A Summary of Potential Geologic Hazards in Holmes Run Valley in the Landmark Area, Alexandria, Virginia

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Introduction

This note summarizes geologic conditions for a portion of Holmes Run Valley where concerns have been raised about the proposed construction of two 9-story high-rise additions to the existing 14-story Parcview Apartments at 5380 Holmes Run Parkway, and its potential to exacerbate existing slope instability and other geologic hazards. The area of interest ("the site", fig. 1) is located east of Landmark Mall and is bounded by North Van Dorn Street on the west, Duke Street (Route 236) on the south, Holmes Run on the north, and North Pickett Street on the east. This moderately to steeply sloping tract is dominantly multifamily housing consisting of a mix of apartments and condominiums in structures that range from 3 to 15 stories in height, most of which were constructed several decades ago. The estimated population is about 7,000.

The proposed building site lies at the foot of the south valley wall of Holmes Run, which in physiographic terms is a retreating escarpment that contributes a large amount of sediment and water to the toeslopes and floodplains along Holmes Run. Potential geologic hazards identified in the area include: unstable hillsides characterized by soils with high shrink-swell potential, a long historical record of landslides, a strongly sloping water table in the lower Potomac aquifer that causes a large volume of groundwater to flow towards and under the site, and wet sandy soils in the lowest part of the site that may be susceptible to seismic amplification and liquifaction.

Using maps of the site adapted from the Geologic Atlas of Alexandria[1], this note briefly highlights three key topics pertinent to the site – Geologic Setting, Slope Instability, and Groundwater. Many additional details about the geologic formations and their properties, landforms, geologic hazards, and groundwater resources can be found in the online geologic atlas and in the other publications referenced therein. Geologic hazards that could potentially be exacerbated by the proposed construction are summarized in the final section and illustrated schematically with a geologic cross section through the site.

It is important to note that no on-site fieldwork was performed specifically for the preparation of this summary. The descriptions of the site presented herein are based on published information of a regional nature, based on spatially variable data quantity and quality, as shown on plate 1 of the Alexandria Geologic Atlas. A site-specific investigation of the building site could yield new information and different conclusions. The chief purpose of this memo is to call attention to geologic conditions and hazards known to be present in the site area so that they may be considered in future site assessments.

