CHARACTERIZATION OF FLOW DYNAMICS IN COASTAL AQUIFERS BASED ON HYDRAULIC TOMOGRAPHY.

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OUTLINE

01 Introduction

- Background
- Objectives
- Work flow
- Study area

02 Methodology

- Filed experiment
- Lab experiment
- VSAFT 2
- Conceptual Model setup

03 Results and discussion

- Pumping test result
- Example profile

04 Future work

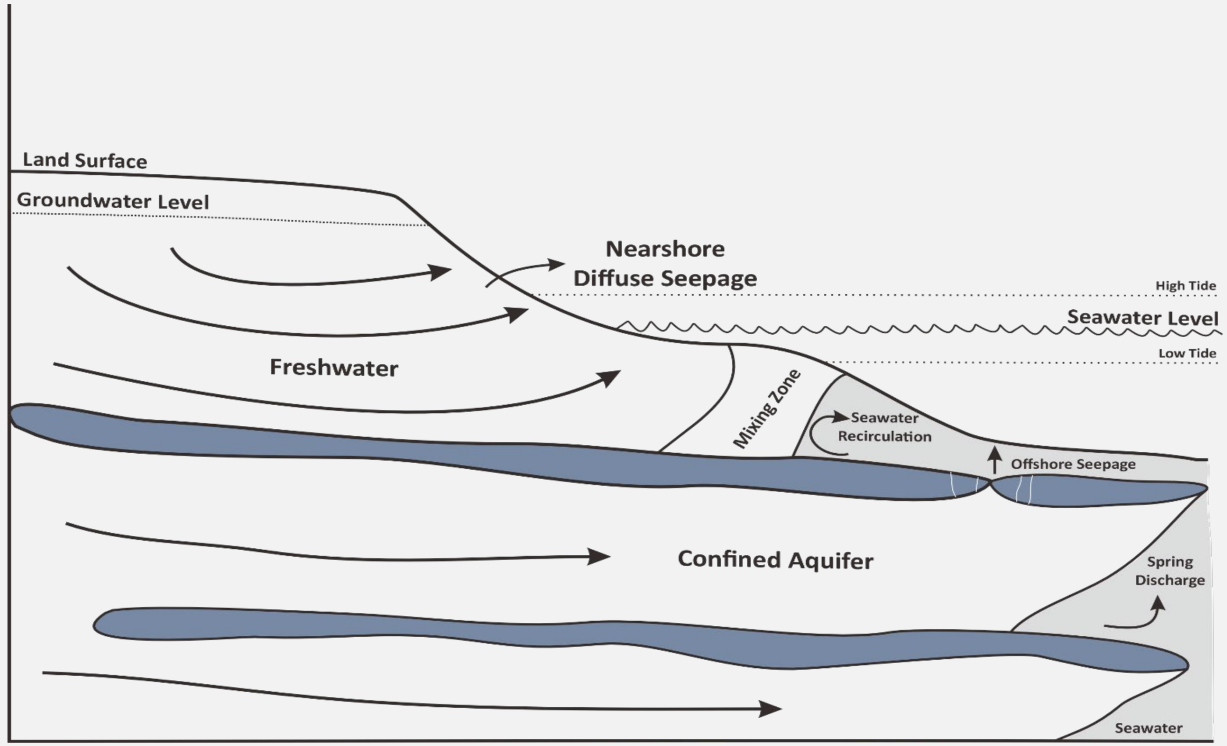
BACKGROUND

- Submarine groundwater is richer then surface water, and has been considered to be an essential component of biological production in marine coastal ecosystems. (Fujita et al., 2019).

- Submarine groundwater discharge (SGD) links land and marine systems, but has often been overlooked in coastal nutrient budgets because it is difficult to quantify (R. Santos et al., 2021).

BACKGROUND

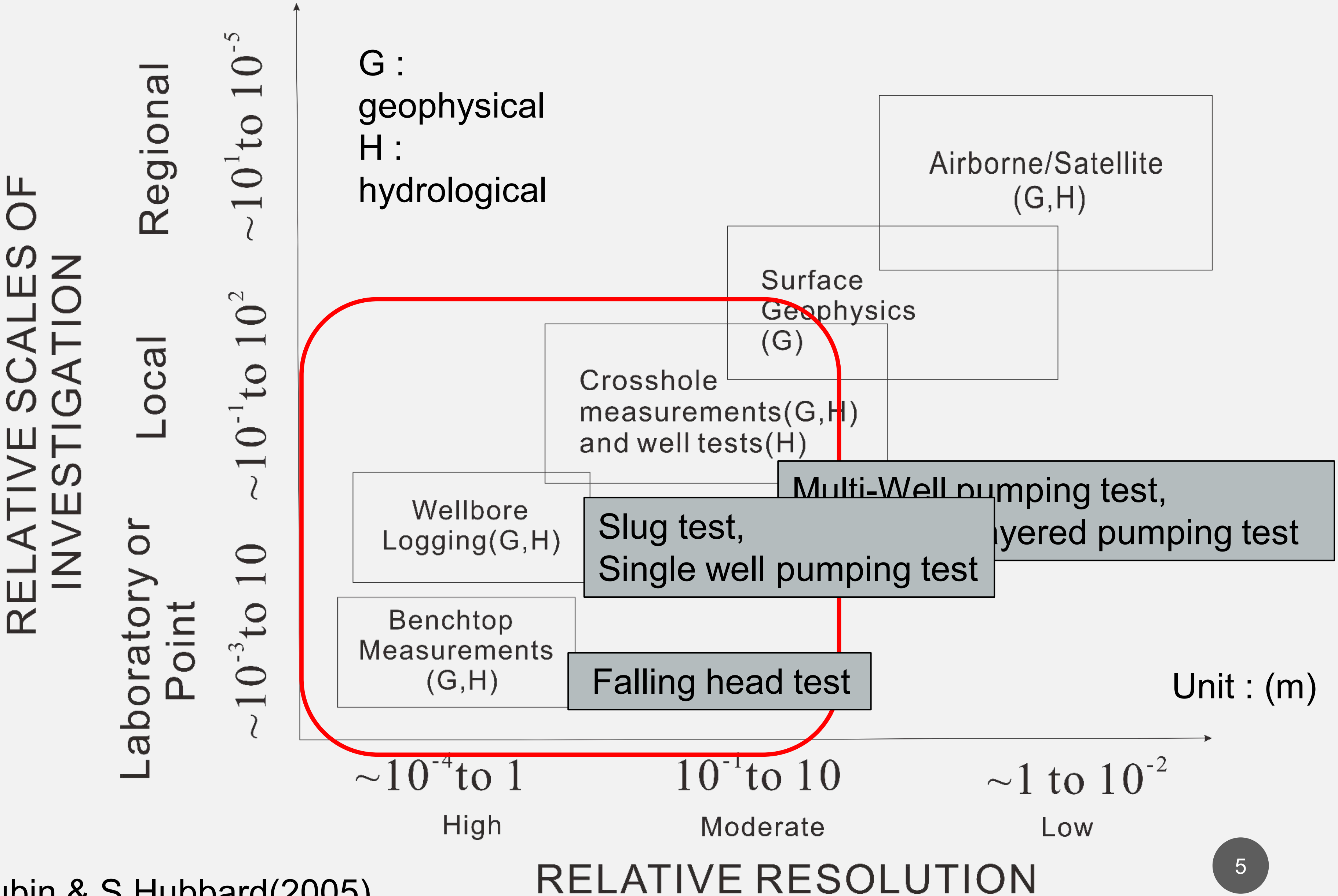
- Influenced by oceanic oscillation and inland head → Complex flow and transport process (Li et al., 2010).



BACKGROUND

- Combine hydrogeological and geophysical data allowed for the construction of a hydrogeophysical model of the multi-layered system(R. Di Maio, 2014).

