Appendix B

Geology & Soils Report

DRAFT EARTH ELEMENT TECHNICAL REPORT
FORT LAWTON ARMY RESERVE CENTER REDEVELOPMENT PROJECT
SEATTLE, WASHINGTON

HWA Project No. 2024-127-21

Prepared for:
Landau Associates, Inc.

January 23, 2025

HWA GeoSciences Inc.
DBE/MWBE

Geotechnical Engineering
Pavement Engineering
Geoenvironmental
Hydrogeology
Inspection & Testing

HWA GeoSciences Inc.
DBE/MWBE

January 23, 2025
HWA Project No. 2024-127-21

Landau Associates, Inc.
155 NE 100th Street, Suite 302
Seattle, Washington 98125

Attention: Amy Maule

Subject: **DRAFT EARTH ELEMENT TECHNICAL REPORT**
Fort Lawton Army Reserve Center
Redevelopment Project
Seattle, Washington

Dear Ms. Maule,

HWA Geosciences Inc. (HWA) is pleased to present the attached draft Earth Element technical report that was prepared for the proposed Fort Lawton Army Reserve Center Redevelopment project in Seattle, Washington. The attached draft report presents the results of HWA's desktop study and summarizes geotechnical considerations for use in preparation of the draft Supplemental Environmental Impact Statement (SEIS) for the project.

We appreciate the opportunity to provide geotechnical engineering services for this project. Please contact me if you have any questions or comments concerning this report, or if we may be of further service.

Sincerely,

HWA GEOSCIENCES INC.

Steven R Wright, P.E.
Geotechnical Engineer, Vice President

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DRAFT EARTH ELEMENT TECHNICAL REPORT
FORT LAWTON ARMY RESERVE CENTER
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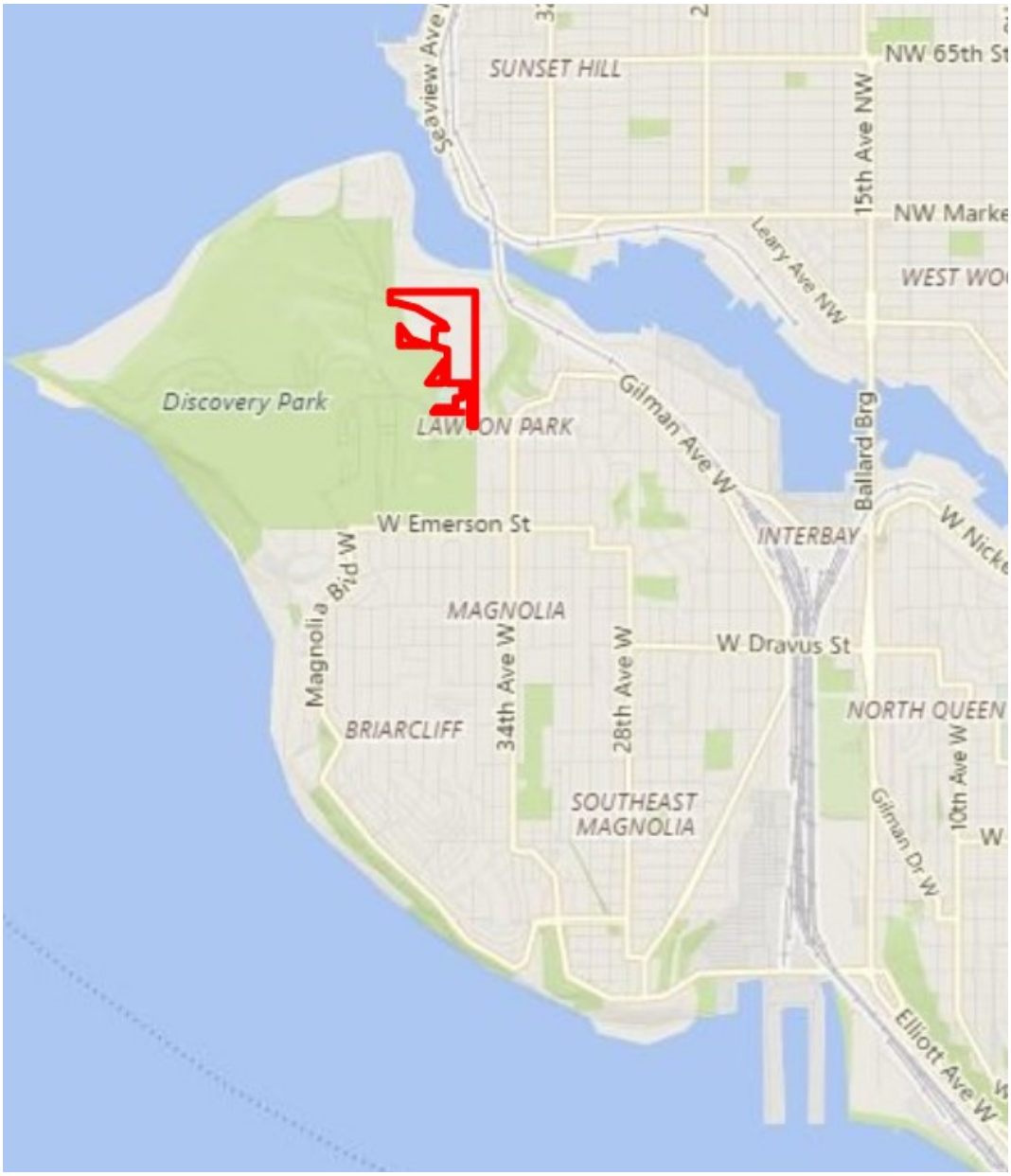
SEATTLE, WASHINGTON

1.0 INTRODUCTION

This Earth Element technical report provides background information to support preparation of the Earth Element section of the draft Supplemental Environmental Impact Statement (SEIS) for the proposed redevelopment of the Fort Lawton Army Reserve Center site in Seattle, Washington. The location of the project site and its limits are shown in the following image.



