

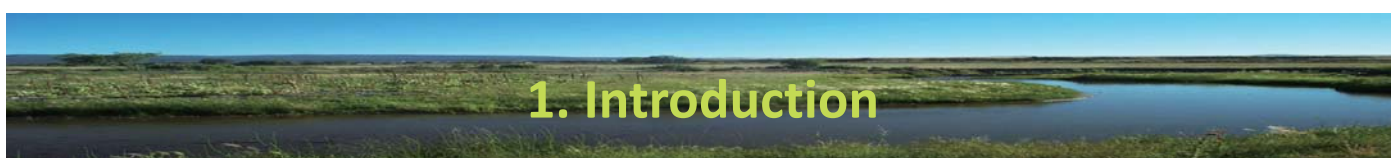
Borehole Hydrogeological Unit in Mountainous Region of Central Taiwan: A Case Study in Mid-Jhuoshuei River



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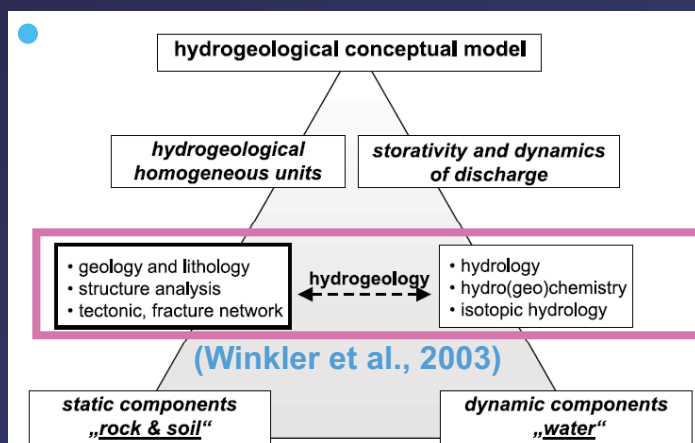
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1. Introduction

- **Central Geological Survey** initiated a full-scale project entitled **"Ground-water Resources Investigation Program for Mountainous Region of Taiwan(2010~2013)"**.

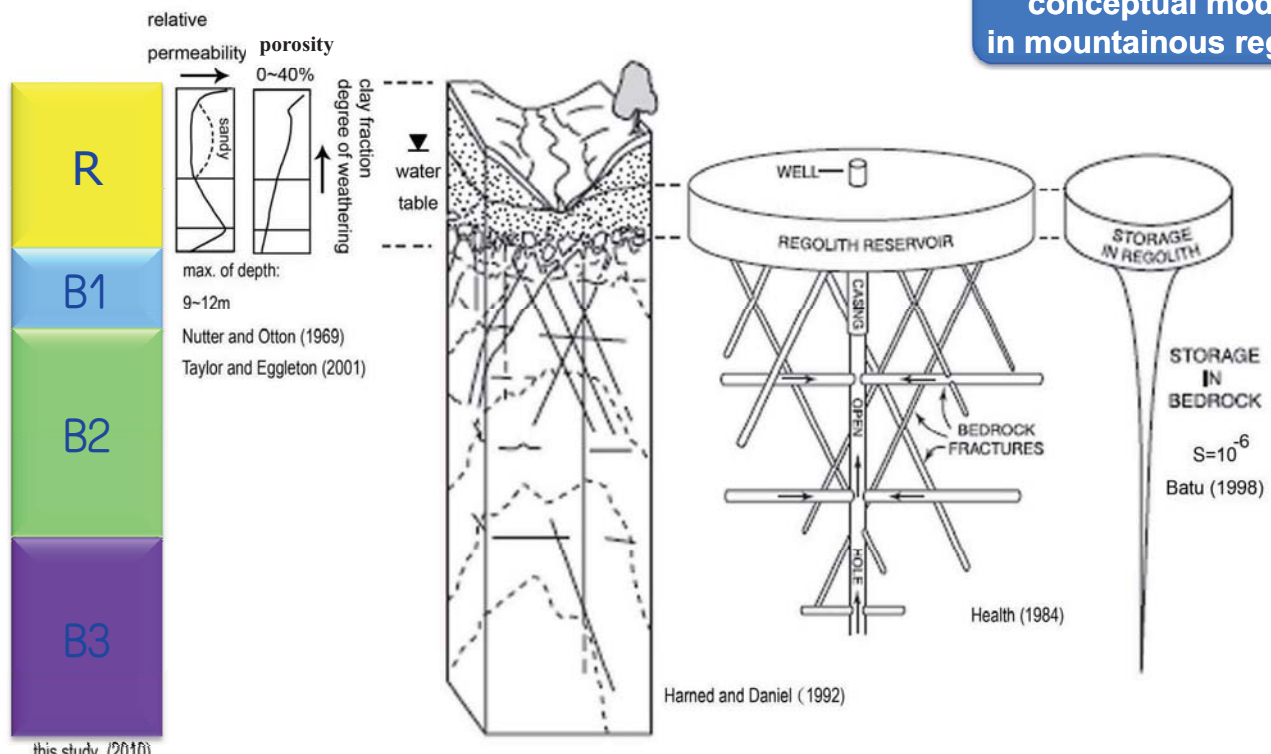
- 1.potential yield of ground-water resources
- 2.the amount of ground-water recharge
- 3.hydrogeological database



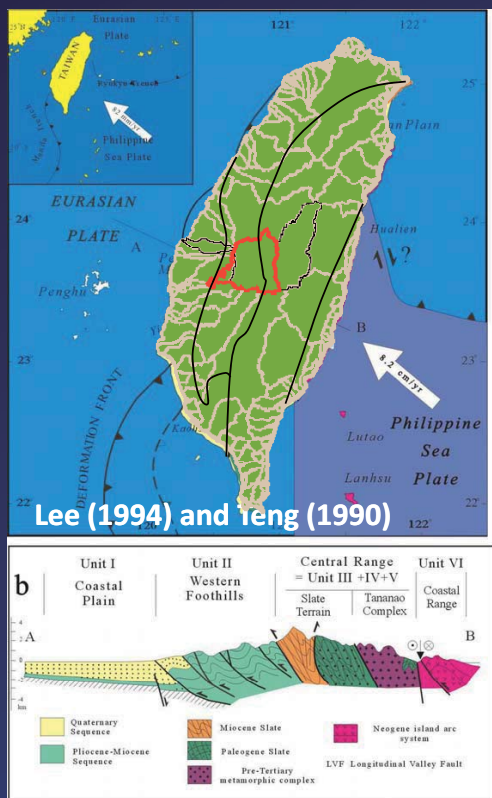
In this study
29 borehole data (2010)
Hydrogeological framework