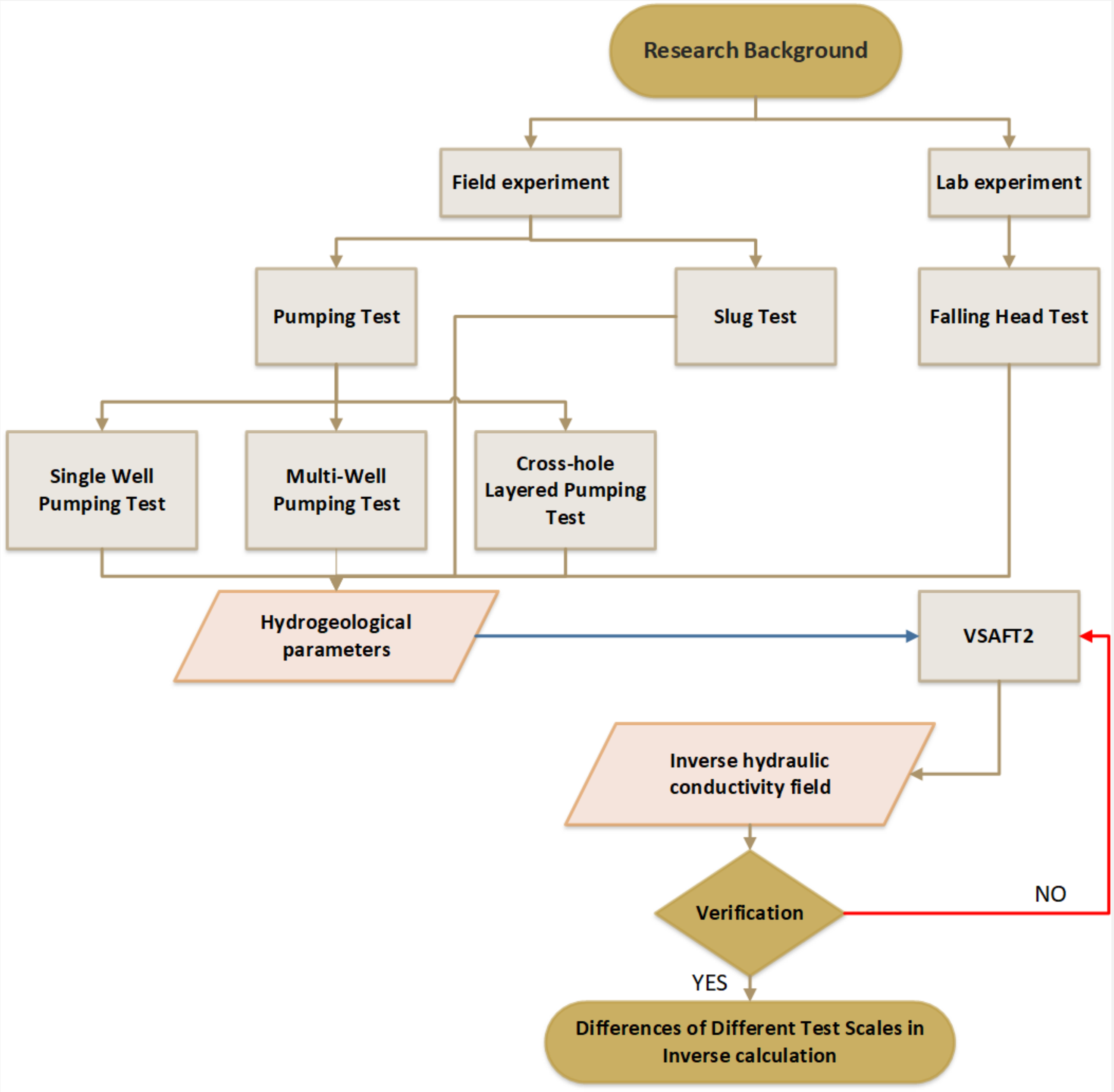
- In some cases, core, slug, geophysical data may be collected and use to condition the inverse modeling results(A. Illman, 2007).



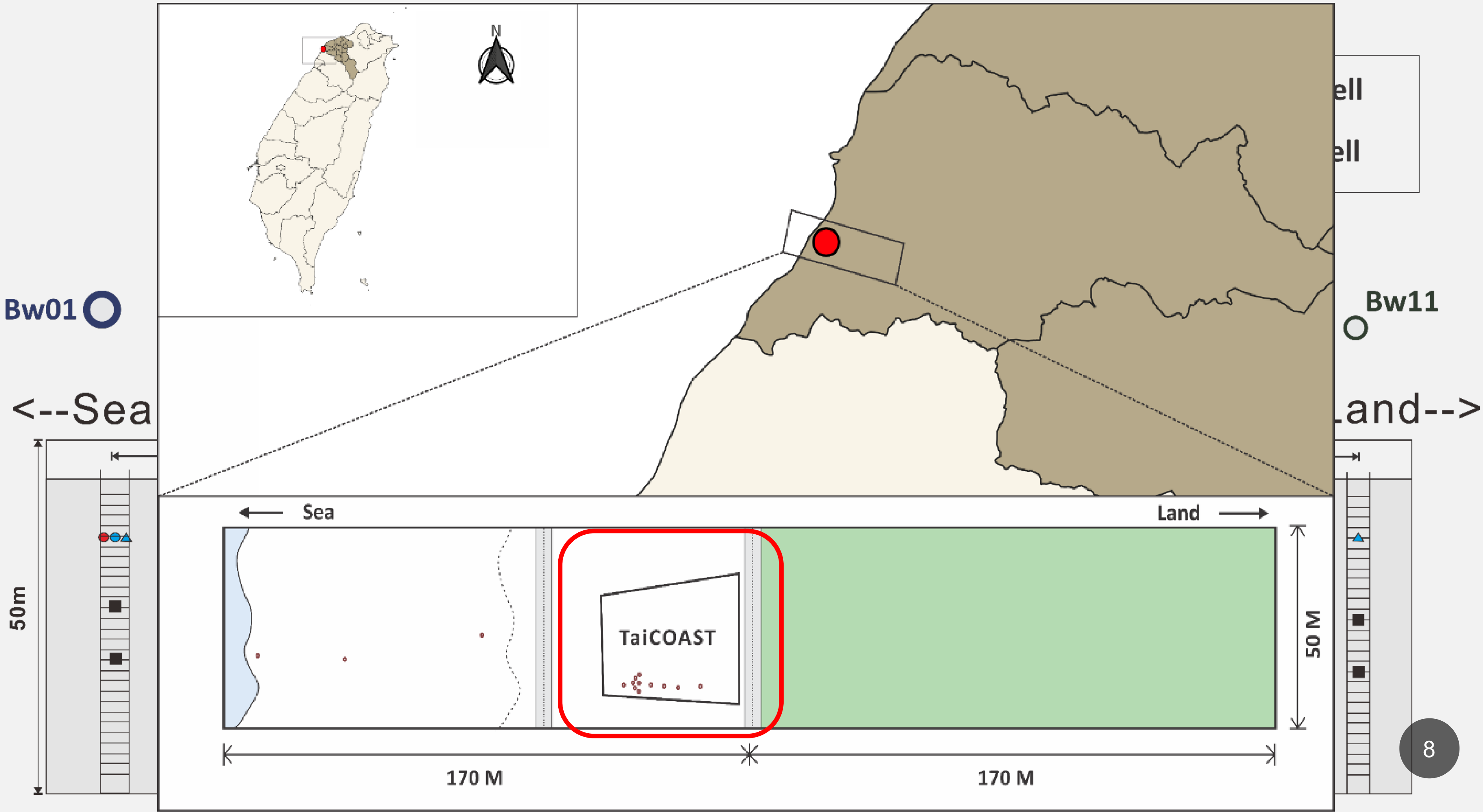
Rubin & S.Hubbard(2005)

OBJECTIVES

- Determining aquifer parameters (K) by field measurement and inversion.
- Using the inverse method to estimate the hydraulic conductivity distribution.
- Using field experiment data with different scales to compare the differences in inverse results.


Research Background
Field experiment
Lab experiment
Pumping Test
Slug Test
Falling Head Test
Single Well Pumping Test
Multi-Well Pumping Test
Cross-hole Layered Pumping Test
Hydrogeological parameters
VSAFT2
Inverse hydraulic conductivity field
Verification
NO
YES
Differences of Different Test Scales in Inverse calculation

STUDY AREA


Bw01
Bw11
ell
ell
<--Sea
Land-->
50m
N
Sea
Land
TaiCOAST
50 M
170 M
170 M

<--Sea Land-->

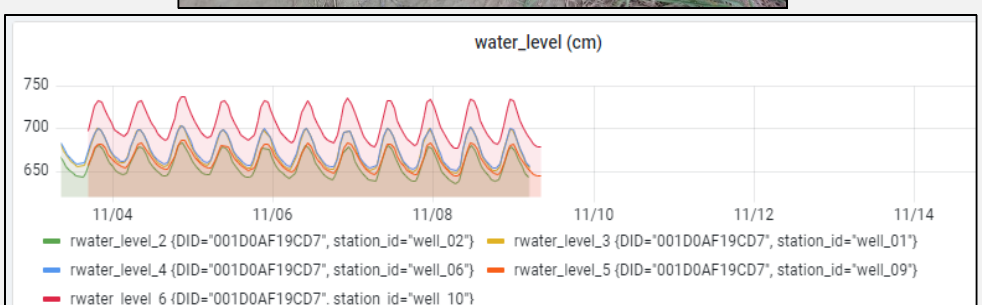
Well Number	Falling Head Test	Slug Test	Single Well Pumping Test	Multi-Well Pumping Test	Cross-hole Layered Pumping Test
BW01	✓		✓		
BW02			✓	✓	
BW03			✓	✓	✓
BW09		✓	✓	✓	✓
BW10		✓	✓	✓	✓
BW11	✓			✓	✓

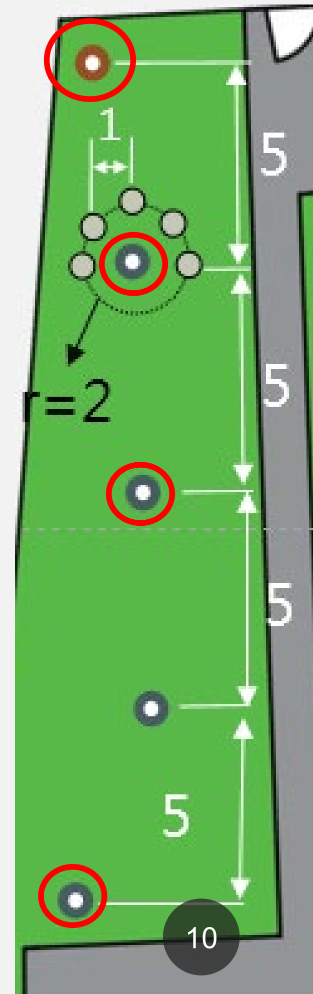
●	Pump+OBS
▲	OBS
★	Slug Test
■	Falling Head Test

	Single Well Pumping Test
	Multi-Well Pumping Test
	Cross-hole Layered Pumping Test

GROUNDWATER LEVEL MONITORING

- Auto monitoring: 1 data/hour, 1 month, 5 wells.
- Purpose: set the boundary of the model.
- Due to the tidal period, the equipment at least set up for 1 month.