Geologic Setting

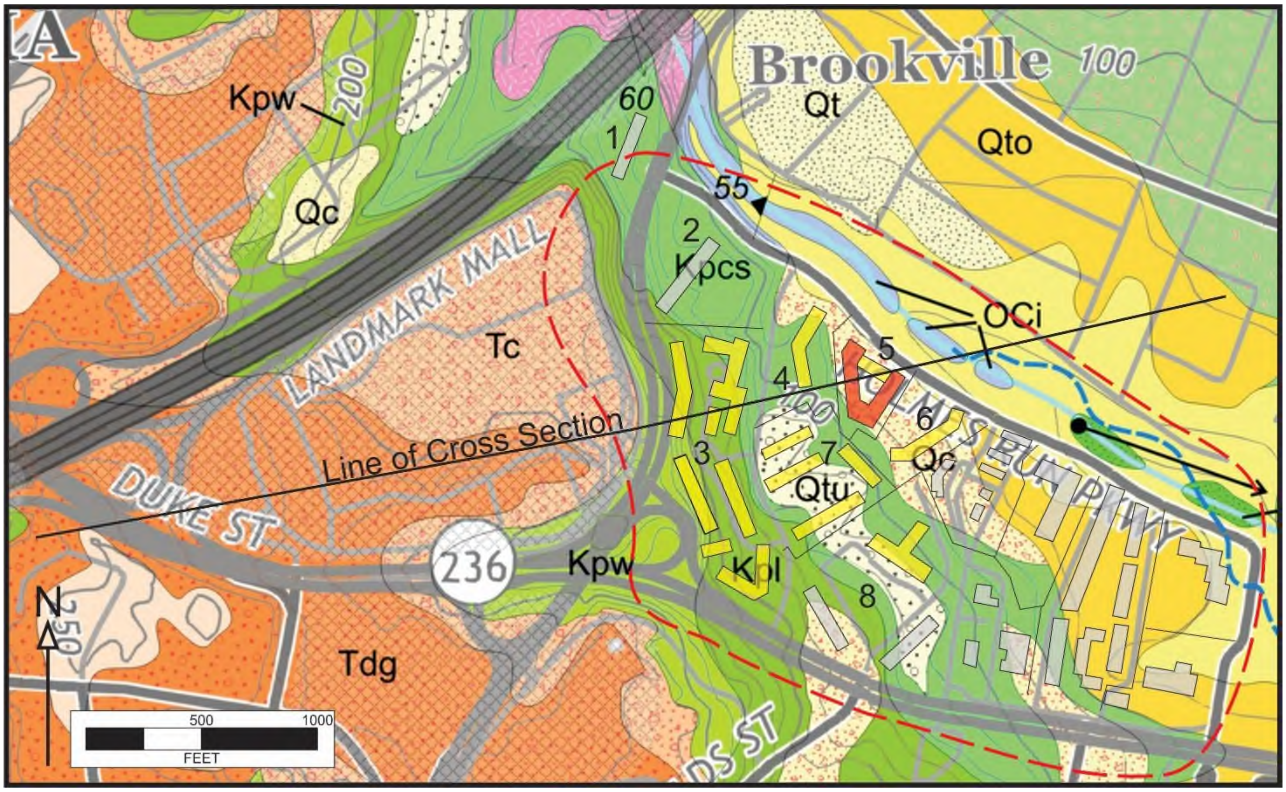

Figure 1. Geologic map of the site (outlined in red) and its surroundings. Site geology is best thought of as a series of alternating layers of clay and sand (or gravel) with strongly contrasting properties in terms of slope stability, shrink-swell potential, ability to transmit groundwater, and other parameters. Three members of the Potomac Formation (green colors) are of particular importance: The steep upper slopes are underlain by the unstable Lincolnia silty clay (Kpl), which is a major landslide-maker in this part of the City. This unit is interbedded at places with Winkler sand (Kpw), which commonly contains a perched water table that acts to soften and wet the enclosing clay. Lower slopes are developed on the Cameron Valley sand (Kpcs), a thick, water-bearing sand and gravel body at the base of the formation that makes up the regionally significant lower Potomac aquifer. Hillsides are frequently blanketed by landslide debris and a variety of loose, gravelly colluvium (Qc), along with terrace deposits of ancestral Holmes Run (Qtu). A sheet of old, orange-weathering river gravel (Tdg, Tc) underlies the upland to the west, while the bottomland along Holmes Run consists of saturated sandy alluvium (Qa) deposited recently by Holmes Run along with several slightly higher, generally sandy or gravelly stream terraces (Qt, Qto). The cross-section line indicates the location of figure 6.

Parcview Apartments is identified as building 5 on the map. It currently consists of a 14-story high rise constructed in 1974 (shown in yellow) on a lot of about 3 acres. The proposed construction project would add two attached, 9-story wings (orange on map), each with a two-story subterranean parking garage, resulting in an overall, southwest-pointing "V" shaped structure around the original building. Neighboring buildings identified by numbers on the map are: 1) Broadstone on Van Dorn, 9 stories, built in 1964; 2) Place One, a 15-story high rise tower built in 1974; 3) The Assembly (formerly Barton's Crossing), 4-5 stories, built in 1989; 4) Claridge House, 12 stories, built in 1981; 6) Pavilion on the Park, 15 stories, built in 1967; 7) 101 North Ripley, 3 stories, built in 1963; and 8) London Park Towers, 15 stories, built in 1963. Each of these structures may be exposed to some level of risk resulting from the alteration of subsurface geology, groundwater flow patterns, and slope forces by the proposed construction and potential acceleration of existing geologic hazards.

