associated earth sciences incorporated

Technical Memorandum

Date:	January 4, 2018	**From:**	
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	Kirkland, Washington 98033	**Project Name:**	Kirkland GHC Update
Attn:	Mr. Jeremy McMahan	**Project No:**	160684E001
Subject:	Geologic Hazard Code Update - Gap Analysis and Best Available Science Consistency Review		

The City of Kirkland is in the process of reviewing and revising the City of Kirkland geologic hazard code which specifies standards for development in and around geologic hazard areas. Associated Earth Sciences, Inc. (AESI) is assisting the City in their review and revision of the critical area code. Specifically, our scope of work is limited to a review of the portions of the code addressing development within geologic hazard areas, primarily Chapter 85 of the Kirkland Zoning Code.

Under Washington's *Growth Management Act* (GMA), and the *Revised Code of Washington* (RCW) 36.70A, protection of environmentally critical areas must take into account Best Available Science (BAS). This memo provides a summary of the BAS as it relates to the geologic hazard code. The suggested code revisions are intended to allow use of BAS for protection of critical areas, reduce the risk of damage to property by geologic hazards while avoiding excessively conservative restrictions on land use in those areas where mitigation of geologic hazards can reasonably be achieved.

Review of Existing Regulations

Geologic hazard codes in the cities and counties in the Puget Lowland are generally crafted to mitigate landslide hazards by establishing buffers and/or building setbacks from high risk areas, or by restricting these areas to limited activities or uses. Complexities in the codes arise in describing details, such as exemptions, variances, permitted alterations, performance standards, buffer/building setbacks, or minimum standards for geotechnical studies. In some cases, key terms, requirements, or references in the code are poorly defined, not applicable to site conditions, or are inconsistent with standards of practice or BAS, which can lead to disputes. The following is a summary of the existing geologic hazard codes in the City of Kirkland. For comparison purposes, we have also included summaries of the geologic hazard codes for Redmond, Bellevue, and Snohomish County. The Redmond, Bellevue, and Snohomish County geologic hazard codes were last revised in 2011, 2006, and 2015, respectively. The code descriptions are intended to provide a brief overview of the regulations in each municipality. The full text of the codes in these cities and other area municipalities may be viewed at the Municipal Research and Services Center website.[1]

[1] http://mrsc.org/Home/Research-Tools/Washington-City-Codes.aspx
http://mrsc.org/Home/Research-Tools/Washington-County-Codes.aspx

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City of Kirkland

The existing City of Kirkland geologic hazard code defines Geologically Hazardous Areas as Landslide Hazard Areas, Erosion Hazard Areas, and Seismic Hazard Areas. Landslide Hazard Areas are divided into High Landslide Hazard Areas and Moderate Landslide Hazard Areas. High Landslide Hazard Areas are defined as areas sloping 40 percent or greater, areas subject to previous landslide activities, and areas sloping between 15 and 40 percent with zones of emergent ground water or underlain by or embedded with impermeable silts or clays. Moderate Landslide Hazard Areas consist of areas sloping between 15 and 40 percent and underlain by relatively permeable soils consisting largely of sand and gravel or highly competent glacial till.

Seismic Hazard Areas are defined as those areas subject to severe risk of earthquake damage as a result of seismically induced settlement or soil liquefaction, which occur in areas underlain by cohesionless soils of low density usually in association with a shallow ground water table.

Erosion Hazard Areas are defined as those areas containing soils which, according to the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) 1973 *King County Soil Survey*, may experience severe to very severe erosion hazard.

Development within both Landslide Hazard Areas and Seismic Hazard Areas is allowed pending approval by the City of a geotechnical report that provides recommendations for mitigation of geologic hazards. The report must:

- Describe how the development will or will not affect slope stability, surface and subsurface drainage, erosion and seismic hazards on the subject site and adjacent properties.

- Include a discussion of the relative risks and slide potential prior to construction, during construction, and after all development activities are completed.

For the project to be approved, the report must demonstrate that the development will not cause serious erosion hazards, sedimentation problems, or landslide hazards on the subject property or on adjacent properties, or cause property damage or injury to persons on or off the subject property. The code also indicates that mitigation of erosion hazards shall be accomplished by implementing appropriate source control Best Management Practices (BMPs) as described in the 2016 *King County Stormwater Pollution Prevention Manual*.

