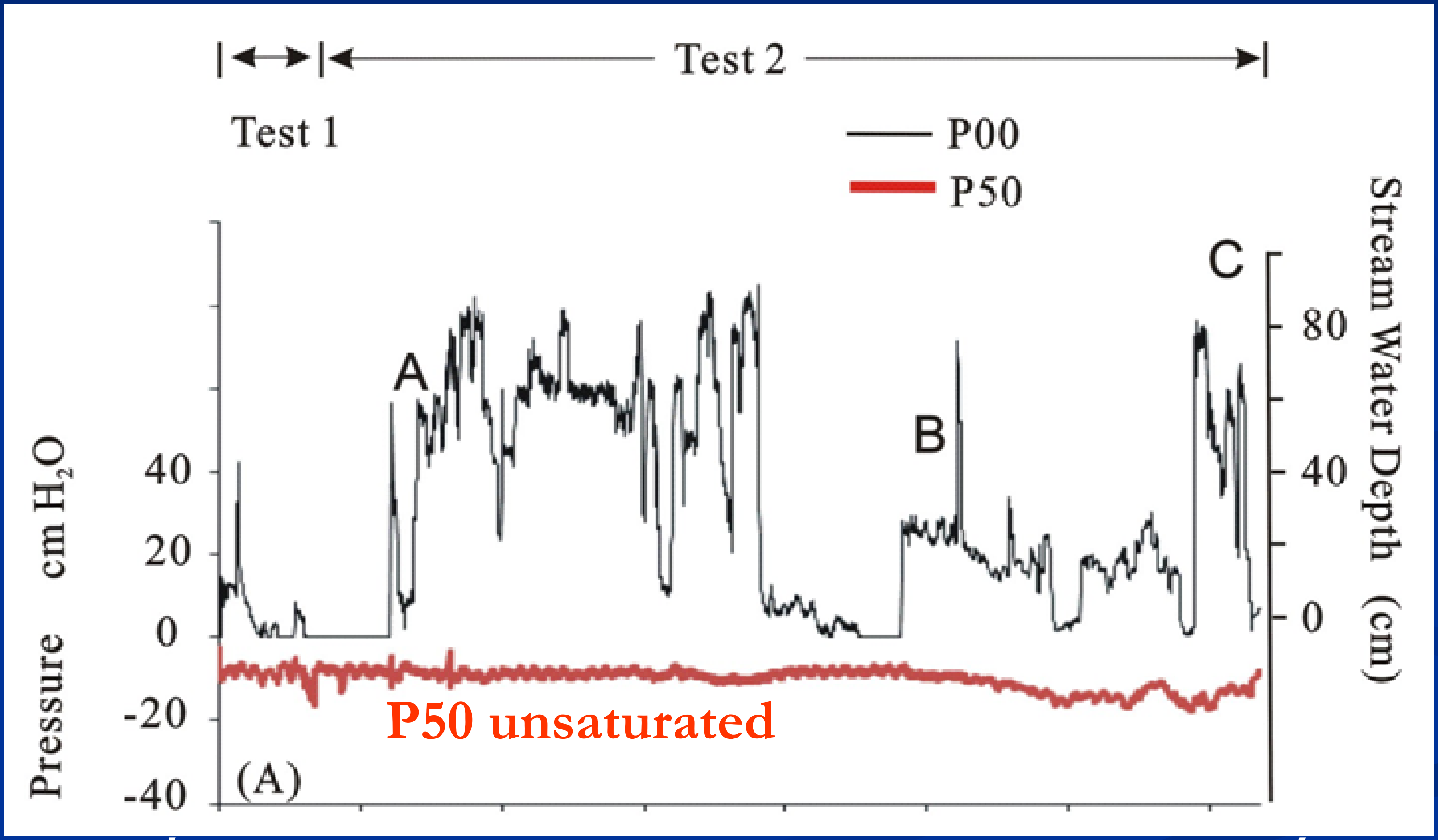
Results

Table 5. The Test Date, Saturated Condition, Probes Depth and Flood Events

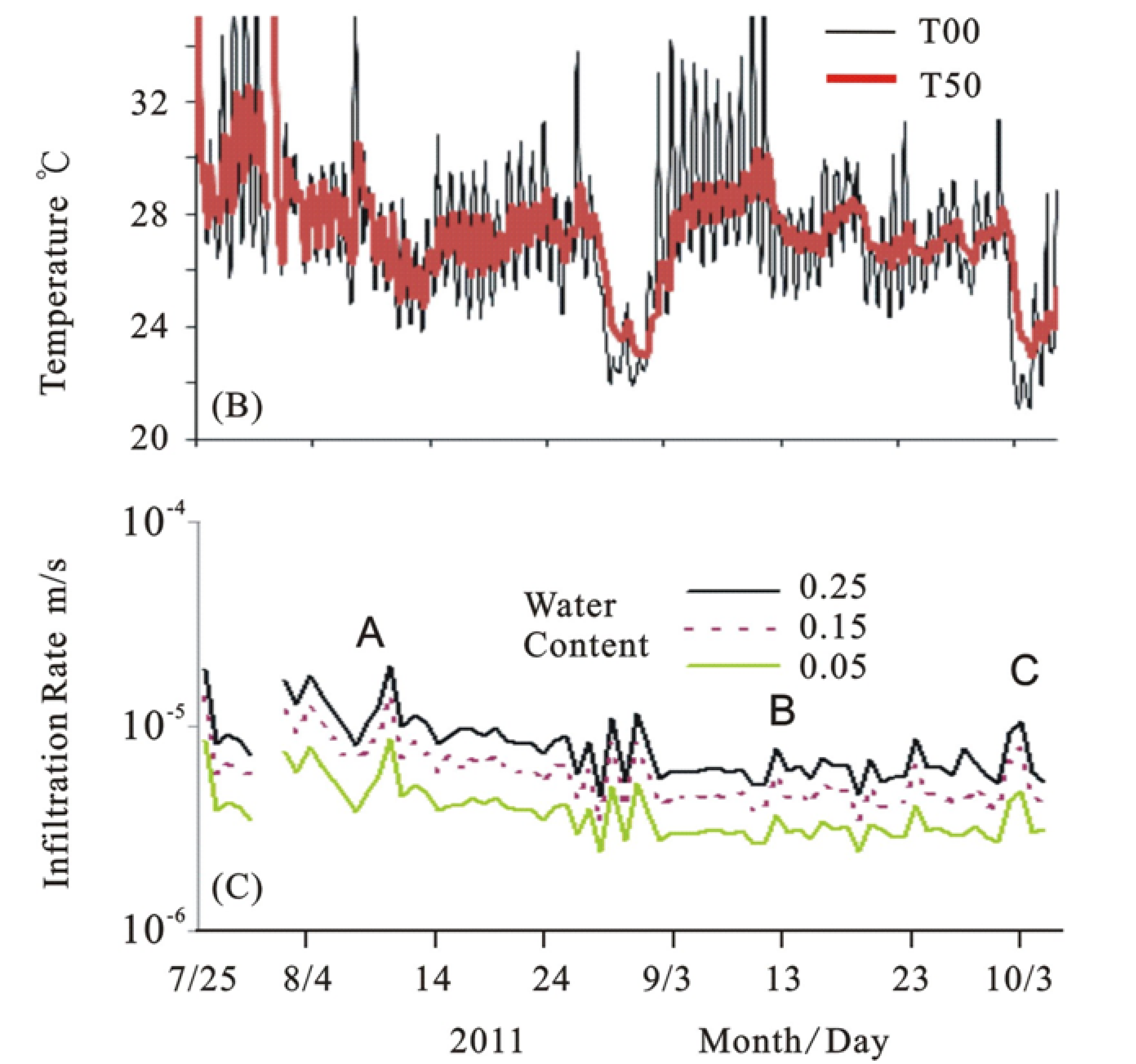
	Date 2011	Condition	Probes Initial Depth (cm)	Flood Event: Scour/Fill* (cm)
Test 1	25 July - 2 Aug	Unsaturated	0-50	
Test 2	2 Aug - 5 Oct	Unsaturated	0-50	A (6 Aug): -4 B (11 Sep): -2 C (3 Oct): -4
Test 3	7 Oct - 19 Dec	Saturated-Unsaturated	0-7-50	D (26 Oct): -11 E (11 Nov): -19

*Symbol + for Fill; - for Scour.

