Hydrohill: A great public works created by Wei-Zu Gu for experimental hydrology

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Abstract

Hydrology has a long history due to its early origin, but it is still considered young due to lack of a solid scientific foundation as a natural science. To lay a solid foundation of hydrology, field experimentation is crucial for investigating hydrological processes and revealing hydrological mechanisms. Professor Wei-Zu Gu (1932–2022) was an internationally renowned scientist in the field of hydrology and is recognized as the greatest pioneer of experimental hydrology and isotope hydrology in China. He created the Hydrohill experimental catchment, which serves as both a great public works for experimental hydrology and a valuable legacy for future researchers to conduct hydrological experiments. This legacy represents an innovative infrastructure that bridges the gap between natural watershed experiments and artificial physical models. The Hydrohill is an intensively-instrumented experimental catchment, allowing for comprehensive measurement of elements of the hydrologic cycle and their tracing indicators in a sophisticated manner. To provide an in-depth understanding of the Hydrohill, this paper presents its short history, experimental objectives, site description (including location, construction, and instrumentation), site conditions (such as soil, hydrological and meteorological properties), and contributions to hydrologic science. We pay our respects to Professor Gu for his hard work in creating the Hydrohill for experimental hydrology and enhancing our understanding of hydrological processes and mechanisms. Finally, we hope that with healthy operation at Chuzhou Scientific Hydrology Laboratory (CSHL) along with support from Professor Gu's friends, CSHL will enable the continued growth of the Hydrohill so that it can address some unsolved problems in hydrology.

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FIGURE LEGENDS

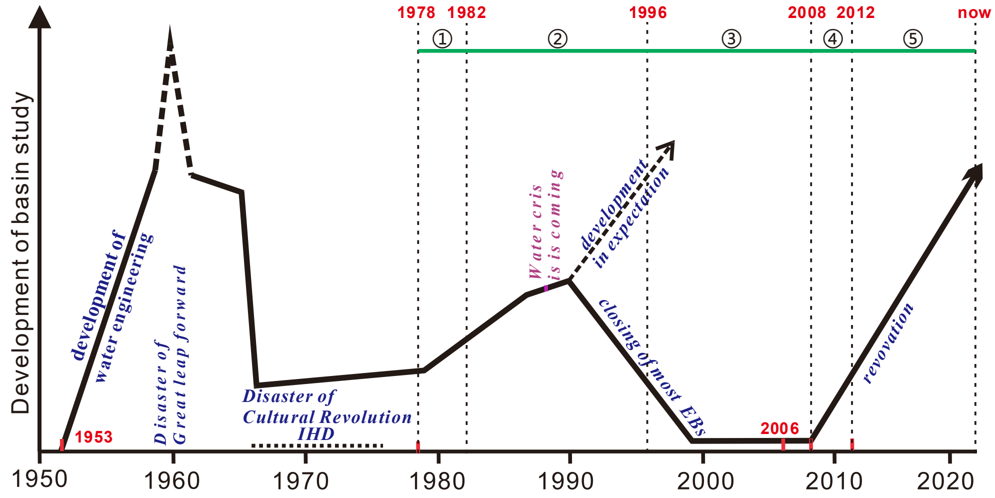

Figure 1. A short history of the Hydrohill with the development of basin study in China as its background. The green line denotes the development of the Hydrohill with five periods: ①the construction period, ②the first operation period, ③pause period, ④re-construction period, and ⑤the second operation period. Note that the development of basin study in China was often presented by Professor Gu to manifest the hardship of hydrologic experimental works.

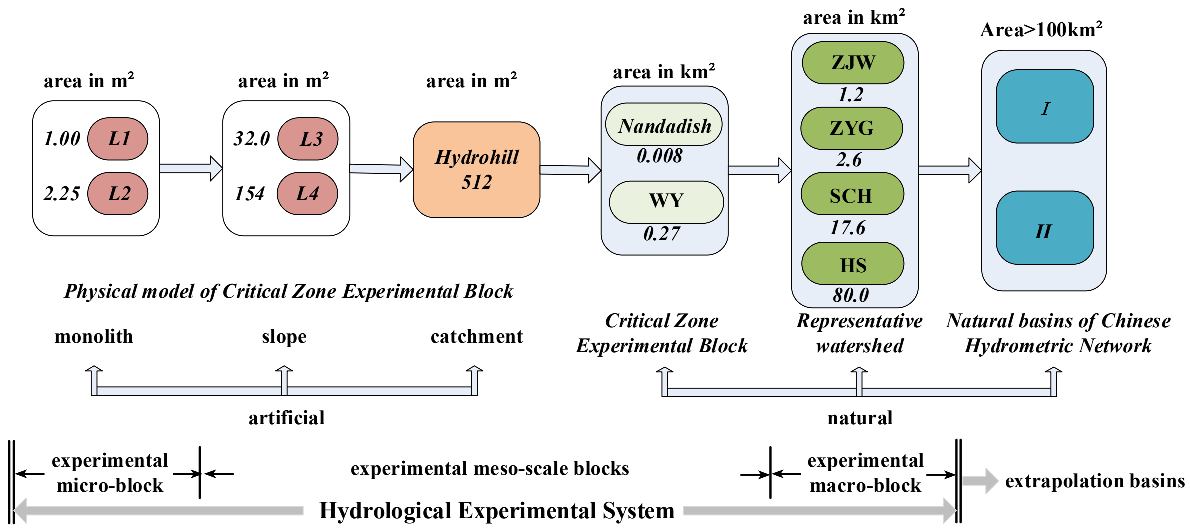

Figure 2. Scheme of Hydrological Experimental System (HES) in the Chuzhou Scientific Hydrology Laboratory (CSHL), China. Two intermediate scale catchments—a natural catchment called Nandadish and an artificial catchment called Hydrohill; L1 to L4, Lysimeters 1 to 4; WY, Wangying; ZJW, Zhangjiawa; ZYG, Zhuyuangou; SCH, Sanchahe; HS, Huashan; CZEB, Critical Zone Experimental Block. This figure is based on Gu *et al*. (2018).

