24S-183

Hydrogelogical Evaluation of Unsaturated Zone In-situ Test Facility Designed for Small-scale Field Infiltration Test

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Abstract

The long-term stability of deep disposal facilities hinges significantly on reactive boundary interfaces formed along groundwater pathways. Rainfall seeps into the surface, moving through unsaturated zones and aquifers, undergoing geochemical changes as it progresses towards the deep subsurface. During this process, the migration of redox transition zones can weaken the natural barriers' buffering capacity. Therefore, a thorough understanding of groundwater flow characteristics from the surface to the disposal facility's surrounding bedrock is crucial. To achieve this understanding, we are planning small-scale field infiltration tests to investigate the movement of groundwater from the surface to the groundwater table. This study provides a comprehensive analysis of the hydrogeological features of UNsaturated zone In-situ Test facility (UNIT), designed specifically for conducting small-scale field infiltration tests. Future studies will focus more on field-scale experiments, including tracer tests, with an emphasis on field infiltration tests, utilizing various tracers based on the results. These small-scale experiments will be utilized to derive methodologies for assessing the background characteristics of the study area, serve as input data for an integrated surface-subsurface hydrologic model to evaluate the long-term performance of natural barriers, and assess the performance of models simulating the unsaturated zone. Such research at a small scale will serve as a foundation for developing larger watershed-scale models, essential for evaluating the long-term safety of deep disposal repositories.

KEY WORDS: groundwater level, pumping test, transmissivity, hydraulic conductivity

Introduction

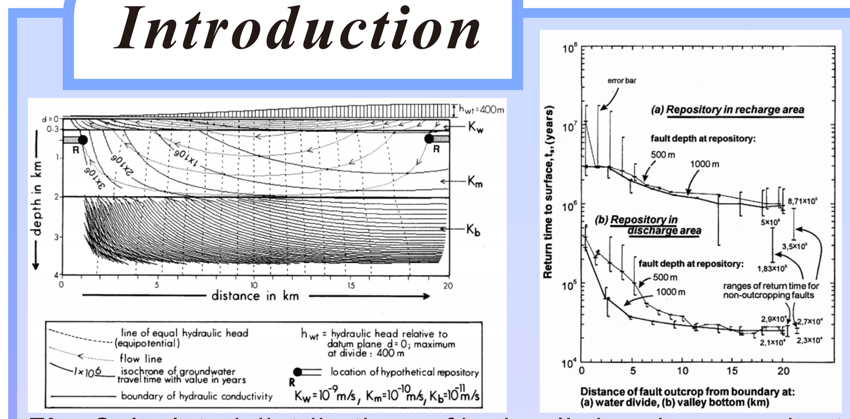


Fig. Calculated distributions of hydraulic heads, groundwater flow lines, and isochrones of groundwater travel times [1]

In the satety assessment of deep geological disposal, it is necessary to consider the long-term evolution of the land surface environment, and therefore understanding the unsaturated zone is significant.

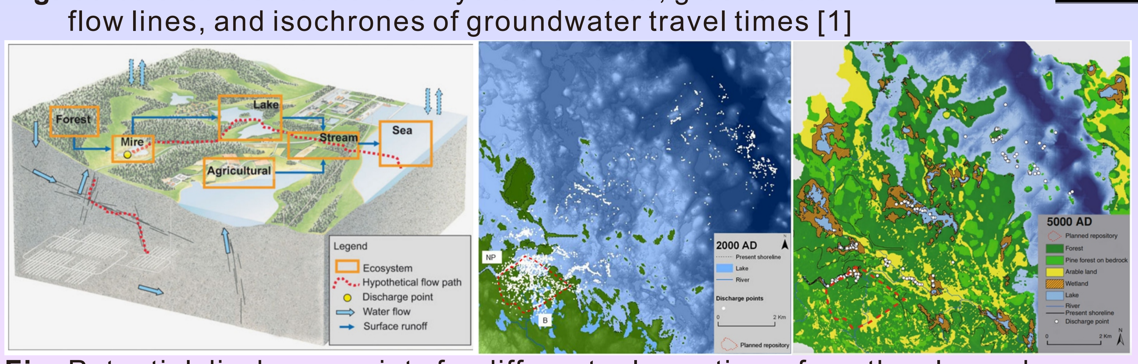


Fig. Potential discharge points for different release times from the planned repository in Forsmark, Sweden [2]