City of Redmond

Seismic and Erosion Hazard Areas as defined in the Redmond code are similar to those in the Kirkland code. However, Landslide Hazard Areas under the Redmond code are not divided into medium and high risk categories and there are some differences in the definition. For example, slopes with inclinations in excess of 40 percent are defined as Landslide Hazard Areas only if they exceed 10 feet in height. Areas that have undergone previous movement classify as Landslide Hazard Areas only if the movement occurred during the past 10,000 years (during the Holocene Epoch). Areas between 15 and 40 percent slope are only considered Landslide Hazard Areas if the slope intersects geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment with emergent seepage (springs). Additional characteristics that define Landslide Hazard Areas in the City of Redmond include:

- Slopes with inclinations exceeding 80 percent subject to rockfall during seismic shaking;
- Slopes that are parallel or subparallel to planes of weakness in subsurface materials; and,
- Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action.

The Redmond code requires that a 50-foot buffer be established around all Landslide Hazard Areas. The buffer width may be decreased to as small as 15 feet upon approval by the City of a geotechnical report that demonstrates that the reduced buffer will protect the proposed development and surrounding area. Alterations or development within Landslide Hazard Areas is generally prohibited with some exceptions for stream and wildlife corridor enhancement projects and construction and installation of streets and utilities. In some cases, approval for limited development within Landslide Hazard Areas may be granted through a reasonable use exception.

Alteration of Erosion Hazard Areas is permitted if it can be demonstrated through geotechnical analysis that the alteration will not adversely impact adjacent properties or other critical areas. Alteration of Seismic Hazard Areas is also permitted under the Redmond code subject to an evaluation of the site response, liquefaction potential, and implementation of suitable mitigation where appropriate.

City of Bellevue

In the City of Bellevue, Geologic Hazard Areas are limited to Landslide Hazard Areas, Steep Slope Areas, and Coal Mine Hazard Areas. The definition of Landslide Hazard Areas in the Bellevue code is generally similar to that in the Redmond code. Exceptions include areas in excess of 40 percent and at least 10 feet in height also must occur over an area of at least 1,000 square feet and these areas are considered Steep Slope Areas rather than Landslide Hazard Areas.

The code requires a default buffer from the top of Landslide Hazard and Steep Slope Areas of at least 50 feet and a toe of slope setback for structures of at least 75 feet. The buffer and setbacks may be modified or eliminated upon approval of a critical area report that addresses geologic hazards associated with the development. Development within Landslide Hazard and Steep Slope Areas is allowed subject to certain performance standards including minimizing alteration of the natural contours, preferred use of retaining walls over regrading, use of retaining walls that are a part of the building foundation rather than separate, stand-alone walls, and the use of stepped foundations or pole-type construction. The critical area report must demonstrate that the proposed modification:

- will not increase the threat of the geologic hazard to adjacent properties;
- will not adversely impact other critical areas;
- is designed so that the hazard to the project is eliminated or mitigated to a level equal to or less than the existing condition;
- is certified as safe as designed and under anticipated conditions by a licensed engineer or geologist;
- complies with recommendations of the geotechnical support;
- does not significantly impact habitat associated with species of local importance; and,
- will have no adverse impacts on stability of adjacent slopes or structures and complies with City stability analysis requirements.

Stability analysis requirements in the Bellevue code include the following minimum factors of safety for permanent slopes:

Condition	Minimum Factor of Safety	
	Low Threat Upon Failure	High Threat Upon Failure
Static	1.40	1.50
Dynamic	1.10	1.15

Permanent slopes termed “Low Threat Upon Failure” are those slopes whose failures will not impact structures inhabited by humans. Permanent slopes termed “High Threat Upon Failure” are those slopes whose failure will impact structures inhabited by humans. For dynamic (seismic) conditions, the design horizontal acceleration shall be based on a peak ground acceleration with a 10 percent probability of exceedance in 50 years.

Snohomish County

Geologic hazard areas in the Snohomish County code include Seismic, Erosion, and Landslide Hazard Areas, as well as Mine, Tsunami, and Volcanic Hazard Areas.

The definition of Seismic Hazard Areas includes areas that may be subject to liquefaction (similar to the existing Kirkland code), but also includes areas potentially subject to seismically induced landslides or ground rupture. The definition of Erosion Hazard Areas in the Snohomish County Code (SCC) is also similar to that in the existing Kirkland code, but includes channel migration zones and shoreline areas subject to wind and wave erosion.