Stream water depth and p50

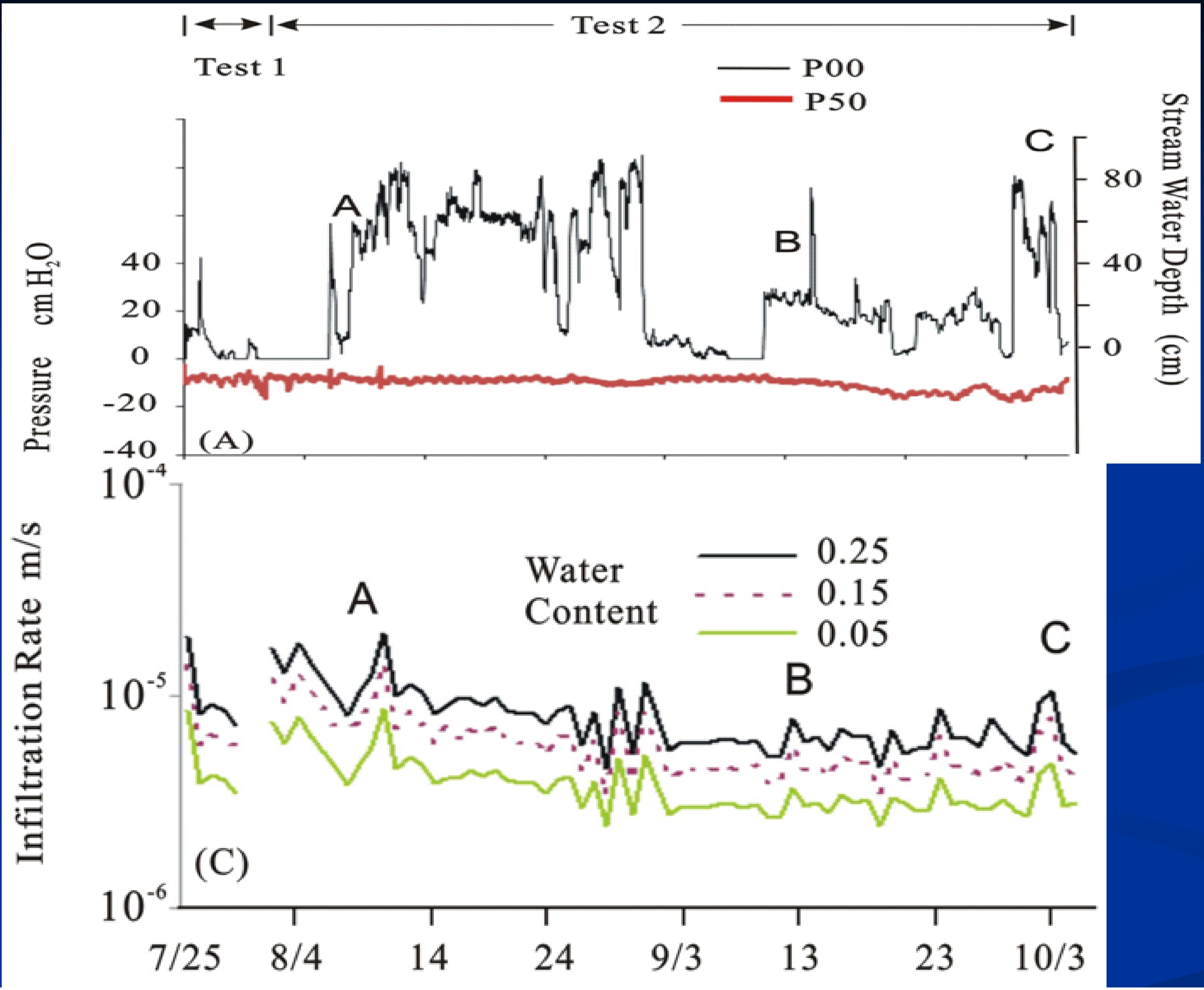


7/25 10/6


T00
T50
Temperature ℃
32
28
24
20
(B)
Infiltration Rate m/s
10^{-4}
10^{-5}
10^{-6}
Water Content
0.25
0.15
0.05
A
B
C
(C)
7/25
8/4
14
24
9/3
13
23
10/3
2011
Month/Day

Result of Test 1

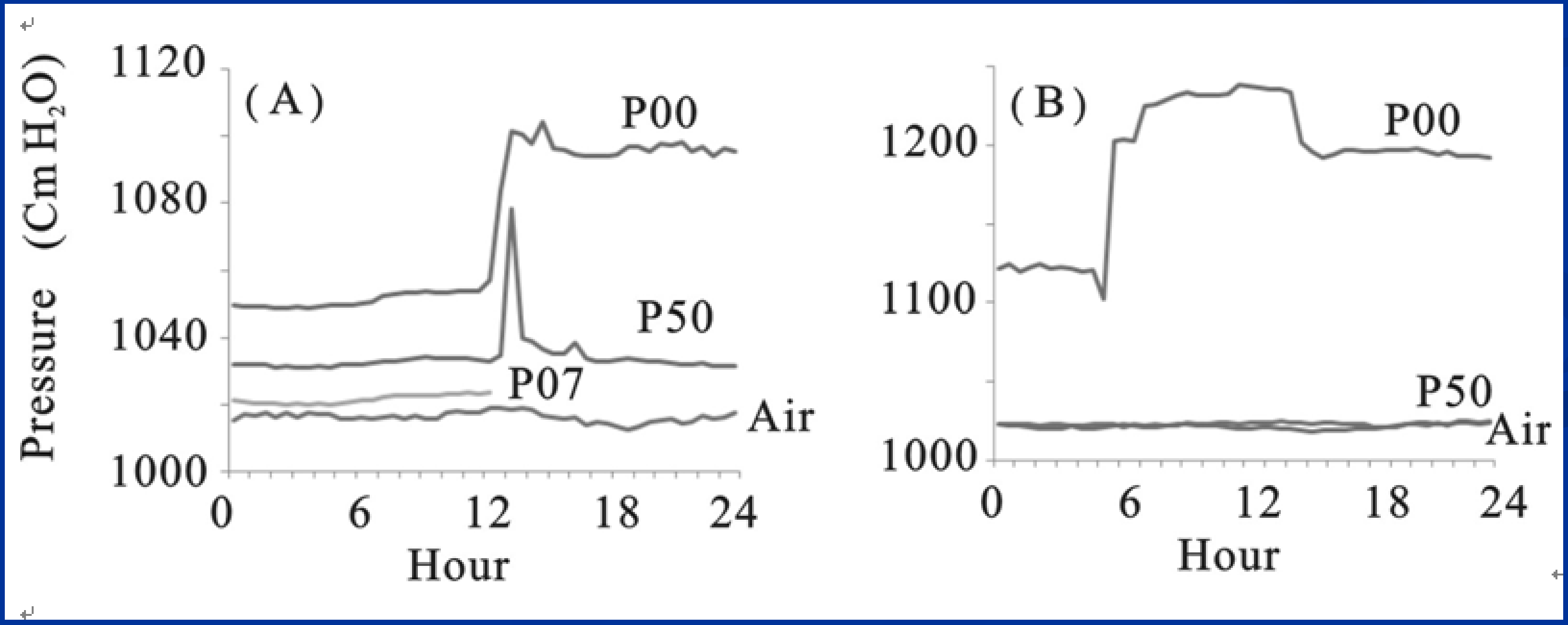
- Stream water level max to 80 cm
- Erosion 10cm
- P50 was unsaturated
- Suspended load 850-6530 mg/l
- Infiltration rates $3\text{-}5\times10^{-6}$ m/s



