Local-Scale Groundwater Modeling of Fractured Rock Aquifer in Mid-Taiwan Mountainous Region

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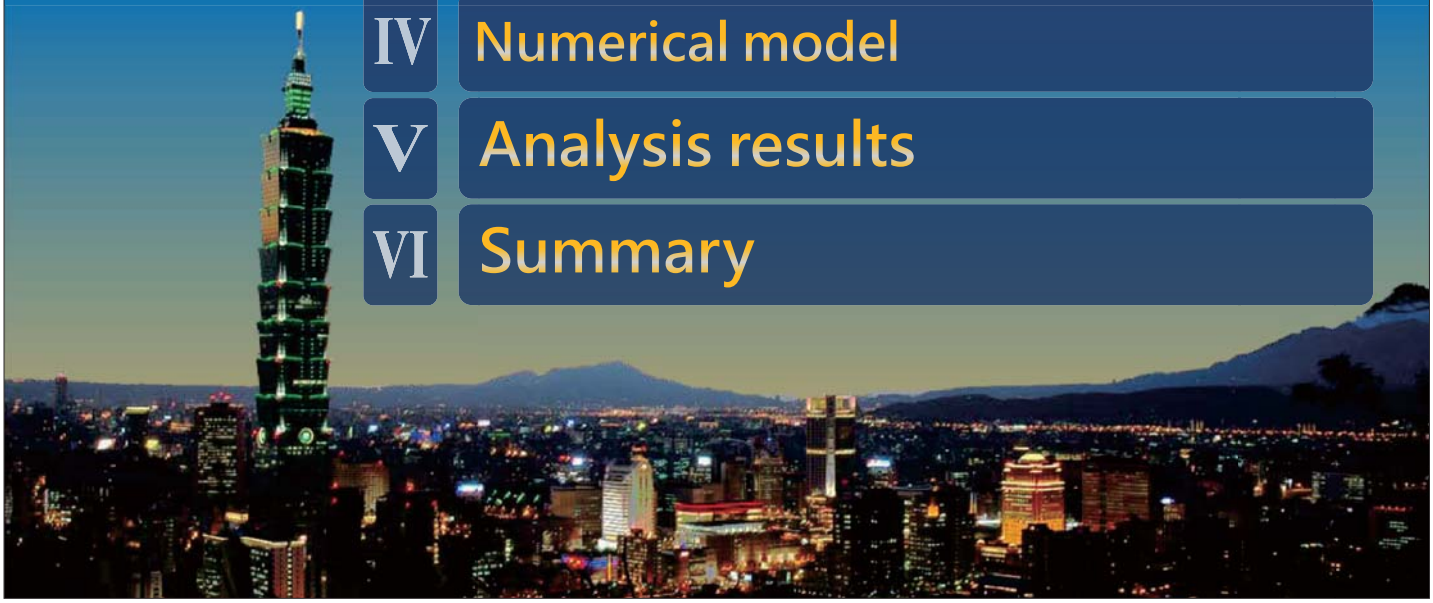

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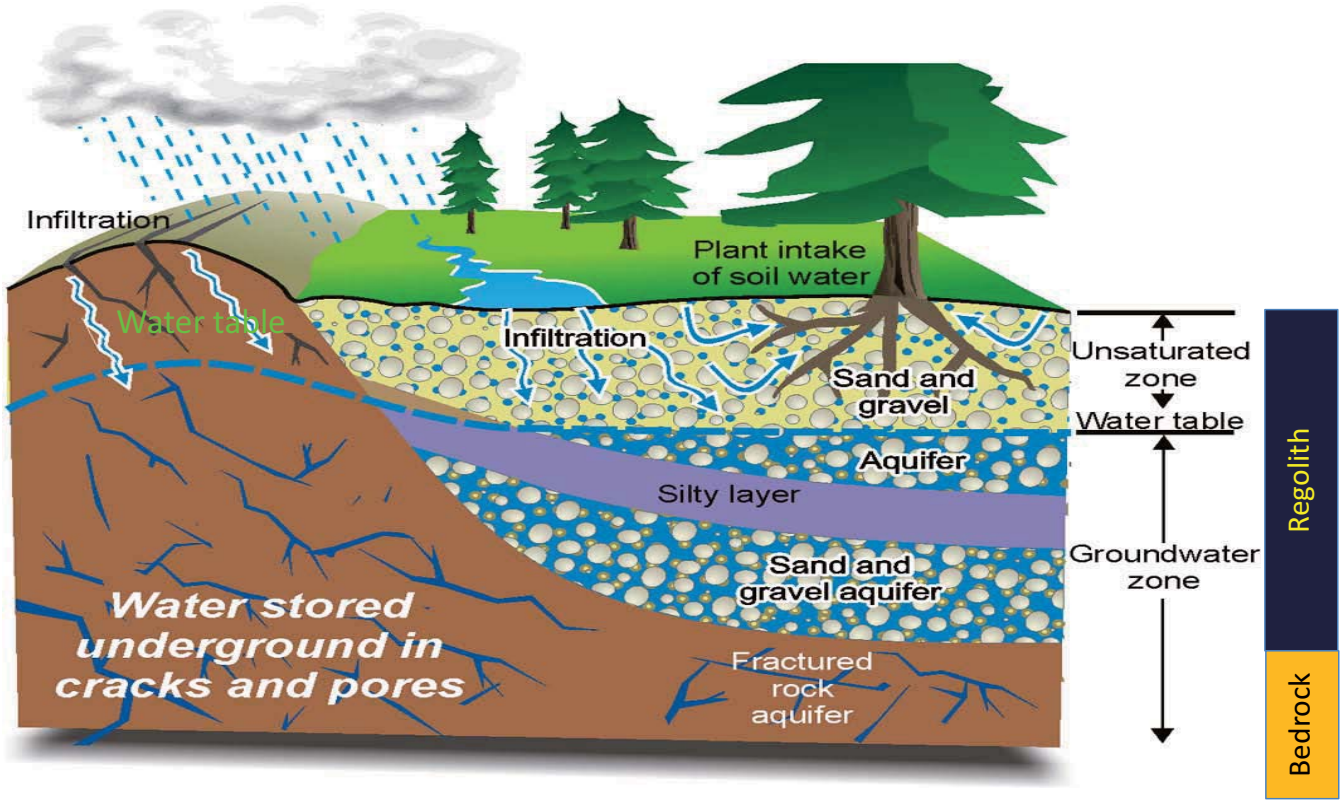
I INTRODUCTION