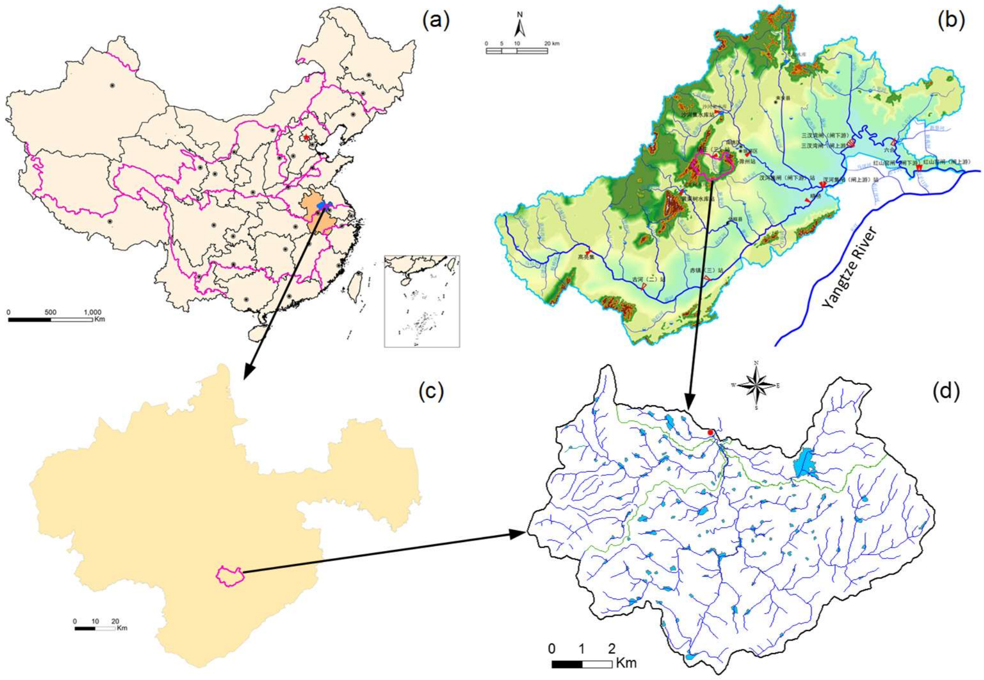

Figure 3. Location of Hydrohilll: (a) China; (b) Chuhe basin which is the first-order tributary of Yangtze River; (c) Chuzhou city with Hushan watershed in the middle south; (d) Hushan watershed with Hydrohill in the outlet (the red cycle).

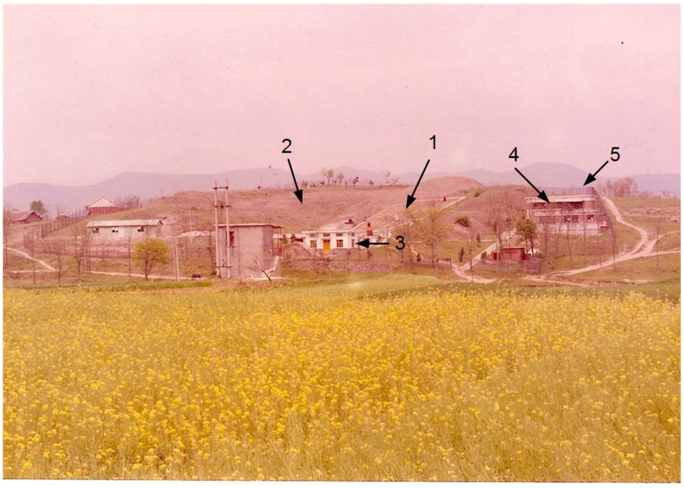

Figure 4. Site selection of the Hydrohill: 1-the Hydrohill experimental catchment; 2-the Morning-glory experimental catchment which includes the Hydrohill inside its domain; 3-the gauging room for measuring the separate runoffs of the Hydrohill and the total runoff of the Morning-glory experimental catchment; 4-the house has been named as Gu Residence because Mr. Gu Wei-Zu had stayed at this small house for a long time to conduct hydrological experiments in CSHL; 5-the fence acts as the boundary of the Hydrohill experimental field.

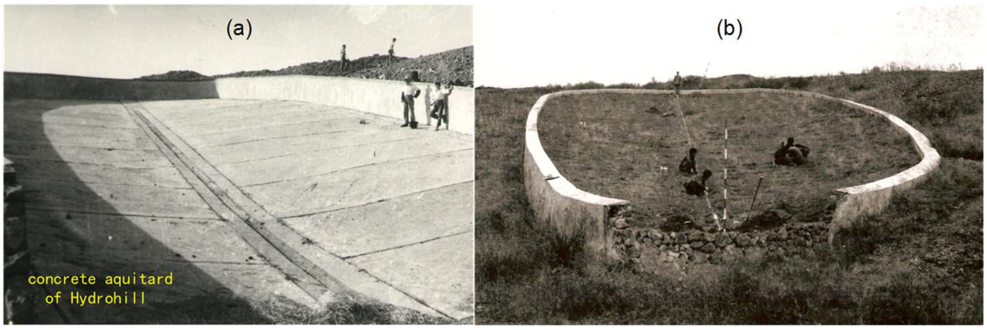

Figure 5. Constructions of Hydrohill: (a) the artificial aquiclude and surrounding wall; (b) view of the artificial catchment while soil was filled up, and it was in idle for 3 years and then the measuring sensors were installed.

Figure 6. Construction of groundwater monitoring well: (a) the slotted part of steel tube wrapped up by plastic net; (b) making clay balls for using; (c) during installing, the space between the tube and drilling hole above the slotted lengths should be carefully stuffed up by small dried clay balls using a special designed tool; (d) a part of resulted networks showing well for groundwater, access tube for neutron moisture gauge and the tensiometer with connection plastic tubes to the scanner.