1. Introduction

Groundwater conceptual model in mountainous region

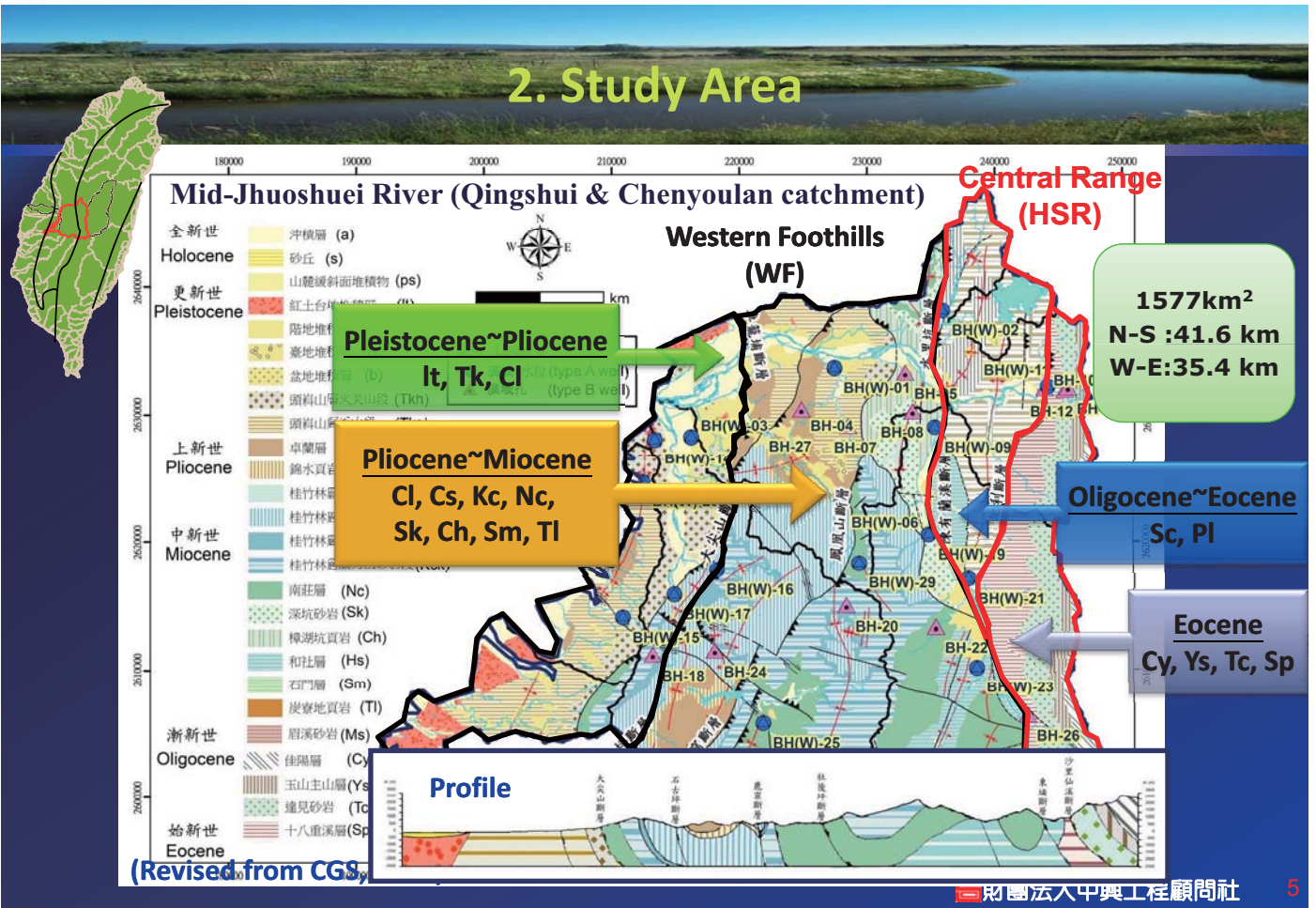


2. Study Area



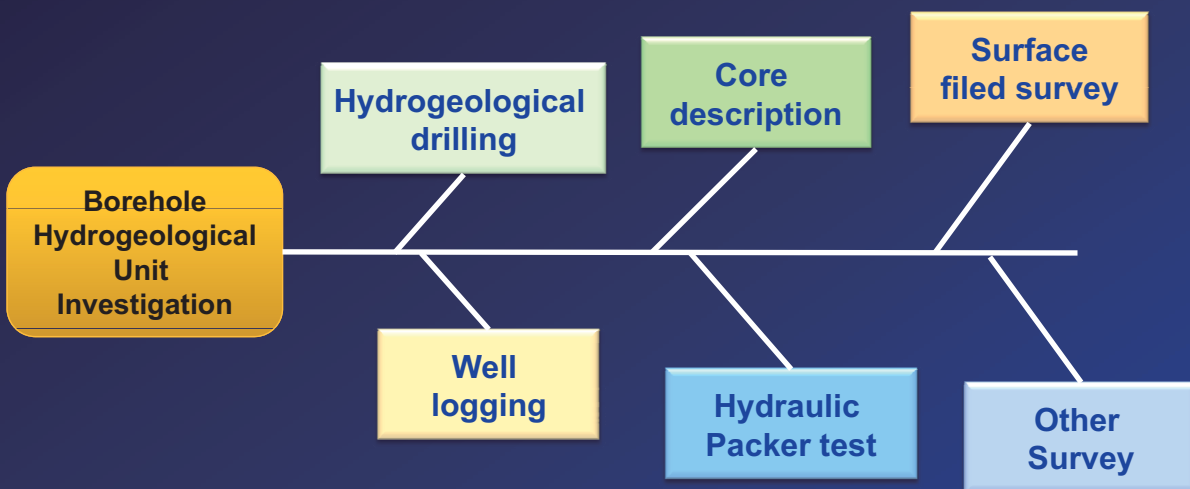
- **Philippine Sea Plate V.S. Eurasian Plate**
- **Overall geology of Taiwan:**
 1. Coastal Plain
 2. Western Foothills (WF)
 - (1) HSR
 - (2) WCR
 - (3) ECR
 4. Coastal Range

