



CITY OF KIRKLAND
Planning and Building Department
123 5th Avenue, Kirkland, WA 98033
425.587.3600- www.kirklandwa.gov

MEMORANDUM

To: Planning Commission
Houghton Community Council

From: David Barnes, Senior Planner
Jeremy McMahan, Planning Manager - Development Services
Adam Weinstein, AICP, Deputy Planning and Building Director

Date: January 2, 2018

Subject: **Joint Meeting on Chapter 85 KZC Amendments (Critical Areas: Geologically Hazardous Area Regulations), File No. CAM17-00681**

I. RECOMMENDATION

Staff recommends that the Planning Commission and the Houghton Community Council (HCC) have a presentation on the following topics, ask questions and provide direction to staff. The following documents provide the foundation for the upcoming code amendments.

- Landslide Susceptibility Map (see Attachment 1)
- Liquefaction Potential Map (see Attachment 2)
- Best Available Science Technical Memo (see Attachment 3)
- Gap Analysis Matrix (see Attachment 4)

Staff also recommends that the Planning Commission and Houghton Community Council raise any policy issues that they would like addressed and/or identify any additional information that would be helpful. Based on direction, staff will prepare draft code for review at future study sessions.

The City Council was briefed on the geologic mapping project at a study session on November 21, 2017.

II. BACKGROUND

A. Best Available Science Standards under GMA

The Growth Management Act (GMA), [RCW 36.70A.040](http://rcw.wa.gov/title36/chapter070A/section040), requires that cities provide periodic updates to their critical areas ordinance. RCW [36.70A.030](http://rcw.wa.gov/title36/chapter070A/section030) defines Critical areas to include geologically hazardous areas. Geologically Hazardous are defined as "areas that because of their susceptibility to erosion, sliding, earthquake, or other geological

events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns”.

[WAC 365-195-900](#) and [RCW 36.70A.172 \(1\)](#) require that cities and counties must include the “best available science” or BAS information when developing policies and regulations for critical areas.

The City recently updated KZC Chapter 90 (Critical Areas: Wetlands, Streams, Minor Lakes, Fish and Wildlife Habitat Conservation Areas, and Frequently Flooded Areas) and is now embarking on the update to KZC Chapter 85 (Critical Areas: Geologically Hazardous Areas). See Attachment 5 for the current text of KZC 85.

B. Geologically Hazardous Area Mapping

Kirkland’s Comprehensive Plan provides policy support for mapping and code amendments related to development in geologically hazardous area (see Attachment 6). Available technology for mapping and understanding geologically hazardous areas has advanced with tools such as Light Detection and Ranging ([LIDAR](#)), which is a remote sensing method to examine the surface of the earth (see Attachment 7). The City completed LIDAR mapping earlier this year to assist with producing updated hazard maps.

Washington State is one of the most landslide-prone areas in the country and has the second highest risk of large and damaging earthquakes in the United States. King County and the Puget Sound Basin are especially vulnerable. But it was the massive Oso landslide in March of 2014, which destroyed or damaged 49 homes and claimed the lives of 43 people that convinced City of Kirkland officials that more must be done to protect our community. Therefore, a mapping project was initiated by the City in 2016. Kathy Troost and the University of Washington was contracted to produce updated maps that will help educate citizens about the risks related to landslide hazard areas and inform the City as a basis for the code update to KZC Chapter 85 (Critical Areas: Geologically Hazardous Areas).

The first step in updating the hazard maps was to update the basic geology map of Kirkland. The City, working with Kathy Troost, had completed a comprehensive geologic mapping of the pre-annexation portion of the City in 2008. However, that left a large gap in the data for the parts of Kirkland annexed in 2011, requiring extensive research to bring our understanding of the area geology up to the same standard as the rest of the City. This work has now been completed for the new neighborhoods, with compilation of subsurface data from GeoMapNW, visits to over 651 exposures (open excavations of current developments) and collection of 5,544 exploration points from the historical geological investigations. In addition, many of the gullies in the City were walked and more than 90% of the roads were driven in an effort to gather more extensive geologic information. The Executive Summary and draft Kirkland Geology, and Hazard Mapping Project Report is provided in Attachment 8.

The maps depict the general location and presence of hazardous areas based on available geologic and soils information. The City’s current mapping, Geologically

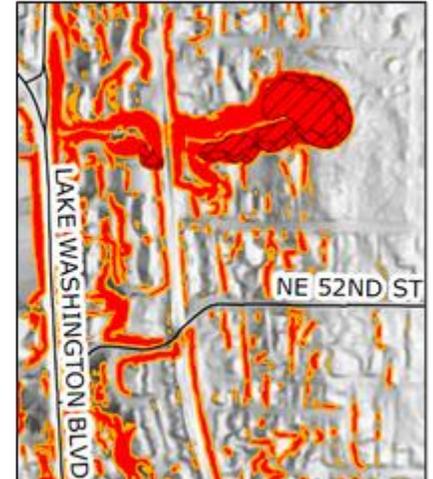
Hazardous Areas, identifies seismic hazard and landslide hazard areas (defined as either medium or high hazard) and was produced in partnership with King County in the early 1990's. The images below provide a comparison between the 1990's landslide mapping map and the new 2017 landslide mapping. The map snapshots show an areas around Carillon Woods Park in the Lakeview neighborhood. The existing mapping is based on the limited topographic and geologic data that was available to geologists in 1990. The LIDAR image in the center shows how far technology has progressed, with the ability to now look through the tree canopy to see the topography, historic landslide and associate headscarps. Combined with LIDAR information, the updated maps on the right are based on more accurate geologic information about subsurface conditions. Rather than the older hand drawn maps estimating landslide susceptibility based on limited information, the updated maps are based on a sophisticated computer model that is now being used throughout Oregon and Washington as best available science. This results in a much more accurate representation of potential hazards and, because it is based on a common methodology, with integrate with regional and statewide mapping efforts.



Existing Landslide Mapping



New LiDAR Data



2017 Landslide Mapping

The following databases and maps have been created:

- **Database of Subsurface Explorations and Exposures** (houses all of the field information acquired and used for the map products)
- Map of Subsurface Explorations (shows where we have information about the material at or beneath the ground surface)
- **Geologic Map** (shows the types of material, such as sand or clay, at the ground surface, its strength and other characteristics)
- **Map of Springs and Depth to Groundwater** (shows where springs are located and where we have depth to groundwater information, the map also lists the groundwater depth as encountered during a subsurface exploration project)
- **Conceptual Level Infiltration Potential Map** (shows relative infiltration potential, such as sandy vs. clayey materials)

- **Landslide Inventory** (a database and map that shows where landslides have occurred in the City based on documentation, field observations, or interpretations of lidar data. Lidar is a survey method that allows us to render the ground in 3-D)
- **Map of Landslide Susceptibility** (shows susceptibility to landsliding based on steepness of slope and strength of geologic materials) (see Attachment 1)
- **Description of Seismic Hazards** (lists the known earthquake sources and locations of active faults close to Kirkland)
- **Map of Liquefaction Potential** (shows where we have deposits that could liquefy in the event of earthquake shaking) (see Attachment 2)

Although extensive work has been done and multiple maps were produced, the major focus for the City in the coming months is on the hazard maps, both to inform the community about risks and to update Kirkland’s regulations related to development on or near these hazard areas. These maps show high and medium landslide areas and seismic hazard areas. The maps have been produced utilizing all the latest data, science and technology available. This information will help in understanding the potential risks and how development should be regulated in hazardous areas.

The mapping project will be complete in December 2017, with additional refinements to the maps and supporting documentation.

C. State Approval Process

The Department of Commerce is responsible to ensure that jurisdictions are compliant with GMA. The Department coordinates with other agencies who also have review authority for GMA.

III. CODE AMENDMENTS

BAS guidance on the subject of geologically hazardous areas has not advanced significantly since the adoption of the current regulations in KZC Chapter 85 and, with some relatively modest amendments generally meet GMA requirements. As staff and City consultants discuss below, there are a number of amendments that will bring the regulations into compliance with GMA requirements, correct and improve the code language, and ensure improved public safety based on current knowledge of these hazards. In addition, staff presents some policy decisions for Planning Commission and HCC direction regarding how the regulations are administered.

Associated Earth Science Inc. (AESI, a local Kirkland business) was retained by the City to assist with the following technical tasks:

- Peer Review of database, modeling and maps produced by the University of Washington
- Produce a Best Available Science (BAS) Technical Memo (see Attachment 3)
- Produce a Gap Analysis (what does the City’s Zoning Code (KZC Chapter 85) have provisions for and what does it need (see Attachment 4).
- Make Recommendations to City on potential zoning code amendments utilizing:

- Best Available Science (BAS)
- Gap Analysis of Kirkland Zoning Code Chapter 85
- Public presentations, Open houses, Study Sessions and Hearing (Planning Commission and Houghton Community Council)

A. Best Available Science Technical Memo

The BAS Technical memo (see Attachment 3) explains AESI’s review of the existing KZC 85 and discusses necessary components that are required pursuant to the Growth Management Act (GMA) and the Revised Code of Washington 36.70A. The memo uses BAS as a lens and for comparative purposes. It also provides a summary of how neighboring communities regulate geologically hazardous areas.

B. Gap Analysis

The Gap Analysis Matrix (see Attachment 4) examines the City’s Codes and provides suggestions to comply with BAS. The matrix also helps explain what is missing in the code and what should be required in order to make determinations regarding the mitigation of risk of on properties susceptible to landslide or seismic events. The recommended changes vary, many are minor in nature and do not require discussion/direction from the Commission and HCC. Others are more substantive and/or policy related. While staff is interested in any feedback related to the Gap Analysis, we have identified the following key topics where policy discussion/direction is needed to draft potential code amendments:

1. **Trigger for Requiring a Geotechnical Report:** Currently, KZC 85.15 states the City **may** require the applicant to submit a topographic survey, geotechnical investigation or report for any proposed development within a landslide hazard areas or seismic hazard area based on the City’s geologically hazardous area maps or preliminary field investigation by the Planning Official.

KZC 85.15.3 AESI recommends a LIDAR based shaded relief map be provided with a geotechnical report when the subject property is located within 100 feet of a High Landslide Hazard Area.

KZC 85.15.3 – Required Contents of Geotechnical Report: AESI recommends that the geotechnical report include a slope stability analysis for development located within a High Landslide Hazard Area. The analysis should also be required for development within 50 feet of the high landslide area or within an area equal to the height of the slope (whichever is greater).

Requested Discussion/Direction

Review and discuss the trigger points for required information with AESI. Staff will continue to work with AESI to develop draft code language with clear triggers for required information.

2. **Buffers on Sites located in geologically hazardous areas:** The Cities of Redmond and Bellevue both have codified buffer requirements from landslide hazards. They require a geotechnical report to consider reducing the pre-determined buffers.

Requested Discussion/Direction

AESI states in the BAS technical memo that current best available science is to evaluate the presence of geological hazards based on a geotechnical report, which makes recommendations such as risk mitigation and buffers based on site-specific characteristics. Other municipalities require site specific reports and do not rely on pre-determined buffers. Should the City consider pre-determined buffers or should we defer to the site-specific geotechnical report to make recommendations?

Policy Direction

3. **Regulatory Approach:** The City’s current regulations are “permissive” – development is allowed in landslide hazard areas provided the applicant submits information demonstrating compliance with the standards listed and a geotechnical opinion that the development is safe and feasible. Decisions are made by the Planning Official (in conjunction with subject matter experts in Public Works and Building). In contrast, code examples provided in the Technical Memo for jurisdictions like Redmond and Bellevue are “prohibitive”. These codes start with the premise that development is not allowed in landslide hazard areas and their related buffers. The codes then establish a permit process for an applicant to propose development in these areas (i.e. – reasonable use or variance type process), with information demonstrating compliance with the standards listed and a geotechnical opinion that the development is safe and feasible.

Another more restrictive approach to development in or near geologically hazardous areas would be to limit development potential based on the geologic constraints of the site. Currently, KZC Chapter 85 does not have provisions that limit density based on the presence of geologically hazardous areas. KZC Chapter 90 (Critical Areas: Wetlands and Streams) requires a maximum development potential calculation for properties with regulated critical areas such as wetlands and streams. This calculation can have the effect of limiting density.

Requested Discussion/Direction

Should the City keep the current “permissive” approach, or should the City consider a “prohibitive” approach similar to neighboring cities? While the current approach has generally served the community well, staff identifies the issue due to the constrained nature of much of the land that has not been developed and due to updated mapping and knowledge of the hazards present. If the City adopted a “prohibitive” approach, we would need to define the appropriate review process for exceptions. Is there is interest in other specified limitations on development potential?

4. **Requirements for Peer Review of Geotechnical Reports:** The existing performance standards in KZC Section 85.25.3 allow the City to require peer review of geotechnical reports that is funded by the applicant. However, it is generally up to the Planning Official to determine when peer review is required on a case-by-case basis. As the contents of geotechnical reports and related City analysis become more technical in

nature, staff may not have the expertise to make determinations in a time efficient manner.

Requested Discussion/Direction

The City currently requires other Critical Area reports (wetland, streams) to be peer reviewed by a City consultant. Up front peer review creates a consistent review by a qualified professional that allows the applicant and staff to understand the conditions under which a site with geotechnical hazard area may or may not be developed prior to submitting a land use or development permit application. Should the City require peer review of all geotechnical reports? If not, is there another clear threshold for requiring peer review?

- 5. **Code Authority:** Currently, KZC Chapter 85 does not specifically note the decision maker may approve, deny or condition an application based on applicable information.

Requested Discussion/Direction

Staff recommends that a section is added to Chapter 85 noting specifically that the decision can be approved, denied or conditioned based on applicable information.

IV. PUBLIC OUTREACH PROCESS

The public outreach process for this geohazards project has two basic components. The first is to get the information about risks and risk management into the hands of the community. This will be accomplished by sharing the recently updated geologically hazardous area maps so the public can easily access and view the maps with the descriptions of what the maps signify. The maps will be available on the Planning Department’s webpage along with links to helpful websites and information that can help the community answer the questions they may have about what they can do to mitigate risks on their property. The City’s Communication Program Manager and the Office of Emergency Management (OEM) will assist with getting the word out to engage the public. Section A outlines the Program Manager’s recommended outreach. The OEM’s webpage will be updated to provide some guidance regarding available external resources. Section B addresses OEM’s plan which aims to help guide the public in how they can be proactive and learn about the known available resources to mitigate risks related to landslide hazards, and to explain how OEM will educate first responders using the updated geologic hazard area maps so they are prepared based on the type of emergency.

The second component is to involve the community in updating Chapter 85 and related regulations that apply when development is proposed on or near these hazard areas. Citizens will have many opportunities to learn more about the code update process. A public lecture on December 11th was held with experts to present Kirkland’s updated landslide and seismic maps and to answer questions from the audience. Early in January 2018, the Kirkland Alliance of Neighborhoods will be briefed to increase participation from all neighborhoods in Kirkland. The joint study sessions and a hearing with the Planning Commission and the Houghton Community Council will also present opportunities for the community to contribute to the code amendment process and share their concerns with the City.

The proposed schedule of meetings, study sessions, public lecture and open houses that have or will be conducted are shown in Attachment 9. These meetings are the next steps in the Code amendment process to update KZC Chapter 85 (Critical Areas: Geologically Hazardous Areas). Staff will conduct public open houses prior to the Planning Commission/Houghton Community Council study sessions and hearings to display maps, listen and respond to questions raised by attendees.

As an update to the outreach process, the public lecture given by Kathy Troost (UW) on December 11, 2017 was well attended and allowed citizens to learn about Kirkland's geology and how the maps created could provide information that could be helpful to them. Staff and Kathy Troost were there to help answer questions before after the presentation. This presentation was recorded ([link to presentation](#)) and was placed on the City's website along with the project schedule, geologically hazardous maps, and links to helpful websites that can be a resource to the community.

A. Communication

Staff is working with the City's City Communication Program Manager to get Geologically Hazardous Area Map information out to the general public. The mission is to create awareness of the maps and of opportunities to learn and contribute to the discussion before and during the code amendment process. Some of the methods that will be employed to effectively communicate this information are as follows:

- Press Release distributed to Puget Sound area press followed by press calls to local press
- "Mentions" with links to the release and website in weekly e-newsletter This Week in Kirkland
- "Mentions" on all social media channels including City Facebook, Twitter, OEM Facebook and Twitter, Nextdoor, BeNeighborly groups and neighborhood Facebook groups
- Article in January edition of City Update
- Paid advertisement in Kirkland Reporter
- Guest editorial in Kirkland Reporter about why the maps are important
- Announcement directed toward realtors in Chamber of Commerce and Kirkland Downtown Association emailed to their memberships
- Re-air the video previously on Currently Kirkland about LIDAR mapping coupling it with a studio conversation with Kathy Troost now that the maps are being considered
- The same LIDAR video can also be embedded on the Geo Hazard Mapping Initiative website on Kirklandwa.gov
- Presentation at the Kirkland Alliance of Neighborhoods meeting in January 2018.

B. Office of Emergency Management (OEM)

The Office of Emergency Management is another partner within the City that can assist in helping the public understand the resources that currently exist to answer the question, what can I do with the updated Geologically Hazardous Area Map? And

other questions that may arise related to the City's response if an emergency occurs.

The release of hazard maps, of any kind, but particularly of landslide risk, have been known to prompt public concern and attention. As the City of Kirkland prepares to present the updated landslide risk mapping information, the Office of Emergency Management is enhancing the mitigation and response information related to landslides that is available to the public through the [OEM website](#) and preparedness handouts. Much like all disaster risks, landslides are specific and unique to the individual; therefore the primary mitigation approach is to encourage residents to be informed, make a plan, and take appropriate actions as recommended by landslide experts.

Examples of resources being made available include:

WA Dept. of Natural Resources Landslides Program

<https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/landslides>

WA Dept. of Natural Resources Emergency Prep - Landslides

<https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/emergency-preparedness>

USGS Landslide Hazards Program

<https://landslides.usgs.gov/>

USGS Landslide Handbook

<https://pubs.usgs.gov/circ/1325/>

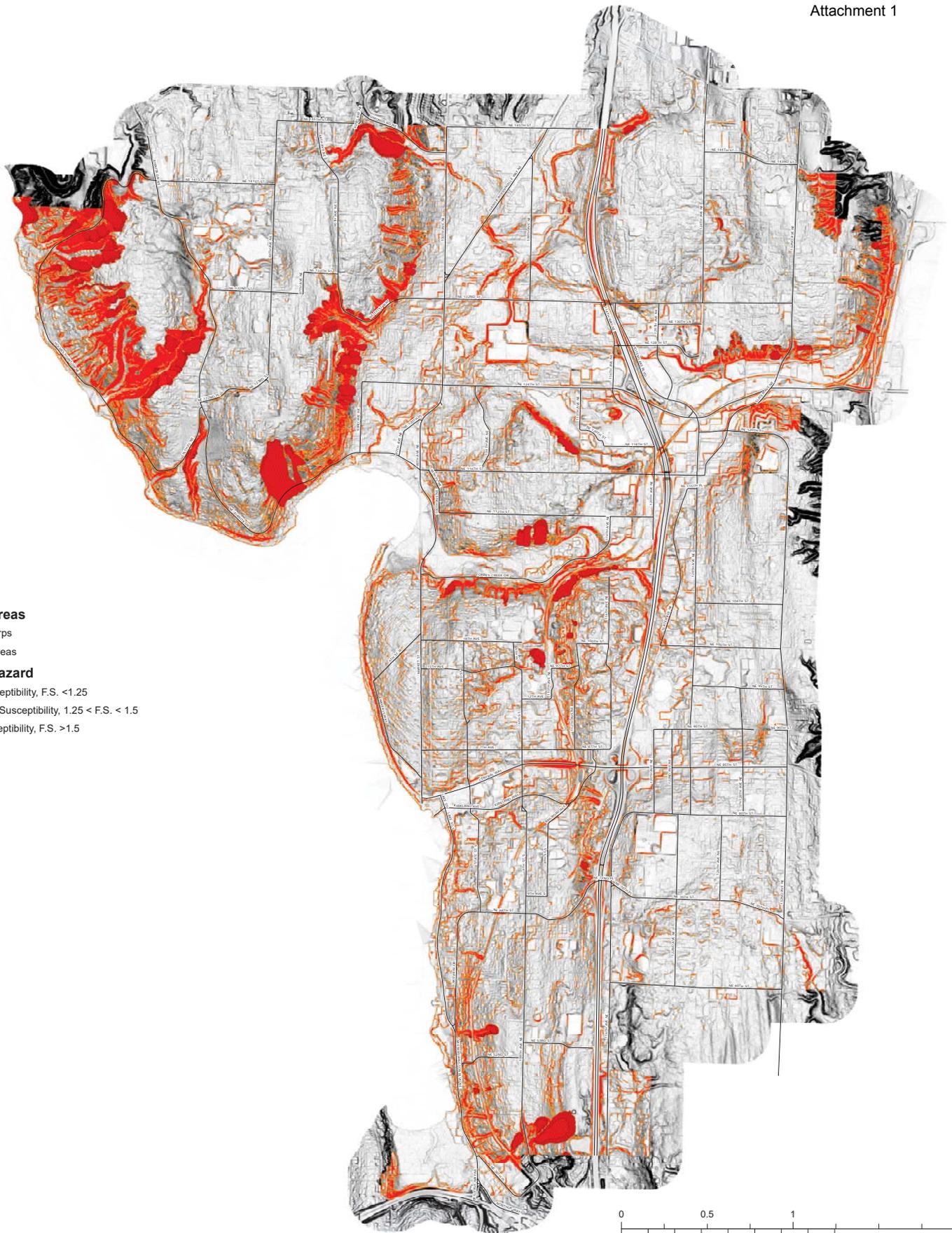
V. NEXT STEPS

The next steps include preparation for the February 22, 2018 Planning Commission meeting to bring proposed code amendments for consideration based on AESI's recommendations and policy direction. The full project schedule is included as Attachment 9.