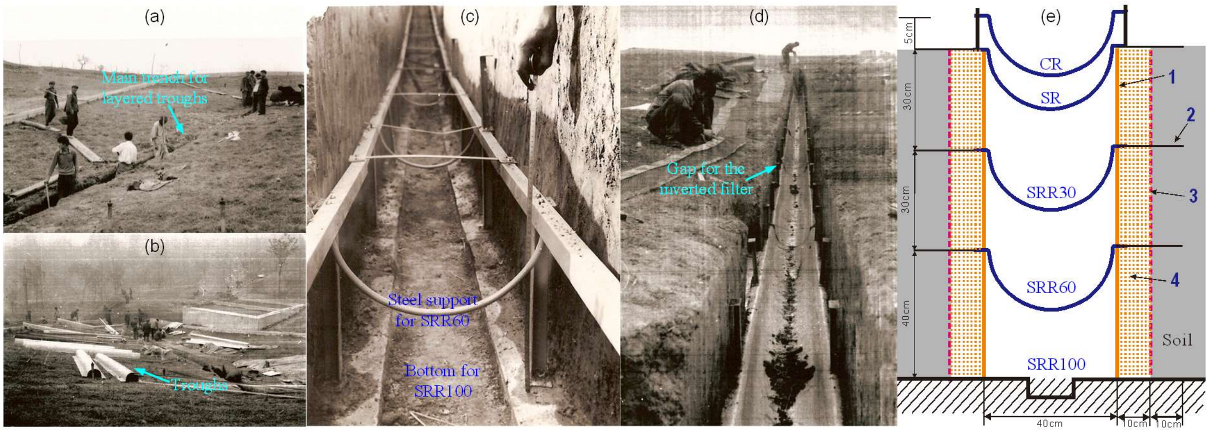

Figure 7. Construction of layered troughs for collecting separate runoffs: (a) excavate a drainage trench for layered troughs; (b) install splicing fiberglass troughs and steel supports; (c) the rectangular bottom trough for SSR100 and steel supports for SSR60 trough; (d) the gap for inverted filter and the nylon net in preparing; (e) scheme of layered troughs, CR-the channel for collecting rain, SR-surface runoff, SRR30, SRR60 and SRR100-subsurface runoffs generating from the soil layers at the depth of 0~30, 30~60 and 60~100 cm; 1-stainless steel screen (slots of 15×30 mm), 2-aluminum plate, 3-Nylon net (holes of 0.5-0.6 mm), 4-inverted filter of silica sand (0.1-1.0 mm inner side, 1.0-2.0 mm outer side).

Figure 8. Discharge measuring structures of version 1 (1982–1995): (a) a curved connection trough installed between the catchment outlet and the gauging room; (b) a curved connection trough in the gauging room; (c) combining V-notch and logarithm sharp crested weirs to measuring the discharge of the Hydrohill, SR-surface runoff, SRR30, SRR60 and SRR100-subsurface runoffs generating from the soil layers at the depth of 0~30, 30~60 and 60~100 cm.

Figure 9. The two versions of the Hydrohill: (a) the previous version (1982–1995) and renovation version (since 2012).

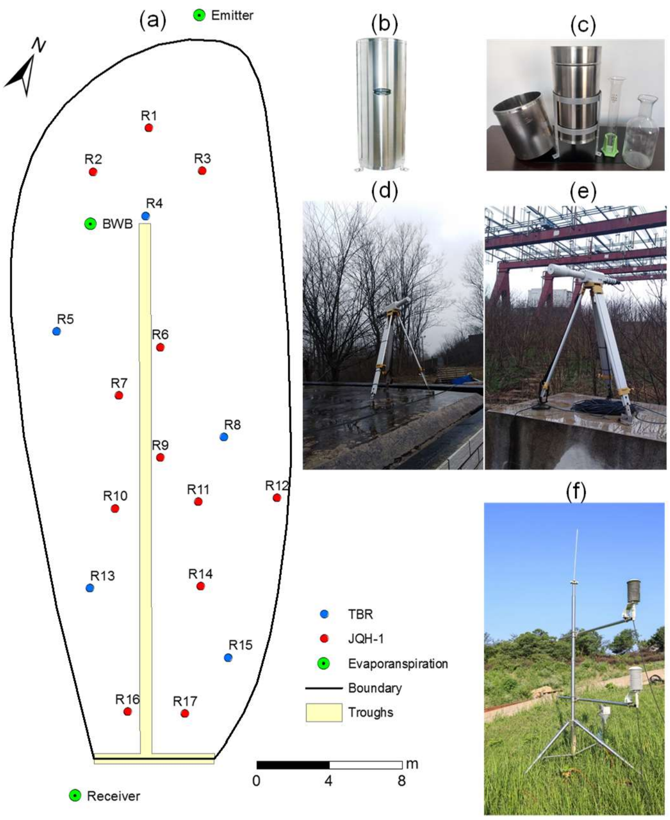

Figure 10. Precipitation and evaporation devices in the Hydrohill catchment: (a) Location; (b) tipping-bucket rain gauge; (c) standard rain gauge; (d) the receiver of small aperture scintillometer; (e) the emitter of small aperture scintillometer; (f) Bowen ratio and energy balance system (BWB).

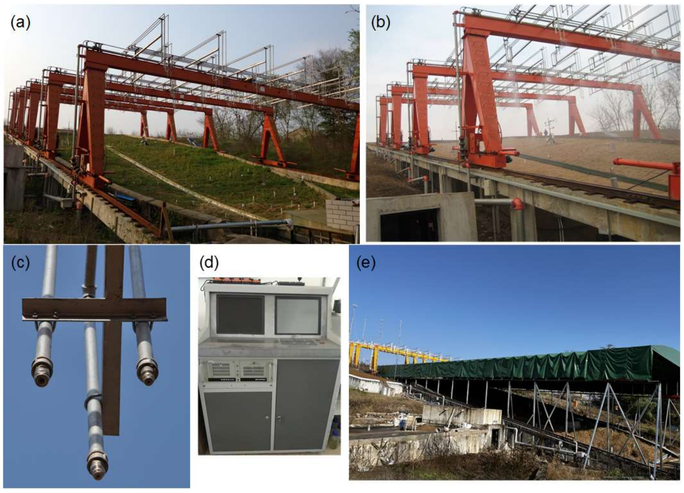

Figure 11. Rainfall simulator system and mobile canopy in Hydrohill: (a) before the rainfall simulating; (b) during the rain simulating; (c) combination of different sizes of sprinkle nozzles; (d) the rainfall simulator control platform located in the gauging room; (e) the mobile canopy.

