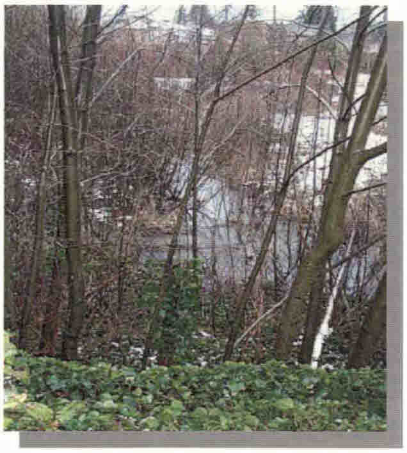
BELLEVUE CRITICAL AREAS UPDATE
GEOLOGICALLY HAZARDOUS AREAS INVENTORY

March 2003



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1.0 INTRODUCTION

This inventory of Bellevue's geologically hazardous areas has been prepared to support an update of policies and regulations for the management of critical areas in the City. Washington's Growth Management Act defines geologically hazardous areas as critical areas. Geologically hazardous areas include areas susceptible to erosion, sliding, earthquake, or other geological events (WAC 365-190). Specifically, areas that are susceptible to one or more of the following types of hazards shall be classified as a geologically hazardous area:

- Steep slopes/landslide hazard areas, including areas potentially susceptible to landslide based on a combination of geologic, topographic, and hydrologic factors;
- Erosion hazard areas, including at least those areas identified by the U.S. Soil Conservation Service (now Natural Resources Conservation Service) as having a "severe" rill and inter-rill erosion hazard;
- Siesmic hazard areas, including areas subject to severe risk of damage as a result of earthquake-induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting; and
- Areas subject to other geological events such as coal mine collapse, including areas underlain by, adjacent to, or affected by mine workings such as tunnels, drifts, or air shafts.

Other potential hazard areas in Bellevue include tsunami or "seiche" hazard areas, due to the City's shoreline location on Lake Washington and Lake Sammamish.

Geologic hazards pose a threat to the health and safety of citizens when commercial, residential, or industrial development is inappropriately sited in areas of significant hazard. Some geologic hazards can be reduced or mitigated by engineering, design, or modified construction practices. When technology cannot reduce risks to acceptable levels, building in geologically hazardous areas is best avoided (WAC 365-190).

The City of Bellevue presently regulates development on and near steep and potentially unstable slopes and coal mine areas through Chapter 20.25 of the Municipal Code and Section 6 of the City of Bellevue Sensitive Areas Notebook. Erosion hazard areas, seismic hazard areas and tsunami (seiche) hazard areas, however, are not specifically addressed in the Code or Notebook.

2.0 METHODOLOGY

To portray geologic information pertinent to the evaluation of critical areas in Bellevue, existing information was reviewed to assess the type and location of steep slope areas, erosion prone areas, coal mine hazard areas, and areas in the vicinity of the Seattle Fault Zone in Bellevue. These included maps from U.S. Geological Survey, Washington Department of Natural Resources, and the former U.S. Soil Conservation Service, as referenced below and as presented in the reference section, and documentation from the City of Bellevue regarding topography, as also referenced below. No field reconnaissance was performed at this stage of the study.

Attached to this report are two maps. Figure G-1 depicts surface geology in Bellevue as derived from King County records (Booth, 1992); geologic units shown on the map are discussed under General Geology below and referenced in parentheses. Figure G-2 shows geologic hazard areas, including steep slopes and erosion prone areas.

3.0 GENERAL GEOGRAPHY AND GEOLOGY

Bellevue is dominated by a series of north-trending ridges and valleys, owing their positions primarily to the effects of the last glaciation of the central Puget Lowland. The maximum relief is about 1,385 feet, from the shoreline of Lake Washington at about elevation 16 feet to the south slope of Cougar Mountain in the southeast portion of the City at about elevation 1,400 feet. The deepest canyon is Lewis Creek in southeast Bellevue at about 400 feet; other ravines and valleys range from 100 to 300 feet deep. Many of Bellevue's topographic troughs are presently filled with water bodies or wetlands or have been infilled with sediment since the melting of glacial ice about 13,500 years ago.

The northern edge of the Seattle Fault Zone extends east-west through the southern part of Bellevue, just north of Interstate I-90. To the north of this zone, bedrock is deeply buried by Pleistocene and Holocene glacial and non-glacial deposits that have accumulated in the past 2 million years to a depth of 600 to 1,200 feet. To the south of the leading edge of the fault zone, bedrock is either exposed at the ground surface or covered with a thin layer of glacial soil (Booth et al, in press; Yount and Gower, 1991).