Attachments:

1. Landslide Susceptibility Map
2. Liquefaction Potential Map
3. Best Available Science Technical Memo prepared by AESI
4. Gap Analysis Matrix prepared by AESI
5. Existing text of KZC 85
6. Comprehensive Plan Goals and Policies related to geologically hazardous areas
7. City of Kirkland Bare Earth Map
8. Executive Summary and draft Kirkland Geology, and Hazard Mapping Project Report
9. Code Amendment Process Schedule

cc: CAM17-00681



Landslide Areas

-  Head Scarps
-  Deposit Areas

Landslide Hazard

-  High Susceptibility, F.S. <1.25
-  Moderate Susceptibility, 1.25 < F.S. < 1.5
-  Low Susceptibility, F.S. >1.5

Landslide Susceptibility Map

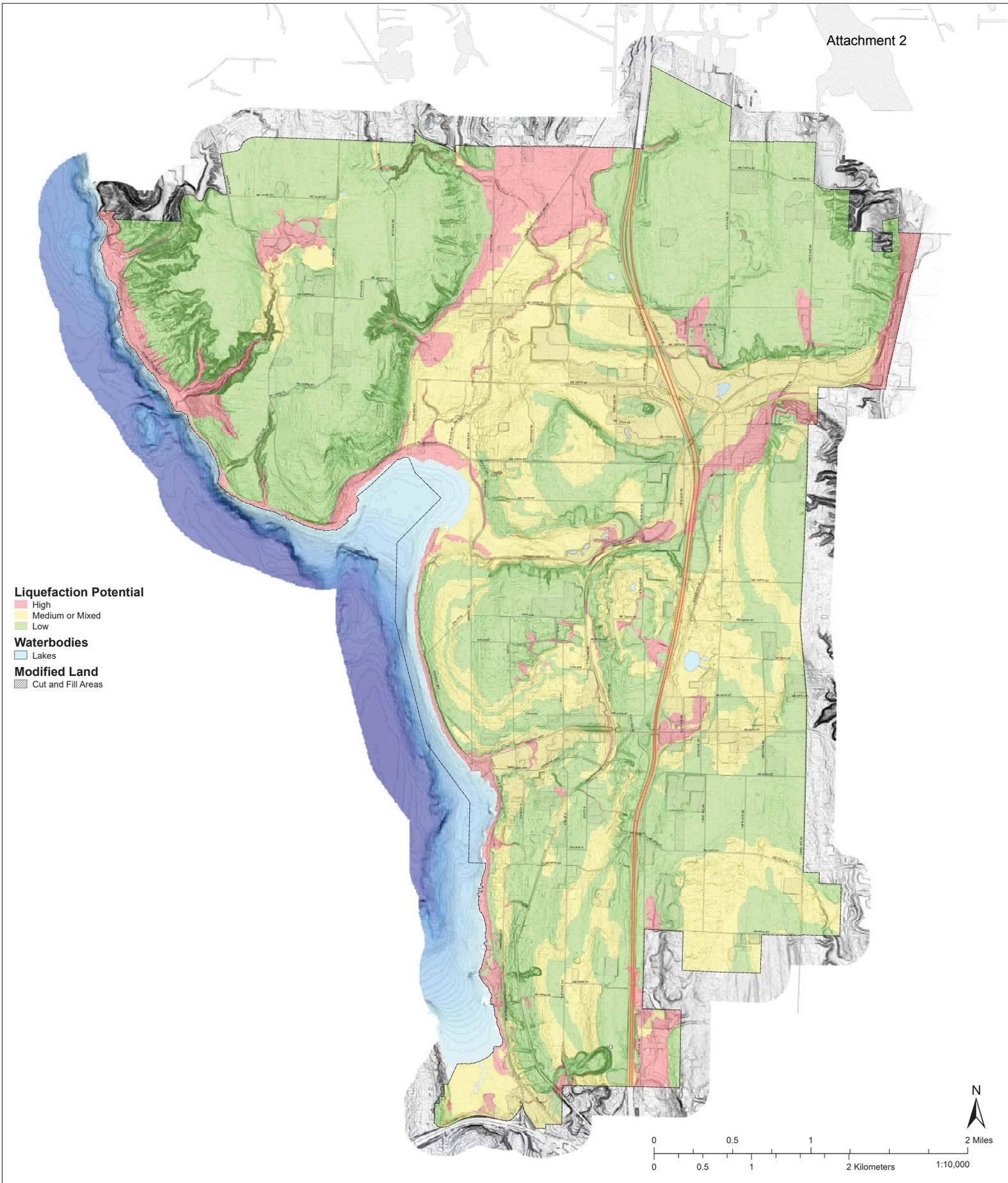
1) Landslide susceptibility was determined following the modeling protocol developed by the Oregon Department of Geology and Mineral Industries and the Washington Geological Survey, and is based on a factor of safety (F.S.) analysis using slope, geotechnical properties, distribution of geologic materials, known landslides, and wet weather conditions. Refer to the accompanying technical report for more details.

2) The landslide features and locations shown were identified on the basis of geomorphic criteria, historical documentation, and geotechnical documents in the database.

3) Landslide deposits were primarily identified by hummocky topography and disturbed deposits. Scarp flanks were primarily identified by distinct arcuate shape and steep face. Landslide scarps were primarily identified by distinct arcuate shape and steep face.

4) Basemap from 2016 LIDAR; DEM colored by elevation and draped over a shaded slope map.





Liquefaction Potential in Kirkland

1) Basemap from 2016 LIDAR; DEM shaded by elevation and draped over a shaded slope map.

2) Lake Washington bathymetry from NOAA surveys, colored by depth and draped over a shaded slope map.

3) Liquefaction potential was determined using a weighted matrix method using the geologic parameters of grain size, density, organic content, and uniformity of deposit.

4) All contact locations are approximate.





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e a r t h s c i e n c e s
i n c o r p o r a t e d

Technical Memorandum

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| | | | |
|-----------------|--|-----------------------------|--|
| Date: | January 4, 2018 | From: | |
| To: | City of Kirkland Planning and Building Department | Project Manager: | Timothy J. Peter, L.E.G., L.Hg. |
| | 123 5 th Avenue | Principal in Charge: | Curtis J. Koger, L.G., L.E.G., L.Hg. <i>CK</i> |
| | 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>

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 exists 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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**City of Kirkland
Geologic Hazard Code (GHC) Update
Best Available Science Review and Gap Analysis Matrix**

| Existing GHC Provision KMZ Chapter / Section | Consistency with BAS & Guidance | Reason For Lack of Consistency | Suggested Change | Rationale/ Basis for Suggested Change | Direction from City | Code Update Tracking – provide comments about any questions / remaining issues within updated code. |
|--|------------------------------------|--|---|--|---------------------|--|
| CHAPTER 85 KZC – CRITICAL AREAS: GEOLOGICALLY HAZARDOUS AREAS | | | | | | |
| 85.12 | BAS | The existing code references the “Geologically Hazardous Areas” map. | Revise this section of the code to reference the new geologic hazard maps to be adopted by the City and provide a link in the code to the maps. | The new maps replace the old map. | | |
| 85.12 | Guidance | The geologic hazard maps do not determine the presence of a geologic hazard area. They are intended to identify areas of the city that may contain geologic hazard areas. | Revise the second sentence to read: The maps are used as a guide only to determine the <u>possible</u> presence of seismic hazards, erosion hazards, and landslide hazards... | Clarifies the intent of the geologic hazard maps. | | |
| 85.13 (1) | BAS | The existing code references the old USDA Soil Conservation Service (SCS) King County Soil Survey from 1973. This information is now available on-line through the Natural Resource Conservation Service (NRCS) Web Soil Survey. The SCS has been renamed the NRCS. | Change definition of Erosion Hazard Area to read as follows: Erosion Hazard Areas – Those areas containing soils, which according to the Natural Resource Conservation Service <i>Web Soil Survey</i> (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) may experience severe to very severe erosion hazard. This group of soils includesand Indianola loamy fine sands (InD). 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. | The 1973 SCS soil survey is no longer in print and has been replaced by the NRCS on-line Web Soil Survey. 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. | | |
| 85.13(3)(a) | Guidance | As written, the definition of High Landslide Hazard Areas includes areas of historic landslide activity regardless of age and areas of 40 percent or steeper regardless of height. | Revise the definition as follows: High Landslide Hazard Areas – Areas that include the following: 1. Areas that have shown movement during the Holocene epoch (from | 1. Excludes areas of older (Pleistocene aged) landslides that occurred as the result of topographic and geologic processes that no longer exist. | | |

| Existing GHC Provision KMZ Chapter / Section | Consistency with BAS & Guidance | Reason For Lack of Consistency | Suggested Change | Rationale/ Basis for Suggested Change | Direction from City | Code Update Tracking – provide comments about any questions / remaining issues within updated code. |
|--|------------------------------------|--|--|---|---------------------|--|
| | | | <p>10,000 years ago to the present) or that are underlain or covered by mass wastage debris of that epoch.</p> <p>2. Areas with both of the following characteristics:</p> <p>A. Slopes steeper than 15% that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment.</p> <p>B. Springs.</p> <p>3. Areas potentially unstable because of rapid stream incision, stream bank erosion, or undercutting by wave action.</p> <p>4. Any area with a slope of 40 percent or steeper over a height of at least 10 feet.</p> | <p>2. Clarifies the existing definition.</p> <p>3. Adds an area of potentially unstable ground (eroding streambanks and shorelines) not included in the current code.</p> <p>4. Eliminates 40 percent slopes less than 10 feet in height. This is consistent with most geologic hazard area codes in the project region and eliminates small steep slope areas that generally present a lower risk of damage.</p> | | |
| 85.15(2) | Guidance | The intent of licensing is to establish that the license holder is “qualified”. | <p>Replace the word “qualified” with “licensed” so the sentence reads as follows:</p> <p>A geotechnical investigation, prepared by a licensed geotechnical engineer or engineering geologist...</p> | Licensing of the geotechnical professional establishes their qualifications. | | |
| 85.15(3) | Guidance | The intent of licensing is to establish that the license holder is “qualified”. | <p>Replace the word “qualified” with “licensed” so the sentence reads as follows:</p> <p>A geotechnical report, prepared by a licensed geotechnical engineer or engineering geologist...</p> | Licensing of the geotechnical professional establishes their qualifications. | | |
| 85.15(3)(e) | BAS | Recent updates to geologic mapping provide extensive data on the types and distribution of geologic units throughout the city which aids in identification of the geologic units encountered in geotechnical explorations. | <p>Revise to read:</p> <p>Subsurface exploration logs sufficient to assess geologic hazards at the site. Soil descriptions on the logs shall be in accordance with the Unified Soil Classification System. The logs shall also identify each of the geologic</p> | The suggested code change clarifies the required basic subsurface information used to assess geologic hazards. Because individual geologic units often have characteristic physical properties, identification of the geologic units on the logs is | | |

| Existing GHC Provision KMZ Chapter / Section | Consistency with BAS & Guidance | Reason For Lack of Consistency | Suggested Change | Rationale/ Basis for Suggested Change | Direction from City | Code Update Tracking – provide comments about any questions / remaining issues within updated code. |
|--|------------------------------------|---|--|--|---------------------|--|
| | | | units encountered (e.g. fill, Vashon lodgement till, Vashon advance outwash, etc.). | useful. This information is not consistently included on geotechnical logs. The existing code mistakenly references the <u>United</u> Soil Classification System. | | |
| 85.15(3) | BAS | The current code does not specify the use of LiDAR shaded relief mapping for evaluation of landslide hazards. | <p>In the listed geotechnical report content include:</p> <p>Review of LiDAR based shaded relief mapping for evaluation of landslide hazards in areas where the subject site is located on or within 100 feet of a High Landslide Hazard Area.</p> <p>The shaded relief map should be based on the most current available LiDAR imagery such as that available on the City’s website at:</p> <p>http://www.kirklandwa.gov/Assets/IT/GIS/Kirkland+Lidar+Derived+Elevation+Data.pdf</p> <p>A copy of the shaded relief map shall be included in the report along with a discussion of the interpretation of the features shown on the map.</p> | LiDAR is a relatively new remote sensing technology that is used to generate shaded relief maps that can reveal landslides and other geomorphic features that may not be readily apparent during a ground reconnaissance or in conventional aerial photos and topographic surveys. | | |
| 85.15(3) | BAS | The current code lacks a requirement for analysis of slope stability in higher risk landslide hazard areas. | <p>In the listed geotechnical report content include:</p> <p>A quantitative slope stability analysis for any project involving development in a High Landslide Hazard Area or within a horizontal distance “H” of a High Landslide Hazard Area where “H” is equal to 50 feet or the height of the slope within the High Landslide Hazard Area, whichever is greater.</p> <p>Evaluation of landslide hazards under seismic conditions shall be based on a horizontal acceleration equal to ½ of the peak horizontal ground acceleration based on a seismic event with a 2 percent in 50 year probability</p> | User-friendly software for evaluation of slope stability is readily available, its use has become a common standard of practice for geotechnical professionals, and it is a valuable tool for evaluation of landslide hazard risks and mitigation options. | | |

| Existing GHC Provision KMZ Chapter / Section | Consistency with BAS & Guidance | Reason For Lack of Consistency | Suggested Change | Rationale/ Basis for Suggested Change | Direction from City | Code Update Tracking – provide comments about any questions / remaining issues within updated code. |
|---|---------------------------------|--|---|---|---------------------|---|
| | | | of exceedance as defined by the current version of the International Building Code. | | | |
| 85.15(3) | Guidance | N/A | <p>In the listed geotechnical report content include:</p> <p>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.</p> | <p>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.</p> | | |
| 85.15(3) | BAS | The current code lacks a requirement for estimation of potential seismically induced settlement in Seismic Hazard Areas. | <p>In the listed geotechnical report content include:</p> <p>An estimate of the magnitude of seismically induced settlement that could occur during a seismic event is required for any project involving development in a Seismic Hazard Area. Estimation of seismically induced settlement shall be based on a peak horizontal ground acceleration based on a seismic event with a 2 percent in 50 year probability of exceedance as defined by the current version of the International Building Code. An estimate of the magnitude of seismically induced settlement need not be included in the report if it can be demonstrated that construction methods will completely mitigate the risk of damage to the proposed structure(s) by seismically induced settlement.</p> | <p>Estimation of the magnitude of seismically induced settlement for the design seismic event allows an evaluation of the damage that could occur and aids in evaluating suitable options for mitigation of the settlement.</p> | | |
| 85.15(4) | Guidance | The intent of licensing is to establish that the license holder is “qualified”. | Replace the word “qualified” with “licensed” so the sentence reads as follows: | Licensing of the geotechnical professional helps to establish that they are qualified. | | |

City of Kirkland- Geologic Hazard Code Update– Gap Analysis Matrix

| Existing GHC Provision KMZ Chapter / Section | Consistency with BAS & Guidance | Reason For Lack of Consistency | Suggested Change | Rationale/ Basis for Suggested Change | Direction from City | Code Update Tracking – provide comments about any questions / remaining issues within updated code. |
|--|---------------------------------|---|---|---|---------------------|---|
| | | | Geotechnical recommendations, prepared by a licensed geotechnical engineer ... | | | |
| 85.25 | BAS | Establishes minimum factors of safety for slope stability, consistent with the requirement for a slope stability analysis in High Landslide Hazard Areas as recommended for KZC 85.15(3). | Revise this section of the code to include the following: For those areas where slope stability analysis is required [as specified in 85.15(3)], proposed development shall provide a factor of safety of at least 1.5 for static conditions and at least 1.1 for seismic conditions. | If a slope stability analysis is required under the code, the performance standards in the code should specify minimum acceptable factor of safety values. | | |
| 85.25 | Guidance | Requirement is consistent with the requirements of many of the other municipalities in the project region. | Revise this section of the code to include the following: A written statement by the geotechnical engineer stating that he/she has reviewed the project plans and that they conform to his/her recommendations. | This is a quality control measure to confirm that the plans comply with the geotechnical engineer's recommendations. | | |
| 85.25(1) | Guidance | N/A | Recommend revising to read: Implementation of the geotechnical recommendations to mitigate identified impacts <u>and geologic hazards</u> ... | Although a development may not result in increased risk of landsliding or liquefaction, the existing level of risk may be high and therefore should be mitigated. | | |
| 85.25(7) | Guidance | N/A | Recommend revising 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. <u>Significantly alter drainage patterns in a manner that would adversely impact the subject property or adjacent properties</u> ; c. Cause serious erosion... | 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. | | |

City of Kirkland- Geologic Hazard Code Update– Gap Analysis Matrix

| Existing GHC Provision KMZ Chapter / Section | Consistency with BAS & Guidance | Reason For Lack of Consistency | Suggested Change | Rationale/ Basis for Suggested Change | Direction from City | Code Update Tracking – provide comments about any questions / remaining issues within updated code. |
|--|------------------------------------|--------------------------------|---|---|---------------------|--|
| 85.50(1) | Guidance | N/A | <p>Revising the first sentence and revising the second sentence as follows:</p> <p>The determination of whether a geologically hazardous area <u>may</u> exist 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 based on actual site conditions.</p> | <p>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, this determination should be the responsibility of the applicant.</p> | | |

Chapter 85 – CRITICAL AREAS: GEOLOGICALLY HAZARDOUS AREAS

Sections:

- [85.05](#) User Guide
- [85.10](#) Applicability
- [85.12](#) Critical Area Maps
- [85.13](#) Definitions
- [85.14](#) Erosion Hazard Areas
- [85.15](#) Required Information – Landslide Hazard Areas and Seismic Hazard Areas
- [85.20](#) Required Review – Landslide Hazard Areas and Seismic Hazard Areas
- [85.25](#) Performance Standards – Landslide Hazard Areas and Seismic Hazard Areas
- [85.30](#) Appeals
- [85.35](#) Bonds
- [85.40](#) Dedication
- [85.45](#) Liability
- [85.50](#) Request for Determination

85.05 User Guide

1. This chapter establishes special regulations that apply to development on property containing geologically hazardous areas. These regulations add to and, in some cases, supersede other regulations of this code. See Chapter [95](#) KZC for additional regulations that address trees and other vegetation within and outside of geologically hazardous areas.
2. If you are interested in developing property that contains a geologically hazardous area, or if you wish to participate in the City's decision on a proposed development on any of these areas, you should read this chapter.
3. For properties within jurisdiction of the Shoreline Management Act, see Chapter [83](#) KZC.

(Ord. 4252 § 1, 2010; Ord. 4010 § 3, 2005)

85.10 Applicability

1. General – This chapter applies to any property that contains any of the following:
 - a. An erosion hazard area.
 - b. A landslide hazard area.
 - c. A seismic hazard area.
2. Conflict with Other Provisions of this Code – The provisions of this chapter supersede any conflicting provisions of this code. The other provisions of this code that do not conflict with the provisions of this chapter apply to property that contains a geologically hazardous area. If more than one (1) provision of this chapter applies to the subject property because of the presence on the subject property of more than one (1) type of geologically hazardous area, then the regulations that

provide the greatest protection from the hazardous area shall apply to the area governed by multiple regulations.

3. SEPA Compliance – Nothing in this chapter or the decisions made pursuant to this chapter in any way affect the authority of the City to review, condition, and deny projects under SEPA.

85.12 Critical Area Maps

As part of the City's Comprehensive Plan, City Council from time to time amends the critical area maps. Included in the critical area maps is a map entitled "Geologically Hazardous Areas." The maps are used as a guide only to determine the presence of seismic hazards, erosion hazards, and landslide hazards, and the determination regarding whether these hazards exist on or near the subject property will be based on the actual characteristics of these areas and the definitions of this code.

(Ord. 4551 § 4, 2017)

85.13 Definitions

The following definitions apply throughout this code, unless, from the context, another meaning is clearly intended:

1. Erosion Hazard Areas – Those areas containing soils which, according to the USDA Soil Conservation Service King County Soil Survey dated 1973, may experience severe to very severe erosion hazard. This group of soils includes, but is not limited to, the following when they occur on slopes of 15 percent or greater: Alderwood gravelly sand loam (AgD), Kitsap silt loam (KpD), Ragnar Indianola Association (RdE) and portions of the Everett gravelly sand loams (EvD) and Indianola Loamy fine sands (InD).
2. Geologically Hazardous Areas – Landslide hazard areas, erosion hazard areas and seismic hazard areas.
3. Landslide Hazard Areas – Both of the following:
 - a. High Landslide Hazard Areas – Areas sloping 40 percent or greater, areas subject to previous landslide activities and areas sloping between 15 percent and 40 percent with zones of emergent groundwater or underlain by or embedded with impermeable silts or clays.
 - b. Moderate Landslide Hazard Areas – Areas sloping between 15 percent and 40 percent and underlain by relatively permeable soils consisting largely of sand and gravel or highly competent glacial till.
4. Seismic Hazard Areas – Those areas subject to severe risk of earthquake damage as a result of seismically induced settlement or soil liquefaction, which conditions occur in areas underlain by cohesionless soils of low density usually in association with a shallow groundwater table.

(Ord. 4551 § 4, 2017)

85.14 Erosion Hazard Areas

Regulations to control erosion are contained within KMC Title [15](#) and in other codes and ordinances of the City. Development activity within erosion hazard areas is regulated using these other provisions of this code and other City codes and ordinances and may be subject to increased scrutiny and conditioning because of the presence of an erosion hazard area.

85.15 Required Information – Landslide Hazard Areas and Seismic Hazard Areas

The City may require the applicant to submit some or all of the following information, consistent with the nature and extent of the proposed development activity, for any proposed development activity in a landslide hazard area or seismic hazard area or on property which may contain one (1) of these areas based on the geologically hazardous areas maps or preliminary field investigation by the Planning Official:

1. A topographic survey of the subject property, or the portion of the subject property specified by the Planning Official, with contour intervals specified by the Planning Official. This mapping shall contain the following information:
 - a. Delineation of areas containing slopes 15 percent or greater.
 - b. The proximity of the subject property to wetlands, streams and lakes.
 - c. The location of structured storm drainage systems on the subject property.
 - d. Existing vegetation, including size and type of significant trees.
2. A geotechnical investigation, prepared by a qualified geotechnical engineer or engineering geologist, to determine if a landslide hazard area or seismic hazard area exists on the subject property.
3. A geotechnical report, prepared by a qualified geotechnical engineer or engineering geologist, showing and including the following information:
 - a. A description of how the proposed development will or will not affect slope stability, surface and subsurface drainage, erosion, and seismic hazards on the subject and adjacent properties.
 - b. Evidence, if any, of holocene or recent landsliding, sloughing, or soil creep.
 - c. The location of springs, seeps, or any other surface expression of groundwater, and the location of surface water or evidence of seasonal runoff or groundwater.
 - d. Identification of existing fill areas.
 - e. Soil description in accordance with the United Soil Classification Systems.
 - f. Depth to groundwater and estimates of potential seasonal fluctuations.
4. Geotechnical recommendations, prepared by a qualified geotechnical engineer, for special engineering or other mitigation techniques appropriate to the hazard area along with an analysis of

how these techniques will affect the subject and adjacent properties, including discussions and recommendations on the following:

- a. The present stability of the subject property, the stability of the subject property during construction, the stability of the subject property after all development activities are completed and a discussion of the relative risks and slide potential relating to adjacent properties during each stage of development.
- b. Location of buildings, roadways, and other improvements.
- c. Grading and earthwork, including compaction and fill material requirements, use of site solids as fill or backfill, imported fill or backfill requirements, height and inclination of both cut and fill slopes and erosion control and wet weather construction considerations and/or limitations.
- d. Foundation and retaining wall design criteria, including bearing layer(s), allowable capacities, minimum width, minimum depth, estimated settlements (total and differential), lateral loads, and other pertinent recommendations.
- e. Surface and subsurface drainage requirements and drainage material requirements.
- f. Assessment of seismic ground motion amplification and liquefaction potential.
- g. Other measures recommended to reduce the risk of slope instability.
- h. Any additional information believed to be relevant by the geotechnical engineer preparing the recommendations or requested by the Planning Official.