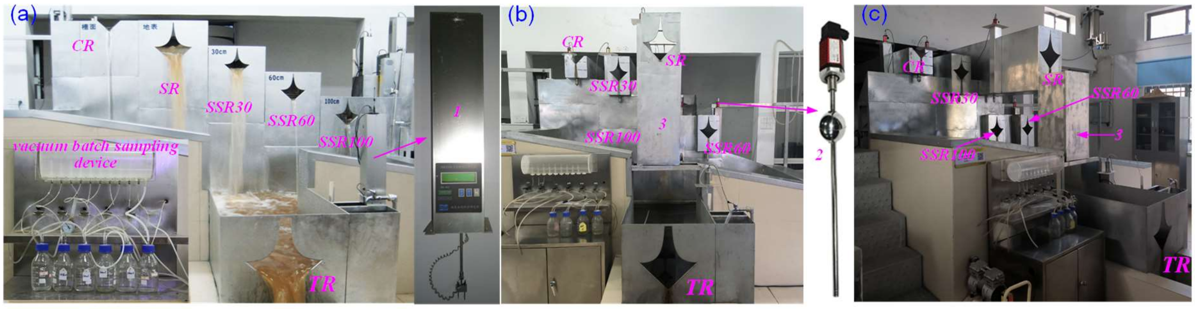

Figure 12. Runoffs measuring equipment since the reborn of CSHL: (a) version 2 of discharge measuring structure (2012–2022), 1-probing-needle water level gauge; (b) front view of discharge measuring structure version 3 (2022-), 2- magnetostriction water level gauges, 3-buffer box reducing the inference to the discharge measurement of the total runoff; (c) lateral view of discharge measuring structure version 3. CR-the channel for collecting rain, SR-surface runoff, SRR30, SRR60 and SRR100-subsurface runoffs generating from the soil layers at the depth of 0~30, 30~60 and 60~100 cm, TR-the total runoff.

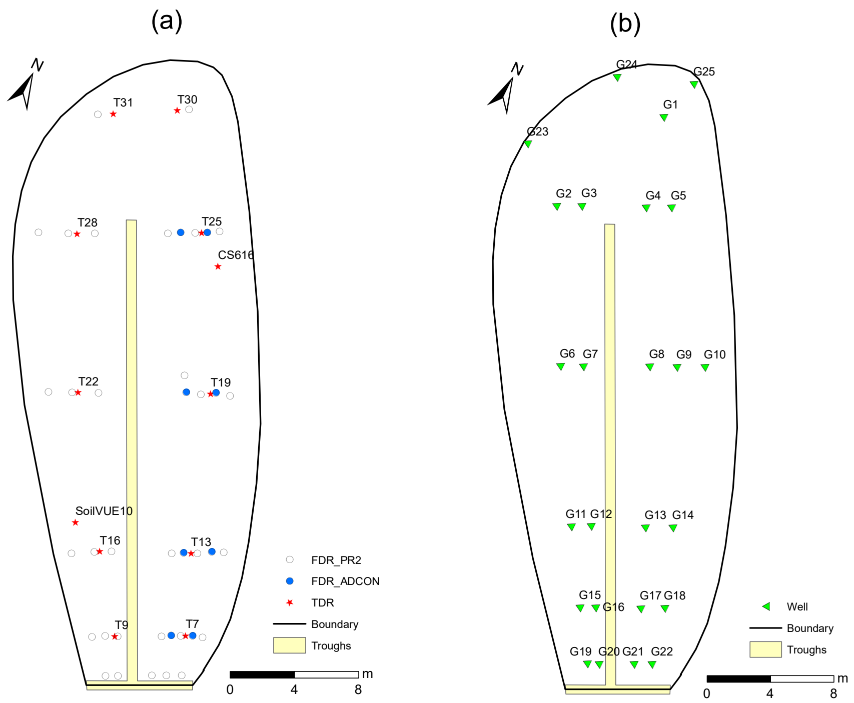

Figure 13 Soil moisture and groundwater level devices in the Hydrohill catchment: (a) Soil moisture sensor; (b) groundwater level sensor.

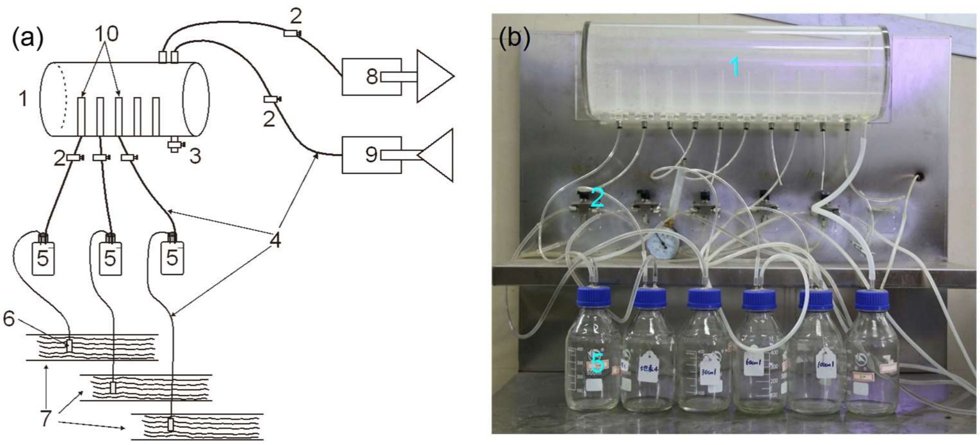

Figure 14. Separate runoff sampling in Hydrohill: (a) schematic of the batch sampling system including 1-the negative-pressure extender, 2-three-way valve, 3-safe valve to drain away water , 4-soft tubes, 5-water collecting bottle, 6-a stainless steel tube head enclosed by a yarn to stop sand and litter into the sampling tube, 7-troughs, 8-a vacuum pump, 8-an air compressor to keep the old water from soft tubes; (b) photo of a batch sampling system based on negative pressure.