<u>Slope Instability</u>

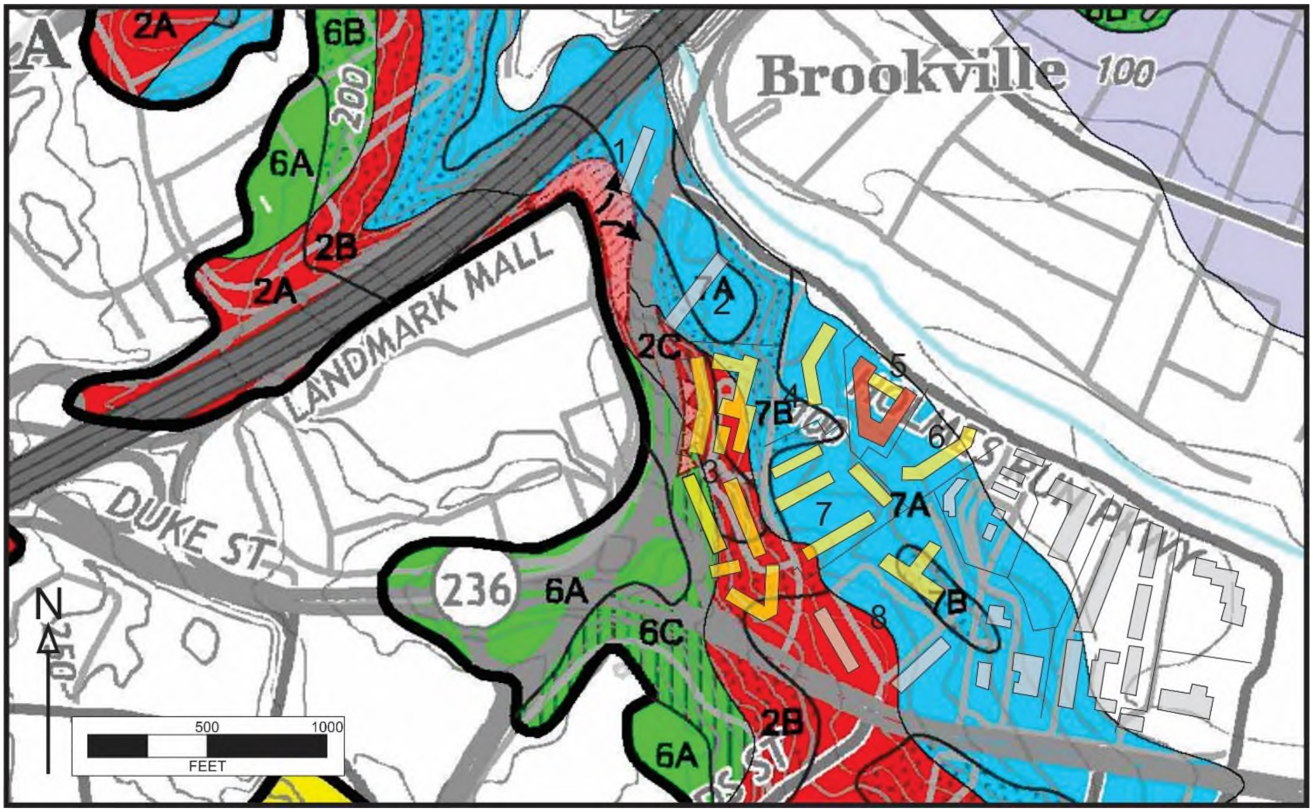

Figure 2. Landslide susceptibility map of the site and its surroundings. The upper slopes (red) are characterized by highly expansive soils and are demonstrably susceptible to slope failures, with much of the area in the most vulnerable slope steepness classes (units 2B and 2C). Recently active landslides are visible above Broadstone at Van Dorn (1) and elsewhere, while a geotechnical report on file with the city details efforts to remediate slope failures at The Assembly (3) shortly after its construction. Map unit 7 (blue), which makes up the lower part of the slopes, is less susceptible to landslides, mainly due to lesser clay content and slope steepness, but the geology is sufficiently variable (e.g., unpredictable silt-clay lenses) that disturbances to terrain or hydrology can trigger localized problems such as differential shrink-swell and instability.

Figure 3. Evidence of enhanced downslope creep is visible throughout the slopes at the site, including leaning trees with an upwards-bending growth habit (left), displaced drain connections (center), and out-of-plumb buildings and tilted infrastructure components (right). In this unstable geologic setting, cosmetic damage to buildings may presage more serious long-term structural issues that typically appear years later. The risk of slope failures is heightened by disturbances to terrain, notably the loading of the crowns of slopes with infrastructure or artificial fill and the cutting of toeslopes for building foundations and streets. All of these risk factors are already present at the site.