Since completion of the draft environmental impact statement for the project in 2017, Landau Associates' (Landau) geotechnical group has been acquired by HWA GeoSciences Inc. (HWA) and the staff that supported the project while at Landau are now employed by HWA and continue to be involved with this project. HWA's services for this project were provided in accordance with a Task Order Per Master Services Agreement between Landau and HWA, dated September 9, 2024.

This document has been prepared in support of planning efforts for the Fort Lawton Army Reserve Center Redevelopment project and should not be used beyond the planning stage. Additional site-specific analyses should be performed as part of the specific design and permitting of infrastructure and buildings associated with future site development.

1.1 PROJECT DESCRIPTION

The Seattle of City (City) is proposing an update to the Fort Lawton Army Reserve Center Redevelopment Plan analyzed in a 2018 EIS. The Fort Lawton Army Reserve Center Update is proposed, among other things, to increase the number of affordable housing units on site consistent with existing zoning, and to increase the infrastructure cost efficiency compared to the alternatives analyzed in the 2018 EIS.

The City's goals are to produce supportive housing for formerly homeless people and affordable rental and ownership housing for low-income families and individuals, as well as create public park uses (including both active and passive uses) and meet park maintenance needs. It is expected that full buildout of the Fort Lawton Project would occur by 2032. However, actual buildout could depend on specific economic and market conditions.

As a result of EIS scoping, the City identified the following SEIS alternatives:

- Alternative 1 (Proposed Action) – Mixed Income Affordable Housing and Public Park Uses
- Alternative 2 – No Action Alternative

The following are the City's primary objectives for the Fort Lawton proposal:

- Redevelop an approximately 34-acre former U.S. Army Reserve Center site into an affordable, livable community that meets Seattle's increasing need for affordable housing, and open space and recreation areas.
- Affirmatively further fair housing by providing quality, affordable housing choices for low-income people, particularly in areas with few affordable housing options.
- Provide a mix of safe, quality and affordable housing options for people with low to no incomes. The City is planning for up to 500 housing units on the site consisting of:

  - 100 units of formerly homeless senior/veteran housing,
  - 150 to 200 units of affordable ownership housing for first time homeowners with 35 to 45 of these units being townhouse, and
  - 200 to 250 units of affordable rental units. Partner with community organizations and public agencies to support low-income households to thrive.
- Preserve existing natural areas and support wildlife habitat.
- Provide new public park amenities that serve the needs of current and future neighborhood residents, as well as the broader community.
- Reduce existing public maintenance costs at Discovery Park.
- Work cooperatively with the Seattle Department of Construction and Inspections to adopt necessary land use approvals.
- Ensure that the redevelopment is financially feasible and sustainable.
- Utilize this unique opportunity to leverage public property for community benefit.
- Facilitate an efficient redevelopment process to enable completion of urgently needed affordable housing as quickly as possible.

2.0 EARTH

This section describes the affected earth environment and existing geologic conditions on and in the vicinity of the Fort Lawton site, the anticipated impacts from the existing geologic conditions related to the proposed development, potential mitigation measures that may be implemented to address these impacts, and significant unavoidable adverse impacts.

3.0 AFFECTED ENVIRONMENT

The information summarized in this document is based on a review of readily available geotechnical information and published sensitive area maps and surficial geologic maps for the project area. The literature review included both in-house project files and outside sources. Outside sources of information included US Geological Survey (USGS) maps; geologic maps from the Washington State Department of Natural Resources Division of Geology; Soil Survey of King County; borehole logs from the Washington State Department of Natural Resources Division of Geology; Sensitive Areas Maps from the City of Seattle; the online Washington State Department of Ecology well records; and other sources. The sources of information referred to within this technical report are listed in the references section of this report.

The subsurface data collected in support of this document varied across the project area in level of detail, depth of exploration, quality, usefulness, and availability. However, the level of information gathered is considered adequate for a SEIS-level report and for the purpose of

characterizing subsurface conditions in the study area, understanding the potential impacts, and identifying proposed and possible mitigation measures for site development.

The following sections describe the affected environment related to the proposed redevelopment at the Fort Lawton site.

3.1 General Geology and Topography

The Fort Lawton site, in the Magnolia neighborhood in northwest Seattle, Washington, is located within the central portion of the Puget Lowland physiographic province, an elongated north-south trending topographical and bedrock structural depression situated between the Olympic Mountains and the Cascade Range in western Washington. The topography surrounding the project area is dominated by a series of north-south trending elongated ridges and glacial uplands. The uplands are separated by large, glacially carved troughs that are now partially occupied by tidal waters or large lakes that have been modified by fluvial processes following the retreat of the most recent ice sheet. The major troughs are now partially occupied by Puget Sound, Hood Canal, Lake Washington, Lake Sammamish, and the other large water bodies of western Washington (Booth, 1987, Liesch et al., 1963, Mullineaux et al., 1965).