(Ord. 4551 § 4, 2017)

85.20 Required Review – Landslide Hazard Areas and Seismic Hazard Areas

1. General – Except as specified in subsection (2) of this section, the City will administratively review and decide upon any proposed development activity within a landslide hazard area or seismic hazard area.
2. Other Approval Required – If the proposed development on the subject property requires approval through Process I, IIA, or IIB, described in Chapters [145](#), [150](#), and [152](#) KZC, respectively, the proposed development activity within the landslide hazard area or seismic hazard area will be reviewed and decided upon as part of that other process.

85.25 Performance Standards – Landslide Hazard Areas and Seismic Hazard Areas

(See also Chapter [95](#) KZC)

As part of any approval of development in a landslide hazard area or seismic hazard area, the City may require the following to protect property and persons:

1. Implementation of the geotechnical recommendations to mitigate identified impacts, along with a written acknowledgment on the face of the plans signed by the architect, engineer, and/or designer that he/she has reviewed the geotechnical recommendations and incorporated these recommendations into the plans.
2. Funding of a qualified geotechnical engineer or engineering geologist, selected and retained by the City subject to a 3-party contract, to review the geotechnical report and recommendations.
3. That a qualified geotechnical professional be present on-site during land surface modification and foundation installation activities, and submittal by a geotechnical engineer of a final report prior to occupancy, certifying substantial compliance with the geotechnical recommendations and geotechnical-related permit requirements.
4. The retention of any and all trees, shrubs, and groundcover, and implementation of a revegetation plan including immediate planting of additional vegetation.
5. Specifically engineered foundation and retaining wall designs.
6. The review of all access and circulation plans by the Department of Public Works.
7. 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. Cause serious erosion hazards, sedimentation problems or landslide hazards on the subject property or adjacent properties; or
 - c. Cause property damage or injury to persons on or off the subject property.
8. Dedication of one (1) or more natural greenbelt protective easements or tracts.

(Ord. 4010 § 3, 2005)

85.30 Appeals

All classifications, decisions, and determinations made under this chapter are appealable using, except as stated below, the applicable appeal provisions of Chapter [145](#) KZC:

1. The appeal may be filed by the applicant or any other aggrieved person within 15 days of the date of the City's written classification, determination, or decision.
2. If a proposed development activity on the subject property required approval through Process IIA or IIB, described in Chapters [150](#) and [152](#) KZC, respectively, any appeal of a classification, determination, or decision under this chapter will be heard as part of that other process.

85.35 Bonds

The City may require a bond under Chapter [175](#) KZC and/or a perpetual landscape maintenance agreement to ensure compliance with any aspect of this chapter or any decision or determination made under this chapter.

85.40 Dedication

The City may require that the applicant dedicate development rights, air space, or an open space easement to the City to ensure the protection of any landslide hazard area or seismic hazard area on the subject property.

85.45 Liability

Prior to issuance of any development permit, the applicant shall enter into an agreement with the City, which runs with the property, in a form acceptable to the City Attorney, indemnifying the City for any damage resulting from development activity on the subject property which is related to the physical condition of the property. The applicant shall record this agreement with the King County Recorder's Office.

(Ord. 4491 § 11, 2015)

85.50 Request for Determination

1. General – The determination of whether a geologically hazardous area exists 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.
2. Application Information – The applicant shall submit a letter of request along with a vicinity map and site plan indicating the location of the potential geologically hazardous area and other information, as appropriate.
3. Review – A request for determination of whether a geologically hazardous area exists on the subject property, the location of the geologically hazardous area, and the type of geologically hazardous area will be made using the definitions, procedures, and criteria of this chapter, as appropriate.
4. Decision – Determinations regarding geologically hazardous areas pursuant to this section will be made by the Planning Official.
5. Appeals – Appeals from decisions made under this section will be reviewed and decided upon pursuant to KZC [85.30](#).
6. Effect – Any decision made under this section will be used by the City in any development activity proposed on the subject property for which an application is received within two (2) years of the final decision of the City under this section; provided, that the City may modify any decision made under

this section any time physical circumstances have markedly and demonstrably changed on the subject property or the surrounding areas as a result of natural processes or human activity.

The Kirkland Zoning Code is current through Ordinance 4619, passed November 21, 2017.

Disclaimer: The City Clerk's Office has the official version of the Kirkland Zoning Code. Users should contact the City Clerk's Office for ordinances passed subsequent to the ordinance cited above.

2035 Comprehensive Plan Policies and Goals for Geologically Hazardous Areas

SOILS AND GEOLOGY

Geologically hazardous areas are defined as critical areas under the Growth Management Act. These consist of landslide, erosion and seismic hazard areas. They pose a potential threat to the health and safety of the community. Many areas of the City have steep slopes and ravines subject to erosion and hazardous conditions (earthquakes and landslides). Geologically hazardous areas are mapped depicting the general location and presence of these areas based on available geologic and soils information. (See Figure E-2, Geologically Hazardous Areas).

Landslides are highly probable in many steep and unstable slope areas, regardless of development activity. Landslides may be triggered by grading operations, land clearing, irrigation, or the load characteristics of buildings on hillsides. Damage resulting from landslides may include loss of life and property, disruptions to utility systems, or blockage of transportation and emergency access corridors. For these reasons, development is regulated where landslides are a potential hazard. In some cases, regulation may result in severe limitations to the scale and placement of development, and land surface modification should be limited to the smallest modification necessary for reasonable site development.

In the Puget Sound area, possible damage to structures on some unstable slopes or wetland areas can be caused by low-intensity tremors. This is especially true when hillsides composed of clay and/or organic materials are saturated with water. Slopes with grades of 15 percent or steeper are also subject to seismic hazards. Areas with slopes between 15 and 40 percent or greater are particularly vulnerable. Low-intensity earth tremors could cause liquefaction and damage development in wetland areas composed of organic or alluvial materials. In hillside and wetland areas, structures and supporting facilities need to be regulated and designed to minimize hazards associated with earthquakes. The City should provide information to the public about potential geologic hazards, including site development, building techniques and disaster preparedness.

Goal E-3: Improve public safety by avoiding or minimizing impacts to life and property from geologically hazardous areas.

Policy E-3.1: Require appropriate geotechnical analysis, sound engineering principles and best management practices for development in or adjacent to geologically hazardous areas.

The City's Landslide and Hazard Areas Map shows the general location of these areas. The determination of the actual conditions and characteristics of these hazards on or near property is based on detailed scientific and geotechnical engineering analysis and principles. The City can require geotechnical investigations, reports and recommendations by a qualified engineer when development is proposed or restoration activities are being considered in or adjacent to geologically hazardous areas. The City should continue to identify landslide areas and provide this information to the public.

Policy E-3.2: Regulate land use and development to protect geologic, vegetation and hydrological functions and minimize impacts to natural features and systems.

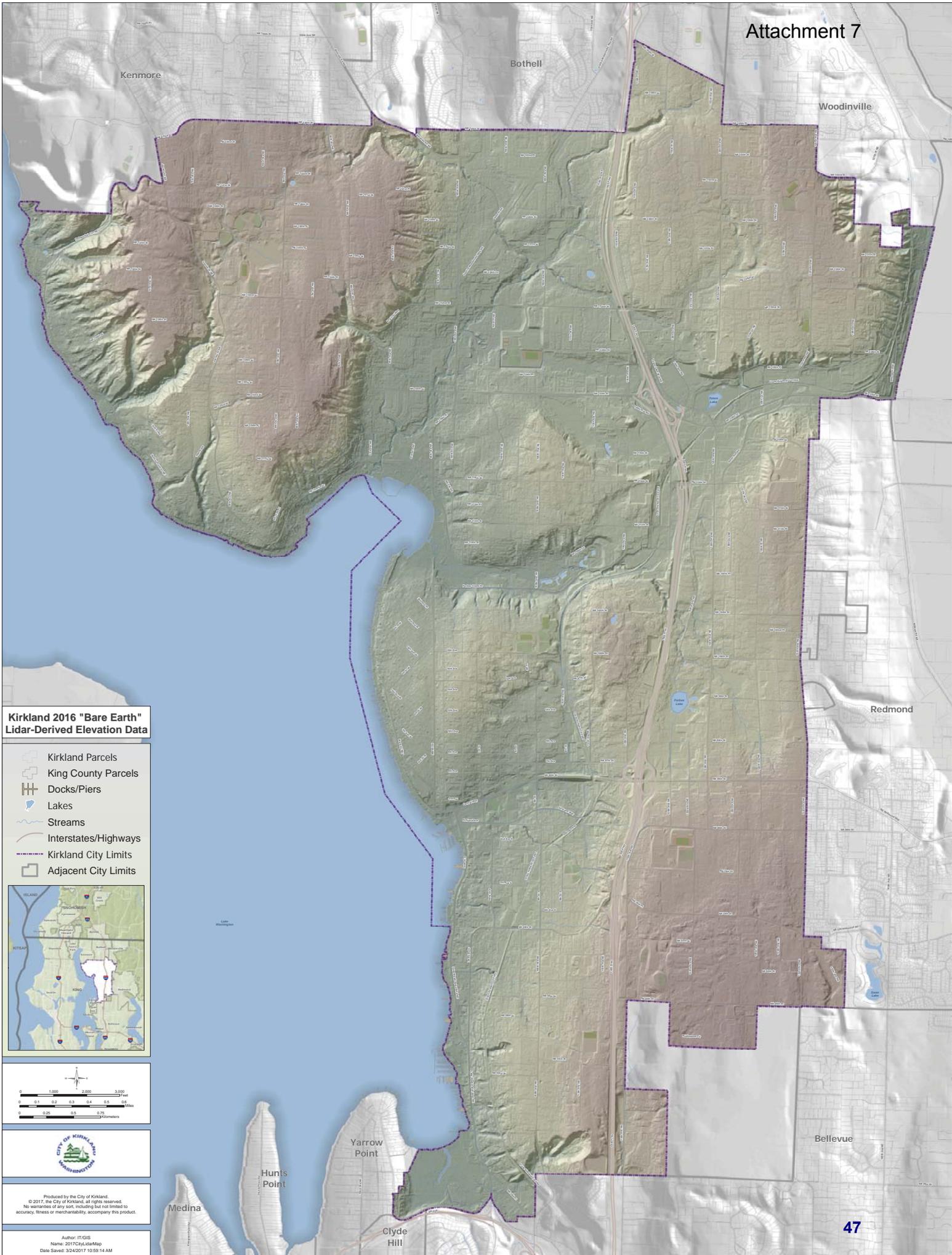
Geologically hazardous areas, especially steep forested slopes and hillsides, provide multiple critical area functions. Performance standards, mitigating conditions, or limitations and restrictions on development activity may be required. Clustering of development away from these areas should be encouraged or required. Using natural drainage systems, retention of existing vegetation and limitations on clearing and grading are preferred approaches.

Policy E-3.3: Utilize best available science and data for seismic and landslide area mapping.

Governor Jay Inslee convened an SR 530 Landslide Commission to identify lessons learned from this catastrophic event. The Commission released its report in December, 2015 and noted the following:

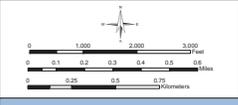
The SR 530 Landslide highlights the need to incorporate landslide hazard, risk, and vulnerability assessments into land-use planning, and to expand and refine geologic and geohazard mapping throughout the State. The lack of current, high-quality data seriously hampers efforts under the Growth Management Act (RCW [36.70A](#)) and other regulatory programs to account and plan for these hazards. Use LIDAR (Light Detection and Ranging) mapping to target high priority areas hazardous to people or property. Ensure that landslide hazard and risk mapping occur in the highest priority areas first, including transportation corridors, such as the Everett-Seattle rail line and the trans-Cascades highways, residential areas, urban growth areas, emergency evacuation routes, and forest lands...

The City has relied on geologic and soils mapping done by King County in the early 1990s. In 2011 the City undertook a comprehensive geologic detailed mapping of the pre-annexation portion of the City. The City should complete the surficial and soils mapping for the entire City and conduct a hazard and risk assessment utilizing best available science. Kirkland's programs, practices and regulations relating to geologic hazard areas, clearing and grading, vegetation, and critical areas should be evaluated once the assessment has been completed. As new information or better science evolves or as conditions change, policies, regulations and programs should be regularly updated to protect these areas.



**Kirkland 2016 "Bare Earth"
Lidar-Derived Elevation Data**

-  Kirkland Parcels
-  King County Parcels
-  Docks/Piers
-  Lakes
-  Streams
-  Interstates/Highways
-  Kirkland City Limits
-  Adjacent City Limits



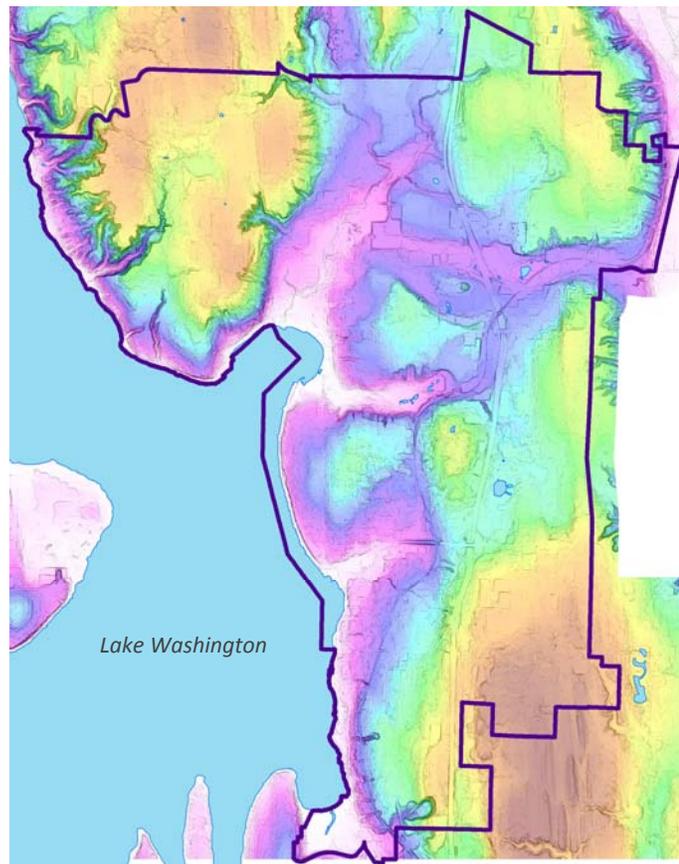
Produced by the City of Kirkland.
© 2017, the City of Kirkland, all rights reserved.
No warranties of any sort, including but not limited to
accuracy, fitness or merchantability, accompany this product.

Author: ITGIS
Name: 2017CityLidarMap
Date Saved: 3/24/2017 10:59:14 AM

Executive Summary

Kirkland Geology, Groundwater, and Hazard Mapping

Geologists at the University of Washington are finalizing a new suite of maps and products for updates to Kirkland Zoning Code Chapter 85 (Critical Areas: Geologically Hazardous Areas) which is required under the Growth Management Act, and to improve public and infrastructure safety. In part, this project was undertaken to map the recently annexed areas of Kirkland. These maps relate to the geology, groundwater, and geologic hazards present in the City of Kirkland and will be available online for the public and professionals to use. The City will use these data to update their critical areas maps and ordinances. Understanding where geologic hazards are present is necessary in keeping the public safe.



Map showing the landscape of Kirkland. Color indicates elevation, with the lowest elevation shown in white and the highest in brown.

Our integrated mapping approach will improve the quality and efficiency of public and private development projects. City engineers and planners will use this information for projects like suitability studies, infiltration studies, seismic hazard assessments, planning hazard mitigation strategies, and prioritizing facility upgrades. This new geologic information will save time and

money in planning for construction projects that will require excavation, installation of foundations, or even creation of backyard rain gardens.

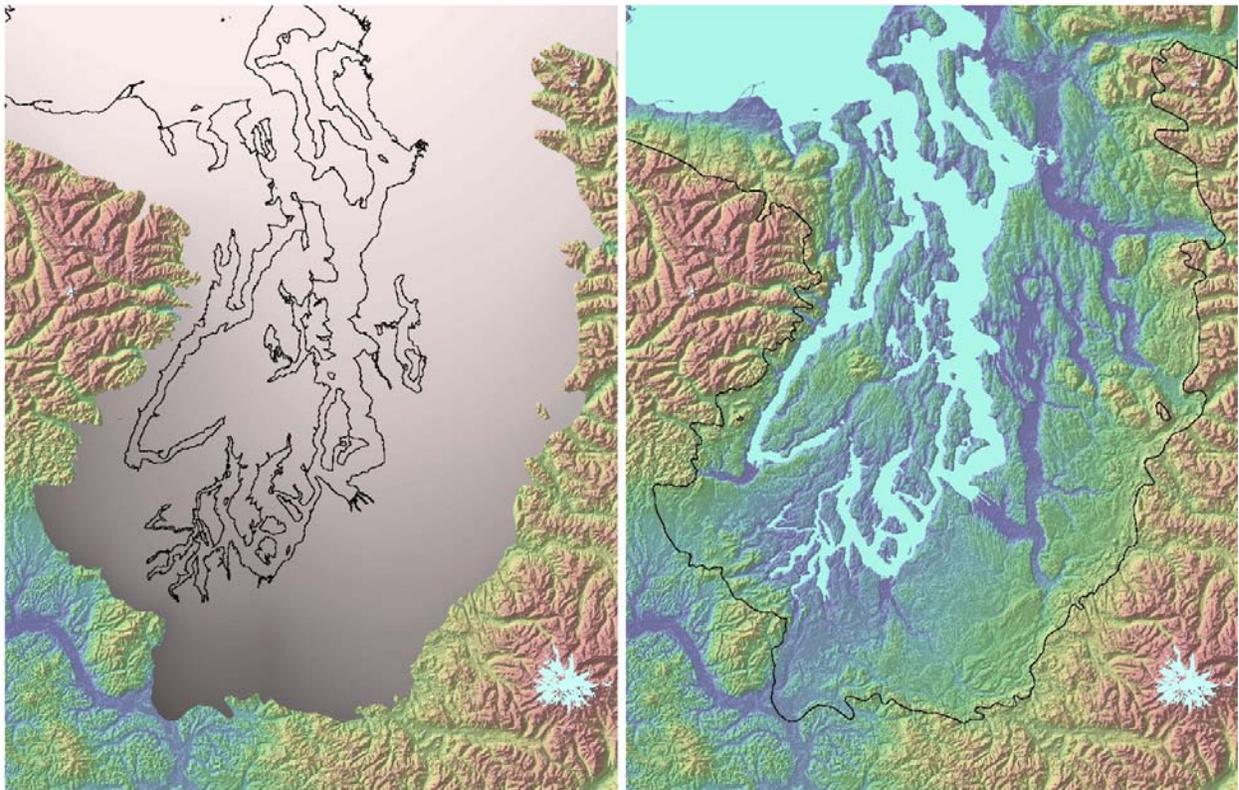
The suite of new maps and products consists of:

- **Database of Subsurface Explorations and Exposures** (houses all of the field information acquired and used for the map products)
- **Map of Subsurface Explorations** (shows where we have information about the material at or beneath the ground surface)
- **Geologic Map** (shows the types of material, such as sand or clay, at the ground surface, its strength and other characteristics)
- **Map of Springs and Depth to Groundwater** (shows where springs are located and where we have depth to groundwater information, the map also lists the groundwater depth as encountered during a subsurface exploration project)
- **Conceptual Level Infiltration Potential Map** (shows relative infiltration potential, such as sandy vs. clayey materials)
- **Landslide Inventory** (a database and map that shows where landslides have occurred in the City based on documentation, field observations, or interpretations of lidar data. Lidar is a survey method that allows us to render the ground in 3-D.)
- **Map of Landslide Susceptibility** (shows susceptibility to landsliding based on steepness of slope and strength of geologic materials)
- **Description of Seismic Hazards** (lists the known earthquake sources and locations of active faults close to Kirkland)
- **Map of Liquefaction Potential** (shows where we have deposits that could liquefy in the event of earthquake shaking)

A copy of each of these maps and a description of each product follows.

Introductory Geology of Kirkland

The City of Kirkland, lies within the Puget Sound Lowland, an elongate structural and topographic basin between the Cascade Range and Olympic Mountains. The area has been impacted by repeated glaciation, in the past 2.4 million years, and crustal deformation related to the Cascadia subduction zone. The present landscape largely results from those repeated cycles of glacial scouring and deposition and tectonic activity, subsequently modified by landsliding, stream erosion and deposition, and human activity. The last glacier to override the area, the Vashon glacier, reached the Kirkland area about 17,000 years ago and retreated from this area by about 16,000 years ago.



Maps showing the extent of the last glaciation, left, and the troughs in the Puget Lowland, right. From http://rocky.ess.washington.edu/areas/Puget_Lobe/

The Kirkland area sits atop a complex and incomplete succession of glacial and interglacial deposits that extends below sea level and overlies a deep irregular bedrock surface that is thousands of feet in depth. The glacial and interglacial deposits show a wide degree of

variability, are truncated by many unconformities (older landscape surfaces created largely by subsequent glacial deposition and erosion), and are deformed by gentle folds and faults. Sediments that predate the last glacial–interglacial cycle are exposed where erosion has sliced into the upland, notably along the shorelines of Lake Washington and in steep ravines.