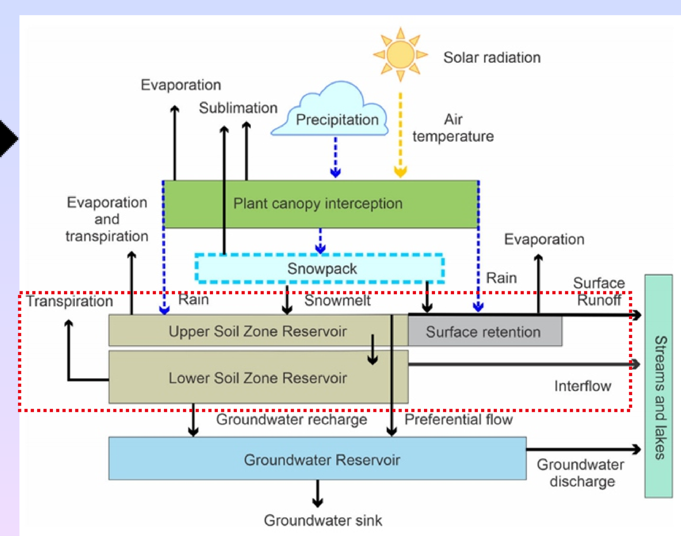


Fig. Water budget in a hydrological model [3]

Laboratory-scale Experiments

Grain size and soil texture analyses were performed using soil samples from four depths. The mean grain sizes ranged from 0.35 to 0.53 mm, indicating **medium sand**, with hydraulic conductivity expected to fall within the range of 1e-6 to 1e-2 m/s [4]. Therefore, the **constant rate test** was determined as in-situ hydraulic test method for the study area [5].