The geology of the Puget Sound region includes a thick sequence of overconsolidated glacial and normally consolidated, non-glacial soils overlying bedrock. Glacial deposits were formed by ice sheets originating in the mountains of British Columbia and from alpine glaciers that descended from the Olympic and Cascade Mountains. These ice sheets invaded the Puget Lowland at least four times during the early to late Pleistocene Epoch (approximately 150,000 to 10,000 years before present). The southern extent of these glacial advances was near present-day Olympia, Washington. Between these glacial advances and after the last glaciation, portions of the Puget Lowland filled with alluvial sediments deposited by rivers that drain the western slopes of the Cascades and the eastern slopes of the Olympics.

The most recent glacial advance, the Fraser Glaciation, included the Vashon Stade, during which the Puget Lobe of the continental ice sheet advanced and retreated through the Puget Sound Basin. Radiocarbon dating indicates that the Vashon ice sheet occupied the Puget Sound area about 15,000 years ago and retreated to the north approximately 13,000 years ago (Thorson 1980). Existing topography, surficial geology, and hydrogeology in the project area were heavily influenced by the advance and retreat of the Vashon ice sheet.

The Fort Lawton redevelopment site is situated within a glacial upland that is locally referred to as the Magnolia Bluff. Magnolia Bluff is bounded by Shilshole Bay and Salmon Bay to the north, Elliott Bay and Smith Cove to the south, Puget Sound to the west, and the Interbay Trough to the east. Glacial uplands such as the Magnolia Bluff are generally composed of very dense and hard glacial soils that were laid down during the advance and retreat of several glaciers. Since the late 19th century, the project site has been home to the Fort Lawton US Army Reserve Center and as a result, grading has occurred across the site.

3.2 SURFICIAL GEOLOGY

An understanding of the surficial geology of the Fort Lawton site was derived from a review of *The Geologic Map of Seattle – a Progress Report* (Troost et al., 2005), published by the USGS. Generally, the surficial geology of the project site is mapped as advance outwash.

3.3 GEOLOGIC UNITS

Various geologic units are reported to have been encountered by others in the deeper subsurface explorations reviewed for the Fort Lawton site; these units are referred to throughout this document and are described in the following section.

Very few geologic units have precise boundaries or contacts, and the geology of an area can change drastically both horizontally and vertically within a few feet or, in some instances, can remain relatively consistent for hundreds of feet. Typical descriptions of the geologic units reportedly encountered by others at or in the vicinity of the Fort Lawton project site are presented below. In general, the geologic units are ordered from the most recent, or younger deposits, to the oldest. The geologic units that are younger than Vashon-age glacial till have not been glacially over-ridden. The Vashon-age glacial till and the older units have been glacially consolidated and are typically very dense or hard.

3.4 VASHON GLACIAL TILL

Glacial till typically consists of a heterogeneous mix of gravelly sand with scattered cobbles and boulders in a clay/silt matrix that was deposited beneath glacial ice. This very dense unit is locally referred to as “hardpan.” Glacial till typically exhibits high shear strength and low compressibility characteristics. Competent sections of till often form bluffs above Puget Sound. Vashon till deposits in the vicinity of the Fort Lawton site are typically 3 to 30 feet (ft) thick.

3.5 VASHON-AGE ADVANCE OUTWASH

Meltwater streams emanating from advancing glaciers deposited stratified glacial advance outwash. Glacially over-ridden advance outwash typically consists of unoxidized to slightly oxidized, dense to very dense, well-sorted sand and gravel with cobbles and occasional boulders. Advance outwash locally sits atop Lawton clay deposits and grades downward with increasing silt content. This unit may include overlying areas of Vashon till too small to show at map scale. This unit is regionally important as an aquifer. Where it is thick, groundwater saturated sections occur (Turney et al., 1995). Where underlain by low permeability sediment, the unit may discharge spring water from surface outcrops. In the vicinity of the Fort Lawton site, advance outwash deposits are known to be more than 200 ft thick.

3.6 LAWTON CLAY

Lawton clay typically consists of stiff to hard, laminated to massive silt, clayey silt, and silty clay that was deposited in lowland or proglacial lakes. Dropstones may be locally present, as well as

fine grained sediment of the underlying Olympia beds. The thickness of Lawton clay deposits ranges from a few feet to more than 100 ft.

3.7 OLYMPIA BEDS

Olympia beds typically consist of very dense or hard, thinly interbedded sand, silt, gravel, and peat deposited by lowland streams or in floodplain and/or lacustrine environments during the Olympia non-glacial interval. Following the Olympia non-glacial interval, the Olympia beds were overridden by the Vashon glacial advance.

3.8 GROUNDWATER

Due to the anticipated thick deposits of advance outwash at the surface overlying Lawton clay deposits, it is likely that any groundwater present at the Fort Lawton site is perched atop the relatively impermeable Lawton clay. Previous subsurface investigations conducted by others (CH2M HILL and Associated Firms, 1989) have identified groundwater levels in the vicinity of the Fort Lawton site at a maximum of approximately 160 ft below ground surface (bgs). Previous analyses conducted by others (Booth et al., 2005) generally indicate groundwater flows laterally to the steep hillsides along the coast and deep ravines, such as the Interbay Trough, where groundwater ultimately discharges into Elliott Bay. Furthermore, it is anticipated that groundwater conditions will vary depending on local subsurface conditions, the season, recent weather patterns, and other factors.