Surficially exposed bedrock in the southern portions of Bellevue includes two late Tertiary (2 to 65 million years old) bedrock formations: the Blakeley Formation (Tb), and an unnamed unit of sandstone and conglomerate. The Blakeley Formation, about 23 to 43 million years old, is comprised of fresh to slightly weathered sandstone, conglomerate, and minor amounts of siltstone. The unnamed sandstone/conglomerate unit also contains interbeds of low-grade coal, including logs that are well preserved.

Two older geologic units, the Tukwila Formation (Tpt) and the Renton Formation (Tpr), underlie the younger late Tertiary rocks at the southern margins of the Bellevue City limits. Coal beds within the Renton Formation were mined between the 1860s and the 1960s but have since been abandoned. These abandoned mine openings, however, remain open (Walsh, 1983). King County has identified these areas as coal mine hazard areas (Figure G-2). Deposits from the last interglacial period (Qob) from about 18,000 to 80,000 years ago are found at the present surface only along the steep slopes along the eastern border of the City, overlooking Lake Sammamish. They are comprised of slightly oxidized sand and gravel, silt, and fine sand that contains organic fragments.

The ground surface to the north of the Seattle fault zone is nearly all covered with glacial sediment deposited during some phase of the Vashon Stade (12,000 to 18,000 years ago) of the Fraser Glaciation that covered the Bellevue area between about 13,500 and 15,000 years ago. As the glacial ice advanced southward from British Columbia to the northern part of Puget Sound, a large lake formed to the south of the ice (including the present location of Bellevue) into which fine-grained soils (silt and clay) were deposited (Qtb). These are presently exposed along the east and west edges of the ridges. These glaciolacustrine deposits were eventually overlain by a thick deposit of glacial outwash sand and gravel (Qva) as the ice advanced southward, displacing the lake. Advance outwash is currently found at the edges of the upland plateau and extends part of the way down the bordering slopes, such as the slopes above Lake Sammamish, the slopes around Woodridge Hill, the slopes on the south side of Meydenbauer Bay, and the sides of valleys in the north end of Bellevue (Qva). As the ice overrode the land, till (Qvt) was deposited beneath the ice. Till deposited at that time presently blankets most of the upland areas of Bellevue. All of the deposits under the ice were consolidated by the pressure of about 3,000 feet of ice (Laprade, 1982).

During the recession and melting of the Vashon ice, recessional glacial deposits were laid down in front of or underneath the ice. Recessional outwash (Qvr), consisting of sand or sand and gravel, and recessional lacustrine deposits (Qvrl) comprised of fine sand, silt and clay, were deposited primarily in the troughs which are now the valley areas in Bellevue, such as the areas around Larson Lake, Mercer Slough, and the Eastgate area (Galster and Laprade, 1991).

Since the melting of the ice from the Bellevue area about 13,500 years ago, stream erosion and deposition and mass wasting have further modified the landscape. Such deposits as alluvial fans (Qf) have formed at the mouths of streams, landslide deposits have formed on and at the toes of steep slopes, alluvium (Qyal) has been laid down in stream beds, and organic wetland deposits (Qw) have accumulated in depressions. The most prominent depression filled with organic deposits is Mercer Slough. Some land has also been modified by excavation and filling associated with development (m).

3.1 Steep Slopes/Landslide Hazard Areas

3.1.1 Location and Description

Slope instability in the Bellevue area occurs mainly in areas where the inclinations of the slopes exceed 40 percent. Geologic factors, particularly those in which pervious geologic units overlie soil or bedrock units of lower permeability, are responsible for much of the slope instability in the Bellevue area. To the north of the Seattle Fault Zone, the underlying impervious layer is likely to be glaciolacustrine silt and clay; whereas on the south side of the fault zone, the impervious layer is more likely to be bedrock or till that overlies bedrock. Other cases of slope instability in Bellevue occur where fill materials are placed on sloping ground without proper drainage or engineering oversight.

A combination of geologic maps and topographically steep areas (steeper than 40 percent) were used to evaluate landslide-prone areas. Geologic mapping was taken from a compilation of geologic maps produced by the USGS (Booth, 1992; Minard, 1988a; Minard, 1988b). Topographic information used to create a slope classification map of slopes steeper than 40 percent was taken from two sources: 10-foot contour contours developed from high resolution orthophotography by Merrick Company in 1995 through 1998, and a Digital Terrain Model developed by Triathalon, Inc. in 2001 (Figure G-2).

Based on this information, general primary areas of known instability or with geologic factors (as discussed above) that make them susceptible to landsliding are:

- Northwest Bellevue (west of I-405);
- Cougar Mountain;
- Lakemont;
- Meydenbauer Bay;
- Newport Hills;
- Somerset;
- Woodridge Hill;
- Lewis Creek ravines;
- Rosemont Beach/Lake Sammamish; and
- Vasa Park ravines.