Groundwater

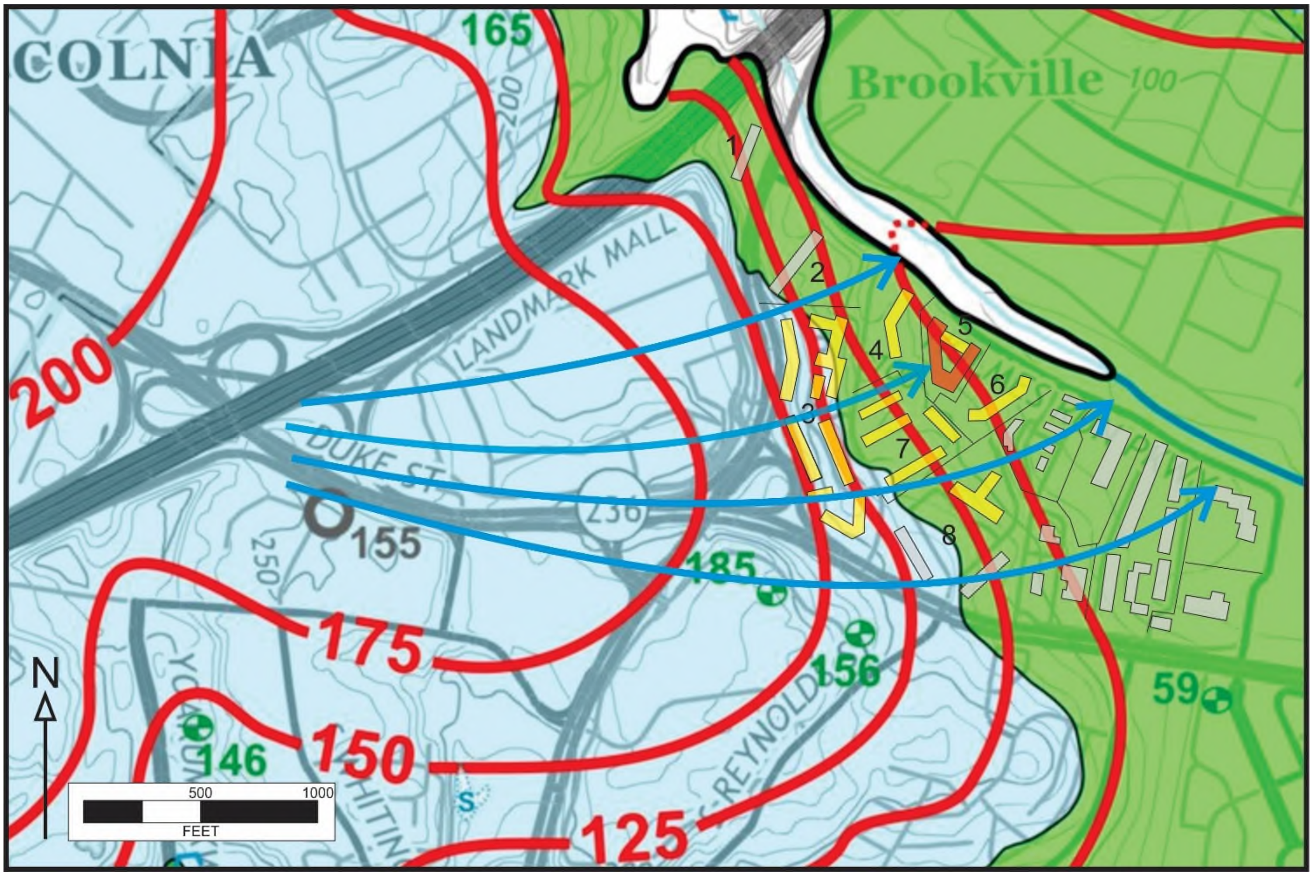

Figure 4. Water levels in the lower Potomac aquifer at the site and its surroundings. Heavy red contours are lines of equal water level elevation in the aquifer. The aquifer is under artesian conditions (water levels above the top of the aquifer) in the light blue area, and under water table conditions (water levels below the top of the aquifer) in the green polygon. The contours indicate that water levels slope sharply eastward across the site from the recharge area to the west. Blue arrows show the general direction of groundwater flow under the site. These relations indicate that: 1) a large volume of groundwater is moving into and under the site, which is expected to produce sizable hydrostatic force against subsurface objects (such as a foundation wall) installed below the water table; 2) the saturated thickness of the aquifer decreases downgradient as the aquifer becomes thinned by erosion. This is expected to lead to a shallow water table at the proposed building site and adjacent areas, in order to accommodate the same volume of groundwater through a thinner saturated thickness of aquifer; and 3) groundwater velocity is likely quite high beneath the site, again to transmit the same volume of groundwater through a progressively thinner section of aquifer.