••• Introduction •••



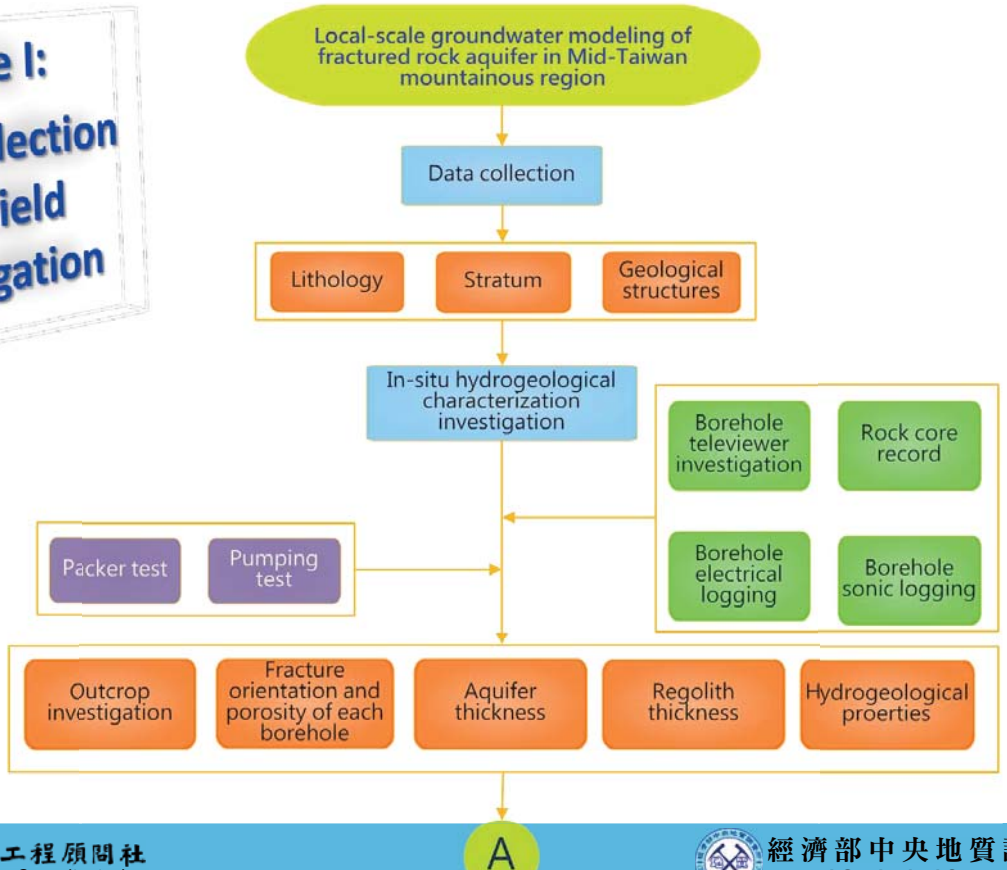
••• Introduction •••

Objectives of this study:

- To combine the use of geological and borehole geophysical investigation with hydraulic test to develop a hybrid discrete fracture network (DFN)/equivalent porous medium (EPM) to model groundwater flow in fractured rock aquifer of mountainous region.
- To evaluate the potential groundwater resources in the regolith-bedrock interconnection zones.
- To analyze the fracture connectivity between boreholes and regolith-bedrock interconnected fracture zones of specific site in the mountainous region.