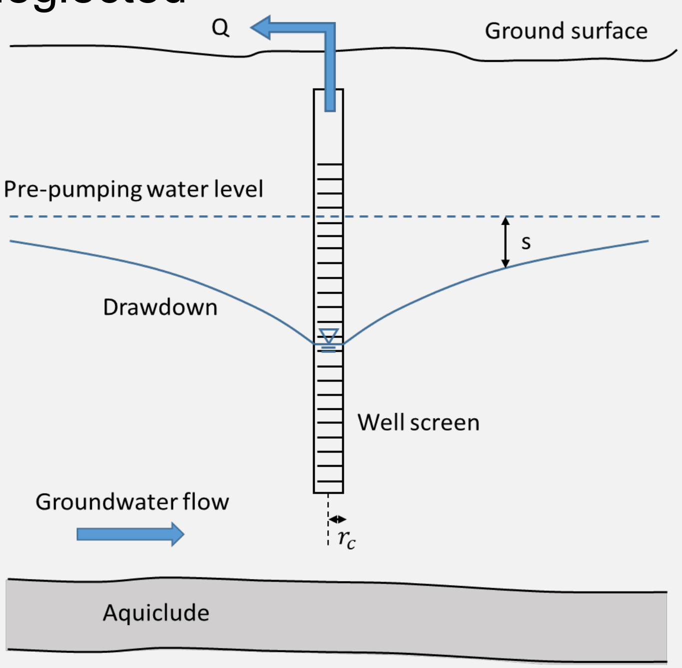




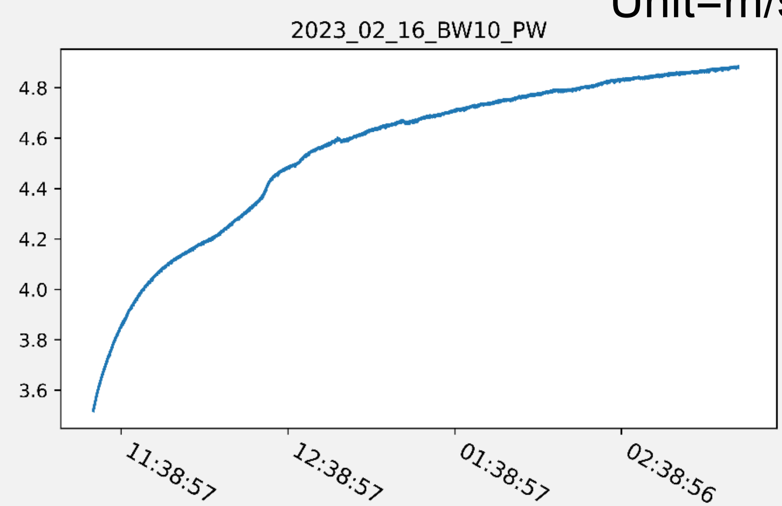
SINGLE WELL PUMPING TEST

- Aquifer has infinite areal extent
- Aquifer is homogeneous, anisotropic and of uniform thickness
- Control well is fully or partially penetrating
- Diameter of a pumping well well is very small so that storage in the well can be neglected

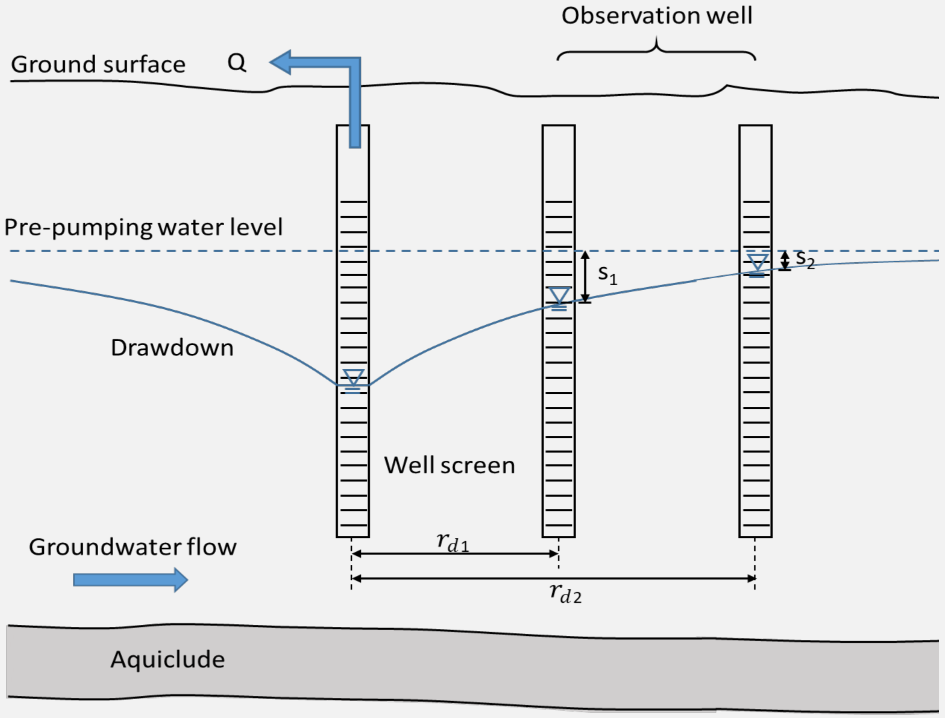
- Analysed by Theis solution.