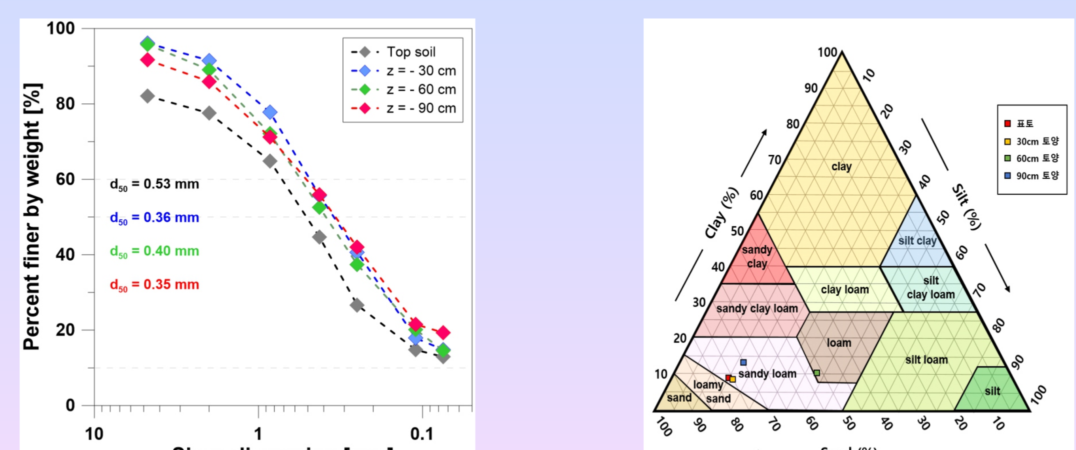
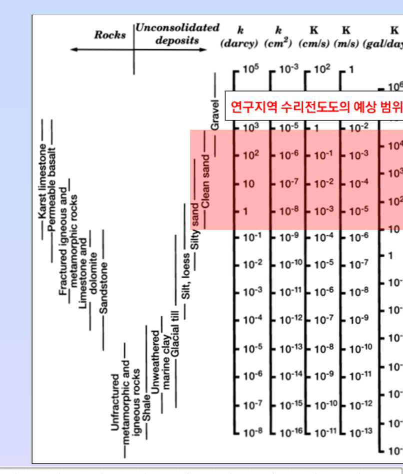
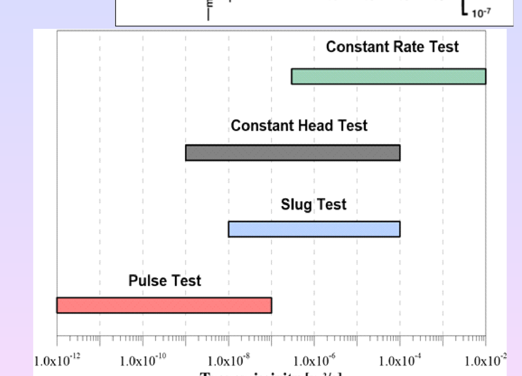
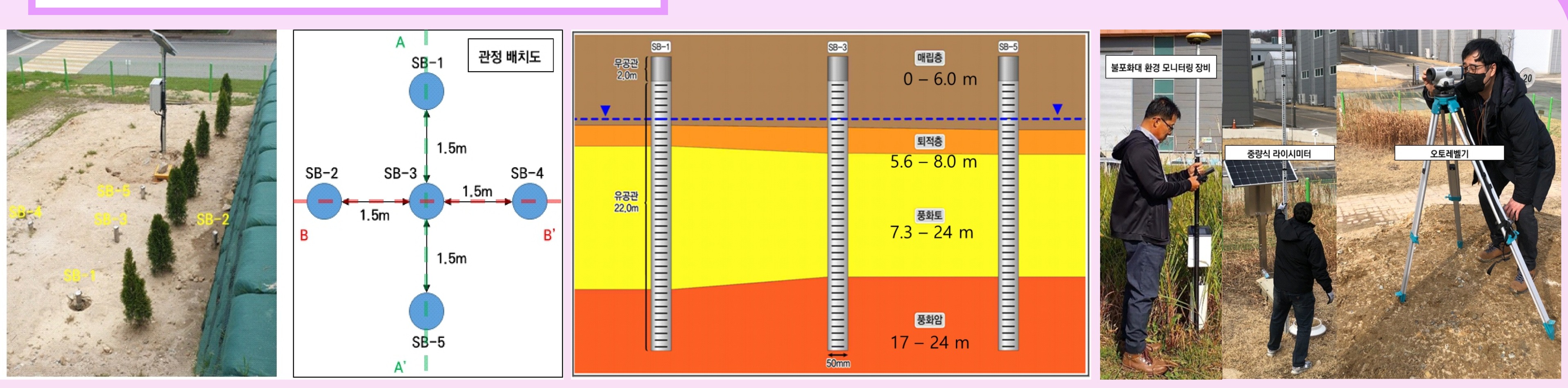


Fig. The results of grain size & soil texture analysis for soil samples by depth (topsoil, 30 cm, 60 cm, and 90 cm)