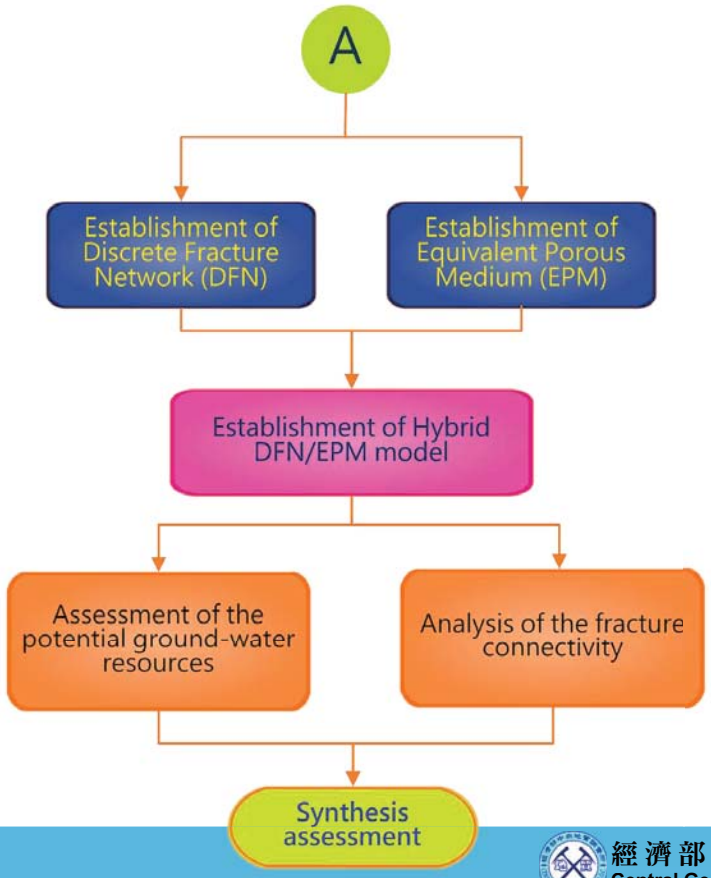
••• Flowchart •••

Stage I:
Data collection and field investigation



Flowchart

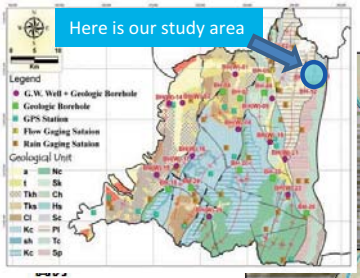
Stage II:
Hybrid model developed and synthesis assessment



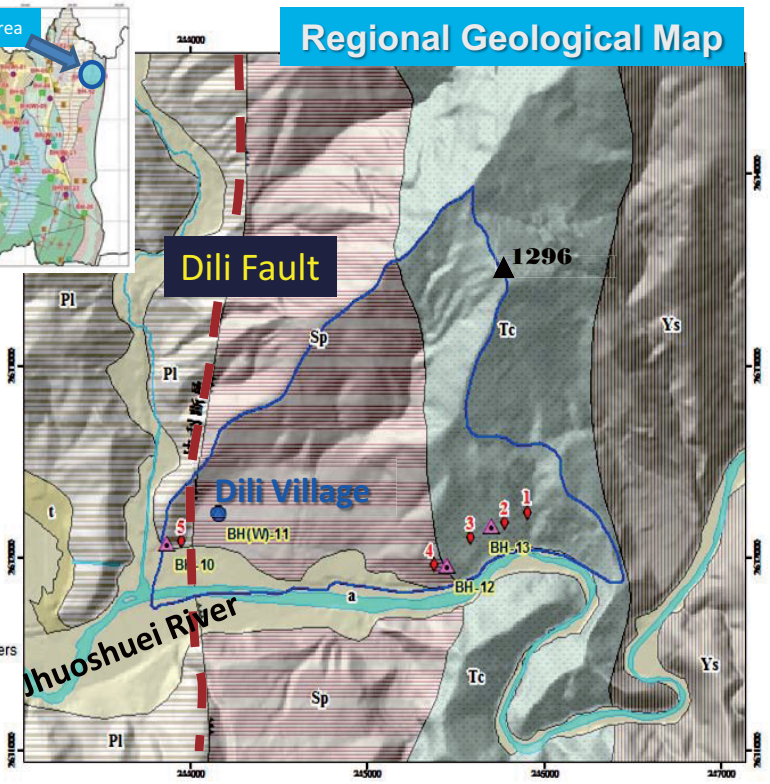
II AOGS 2011 STUDY AREA

•••Dili Fault Zone•••

- Location: Mid-stream of Jhuoshuei river
- Area: 2.7 km^2
- Annual precipitation : 2125mm
- Thrust fault
  - Upthrow block: Sp and Tc Formation
  - Downthrow block: Pl Formation
  - Strike/Dip: N10E/77E