Landslide Hazard Areas in the SCC include areas of historic landslide activity (including avalanches), and areas in canyons or within active alluvial fans susceptible to inundation by debris flows or catastrophic flooding. Areas with slope inclinations greater than 33 percent that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock, and which contain emergent seepage are also considered Landslide Hazard Areas. For the above-described areas, the SCC indicates that the Landslide Hazard Area also includes lands within a distance from the top of the slope equal to the slope height, and lands within a distance from the toe of the slope equal to twice the slope height.

Development activities in or within 200 feet of a Seismic Hazard Areas is allowed with County approval of a geotechnical report “that confirms the site is suitable for the proposed development.” Development activities in Erosion Hazard Areas is allowed provided that the activity utilizes best management practices to avoid increased risk of property damage or injury. Additional standards and requirements apply for activities in Channel Migration Zones.

Development activities in Landslide Hazard Areas is generally not allowed unless the applicant can demonstrate that certain criteria are met, including:

- There is no alternate location for the structure on the property.
- A geotechnical report demonstrates that the development will provide protection commensurate to being located outside of the Landslide Hazard Area.
- Minimum factors of safety for landslide occurrences shall not be below 1.5 for static conditions or 1.1 for dynamic conditions where analysis of dynamic conditions are based on horizontal acceleration as established by the current version of the International Building Code.

The SCC also includes some additional requirements regarding grading, utility installation, and stormwater practices in Landslide Hazard Areas.

The following is a discussion of the three geologic hazard categories addressed in the Kirkland code.

LANDSLIDE HAZARDS

Although landslides are often associated with steep slopes, other factors such as geology, land use, grading, precipitation patterns, drainage, and other factors can contribute to landslide hazard risk over a wide range of topographic conditions. In the Puget Lowland topographic and geologic conditions vary greatly over a relatively small area and it is therefore important to understand the conditions and processes associated with landslide hazard risk. For this reason, critical area codes typically include requirements for geologic hazard studies by qualified geotechnical professionals to evaluate hazard risk and mitigation options in areas of suspected risk. The landslide hazard code is designed to provide screening criteria to identify areas of potential risk, and to establish minimum standards for further geotechnical study and development standards in these areas.

The following is a discussion of development trends, advancements in landslide hazard studies, and area-specific conditions.

Development in Landslide Hazard Areas

The rapid population growth in the Puget Lowland in recent decades has resulted in widespread development, decreased availability of land, and increasing development costs. In response to this trend, property owners seek to maximize use of the developable portions of their land within the constraints of the local critical area codes. In response to land development pressures and the need to protect the environment and public safety, many municipalities require site-specific studies by qualified professionals for proposed developments in geologic hazard areas to evaluate site conditions, identify potential impacts and risks, and provide options for suitable mitigation of hazards. These site-specific studies qualify as BAS based on the criteria presented in Chapter 365-195-905 WAC by providing relevant data to evaluate landslide hazard risks and recommendations for mitigation of those risks. Municipalities lacking in-house expertise to evaluate the adequacy of these site-specific critical area studies have the option of requiring a third party geotechnical peer review. This review process and code-specified report requirements encourages BAS.

Identification of Existing Landslide Features and Landslide Susceptibility

A relatively recent technological advance that has improved the ability to identify existing landslide features is Light Detection and Ranging (LiDAR)-based imagery. High quality, LiDAR-based imagery has become increasingly available throughout Western Washington and is currently available for the entire Puget Lowland

(Puget Sound LiDAR Consortium). LiDAR uses airborne scanning lasers generating topographic surveys of the ground and top of vegetation, referred to as first returns and last returns. These laser transmitters fire thousands of pulses per second. Typically the data is gathered in winter when leaves are off. Data is filtered by travel time of laser pulses to determine ground surface versus top of vegetation or built environment (Harding, 2000). The bare earth data is particularly useful in areas such as Western Washington where surface features are typically obscured by heavy vegetation. For this reason, LiDAR-based shaded relief maps have been found to be a useful tool in identifying landslide features not readily recognizable by conventional aerial photography or ground reconnaissance (Baum et al., 2007; McKenna et al., 2008). A LiDAR-based shaded relief map of the City of Kirkland is available on-line.[2]