Only one or two days infiltration rates increase

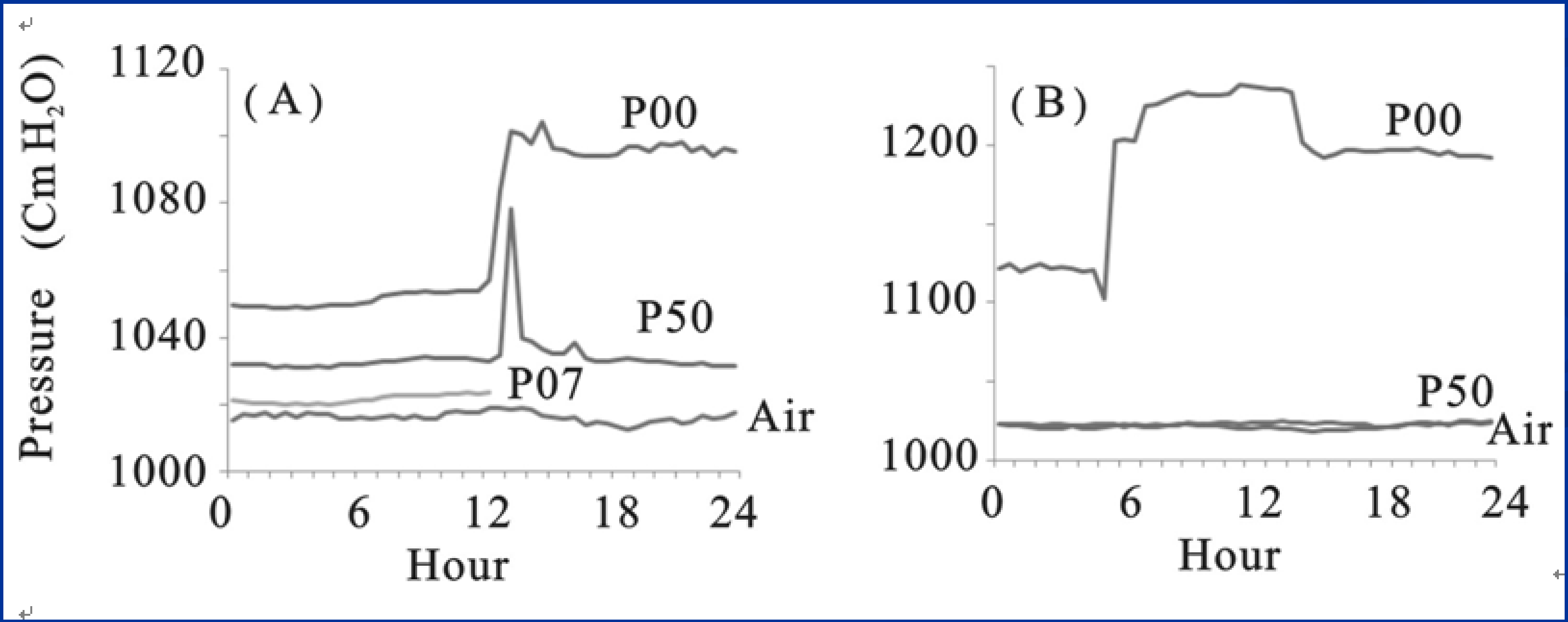
Pressure data

- Flood D, the stream water depth increased by approximately 50 cm and the streambed was eroded by 11 cm; but only one point of pressure in P50 changed for 26 Oct