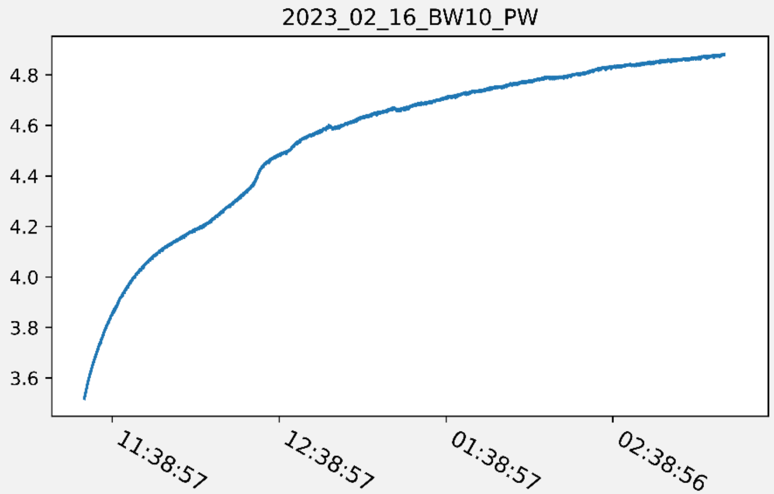


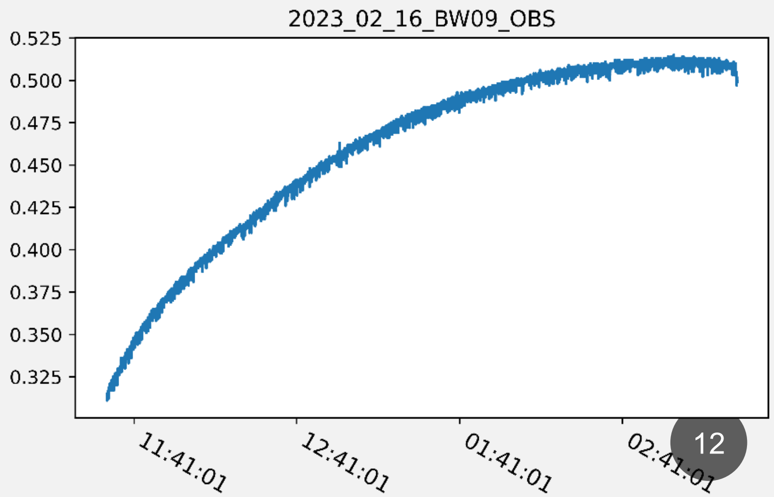
Unit=m/sec



MULTI-WELL PUMPING TEST

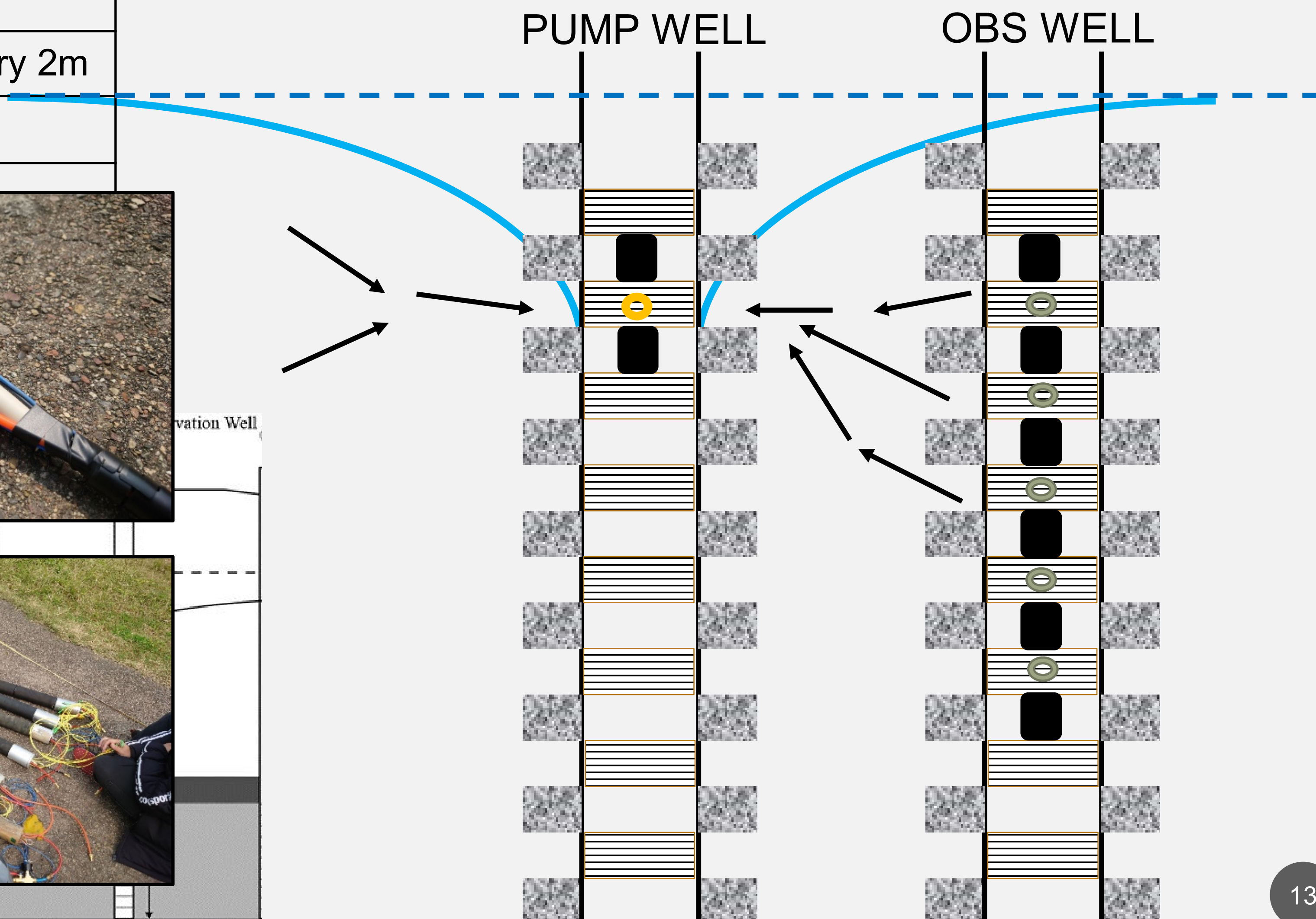






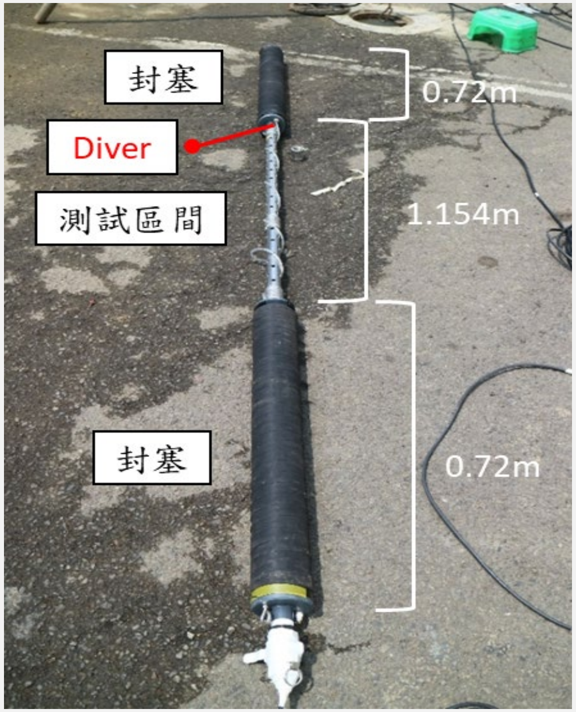
legend	
	Bentonite: every 2m
	Screen: every 2m
	Packer
	[illegible]

CROSS-HOLE LAYERED PUMPING TEST



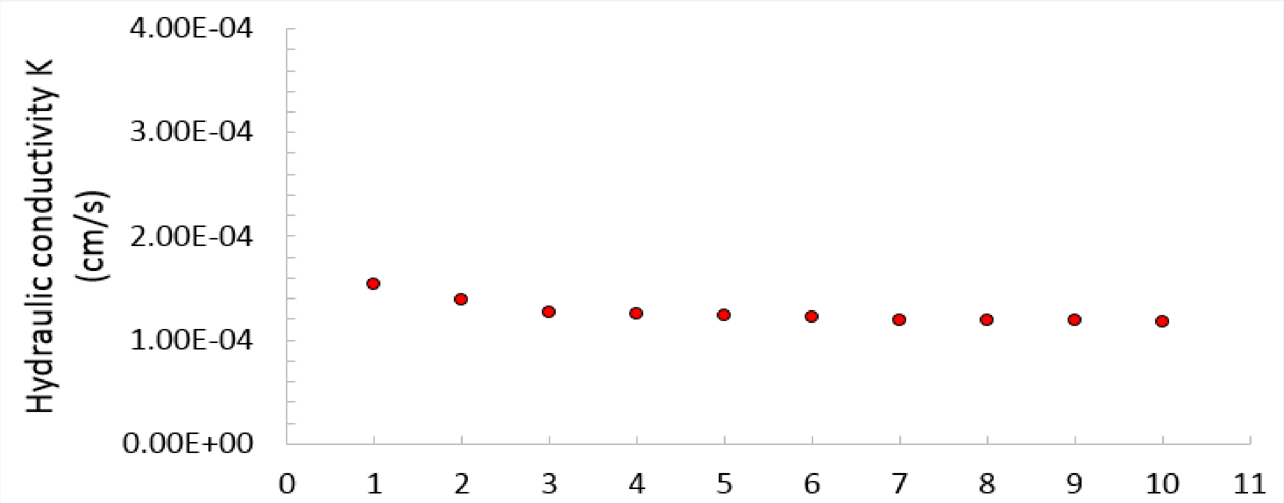
MULTI-LEVEL SLUG TEST

- Separate different layers to do the slug test : every 2 meters.



FALLING HEAD TEST

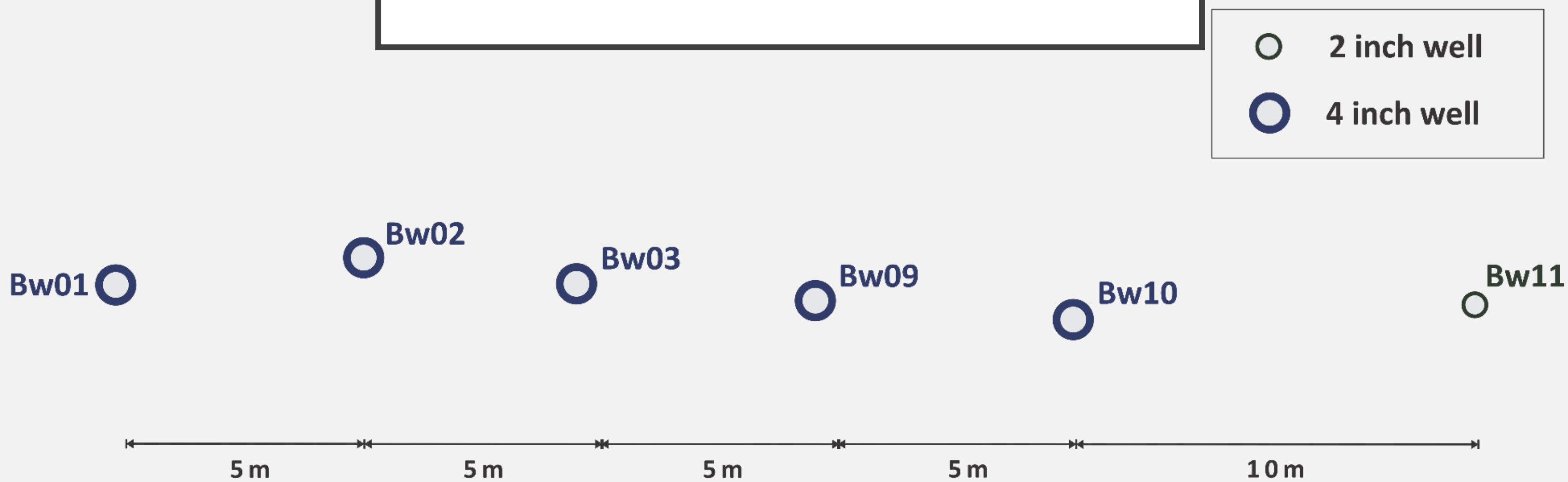
- Determine K Value.
- Choose a specific depth to do the experiment.