Updated mapping currently in preparation by GeoMapNW in partnership with the University of Washington Department of Earth and Space Sciences (UW) includes the following:

- Surficial Geology of Kirkland
- Landslide Features in Kirkland
- Shallow Landslide Susceptibility in Kirkland
- Deep Landslide Susceptibility in Kirkland

The updated mapping is based on extensive field reconnaissance work, review of subsurface exploration data collected from across the city, review of LiDAR imagery and analysis in accordance with protocols established by the Washington Department of Natural Resources and the Oregon Department of Geology and Mineral Industries (Slaughter et al., 2017; Burns and Madin, 2009; Burns et al., 2012, and Burns and Mickelson, 2016). The current maps represent BAS for geologic hazard mapping in the City of Kirkland.

Area-Specific Conditions

Review of mapping of surficial geology, existing landslide features, and landslide susceptibility currently in preparation by GeoMapNW/UW indicates that areas of historic landslide activity and landslide susceptibility occur primarily on the sloping flanks of till uplands, such as in the Holmes Point and Goat Hill neighborhoods and in ravines along the eastern flank of Finn Hill. Scattered areas of historic landslide activity have also been identified in other portions of the city such as in steeply sloping areas along the north flank of the Forbes Creek corridor, along the west flank of the Sammamish River valley east of Kingsgate, and in South Kirkland in the area around Watershed Park. Although the areas of historic landslide activity are clustered in the more steeply sloping portions of the city, there is also the potential for landslides to occur in more moderately sloping areas of the city, particularly in areas where imprudent grading practices or stormwater discharge may have adversely impacted the stability of natural slopes.

SEISMIC HAZARDS

Two factors that contribute to earthquake damage are ground motion and the presence of loose, saturated soils that lose strength during seismic events.

[2] http://www.kirklandwa.gov/Assets/IT/GIS/Kirkland+Lidar+Derived+Elevation+Data.pdf

Regional Seismic Issues

All of Western Washington is at risk of strong seismic events resulting from movement of tectonic plates in the Cascadia Subduction Zone (CSZ). Geologic studies have documented large CSZ earthquakes in the past, such as the estimated M 9.0 earthquake that struck the Pacific Northwest in January 1700 (Obermeier and Dickenson, 2000). This earthquake was centered near the Washington coast. Other potential sources of strong ground motion events in the Kirkland area include the South Whidbey Island Fault Zone (SWIFZ) and the Seattle Fault.

The SWIFZ consists of a series of northwest-trending fault strands that are believed to span from near Vancouver Island to the Cascade foothills near Snoqualmie. Lineaments (linear features on the ground surface) related to the SWIFZ are based on geophysical and geomorphological data, along with some borehole data. No lineaments associated with the SWIFZ have been mapped to date within Kirkland city limits, but there is some evidence to suggest that a portion of the SWIFZ may extend through the city. Studies have identified evidence of a large (M 6.5 to 7) seismic event near the SWIFZ approximately 2,800 to 3,200 years ago (Sherrod et al., 2005).

The Seattle Fault consists of an east-west-trending fault zone, that passes through Seattle, extending east in the vicinity of the I90 corridor south of Kirkland (Johnson et al., 2004). Studies have indicated that movement along the Seattle Fault caused an earthquake with an estimated magnitude of 7.5 approximately 1,000 years ago (Brink et al., 2006). Earthquakes could also originate from movement along other crustal faults, such as the M 6.8 Nisqually earthquake in 2001.

Liquefaction

During an earthquake, subsurface soils are subjected to a series of cyclic shear stresses that vary in magnitude. Saturated, loose granular sediments subjected to these cyclic loading conditions can develop rapid increases in the pore pressures within the sediments sufficient to cause a sudden loss of strength. This rapid increase in pore water pressure can transform loose, saturated, granular soil to a liquid state (liquefaction), with a loss in the ability to support loads resulting in settlement. Seismically induced settlement of unsaturated sediments, known as dynamic settlement, can also occur. Soil types most susceptible to dynamic settlement are similar to those prone to liquefaction.