The current proposal is for a two-story subterranean parking garage beneath both Parcview additions; such a structure will almost certainly extend vertically through the entire saturated thickness of the aquifer and into the underlying (largely impermeable) crystalline bedrock, thereby creating a major obstruction to groundwater flow and imposing large, permanent dewatering costs to maintain dry conditions in the parking facility. Interrupting groundwater flow or altering subsurface moisture conditions could create or exacerbate a number of issues, such as: more frequent surface collapses (“sinkholes”), which are currently present in the lower parts of the site and may be associated with buried ravines or infrastructure such as sewers or the old millrace, and are likely exacerbated by groundwater erosion; development of a groundwater mound on the upgradient side of the obstruction, leading to even greater hydrostatic forces on the structure itself, surrounding foundations, and adjacent sections of the hillside, including unstable clays; and increased groundwater velocity adjacent to the obstruction to compensate for loss of aquifer volume.

Another hazard that closely corresponds to water table depth is the potential for amplification of seismic waves and liquefaction of saturated sediment, leading to a loss of bearing strength. Damaging seismic waves may be generated by moderate to strong earthquakes in the Central Virginia Seismic Zone, such as the one that occurred in 2011 and was strongly felt by more than 1,000 Alexandria residents[2], or from more local sources of seismic energy, such as pile driving or other construction activities, which tend to produce smaller and more localized effects whose extent and strength depend greatly on local geologic conditions.