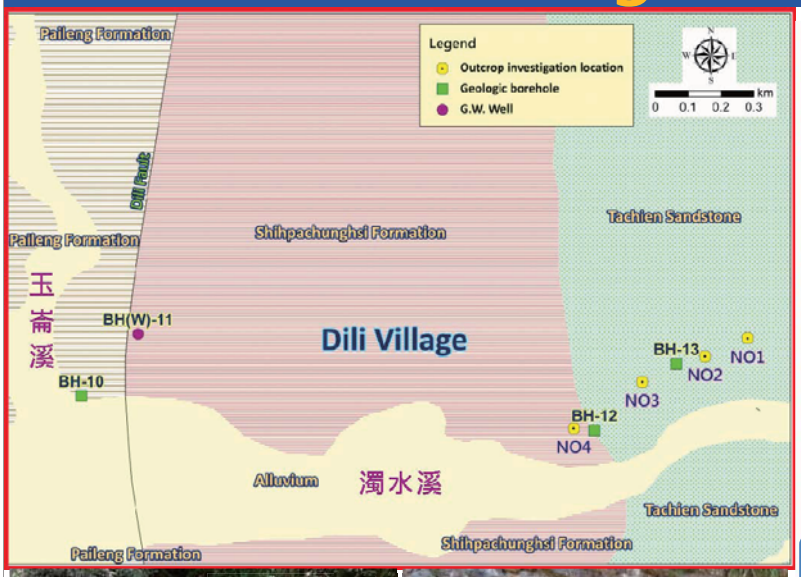


Regional Geological Map

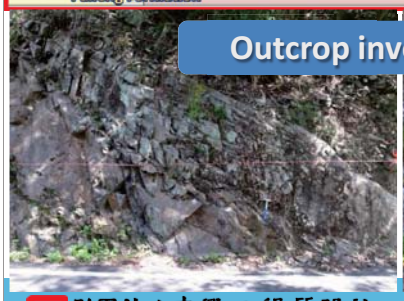


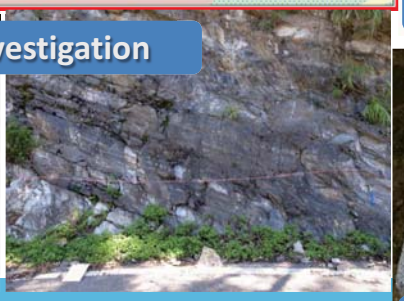
III AOGS 2011 FIELD INVESTIGATION

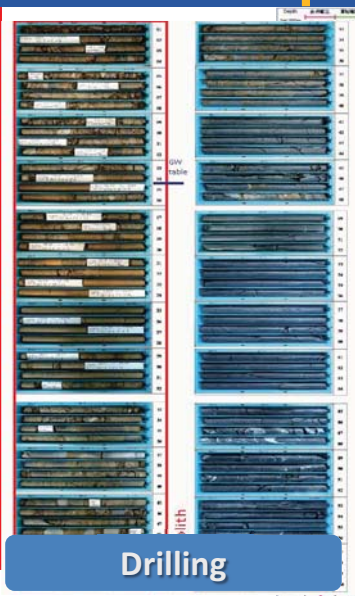
••• Field investigation techniques •••



Outcrop investigation

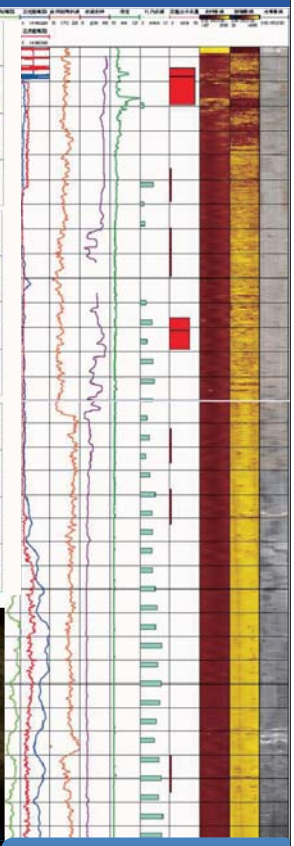






Drilling

G.W. Obs. Well



Geophysical logging

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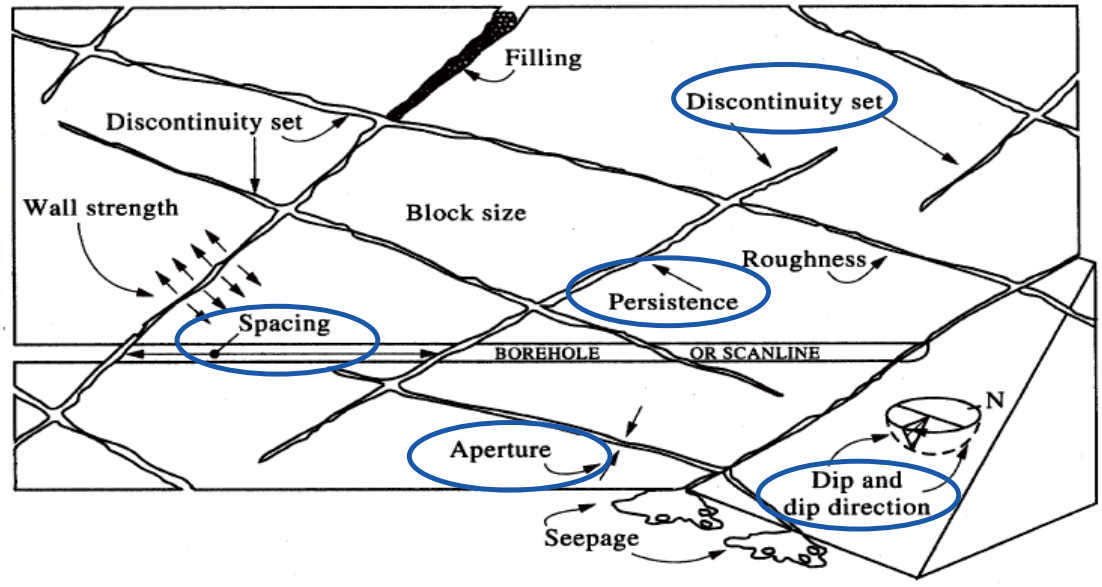
••• Field investigation techniques •••

- **Outcrop investigation:** to obtain the fracture geometry parameter and its statistical characteristic of each formation.
- **Hydrogeological drilling:** to obtain the lithology and regolith thickness of each borehole.
- **Geophysical logging:** to obtain the fracture orientation, spacing and aperture of each borehole.
- **Ground-water monitoring well construction:** to obtain the fluctuation of ground-water table and aquifer characteristic.

••• Outcrop investigation •••

Fracture geometric parameters



- The main investigation features of fracture geometric parameters include spacing, orientation (dip direction/dip angle), persistence (size and shape), aperture, and discontinuity set.