The most significant BAS document for liquefaction hazards in the city of Kirkland is the *Liquefaction Potential in Kirkland* map currently in preparation by GeoMapNW/UW. Review of this map indicates that areas of Kirkland most susceptible to liquefaction primarily consist of low lying portions of the city underlain by normally consolidated alluvium, lake deposits, and Vashon recessional outwash. These areas are mostly located along the Lake Washington shoreline, along the large paleo-outwash channel in the Juanita Creek and Totem Lake areas, and in other scattered locations in central and south Kirkland.

Ground Motion

Another important source of information for seismic data in the city of Kirkland is the U.S. Geological Survey Earthquake Hazards Program website.[3] This source of information provides seismic design maps for the

[3] https://earthquake.usgs.gov/designmaps/us/application.php

entire U.S., including probabilities of earthquake ground motions which are used to provide design values for the seismic provisions of building codes, risk assessment, and public policy.

The following engineering manuals are periodically updated to address potential ground motions for design of buildings and other structures. The methodologies for obtaining engineering design values are based on the current USGS probabilistic and deterministic ground motion parameters for designing structures.

- 2015 *Minimum Design Loads for Buildings and Other Structures*, ASCE 7 ("2016 ASCE-7 Standard") (ASCE, 2016); and,

- 2015 *International Building Code* (International Code Council, 2015).

These manuals represent the BAS for seismic design of structures.

EROSION HAZARDS

Soil erosion is defined as the wearing away of the earth's surface as a result of the movement of wind, water, or ice. Factors influencing erosion potential include soil characteristics, vegetative cover, topography, and climate. Water is typically the primary agent contributing to erosion in Western Washington. Sedimentation is defined as the gravity-induced settling of soil particles transported by water. In order to mitigate impacts associated with erosion and sedimentation, Temporary Erosion and Sedimentation Control (TESC) plans are generally required by municipalities for grading activities. In addition, seasonal grading restrictions are also commonly implemented to reduce the risk of erosion hazards during the wet season (typically between October 31st and April 1st). In areas where seasonal grading restrictions are imposed, it is common for exceptions to be granted where merited by project conditions.

Erosion Hazard Impacts

Potential impacts of erosion and sedimentation include (Washington State Department of Ecology [Ecology] *Stormwater Management Manual for Western Washington* [Ecology, 2014]):

1. Natural, nutrient-rich topsoils erode. Re-establishing vegetation is difficult without applying soil amendments and fertilizers.

2. Silt fills culverts and storm drains, decreasing capacities and increasing flooding and maintenance frequency.

3. Detention facilities fill rapidly with sediment, decreasing storage capacity and increasing flooding.

4. Sediment clogs infiltration devices, causing failure.

5. Sediment causes obstructions in streams and harbors, requiring dredging to restore navigability.

6. Shallow areas in lakes form rapidly, resulting in growth of aquatic plants and reduced usability.

7. Nutrient loading from phosphorus and nitrogen attached to soil particles and transported to lakes and streams cause a change in the water pH, algal blooms, and oxygen depletion, leading to eutrophication and fish kills.

8. Water treatment for domestic uses becomes more difficult and costly.

9. Turbid water replaces aesthetically pleasing, clear, clean water in streams and lakes.

10. Eroded soil particles decrease the viability of macro-invertebrates and food-chain organisms, impair the feeding ability of aquatic animals, clog gill passages of fish, and reduce photosynthesis.

11. Sediment-clogged gravel diminishes fish spawning and can smother eggs or young fry.

Erosion Hazard Mapping

The USDA Natural Resource Conservation Service (NRCS) has mapped soils throughout King County and provides erosion hazard ratings for each of the mapped soil types. The predecessor of the NRCS, known as the Soil Conservation Service, (SCS) published the *Soil Survey for King County* in 1973. Updated soil survey data is now available on-line through the NRCS through their Web Soil Survey.[4] This is the best source of information for soil erosion hazards in the city of Kirkland and represents BAS. However, we have noted some errors in the on-line data that were apparently introduced during conversion from the original print version to the electronic version. Some mapping errors have also been observed. Should a discrepancy be observed between data sources and/or field observations, the geotechnical consultant should discuss the discrepancy and provide justification for actual site characterization.

Erosion and Sedimentation Control

Regulatory protection for Erosion Hazard Areas in Western Washington typically include the following:

- Required preparation and implementation of a Stormwater Pollution Prevention Plan (SWPPP) for land-disturbing activities. The 13 essential elements of a SWPPP are defined in the 2014 Ecology *Stormwater Management Manual for Western Washington*, typically referred to as the "Ecology Manual."