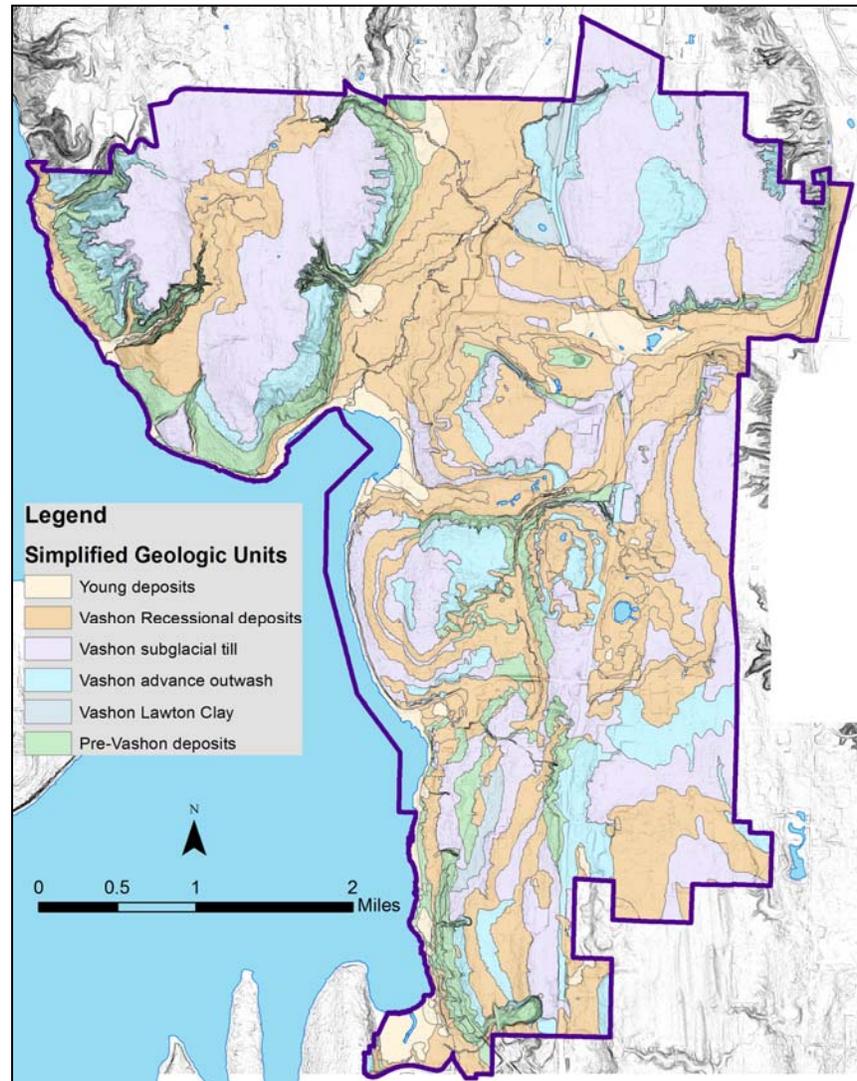
Glacial and interglacial cycles leave distinctive deposits. Today is a good analog for previous interglacial periods with deposits accumulating in lakes, streams, and wetlands; development of topsoil; and even an occasional volcanic eruption leaving a layer of ash.

In the geologic past, when global climate cooled, glaciers advanced from the Coast Ranges in Canada into the Puget Lowland. As a glacier advanced into our region, the deep basin of Puget Sound was dammed and thick silt and clay accumulated in the bottom of the lake (most recently the Lawton Clay). With nearing of the glacier front, outwash was spread across the Puget Lowland (most recently the Vashon advance outwash, blue in the map below). As ice overrode the region, till (most recently the Vashon till, purple in the map below) was deposited at the base of the glacier. When the glacier retreated, due to a warming of the climate, recessional outwash (most recently Vashon recessional outwash, orange in the map below) was deposited in large deep lakes (again damming the Sound) and in large stream channels.

The troughs of Puget Sound, Lake Washington, and Lake Sammamish were scoured by highly pressurized streams under the glacier. This channelized scouring left deep valleys with steep sides.

Today, the landforms and near-surface deposits that cover much of Kirkland record a brief period in the geologic history of the region. Upland till plains in many areas are cut by glacial recessional meltwater channels and modern river channels. Till plains display drumlins (north-south ridges) with their long axes oriented in ice-flow direction. Glacially overridden deposits underlie the drumlins and most of the uplands. Whereas loosely consolidated post-glacial deposits fill deep valleys and recessional meltwater channels. Ice-contact deposits are found in isolated locations across the uplands and along the margins of the uplands, and outwash deposits lines upland recessional channels. Soft organic-rich deposits fill former lakes and bogs.

Vashon till (purple, at right) mantles about 1/3 of the upland surfaces within the City. Although Vashon till is typically a very dense, matrix-supported gravelly silty sand or sandy silt, frequent discontinuities within the till increase its permeability by several orders of magnitude. The discontinuities may consist of intermixed sand and silt layers, joints, and bedding. Known as “hardpan” by the construction trade, till is one of the most stable substrates in the region. It

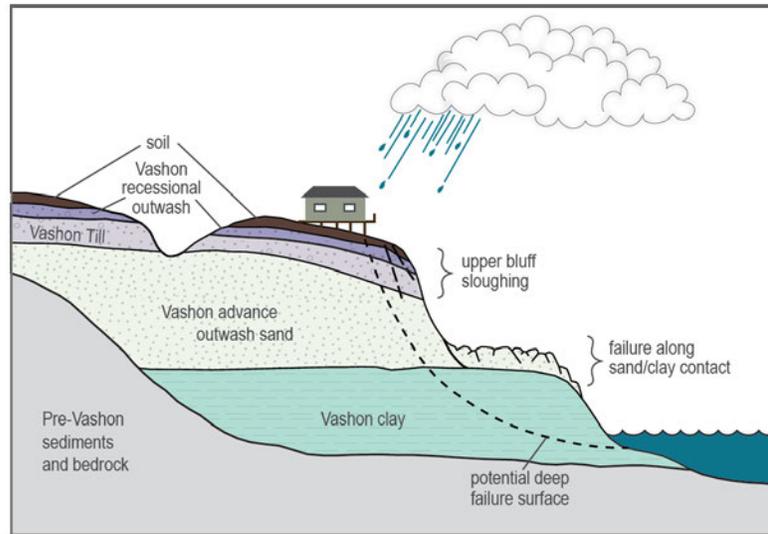


is rarely implicated in landsliding.

Simplified Geologic Map of Kirkland

Rapid surface-water runoff and surface erosion, however, is common over the till where overlying soil has been stripped or compacted.

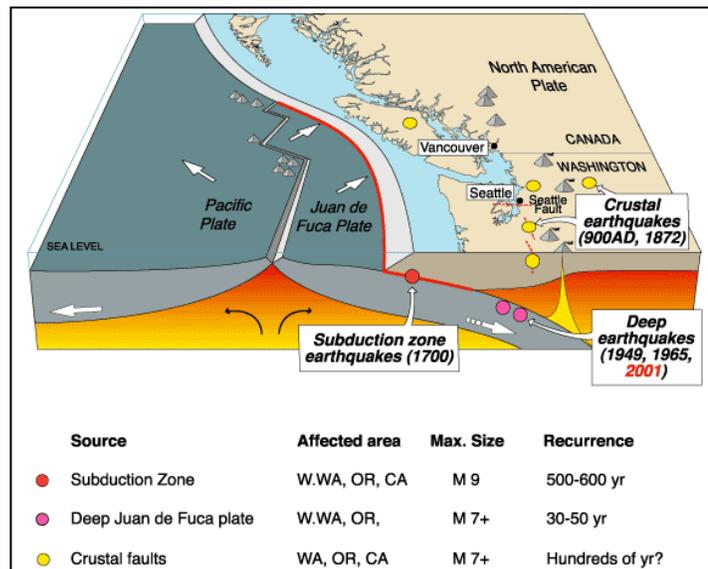
Landslides are common where sandy deposits, mostly outwash layers, overlie fine-grained deposits (lake silt and clay, and till) and where those contacts are exposed on steep slopes. Rain water infiltrates down through the sandy deposits and pools at the



Generalized layering in the Kirkland area showing susceptibility to landslides. Drawing from WGS.

contact, exiting the hills at steep slopes as springs. This increase in groundwater near the contact, creates unstable slopes.

The City is at risk from 3 different earthquake source zones because of our tectonic setting: the Cascadia Subduction Zone, Deep (Benioff) Zone, and Active crustal faults. Kirkland has been shaken by earthquakes from all three sources. Certain post-glacial deposits in Kirkland are prone to liquefaction from

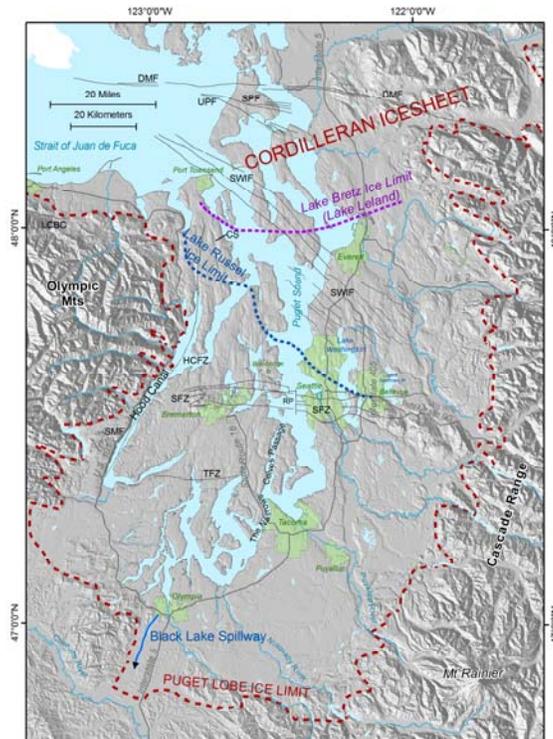


Earthquake source zones for the Pacific Northwest, from USGS.

earthquakes of sufficient size and duration.

The region as a whole has experienced many “deep” historic earthquakes, most recently the magnitude 6.8 Nisqually Earthquake occurred on February 28, 2001. Shaking from the Nisqually earthquake caused ground failures throughout the Puget Lowland, particularly in Olympia and Seattle.

Two active fault zones pass by the City of Kirkland: the south Whidbey Island fault zone (SWIF) and the Seattle fault zone. The locations of all of the strands of the SWIF are not known. One potential strand may extend into the City. Research is ongoing. The 6 km-wide Seattle fault zone runs west to east south of the City. A young strand of the Seattle fault last moved about 1100 years ago causing uplift and subsidence of land on either side of the fault, a tsunami in Puget Sound, and a tsunami in Lake Washington.



Map showing crustal faults in the Puget Lowland. SWIF=South Whidbey Island Fault Zone; SFZ=Seattle Fault Zone.

The new geologic map of Kirkland utilizes a dataset of over 6000 geotechnical boreholes and exposures, geomorphic analyses of lidar, new field mapping, excavation observations, geochronology, and integration with other geologic and geophysical information. Findings of the new mapping include recognition that about 50% of the large drumlins are cored with pre-Vashon glacial and nonglacial deposits and 50% with Vashon deposits, and that numerous unconformities are present in the subsurface. These old landscape surfaces display 600 feet of relief.

The surficial deposits of Kirkland can be grouped into the following categories to exemplify the distribution of geologic materials across the City: post glacial deposits 5%, late

glacial deposits 34%, Vashon glacial deposits 52%, and pre-Vashon deposits 9%. Of these, 43% are considered fine-grained deposits, 33% are considered intermediate or interbedded deposits, and 24% are considered coarse-grained deposits. These percentages include only the primary geologic units and not the overlying fill and colluvial deposits.

Subsurface Explorations Database

INTRO

The database consists of subsurface exploration data extracted from geotechnical engineering reports obtained from municipal and private sources. The database contains information for 3 main components: geotechnical documents, exploration points, and subsurface layers. Metadata about each of these components as well as the descriptions on the exploration logs are compiled in the database. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

Documents: 1188 Exploration Points: 5518 Exposures: 651 Layers: 20,721

SOURCES

Geotechnical documents were compiled from 29 different sources and reports were prepared by 153 unique authors. The top five data sources, based on number of documents in the database, are: City of Kirkland, Department of Ecology, AESI, King County, and WSDOT. The top five authors, based on number of documents in the database, are AESI, Cascade Geotechnical, Earth Consultants, Terra Associates, and Geotechnical Consultants, Inc. 96% of the data are from subsurface exploration work completed in 1970 and later.

DEPTHS

78% of the explorations within the database are shallow in depth, i.e. less than twenty feet. Less than 1% are deeper than 100 feet. 90% of the explorations are from test pits (N=3245) and borings (N=1874). 10% of the data are from exposures which consist of outcrops along roads and in gullies, and from observations at excavations.

METADATA

Metadata tracked in the database about each report consists of: a unique document id, document type, source, local identification numbers (i.e. permit number), author, document title, document date, project type, project address, completeness of data, date entered into database and name of data entry person, and shape area. Metadata tracked in the database about each exploration consists of: a unique exploration id, document id, exploration name, exploration type, location confidence, depth, elevation,

elevation source, datum, author, exploration date, method, contractor, number of wells, date created and by whom. Each layer description tracks the following: unique layer id, exploration id, layer number, layer type, top and bottom depths, description on log, density, minor constituents, major constituent, presence of organic matter, presence of debris, USCS, log unit, date created and by whom.

PDFS

Each geotechnical document has a corresponding pdf that is labeled by the unique document id. The first page of the cover sheet shows some of the metadata and when data entry and QA of the data entry were completed.

LONG-TERM ACCESS

The City of Kirkland and GeoMapNW will have a complete copy of the database. The data collected and compiled will be stored in the Washington Geological Survey master database accessible at: <https://geologyportal.dnr.wa.gov/#subsurface> in the Subsurface Geology Information System Theme. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

LIMITATIONS

The data contained in the database were obtained from outside sources and no guarantee of the validity/quality of the original data is implied. Data were entered into the database using trained students and data entry forms to reduce errors, then data entry underwent QA. The subsurface data reflect time dependent observations. Conditions vary horizontally and vertically so these data should not be used in lieu of obtaining site-specific information.

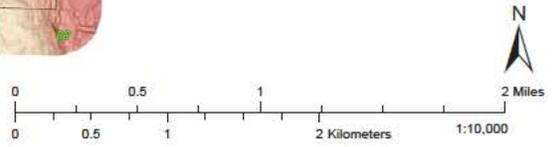
REVIEW

This document, the database, and the map were reviewed by the City of Kirkland and peer reviewed by AESI.

- Explorations**
- Borings from GeomapNW 2010
 - Borings from GeomapNW 2016-17
 - ▲ Probes from GeomapNW 2010
 - ▲ Probes from GeomapNW 2016-17
 - Test Pits from GeomapNW 2010
 - Test Pits from GeomapNW 2016-17
- Wells**
- We Is from GeomapNW 2010
 - We Is from GeomapNW 2016-17
- Exposures**
- ◆ Exposures from GeomapNW 2010
 - ◆ Exposures from GeomapNW 2016-17

| Exploration Totals | GeomapNW 2010 | GeomapNW 2016-17 | Subtotal |
|--------------------|---------------|------------------|-------------|
| Borings | 1212 | 662 | 1874 |
| Test Pits | 2208 | 959 | 3240 |
| Probes & CPT | 37 | 32 | 69 |
| Wells | 297 | 73 | 330 |
| Exposures | 393 | 258 | 651 |
| Total | 4185 | 1984 | 6169 |

Lake Washington



Subsurface Explorations in Kirkland

1) This map shows the locations of subsurface explorations, located within or adjacent to the City of Kirkland.
 2) Refer to database for assessment of local confidence, methods about the explorations, and subsurface layer information.
 3) Basemap from 2016 LiDAR DEM, colored by elevation and draped over a shaded slope map.
 4) Lake Washington bathymetry from NOAA surveys, colored by depth and draped over a shaded slope map.



Geologic Mapping

INTRO

The geology database consists of information needed to produce a Surficial Geologic Map of Kirkland. The layers of the map include polygons showing the uppermost geologic unit and polygons showing large areas of modified land (either filled and/or graded). The geologic units were determined using: geomorphic analyses of LiDAR data; field observations in excavations, gullies, and roadcuts; subsurface data from exploration logs in geotechnical documents; and geologic principles. Data points, exploration and exposures should be used with the geologic map because they provide locations of observational data where map confidence may be highest. Metadata about each of these components are compiled in the database. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

Exploration Points: 5544 Exposures (excavations and outcrops): 651

SOURCES

Most of the deeper gullies were walked and more than 90% of the roads were driven in an effort to obtain geologic information. City of Kirkland staff provided lists of open excavations to improve the number of field geologic observations. Exploration points came from the subsurface database.

GEOLOGIC UNITS

Each geologic unit displayed on the map is described on an accompanying table "Description of Map Units" (DMU). The DMU provides information about the range of materials, grain size, origin, thickness, degree of consolidation, permeability, and relative age. In most areas, weathered parent material and/or topsoil is present at the ground surface, but is not mapped.

CONFIDENCE AND SCALE

Although the geology is provided in digital form, and was compiled at scales of 1:6000 and larger the map scale should be considered 1:12,000. The highest confidence within the map and geologic contacts is at data points (explorations and exposures). However not all data points are of high quality or provided definitive information. All geologic information is inferred between data points using standard

geologic mapping principles and most contacts are concealed beneath vegetation, fill, colluvium, or structures.

PREVIOUS MAPPING

As with the 2010 Geologic Map of Kirkland by Troost and Wisher, the new map, which includes the recently annexed areas, shows much more detail and uses a LiDAR base map. Compared to the 1983 geologic map of the area, the new map has 5x the number of geologic units, less till at the ground surface, and more sandy material at the ground surface. In addition large fill areas are mapped.

LONG-TERM ACCESS

The City of Kirkland and GeoMapNW will have a complete copy of the geology database. The data collected and compiled will be stored in the Washington Geological Survey master database accessible at: <http://www.dnr.wa.gov/geologyportal> in the Washington Interactive Geologic Map Theme. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

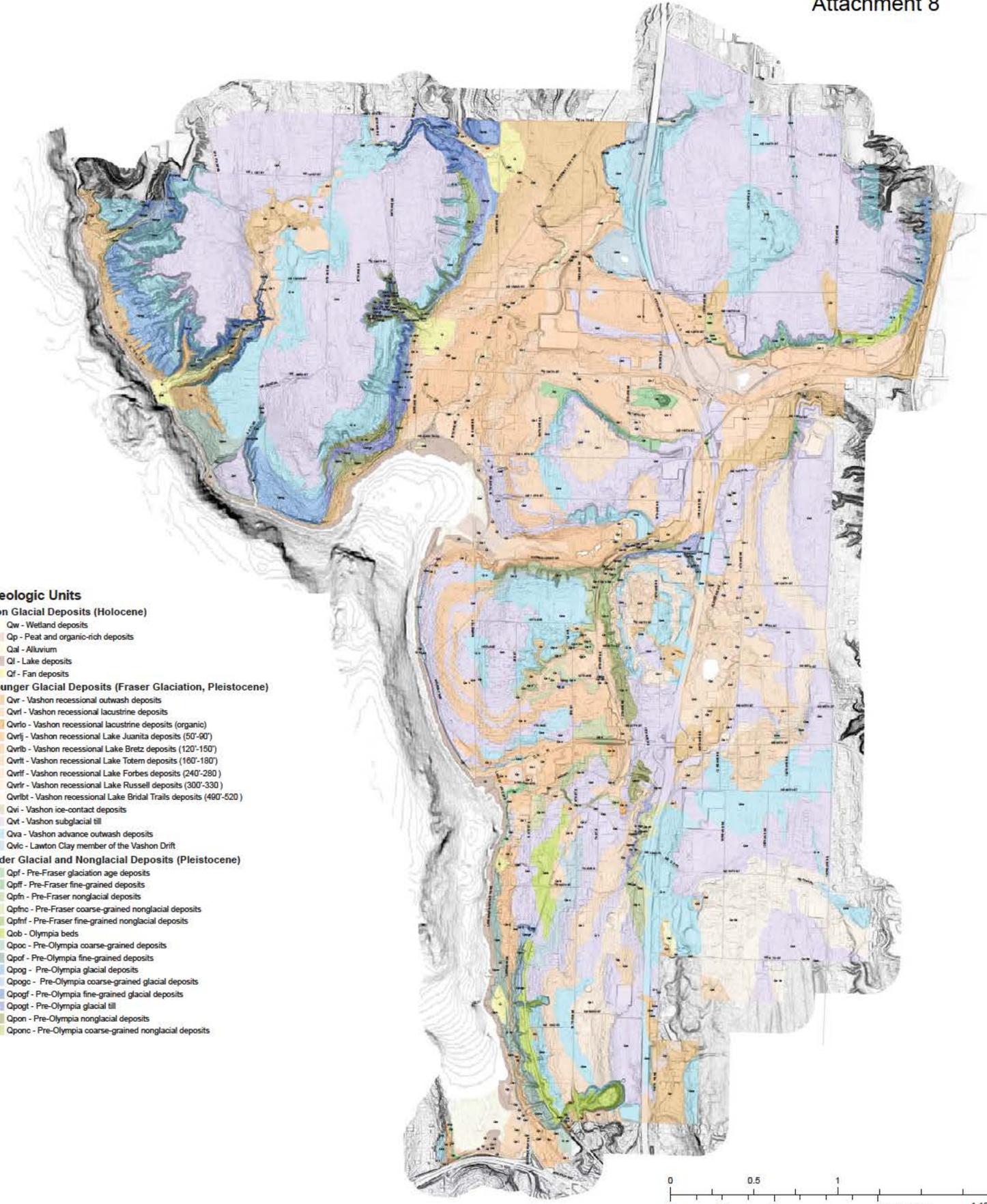
LIMITATIONS

The geologic map is based on over 6000 data points as well as standard geologic interpretation. The exploration data contained in the database were obtained from outside sources and no guarantee of the validity/quality of the original data is implied. Data were entered into the database using trained students and data entry forms to reduce errors, then data entry was underwent QA. Data gaps are present and reflect the lack of subsurface explorations in older residential neighborhoods with few critical areas. Additional data gaps exist where vegetation is heavy and/or where the land has been modified by the addition of fill, coverage by colluvium on slopes, and obscured by development. The geologic map should be used to evaluate and understand the character of the City as a whole and should not be used for site-specific evaluations.