2. Study Area



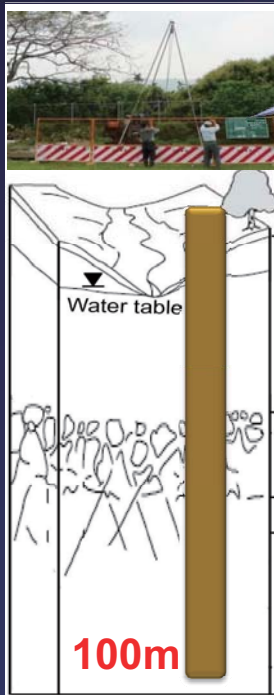
3. Methodology

❖ Work Items



3. Methodology

1. Hydrogeological drilling and core description



Drilling & Core record standards:

- Ministry of Economic Affairs Central Geologic Survey (CGS, MOEA)
- ISRM(1981) and others

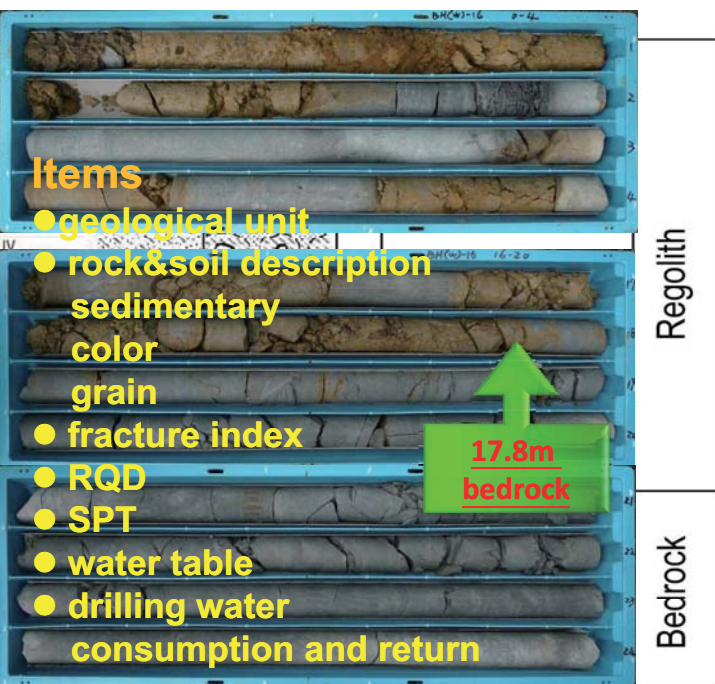
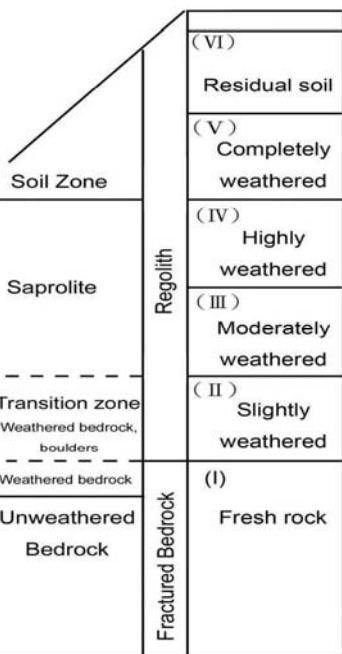
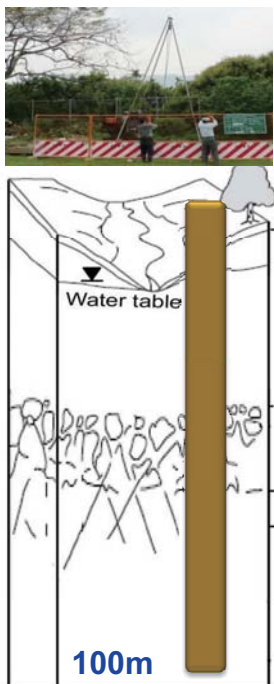
Engineering geology database:

- Geo2010

深度 (m)	地質描述	含水層	地下水位
0.00	黃褐色紅土層		
1.50	灰褐色粉砂質粘土，夾細砂，含生機化石與碎屑物		
4.20	綠色泥質粉砂質粘土，含細砂，含生機化石，含鐵質，含錳質		
8.00	灰色粉砂質粘土，含細砂，含生機化石，含鐵質，含錳質		
17.00	灰色粉砂，含泥質，含鐵質，含錳質		
20.00	38.60 灰色粉砂，含泥質，含生機化石與碎屑物，砂質泥		
26.80	49.40 灰色粉砂，含泥質，含生機化石		
49.40	67.80 灰色粉砂，含泥質，含生機化石，砂質粉砂，砂質泥		
67.80	76.40 灰色粉砂，含泥質，含生機化石，砂質粉砂，砂質泥		
76.40	100.00 灰色粉砂，含泥質，含生機化石，砂質粉砂，砂質泥		