3.9 GEOLOGIC HAZARDS

Washington State's Growth Management Act (Chapter 36.70A of the Revised Code of Washington [RCW]) requires all cities and counties to identify critical areas within their jurisdictions and to formulate development regulations for their protection. Among the critical areas designated by the Growth Management Act are geologically hazardous areas, defined as such because of their potential susceptibility to erosion, sliding, earthquake, or other geologic events, or because of their past use (i.e., landfill). These areas may not be suited for development consistent with public health and safety concerns without conducting specific studies during the design and permitting process.

The City defines and identifies geologic hazard areas in its Environmentally Critical Areas Ordinance (Chapter 25.09.020 of the Seattle Municipal Code [SMC]) and has developed a folio of maps of the geologically hazardous areas. In general, before development is allowed in or immediately adjacent to mapped critical areas, detailed geotechnical studies must be conducted to address specific standards relating to site geology and soils, seismic hazards, and facility design.

A discussion of steep slope and landslide, seismic, landfill, erosion, and flood hazards is provided below.

3.9.1 Steep Slope and Landslide Hazards

Steep slope areas are generally defined as those areas that rise at an inclination of 40 percent or more with a vertical change in elevation of at least 10 ft. Generally, landslide hazard areas can be defined as any area with a combination of:

- Slopes greater than 15 percent
- Impermeable soils (typically silt and clay) frequently interbedded with granular soils (predominantly sand and gravel)
- Springs or groundwater seepage
- Shows evidence of movement during the Holocene Epoch (from 10,000 years ago to present) or is underlain by mass wastage debris of that epoch
- Subject to instability as a result of rapid stream erosion, stream bank erosion, or undercutting by wave action
- Shows evidence of, or is at risk from, snow avalanches
- Located on an alluvial fan that is presently subject to, or potentially subject to, inundation by debris flows or deposition of stream-transported sediments.

Areas of known landslides are included in the City of Seattle's mapped critical areas. Some of these areas have a history of repeated landsliding. Frequently, these areas of repeated landsliding are located within areas mapped as steep slope hazard areas. Landslide deposits and landslide scars are indicators of past landslides.

The degree of potential sloughing and sliding varies with the steepness and height of the slope. Steeper, higher slopes are more likely to create larger slides, whereas shorter slopes tend to produce smaller surficial sloughs. Slopes that are susceptible to movement under non-earthquake (static) conditions also present a hazard under earthquake loading conditions.

According to the City of Seattle Department of Planning and Development GIS website, the northern portion as well as an area along the western portion of the Fort Lawton site are mapped as potential slide areas with smaller, localized areas mapped as steep slopes (City of Seattle; accessed October 14, 2024). Additionally, the City has identified previous slide activity both to the north and south of the Fort Lawton site. Site-specific analyses for future improvements at the Fort Lawton site are needed prior to any construction to ensure compliance with City of Seattle requirements for setback and design.

3.9.2 Seismic Hazards

Seismic hazard areas are generally defined as those areas subject to severe risk of earthquake damage as a result of ground shaking, ground rupture, or soil liquefaction. Ground shaking can occur large distances from the earthquake source, ground rupture occurs only along active fault

traces, and liquefaction requires a certain combination of soil and groundwater conditions at the site.

3.9.3 Ground Shaking and Ground Motion Amplification

The entire Puget Sound region lies within a seismically active area, and moderate to high levels of ground shaking should be anticipated during the design life of the proposed Fort Lawton project. Due to the previous development at the Fort Lawton site, there is potential for undocumented near surface deposits of relatively loose/soft fill soils that may be susceptible to amplified earthquake ground motions at various frequencies. Consequently, the near-surface soils at the Fort Lawton site could affect the level of earthquake ground shaking felt in the area. Seismic design using current design codes and generally accepted engineering standards and practices would be conducted during the design phase of future site improvements. This includes use of the current version of the International Building Code (IBC) as amended by the City of Seattle, which contains provisions to address life safety issues and incorporates data obtained from recent seismic events in the seismic design standards (ICC 2020).

3.9.4 Ground Rupture

The Puget Sound region contains numerous fault zones and the Seattle Fault Zone, located about 6 miles south of the Fort Lawton site, is the closest reported fault zone to the project site. The Seattle Fault Zone is about 3 to 4 miles wide and consists of a series of east-west trending faults. Future ground rupture may occur within the Seattle Fault Zone; however, the actual risk at the Fort Lawton site posed by such ground rupture is considered to be relatively small given the relatively thick deposits of glacial soils and the distance between the site and the fault zone. Consequently, design to account for ground rupture will likely not be a significant part of the site-specific seismic design for future site improvements.

3.9.5 Liquefaction

When shaken by an earthquake, certain soils lose strength and temporarily behave as if they were a liquid. This phenomenon is known as liquefaction. The seismically induced loss of strength can result in loss of bearing capacity for shallow foundations, reduction in vertical and lateral deep foundation capacities, downdrag forces on deep foundations, ground surface settlement, embankment instability, and lateral spreading. Seismically induced liquefaction typically occurs in loose, saturated, sandy material commonly associated with recent river, lake, and beach sedimentation. In addition, seismically induced liquefaction can be associated with areas of loose, saturated fill.