••• Outcrop investigation •••

Cluster analysis results

		Outcrop investigation results
Set of clusters	Bedding	1
	Fractures	3
Number of poles	Bedding	21
	Fractures	142
Orientation of bedding (trend/plunge)		278/67
Orientation of fractures (trend/plunge)		①237/17②337/14③62/8
Major fracture set (trend/plunge)		62/8

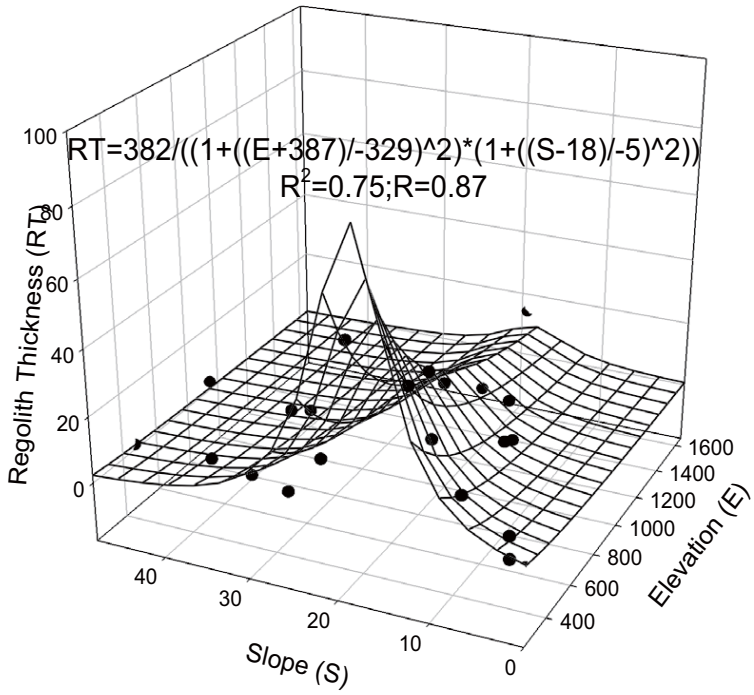
- **Statistics characteristics of fracture geometric parameters are as follows:**
  - Orientation: Normal distribution
  - Spacing(Density): Lognormal distribution
  - Trace length(Size): Negative exponential distribution
  - Aperture: Lognormal distribution

••• Hydrogeological drilling •••

Governing factors for regolith thickness

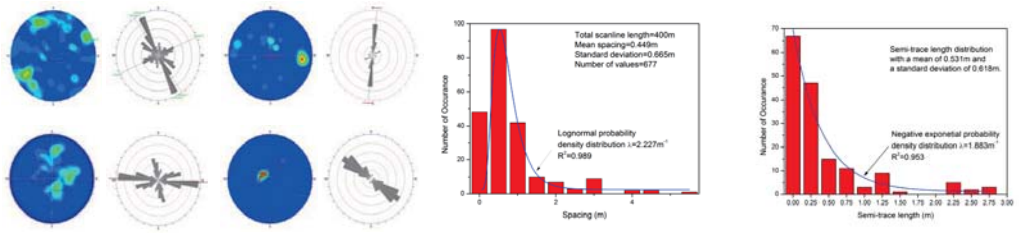
- **Elevation**
- **Local slope**

Lorentz curve distribution



••• Field investigation results •••

Fracture characteristics analysis



Borehole drilling data

Site name	Elevation (m)	Slope gradient (Degree)	Regolith thickness (m)	Fractured bedrock thickness (m)	G.W. elevation (m)
BH-10 Dili 1	357	27.67	4.4	352.6	349.5
BH(W)-11 Dili E.S.	391	21.61	50.2	340.8	375.4
BH-12 Dili 2	472	18.04	1.6	470.4	428.5
BH-13 Dili 3	468	48.25	0.6	467.4	419.3

Hydraulic test

Borehole/Site	Fractured bedrock		
	Depth(m)	Hydraulic conductivity (m/s)	Storage coefficient
BH-10 地利1	8.1 - 9.6	5.97×10^{-6}	3.28×10^{-6}
	23.0-24.5	4.77×10^{-6}	3.28×10^{-6}
	32.7-34.2	4.05×10^{-7}	3.28×10^{-6}
	43.6-45.1	2.40×10^{-8}	6.02×10^{-5}
	57.1-58.6	3.38×10^{-8}	3.28×10^{-6}
	82.5-84.0	3.22×10^{-5}	3.28×10^{-6}
BH(W)-11	54.0-55.5	7.19×10^{-9}	3.28×10^{-6}

K(Hydraulic conductivity): 10^{-8}~10^{-5})

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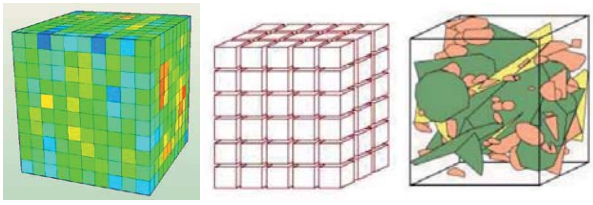
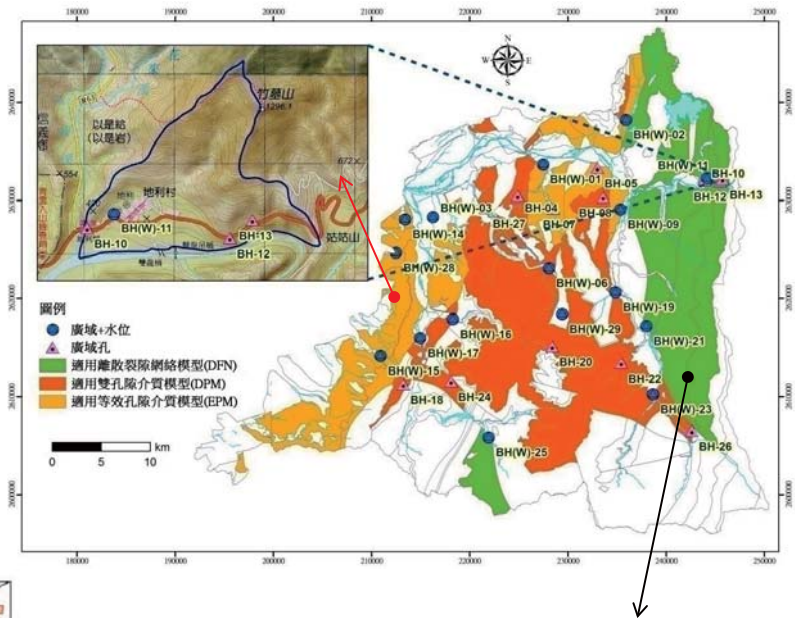
IV NUMERICAL MODEL