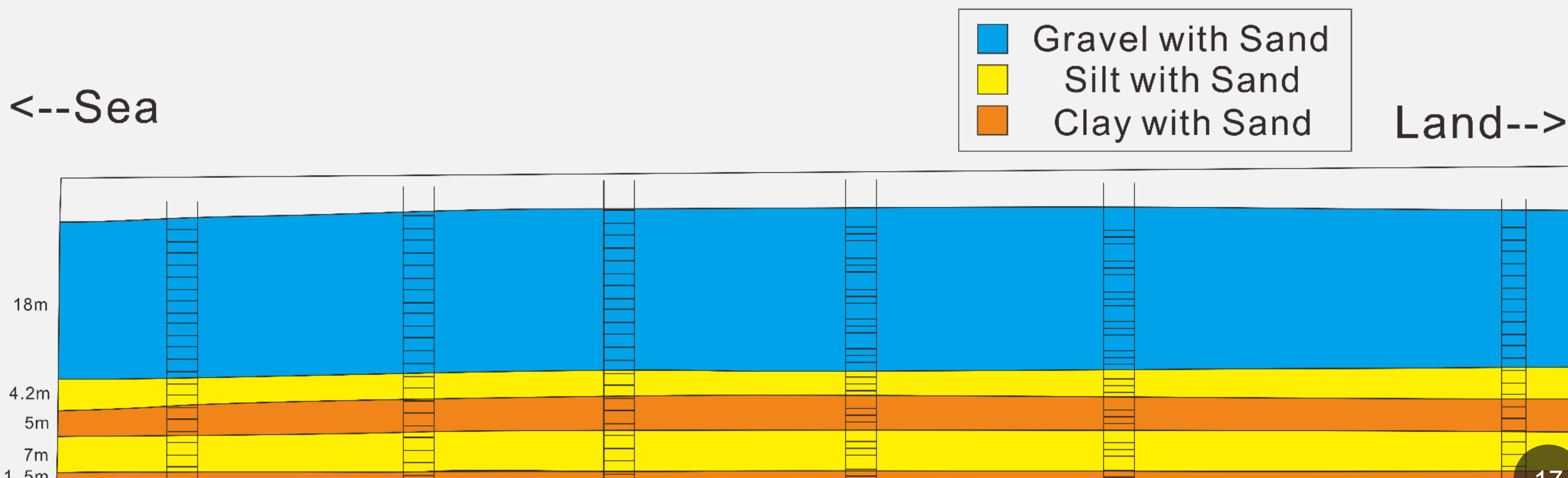


VSAFT 2

- VSAFT2 is a windows Graphical User Interface (GUI) for setting up, running and calibrating a variably saturated flow and transport finite element model (Yeh, et al., 1993) in two-dimensional.
- VSAFT2 now includes several geostatistical model setup features such as random field generation of input parameters.

