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Confined groundwater near the rockhead in igneous rocks in the Mid-Levels area, Hong Kong, China

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Abstract

It is customary in Hong Kong to assume that the hydraulic conductivity of weathered igneous rocks decreases with depth or as the rock mass becomes less weathered. Such a hydraulic conductivity pattern can only lead to an unconfined aquifer. This paper presents a case study in the regions in and around the Mid-Levels area in Hong Kong regarding a possible relatively high hydraulic conductivity (K) zone and confined groundwater along the rockhead. The Mid-Levels area is located at the lower part of the north-facing slopes of Victoria Peak on Hong Kong Island and is prone to landslides. Although this site has a long history of geotechnical studies because of extensive urban development along the coast and public concern on slope stability, hydrogeology of the site remains poorly understood. This paper reexamined the hydraulic conductivity data in 7 boreholes conducted in the 1970s and found that 4 of them indicate an increase in K at the rockhead. Groundwater conditions revealed by tunnel construction at the coast suggest that K close to the rockhead is about 10 times greater than above rockhead. A careful analysis of storm response of a piezometer group with tips in different depths indicates that there was an upward flow from the bedrock to the colluvium. A field study of two overflow standpipes conducted by the authors showed that the water level can be 0.64 and 3.73 m above the ground surface, which illustrates that the deep groundwater is significantly artesian. A search of the archived site investigation reports from the government and private companies has led to an identification of about 24 sites with overflow boreholes, which suggests that overflow phenomenon is quite common in the study area. The paper then concludes that in the study area there is a relatively high K zone along the rockhead and the groundwater in the zone is confined. It is recommended that geotechnical engineers should carry out a more careful field study on an overflow borehole because such a borehole indicates a confined groundwater condition important for slope stability study and foundation design.

Keywords: Confined aquifer; Artesian groundwater; Hydrogeology; Hydraulic conductivity; Rockhead; Weathered igneous rock; Saprolite

1. Introduction

The study area is located at the lower part of the north-facing slopes of Victoria Peak on Hong Kong Island, Hong Kong Special Administrative Region, China (Fig. 1). The study area can be divided into two parts with significantly different modes of development. The upper part of the area (>170 mPD) is essentially a natural slope (see the area with topography contour lines in Fig. 1) with minimal urban development. In contrast, the lower part of the area has been extensively urbanized (see the area with street lines in Fig. 1).

The study area is centered by the Mid-Levels area (see Fig. 1). A rather comprehensive study on geology