Due to the glacially consolidated nature of the soils and deep depth to groundwater at the Fort Lawton site, it is not anticipated that liquefaction will pose a large hazard to the proposed site development. While there may be undocumented fill at the site, it is unlikely that it will be thick enough or saturated enough to pose a serious liquefaction threat to the proposed development.

According to the City of Seattle Department of Planning and Development GIS website, no areas prone to liquefaction are mapped within the site area (City of Seattle; accessed October 14, 2024). However, the City of Seattle has identified a liquefaction prone area approximately 650 feet northeast of the Fort Lawton site.

3.9.6 Erosion Hazards

Erosion hazard areas are defined as those areas containing soil that may experience severe to very severe erosion from construction activity. The susceptibility to erosion is generally a function of soil type, topography, occurrence of groundwater seepage or surface runoff, and the built environment.

The surficial geology at the Fort Lawton site has been identified as advance outwash and likely undocumented fill. When unvegetated and/or disturbed, advance outwash and fill materials may experience severe to very severe erosion hazards on slopes exceeding 15 percent.

3.9.7 Landfill Areas

No landfills are known to exist in or adjacent to the Fort Lawton site.

3.9.8 Flood Hazard

The Fort Lawton site is not mapped in a flood hazard area.

4.0 IMPACTS OF THE PROPOSED DEVELOPMENT

This section evaluates the potential impacts that the existing earth elements at the site may have on the proposed redevelopment of the Fort Lawton site, as well as how the development could impact the earth elements at the site. These impacts include both short-term construction impacts and long-term operational impacts. For identified impacts, some potential mitigation measures are noted in this section to supplement the discussion in the subsequent required/proposed Mitigation Measures section of this document.

The following sections describe impacts related to the proposed redevelopment at the Fort Lawton site.

4.1 GEOLOGIC HAZARD IMPACTS

Geologic hazard impacts are discussed below in terms of how existing geologic conditions at the site could affect the Fort Lawton site under the proposed development.

4.1.1 Settlement

The surficial soil anticipated at the Fort Lawton site is not expected to have unfavorable settlement characteristics for the proposed development.

4.1.2 Landsliding/Steep Slopes

There is a potential for landsliding of existing, steep, landslide–prone slopes in the northern and western portions of the Fort Lawton site. Landsliding could be triggered by a seismic event; the natural process of stabilization of a steep slope to a flatter profile; an increase in pore water pressure from excessive rainfall that could destabilize the slope; or construction that traverses or cuts into a steep slope. The impact of landsliding is considered to be moderately high for the proposed development because some of the proposed structures are located in or adjacent to landslide hazard areas; however, through good site planning, it would likely be possible to avoid this potential adverse impact. Furthermore, site-specific analyses for future improvements in the vicinity of areas mapped as landslide hazard areas are needed prior to any construction to ensure compliance with City of Seattle requirements for setback and design. Landslide mitigation may include the construction of retaining walls and/or the use of deep foundations such as driven or drilled piles.

4.1.3 Erosion

The surficial geology at the Fort Lawton site has been identified as advance outwash and likely undocumented fill. When unvegetated and/or disturbed, advance outwash and fill materials may experience severe to very severe erosion hazards on slopes exceeding 15 percent.

Portions of the site have slopes that exceed 15 percent and development in these areas will require analysis on a case-by-case basis and site-specific analyses would need to be performed for each structure to mitigate this impact. Additionally, construction on slopes would include employing temporary erosion control measures and Best Management Practices (BMPs) during construction to mitigate erosion impacts (see the Mitigation Measures section of this document for details).

4.1.4 Ground Shaking and Ground Motion Amplification

The entire Puget Sound region lies within a seismically active area, and moderate to high levels of ground shaking should be anticipated during the design life of the proposed Fort Lawton development. Due to the previous development at the Fort Lawton site, there is potential for undocumented near-surface deposits of relatively loose/soft fill soils that may be susceptible to amplified earthquake ground motions at various frequencies. Consequently, the near-surface soils at the Fort Lawton site could affect the level of earthquake ground shaking felt in the area. Seismic design using current design codes (including the IBC as amended by the City of Seattle) and generally accepted engineering standards and practices would be conducted during the

design phase of future site improvements to reduce the potential impacts to buildings and infrastructure due to ground shaking.

4.1.5 Ground Rupture

The Fort Lawton site is located about 6 miles north of the Seattle Fault Zone. The Seattle Fault Zone is about 3 to 4 miles wide and consists of a series of east-west trending faults. Future ground rupture may occur within the Seattle Fault Zone; however, the actual risk at the Fort Lawton site posed by such ground rupture is considered to be relatively small given the relatively thick deposits of glacial soils and the distance between the site and the fault zone. Consequently, design to account for ground rupture will not be a significant part of the site-specific seismic design for future site improvements.

4.1.6 Liquefaction

Due to the glacially consolidated nature of the soils and deep depth to groundwater at the Fort Lawton site, it is not anticipated that liquefaction will pose a major hazard to the proposed site development. While there may be undocumented fill at the site, it is unlikely that it will be thick enough or saturated enough to pose a serious liquefaction threat to the proposed development.

4.1.7 Seismically Induced Landslides

While the surficial soils at the Fort Lawton site are not considered to be liquefiable, slope failures may occur near the proposed structures as the dynamic shear stresses produced by earthquake shaking increase the load along a potential failure plane. To address the potential impact of such slope movement, mitigation measures would include site-specific slope stability analysis and design of any structures proposed near steep slope or landslide hazard areas.