Other areas of potential landslide hazards include:

- Areas designated as Quaternary slumps, earthflows, mudflows, or landslides on maps by the U.S. Geological Survey, the Washington Department of Natural Resources, King County Department of Natural Resources;
- Areas that have shown movement during the Holocene Epoch (the past 13,500 years) or are underlain by landslide deposits;
- Slopes that are parallel or subparallel to planes of weakness in subsurface materials; and
- Areas of potential instability because of rapid stream incision, stream bank erosion and undercutting by wave action.

Such areas are very generalized sectors of the City and are intended to guide planners or plan reviewers in focusing scrutiny during review of proposed construction. To further delineate specific slide-prone areas would require site-specific geologic studies. Based on discussions with the City of Bellevue staff, it is understood that no landslide historical information is maintained by the City and no maps exist that would indicate slide-prone zones within the City.

In many jurisdictions in western Washington, setback or buffer distances are established between a structure and the top and toe of a steep or unstable slope. Although not universally used and not based on findings of specific studies, 50 feet is a very common and reasonable distance based on records of land use practices in the region. The Washington Office of Community Development has referenced it in previous versions of the draft Model Critical Areas Code Recommendations. The setback requirements may be decreased, based on recommendations from a geotechnical engineer and engineering geologist, but in no case less than 10 feet. In some cases where warranted, setbacks can also be increased based on site-specific conditions.

3.1.2 Other Functions of Steep Slopes

Steep slopes may serve several other functions and possess other values for the City and its residents. As noted in Section B, Wildlife Inventory, several of Bellevue's remaining large blocks of forest are located in steep slope areas, providing habitat for a variety of wildlife species, including several "special status" species, and important linkages between habitat areas in the City (see wildlife inventory). These steep slope areas may also act as conduits for groundwater, which drains from hillsides to provides a water source for the City's wetlands and stream systems. Vegetated steep slopes also provide a visual amenity in the City, providing a "green" backdrop for urbanized areas.

3.2 Erosion Hazard Areas

There are no existing maps specifically prepared for Bellevue that indicate zones of soils that are susceptible to erosion. However, as discussed in WAC 365-190, other jurisdictions, such as Bainbridge Island and Burien, have used the characteristics of soils, as described in the soil surveys completed by the former U.S. Soil Conservation Service (SCS), to identify erosion hazard areas. Based on a survey of government agencies and senior geologists working in the Puget Sound region and a recommendation by the Washington Department of Natural Resources, this is a reasonable approach to creating a map that portrays erosion-susceptible zones. Figure G-1 contains a compilation of the soil units that have a very severe or severe erosion classification, according to Snyder, et al. (1973). Under this classification for King County, erosion hazard is rated according to the risk of erosion in forested areas. The hazard is "severe" or "very severe" if steep slopes, rapid or very rapid runoff, and past erosion make the soil highly susceptible to erosion.

Because there is no separate text to accompany this map, the Soil Survey of King County Area, Washington was used to determine those soil series present in Bellevue with severe to very severe erosion potential based on slopes and runoff potential (Snyder, et. al, 1973). The soil series used to create the erosion-susceptible areas shown on Figure G-1 are:

- Alderwood gravelly sandy loam, 15 to 30 percent slopes;
- Alderwood and Kitsap, very steep;
- Beausite gravelly sandy loam, 15 to 30 percent slopes;
- Kitsap silt loam, 15 to 30 percent slopes;
- Ovall gravelly loam, 15 to 25 percent slopes; and
- Ragnar-Indianola association, moderately steep.

Best Management Practices (BMPs) for development on erosion-prone soils, such as seeding, mulching, and use of silt-retaining fences, helps to control erosion and fine sediment migration from cleared sites, particularly those areas close to streams and wetlands where sediment delivery can result in increased turbidity and sedimentation of wetlands and stream habitat. Use of BMPs in these areas can also result in reduced costs to the City in the maintenance of stormwater conveyance and detention systems by limiting the delivery of sediments to these systems.

City records document violations or complaints regarding erosion problems; however, those records do not indicate whether the problems were induced by poor construction practices, by the site soils, or a combination of these. To determine such differentiation would warrant a study outside the scope of this critical areas update.

3.3 Seattle Fault Zone

The Seattle Fault Zone is a collective term for a series of four or more east-west trending fault strands that coalesce at depth to a south-dipping master fault within the Puget Lowland. This thrust fault zone is approximately 2 to 4 miles wide (north to south) and extends from the Kitsap Peninsula near Bremerton on the west to the Sammamish Plateau east of Lake Sammamish on the east. Figure G-1 displays the known, mapped western-most extent of this fault zone in Bellevue. Geologic evidence gathered over the past 10 years suggests that movement of this fault zone occurred as recently as about 1,100 years before present (Bucknam et. al, 1992). Recent trenching has been performed along the fault traces, indicating that there have been about three surface rupturing events in the past 10,000 years (Nelson et. al, in press). The Seattle Fault is considered capable of generating an earthquake with a magnitude of about 7.0 to 7.5.