REVIEW

This document and the map were reviewed by the City of Kirkland and peer reviewed by AESI.

- Geologic Units**
- Non Glacial Deposits (Holocene)**
- Qw - Wetland deposits
 - Qp - Peat and organic-rich deposits
 - Qal - Alluvium
 - Ql - Lake deposits
 - Qf - Fan deposits
- Younger Glacial Deposits (Fraser Glaciation, Pleistocene)**
- Qvr - Vashon recessional outwash deposits
 - Qvrl - Vashon recessional lacustrine deposits
 - Qvrla - Vashon recessional lacustrine deposits (organic)
 - Qvrlj - Vashon recessional Lake Juanita deposits (50'-90')
 - Qvrlb - Vashon recessional Lake Bretz deposits (120'-150')
 - Qvrlt - Vashon recessional Lake Totem deposits (160'-180')
 - Qvrlf - Vashon recessional Lake Forbes deposits (240'-280')
 - Qvrlr - Vashon recessional Lake Russell deposits (300'-330')
 - Qvrlbt - Vashon recessional Lake Bridal Trails deposits (490'-520')
 - Qvi - Vashon ice-contact deposits
 - Qvt - Vashon subglacial till
 - Qva - Vashon advance outwash deposits
 - Qwic - Lawton Clay member of the Vashon Drift
- Older Glacial and Nonglacial Deposits (Pleistocene)**
- Qpf - Pre-Fraser glaciation age deposits
 - Qpff - Pre-Fraser fine-grained deposits
 - Qpfn - Pre-Fraser nonglacial deposits
 - Qpfc - Pre-Fraser coarse-grained nonglacial deposits
 - Qpfnf - Pre-Fraser fine-grained nonglacial deposits
 - Qob - Olympia beds
 - Qpoc - Pre-Olympia coarse-grained deposits
 - Qpof - Pre-Olympia fine-grained deposits
 - Qpog - Pre-Olympia glacial deposits
 - Qpogc - Pre-Olympia coarse-grained glacial deposits
 - Qpogf - Pre-Olympia fine-grained glacial deposits
 - Qpogt - Pre-Olympia glacial till
 - Qpon - Pre-Olympia nonglacial deposits
 - Qponc - Pre-Olympia coarse-grained nonglacial deposits



1) This map shows the locations of subsurface explorations, located within or adjacent to the City of Kirkland.

2) Refer to database for assessment of local ion confidence, metadata about the explorations, and subsurface layer information.

3) Base slope map derived from 2016 LIDAR DEM.

4) Lake Washington slope map derived from NOAA bathymetry surveys.

5) Geo-logic units were mapped on the basis of geomorphology, geologic principles, descriptions from subsurface explorations, and observations at file exposures.

6) All contact locations are approximate.

Subsurface Explorations in Kirkland



DESCRIPTION OF MAP UNITS FOR GEOLOGIC MAP OF THE CITY OF KIRKLAND, November 2017

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|---------------------|---------------------|---|--|---|--|
| Holocene | NONGLACIAL DEPOSITS | | | | |
| m | Modified land | Fill and/or graded natural deposits that obscure or alter the original deposit. Difficult to discern how much fill vs. grading has occurred. See descriptions of units af and gr below. Locally divided into units af and gr: | Widespread across the map area. | Very soft to stiff or very loose to dense; variable degree of compaction during fill placement or amount of material removed. | Voids common; variable and unpredictable grain size; angular and large particles common; variable degree of compaction |
| af | Artificial fill | Gravel, sand, silt, concrete, garbage, slag, and other materials, placed as a direct result of human activity, of substantial areal extent or thickness. Mapped where boring data provide sufficient information to delineate extent or where topography and overlying development suggests likelihood of fill, and where greater than ~ 2 m in thickness. Thin deposits of fill are commonly present elsewhere throughout the map area but not mapped due to lack of information or control. Fill beneath most roadways, parking lots, and adjacent to buildings not mapped. Locally divided into unit gr: | Mapped where >2 m; but 1m of fill common across most of the area; 2 m to > 7 m beneath I-405 and roadways, in gullies, ravines, on peat and former lake beds, in other low-lying places, at upland edges, and on slopes. | Very soft to stiff or very loose to dense; variable degree of compaction during placement | Voids common; variable and unpredictable grain size; angular and large particles common; variable degree of compaction |
| gr | Graded land | Land substantially altered by excavation or grading, may include substantial thicknesses of fill too subtle to map or where boring data are insufficient to delineate extent. Gradational with units af and m | Large areas for I-405 and other roadways (smaller roadways not mapped) | Very soft to hard or very loose to very dense; variable degree of compaction | Depends on thickness of material removed, grain size, and degree of compaction of fill or native deposits |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|---------------------|-----------------------|---|--|---|---|
| Qmw | Mass-wastage deposits | Colluvium, soil, and landslide debris with indistinct morphology. Mapped on steep slopes. Numerous unmapped areas of mass-wastage deposits occur elsewhere along ravines. Deposits, both mapped and unmapped, include abundant discrete landslides up to 300 m (1000 ft) in lateral extent. Locally subdivided into unit Qls: | Typically about 3 m, locally >10 m; along steep slopes | Loose to dense and soft to stiff | Intermixed fine and coarse-grained deposits |
| Qls | Landslide deposits | Diamict of broken to internally coherent surficial deposits transported down slope <i>en masse</i> by gravity. Blocks of native material are commonly fractured, have rotated or deformed bedding, and have abundant slickensided surfaces. Numerous unmapped areas of both landslide and related mass-wastage deposits occur along slopes and ravines draining east to Lake Washington and draining into Forbes valley, particularly where coarse-grained deposits overlie fine-grained deposits. Vegetation, such as trees and roots, is commonly incorporated into the deposit | Variable, up to 20 m; along steep slopes | Very loose to very dense or soft to hard | Intermixed fine and coarse-grained deposits, voids common |
| Qw | Wetland deposits | Organic-rich sediment, peat, and fine-grained alluvium, poorly drained and intermittently wet. Areas identified from vegetation, maps, and topography; not all such deposits have been delineated | Typically 2 to 3 m | Very soft to medium stiff or very loose to medium dense | Commonly saturated |
| Qp | Peat | Predominantly organic matter consisting of plant material and woody debris, accumulated in bodies greater than about 1 m in thickness and of mappable extent. Accumulations are greatest in the floors of recessional-outwash channels, like between Main St. and 3 rd St near downtown and where lowering of Lake Washington has exposed extensive lake-floor deposits. Commonly interbedded with silt and clay. Gradational with units Qw, Ql, Qal, and Qvrl | >1 to 7 m, thickest along Lake WA at Juanita and Forbes Creeks | Very soft to medium stiff or very loose to medium dense | Commonly saturated |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|---------------------|---|---|--|---|--|
| Qal | Alluvium | Sand, silt, gravel, and cobbles deposited by streams and running water. May include landslide debris and colluvium at margins. Locally contains very soft peat lenses, silt lenses, and woody debris. Locally subdivided into unit Ql and unit Qf: | A few m in stream valleys | Loose to dense or soft to stiff | Predominantly sandy and horizontally bedded, fine- and coarser-grained lenses |
| Ql | Lake deposits | Silt and clay with local sand layers, peat, and other organic sediments, deposited in slow-flowing water. At many locations, the lake deposits are thin and overlie a dense substrate. Unit Ql mapped at elevation 20 to 30 are lake-bottom sediments exposed by the lowering of Lake Washington in 1916. Commonly capped by fill to improve building sites. Locally gradational with units Qvrl, Qal, and Qp | Typically 3 to 5 m on upland in recessional channels; 1 to 7 m adjacent to Lake WA | Very soft to medium stiff or very loose to medium dense | Predominantly fine grained and horizontally bedded, sand laminations common |
| Qf | Fan deposits | Sand, silt, gravel, and cobbles deposited in lobate form where streams emerge from confining valleys and reduced gradients cause sediment loads to be deposited. Gradational with unit Qal | 3 to 5 m | Loose to dense or soft to stiff | Variable grain size |
| Pleistocene | YOUNGER GLACIAL DEPOSITS | | | | |
| Qv | Deposits of Vashon stade of Fraser glaciation of Armstrong and others (1965) , not used as a map unit | | | | |
| Qvr | Recessional outwash deposits | Stratified sand and gravel, moderately sorted to well sorted, and less common silty sand and silt. Deposited in outwash channels that carried south-draining glacial meltwater during ice retreat away from the ice margin. Also includes deposits that accumulated in or adjacent to recessional lakes. Discontinuous. May include thin lag on glacial till uplands although deposits less than about 1 m (3 ft) | ~1 to 6 m; typically in channels | Loose to dense | Horizontally bedded to cross bedded, uniformly to well graded, channelized, coarse lag deposits common |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/ Hardness | Permeability Factors |
|---------------------|---|--|--|----------------------|--|
| | | thick not shown on map. May include areas of till extending up through the outwash. Major recessional channels within the City of Kirkland include Totem lake or York channel, Forbes Creek channel, and the downtown channel. Locally divided into units Qvrl: | | | |
| | Qvrl Recessional lacustrine deposits | Laminated silt and clay, low to high plasticity, with local sand layers, peat, and other organic sediments, deposited in slow-flowing water and ephemeral lakes. Locally includes high-plasticity clay with swell potential. Lenses and layers of ash and diatomite may be present. Gradational with units Qvr, Qp, and Ql. Locally divided into units Qvrla, Qvrlj, Qvrlb, Qvrlt, Qvrlf, Qvrlr, Qvrlbt | 1-2 m typically on uplands; up to 3 m at the heads of recessional channels | Very soft to stiff | Horizontally bedded; sandy channels may breach the lacustrine deposits |
| | Qvrla Recessional lacustrine deposits-organic | Laminated silt and clay, low to high plasticity, with local sand layers, peat, and other organic sediments, deposited in slow-flowing water and ephemeral lakes. More organic matter present than in unit Qvrl, more peat lenses and organic-rich sediment | 3 m typically on uplands; up to 4 m at the heads of recessional channels | Very soft to stiff | Horizontally bedded; sandy channels may breach the lacustrine deposits |
| | Qvrlj Recessional Lake Juanita deposits (50-90') | Laminated to interbedded, silt and silty fine sand, and less clayey silt deposited in slow-flowing water and ephemeral lakes. Present in flat-lying areas around elevations 50 to 90 feet. Grades to a recessional lake that occupied the Lake Washington basin when the Juanita Creek area was a major glacial recessional spillway. Most common near SR-520 and north to downtown, in Forbes valley and, in the Juanita Creek valley | 1m typically | Soft and loose | Horizontally bedded; sandy channels may breach the lacustrine deposits |
| | Qvrlb Recessional Lake Bretz deposits (120-150') | Laminated to interbedded, silt and silty fine sand, and less clayey silt deposited in slow-flowing water and ephemeral lakes. Present in flat-lying areas around elevations 120 to 150 feet. Grades to a recessional lake that occupied the Lake Washington and Puget Sound basins, regionally recognized. Most common in the Juanita Creek valley and on the west-facing slope south of Forbes valley. Deposits can be traced into a | 1m typically | Soft and loose | Horizontally bedded; sandy channels may breach the lacustrine deposits |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/ Hardness | Permeability Factors |
|---------------------|--|--|--------------|----------------------|--|
| | | thin spillway channel following the railroad tracks from the York channel down to the Forbes Creek channel and into the downtown channel | | | |
| Qvrlt | Recessional Lake Totem deposits (160-180') | Laminated to interbedded, silt and silty fine sand, and less clayey silt deposited in slow-flowing water and ephemeral lakes. Present in flat-lying areas around elevations 160 to 180 feet. Grades to a recessional lake that occupied the Lake Washington basin when the York channel, around Totem Lake, was a major glacial recessional spillway from the Sammamish valley. Also known as the York channel. Deposits can be traced into a thin spillway channel following the railroad tracks from the York channel down to the Forbes Creek channel and into the downtown channel | 1m typically | Soft and loose | Horizontally bedded; sandy channels may breach the lacustrine deposits |
| Qvrlf | Recessional Lake Forbes deposits (240-280') | Laminated to interbedded, silt and silty fine sand, and less clayey silt deposited in slow-flowing water and ephemeral lakes. Present in flat-lying areas around elevations 240 to 280 feet. Grades to a recessional lake that occupied the Forbes Lake basin when the local area contained stagnate ice and a temporary lake Forbes Lake, east of I-405, was apparently the result of a kettle. | 1m typically | Soft and loose | Horizontally bedded; sandy channels may breach the lacustrine deposits |
| Qvrlr | Recessional Lake Russell deposits (300-330') | Laminated to interbedded, silt and silty fine sand, and less clayey silt deposited in slow-flowing water and ephemeral lakes. Present in flat-lying areas around elevations 300 to 330 feet. Grades to a recessional lake that occupied the Lake Washington and Puget Sound basins, regionally recognized. Limited to the east side of I-405 and the northeast part of the City | 1m typically | Soft and loose | Horizontally bedded; sandy channels may breach the lacustrine deposits |
| Qvrlbt | Recessional Lake Bridal Trails deposits (490-520') | Laminated to interbedded, silt and silty fine sand, and less clayey silt deposited in slow-flowing water and ephemeral lakes. Present in flat-lying areas around elevations 490 to 520 feet. Grades to a recessional lake that occupied the highest elevations of the Lake Washington and Puget Sound basins to impact this | 1m typically | Soft and loose | Horizontally bedded; sandy channels may breach the lacustrine deposits |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|---------------------|--------------------------|--|--|--|--|
| | | area. Seen only around Bridal Trails park | | | |
| Qvi | Ice-contact deposits | Intercalated till and outwash, irregularly shaped bodies of till and outwash. Outwash consists of sand and gravel, clean to silty, horizontally bedded to steeply dipping. The till consists of matrix supported gravelly sandy silt that may or may not have been glacially overridden. Gradational with units Qvr and Qvt | 3 to 15 m; in patches on the upland, common around Forbes Lake | Loose to very dense; variable | Intermixed irregularly-shaped bodies of till and coarse-grained deposits, may have steep dips |
| Qvt | Vashon till | Compact deposit with a silt-sand matrix supporting subrounded to rounded gravel, glacially transported and deposited under ice. Contains large, often tabular, sand and gravel bodies, cobbles and boulders common. Coarse-grained layers may exceed 50% of the volume of the deposit. May appear to be cemented due to great degree of compaction. Commonly fractured and has intercalated sand lenses. Generally forms undulating, elongated surfaces. Upper +/- 1 meter is commonly weathered: oxidized, medium dense to dense, clean to silty, gravelly sand capping unweathered till. Often present, but not always differentiated on boring logs. May include areas of Qvr too small to separate or be observed during mapping. Locally gradational with units Qva and Qvi | Typically 1 to 10 m, locally absent | Very dense, dense to medium dense in the upper 1m weathered zone | Vertical fractures, sand lenses, sand bodies, and crude sub-horizontal bedding common; commonly capped by +/- 1m of oxidized silty gravelly sand |
| Qva | Advance Outwash Deposits | Well-sorted sand and gravel deposited by streams issuing from advancing ice sheet. May grade upward into till. Silt lenses locally present in upper part and are common in lower part. Generally unoxidized to only slightly oxidized. May be overlain by Vashon till in areas too small to show at map scale. Includes Esperance Sand Member of the Vashon Drift of Mullineaux and others (1965). Grades downward into unit Qvlc with increasing silt content or unconformably overlies older glacial or interglacial deposits. Locally excavated for fill, such as in the Forbes Creek valley. Locally contains groundwater | Locally over 30 m thick; wide-spread; locally absent | Dense to very dense | Predominantly medium grained sand, horizontally to cross bedded, hard silt beds/lenses common throughout, springs and seeps common |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|---------------------|---|--|--|---------------------|--|
| | | that emanates as springs and seeps, such as in Watershed park | | | |
| Qvlc | Lawton Clay of Mullineaux and others (1965) | Laminated to massive silt, clayey silt, and silty clay with scattered dropstones deposited in lowland proglacial lakes. Marks transition from nonglacial to earliest glacial time, although unequivocal evidence for glacial or nonglacial origin may be absent. Deposits of correlative age and texture may be included in older fine-grained units where evidence of age and/or depositional environment is absent. Locally may include fine-grained sediment of unit Qob or distal deposits from the Cascade Mountains where indistinguishable from Qvlc. Best seen on upland near Lakeview Elementary School | > 100 m; generally present in pre-Vashon valleys below 240 ft in elevation | Very stiff to hard | Vertical fractures, fine sand partings common near top and bottom of unit |
| Pleistocene | OLDER GLACIAL AND NONGLACIAL DEPOSITS | | | | |
| Qpf | Deposits of pre-Fraser glaciation age | Interbedded sand, gravel, silt, and diamicts of indeterminate age and origin. Locally divided into: | | Very dense and hard | Localized iron-oxide cemented layers, interbedded and intermixed fine- and coarse-grained layers |
| Qpff | Fine-grained deposits | Silt and clay, may have sandy interbeds, laminated to massive | Up to 7 m | Hard | Localized iron-oxide cemented layers and sandy partings |
| Qpfn | Nonglacial deposits | Sand, gravel, silt, clay, and organic deposits of inferred nonglacial origin, based on the presence of peat, paleosols, and tephra layers; or a central Cascade Range provenance for sedimentary clasts; of undetermined age | 3 to 7 m; discontinuous | Very dense and hard | Localized iron-oxide cemented layers, interbedded and intermixed fine- and coarse-grained layers |
| QpfnC | Coarse-grained nonglacial deposits | Sand and gravel, clean to silty, with some silt layers, with peat and tephra layers, lightly to moderately oxidized | 3 to 10 m | Very dense | Localized iron-oxide cemented layers |
| Qpfnf | Fine-grained nonglacial | Silt and clay, with peat and tephra layers, with some sandy interbeds, laminated to massive | 15 to 25 m | Hard | Localized iron-oxide cemented layers and |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|--------------------------|--|--|----------------|---------------------|--|
| | deposits | | | | sandy partings |
| Qob MIS 3 18-70 ka | Olympia beds of Minard and Booth (1988) | Sand, silt (locally organic-rich), gravel, and peat, discontinuously and thinly interbedded; may contain tephra and/or diatomaceous layers. Sand and gravel clast lithology varies depending on source area, from volcanic to reworked northern lithologies. Assigned to the Olympia interglaciation of Mullineaux and others (1965) on the basis of stratigraphic position, correlation, and radiocarbon dates. Distinguished from Qvlc on the basis of coarser grain size and presence of organics. Locally identified previously as the 'sandy phase of the Lawton'. The sediment that contained the tusk at Lakeview Elementary school. Unit Qob has been radiocarbon dated and the approximate ages from the samples are shown on the map | Absent to 25 m | Very dense and hard | Localized iron-oxide cemented layers, interbedded and intermixed fine- and coarse-grained layers |
| Qpo | Pre-Olympia age deposits | Sand, gravel, silt, clay, and diamict of indeterminate age and origin. Locally divided into: | 5 to 75 m | Very dense and hard | Localized iron-oxide cemented layers and sandy partings |
| | Qpof Fine-grained deposits | Silt and clay, may have sandy interbeds, laminated to massive | 5 to 75 m | Hard | Localized iron-oxide cemented layers and sandy partings |
| | Qpoc Coarse-grained deposits | Sand and gravel, clean to silty, with some silt layers, lightly to moderately oxidized | 3 to 22 m | Very dense | Localized iron-oxide cemented layers and channels |
| Qpog | Glacial deposits | Silt, sand, gravel and till of glacial origin Weakly to strongly oxidized. Underlies Vashon-age deposits and thus must also be of pre-Olympia age. Sediment is of inferred glacial (northern) origin, based on presence of clasts or mineral grains requiring southward ice-sheet transport | 7 to >33 m | Very dense and hard | Localized iron-oxide cemented layers, interbedded and intermixed fine- and coarse-grained layers |
| | Qpogc Coarse-grained glacial deposits | Sand and gravel, clean to silty, with some silt layers, moderately to heavily oxidized | 1 to 15 m | Very dense | Localized iron-oxide cemented layers and channels |

| Age & Geologic Unit | Name | Summary Description | Thickness | Density/Hardness | Permeability Factors |
|---------------------|------------------------------------|--|--------------------------|---------------------|--|
| Qpogf | Fine-grained glacial deposits | Silt and clay, may have sandy interbeds, laminated to massive | 2 to 25 m | Hard | Localized iron-oxide cemented layers and sandy partings |
| Qpogt | Till deposits | Till thick enough to show at map scale. Most extensive on west slopes below I-405 at head of Forbes Creek valley and south of downtown | Discontinuous, 1 to 10 m | Very dense and hard | Localized iron-oxide cemented layers, sandy partings, and lenses |
| Qpon | Nonglacial deposits | Sand, gravel, silt, clay, and organic deposits of inferred nonglacial origin, based on the presence of paleosols, and tephra layers; or a southern Cascade Range provenance for sedimentary clasts | 3 to 23 m | Very dense and hard | Localized iron-oxide cemented layers, interbedded and intermixed fine- and coarse-grained layers |
| Qponc | Coarse-grained nonglacial deposits | Sand and gravel, clean to silt, with silt layers, with peat and tephra layers, moderately to heavily oxidized | 3 to 13 m | Very dense | Localized iron-oxide cemented layers, and channels |
| Qponf | Fine-grained nonglacial deposits | Silt and clay, may have sandy interbeds, laminated to massive | 2 to 25 m | Hard | Localized iron-oxide cemented layers and sandy partings |

Groundwater and Springs Database

INTRO

The groundwater database consists of information from field observations of springs and groundwater data extracted from exploration logs in geotechnical documents. Groundwater data contains information from four main observation types: measured in monitoring wells, encountered during drilling or excavation, seepage in excavations, and inferred from subsurface layer descriptions. Data on springs came from City of Kirkland staff and field observations during geologic mapping. Metadata about each of these components are compiled in the database. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

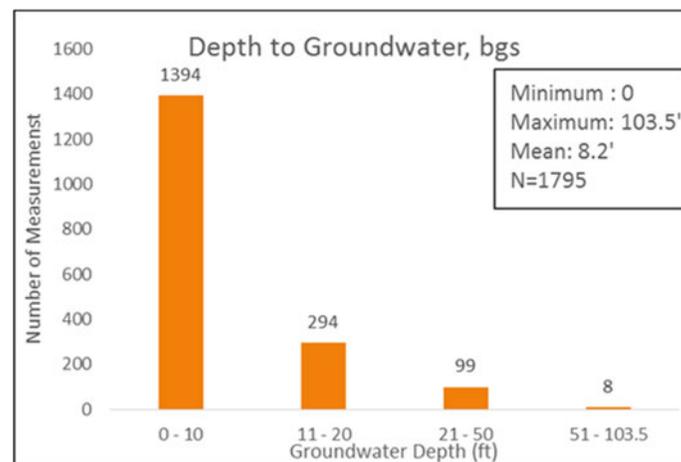
Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

Exploration Points: 5544
Springs: 181

Exploration Points with GW data: 1795

Monitoring Wells: 268



DEPTH TO GROUNDWATER BIAS

78% of the explorations within the database are shallow in depth, i.e. less than twenty feet and therefore the groundwater data will be biased toward shallow depths. Less than 1% of the explorations are deeper than 100 feet. 90% of the explorations are from test pits (N=3245) and borings (N=1874). About 50% of the groundwater depth data are from seepage noted in test pit excavations, also providing a bias toward shallow groundwater data. 10% of the data are from exposures which consist of outcrops along roads and in gullies, and from observations at excavations.

