Hydrogeological significance of a buried polje on dewatering of karst aquifers for a diamond mine in Northern Ontario, Canada

Wanfang Zhou

Hana Engineers and Consultants, LLC., United States of America
wanfang.zhou@hanaengineers.com

Abstract

A series of diamond-bearing kimberlite pipes were emplaced through Paleozoic carbonates during the Jurassic Period in the peatland of Northern Ontario, Canada. One of these kimberlite pipes was mined using a 220-m deep open pit. Borehole drilling and geophysical surveys were conducted during diamond exploration and feasibility study and revealed a unique geologic feature that abutted steeply the northeast side of the kimberlite. The geologic feature encompassed an area of approximately 3 km^2 and cut through most of the carbonates to a depth of at least 250 m. Because dissolution of the carbonate rocks created karst aquifers characterized with sinkholes, caves, and voids in the study area, this geologic feature was likened to an internally drained karst polje, although its formation mechanism was unknown. Because the polje could potentially provide a vertical pathway through which the karst aquifers were hydraulically connected, it was recognized as an essential component in the hydrogeological conceptual site model, and understanding of its hydrogeological properties was critical for predicting groundwater flow, designing dewatering wells, and mitigating water related risks.

Detailed sediment coring from boreholes indicated that the polje was filled with unconsolidated materials including glacial diamictons at the bottom, glaciolacustrine silt and sand in the middle, and silt and clay with fine lamination at the top. Such a deposition sequence was indicative of gradual infilling of the polje. Two constant-rate pumping tests, one 4-day test at 1,830 m^3/day and one 60-day test at 16,350 m^3/day, were conducted in the primary karst aquifer. The log-log plots of drawdown data in monitoring wells installed in the polje followed the classic Theis curves for porous-medium aquifers with minor deviations. No evidence was observed to suggest strong hydraulic connections between the polje and the karst aquifers. Calibration of a numerical groundwater flow model to the 60-day pumping test data resulted in average horizontal and vertical hydraulic conductivities of 0.01 and 0.001 m/day, respectively, for the polje deposits, which were orders of magnitude less than the average hydraulic conductivity of 5 m/day for the karst aquifers. The pumping test and modeling results suggested that the polje was not an impactful pathway for groundwater flow, and the lack of hydraulic connections between karst aquifers was also supported by groundwater geochemistry data that showed a stratification pattern in the polje deposits.

Multiple lines of evidence suggested that the hydrostratigraphic complexities of the buried polje would not have substantial effects on mine dewatering effectiveness and would not pose substantial risks to mining-induced water hazards by functioning as a preferential flow path, as proved by successful operations of the open pit mine for approximately 12 years.