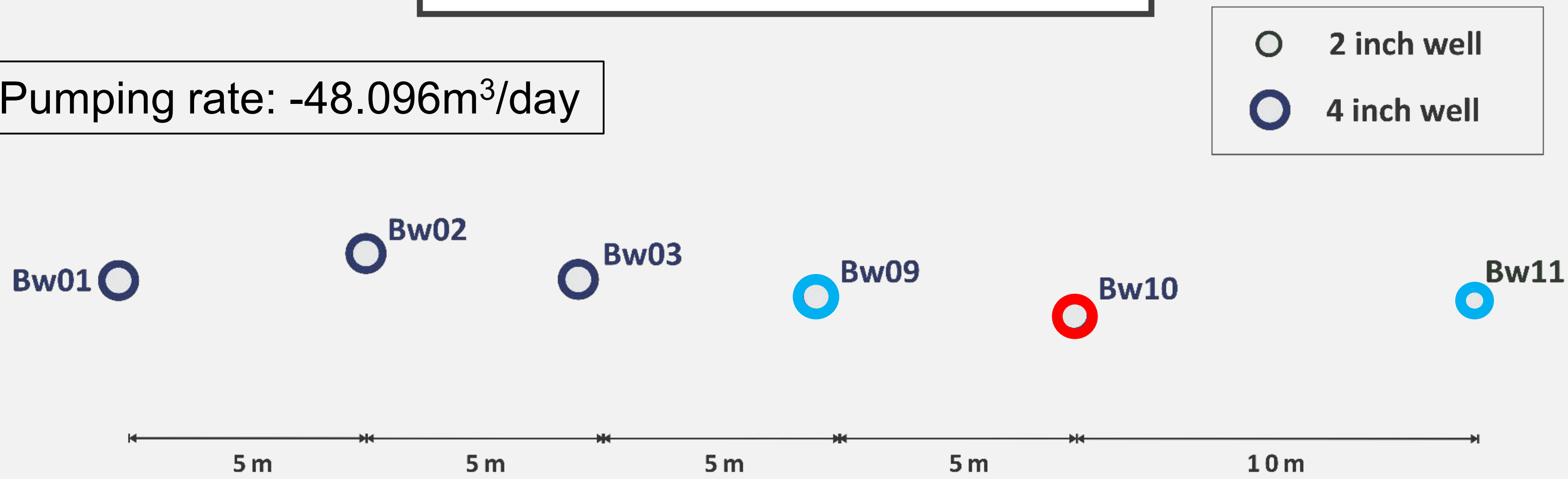
MATERIAL

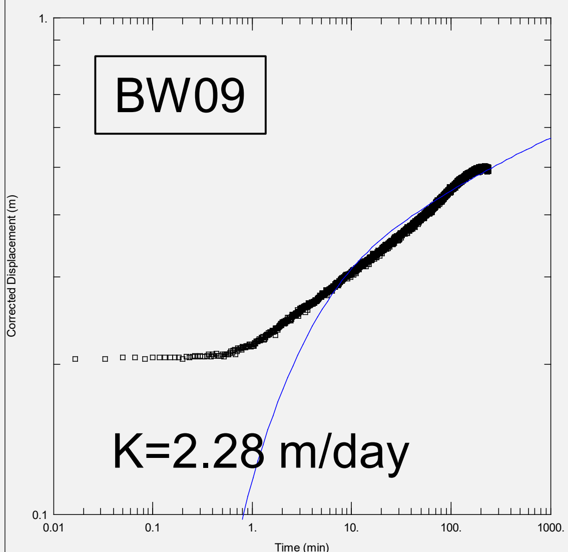

2 inch well
4 inch well
Bw01
Bw02
Bw03
Bw09
Bw10
Bw11
5 m
5 m
5 m
5 m
10 m

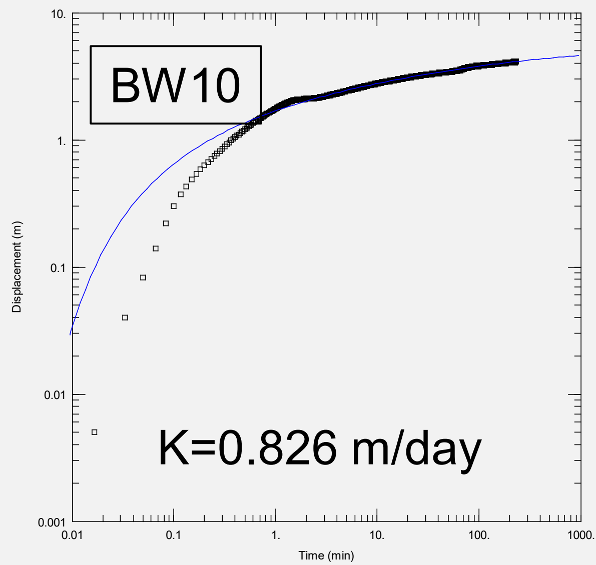

Gravel with Sand
Silt with Sand
Clay with Sand
<--Sea
Land-->
18m
4.2m
5m
7m

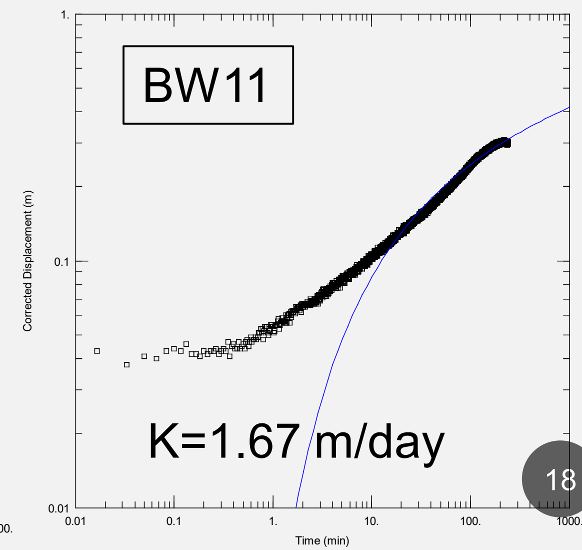
PUMPING TEST

Pumping rate: -48.096m^3/day



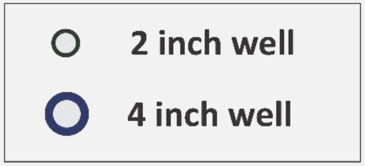


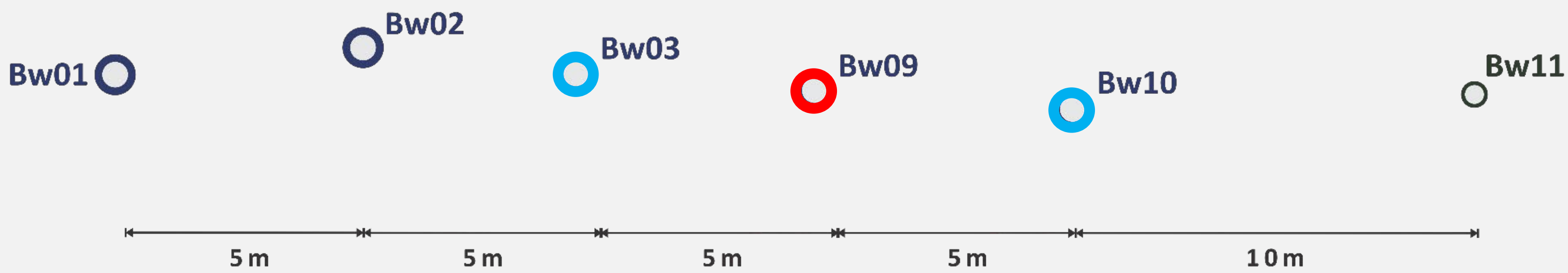


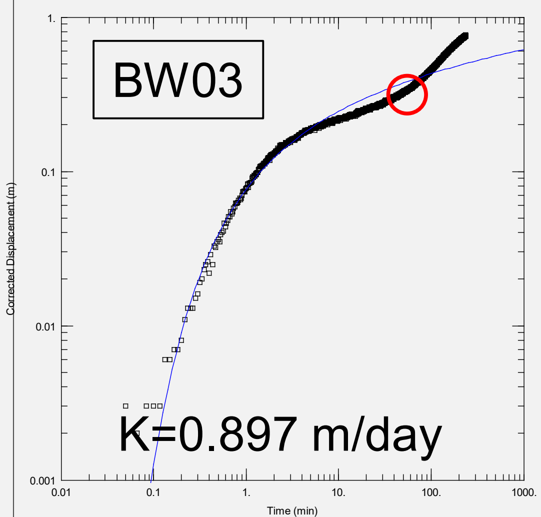


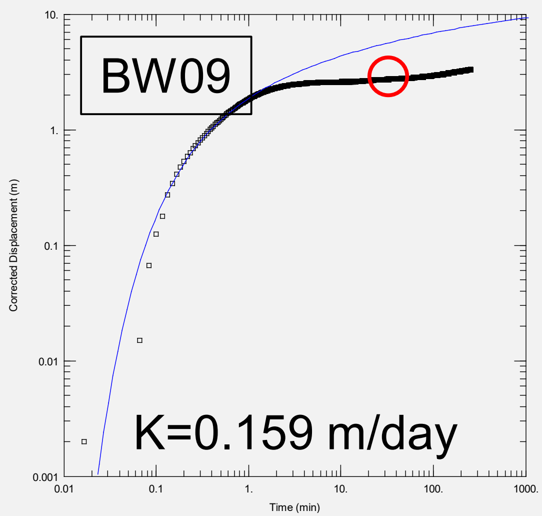
PUMPING TEST

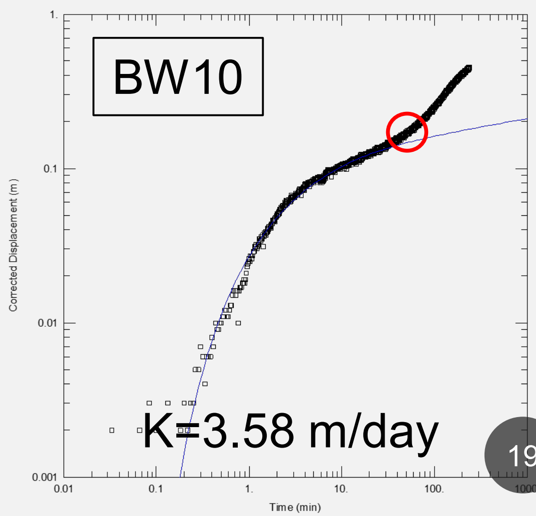
Pumping rate: -48.096m^3/day



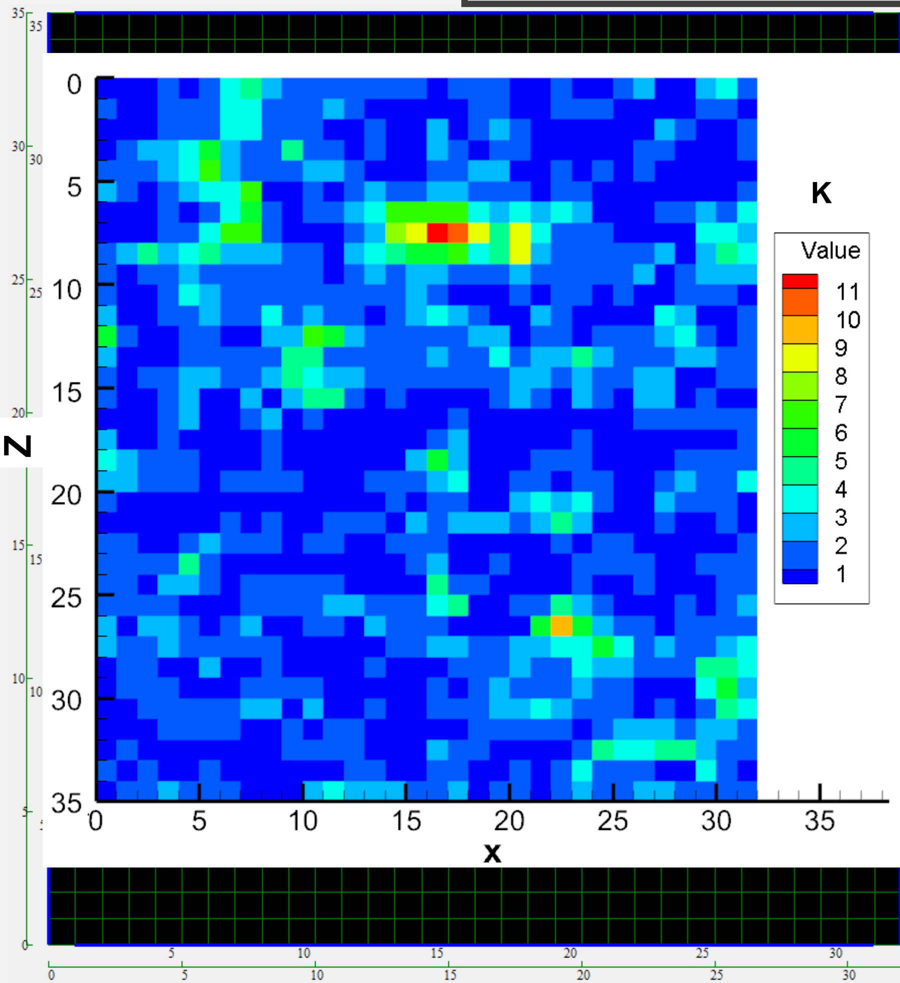