- Implementation of permitting requirements through the Construction Storm Water General Permit (also known as the National Pollutant Discharge Elimination System [NPDES] permit).

- Required TESC monitoring by a Certified Erosion and Sediment Control Lead (CESCL) for the duration of the construction for those projects where the area of disturbance exceeds one acre.

- Vegetation management.

- Seasonal clearing and grading restrictions.

[4] https://websoilsurvey.nrcs.usda.gov/app/

BMPs for erosion and sedimentation control are defined in the 2016 King County *Stormwater Pollution Prevention Manual* which represents BAS.

RECOMMENDED UPDATES TO THE KIRKLAND GEOLOGIC HAZARD CODE

The following is a description of suggested changes to the existing code, organized by category. Some of the suggested changes presented below are discussed in general terms and may not refer to specific code citations. For a more detailed description of the suggested changes, please refer to the Gap Analysis Matrix.

Section 85.12 - Critical Area Maps

- Section 85.12 of the *Kirkland Zoning Code* (KZC) references the existing Geologically Hazardous Areas map. We recommend that the code be revised to reference the revised geologic hazard mapping currently in progress by GeoMapNW/UW. We recommend that the code also be revised to clarify the purpose of the maps, which are intended to be used as a guide to identify areas of the City that may contain geologic hazards. Site-specific geologic hazard studies should be conducted prior to approval of development, grading, utility installation, or other activities to evaluate if a geologic hazard area actually exists, and to assess suitable options for hazard mitigation if appropriate.

Section 85.13 - Definitions

- Section 85.13(1) of the KZC defines Erosion Hazard Areas based on the erosion hazard classification of the underlying soil as cited in the 1973 USDA Soil Conservation Service King County Soil Survey. We recommend that the code be revised to reference the updated USDA Natural Resource Conservation Service (NRCS) *Web Soil Survey*. Because of the potential for mapping errors and other discrepancies in the NRCS data, Erosion Hazard Area designation should be based on actual site conditions as verified in the field by the geotechnical professional.

- We recommend that Section 85.13(3)(a) of the KZC be revised to define High Landslide Hazard Areas as:

    1. Areas that have shown movement during the Holocene epoch (from 10,000 years ago to the present) or that are underlain or covered by mass wastage debris of that epoch.
    2. Areas with both of the following characteristics:
        A. Slopes steeper than 15% that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment.
        B. Springs.
    3. Areas potentially unstable because of rapid stream incision, stream bank erosion, or undercutting by wave action.
    4. Any area with a slope of 40 percent or steeper over a height of at least 10 feet.

    The recommended revision excludes areas underlain by older landslide deposits that occurred as a result of topographic and geologic processes that no longer exist, it eliminates steep slope areas that are of lower risk due to small slope height, and conforms more closely to the typical criteria used to define Landslide Hazard Areas in the Puget Sound region.

Section 85.15 - Required Information – Landslide Hazard Areas and Seismic Hazard Areas

- We recommend that Section 85.15 of the KZC be revised to include as required information for geotechnical reports copies of explorations logs with descriptions of the geologic units underlying the site and a description of the sediments in accordance with the Unified Soil Classification System. In our opinion, this is basic information that should be obtained for evaluation of geologic hazards.

- At several locations in Section 85.15 of the KZC, the code states that geotechnical investigations, reports, and recommendations shall be prepared by a "qualified" geotechnical engineer or engineering geologist. We recommend that the term "qualified" be replaced by "licensed" because licensing of the geotechnical professional establishes his/her qualifications.

- We recommend that the code be revised to require that the geotechnical report include a copy of a LiDAR-based shaded relief map of the project area if the area is located on or within 100 feet of a High Landslide Hazard Area. The shaded relief map should be based on the most current available LiDAR imagery such as that available on the City's website.[5]

  The code should also require that the report include a discussion of the geotechnical professional's interpretation of the LiDAR map.

- We recommend that section 85.15 of the code be revised to require that the geotechnical report include the results of a quantitative slope stability analysis for any project involving development within a horizontal distance "H" of a High Landslide Hazard Area where "H" is equal to the height of the slope within the High Landslide Hazard Areas or 50 feet, whichever is greater. The code should also specify that evaluation of slope stability under seismic conditions shall be based on a horizontal ground acceleration equal to ½ of the peak horizontal ground acceleration with a 2 percent in 50-year probability of exceedance as defined in the current version of the *International Building Code*.