Model Type Selection

- **Criteria**
  - Lithology
  - Permeability
  - Porosity
  - Number of fractures
- **Model types**
  - Discrete Fracture Network (DFN)
  - Dual Porosity Model (DPM)
  - Equivalent Porous Media (EPM)

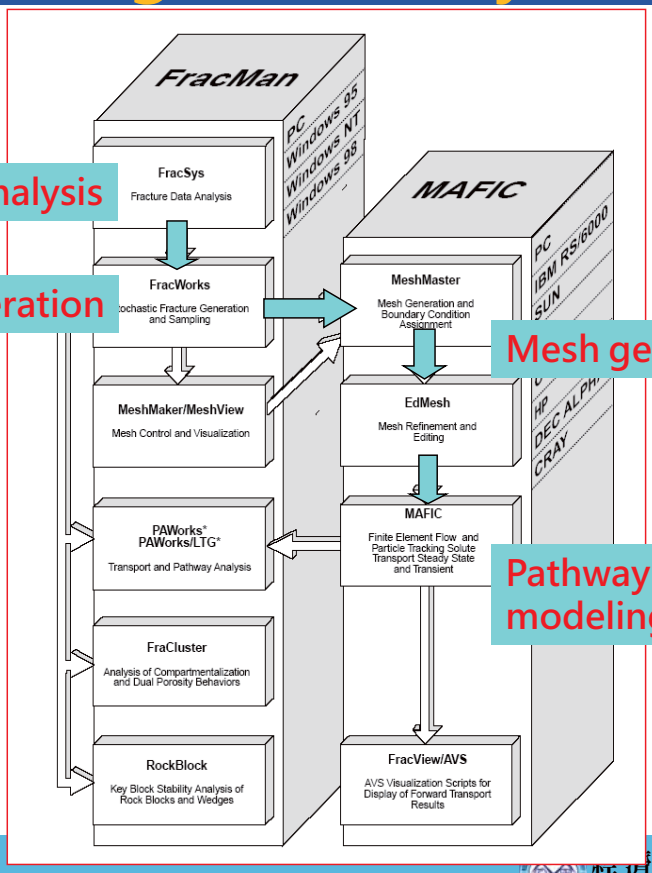


EPM DPM DFN



higher hydraulic conductivity, smaller porosity and greater n umber of fractures

••• Modeling and Analysis Tool •••