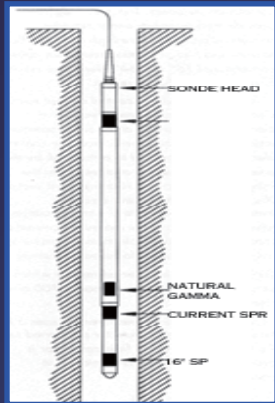
3. Methodology

1. Hydrogeological drilling and core description

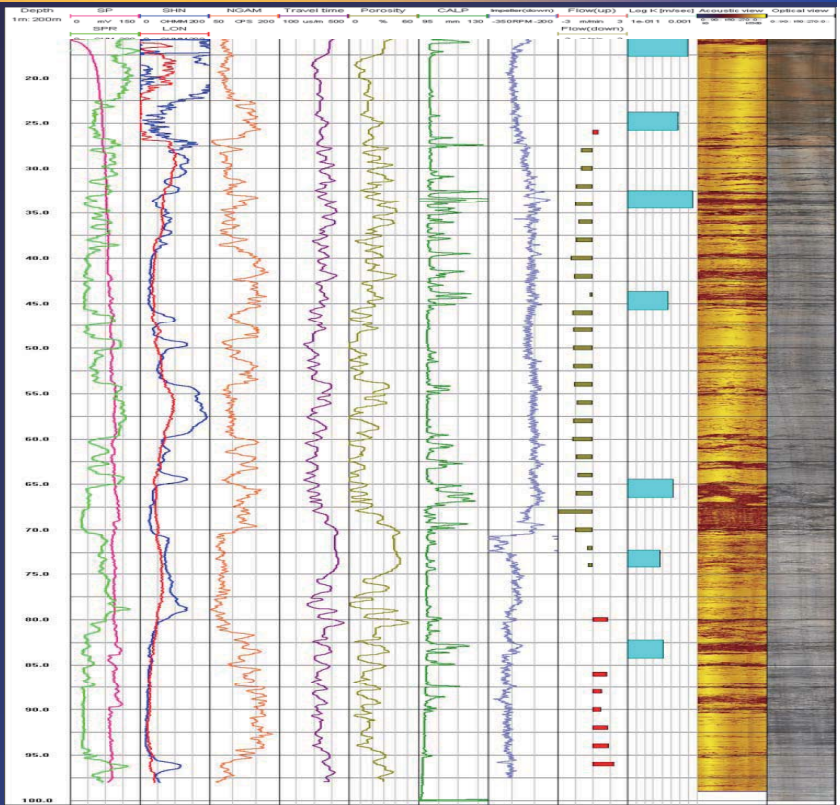


3. Methodology

2. Well logging

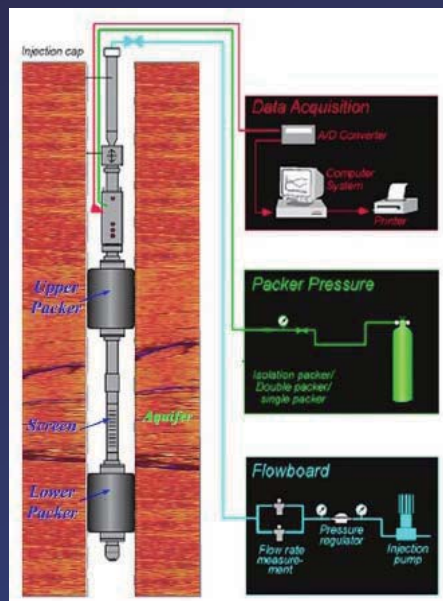


- Televiewer
- Caliper
- Electrical log
- Sonic log
- GW flow



3. Methodology

3. Hydraulic packer test



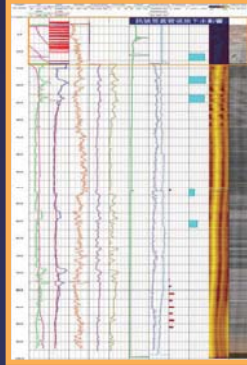
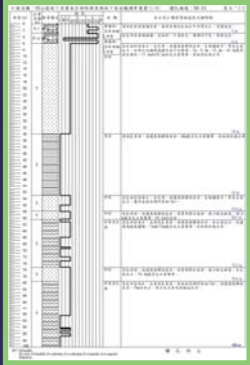
- (A) constant-flow tests
- (B) constant-head tests
- (C) slug tests
- (D) pressure pulse tests (NRC, 1996)

- hydraulic conductivity (K)
- storativity (S)

3. Methodology

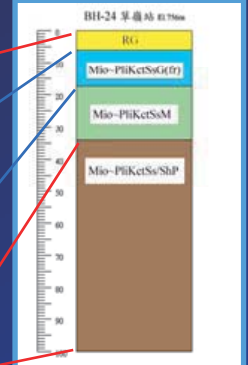
4. Borehole Hydrogeological Unit Delineation

Geological unit + Hydraulic properties = Hydrogeological unit & characteristics



BH-24		岩類	水文地質單元	水文地質描述	層序號	層厚度
0	2.0	砂	砂	砂	1	2.0
3	6.0	砂	砂	砂	2	3.0

Mio~Pli Kct Ss G (fr)



K (cm/s)	10^2	101	$10^0=1$	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	
K (ft/day)	105	10,000	1,000	100	10	1	0.1	0.01	
Relative Permeability	Pervious			Semi-Pervious					
Aquifer	Good			Poor			None		
Unconsolidated Sand & Gravel	Well Sorted Gravel	Well Sorted Sand or Sand & Gravel		Very Fine Sand, Silt, Loess, Loam					
Unconsolidated Clay & Organic				Peat	Layered Clay		Fat / Unweathered Clay		
Consolidated Rocks	Highly Fractured Rocks		Oil Reservoir Rocks	Fresh Sandstone	Fresh Limestone, Dolomite		Fresh Granite		

Bear (1972)

3. Methodology

5. Borehole Hydrogeological Unit Nomination



Example: BH-24 Mio~Pli Kct Ss G (fr) V.S. Mio Nc Ss/Sh G (fr)

① ② ③ ④ ⑤ ① ② ③ ④ ⑤

Mio~Pli, Kct, sandstone, with more fracture, K is good as a good aquifer.