- We recommend that Section 85.15 of the code be revised to require that the landslide hazard evaluation section of all geotechnical reports include a discussion of the presence or absence of site features potentially indicative of historic landslide activity or increased risk of future landslide activity. Such features include, but are not limited to tree trunk deformation, emergent seepage, landslide scarps, tension cracks, reversed slope benches, hummocky topography, vegetation patterns, and area stormwater management practices. This is basic information that should be considered when evaluating the risk of landslide hazards for any property. Evaluation of such features are particularly important when evaluating the risk of shallow landslide activity, which is more difficult to accurately assess from slope stability models.

- We recommend that the code be revised to require that the geotechnical report include an estimate of the magnitude of seismically induced settlement that could occur during a seismic event for any project involving development within a Seismic Hazard Area. Estimation of the magnitude of seismically induced settlement shall be based on a peak horizontal ground acceleration based on a

[5] http://www.kirklandwa.gov/Assets/IT/GIS/Kirkland+Lidar+Derived+Elevation+Data.pdf

seismic event with a 2 percent in 50-year probability of exceedance as defined in the current version of the *International Building Code*. This requirement may be waived if it can be demonstrated that construction methods will completely mitigate the risk of seismically induced settlement.

Section 85.25 - Performance Standards - Landslide Hazard Areas and Seismic Hazard Areas

- We recommend that Section 85.25(1) be revised to read: "Implementation of the geotechnical recommendations to mitigate identified impacts and geologic hazards along with a written acknowledgement on the face of the plans signed by the architect, …". The addition of "and geologic hazards" is recommended to clarify the intent of the mitigation, which is to mitigate the risk of damage not only to the critical area, but also to buildings and other improvements that are a part of the proposed activity.

- We recommend that Section 85.25 of the KZC be revised to state that where slope stability analysis is required, as specified in Section 85.15(3) of the KZC, the proposed development shall provide a factor of safety of at least 1.5 for static conditions and at least 1.1 for seismic conditions. In our opinion, revision of the code to include minimum factors of safety of 1.5 for static conditions and 1.1 for seismic conditions provides a reasonable level of conservatism in line with the common standard of practice and other area jurisdictions, such as Snohomish County. The factor of safety of a slope is defined as the ratio of the forces that resist sliding to the forces that drive sliding. For example, a factor of safety of 1.0 is indicative of a slope where the forces that drive sliding are equal to the forces that resist sliding. Increasing factor of safety values greater than 1.0 are indicative of increased stability.

- We recommend that Section 85.25 of the KZC be revised to require a written statement from the geotechnical engineer stating that he/she has reviewed the project plans and that they conform to his/her recommendations. The intent of this revision is to provide a final quality control check to confirm that the geotechnical engineer's recommendations have been properly incorporated into the plans. It is also consistent with the requirements of other municipalities in the region.

- We recommend that Section 85.25(7)(a) of the KZC be revised to read:

  Limitation or restriction of any development activity that may:

  a. Significantly impact slope stability ~~or drainage patterns~~ on the subject property or adjacent properties.

  b. Significantly alter drainage patterns in a manner that would adversely impact the subject property or adjacent properties;

  c. Cause serious erosion…

  This change is recommended because development, by its nature, will nearly always affect drainage patterns. The proposed modification [the addition of 85.25(7)(b)] provides clarification of what appears to be the intent of the original wording.

Section 85.50 - Request for Determination

- We recommend revising the first and second sentences as follows:

  "The determination of whether a geologically hazardous area may exist~~s~~ on the subject property~~ and the boundaries of that geologically hazardous area~~ will normally be made when the applicant applies for a development permit for the subject property. ~~However, a property owner may, pursuant to the provisions of this section, request a determination from the City regarding whether a geologically hazardous area exists on the subject property and the boundaries of the geologically hazardous area.~~ Confirmation of whether or not a geologically hazardous area actually exists on the property shall be the responsibility of the applicant."

  Because determination of whether or not a geologic hazardous area exists on a property may involve subsurface exploration or knowledge outside of the expertise of City personnel, it is our opinion that confirmation of the presence or absence of a geologically hazardous area should be the responsibility of the applicant.

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