4.1.8 Landfill Areas

No landfills are known to exist on or adjacent to the Fort Lawton site; therefore, there is no anticipated need to mitigate landfill impacts.

4.2 GROUNDWATER

As previously discussed, the primary groundwater system at the Fort Lawton site consists of perched groundwater atop relatively impermeable Lawton clay. Previous subsurface investigations conducted by others (CH2M HILL and Associated Firms, 1989) have identified groundwater levels in the vicinity of the Fort Lawton site to be at a maximum of approximately 160 ft bgs. Previous analyses conducted by others (Booth et al., 2005) generally indicate groundwater flows laterally to the steep hillsides along the coast and deep ravines, such as the Interbay Trough, where groundwater ultimately discharges into Elliott Bay. Furthermore, it is anticipated that groundwater conditions will vary depending on local subsurface conditions, the season, recent weather patterns, and other factors.

The future site improvements for the proposed development will typically replace existing impervious surfaces with new buildings and pavements, and there may be a slight reduction in impervious surfaces at the site; however, no significant loss of recharge to the perched aquifer is anticipated. The project stormwater management system may include retention basins and rain gardens. Depending on the specific location and design of these facilities, there could be some recharge to the aquifer in the vicinity of these facilities.

While temporary excavation dewatering could potentially be required for certain structures and infrastructure, the effect on groundwater would be temporary and localized (also see the Construction Dewatering section below).

4.3 CONSTRUCTION-RELATED IMPACTS

Many of the potential impacts due to geologic hazards could be mitigated by implementing effective design and construction techniques or selecting appropriate foundation types.

The construction of the proposed development at the Fort Lawton site would include removing some of the existing pavement and structures and preparing subgrade soils by grading, placing, and compacting structural fill. Construction of retaining walls and/or deep foundations may be necessary to properly mitigate landslide hazards.

4.4 EROSION DURING CONSTRUCTION

Construction associated with the proposed development could have erosion impacts on exposed soil and soil stockpiles, which could cause onsite and offsite transport of sediment. However, standard temporary erosion and sedimentation control measures and BMPs (as summarized in the Mitigation Measures section of this document) would be implemented during construction of future site improvements to reduce the potential for erosion-related impacts.

4.5 CONSTRUCTION EXCAVATIONS

Temporary excavations will likely be required for the installation of future structures and infrastructure, including new/upgraded underground utilities for the proposed development. Without mitigation, these excavations could have a potentially adverse effect on immediately adjacent existing and future structures (i.e., structures within a distance equal to about the depth of the excavation), utilities, and other improvements. However, standard construction measures, such as use of properly designed and installed temporary shoring systems, would reduce the potential for such adverse impacts.

4.6 CONSTRUCTION DEWATERING

The depth to groundwater at the Fort Lawton site is expected to be relatively deep; however, groundwater may be encountered at relatively shallow depths, particularly during the winter and spring months. Therefore, construction dewatering may be required to control groundwater flow

into certain excavations. The process of excavation dewatering could potentially cause some ground settlement and damage to adjacent existing utilities and structures. The radius of influence of a dewatering system is related to the amount of drawdown of the water table. If extensive dewatering is required, site-specific analyses will determine what structures (existing or future, on site or off site) may be influenced by excavation dewatering. Examples of mitigation measures to control the potential impact of excavation dewatering include minimizing the extent and duration of dewatering, and installing groundwater cut off walls.

4.7 PLACEMENT OF STRUCTURAL FILL

It is anticipated that a substantial amount of surficial onsite soil that is excavated as part of site development will be suitable for reuse as onsite fill, provided that the excavated material is properly handled and moisture-conditioned prior to placement and compaction. All structural fill and backfill material placed as part of future site improvements would be densely compacted, which can cause vibrations and potential settlement of structures in the immediate vicinity of the construction work. Placement of large volumes of fill can also cause settlement/ground subsidence that could impact existing or future structures (on site or off site) in the immediate area of the fill; however, the potential for offsite impacts applies only to significant fills placed for future development at the perimeter of the Fort Lawton site.

It is understood that the proposed structures would be designed to conform to the existing site topography and minimal grading would occur, except possibly toward the south end of the site next to an existing road where site elevations increase. Potential impacts to existing structures on and near the site to be retained (such as the existing Veterans Administration [VA] office off site and the Maintenance Building – Building 245 on site), as well as to future onsite and existing offsite structures, will be mitigated by site-specific analysis and design of fill placement near existing settlement-sensitive structures.

4.8 CONSTRUCTION/EXCAVATION ON OR ADJACENT TO LANDSLIDE-PRONE AREAS

Based on the information available at the time this technical report was written, it is understood that the northern portion as well as the western portion of the proposed development have been identified as landslide hazard areas by the City of Seattle.

The proposed development involves constructing approximately 500 market-rate housing units and 4.4 acres of surface parking. Some of these proposed housing units would be built in the vicinity of landslide hazard areas and as such, site-specific slope stability analyses and design of the residential units and any associated earth retention structures required along the top of the slope would mitigate the potential adverse effect of construction on the stability of these areas. The potential use of pile- or pier-supported foundations would have less impact on steep slopes. Additionally, measures that can be used to reduce construction impacts on the stability of the slope would include employing temporary erosion control measures and BMPs during construction.

