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Integrating Multiple Subsurface Exploration Technologies in Slope Hydrogeologic Investigation: A Case Study in Taiwan

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Taiwan is an island located at a tectonically active collision zone between the Eurasian Plate and the Pacific Plate. Also, the island is in the subtropical climate region with frequent typhoon events that are always accompanied by intense rainfalls within a short period of time. These seismic and climatic elements frequently trigger, directly or indirectly, natural disasters such as landslides on the island with casualties and property damages. Prompted by the urge for minimizing the detrimental effects of such natural disasters, Taiwan government has initiated and funded a series of investigations and studies aimed at better understanding the causes of the natural disasters that may lead to the formulation of more effective disaster contingency plans and possibly some forecasts system.

The hydrogeology of a landslide site can help unveil the detention condition of storm water entering the aquifer system of the slope as well as its groundwater condition which, in turn, plays a critical role in slope stability. In this study, a hydrogeologic investigation employing a series of subsurface exploration technologies was conducted at an active landslide site in the vicinity of Hwa Yuan Village in northern Taiwan. The site, which covers an area of approximately 0.14 km^2 (35 acres) and generally ranges between 25 to 36 degree in slope, was initially investigated with ground resistivity image profiling (RIP) and electrical logging in order to determine the lithology and possibly the water-bearing capacity of the geologic units beneath the slope surface. Subsequently, both acoustic and optical borehole loggings were then applied to identify potentially significant fracture features at depth and their hydrogeologic implications. In addition, flowmeter loggings and hydraulic packer tests were conducted to further characterize the hydrogeologic system of the site and quantitatively determine the hydraulic properties of major hydrogeologic units.

According to the ground resistivity profiles combined with rock core data, the geologic units can be primarily categorized into colluvium and weathered rock at depths of 4-23 m and 23-80 m, respectively. An approximately 20 m shear zone at depths of 45-65 m was found based on the detection outcome of low electrical resistance. Also, according to the borehole electrical logging, the layer of sandstone was identified in the interval of 48-59 m and 68.5-74 m and showed low water-bearing capacity. In addition, the electrical logging identified the layer of shale was in the interval of 59-68.5 m, which possessed a high water-bearing capacity. The velocity profile along the borehole was obtained from the flowmeter logging. A relatively high velocity zone (1.36∼2.23 m/min) was measured in the interval of sandstone and relatively low velocity zone (0.12∼0.78 m/min) was measured in the interval of shale, which is similar to those found in electrical logging. Moreover, 198 discontinuity planes were identified from the borehole image logging. The orientations of all discontinuities were calculated and compiled to draw a stereographic projection diagram. Judging from the discontinuity clusters on the stereographic projection diagram, a plane failure may possibly occur based on Hoek and Brown's criteria. This is a good demonstration that slope failure geometry and type can be determined by stereographic projection diagram analysis. The borehole images also clearly showed the structures of discontinuities at depth. They not only helped to characterize the results of the above investigation technologies but also provided useful indication in selecting specific geologic intervals for packer tests. The packer tests were conducted and the intervals were isolated based on the results of borehole and flowmeter logging. They indicated that the hydraulic conductivities of the shale and sandstone intervals are respectively 1.37×10^{-8} m/sec and 2.68×10^{-5}-3.76×10^{-5} m/sec, which are in good accordance with the hydraulic characteristics inferred by flowmeter logging.

The aforementioned investigation results, including the geology units and water-bearing capacity categorized by RIP and electrical logging, velocity and hydraulic conductivity obtained from flowmeter logging and packer test, and discontinuity structures recorded by borehole image logging, were used to clarify the complexity of the subsurface environment and to establish the hydrogeologic conceptual model of the landslide site.