METADATA

Metadata tracked in the database about groundwater include: exploration id, document id, exploration name, whether groundwater was encountered, depth to groundwater, exploration depth, if the groundwater was flowing above the ground surface and height, date observed, data source, observation type, number of measurements, groundwater depth type, comments, date entered in database and by whom. Metadata tracked in the database about monitoring wells includes: well id, exploration id, well name, well depth, well diameter, top and bottom depth of screen, number of measurements, date of last reading, depth of last reading, if well testing was completed, date entered and by whom, and water level type. Metadata tracked in the database about springs includes location, field station id, observer, and comments.

LONG-TERM ACCESS

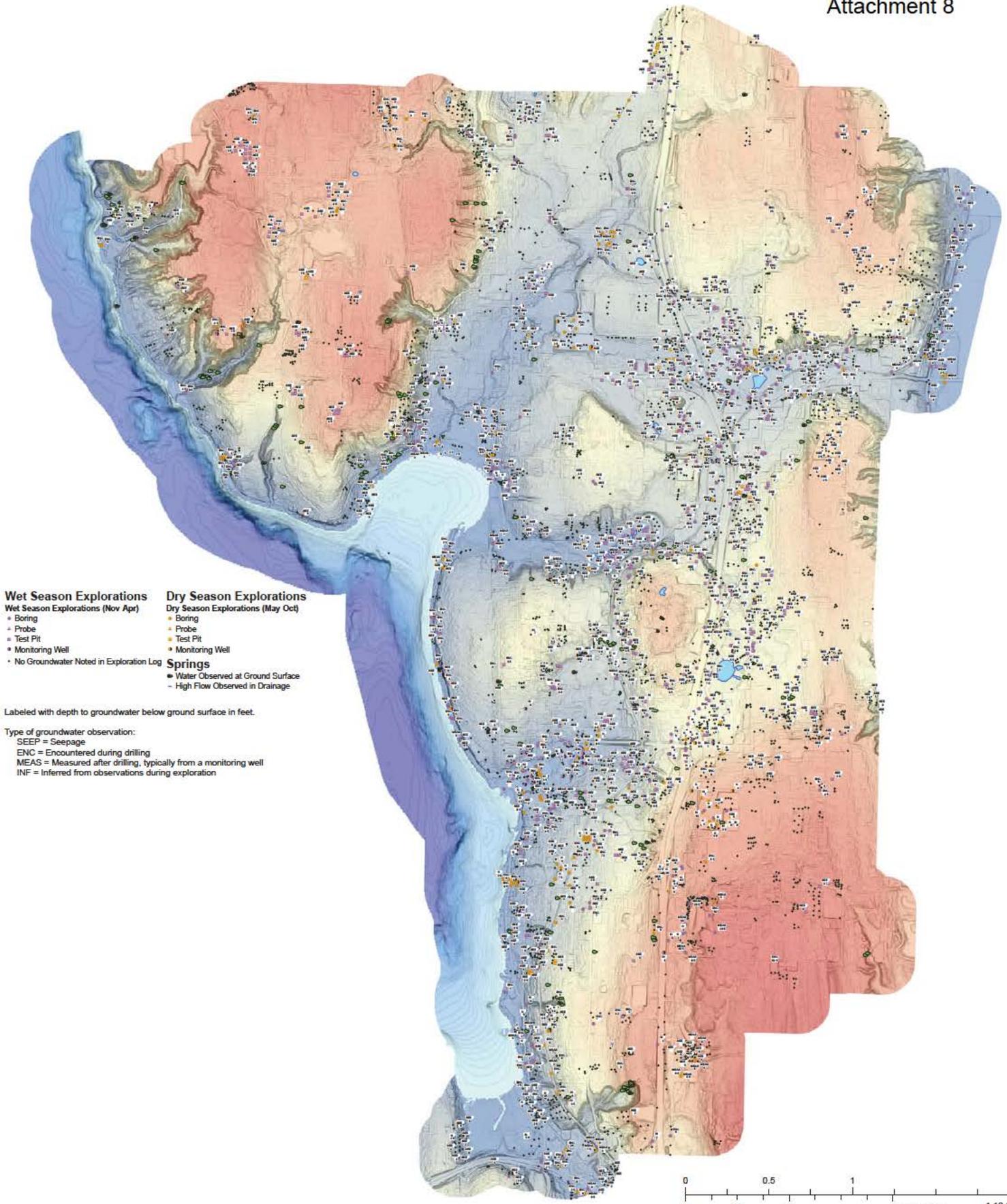
The City of Kirkland and GeoMapNW will have a complete copy of the database. The data collected and compiled will be stored in the Washington Geological Survey master database accessible at: <http://www.dnr.wa.gov/geologyportal> in the Subsurface Geology Information System Theme. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

LIMITATIONS

The data contained in the database were obtained from outside sources and no guarantee of the validity/quality of the original data is implied. Data were entered into the database using trained students and data entry forms to reduce errors, then data entry underwent QA. Observations about groundwater, such as depth, should be considered approximate because of challenges inherent with exploration methods (i.e. not enough time for groundwater to equilibrate before measurements are made and difficulty measuring capillary fringe thickness). Spring locations are approximate and each point mapped should be considered representative of a horizon or zone rather than a specific point. The groundwater data should be used to evaluate and understand the character of the City as a whole, not for site-specific evaluations. The data reflect time dependent observations.

REVIEW

This document and the map were reviewed by the City of Kirkland and peer reviewed by AESI.



Wet Season Explorations
 Wet Season Explorations (Nov-Apr)
 • Boring
 • Probe
 • Test Pit
 • Monitoring Well
 • No Groundwater Noted in Exploration Log

Dry Season Explorations
 Dry Season Explorations (May-Oct)
 • Boring
 • Probe
 • Test Pit
 • Monitoring Well

Springs
 • Water Observed at Ground Surface
 • High Flow Observed in Drainage

Labeled with depth to groundwater below ground surface in feet.

Type of groundwater observation:
 SEEP = Seepage
 ENC = Encountered during drilling
 MEAS = Measured after drilling, typically from a monitoring well
 INF = Inferred from observations during exploration

1) This map shows the locations of subsurface explorations, located within or adjacent to the City of Kirkland.
 2) Refer to database for assessment of location confidence, metadata about the explorations, and subsurface layer information.
 3) Basemap from 2016 LIDAR, DEM colored by elevation and draped over a shaded slope map.
 4) Late Washington bathymetry from NOAA surveys, colored by depth and draped over a shaded slope map.
 5) Depth to groundwater data taken from subsurface exploration logs.
 6) Springs and seeps layer includes locations of high flow in drainage pipes. All local ones are approximate.
 7) Refer to groundwater geodatabase for details and information.

Kirkland Groundwater Data



Infiltration Potential

INTRO

The infiltration potential map consists of a qualitative assessment of the ability of geologic materials to infiltrate water. The layers of the map include polygons showing four categories of infiltration potential based on a weighted matrix of geologic parameters including, grain size, age of deposit, density, and depth to water. Areas of modified land (either filled and/or graded), provided as a separate layer, should always be included on the map because they significantly impact the infiltration potential. The geologic units were determined using: geomorphic analyses of LiDAR data; field observations in excavations, gullies, and roadcuts; subsurface data from exploration logs in geotechnical documents; and geologic principles. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

| | | | |
|--------------------------|---|------------------------|---------|
| Exploration Points: 5544 | Exposures (excavations and outcrops): 651 | | |
| High: 4.18 sq mi or 24% | Mixed: 6.86 sq mi or 33% | Low: 6.77 sq mi or 39% | Wet: 4% |

INFILTRATION POTENTIAL CATEGORIES

The four qualitative infiltration potential categories consist of: high, mixed, low, and shallow groundwater. Most of the land surface area of Kirkland falls into the low category. The high infiltration potential category includes sandy and gravelly deposits like: alluvial fan deposits, glacial outwash, and nonglacial fluvial deposits. The mixed infiltration potential category includes unconsolidated silty deposits like glacial recessional lake deposits, interbedded sandy and silty deposits, undifferentiated glacial and nonglacial deposits, and the named recessional lake deposits. The shallow groundwater infiltration potential category includes deposits exposed from the 1916 Lake Washington shoreline lowering, peat and wetland deposits, and alluvium. The low infiltration potential category includes glacially overridden silty and clayey deposits like till, and glacial and nonglacial lake deposits.

DEPTH OF INFLUENCE

The potential infiltration map reflects an assessment of surficial geologic units and so does not reflect potential for deep infiltration. The depth of influence varies by location and underlying geology. In general, the assessment reflects the upper 10 to 20 feet, except where fill and colluvium are present. Colluvium is present and thickest across most slopes steeper than 20 degrees. The map does not reflect

the influence of the topsoil layer since it is assumed to have essentially the same influence everywhere. Where development is absent and the upper weathered layer of Vashon till is still present, the infiltration potential is greater than for undisturbed till.

CONFIDENCE AND SCALE

Although this map is provided in digital form, the map scale should be considered 1:12,000. The highest confidence within the map and contacts is at data points (explorations and exposures). However not all data points are of high quality or provided definitive information. All geologic information is inferred between data points using standard geologic mapping principles and most contacts are concealed beneath vegetation, fill, colluvium, or structures.

LONG-TERM ACCESS

The City of Kirkland and GeoMapNW will have a complete copy of the database. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

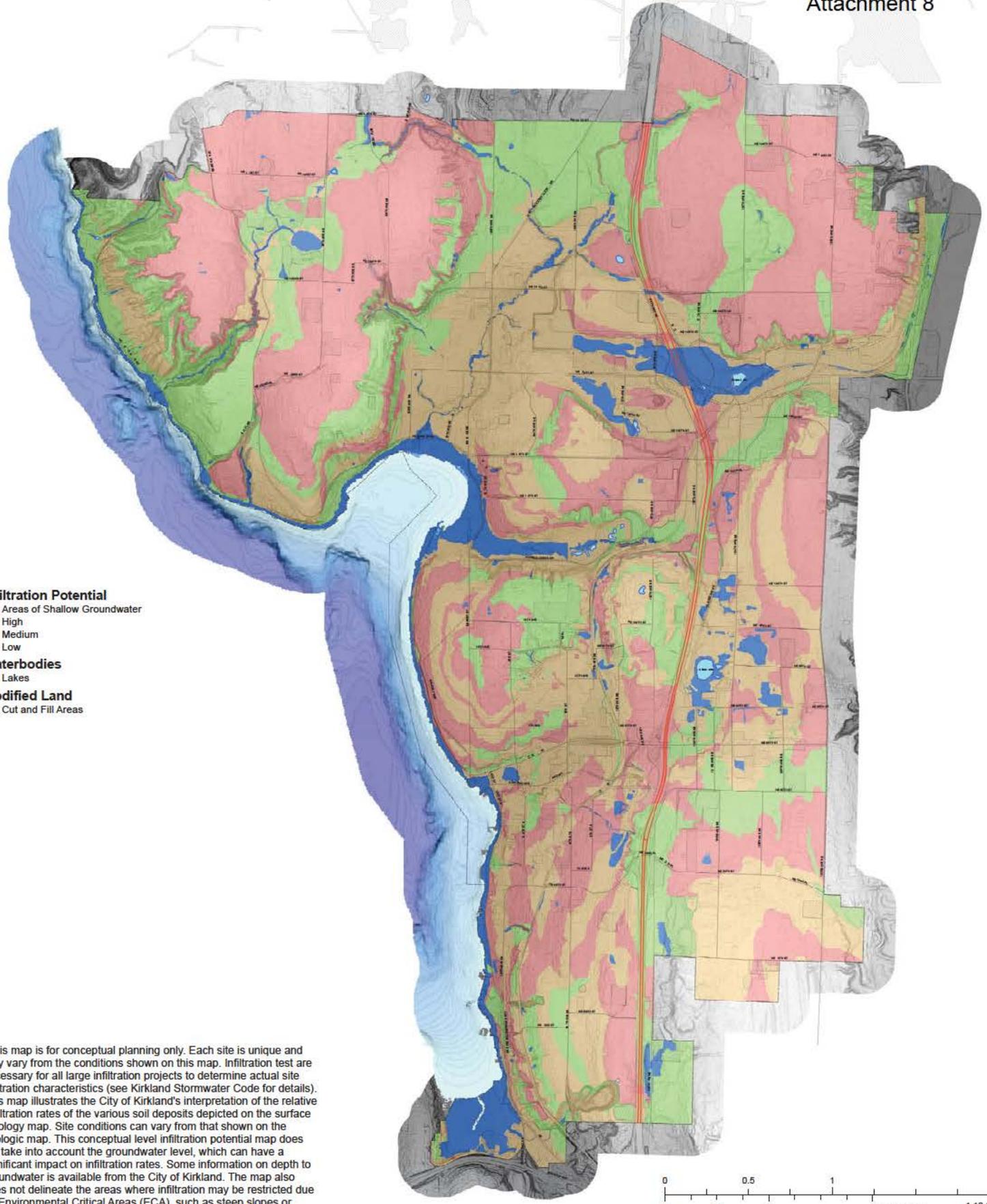
LIMITATIONS

The infiltration potential map is based on over 6000 data points as well as standard geologic interpretation. The exploration data contained in the database were obtained from outside sources and no guarantee of the validity/quality of the original data is implied. Data were entered into the database using trained students and data entry forms to reduce errors, then data entry was underwent QA. Data gaps are present and reflect the lack of subsurface explorations in older residential neighborhoods with few critical areas. Additional data gaps exist where vegetation is heavy and/or where the land has been modified by the addition of fill, coverage by colluvium on slopes, and obscured by development. This qualitative infiltration potential map should be used to evaluate and understand the character of the City as a whole and should not be used for site-specific evaluations. The map does not show where water should be prevented from entering the ground such as in steep slope areas or areas of shallow groundwater.

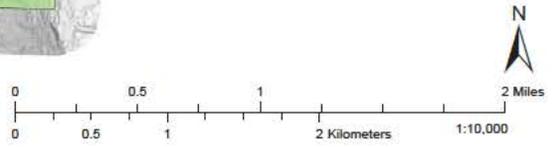
REVIEW

This document and the map were reviewed by the City of Kirkland and peer reviewed by AESI.

- Infiltration Potential**
- Areas of Shallow Groundwater
 - High
 - Medium
 - Low
- Waterbodies**
- Lakes
- Modified Land**
- Cut and Fill Areas



*This map is for conceptual planning only. Each site is unique and may vary from the conditions shown on this map. Infiltration test are necessary for all large infiltration projects to determine actual site infiltration characteristics (see Kirkland Stormwater Code for details). This map illustrates the City of Kirkland's interpretation of the relative infiltration rates of the various soil deposits depicted on the surface geology map. Site conditions can vary from that shown on the geologic map. This conceptual level infiltration potential map does not take into account the groundwater level, which can have a significant impact on infiltration rates. Some information on depth to groundwater is available from the City of Kirkland. The map also does not delineate the areas where infiltration may be restricted due to Environmental Critical Areas (ECA), such as steep slopes or setbacks from steep slopes.



Conceptual Level Infiltration Potential Map*

1) Basemap from 2016 LIDAR; DEM shaded by elevation and draped over a shaded slope map.
 2) Lake Washington bathymetry from NOAA surveys, colored by depth and draped over a shaded slope map.
 3) Infiltration potential was determined using a weighted matrix method of geologic parameters of grain size, density, organic content, and uniformity of deposit.
 4) All contact locations are approximate.
 5) This map is for conceptual planning purposes only.



Map of Landslide Features

INTRO

The map of landslide features is one part of a 3-part landslide hazard product which consists of a landslide inventory, a shallow landslide hazard model, and a deep-seated landslide hazard model. The map, a representation of the landslide inventory, includes polygons showing the locations of landslide head scarps, lines marking internal scarps, polygons of landslide deposits, and exploration data points where landslide deposits were noted. The landslide features were identified using: geomorphic analyses of LiDAR data, field observations, subsurface data from exploration logs in geotechnical documents, and information from City of Kirkland staff. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

| | |
|--------------------------|---|
| Exploration Points: 5544 | Exposures (excavations and outcrops): 651 |
| Landslide deposits: 120 | Landslide headscarps: 120 Internal scarps: 225 Points: 36 |

LANDSLIDE MAPPING PROTOCOLS

The landslide mapping and modeling efforts followed the guidance provided by the Washington Geological Survey (WGS), King County, and Oregon Department of Geology and Mineral Industries (DOGAMI). Specifically the inventory followed the DOGAMI guidance of Burns and Madin (2009) as amended by the WGS in Bulletin 82 by Slaughter and others (2017). The shallow landslide susceptibility model followed the DOGAMI guidance of Burns and others (2012). The deep-seated landslide susceptibility mapping followed the DOGAMI guidance of Burns and Mickelson (2016). Information about subaqueous landslides in Lake Washington came from work by Karlin and others (2004) and geomorphic analyses of bathymetric data. Modeling efforts are based on the inventory, a slope map, a geologic map, and an assessment of geotechnical parameters such as: material type, cohesion, friction, degree of saturation, and unit weight. These parameters were obtained from publications about the regional geologic units and an assessment during the peer review by AESI.

CONFIDENCE AND SCALE

Although this map is provided in digital form, the map scale should be considered 1:12,000. The highest confidence within the map and contacts is at locations of recent landslides where the geomorphic signature is the strongest. Older landslides and shallow landslide do not show up well on LiDAR maps

and hence may be under represented on the map and in the models. All geologic information is inferred between data points using standard geologic mapping principles. Some landslides are concealed beneath vegetation, fill, colluvium, or structures.

LONG-TERM ACCESS

The City of Kirkland and GeoMapNW will have a complete copy of the database. The data collected and compiled will be stored in the Washington Geological Survey master database accessible at: <http://www.dnr.wa.gov/geologyportal> in the Natural Hazards Theme. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

LIMITATIONS

The landslide features map is based on over 6000 data points as well as standard geomorphic analyses and interpretation of LiDAR data. Data gaps exist where vegetation is heavy and/or where the land has been modified by the addition of fill, coverage by colluvium on slopes, and obscured by development. This landslide features map should be used to evaluate and understand the character of the City as a whole and should not be used for site-specific evaluations. .

REVIEW

This document and the map were reviewed by the City of Kirkland and peer reviewed by AESI.

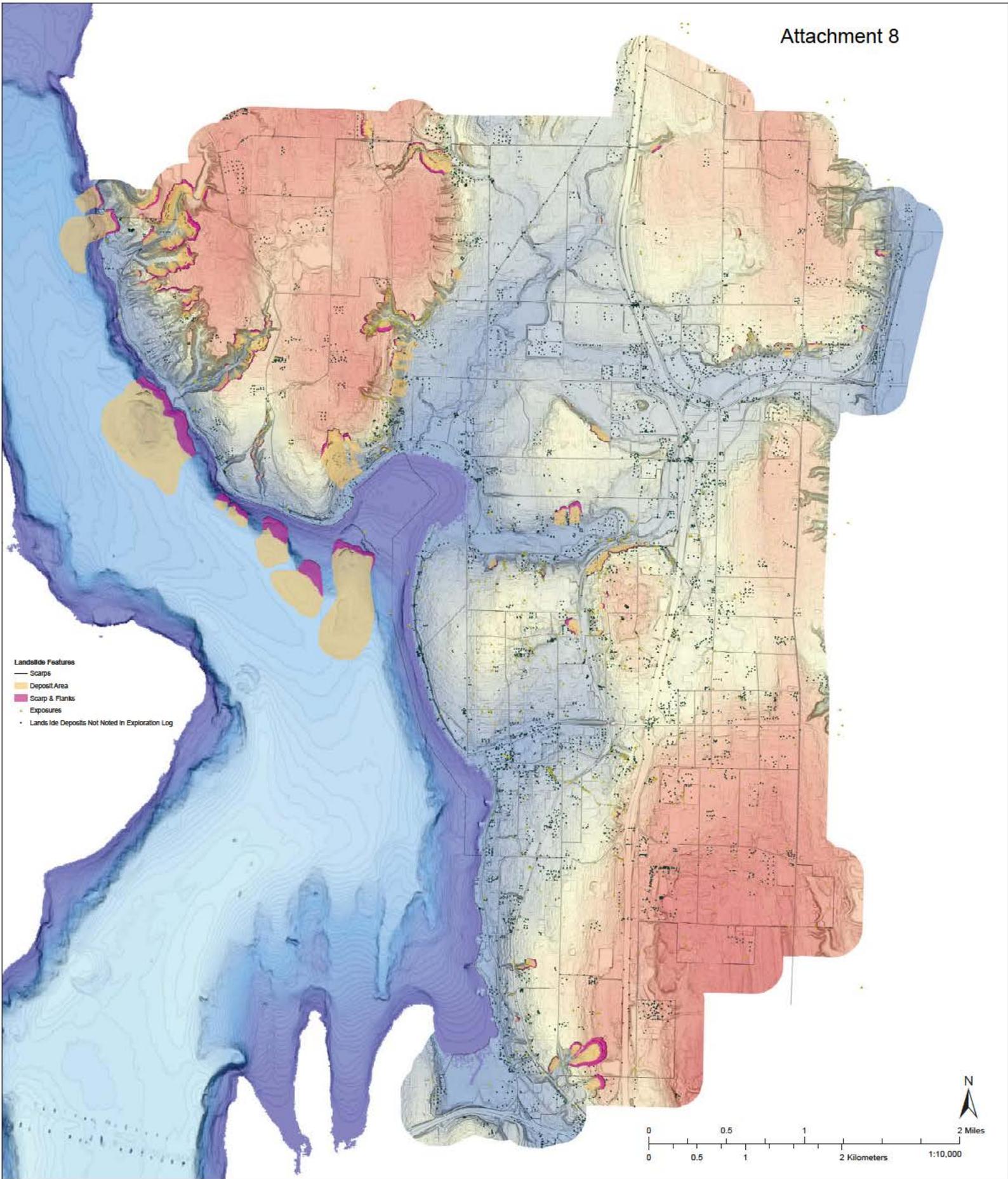
REFERENCES

Burns, W.J. and Madin, I.P., 2009, Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (Lidar) Imagery, DOGAMI Special Paper 42.