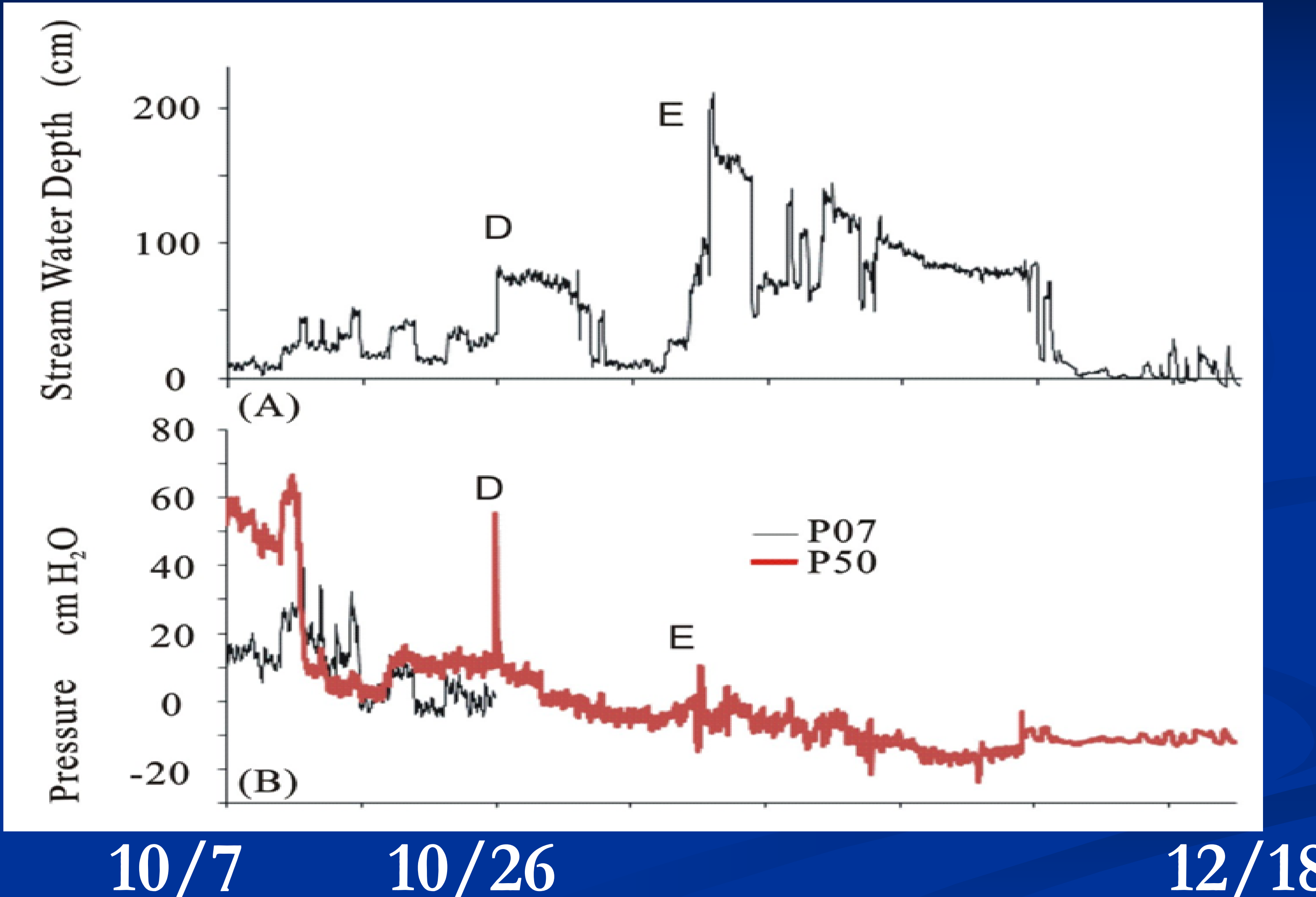
Pressure data

- stream water depth increased by 140 cm, the streambed eroded by 19 cm, and none of the pressure increased in P50 for 11 November for Flood E.