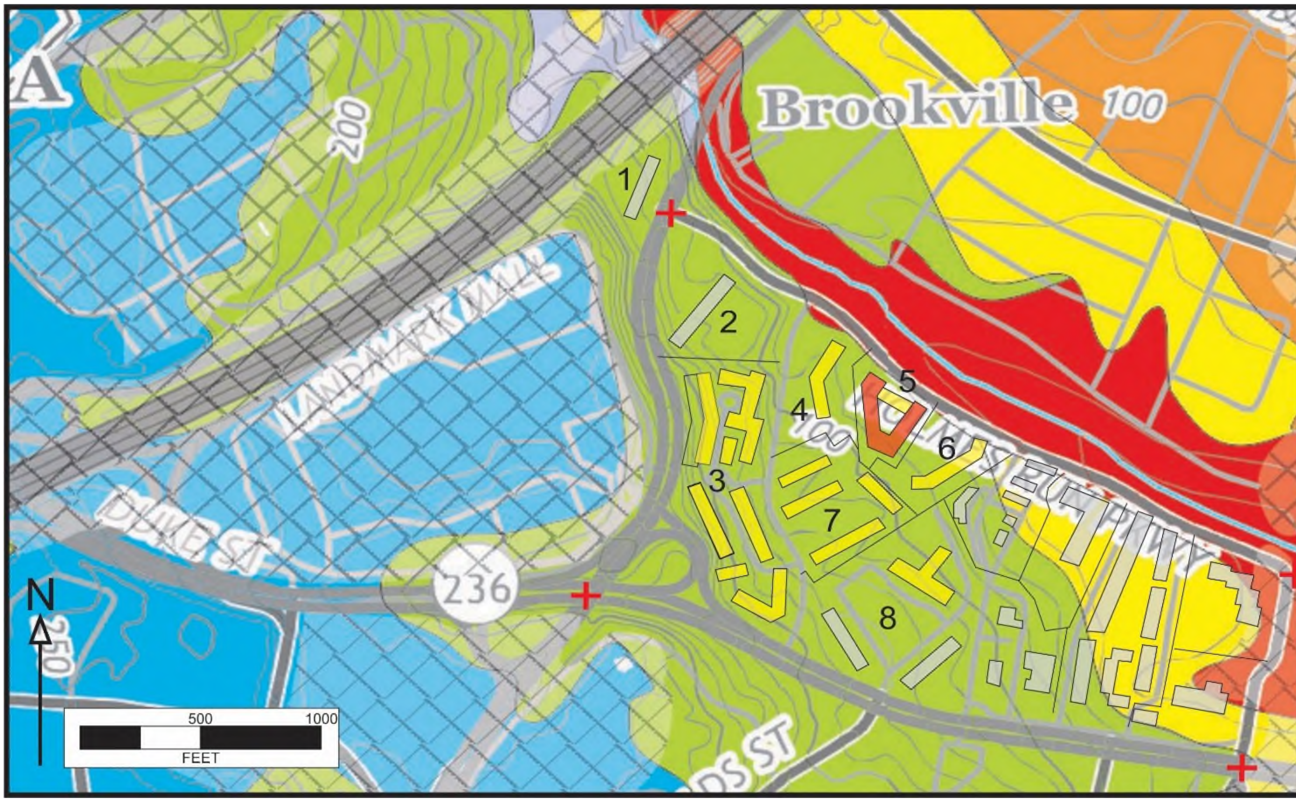

Figure 5. Map of the site and its surroundings showing estimated relative potential for amplification of seismic waves in relation to surficial geology. The red polygon along Holmes Run and Holmes Run Parkway consists of sandy alluvium with a shallow water table, a condition favorable to amplification of seismic waves and prone to liquefaction upon strong shaking. Yellow and green polygons have low to moderate abilities to amplify seismic waves and generally low liquefaction potential unless the water table is shallow, in which case liquification potential may be higher. Major areas of artificial fill are indicated with a mesh overlay and have the potential to rank at or near the top of the scale for amplification of seismic shaking, depending on their composition, how well they were compacted when emplaced, water table depth, and other factors. Additional areas of artificial fill too small to show at the map scale are likely present at the site, especially in the lower-lying areas closer to Holmes Run. In short, the potential for seismic wave amplification is exquisitely dependent on local near-surface geologic conditions, which can vary greatly across short distances in a highly altered landscape like Alexandria's.