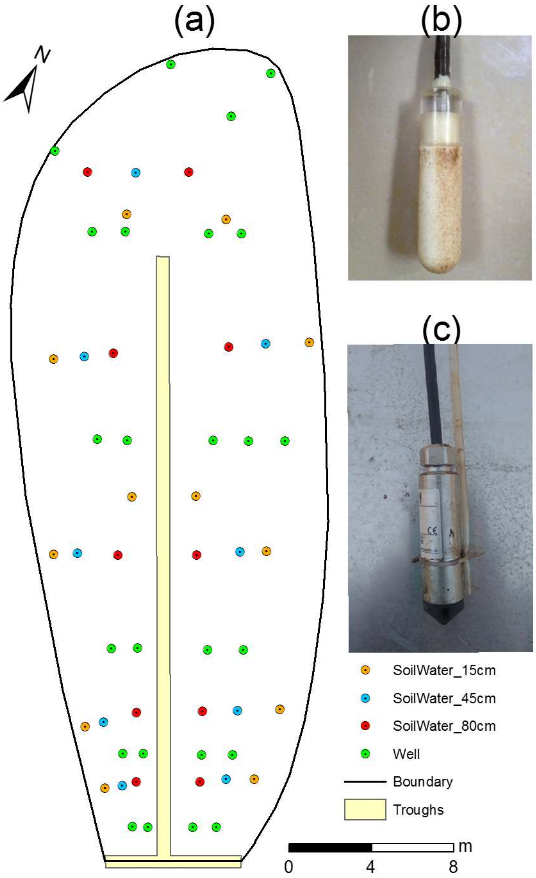

Figure 15. Soil water and groundwater sampling in Hydrohill: (a) locations of the sampling points of the soil water and groundwater; (b) photo of a suction lysimeter; (c) the tube previously fixed on the level sensor to sample groundwater.

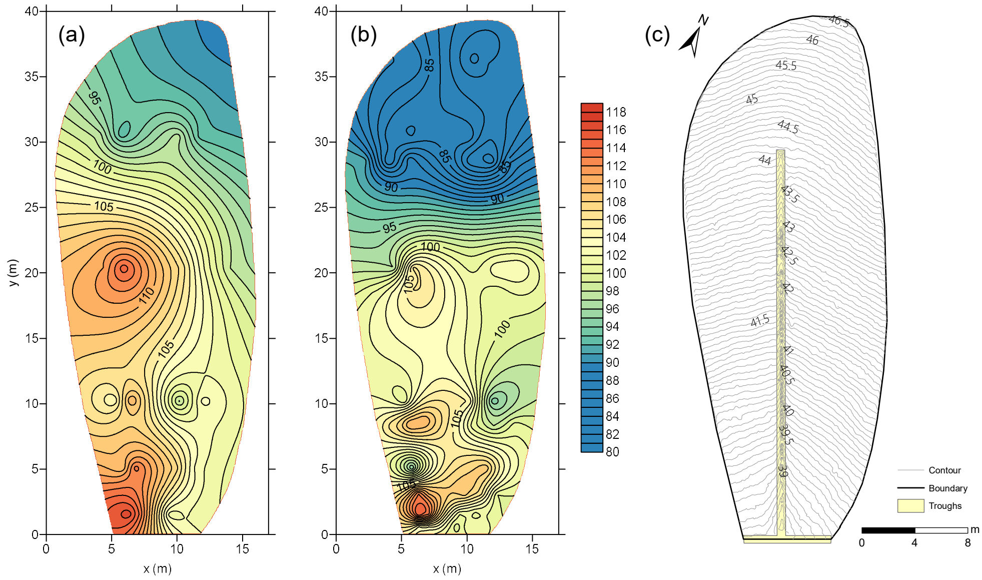

Figure 16. The soil thickness of Hydrohill in two year: (a) 1982, (b) 2018, (c) the topographic map in 2018 scanned with a 3D laser scanning system (Type: RIEGL VZ-1000).