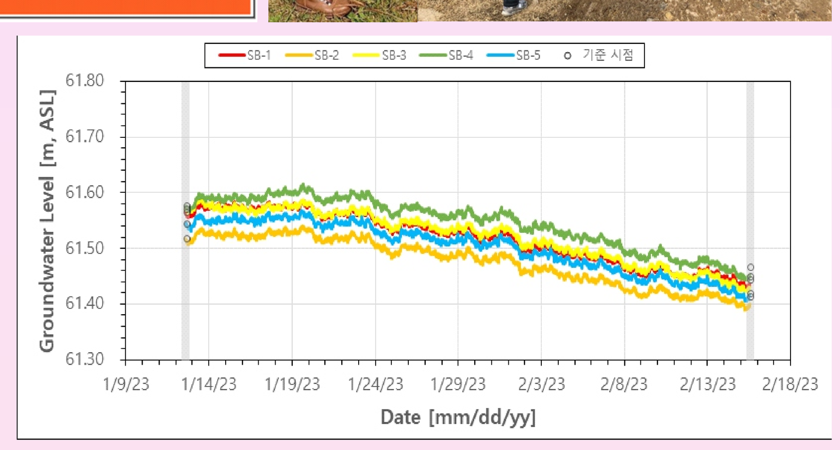




Field-scale Experiments



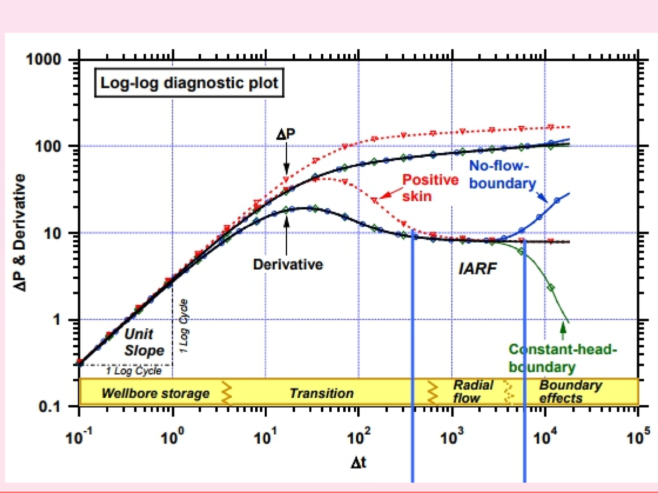
To conduct field experiments such as hydraulic testing or tracer tests for observing groundwater level fluctuations and assessing aquifer characteristics, a total of five boreholes were installed within UNIT, penetrating through weathered soil layers. The research area comprises landfill layers, sedimentary layers, weathered soil, and weathered rock. To accurately measure the groundwater level, automatic and manual measurements were performed concurrently to determine the elevation.

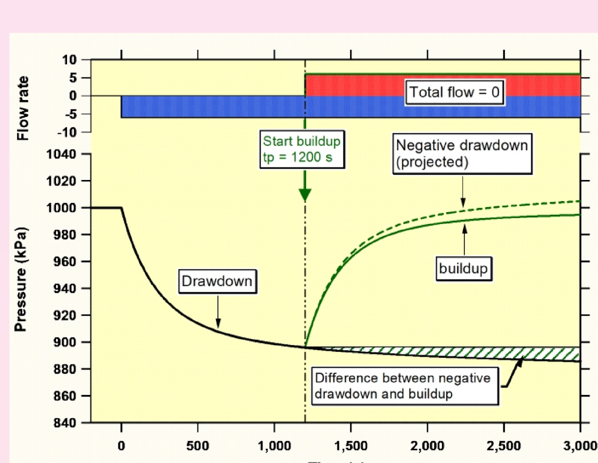


Pumping Test → Type Curve Fitting → Diagnostics → Recovery Test

For multi-well test
- IB-4 (PW), all (MW)
- 27.87 m/d for 2hrs

For single-well test
- all (PW), all (MW)
- 18 m/d for 0.25 hrs





Key References

[1] J. Toth and G. Sheng, Enhancing safety of nuclear waste disposal by exploiting regional groundwater flow: The recharge area concept, Hydrogeological Journal 4(4), 4-25, 1996.

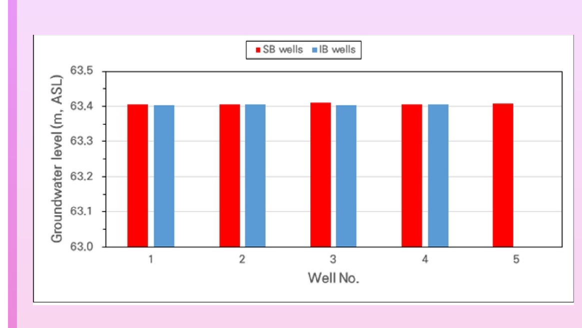
[2] S. Berglund, et al.., Identification and characterization of potential discharge areas for radionuclide transport by groundwater from a nuclear waste repository in Sweden. Ambio, 42, 435-446, 2013.