Observations at a recent excavation west of Vasa Park in Bellevue indicate the presence a surface-rupturing fault in the City. The location of this fault is consistent with the alignment of the northern edge of the fault zone, as previously hypothesized from geophysical and geologic data (Blakely, et. al, 2002). The alignment of the northern edge of the Seattle Fault Zone is based on geophysical data generated by the USGS and on the northern limit of bedrock outcrops. Three strands within the fault zone are shown on Figure G-1, but all of the area south of the northernmost strand should be considered to be within the fault zone.

Management of development activities in fault zones is important for the protection of public health and safety, and to minimize potential property damage during seismic events on faults within the zones. Management also limits risk of liability for the City and for private property owners.

In considering management of hazard, the risk of ground rupture should be considered. Specifically, in the current version of the Uniform Building Code (UBC, 1997) adopted for use in Washington State, seismic design of structures is based on a 10 percent probability that ground motions of a certain magnitude will be exceeded in a 50 year-period, or about a 475-year return period. Current geologic evidence indicates that the recurrence of large, ground-rupturing earthquakes in the Seattle Fault Zone is on the order of thousands of years. Consequently, under current building codes, ground rupture within the Seattle Fault Zone would not necessarily be considered in building design because the probability of ground rupture (i.e., the risk) is much less than 10 percent over 50 years required by the UBC.

In contrast, seismic design in the International Building Code (2000), which has not been adopted by Washington State, is based on ground motions with a 2 percent probability of occurrence in 50 years, or about a 2,500-year return period. The apparent recurrence interval and risk associated with ground surface rupture in the Seattle Fault is on the same order of magnitude as the risk level specified in this newer code. Consideration of potential ground surface rupture within the fault zone would be consistent the lower risk levels specified by this code.

Management of the ground rupture risk in Bellevue will depend on the level of risk acceptable to the city (e.g., risk levels associated with current, adopted building codes or newer but not adopted codes). Under risk levels inherent in the current building code, management may be limited to public education about the potential risks of ground rupture.. Under a lower level of acceptable risk, provisions could be developed similar to those in other states with active surface faulting. For example, California's Alquist-Priolo Act or Nevada's Association of Engineering Geologist Guidelines that require a structure for human occupancy or critical structure cannot be placed over the trace of the fault and must be set back 50 feet from the trace.

3.4 Coal Mine Hazard Areas

As previously discussed, coal beds in the Renton Formation in southern portions of Bellevue were mined by underground techniques between the 1860s and the 1960s. Abandoned mining shafts are located on the south side of Cougar Mountain and the extreme southern edge of the city (Walsh, 1983). Many, but not all, of the mine locations and mine conditions are publicly recorded or documented (Figure G-2).

Abandoned mine openings are located from near surface to several hundred feet below the ground surface. Subsidence can occur over a large area that extends beyond the limits of the mine workings, and it can occur in very localized areas as sinkholes.

The City of Bellevue adopted Coal Mine Subdivision, Development, and Building Permit Regulations in 1993. These regulations, which also include a map of the coal mine hazard zones, include definitions of the coal mine hazard zones, describe development application requirements, and identify specific geotechnical report requirements.

3.5 Tsunami (Seiche) Hazard Areas

Seiches are oscillations of an enclosed body of water caused by seismic motion or large landslide displacement. Such movement of the waters of Lake Washington and Lake Sammamish could occur, and could cause runup as high as 5 feet above lake level with little warning. This would affect structures located along the shorelines of both lakes. Studies are presently being conducted to determine the potential frequency and risk of such occurrences.

3.6 Liquefaction Hazard Areas

Liquefaction occurs in saturated soil (e.g., sand below the water table where the spaces between sand particles, or pores, are filled with water). Pore water exerts a pressure on the soil particles that approaches the effective vertical stress. During an earthquake, loose soils (with water-filled pores) will tend to densify. If pore water is present in the soil, the water pressure will increase as the soil particles attempt to arrange themselves in a denser or more compact configuration. A "quicksand" or liquefied soil will result as the pore water pressure approaches the vertical stress from the weight of the soil. Liquefaction can cause a drastic reduction in the soil's shear strength. As a result of this shear strength reduction, ground displacements of several feet can occur on even relatively flat ground. The soil many lose much of its capacity to support foundations, which can cause a structure to settle differentially, laterally displace, and in some cases topple over.