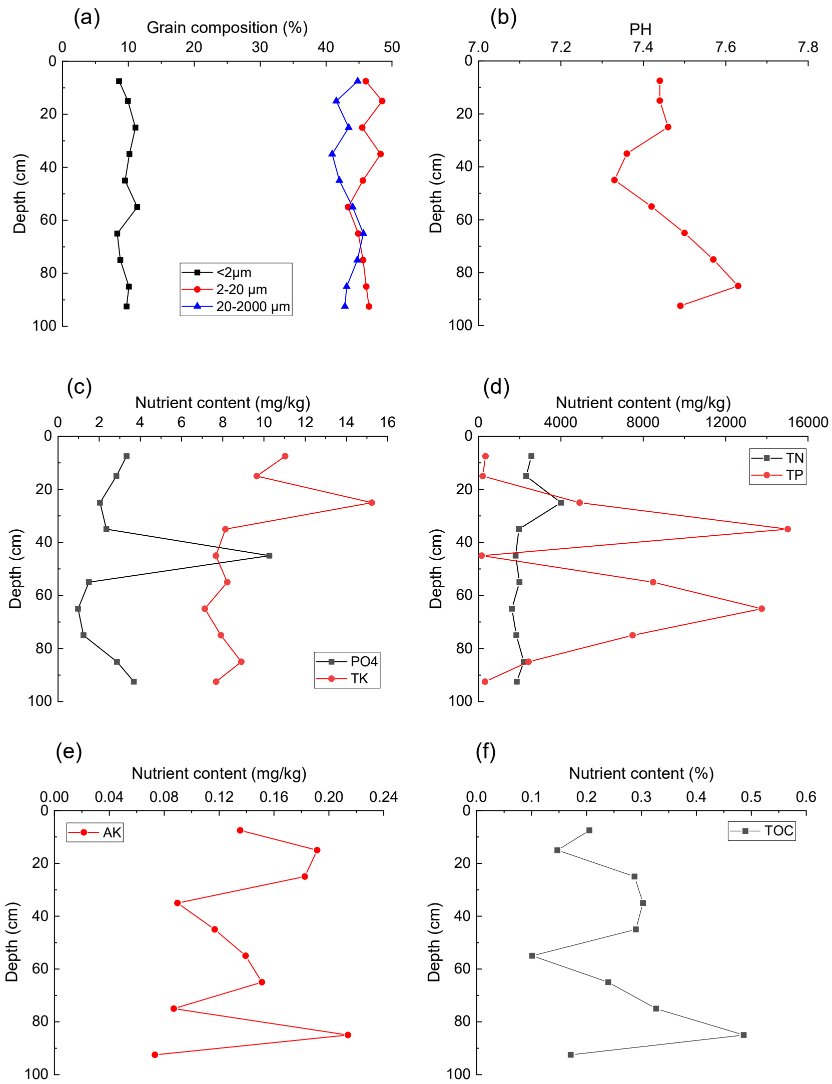

Figure 17. The distributions of soil parameters in different depths in the Hydrohill: (a) soil grain composition; (b) PH; (c) PO4 and total potassium (TK); (d) total nitrogen (TN) and total phosphorus (TP); (e) available potassium (AK); (f) total organic carbon (TOC).

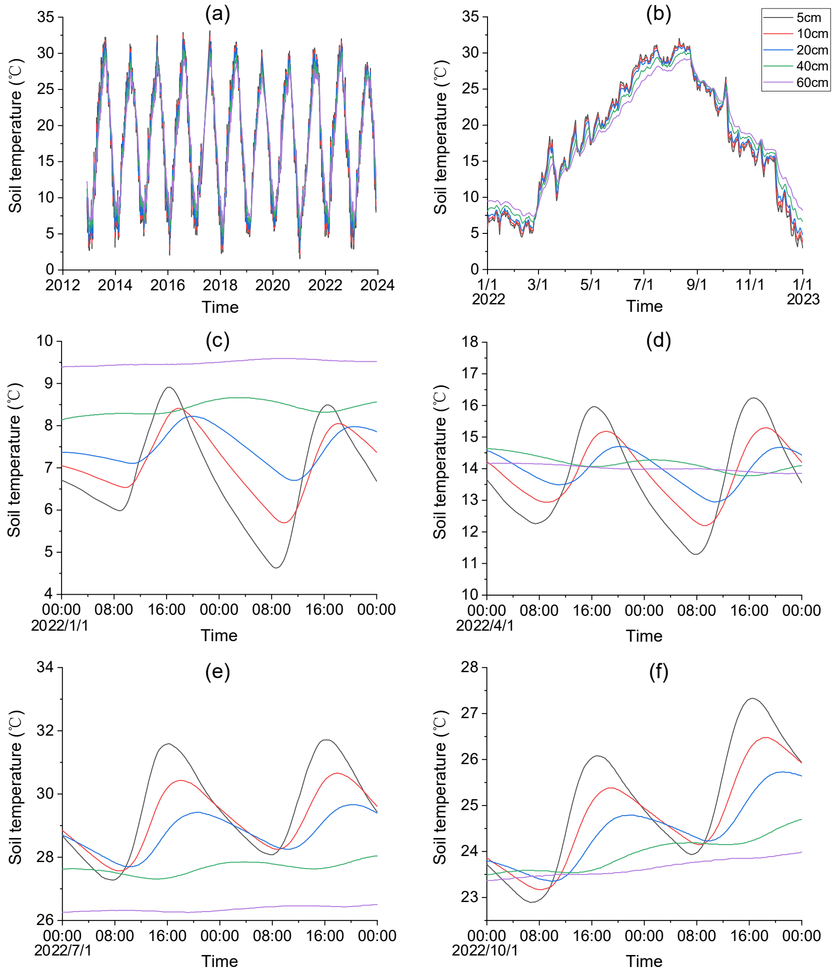

Figure 18. The soil temperature profile in the Hydrohill: (a) Interannual variability using the data of the daily mean soil temperature from 2012/12/1 to 2023/12/5; (b) Intra-annual variability using the data of the daily mean soil temperature in 2022; (c) daily variability in winter using the data of the 10-minute soil temperature from 2022/1/1 to 1/2; (d) daily variability in spring using the data of the 10-minute soil temperature from 2022/4/1 to 4/2; (e) daily variability in summer using the data of the 10-minute soil temperature from 2022/7/1 to 7/2; (f) daily variability in autumn using the data of the 10-minute soil temperature from 2022/10/1 to 10/2.

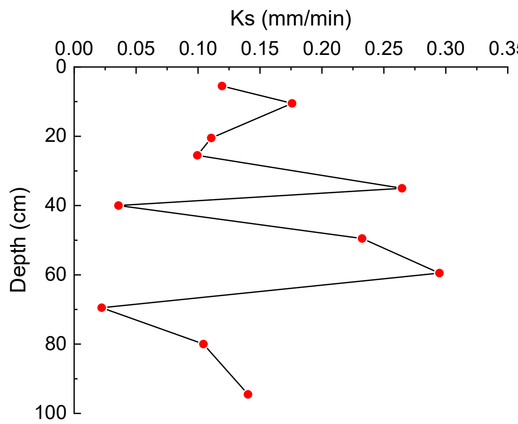

Figure 19. the distribution of saturated hydraulic conductivity (K_s) at a soil profile of the Hydrohill.