VSAFT 2



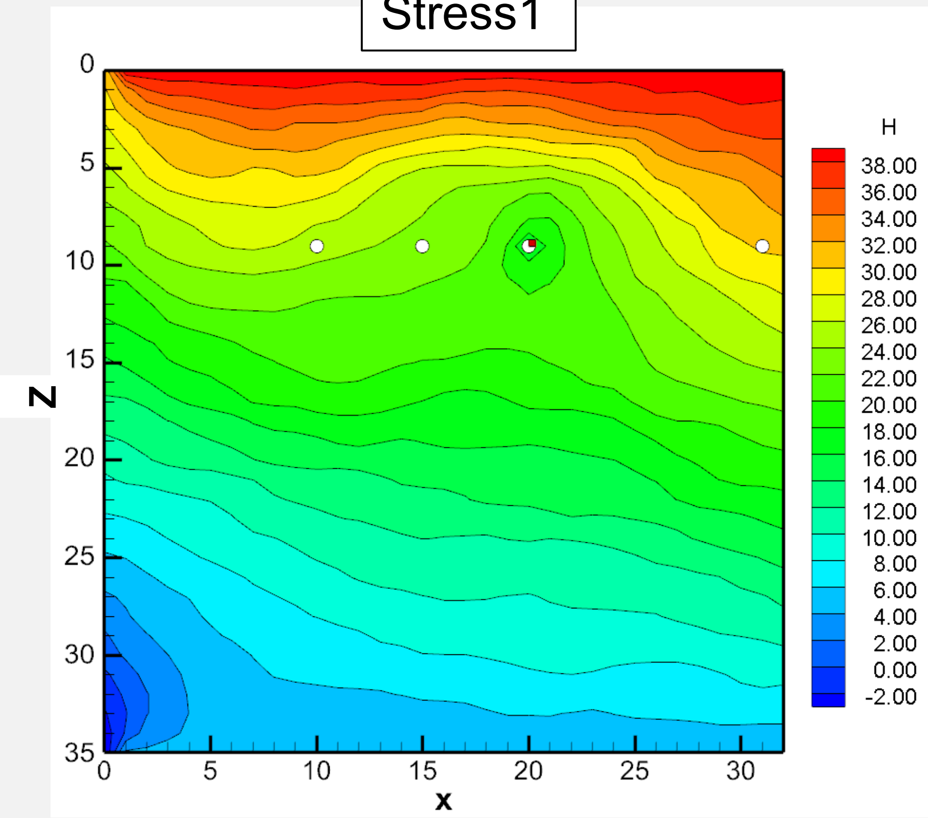
Material	Ksx	Ksy
Black	1.57	1.57

	Stress 1	Stress 2
BW09	-48.096	OBS
BW10	OBS	-48.096
BW11		OBS
BW03	OBS	

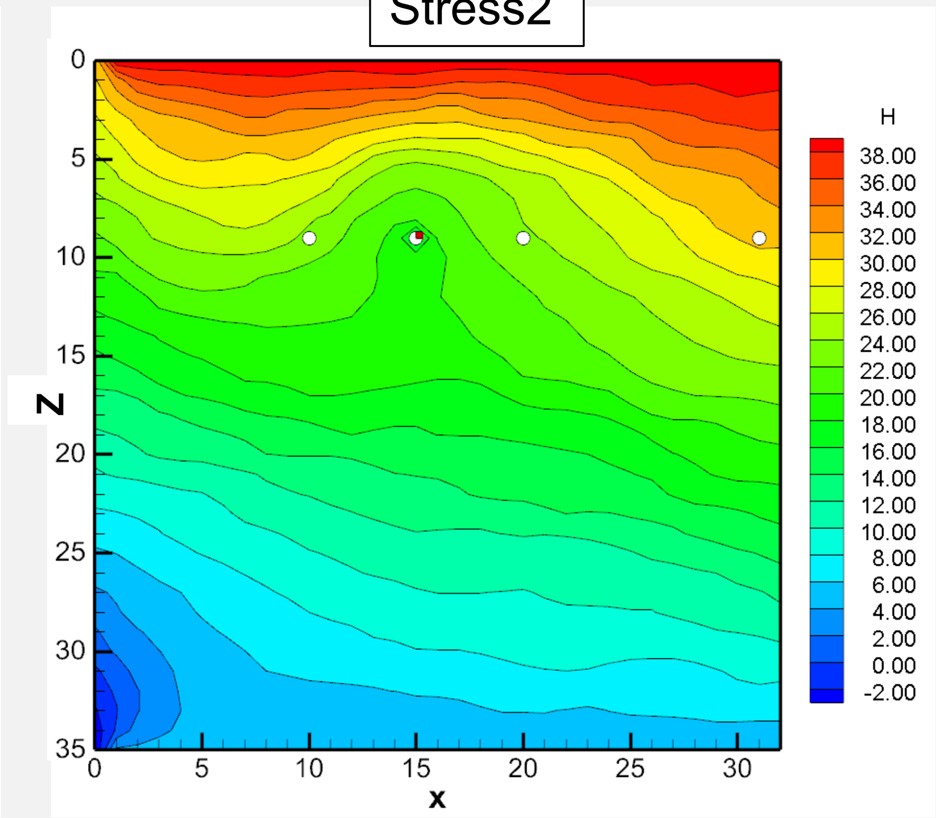
Grid	35*30(row*col)
Flow	Steady State
Material	Heterogeneous
Initial condition	Pressure head : 4.317m
Well	4 wells
Boundary	Left: pres.head/-4.317 Right: pres.head/4.513m

VSAFT 2

Stress1

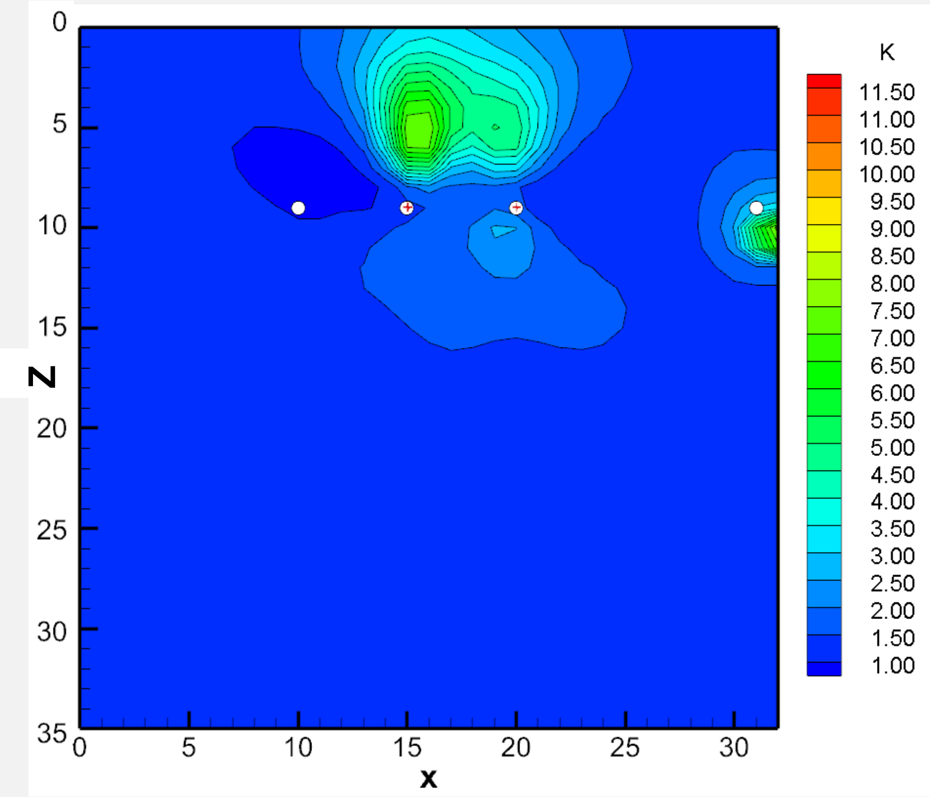


Stress2

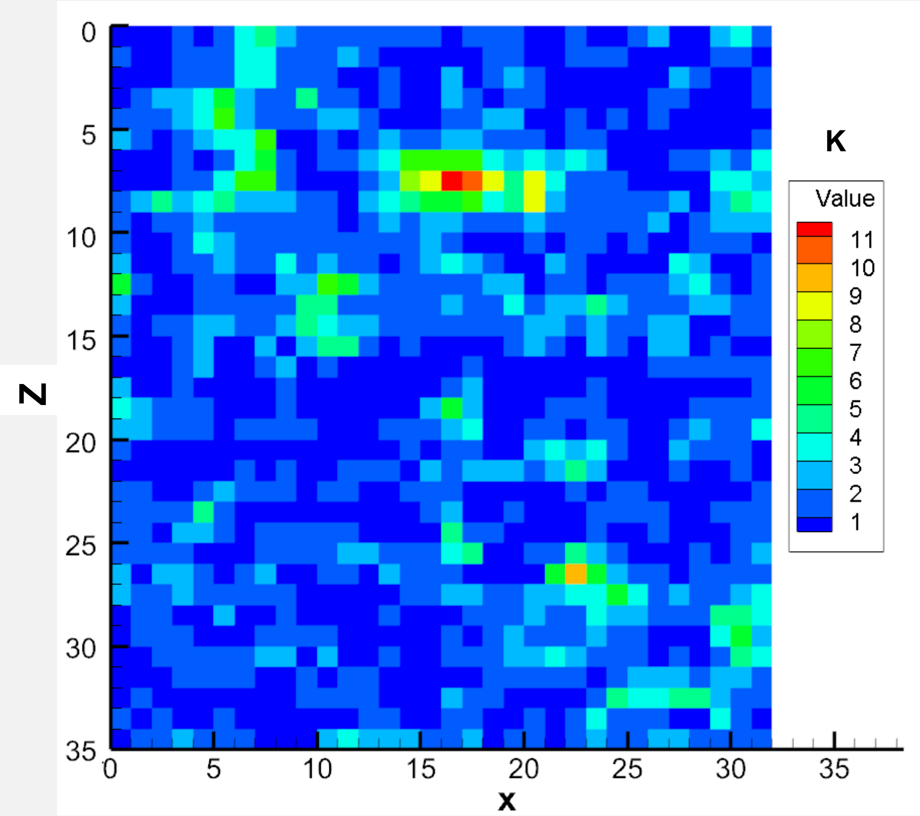


VSAFT 2

Inverse result



Forward result



FUTURE WORK

- Finish all lab and field experiment.
- Modify the inverse K field.
- Using the K field to construct the hydraulic tomography.