Soils that are susceptible to liquefaction are generally geologically recent deposits and non-engineered fills. Liquefaction hazard mapping studies for other areas in the region have found that the non-engineered fills and Holocene (i.e., recent) alluvium typically have a high susceptibility to liquefaction. Older sediments that have not been overridden by glacial ice (e.g., Vashon Recessional Outwash) may have a moderate susceptibility to liquefaction. The susceptibility of glacially-overridden sediment (i.e., Vashon Till and older) to liquefaction is very low, while bedrock has no susceptibility to liquefaction.

Figure G-1 shows those areas in Bellevue with a high susceptibility to liquefaction. Liquefaction hazard maps for the City of Bellevue have recently been published by the Washington State Department of Natural Resources (DNR) for the Bellevue area (Palmer, et al., 2003).

Management of development activities on soils susceptible to liquefaction is important to protect public health and safety and to minimize potential property damage during an earthquake. Such management also limits risk of liability of the City and for private property owners. Risk management can include requiring site-specific liquefaction assessments for projects located on soils with a moderate to high liquefaction hazard. A liquefaction assessment would generally include an assessment of the risk of occurrence, and also should consider potential associated effects, such as lateral spreading, differential settlement, and potential loss of soil/foundation capacity.

4.0 DATA GAPS

- The City of Bellevue has not maintained files documenting the locations of and conditions associated with previous landslides in the City. Similarly, while the City does maintain records of erosion complaints, it is unknown, according to City staff, how many of these complaints are associated with the failure of contractors in adherence to erosion control practices, and how many are the result of underlying geologic conditions. Such files would aid in establishing a record of the locations of landslides and erosion hazards, the associated geologic conditions, and with factors contributing to initiation of the landslide or erosion event. This information could be recorded on a GIS-related database, so all data is spatially recorded. In future years, sufficient information will be available to delineate landslide-prone and erosion-susceptible zones in the city.
- The landslide information presented in this inventory is based on a map assessment of geologic conditions and topography and presents only approximate locations of landslide prone-areas. This mapping exercise, however, is not of sufficient detail to delineate the boundaries of landslide hazard areas, nor is it adequately detailed to present degrees of risk of landslides. More detailed field reconnaissance would be required to develop this additional, more detailed level of information that would benefit private property owners as well as City reviewers and regulators.

- Knowledge about the location and conditions associated with the Seattle Fault Zone improves as the USGS continues to study this feature. At the present time, however, the exact location of the fault traces in Bellevue, particularly in eastern portions of the City, is relatively unknown.
- The City of Seattle and south Snohomish County have benefited from recent geologic mapping using sophisticated mapping and testing techniques. The City, its residents, and developers may be able to more accurately identify and address geologic hazards on a site-specific level by funding a similar geologic mapping project. Such new information could include improved soil unit delineation for hydrologic studies, better demarcation of landslide areas, a database of subsurface explorations, and further delineation of strands of the Seattle Fault within the fault zone.
- Existing geologic maps can be used in a general sense to identify areas susceptible to liquefaction. The DNR is currently developing more quantitative liquefaction hazard maps. Final drafts of the liquefaction hazard maps are being reviewed, and the final maps should be published within the year.

5.0 FINDINGS

5.1 Steep Slope Areas

- In areas of steep slopes (steeper than 40 percent), Bellevue presently requires geotechnical review and reporting for development in those areas; however, for areas inclined at 15 to 40 percent, the City does not have a tool to determine the appropriate level of geologic review. A map of geologic conditions could be used for this purpose by overlaying the geologic map (Figure G-1) on a map indicating 15 to 40 percent slopes to identify the risk associated with various geologic units in the City.
- Other criteria that could be added to the list of criteria for potentially unstable slope are:
  - (1) Areas designated as Quaternary slumps, earthflows, mudflows, or landslides on maps by the U.S. Geological Survey, the Washington Department of Natural Resources, and King County Department of Natural Resources;
  - (2) Areas that have shown movement during the Holocene Epoch (the past 13,500 years) or are underlain by landslide deposits;
  - (3) Slopes that are parallel or sub-parallel to planes of weakness in subsurface materials; and
  - (4) Areas of potential instability because of rapid stream incision, stream bank erosion and undercutting by wave action.
- The City could consider modifying its slope setback standards to include a setback from the toe of slopes to further reduce potential hazards from development on or near steep slopes. While the City presently requires a "primary setback" from the top of slopes, there is presently no requirement for setback from the toe of steep slopes in the City.