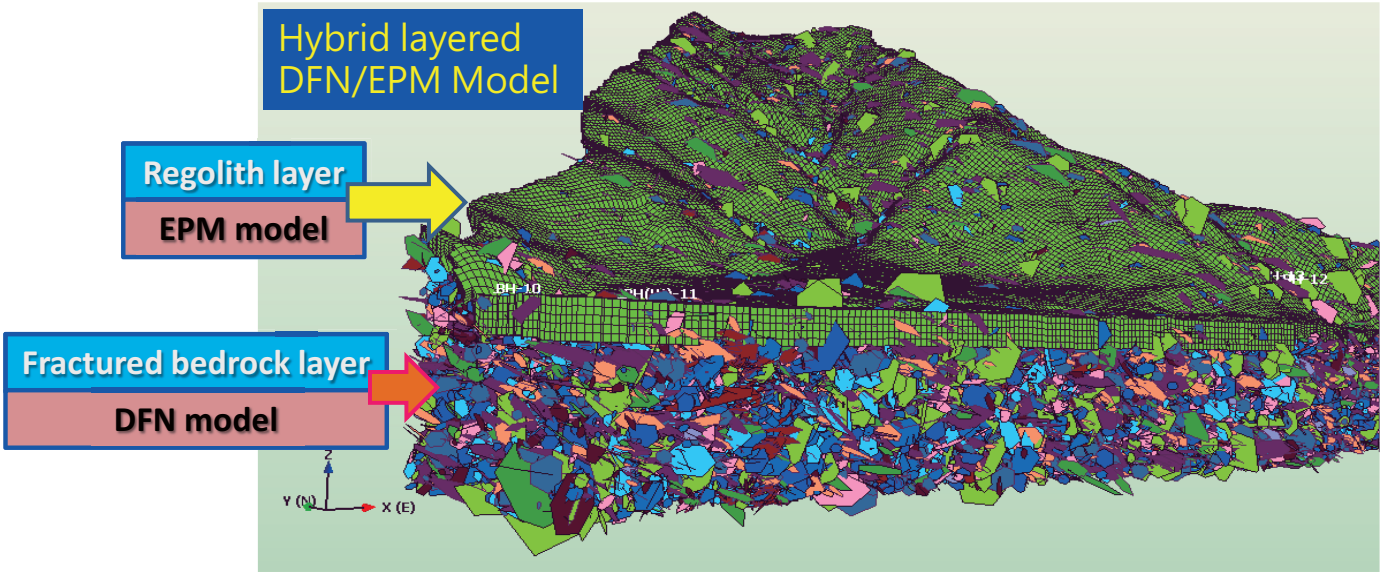
Fracture data analysis

Fracture generation

Mesh generation

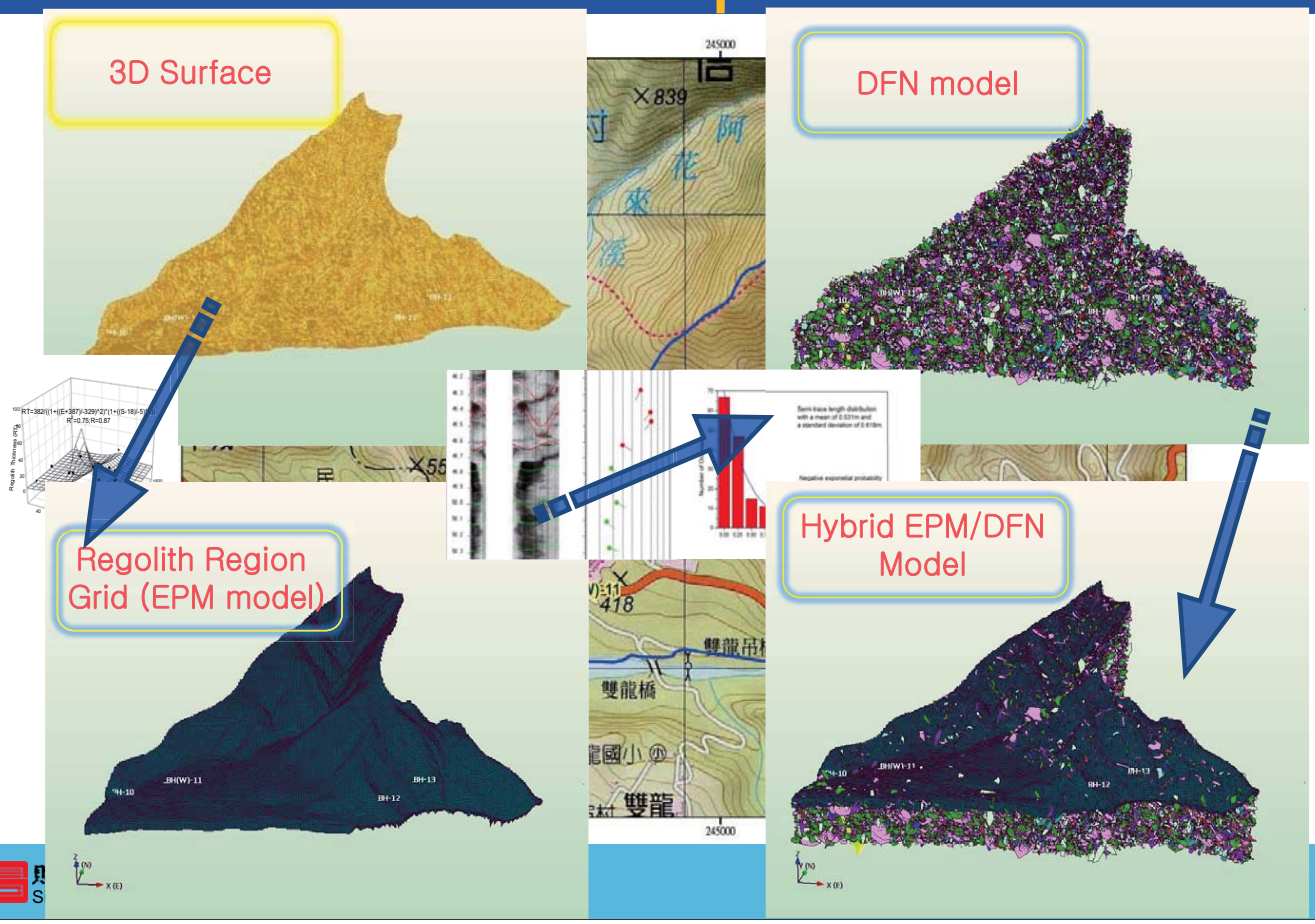
Pathway analysis and flow modeling

••• Hybrid Model •••



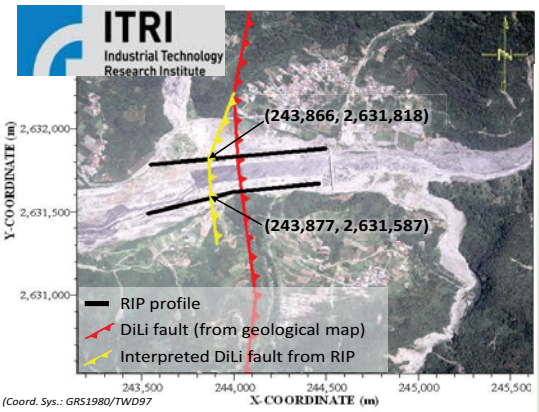
Because of complexity of geological conditions in fault zone, it is difficult to realize the effect of faults on groundwater flow behavior using single numerical model.