4.9 DEEP FOUNDATIONS

Due to the presence of landslide hazard areas in the vicinity of some of the housing units within the proposed development, deep foundations may be used to minimize impacts to the stability of the slopes. Actual pile foundation types to be used for future site improvements would be determined as part of the site-specific design of individual structures and could include driven or drilled piles. The depth of pile foundations would be determined as part of the site-specific slope stability analysis of individual structures and would depend on various factors that include the pile type, the building loads, and site-specific soil conditions.

4.9.1 Driven Piles

During installation of driven piles for foundation support of structures within the proposed development, potential obstructions may be encountered, such as boulders and other debris that could obstruct pile driving and possibly result in damage to some of the piles.

Increased levels of noise and vibration can occur within about 50 to 100 ft of pile driving activities. Peak particle velocities within 10 to 15 ft of pile driving can, in certain cases, exceed 2.0 inches per second (ips), gradually diminishing with distance. Structural damage can occur at peak particle velocities of 2.0 ips or greater.

Soil densification can occur with driven displacement piles when peak particle velocities approach 0.20 ips, which is generally within about 100 ft of pile driving. Soil densification could potentially impact adjacent structures or utilities. The potential impact to existing or future adjacent structures or utilities is directly related to the intensity of the vibration, the diameter of the pile, the inherent density of the soil, and the sensitivity of the adjacent structure or utility to vibrations. The impact of vibrations is difficult to quantify and needs to be addressed on a case-by-case basis and may extend offsite for pile-supported structures located near the perimeter of the Fort Lawton site.

4.9.2 Drilled Piles

Drilled piles could potentially be used in various systems for stabilizing steep slopes in the landslide hazard areas identified on the Fort Lawton site. These systems could include auger-cast piles, micropile root piles, or soldier piles. Construction of drilled piles can be impacted by caving soils, soil heave, and large obstructions. The installation of drilled piles generally does not produce significant vibrations; however, installation of temporary casing can produce ground vibrations and localized ground settlement around the drilled pile construction area. Potential mitigation measures for drilled piles include using casing to control caving soils and monitoring the ground surface during construction.

5.0 NO ACTION ALTERNATIVE

There are no anticipated earth-related impacts to the Fort Lawton site under the no action alternative.

6.0 MITIGATION MEASURES

The following measures are proposed to address the potential earth impacts from construction and operation of the Fort Lawton Army Reserve Center project under the proposed development.

Specific foundation support systems to be used for onsite improvements would be determined as part of the specific design and permitting of infrastructure and individual buildings associated with future site development. Site-specific studies and evaluations would be conducted in accordance with SMC requirements and the provisions of the current version of the IBC (ICC 2020) as amended by the City of Seattle. Methods are available to build out the Fort Lawton site development without resulting in significant unavoidable adverse impacts. Different foundation support options are summarized above in the Impacts section of this document. The mitigation measures to limit impacts from geologic hazards and foundation support options are summarized below.

6.1 GEOLOGIC HAZARDS

6.1.1 Settlement

With proper design and construction procedures, no additional mitigation measures would be required.

6.1.2 Landsliding/Steep Slopes

Development adjacent to or on the steeper slopes in the northern and western portions of the site would require site-specific slope stability analyses prior to construction on or adjacent to the slope. If needed due to soil and slope conditions in certain locations, deep foundations, such as pile or pier supported foundations, could be used to reduce impacts to steep slopes.

The installation of properly designed retaining walls that are constructed near landslide hazard areas in accordance with City of Seattle critical area and grading regulations would reduce impacts to steep slopes.

6.1.3 Erosion

During construction, contractors would employ temporary erosion and sedimentation control measures and BMPs to control erosion. These measures would be consistent with City of Seattle critical area and grading regulations, and could include the following:

- Minimize areas of exposure
- Schedule earthwork during drier times of the year
- Retain vegetation where possible, especially on the steeper slopes within the greenbelt area
- Seed or plant appropriate vegetation on exposed areas as soon as earthwork is completed
- Route surface water through temporary drainage channels around and away from disturbed soils or exposed slopes
- Use silt fences, temporary sedimentation ponds, or other suitable sedimentation control devices to collect and retain possible eroded material
- Cover exposed soil stockpiles and exposed slopes with plastic sheeting, as appropriate
- Use straw mulch and erosion control matting to stabilize graded areas and reduce erosion and runoff impacts to slopes, where appropriate
- Intercept and drain water from any surface seeps, if encountered
- Incorporate contract provisions allowing temporary cessation of work under certain, limited circumstances, if weather conditions warrant.

6.1.4 Ground Shaking and Ground Motion Amplification

With proper design and construction procedures, no additional mitigation measures would be required.

6.1.5 Ground Rupture

With proper design and construction procedures, no additional mitigation measures would be required.

6.1.6 Liquefaction

Due to the glacially consolidated nature of site soils, no mitigation measures are anticipated for soil liquefaction.

6.1.7 Lateral Spreading

Due to the glacially consolidated nature of site soils, no mitigation measures are anticipated for lateral spreading.

6.1.8 Seismically Induced Landslides

While the surficial soils at the Fort Lawton site are not considered to be liquefiable, slope failures may still result as the dynamic shear stresses produced by earthquake shaking increase the load along a potential failure plane. Site-specific analysis of development planned adjacent to

or within the landslide hazard areas would be completed during the design and permit approval process to address specific methods to mitigate potential landslide impacts. The installation of properly designed retaining walls that are constructed near landslide hazard areas in accordance with City of Seattle critical area and grading regulations would reduce impacts to steep slopes. (Also see the Landsliding/Steep Slopes section above.)