- The City could recognize and manage for the multiple functions served by steep slopes, particularly forested slopes in riparian and wildlife corridors such as those found in Coal Creek, Kelsey Creek, and West Lake Sammamish basins, including their value as wildlife habitat (see Section B, Wildlife Inventory). Implementing policies and regulations could include integrating habitat management planning with engineering studies of steep slope areas to address issues such as vegetation retention and setback standards using regulatory or non-regulatory methods.
- With the advent of licensing of geologists, engineering geologists, and hydrogeologists in Washington (effective July 1, 2002), Bellevue's code could recognize the acceptance of licensed geo-professionals to evaluate geologic processes. For evaluations of faulting, erosion, and slope stability, a licensed engineering geologist could be allowed to perform the duties previously only given to a geotechnical engineer. As provided for under the law, engineering design issues are still the responsibility of the geotechnical engineer.
- All drainage pipes that are not buried into the original, undisturbed ground (below the zone of creeping soil) could be fuse-welded, high-density polyethylene (HDPE) on the ground surface. Breakage, pulling-apart of the joints, and crushing of other types of pipes are common (and inevitable), and contribute to slope instability.
- The word "colluvium" could be deleted from the code and notebook. Colluvium is present on nearly all slopes worldwide, and is interpreted differently by many people. Its ambiguity only leads to confusion and unnecessary debate. If it is meant to denote landslide debris deposits, this should be clearly stated. If it is meant to denote run-out debris deposits, that should be stated.
- GIS files containing information about landslides, erosion areas, and Seattle Fault Zone hazards could be started by the City of Bellevue, so that all information is collected in one location and can be used in the future to further refine land use and geologic hazard maps.

5.2 Erosion Prone Areas

- The City could continue to require erosion control measures in erosion-prone areas, particularly near stream and wetland systems. These measures include minimizing areas of grading and vegetation removal where feasible, limiting clearing during wetter times of the year, use of erosion control best management practices (BMPs), and requiring revegetation immediately following development. Recording of erosion-prone areas in the City's GIS files, as discussed above, would be useful in further refining erosion hazard maps.

5.3 Siesmic Hazard Areas

- To collect information on the location of the Seattle Fault, the City could encourage or require development located along the mapped Seattle Fault Zones to document fault locations discovered during excavations. The City could also continue to track ongoing studies by the USGS and incorporate new fault information as it becomes available.
- The City could consider developing public education and outreach materials to provide information to residents and business owners about seismic risks associated with the Seattle

Fault Zone. This information could include building techniques, disaster preparedness, and other general information about ways to minimize safety risks and property damage during seismic events.

- For proposed new structures (buildings, pipelines, roads, etc.) within several hundred feet of the known or postulated Seattle Fault traces, the City could consider requiring a geologic fault rupture evaluation of the building site and proximity (e.g., 50-feet). This evaluation could consist of a shallow trench or geophysical testing methods to observe signs of previous fault rupture. If evidence of previous fault rupture is found, a building setback from the trace could be required, with possibly some requirements to minimize the potential for structure collapse during displacement. Implementation of a fault rupture evaluation and setback for structures within the vicinity of known or suspected surface traces could significantly reduce the risks posed by ground surface rupture within the Seattle Fault Zone.

5.4 Tsunami/Seiche Hazard Areas

- Areas on the shorelines of Lake Washington and Lake Sammamish could be designated as having the potential for seiche runup. Public information about this hazard could be made available to shoreline property owners. The areas should include all land within 5 vertical feet of the annual high water mark of the lakes. A geotechnical analysis could be performed for new development on such land that includes the potential impacts of the seiche and an emergency management plan.

5.5 Liquefaction Hazard Areas

- When the liquefaction hazard maps are published by the DNR for the Bellevue area, the City of Bellevue could incorporate these into the inventory of geologic hazards. These maps could be used to identify soils with a moderate to high susceptibility of liquefaction, and to determine whether a project developer may be required to submit site-specific liquefaction assessment and incorporate mitigation measures.

Development approval could be contingent on the successful demonstration of how the potential effects of liquefaction (if present) will be mitigated. Potential mitigation measures could include:

- Improving the soil structure to densify/cement the soils,
- Utilizing pile foundations to provide support for the structure from below the potential liquefiable soil, and
- Reducing allowable soil-bearing pressures to limit the potential for bearing capacity failures and differential foundation settlements.

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7.0 GLOSSARY

Alluvium: Deposits laid down by streams/running water since the melting of the last glacial ice

Blakely Formation: a sedimentary deposit laid down in central western Washington during the late Eocene (43 million years ago) through Oligocene periods (23 million years ago).