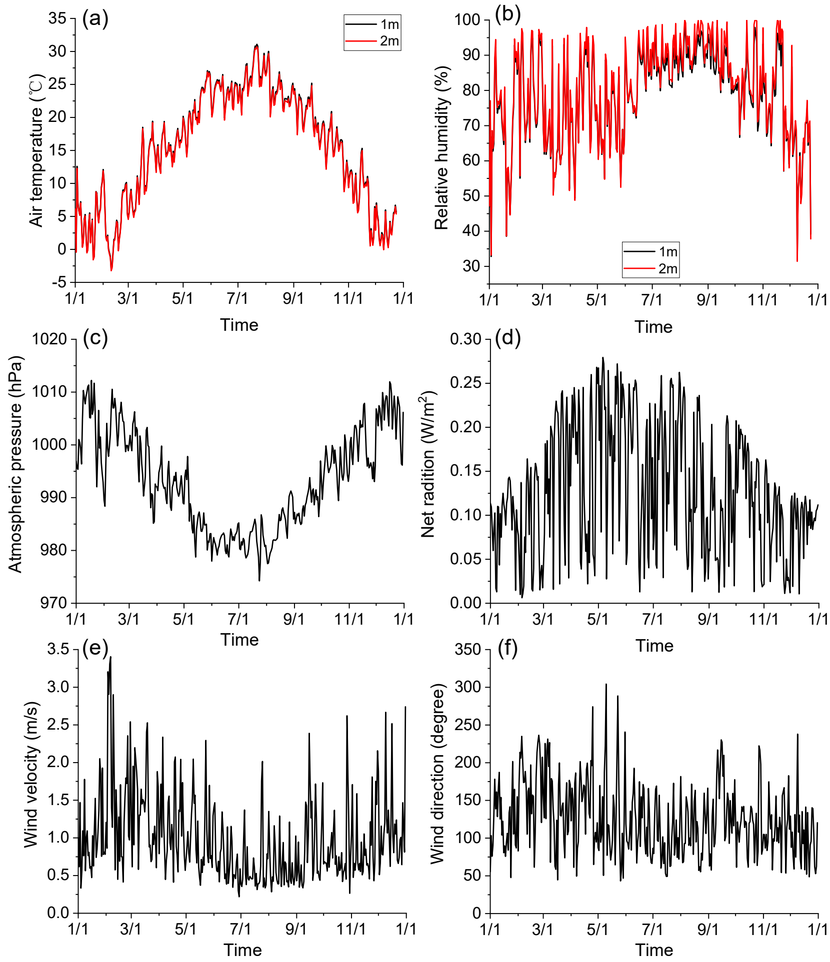

Figure 20. Meteorologic elements for the Hydrohill in 2014: (a) air temperature at 1 and 2 m; (b) air moisture at 1 and 2 m; (c) atmospheric pressure; (d) wind velocity; (e) wind direction; (f) net radition.

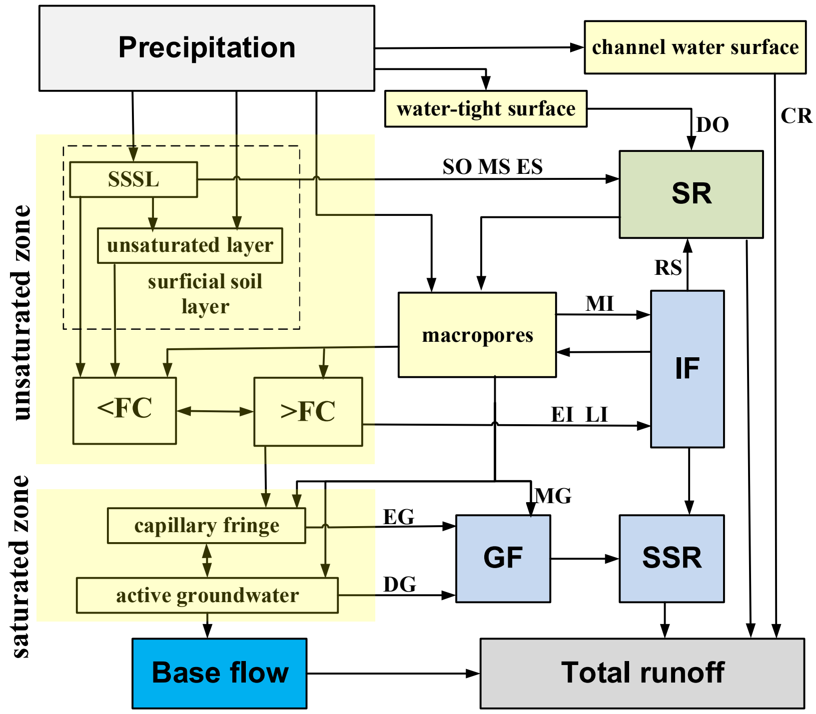

Figure 21. Runoff generation mechanisms system includes a classification of 11 runoff generation mechanisms. 4 types of surface runoff (SR): direct overland flow (DO) overland flow, saturated overland flow (SO), mixed-saturated surface runoff (MS), expellant saturated surface runoff (ES); 4 types of interflow (IF) from the unsaturated zone: piston-like expellant interflow (EI), lateral saturated interflow (LI), macropore interflow (MI), and return flow (RS);, and 3 types of groundwater flow (GF) from the saturated zone: Darcy (DG), expelled-saturated (EG), and macropore groundwater flow (MG); SSSL is a saturated surface soil layer, FC is field capacity. This figure is based on Gu *et al*. (2018).

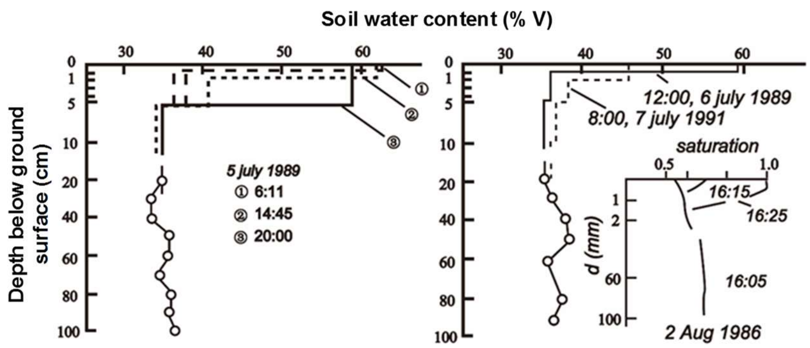

Figure 22. Example for identifying the thin saturated surface soil layer (TSSSL) in the Hydrohill. This figure is based on Gu *et al*. (2018).