3. Methodology

5. Borehole Hydrogeological Unit Nomination

1 geotime	2 stratum	3 rock type	4 aquifer	5 addition
全新世Holocene(Hol)	岩盤覆蓋層 Regolith(R)	礫石 gravel(Gv)	良好的含水層(G)	裂隙發達(fr)
更新世Pleistocene(Ple)	土壤soil(R-s)	砂岩 sandstone(Ss)	較差的含水層(M)	泥質成份高(mud)
上新世Pliocene(Pli)	填方backfill(R-b)	頁岩 shale(Sh)	極差的含水層(P)	
中新世Miocene(Mio)	崩積層 colluvium(R-c)	泥岩 Mudstone(Ms)		
漸新世Oligocene(Oli)	沖積層 alluvium(R-a)	砂頁互層 sandstone and shale(Ss/Sh)		
始新世Eocene(Eoc)	腐土岩 saprolite(R-sl)	板岩 slate(Sl)		
	風化岩塊 saprock(R-sr)	石英岩 quartz(Qtz)		
	盆地堆積層(b)			
	階地堆積層(t)			
	紅土地堆積層(lt)			
	頭嵛山層火災山礫岩(Tkh)			
	頭嵛山層香山砂岩(Tks)			
	卓蘭層(Cl)			
	錦水頁岩(Cs)			
	桂竹林層大窩砂岩(Kct)			
	桂竹林層十六份頁岩(Kcs)			
	桂竹林層關刀山砂岩(Kck)			
	南莊層(Nc)			
	深坑砂岩(Sk)			
	樟湖坑頁岩(Ch)			
	石門層(Sm)			
	炭寮地頁岩(Tl)			
	水長流層(Sc)			
	白冷層(Pl)			
	佳陽層(Cy)			
	玉山主山層(Ys)			
	十八重溪層(Sp)			

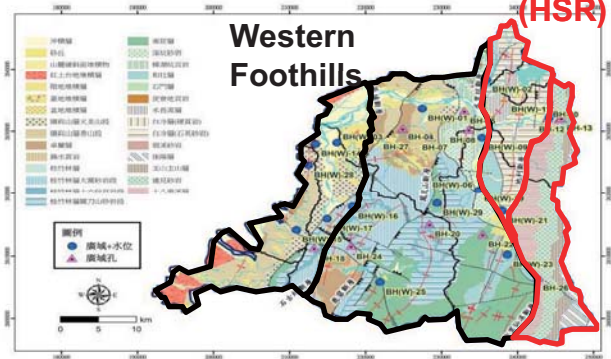
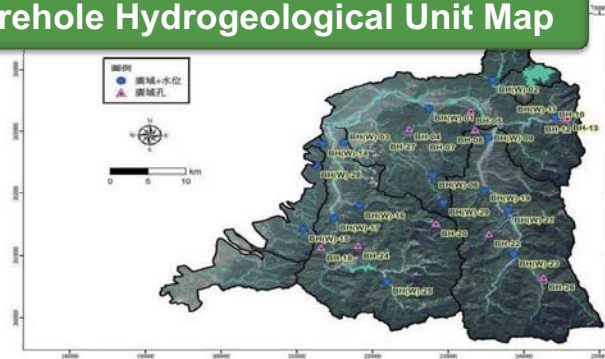
Lists of each element in this study

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4. Results and Discussions

Central Range

Borehole Hydrogeological Unit Map



4. Results and Discussions

Geology

link to

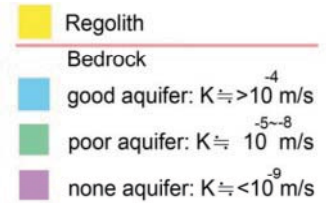
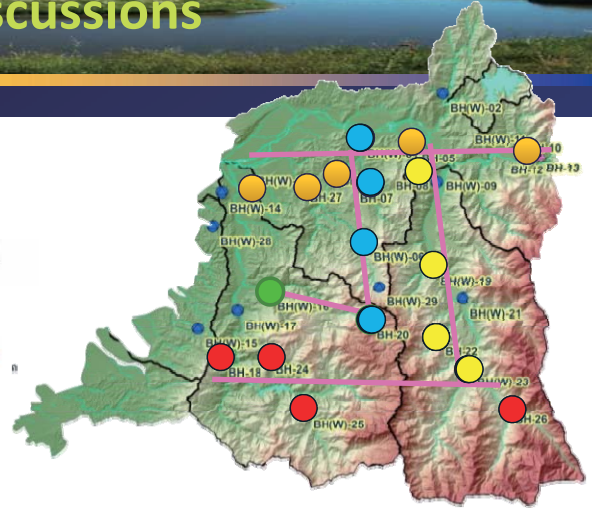
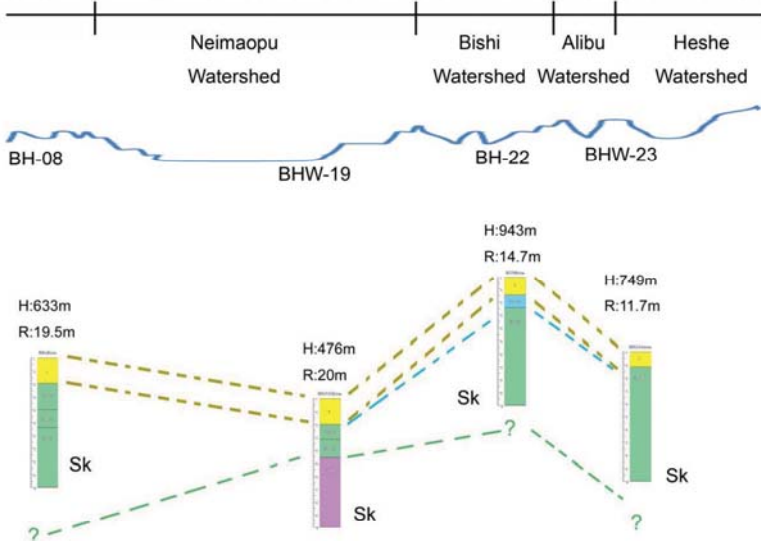
Hydrogeology