[3] S.B. Levin et al, Uncertainties in measuring and estimating water-budget components: Current state of the science. WIREs: Water, 10(4), e1646, 2023.

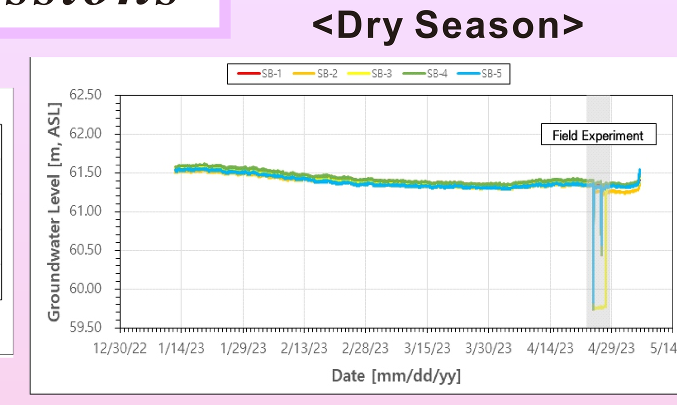
[4] V. Batu, Aquifer hydraulics: A comprehensive guide to hydrogeologic data analysis, John Wiley & Sons, New York, 727p., 1998.

[5] S. Walter et al., 2006, Geo-hydraulic Tests in Rock, 82p.

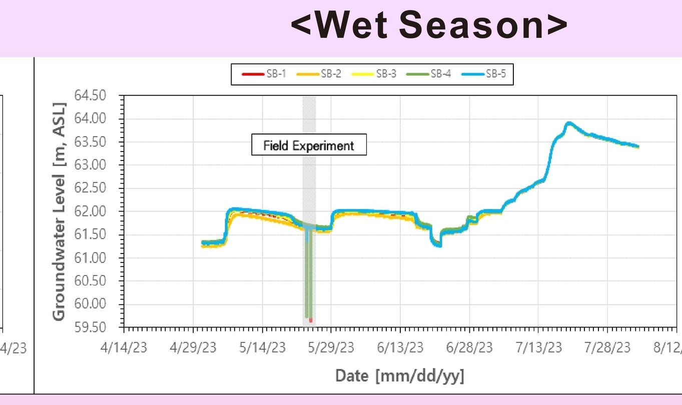
Results & Discussions



<Dry Season>



<Wet Season>



As the boreholes were closely located, significant differences in groundwater levels were not observed. During the dry season, the groundwater level gradually decreased around an elevation of 61 m, while during the wet season, it sharply increased up to 64 m. The unsaturated zone consists of sandy loam and loam with relatively good permeability, and its thickness ranges from 2 to 4 m, causing rapid fluctuations in groundwater levels due to rainfall.

For multi-well pumping test
- IB-4 (PW), all (MW)
- a drawdown of 5.729 m at the pumping well, and only 0.680 m at the nearest observation well, IB-3

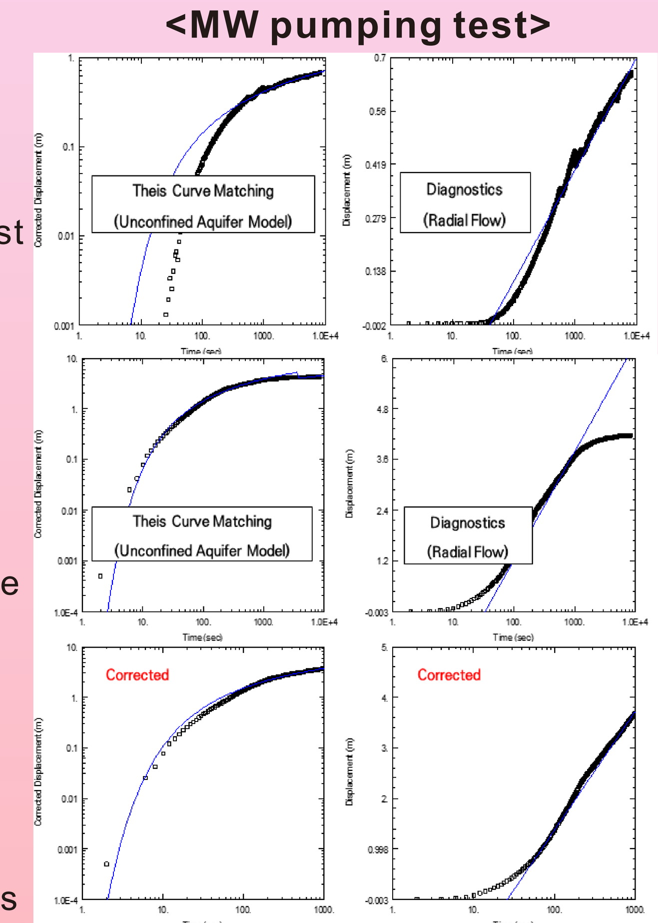
- The transmissivity and hydraulic conductivity of IB-4 are approximately 1/8 of those measured at IB-3.