THANK YOU FOR LISTENING

SSLE

$$\xi_*^{(1)} = \lambda^T \zeta_{\mathrm{obs}} + \mu^T \varepsilon_{\mathrm{obs}}$$

$$\xi_*^{(k+1)} = \xi_*^{(k)} + \omega^{(k)} (\varepsilon_{\mathrm{obs}} - \varepsilon^{(k)})$$

Ni, et al., (2009)

$\xi_*^{(k)}$ is the kth estimation of parameter (i.e., the hydraulic* conductivity K),

ζobs and εobs represent the differ-ences of the parameters (i.e., hydraulic conductivity) and hydraulic heads at observation locations,

$\lambda, \mu, \omega(k)$ are cokriging weighting vectors evaluated by stochastic simulations.

AQTESOLV
THEIS SOLUTION

- Aquifer has infinite areal extent
- Aquifer is homogeneous, anisotropic and of uniform thickness
- Control well is fully or partially penetrating
- Diameter of a pumping well well is very small so that storage in the well can be neglected

- b is aquifer thickness [L]
- Kr is the radial (horizontal) hydraulic conductivity [L/T]
- Kz is the vertical hydraulic conductivity [L/T]
- ID is dimensionless depth to bottom of pumping well screen (l/b)
- Q is pumping rate [L^3/T]
- r is radial distance from pumping well to observation well [L]
- s is drawdown [L]
- S is elastic storage coefficient [dimensionless]
- Sy is specific yield [dimensionless]
- ts is dimensionless time with respect to S
- t is elapsed time since start of pumping [T]
- T is transmissivity [L^2/T]

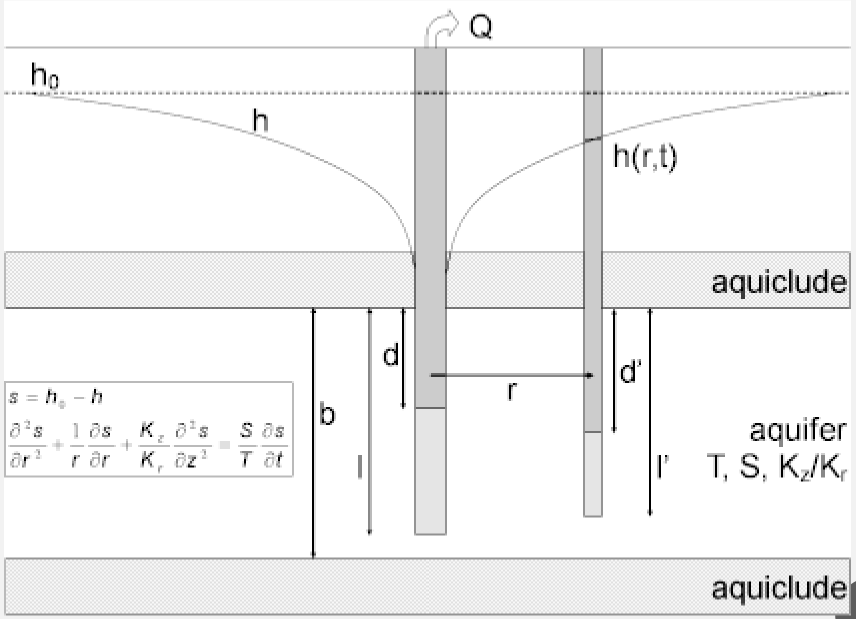
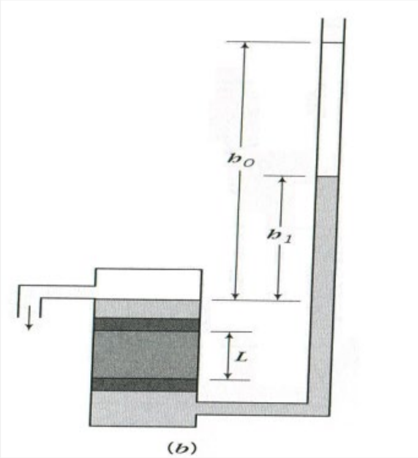


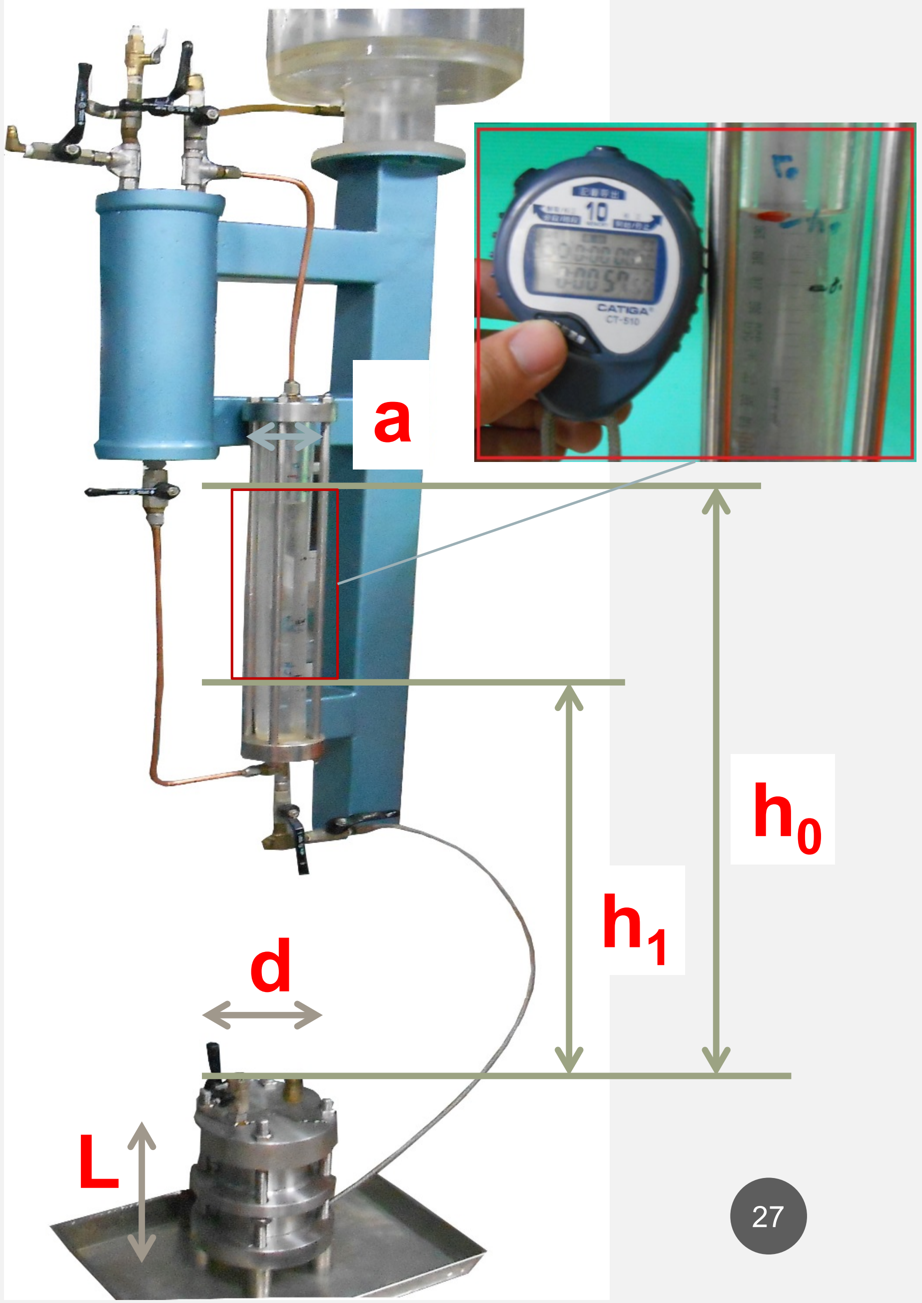
Fig. Theis_method *(Theis, 1935)*



Parameter	Value	Unit
a	7.07	cm^2
L	15	cm
A	44.16	cm^2
ho	84	cm
h1	54	cm
log10(ho/h1)	0.19	

$$K = 2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{h_0}{h_1}$$

- -a: the area of standpipe
- -L: the length of sample
- -A: the area of sample
- $-t_1$-t_0: the time for falling from h_0 to h_1



圖例	
	Bentonite: every 2m
	Screen: every 2m
	Packer
	Piezometer

4 INCH OBS WELL 50M