Conglomerate: a cemented sedimentary rock containing rounded fragments in a finer grained matrix

Deposition: the laying down of soil and rock particles that form new soil or rock units

Fraser Glaciation: glaciation that originated in British Columbia about 21,000 years ago and ended about 10,000 years ago, consisting of three separate pulses, the most prolific of which was the Vashon Stade

Glaciolacustrine: fine grained (silt and clay, primarily) materials that were deposited in a lake that formed in front of the glacial ice, in this case in the Puget Sound area

Interbedded: alternating beds of rock of different rock types or grain size

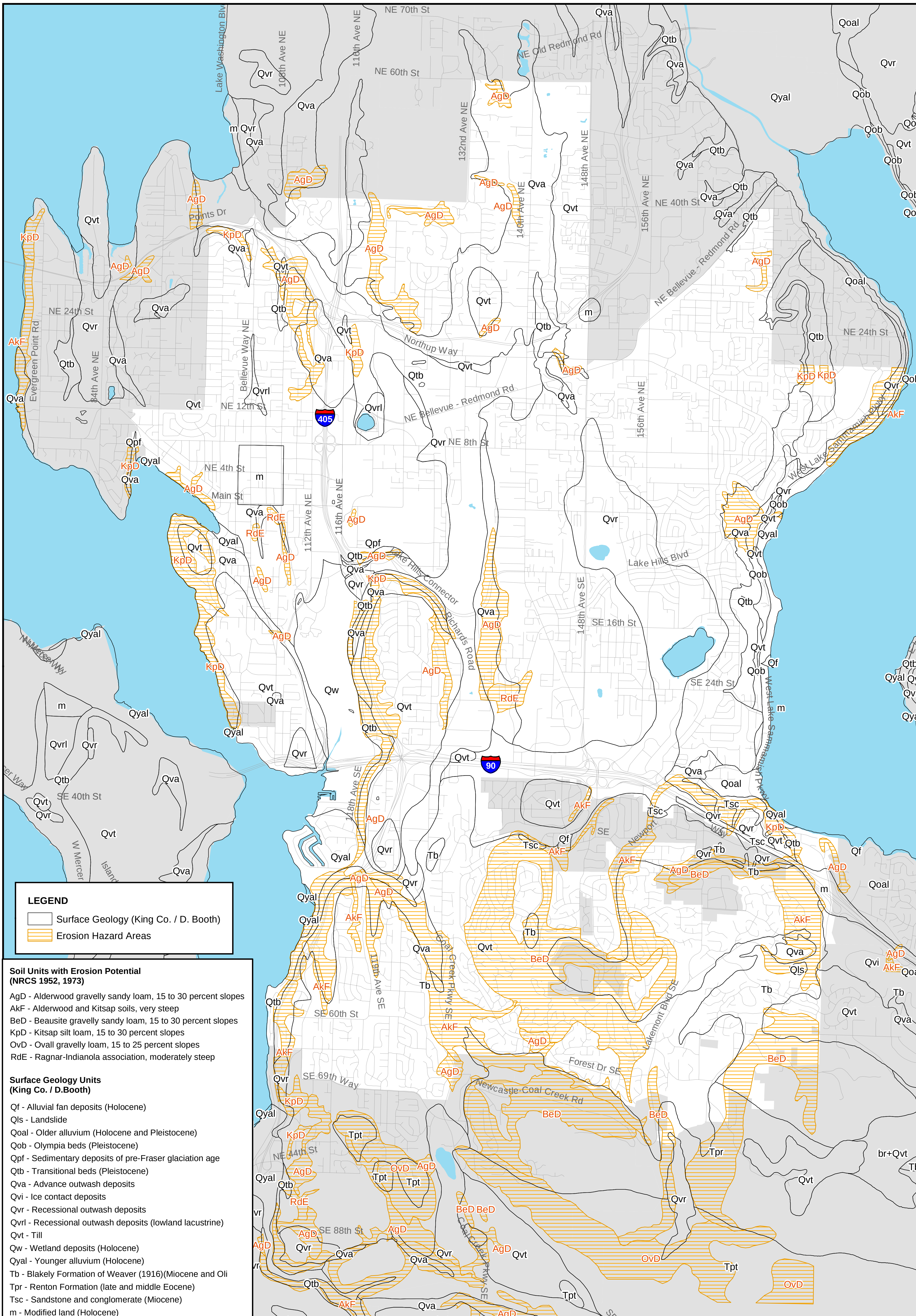
Mass Wasting: a general term for a variety of processes by which large masses of earth material are moved by gravity either slowly or quickly from one place to another

Outwash: deposits from glacial meltwater streams, consisting mostly of sand and gravel, but also including cobbles and boulders

Thrust Fault: a fault characterized by a low angle of movement with respect to horizontal plane in which the upper block moves upward over the underlying block

Till: the heterogeneous deposit that forms beneath glacial ice, referred to locally as hardpan, because it is compressed by the weight of the ice