Table: Geological and Hydrogeological Characteristics in the study area

Geological time	Geological unit (stratum)		Hydrogeological unit		K (m/s)	Porosity (%)	Well yield (L/min)	Lithologic Description		
			Rock type	Aquifer						
Quaternary	Holocene	Regolith	Regolith	good				崩積層、崩積岩或風化岩塊等，淘選度較差的，較多破碎帶，土壤、沖積層或崩積層等岩層或岩塊，含泥質較多，透水性較差。		
			Regolith	poor				土壤或崩積層等基質為泥質或細砂，透水性極差。		
			Regolith	none					紅土或夾中至粗礫岩層，現地推估孔隙率在20~40%，透水性較差。	
Neogene (Neogene)	Pleistocene	紅土台地堆積層(H)	gravel	poor	N.A	20~40%	N.A	紅土或夾中至粗礫岩層，現地推估孔隙率在20~40%，透水性較差。		
			頭嵛山層	火炭山礫岩(Tkh)	gravel	poor	$7.0 \times 10^{-7} \sim 1.2 \times 10^{-8}$	10~50% (gravel:20~40%, with mud:20~25%)	21.67, 62.76	黃灰色或黃棕色礫石、砂與泥為主，膠結度與淘選度差，現地推估孔隙率約10~50%，礫石層較高，約20~40%，含泥質的區段約20~25%，滲水係數約 $7.0 \times 10^{-7} \sim 1.2 \times 10^{-8}$ m/s，透水性較差。
				香山砂岩(Tks)	sandstone	poor	$1.7 \times 10^{-6} \sim 2.4 \times 10^{-8}$	30~50%	11.67, 22.8	黃灰色細至粗砂與灰色黏土為主，間夾細礫岩層，淘選度與膠結度差，膠結良好，裂隙發育，裂隙有泥質填充。
		Pliocene	卓蘭層(CI)	sandstone	poor	$6.4 \times 10^{-8} \sim 4.4 \times 10^{-10}$	20~60%	N.A	灰色細至粗砂與泥質砂岩或互層，淘選度及膠結良好，裂隙發育。	
				sandstone&shale	poor	$4.1 \times 10^{-5} \sim 4.7 \times 10^{-8}$	10~60% (coarse sand: <20%)	N.A	灰褐色至灰色砂岩為主，間夾泥質砂岩，或暗灰色頁岩與灰色細砂岩。	
				sandstone	poor	$1.8 \times 10^{-8} \sim 2.5 \times 10^{-10}$	<40%	N.A	灰色細砂岩為主，含泥質，淘選度與膠結良好，生物擾動多，裂隙發育。	
	Miocene	桂竹林層	大窩砂岩(Kct)	sandstone	poor	$6.2 \times 10^{-5} \sim 5.5 \times 10^{-7}$	<30%	0.6, 5.8, 6.8	灰色細砂岩為主，含泥質，淘選度與膠結良好，生物擾動多，裂隙發育。	
				sandstone	poor	$5.2 \times 10^{-5} \sim 1.4 \times 10^{-7}$	<15%		灰色細砂岩為主，含泥質，淘選度與膠結良好，生物擾動多，裂隙發育。	
				sandstone&shale	poor	$9.0 \times 10^{-8} \sim 1.0 \times 10^{-8}$	20% (fracture zone: 20~45%)		灰色細砂岩為主，含泥質，淘選度與膠結良好，生物擾動多，裂隙發育。	
		南莊層(Nc)	關湖山砂岩(Kck)	sandstone&shale	poor	1.6×10^{-7}	<20%		灰色中砂岩為主，間夾薄層頁岩，膠結良好，裂隙易沿層理發育。	
				sandstone&shale	poor	1.8×10^{-9}	<15%		灰色中砂岩為主，含泥質，淘選度與膠結良好，含生機化石。	
				sandstone	good	$1.8 \times 10^{-4} \sim 1.9 \times 10^{-5}$	<10% (middle sand: 20~60%)	N.A	灰色極細細砂岩，膠結良好，有明顯生機化石與生物擾動現象。	
	南莊層(Nc)	南莊層(Nc)	南莊層(Nc)	sandstone	poor	4.9×10^{-6}	<10%	310	暗灰色極細細砂岩，上層受到強烈生物擾動而形成有殘存生機化石。	
				sandstone	poor	$5.8 \times 10^{-8} \sim 3.6 \times 10^{-10}$	<10%		灰色中砂岩為主，間夾薄層頁岩，膠結良好，裂隙易沿層理發育。	
				sandstone&shale	poor	1.6×10^{-7}	<20%		灰色中砂岩為主，含泥質，淘選度與膠結良好，生物擾動多，裂隙發育。	
南莊層(Nc)		南莊層(Nc)	南莊層(Nc)	sandstone	good	$2.9 \times 10^{-4} \sim 1.2 \times 10^{-5}$	<20% (fracture zone: 40~60%)	310	灰色極細細砂岩，膠結良好，有明顯生機化石與生物擾動現象。	
				sandstone&shale	poor	$2.3 \times 10^{-6} \sim 7.0 \times 10^{-8}$	<20% (fracture zone: 40~60%)		暗灰色極細細砂岩，上層受到強烈生物擾動而形成有殘存生機化石。	
				sandstone	good	$1.1 \times 10^{-4} \sim 9.1 \times 10^{-6}$	<10% (fracture zone: 10~40%)		灰色中砂岩為主，間夾薄層頁岩，膠結良好，裂隙易沿層理發育。	
南港層(和社層)	南港層(和社層)	南港層(和社層)	sandstone	poor	$1.1 \times 10^{-5} \sim 1.1 \times 10^{-8}$	<50%	40, 88.3	灰色厚層細砂岩，淘選度良好，膠結中等，以及緻密深灰色砂岩。		
			sandstone	poor	$3.3 \times 10^{-7} \sim 2.1 \times 10^{-10}$	20~40%		灰色厚層細砂岩，淘選度良好，膠結中等，以及緻密深灰色砂岩。		
			sandstone&shale	poor	$7.1 \times 10^{-6} \sim 2.1 \times 10^{-7}$	<10% (fracture zone: <50%)		灰色厚層細砂岩，淘選度良好，膠結中等，以及緻密深灰色砂岩。		
南港層(和社層)	南港層(和社層)	南港層(和社層)	sandstone	poor	$2.9 \times 10^{-7} \sim 2.9 \times 10^{-7}$	40~55%	11.85	灰色厚層細砂岩，淘選度良好，膠結中等，以及緻密深灰色砂岩。		
			shale	poor	$5.3 \times 10^{-9} \sim 1.4 \times 10^{-10}$	<20%		灰色厚層細砂岩，淘選度良好，膠結中等，以及緻密深灰色砂岩。		
			shale	poor	$6.7 \times 10^{-9} \sim 1.5 \times 10^{-10}$	<25%	8.08	暗灰色厚層頁岩與粉砂岩，淘選度及膠結良好，多處有剪裂帶。		
Pleistocene	Pleistocene	Pleistocene	shale	poor	$3.2 \times 10^{-5} \sim 2.3 \times 10^{-8}$	<10%	106.94	淺灰色極細細砂岩與頁岩互層，淘選度及膠結良好，有較多的剪裂帶。		
			quartzite	poor	$5.6 \times 10^{-5} \sim 4.9 \times 10^{-7}$	<15% (fracture zone: 20~40%)		灰色細砂岩，下層夾深灰色頁岩，淘選度與膠結良好，有較多的剪裂帶。		
			quartzite	poor	$5.4 \times 10^{-5} \sim 2.3 \times 10^{-8}$	<5%	N.A	淺褐色至灰色中粗礫岩，淘選度及膠結良好，有較多的剪裂帶。		
			slate	poor	1.6×10^{-6}	<5%	706.67	暗灰色板岩，岩質新鮮，剪裂面發達，裂隙多石英填充，有結核。		