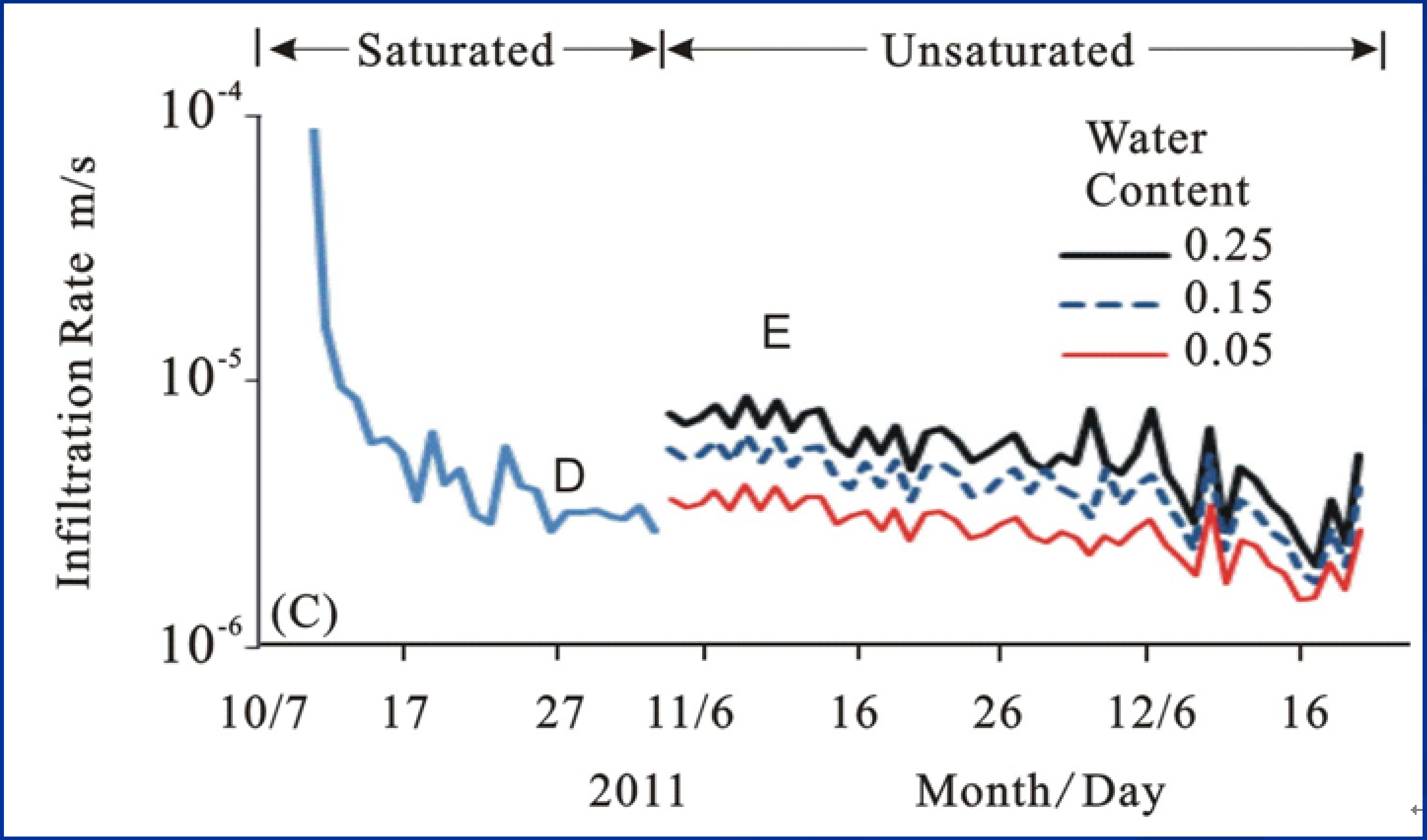


- Several flume studies have indicated that sand infiltration (clogging) in the gravel bed reaches saturated in less than 1 hour, while the fine sediment feed rate is >14 g/s/m2 [*Wooster et al.*, 2008; *Gibson et al.*, 2011].

Test3

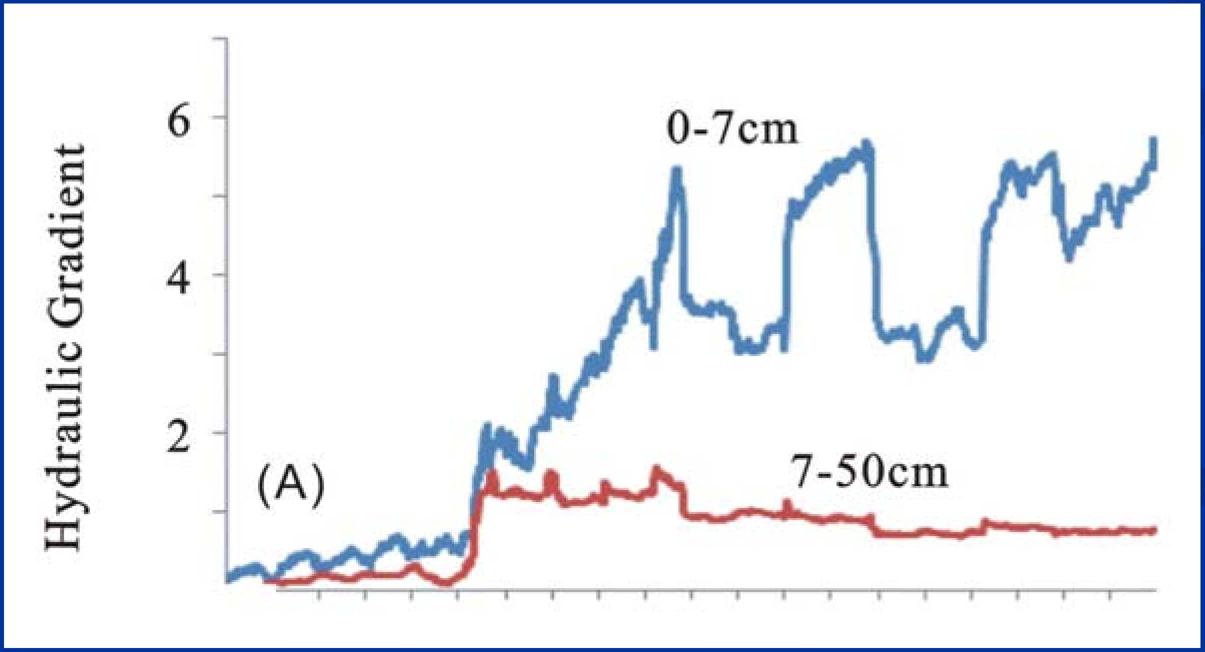

Stream Water Depth (cm)
200
100
0
D
E
(A)
80
60
40
20
0
-20
Pressure cm H_2O
D
E
P07
P50
(B)
10/7
10/26
12/18