Burns, W.J., Madin, I.P., and Mickelson, K.A., 2012, Protocol for Shallow-Landslide Susceptibility Mapping, DOGAMI Special Paper 45.

Burns, W.J. and Mickelson, K.A., 2016, Protocol for Deep Landslide Susceptibility Mapping, DOGAMI Special Paper 48.

Slaughter, S.L.; Burns, W.J.; Mickelson, K.A., Jacobacci, K.E., Biel, A., Contreras, T.A., 2017, Protocol for Landslide Inventory Mapping from Lidar Data in Washington State, WGS, Bulletin 82.



Landslide Features in Kirkland

1) This map shows the locations of subsurface explorations, located within or adjacent to the City of Kirkland.
 2) Basemap from 2016 LIDAR; DEM colored by elevation and draped over a shaded slope map.
 3) Lake Washington bathymetry from NOAA surveys, colored by depth and draped over a shaded slope map.
 4) The landslide features and locations shown were identified on the basis of geomorphic criteria, historical documentation, and geotechnical documents in the database.
 5) Landslide deposits were primarily identified by hummocky topography and disturbed deposits. Scarp flanks were primarily identified by distinct arcuate shape and steep face. Landslide scarps were primarily identified by distinct arcuate shape and steep face.



Map of Landslide Susceptibility

INTRO

The map of landslide susceptibility is the composite product of a 3-part landslide hazard product which consists of a landslide inventory, a shallow landslide hazard model, and a deep-seated landslide hazard model. The map, a representation of the landslide inventory and models, includes polygons showing the locations of landslide head scarps, polygons of landslide deposits, and a factor-of-safety based representation of landslide susceptibility ranked from low to high. The landslide features were identified using: geomorphic analyses of LiDAR data, field observations, subsurface data from exploration logs in geotechnical documents, and information from City of Kirkland staff. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

| | |
|--------------------------|---|
| Exploration Points: 5544 | Exposures (excavations and outcrops): 651 |
| Landslide deposits: 120 | Landslide headscarps: 120 Internal scarps: 225 Points: 36 |

LANDSLIDE MAPPING UNITS AND PROTOCOLS

The composite map shows susceptibility ranks based on a modeled factor of safety (FS) wherein:

- **High Susceptibility** is mapped for slopes having a FS of less than 1.25 (where FS of 1 is on the verge of failure).
- **Moderate Susceptibility** is mapped for slopes having a FS of between 1.25 and 1.5.
- **Low Susceptibility** is mapped for slopes having a FS of greater than 1.5.

The landslide mapping and modeling efforts followed the guidance provided by the Washington Geological Survey (WGS), King County, and Oregon Department of Geology and Mineral Industries (DOGAMI). Specifically the inventory followed the DOGAMI guidance of Burns and Madin (2009) as amended by the WGS in Bulletin 82 by Slaughter and others (2017). The shallow landslide susceptibility model followed the DOGAMI guidance of Burns and others (2012). The deep-seated landslide susceptibility mapping followed the DOGAMI guidance of Burns and Mickelson (2016). Information about subaqueous landslides in Lake Washington came from work by Karlin and others (2004) and geomorphic analyses of bathymetric data. Modeling efforts are based on the inventory, a slope map, a geologic map, and an assessment of geotechnical parameters such as: material type, cohesion, friction, degree of saturation, and unit weight. These parameters were obtained from publications about the regional geologic units and an assessment during the peer review by AESI.

CONFIDENCE AND SCALE

Although this map is provided in digital form, the map scale should be considered 1:12,000. The highest confidence within the map and contacts is at locations of recent landslides where the geomorphic signature is the strongest. Older landslides and shallow landslides do not show up well on LiDAR maps and hence may be under represented on the map and in the models. All geologic information is inferred between data points using standard geologic mapping principles. Some landslides are concealed beneath vegetation, fill, colluvium, or structures.

LONG-TERM ACCESS

The City of Kirkland and GeoMapNW will have a complete copy of the database. The data collected and compiled will be stored in the Washington Geological Survey master database accessible at: <http://www.dnr.wa.gov/geologyportal> in the Natural Hazards Theme. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

LIMITATIONS

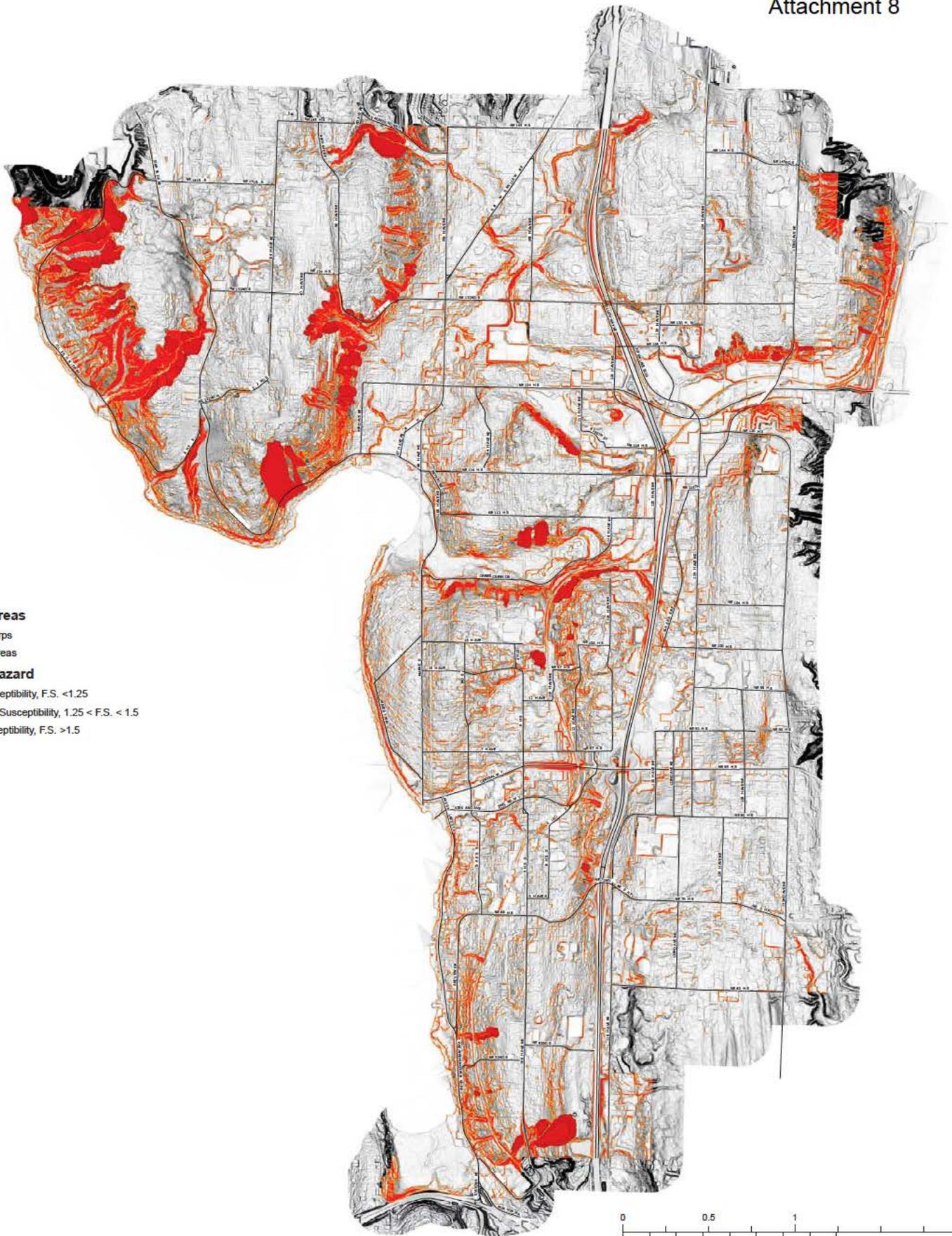
The landslide features map is based on over 6000 data points as well as standard geomorphic analyses and interpretation of LiDAR data. Data gaps exist where vegetation is heavy and/or where the land has been modified by the addition of fill, coverage by colluvium on slopes, and obscured by development. This landslide features map should be used to evaluate and understand the character of the City as a whole and should not be used for site-specific evaluations. .

REVIEW

This document and the map were reviewed by the City of Kirkland and peer reviewed by AESI.

REFERENCES

- Burns, W.J. and Madin, I.P., 2009, Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (Lidar) Imagery, DOGAMI Special Paper 42.
- Burns, W.J., Madin, I.P., and Mickelson, K.A., 2012, Protocol for Shallow-Landslide Susceptibility Mapping, DOGAMI Special Paper 45.
- Burns, W.J. and Mickelson, K.A., 2016, Protocol for Deep Landslide Susceptibility Mapping, DOGAMI Special Paper 48.
- Slaughter, S.L.; Burns, W.J.; Mickelson, K.A., Jacobacci, K.E., Biel, A., Contreras, T.A., 2017, Protocol for Landslide Inventory Mapping from Lidar Data in Washington State, WGS, Bulletin 82.



Landslide Areas

- Head Scarps
- Deposit Areas

Landslide Hazard

- High Susceptibility, F.S. <1.25
- Moderate Susceptibility, 1.25 < F.S. < 1.5
- Low Susceptibility, F.S. >1.5

Landslide Susceptibility Map

1) Landslide susceptibility was determined following the modeling protocol developed by the Oregon Department of Geology and Mineral Industries and the Washington Geological Survey, and is based on a factor of safety (F.S.) analysis using slope, geotechnical properties, distribution of geologic materials, known landslides, and wet weather conditions. Refer to the accompanying technical report for more details.

2) The landslide features and locations shown were identified on the basis of geomorphic criteria, historical documentation, and geotechnical documents in the database.

3) Landslide deposits were primarily identified by hummocky topography and disturbed deposits. Scarp flanks were primarily identified by distinct arcuate shape and steep face. Landslide scarps were primarily identified by distinct arcuate shape and steep face.

4) Basemap from 2016 LiDAR; DEM colored by elevation and draped over a shaded slope map.



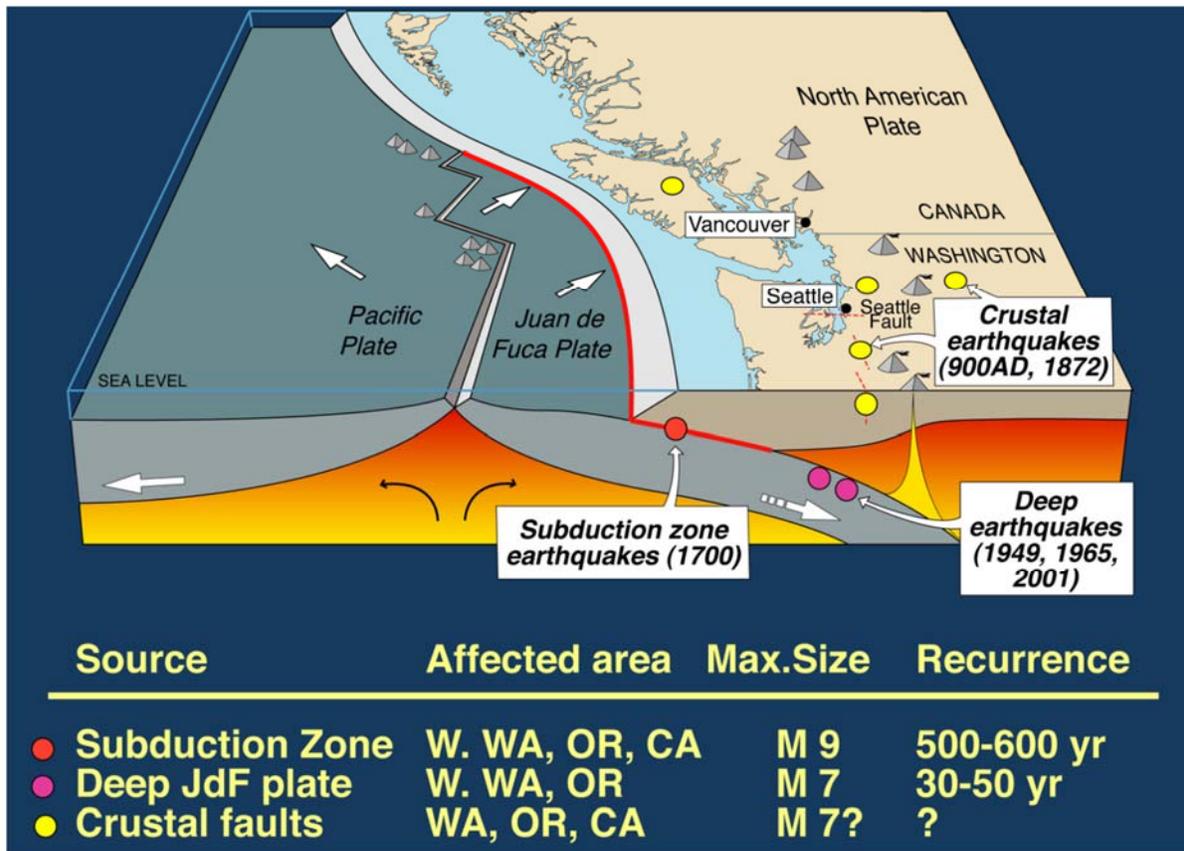
Seismic Hazards

INTRO

Seismic hazards in Kirkland consist of earthquakes, earthquake shaking, earthquake-induced landslides, tsunami and seiche waves in Lake Washington, and fault rupture. Earthquake shaking could cause landslides, subaqueous slides, and ground failures such as liquefaction, compression, and lateral spreading within and adjacent to the City of Kirkland. Poorly consolidated deposits with shallow groundwater will be the most susceptible.

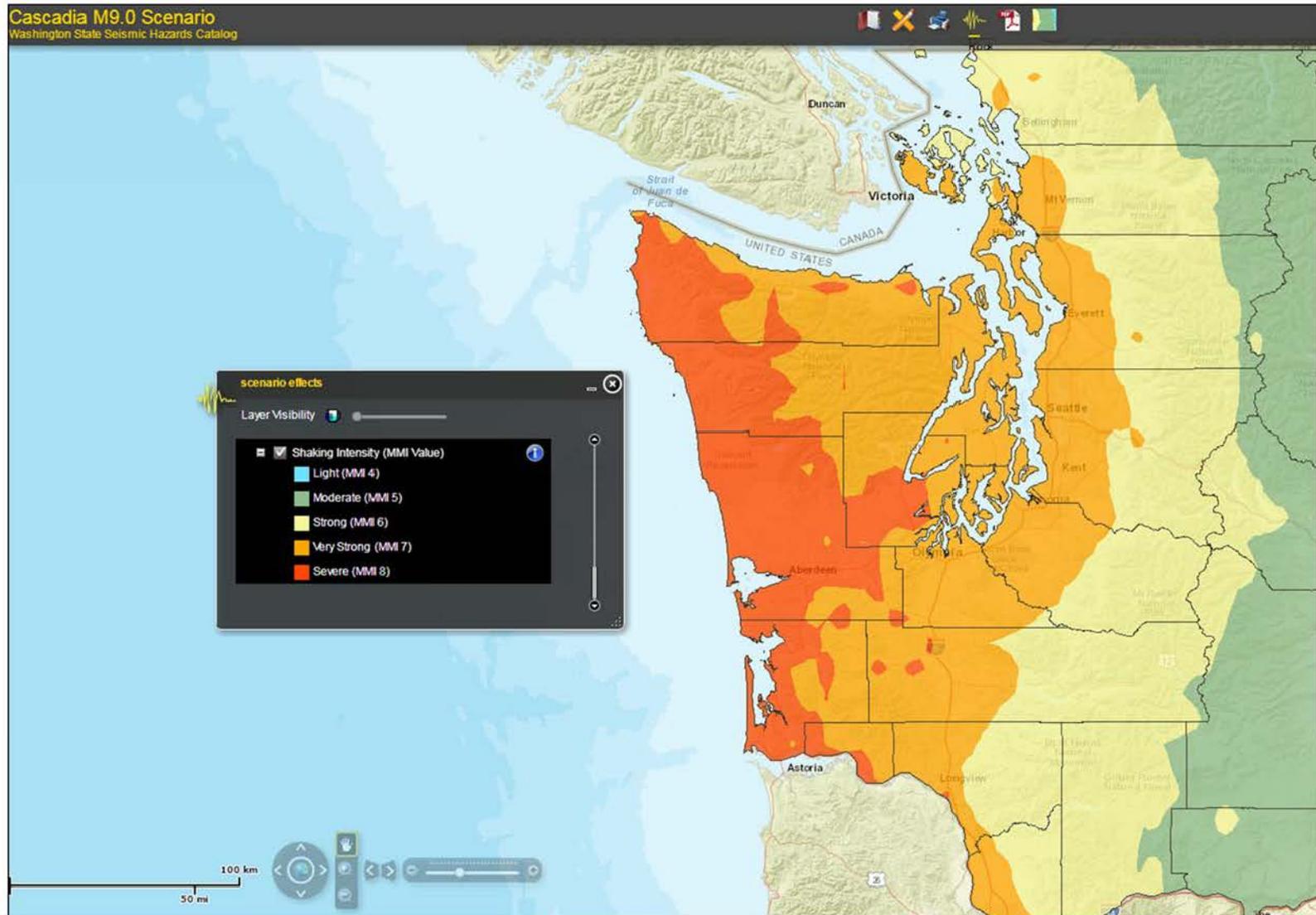
EARTHQUAKES AND FAULTS

Three earthquake source zones have the potential to impact the City of Kirkland:

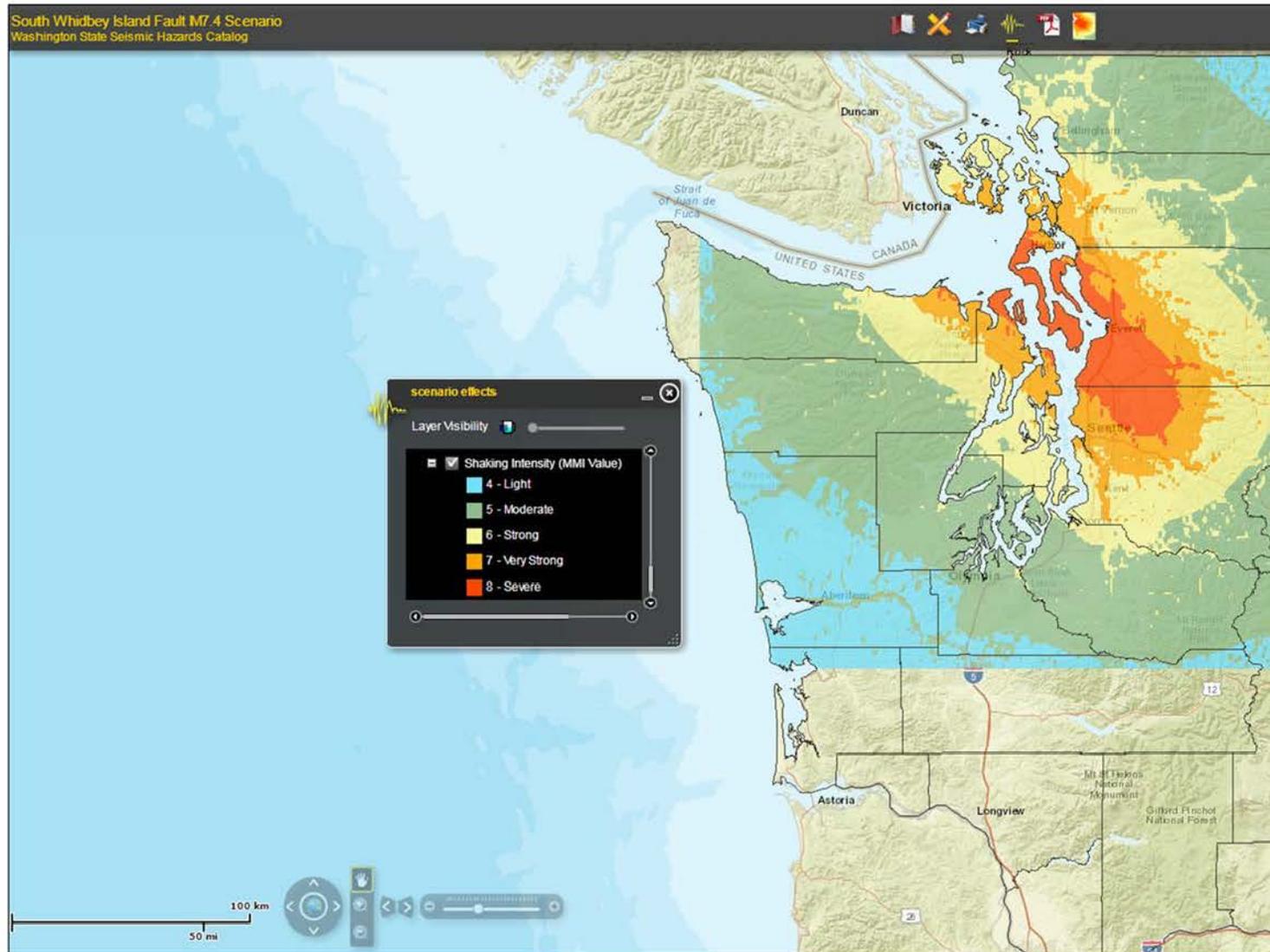


Source: USGS

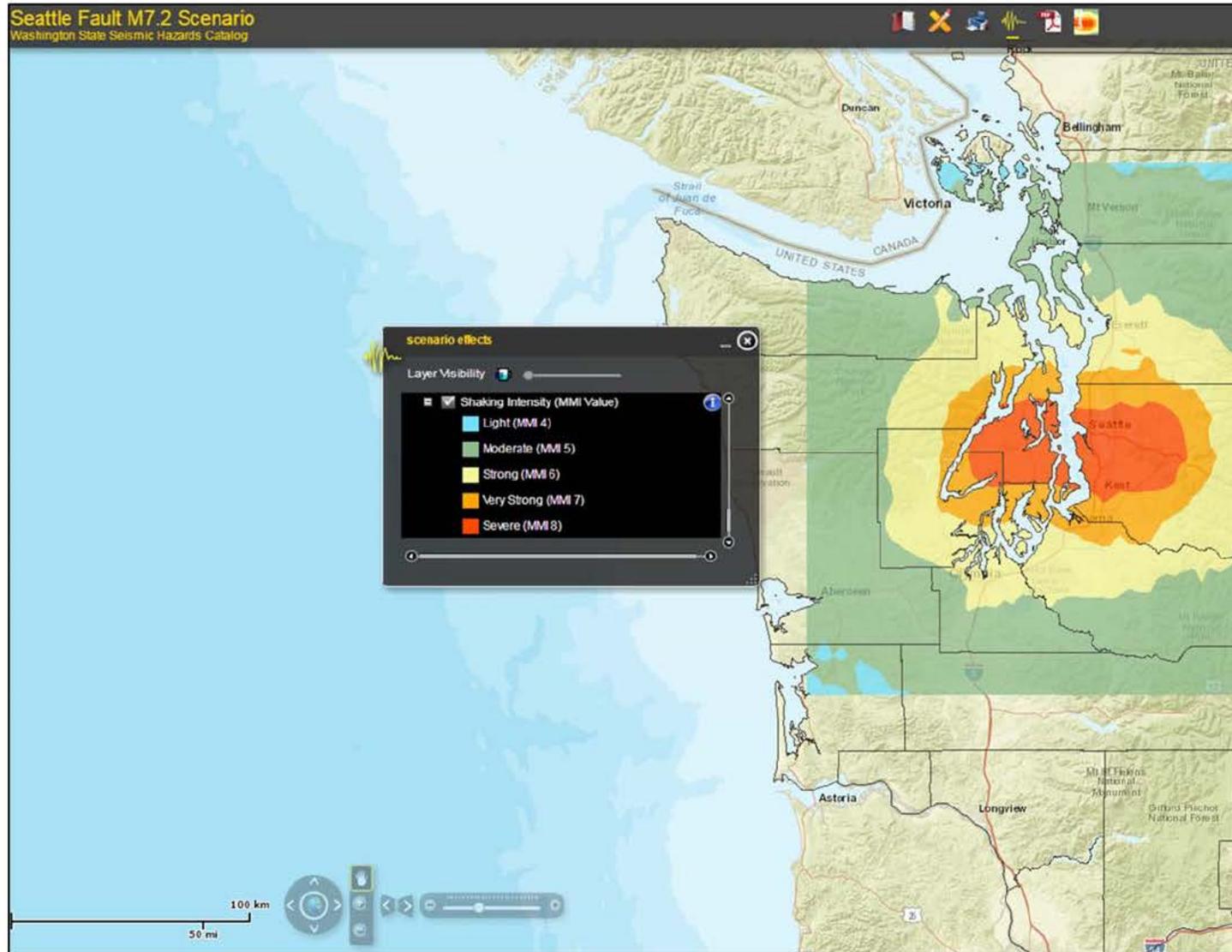
Shaking from a subduction zone earthquake is expected to be “very strong” as shown on this map from the Washington Geological Survey Scenario documents:



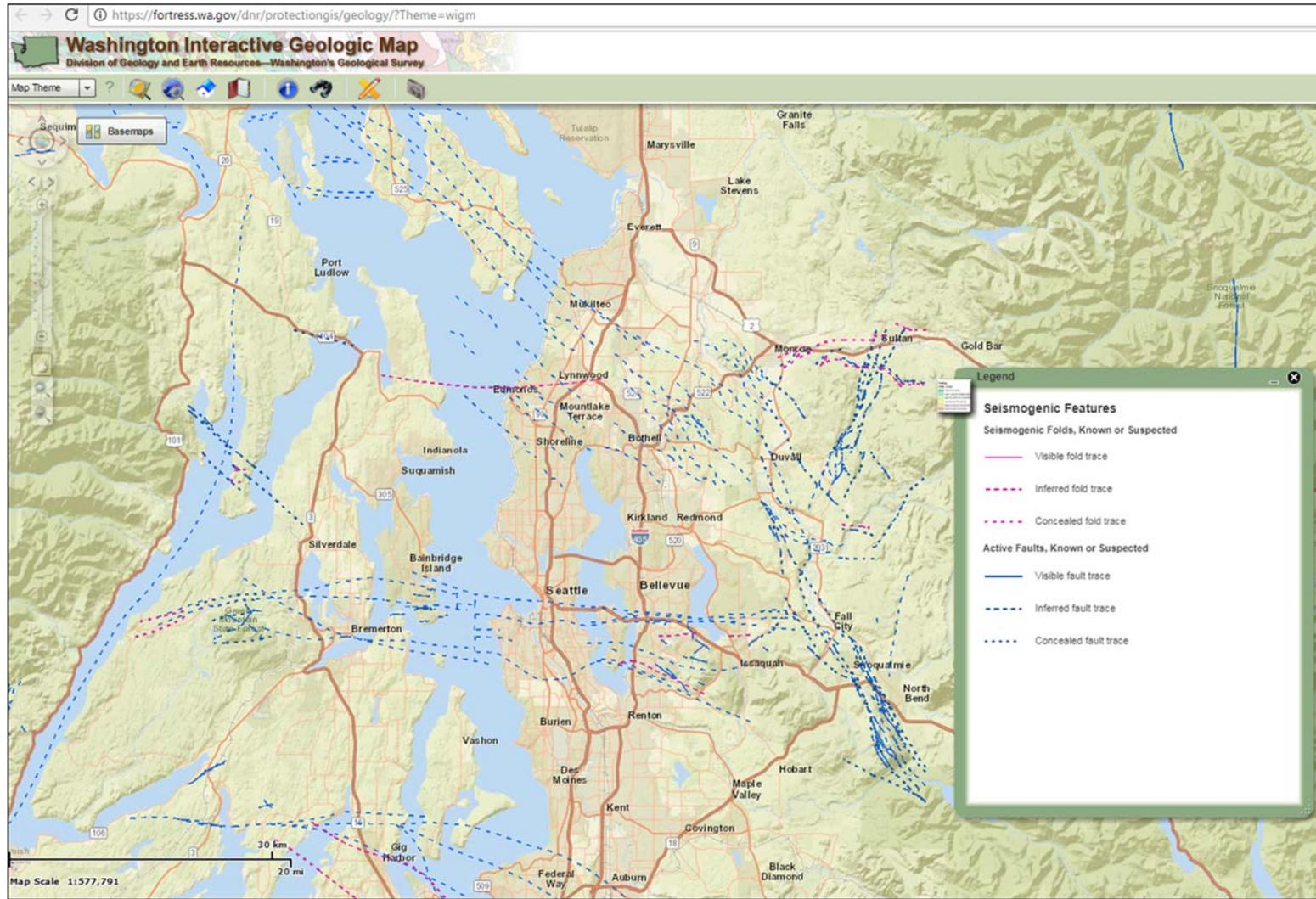
Shaking from an earthquake on the nearest active crustal fault, the South Whidbey Island Fault Zone (SWIF), is expected to be “severe to very strong” as shown on this map from the Washington Geological Survey Scenario documents:

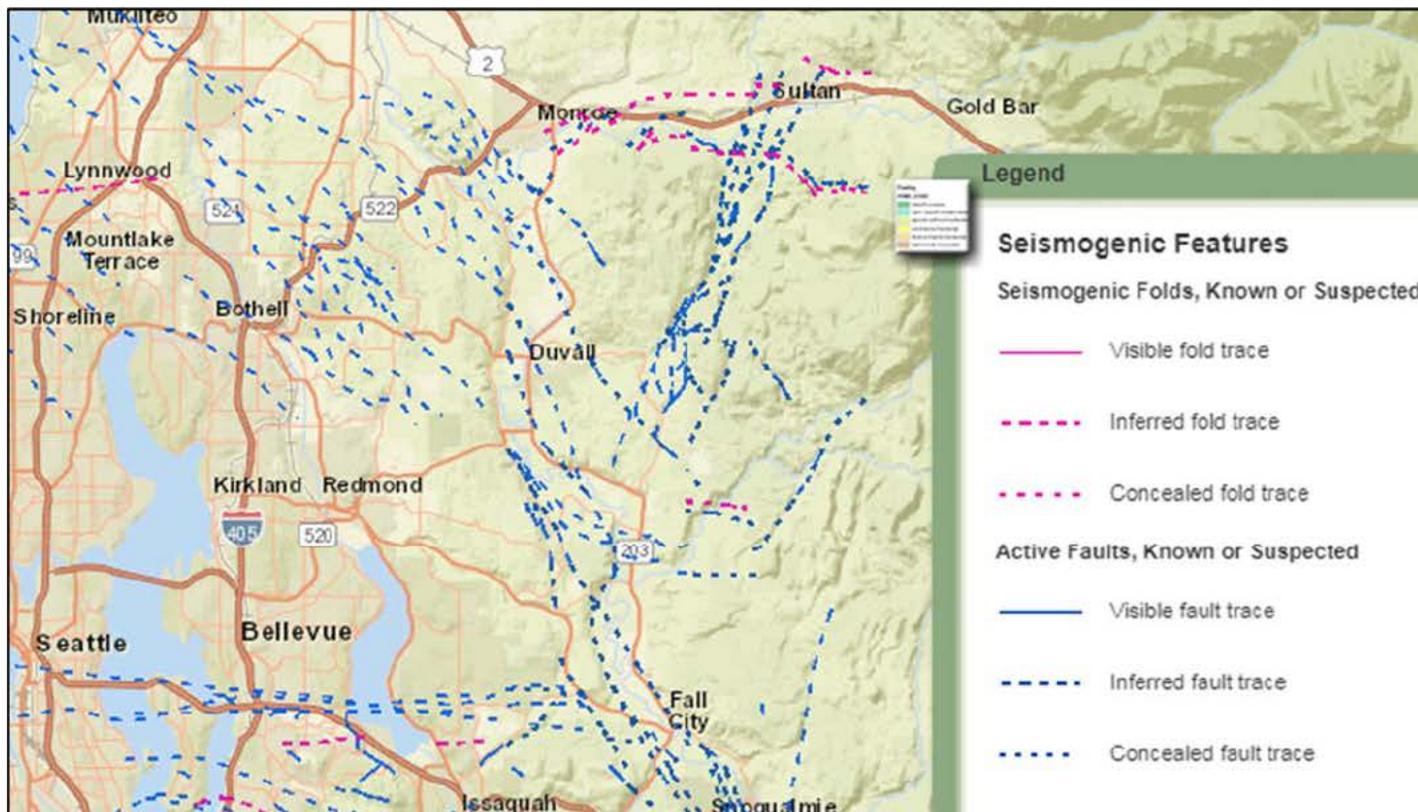


Shaking from the next nearest active crustal fault, the Seattle Fault Zone, is expected to be “severe to very strong” as shown on this map from the Washington Geological Survey Scenario documents:



Lineaments related to the SWIF, are projected to approach and possibly transect the City of Kirkland. These lineaments are based on topographic trends and deep geophysical anomalies. The published lineaments, shown below, stop outside of City limits; however circumstantial evidence suggests that they could continue through the City. These lineaments are *not currently* associated with individual active faults, however, research is ongoing.





TSUNAMI AND SEICHE WAVES

Tsunami and seiche waves have been known to occur in Lake Washington and to run up on land adjacent to the shoreline. These waves can result from fault offset or land tilting, earthquake shaking, and large landslides that enter the Lake or displace a significant amount of water in the Lake. There are no current modeling efforts underway to assess the elevation of potential run up or wave height from all the possible triggers. However, tsunami modelers know that such information is needed. Unpublished work suggests that wave amplitudes could reach 6 to 7 feet in height and horizontal runup could exceed 10 feet, but all estimates are highly dependent on energy and bathymetry.

FAULT RUPTURE

There are no active faults currently mapped within the City, although, the potential for the presence of active faults does exist. Based on current tectonic understanding the risk of fault rupture is considered low.

Liquefaction Potential

INTRO

The liquefaction potential map consists of a qualitative assessment of the potential of geologic materials to liquefy during loading such as from earthquake shaking. Refer to the Seismic Hazards Map for information about the tectonic setting and potential for earthquakes to impact the City of Kirkland. The map includes polygons showing three categories of liquefaction potential based on a weighted matrix of geologic parameters including, grain size, age of deposit, density from standard penetration tests, and depth to groundwater. Areas of modified land (either filled and/or graded), provided as a separate layer, should always be included on the map because they significantly impact the liquefaction potential. The geologic units were determined using: geomorphic analyses of LiDAR data; field observations in excavations, gullies, and roadcuts; subsurface data from exploration logs in geotechnical documents; and geologic principles. These data are stored in a searchable Microsoft SQL database accessed via ArcGIS.

DATES

Data were compiled by GeoMapNW, in the Department of Earth and Space Sciences at the University of Washington, in two phases: 1) prior to 2010 for the City of Kirkland, 2) in 2016-2017 to include the recently annexed areas and updating the 2010 coverage area.

TOTALS

| | |
|---|---|
| Exploration Points: 5544 | Exposures (excavations and outcrops): 651 |
| High liquefaction potential: 1.68 sq mi | Medium: 5.49 sq mi Low: 10.64 sq mi |

LIQUEFACTION POTENTIAL CATEGORIES

The three qualitative liquefaction potential categories consist of: high, medium, and low. Most of the land surface area of Kirkland falls into the low category. The high liquefaction potential category includes loose sandy deposits with shallow groundwater like: alluvium, alluvial fan deposits, young lake deposits, glacial recessional outwash. The medium liquefaction potential category includes unconsolidated silty/sandy deposits like glacial recessional lake deposits, ice-contact deposits, and peat and wetland deposits. The low liquefaction potential category includes glacially overridden silty and clayey deposits like till, and glacial and nonglacial lake deposits.

DEPTH OF INFLUENCE

The liquefaction potential map reflects an assessment of surficial geologic units and so does not reflect potential for deep liquefaction. The thickness of liquefiable deposits varies by location and underlying geology. In general, the assessment reflects the upper 30 feet, except where fill and colluvium are present. Colluvium is present and thickest across most slopes steeper than 15 degrees. The map does

not reflect the influence of the topsoil layer since it is assumed to have essentially the same influence everywhere.

CONFIDENCE AND SCALE

Although this map is provided in digital form, the map scale should be considered 1:12,000. The highest confidence within the map and contacts is at data points (explorations and exposures). However not all data points are of high quality or provided definitive information. All geologic information is inferred between data points using standard geologic mapping principles and most contacts are concealed beneath vegetation, fill, colluvium, or structures.

LONG-TERM ACCESS

The City of Kirkland and GeoMapNW will have a complete copy of the database. Additional information can be obtained from Kathy Troost at ktroost@uw.edu.

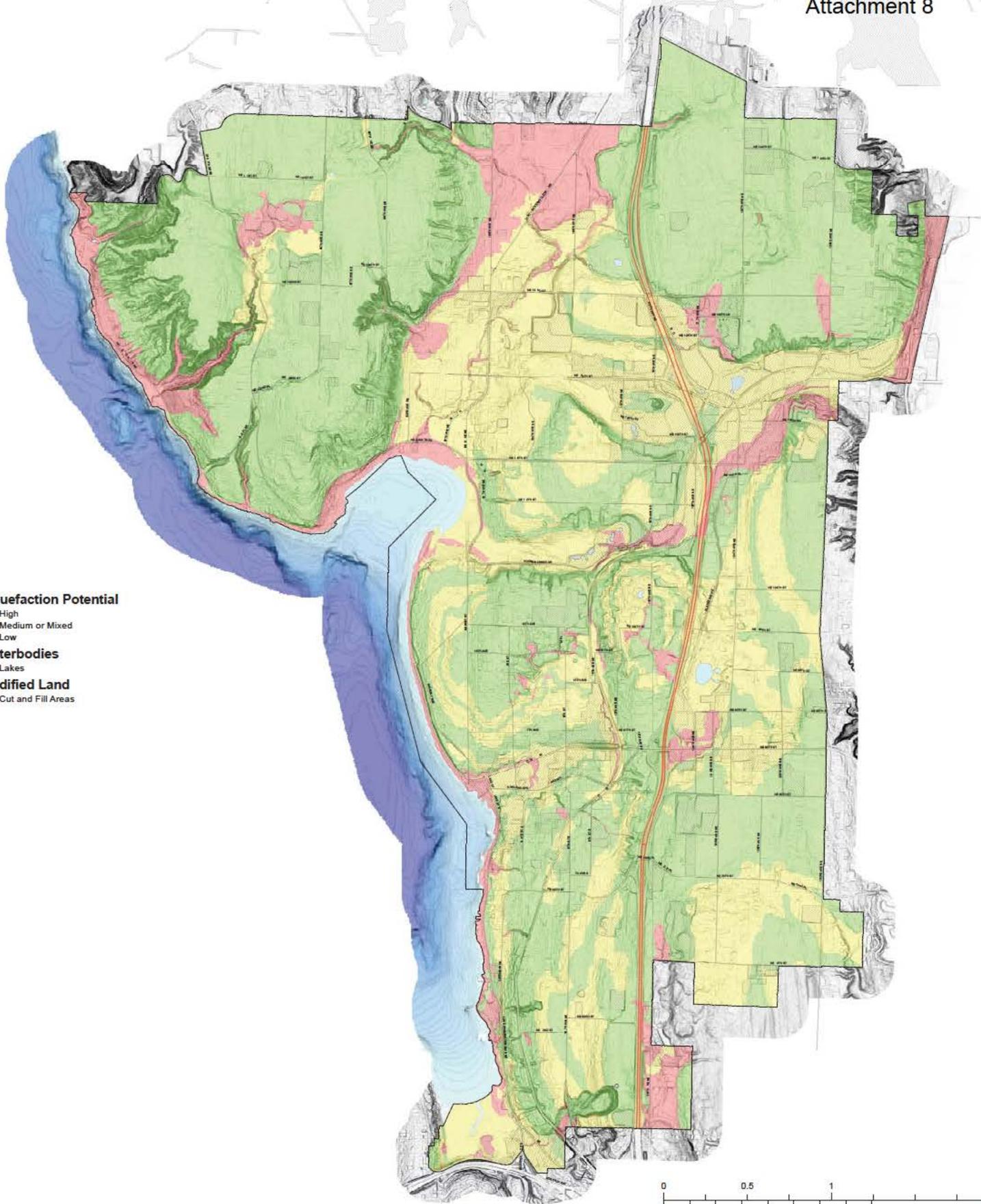
LIMITATIONS

The liquefaction potential map is based on over 6000 data points as well as standard geologic interpretation. The exploration data contained in the database were obtained from outside sources and no guarantee of the validity/quality of the original data is implied. Data were entered into the database using trained students and data entry forms to reduce errors, then data entry was underwent QA. Data gaps are present and reflect the lack of subsurface explorations in older residential neighborhoods with few critical areas. Additional data gaps exist where vegetation is heavy and/or where the land has been modified by the addition of fill, coverage by colluvium on slopes, and obscured by development. This qualitative liquefaction potential map should be used to evaluate and understand the character of the City as a whole and should not be used for site-specific evaluations. The map does not show where ground improvements decrease the potential for liquefaction. Furthermore the map does not reflect the level of impact possible as a result of liquefaction.

REVIEW

This document and the map were reviewed by the City of Kirkland on and peer reviewed by AESI.

- Liquefaction Potential**
 - High
 - Medium or Mixed
 - Low
- Waterbodies**
 - Lakes
- Modified Land**
 - Cut and Fill Areas



Liquefaction Potential in Kirkland

1) Basemap from 2016 LIDAR; DEM shaded by elevation and draped over a shaded slope map.

2) Lake Washington bathymetry from NOAA surveys, colored by depth and draped over a shaded slope map.

3) Liquefaction potential was determined using a weighted matrix method using the geologic parameters of grain size, density, organic content, and uniformity of deposit.

4) All contact locations are approximate.



Kirkland's Geologically Hazardous Areas (KZC 85) Code Update Process Schedule

| Task | Event | Meeting or Event Date | Packet Due Date | Responsible Party |
|------|---|---|--|---|
| 1 | City Council Study Session – Briefing on Mapping Completion, Communication Plan and KZC Chapter 85 Amendments | November 21, 2017 at 6PM in Kirkland Council Chambers | November 9, 2017 | David Barnes – PBD, Kathy Troost –UW Kathy Cummings – CMO Heather Kelly - OEM |
| 2 | Kick off - Community Lecture/Open House on Kirkland's Geology and Updated Geologically Hazard Area Maps | December 11, 2017 at 7PM in Kirkland Council Chambers | N/A – Will need Maps for display and video will be made for lecture/open house | David Barnes – PBD, Kathy Troost – UW Kathy Cummings – CMO Heather Kelly - OEM |
| 3 | Planning Commission/Houghton Community Council Study Session #1 | January 11, 2018 at 7PM in Kirkland Council Chambers | January 3,2018 | David Barnes – PBD, Kathy Troost – UW Associated Earth Sciences (AESI) – Curtis Kroger, Tim Peter |
| 4 | Development Services Staff Presentation (and internal 1st responders) | TBD | N/A | Kathy Troost – UW |
| 5 | Planning Commission Study Session #2 Open house | February 22, 2018 at 7PM in Kirkland Council Chambers Open House at 6PM | February 14, 2018 | David Barnes – PBD, (AESI) – Curtis Kroger, Tim Peter |
| 7 | Planning Commission/HCC Joint Hearing | March 26 th 2018 at 7PM in Kirkland Council Chambers Open House at 6PM | March 18, 2018 | David Barnes – PBD, (AESI) – Curtis Kroger, Tim Peter |
| 8 | City Council – Adoption of Code Amendments | April 17, 2018 at 7:30PM in Kirkland Council Chambers | April 4, 2018 | David Barnes – PBD (AESI) – Curtis Kroger, Tim Peter |