<u>Summary of Geologic Hazards and Potential Impacts</u>

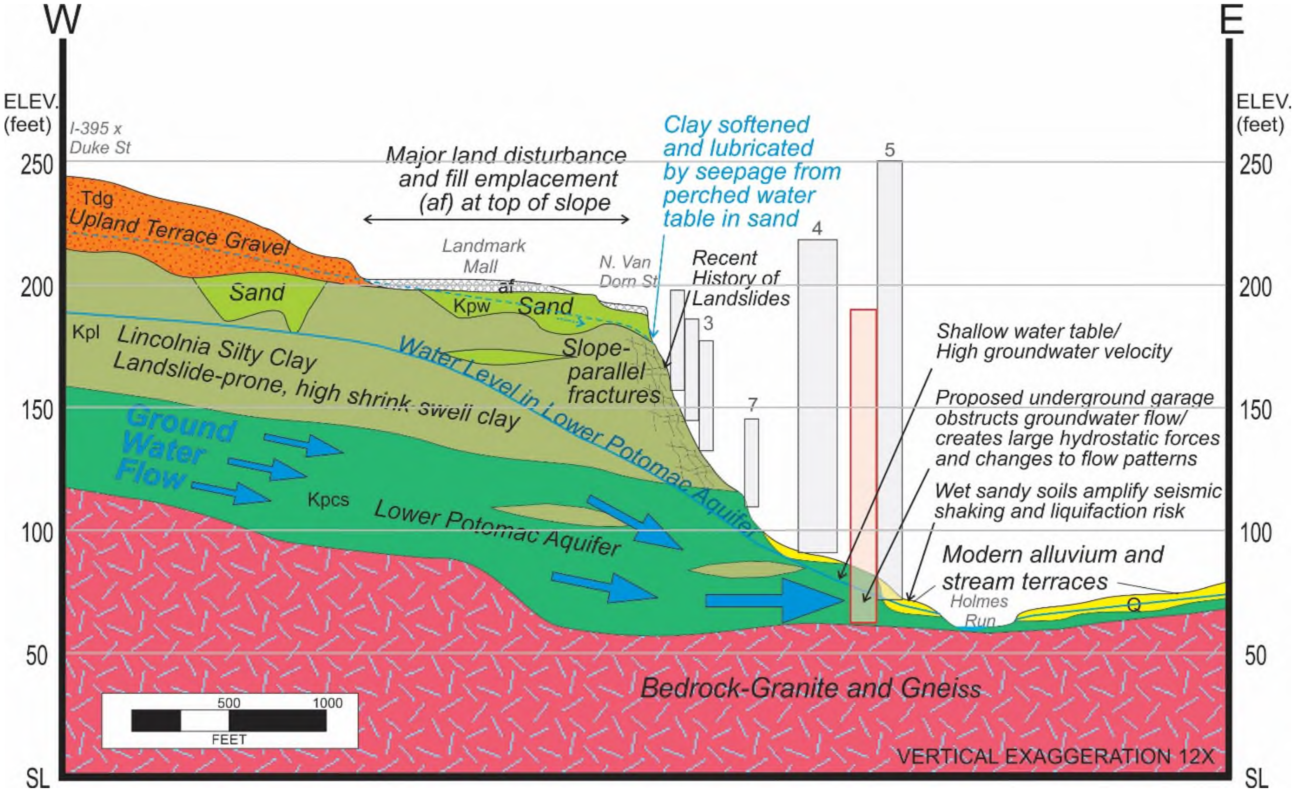

Figure 6. Geologic cross section of the site and its surroundings. Cross sections are like a vertical slice through the subsurface and provide a perspective of the geologic formations, topography, and other features in the third dimension. Geologic map units are generalized from fig. 1, while the water level in the lower Potomac aquifer is the vertical representation of the contours in fig. 4. Silhouettes of existing buildings along the cross-section line are in gray; their foundation details are unknown. The profile of the proposed Parcview addition is in red and shows the 2-story underground parking facility extending to the minimum depth needed to accommodate both levels. Building numbers correspond to fig. 1. Note that the latest FEMA flood map indicates that the base flood elevation of Holmes Run at this location would completely inundate the lower level of the belowground parking facility and potentially some of the higher level.

Several geologic hazards are currently identified at the site and could potentially be exacerbated by the proposed construction as currently contemplated. Some impacts could be felt off site on adjacent properties and structures, rather than or in addition to on the Parcview building site itself.

1) The slopes at this site have naturally evolved over many thousands of years by hillside creep, landslides, and other mass wasting processes, with the lower slopes generally acting as repositories for material shed from the upper slopes. These processes occur exceedingly slowly and/or infrequently under natural conditions but have been accelerated at this site and elsewhere in the general area due to past disturbances, including development of hillsides, emplacement of artificial fill and infrastructure at the crowns of slopes, and removal or cutting of toeslopes that provide a bulwark against strong lateral earth forces emanating from upslope. Further, the geologic formations and their particular arrangement at the site create virtually every aggravating condition described by Stephen Obermeier[3] in his comprehensive analysis of slope stability in northern Virginia. While the proposed building site does not itself appear to lie within unstable clay, judging from the elevations presented in the site plan the proposed construction does contemplate cutting and removing the toeslope at the back of the site, which is a well-known trigger for slope failures further upslope.

2) The building project proposes to install a two-story underground garage that, based on nearby outcrops along Holmes Run, will extend completely through the lower Potomac aquifer and into the top of the underlying crystalline bedrock, which is typically of much lower permeability and functions as a lower flow boundary for the aquifer. Moreover, the long axis of the new building/garage lies at a right angle to the direction of groundwater flow. When completed, the subterranean part of the building will create a monolithic barrier that obstructs the flow of groundwater across most of the width of the Parcview parcel. This could create a number of hydrologic challenges: a large amount of hydrostatic force is expected to be directed against the building/garage foundation on the upgradient side; the need to maintain a substantial and permanent dewatering operation to prevent the garage from filling up with groundwater; the dam-like effect of the subsurface structure is likely to create a groundwater mound on the west side of Parcview, raising water levels and pressure at adjacent properties and possibly on the adjacent unstable slopes; faster groundwater flow velocities in adjacent areas as water is forced to flow around this obstruction; on the other hand, continuously removing a large volume of groundwater via dewatering could create other unintended consequences, such as subsidence, more frequent surface collapses, or differential settlement or shrink-swell of clay-rich zones in response to a new moisture regime.

3) Conditions in the lower part of the site close to Holmes Run Parkway appear conducive to the amplification of seismic waves derived either from earthquakes or construction activities such as pile driving. Wet alluvial soils and artificial fill in this part of the site are potentially prone to liquefaction when subjected to strong shear waves.

4) Some of the potential impacts mentioned in this note have the potential to affect off-site properties and buildings instead of or in addition to the construction site itself. This is especially true of slope failures that might be aggravated by construction activities or hydrologic changes, which may take years to manifest themselves. Based on geotechnical reports available for hundreds of building sites in the City, it is almost unheard of for these engineering analyses to consider off-site conditions and impacts. Yet, in the case of this site, it seems imperative that they do, in order to prevent and mitigate potentially costly impacts on neighboring properties and city infrastructure.

References

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