Infiltration rates during Floods D and E



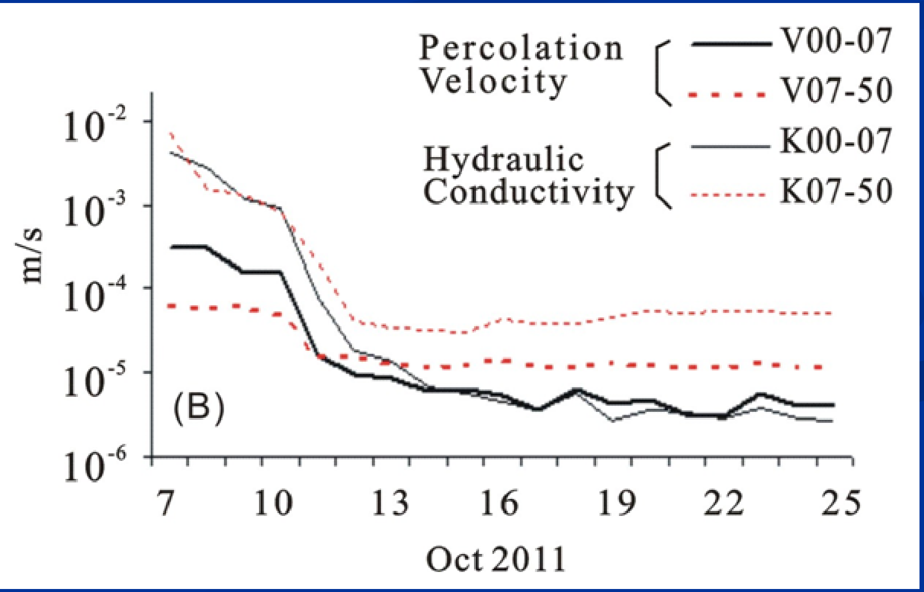
Hydraulic gradients

- the shallow layer (0-7 cm) displayed an increasing trend from 0.24 to 5.88, with variations caused by <u>clogging</u> and stream water level fluctuations



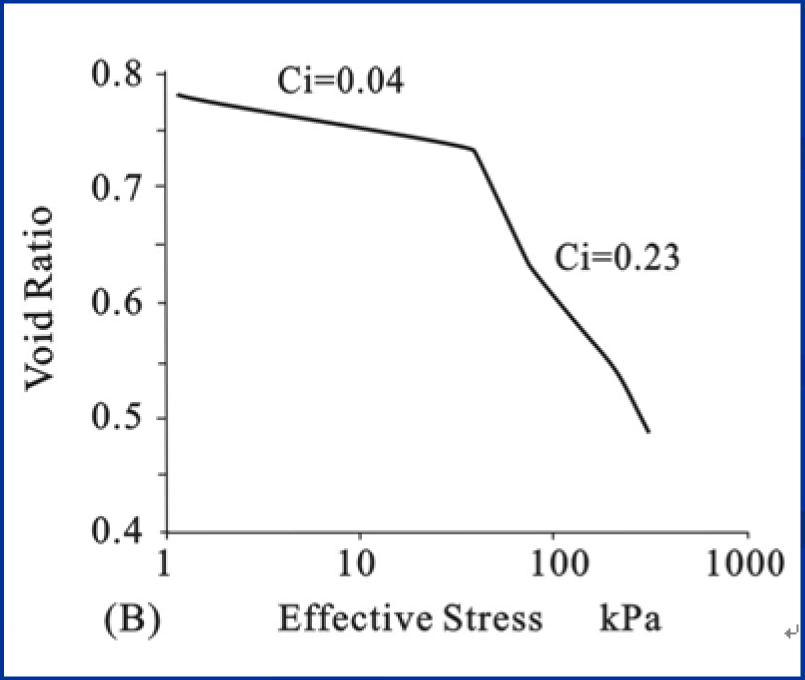
vertical hydraulic conductivity

- The variation of of the two layers
- indicate that clogging initially developed within the 0-50 cm of the streambed, but lastly only in the shallow layer (0-7 cm)



Measured compression index (Ci) for matrix (clogging mud)

- For the lower effective stress loading (1 to 40 kPa, 0.1 to 4 m of water), the compression index (Ci) for the matrix is 0.04



Kozeny–Carman equation

$K = C \times 1/S^2 \times e^3/(1\text{-}e)^2$ Tien, 1989

K hydraulic conductivity m/s

C constant 1/180

S specific surface m^2/kg

spherical $SR=10^{-3}$ (R diameter)

e void ratio

- K is 5.06×10^{-6} m/s
- Increasing one order of water depth (0.1 to 1 m)
- the silt clogged layer may decrease its void ratio to 0.76 (from 0.8)
- the hydraulic conductivity may decrease to 2.96×10^{-6} m/s, nearly half

Conclusions

- A disconnected stream is formed by a deep groundwater table and clogging in the upper part of the streambed.
- In general, for highly suspended sediments in stream water, the time needed to saturate a clogged layer with silt is shorter.
- An old, clogged layer may be removed, but since the suspended load is highest during a flood a new one is quickly formed.

