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# GEOSTATISTICAL EVALUATION OF SPRING WATER QUALITY IN AN URBANIZING CARBONATE AQUIFER

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As part of an investigation of the impacts of urbanization on the hydrology and ecology of Valley Creek watershed near Philadelphia, Pennsylvania, we have analyzed the chemical composition of 110 springs to assess the relative influence of geology and anthropogenic activities on water quality. The 60 kmˆ2 watershed is underlain by productive fractured rock aquifers composed of Cambrian and Ordovician carbonate rocks in the central valley and Cambrian crystalline and siliciclastic rocks (quartzite and phyllite) in the north and south hills that border the valley. All tributaries of the surface water system originate in the crystalline and siliciclastic hills. The watershed is covered by 17% impervious area and contains 6 major hazardous waste sites, one active quarrying operation and one golf course; 25% of the area utilizes septic systems for sewage disposal. We identified 172 springs, 110 of which had measurable flow rates ranging from 0.002 to 5 l/s. The mapped surficial geology appears as an anisotropic pattern, with long bands of rock formations paralleling the geographic orientation of the valley. Mapped development appears as a more isotropic pattern, characterized by isolated patches of land use that are not coincident with the evident geologic pattern. Superimposed upon these characteristics is a dense array of depressions and shallow sinkholes in the carbonate rocks, and a system of major faults at several formation contacts. We used indicator geostatistics to quantitatively characterize the spatial extent of the major geologic formations and patterns of land use. Maximum correlation scales for the rock types corresponded with strike direction and ranged from 1000 to 3000 m. Anisotropy ratios ranged from 2 to 4. Land-use correlation scales were generally smaller (200 to 500 m) with anisotropy ratios of around 1.2, i.e., nearly isotropic as predicted. Geostatistical analysis of spring water quality parameters related to geology (pH, specific conductance, total hardness) revealed isotropic behavior and correlation

scales on the order of 50 m. Geostatistical analysis of water quality parameters related to land use (bromide, chloride, sodium, nitrate, potassium) could not be characterized by variograms as definitively as the geology-related parameters; this is attributed to the influence of structural features such as faults on the groundwater flow system, as well as the isolated nature of anthropogenic activities in this watershed compared to the geologic continuum. Lessons learned include the importance of considering the effects of physical watershed features in addition to types of sources of chemical constituents as influences on water quality. Spatial data visualization (e.g., GIS) is critical in aiding this type of analysis.