APPENDIX G-1: FIGURES

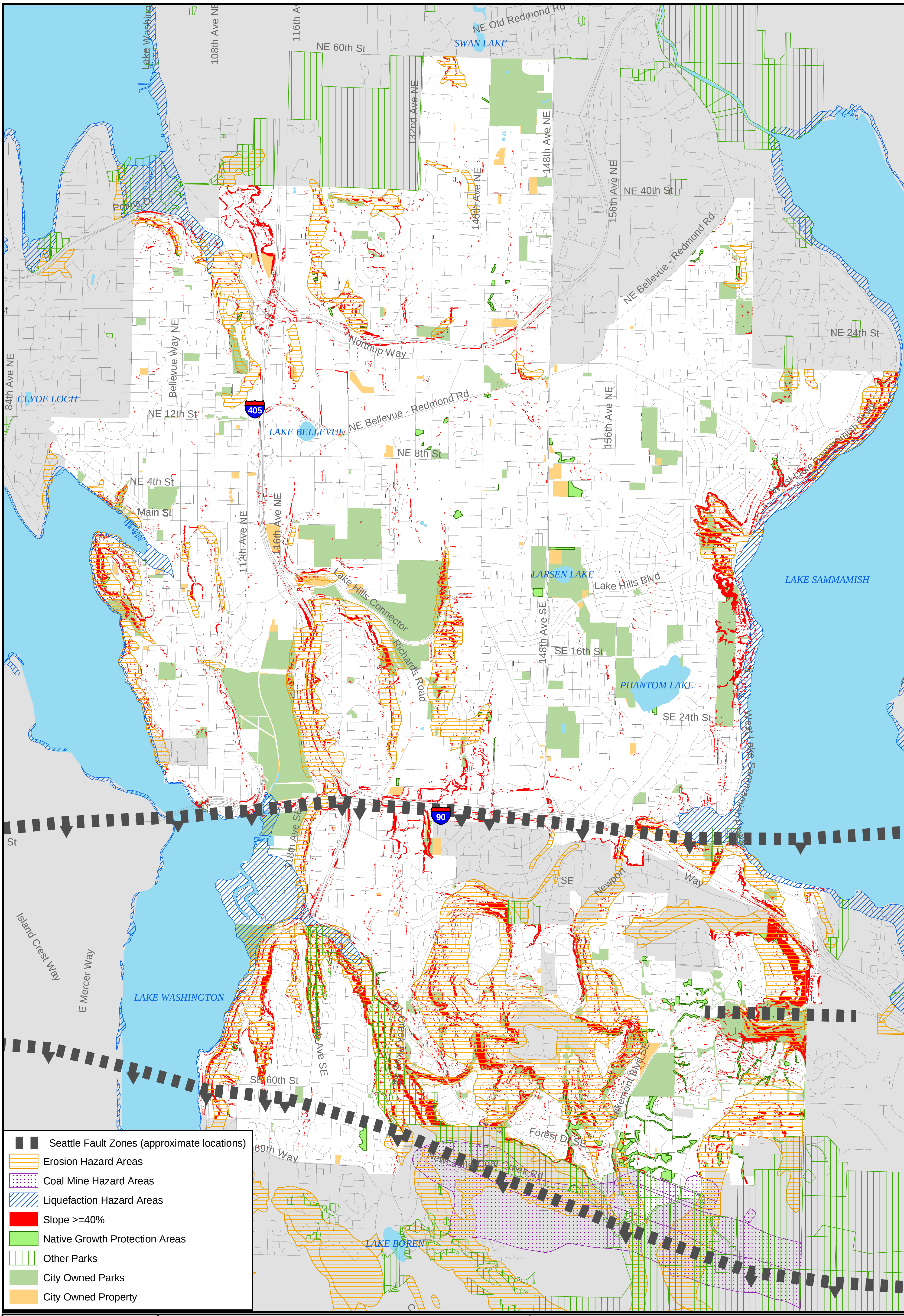


N

Map data shown are the property of the sources listed below. Inaccuracies may exist, and Adolfson Associates, Inc. implies no warranties or guarantees regarding any aspect of data depiction.
Source: City of Bellevue GIS 2001; King County GIS 2001; and Booth, D.B., Haugerud, R.A., and Sackett, J.

0 1,000 2,000 4,000 6,000 Feet

FIGURE G-1.
SURFACE GEOLOGY AND SOILS WITH SEVERE EROSION POTENTIAL
BELLEVUE CAO UPDATE
BELLEVUE, WASHINGTON



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N

Map data shown are the property of the sources listed below. Inaccuracies may exist, and Adolfson Associates, Inc. implies no warranties or guarantees regarding any aspect of data depiction.

Feet
0 1,250 2,500 5,000

Sources: City of Bellevue GIS 2001; King County GIS 2001; NRCS 1952, 1973; Faults: Blakely, et.al. 2002; Moderate to high liquefaction susceptibility: Palmer, Stephen P.; Evans, Brian D.; Schasse, Henry W., 2002, Liquefaction susceptibility of the Greater Eastside area, King County, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-48, 14 p., 1 plate, scale 1:36,000.

FIGURE G-2.

GEOLOGIC HAZARDS

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