4. Results and Discussions

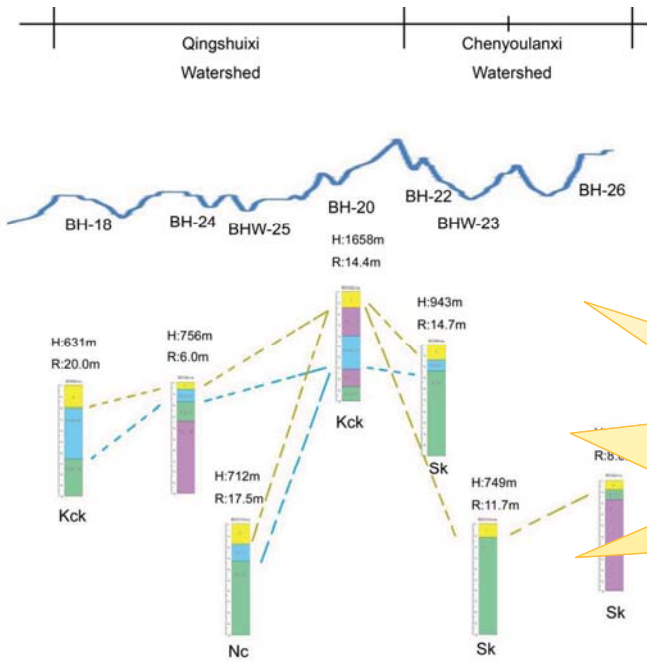
Hydrogeological Framework



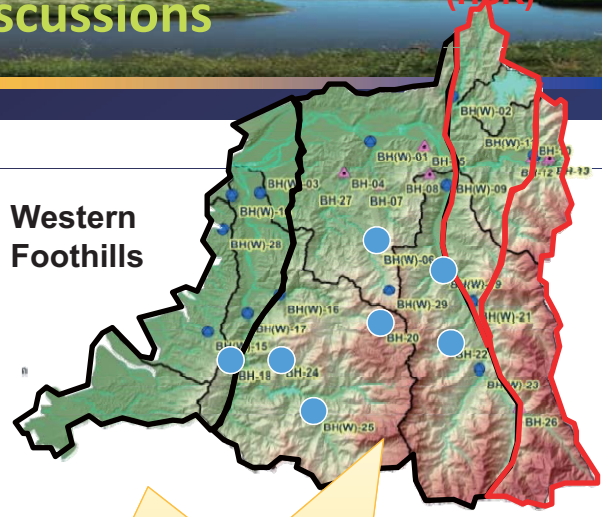
4. Results and Discussions

Central Range (HSR)