- This indicates a lower hydraulic connection between IB-4 and the other observation wells.

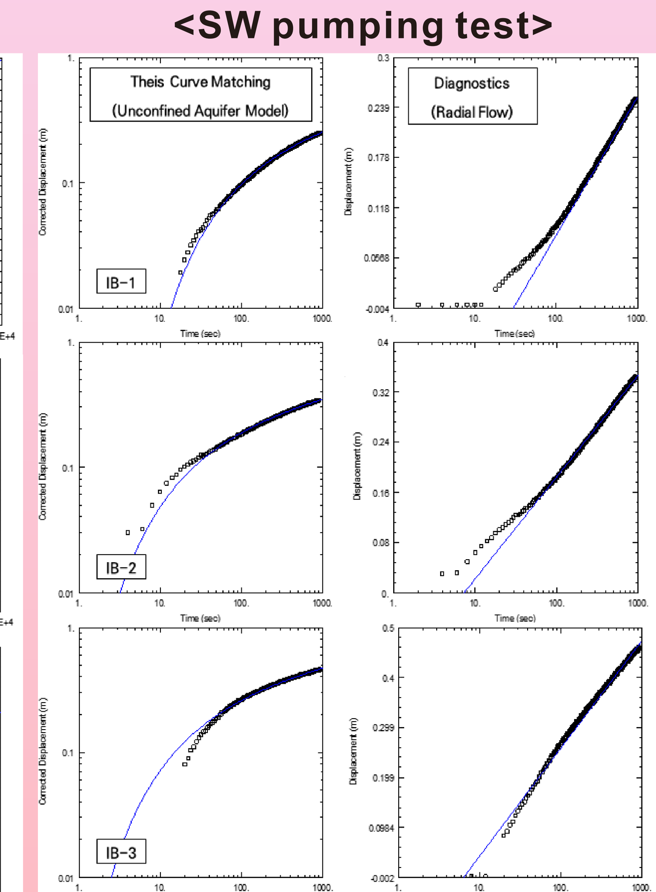
For single-well pumping test
- all (PW), all (MW)

- The groundwater level changes observed at IB-1, IB-2, and IB-3 during the single-well pumping tests indicate rapid attainment of radial flow shortly after pumping.

<MW pumping test>



<SW pumping test>



-The single-well pumping tests were also analyzed using the unconfined aquifer model.

- Transmissivities ranged from 1.770E-4 to 2.355E-4 m^2/s

- Hydraulic conductivities ranged from 1.656E-5 to 2.138E-5 m/s

Table. Analysis results of MW & SW pumping test

Test Type	Well No.	Aquifer Thickness [m]	Pumping Test		Recovery Test	
			T [m^2/s]	K [m/s]	T [m^2/s]	K [m/s]
Multi well	IB-3	10.50	2.013E-4	1.917E-5	-	-
	IB-4	10.50	2.514E-5	2.394E-6	-	-
Single well	IB-1	10.62	2.271E-4	2.138E-5	2.693E-4	2.536E-5
	IB-2	10.72	2.355E-4	2.197E-5	2.610E-4	2.435E-5
	IB-3	10.69	1.770E-4	1.656E-5	2.373E-4	2.220E-5

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