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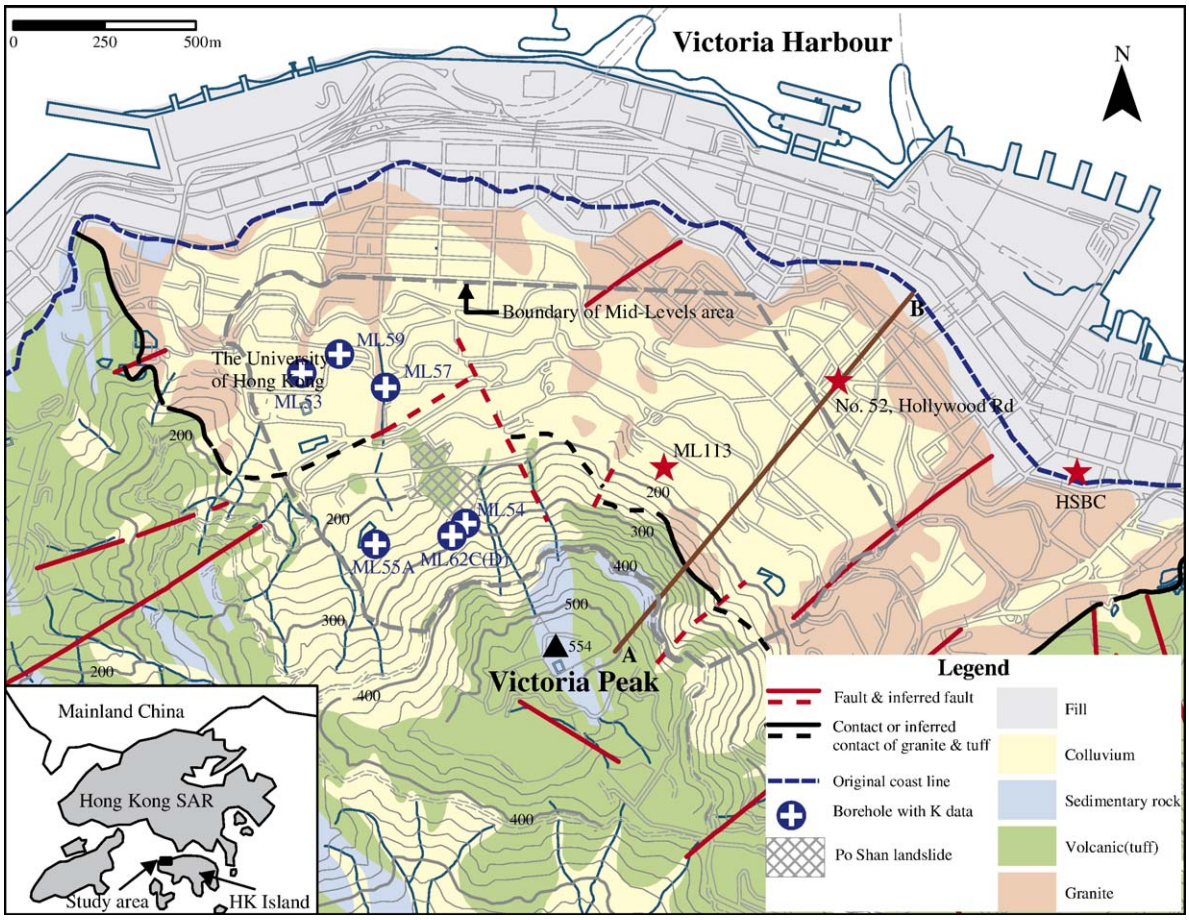

Fig. 1. Location and geology of the study area in and around the Mid-Levels. The location of the geological cross-section A–B shown in Fig. 2 is also presented. This map is based on the Geological Map of Hong Kong (GEO, 1999) and the geological information from GCO (1982).

and hydrology of the Mid-Levels area, called Mid-Levels Study, was carried out by the Geotechnical Control Office (GCO), now Geotechnical Engineering Office (GEO), of Hong Kong Government in the end of the 1970s (GCO, 1982). The main objective of this project was to understand the mechanisms of a fatal landslide, called Po Shan landslide, which occurred in this area in 1972 and killed 67 people. Hundreds of boreholes were drilled in the Mid-Levels area and various hydraulic conductivity (K) tests were carried out. Although these tests were conducted at different depths and different boreholes using various methods, the test data were grouped based on the depth from the ground surface or the degree of weathering. There is a significant scatter but a trend of reducing K with depth is apparent (GCO, 1982), which seems to suggest that K decreases progressively as the depth increases or the rock becomes less decomposed. This pattern has been adopted in GEO manuals and widely used in Hong Kong.

Such a hydraulic conductivity pattern can only lead to an unconfined aquifer system. As the regionally influential and internationally cited Geotechnical Manual for Slopes states (GEO, 1994, p. 55), “in Hong Kong, aquifers are usually unconfined”. All the guidelines in the manual about hydrogeological studies for geotechnical purposes are then largely based on the assumption that the aquifer is unconfined and there is little instruction for the case of a confined aquifer. For example, piezometers (or standpipes) are required to be installed for site investigation purposes. For a typical piezometer with water level below ground surface, the geotechnical engineers conduct falling head or constant head tests to estimate K and monitor the water level for few days to weeks, as required by Geoguide 2 (GEO, 1997b). However, for an overflow piezometer (groundwater flows out of the top of the piezometer), a