••• Model Developed Process •••

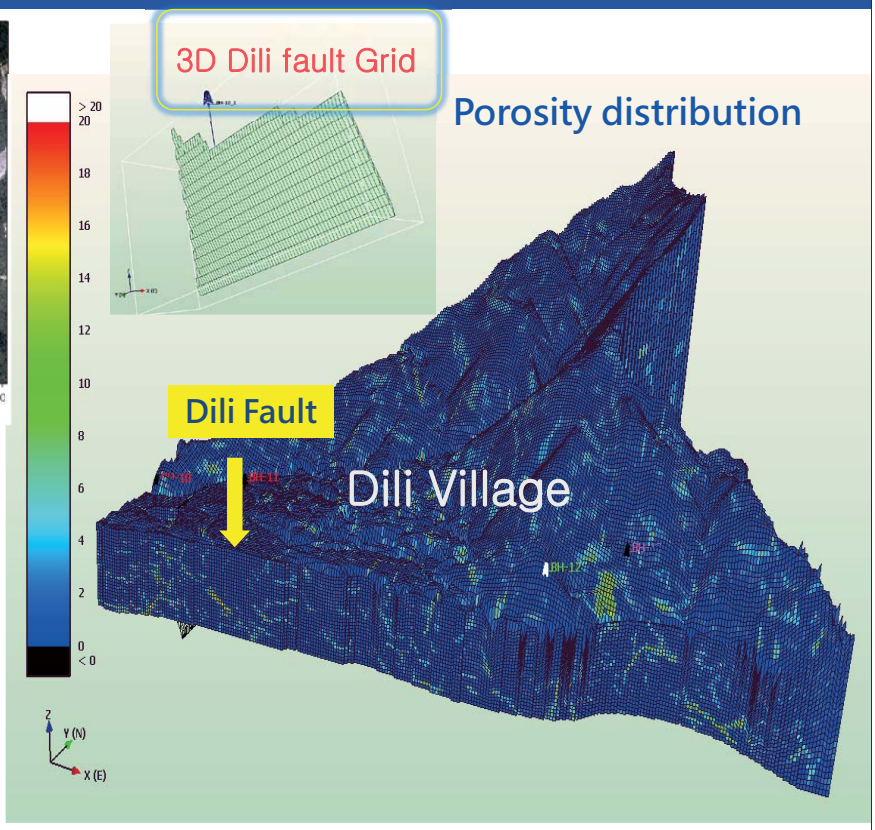


V AOGS 2011 ANALYSIS RESULTS

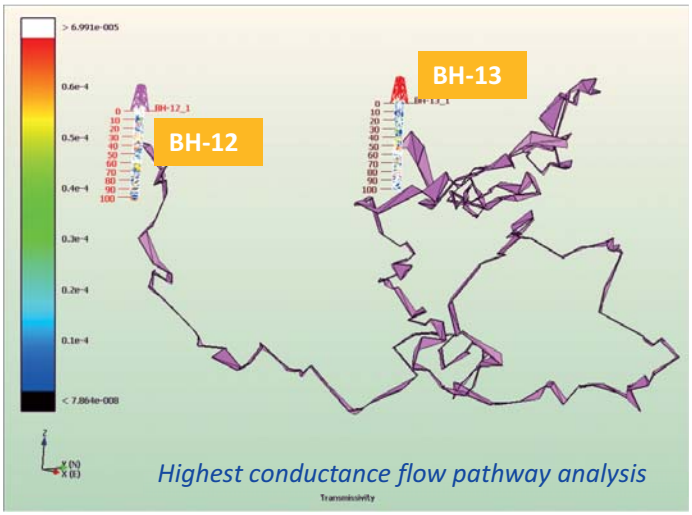
•••Potential Groundwater Resources•••

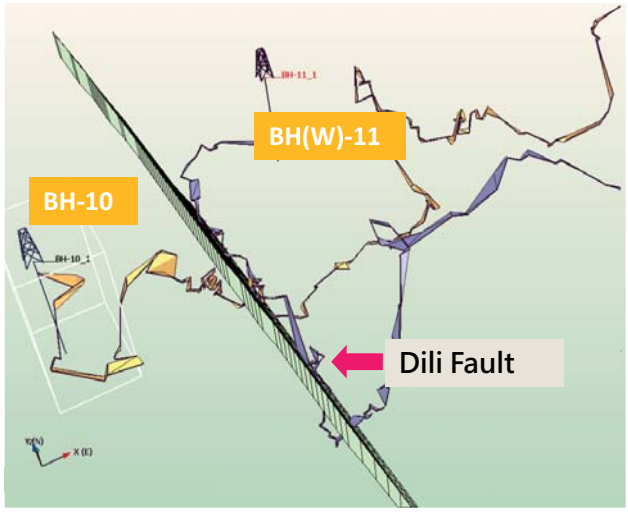


- Potential ground water storage is about 112,500 m^3.
- Minimum available ground water (between regolith and fractured bedrock) is about 54,900 m^3.



•••Analysis of fracture connectivity•••





1. Preferential flow-pathway may exist between BH-10, BH-12 and BH-13.
2. No connection is found between BH(W)-11 and BH-10 because of the low permeability of Dili fault.

Dili fault: a barrier of flow-blocking layer !?

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SUMMARY
VI

••• Summary •••

1. A specific hybrid layered DFN/EPM for mountainous region in Taiwan was developed with boreholes geophysical logging data, hydraulic test data and outcrop investigation results.

2. The potential ground-water storage capacity of regolith-bedrock interconnection zone can be evaluated.

3. The preferential flow pathway between boreholes and the fracture connectivity cross the fault zone can be identified .


Thanks for your attention!