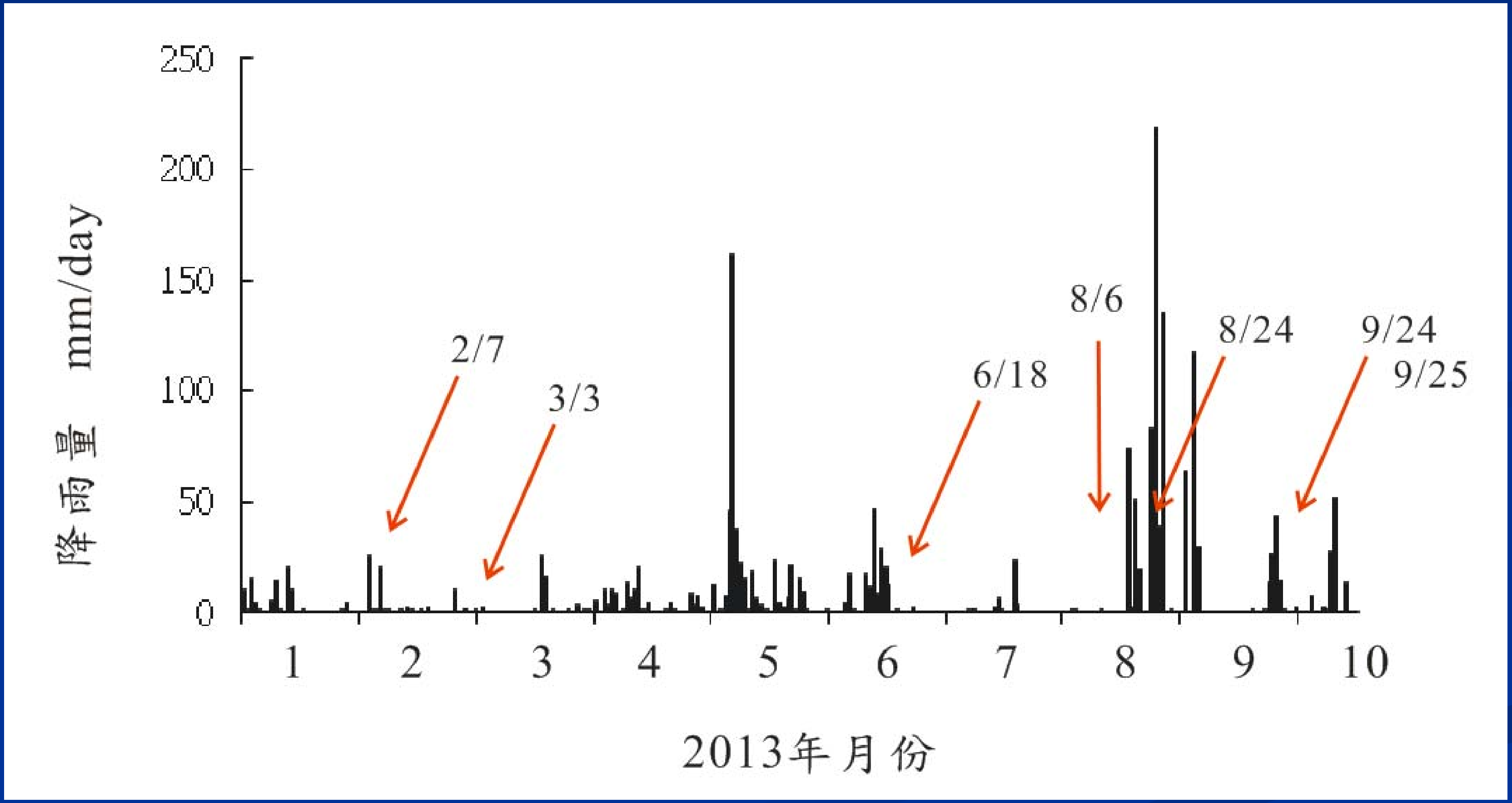
- In this work, we have presented new pressure and infiltration data for a disconnected stream over a period of 167 days for five flood events.
- Our data did not support the theory that flooding linearly increases the infiltration rate.
- Infiltration rates were also low during the flooding season.

- However, the total recharge amount to the aquifer will be increased as a result of the increase of the wet perimeter in the stream during the flood period.

3-1 木瓜溪沖積扇河水出入滲量測

- 溫度法
- 流速流量法

2013年共進行7次量測



流速流量初步結果

	2月7日	3月3日	6月18日	8月6日
仁壽橋流量	4.14±0.28		8.68±0.05	4.03±0.02
木瓜溪橋流量	1.57±0.10	1.96±0.05	9.73±0.03	2.22±0.08
入排			0.15±0.01	
光華街流量		1.53±0.04		
東華大橋流量	4.40±0.02	1.34±0.05	13.48±0.16	1.43±0.03
仁壽橋-木瓜溪橋流量	2.57		-1.05	1.81
長度×寬度	4200×27		4200×23	4200×28
入滲率	2.26×10^{-5}		-1.08×10^{-5}	1.54×10^{-5}
木瓜溪橋-光華街流量		0.43		
長度×寬度		2466×23		
入滲率		7.58×10^{-6}		
木瓜溪橋-東華大橋流量	-2.83	0.62	-3.6	0.79
長度×寬度	4866×24	4866×21	4866×29	4866×21
入滲率	-2.42×10^{-5}	6.06×10^{-6}	-2.52×10^{-5}	7.73×10^{-6}

	8 月 24 日	9 月 24 日	9 月 25 日
仁壽橋流量	13.78	156	128
木瓜溪橋流量	15.13	134(原始) 178(修正)	132(原始) 137(修正)
東華大橋流量	12.60(原始) 15.25(修正)		
仁壽橋-木瓜溪橋流量	-1.35	-22	-9
長度×寬度	4200×35	4200×250	4200×245
入滲率	-9.18×10^{-6}	-2.10×10^{-5}	-8.70×10^{-6}
木瓜溪橋-東華大橋流量	-0.12		
長度×寬度	4866×28		
入滲率	-8.97×10^{-7}		

註：流量 cms；長度 m 寬度 m；入滲率 m/s；正值為入滲、負值為出滲

Thank you for your attention