Hydrogeological Framework



Western Foothills



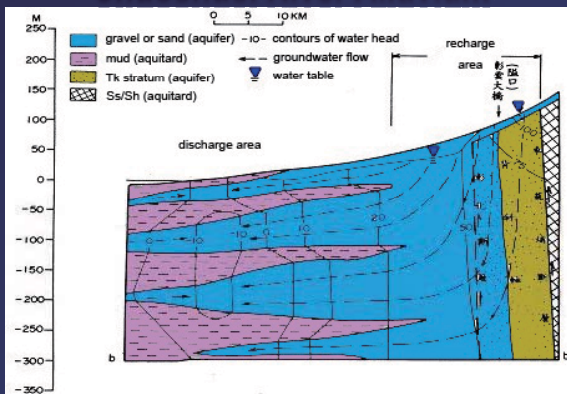
4. Results and Discussions

Central Range

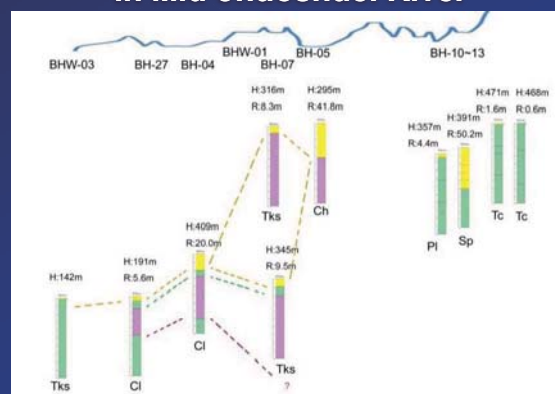
Hydrogeological Framework

Coastal Plain | Western foothills

Jhuoshuei River Alluvium



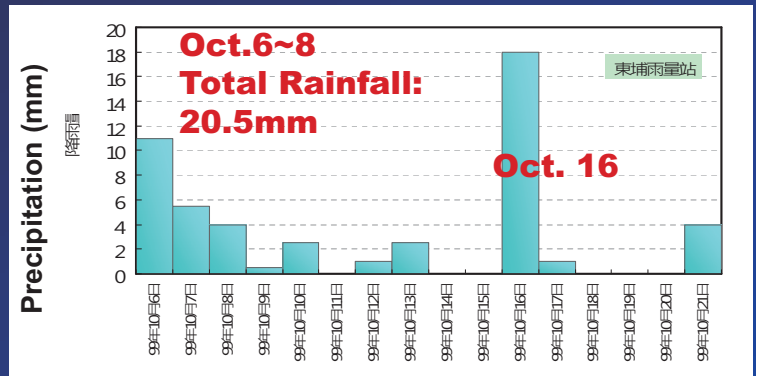
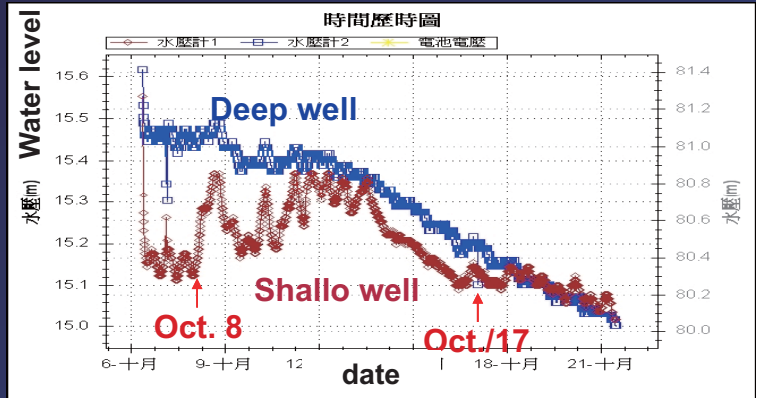
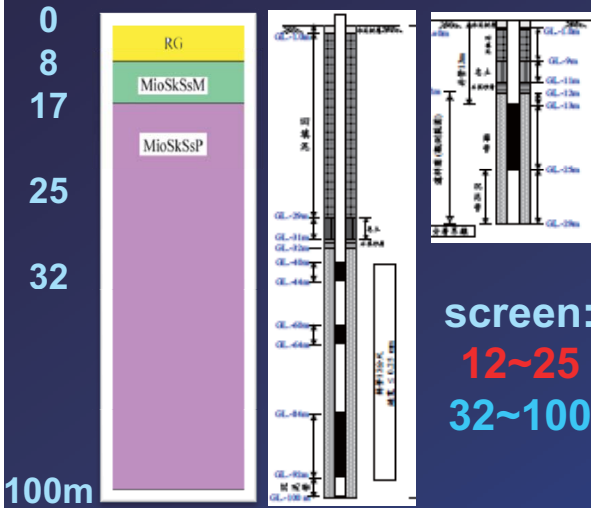
Mountain Region in Mid-Jhuoshuei River



4. Results and Discussions

Applications

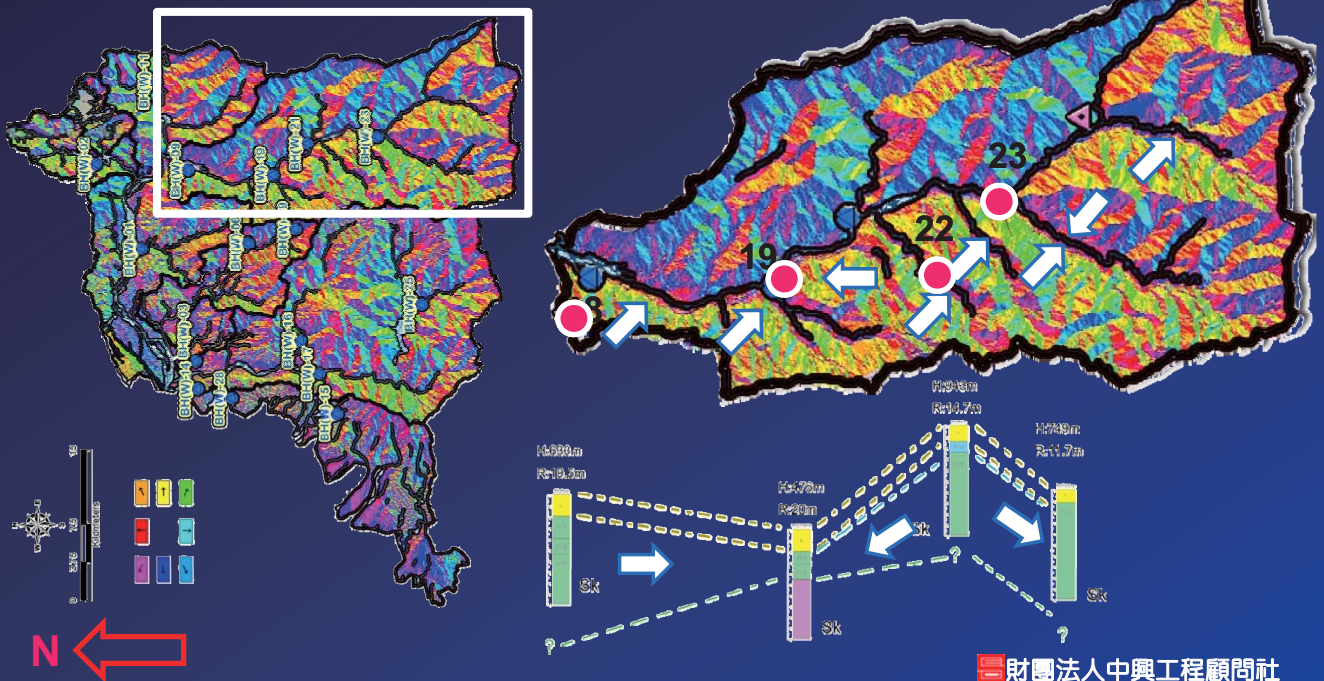
BH-26 station
 Elevation: 1172m
 Regolith: 8m



4. Results and Discussions

Applications

Groundwater flow direction



Thanks for Your Attention !



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