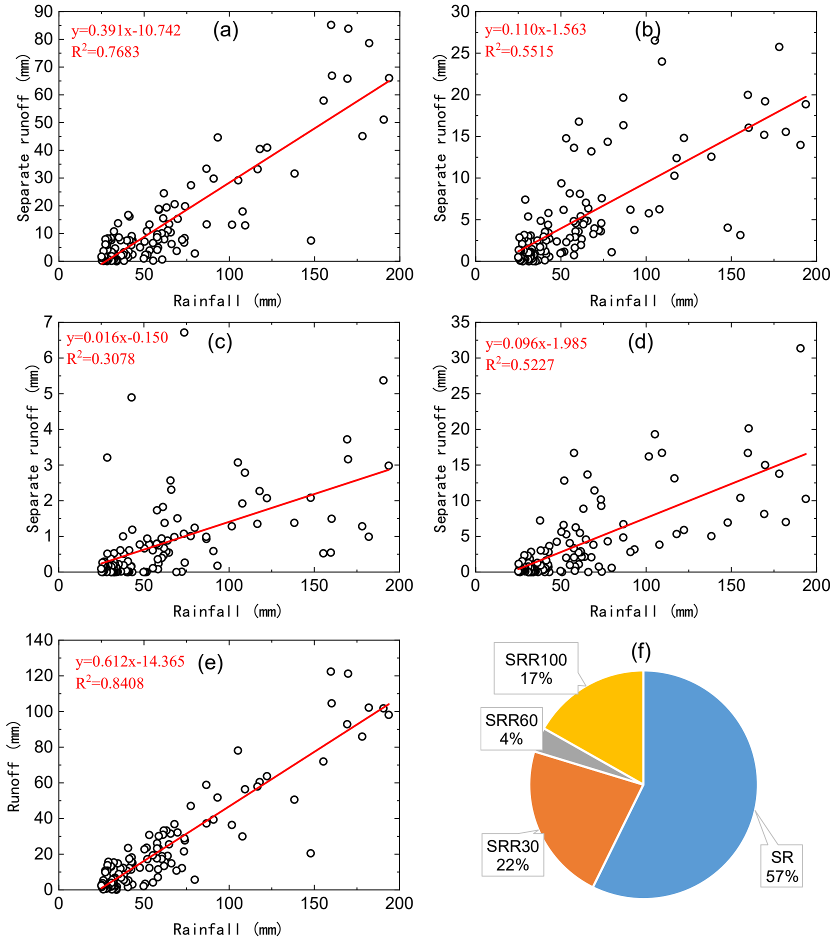

Figure 23. Rainfall-separate runoffs relation of the Hydrohill during 1982-1995 when event rainfall was greater than 25 mm. (a) SR is surface runoff; (b) SRR30 is the subsurface runoff from the soil layer at the depth of 0~30cm; (c) SRR60 is the subsurface runoff from from the soil layer at the depth of 30~60 cm; (d) SRR100 is the subsurface runoff from from the soil layer at the depth of 60~100 cm; (e) TR is the total runoff, (e) the proportions of the four separate runoffs.

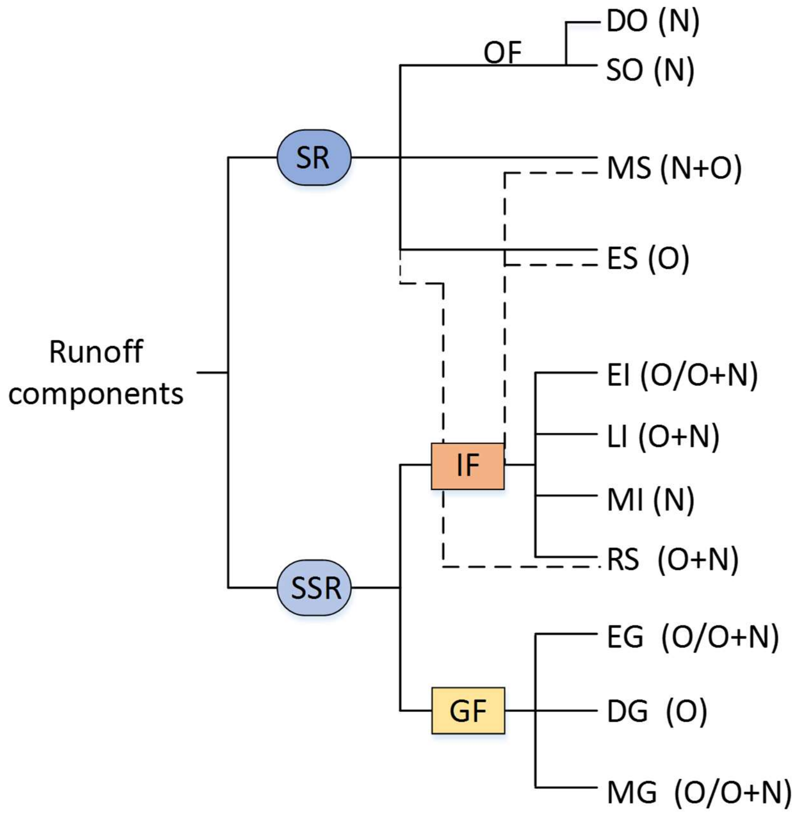

Figure 24. The occurrence pre-event water (O) and/or event water (N) in different types of runoff. SR: surface runoff, SSR: subsurface runoff; OF: overland flow, DO: direct overflow, SO: saturated overland flow, MS: mixed-saturated surface runoff, ES: saturated expellant surface runoff; IF: interflow from the unsaturated zone, EI: piston-like expellant interflow, LI: lateral saturated interflow, MI: macropore interflow, RS: return flow; GF: groundwater flow from the saturated zone, EG: expelled-saturated, DG: Darcy groundwater flow, MG: macropore groundwater flow. This figure is based on Gu *et al*. (1995).