6.1.9 Landfill Areas

No active or former landfills have been identified in the vicinity of the Fort Lawton site; therefore, no mitigation measures are anticipated for landfill hazards.

6.2 Construction Excavations

Impacts from temporary construction excavations could be mitigated through the use of properly designed and constructed excavation shoring systems.

6.3 Construction Dewatering

The impacts associated with temporary excavation dewatering depend on the required drawdown of the water table. Because future below-grade construction will likely be relatively shallow and groundwater is anticipated to be very deep, the associated excavations and degree of drawdown required will likely be correspondingly relatively shallow. Site-specific analyses would determine what structures may be influenced by excavation dewatering. Mitigation measures to control the potential impact of excavation dewatering include minimizing the extent and duration of dewatering, monitoring for settlement, and installing groundwater cut off walls.

6.4 Placement of Structural Fill

Ground subsidence impacts could be mitigated by designing the fill to control adjacent settlements. In addition, adjacent structures/surfaces should be monitored during construction to verify that no adverse settlement occurs. Potential impacts to existing onsite and offsite structures (such as the existing VA office off site and Maintenance Building (Building 245) on site) could be mitigated by limiting the amount of fill placed within 50 ft of these structures or monitoring the structures during construction if it is necessary to place fill within 50 ft of these structures. It is anticipated that a substantial amount of surficial onsite soil that is excavated as part of site development will be suitable for reuse as onsite fill, provided that the excavated material is properly handled and moisture-conditioned prior to placement and compaction.

6.5 Construction/Excavation on or Adjacent to Landslide-Prone Areas

Impacts associated with construction/excavation activities on or adjacent to the landslide hazard areas apply only to the northern area of the proposed development, where residential units would be constructed in the vicinity of the steep slopes. These potential impacts would be mitigated by conducting site-specific slope stability analyses and design prior to any construction activity that

excavates, fills, or traverses on or near the landslide hazard areas. In addition to implementing erosion control measures during construction, earth retention structures could be designed and constructed near the bottom of the steep slopes where needed.

6.6 DRIVEN PILES

Steel pipe piles, potentially fitted with a "conical-shaped" driving point, or concrete piles fitted with a heavy-duty shoe, may be able to penetrate old, buried logs or certain other buried debris. If an obstruction is encountered and the pile cannot be advanced, or if the pile becomes damaged, the pile could be abandoned and a replacement pile could be installed.

To limit the potential for adverse vibration impacts from pile driving on nearby structures, vibration monitoring should be conducted during the installation of test piles and selected production piles. The construction-related impacts from pile driving may extend up to about 50 to 100 ft off site for new onsite structures located near the perimeter of the Fort Lawton site. A site-specific vibration analysis could be conducted to more precisely determine the extent of potential vibration impacts due to pile driving. In addition, pile and pile hammer types should be matched to the specific subsurface conditions to achieve an optimal pile-driving operation, and vibratory hammers could be used instead of impact hammers, when appropriate. Pre- and post-construction inspections, ground elevation surveys, and photographic surveys of structures within about 100 ft of the pile-driving operation is recommended to help document site-specific conditions and the effectiveness of mitigation measures. If appropriate, drilled piles could be used to limit the vibration and ground settlement impacts associated with driven piles.

6.7 DRILLED PILES

Casings could be installed to control caving soils during installation of drilled piles. To minimize the potential for vibration impacts from drilled piles, vibration monitoring and ground elevation surveys should be conducted in conjunction with pre- and post-construction inspections and photographic surveys of settlement-sensitive structures located within about 50 ft of drilled pile construction activities.

Spoils generated during drilled pile installation should be disposed of in accordance with applicable local, state, and federal requirements.

7.0 SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

With implementation of the mitigation measures identified above, no significant unavoidable adverse Earth Element impacts have been determined for the Fort Lawton Army Reserve Center Redevelopment project.

8.0 CONDITIONS AND LIMITATIONS

This draft Earth Element technical report has been prepared for Landau Associates, Inc. and their client for use in the preparation of the draft Supplemental Environmental Impact Statement for the Fort Lawton Army Reserve Center Redevelopment project site in Seattle, Washington. The conclusions and interpretations presented in this report are based on a review of information prepared by others and should not be construed as a warranty of subsurface conditions at the site. Experience has shown that soil and groundwater conditions can vary significantly over small distances and with time. Inconsistent conditions can occur between explorations that may not be detected by a geotechnical study of this scope and nature.

Within the limitations of scope, schedule and budget, HWA provided its services in accordance with generally accepted professional principles and practices in the field of geotechnical engineering in the area at the time the report was prepared. No warranty, express or implied, is made. The scope of our work did not include environmental assessments or evaluations regarding the presence or absence of wetlands or hazardous substances in the soil, surface water, or groundwater at this site.

HWA does not practice or consult in the field of safety engineering. We do not direct the contractor's operations and cannot be responsible for the safety of personnel other than our own on the site. As such, the safety of others is the responsibility of the contractor. However, the contractor should notify the owner if any of the recommended actions presented herein are considered unsafe.

We appreciate the opportunity to provide geotechnical services on this project. Should you have any questions or comments, or if we may be of further service, please do not hesitate to call.

Sincerely,

HWA GEOSCIENCES INC.

Steven R Wright, P.E.
Geotechnical Engineer, Vice President

9.0 REFERENCES

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