Bureau of Development Services FROM CONCEPT TO CONSTRUCTION

CODE GUIDE

TOPIC: Slope Stability-
CC/24/#2, OSSC/18/#2, ORSC/4/#3

CODE: Portland City Code 24
Oregon Structural Specialty Code, 2014 Edition
Oregon Residential Specialty Code, 2014 Edition

APPROVED: [Insert Date]_____, Director

REFERENCE: Portland City Code 24.70
Oregon Structural Specialty Code- Chapter 18
Oregon Residential Specialty Code- Chapter 4

SUBJECT: Requirements and Acceptance Standards for Slope Hazard Evaluations

QUESTION: When is a slope hazard evaluation required? What are the requirements for slope hazard evaluations?

RESPONSE: A slope hazard evaluation is required as described in Section A of this code guide. Requirements for slope hazard evaluations are described in Section B of this code guide. The evaluation of slope hazards is a complex task that should be undertaken by registered design professionals with considerable experience conducting slope hazard evaluations. For additional guidance, please refer to other resource documents, such as Blake et al. (2002) and BSSC (2009).

A. Evaluation Required

A slope hazard evaluation is required for Building, Site Development, and Development Review permit applications for new construction, additions and alterations to existing structures, grading, and other ground disturbing activities as described in sections B.1 through B.7.

Exceptions:

A slope hazard evaluation is not required for the following when approved by the Bureau of Development Services (BDS):

i. Interior alterations to existing structures that do not result in any increase to the footprint of the existing structure unless the development alters foundations or requires mandatory seismic improvements.

ii. When BDS determines the apparent slope hazard presented by the proposed development is negligible.

iii. Risk Category I (OSSC) buildings, provided there is no apparent adverse impact to the slope hazard.

B. Requirements for Slope Hazard Evaluations

Slope stability evaluations must be conducted using an acceptable quantitative (numerical) analysis method for the critical slope cross section or sections that affect the development and/or adjacent properties. The evaluation must be conducted by or under the supervision of a Professional Engineer with expertise in geotechnical engineering or a Certified Engineering Geologist. Qualitative evaluations based on site reconnaissance alone will not be considered sufficient except as described below or as otherwise approved by BDS.

Slope hazard evaluations must, at a minimum, address the following potential hazards:

1. Surficial Slope Stability

   The stability of slope surfaces must be evaluated based on an infinite slope analysis where permanent slopes are proposed to be steeper than 2H:1V (horizontal to vertical). Infinite slope stability must be evaluated using the method described by Campbell (1975) or other method approved by BDS. Surficial instability typically occurs during periods of prolonged or intense precipitation. Subsurface water conditions assumed in the analysis must be commensurate with such conditions and consider the potential for perched groundwater conditions and/or seepage parallel to the slope. The minimum factor of safety against surficial slope instability is 1.5.

2. General Slope Stability

   General slope stability must be evaluated where:

   a. Existing or proposed development slopes are steeper than 2H:1V.
   b. Foundation setback requirements of OSSC 1808.7 or ORSC 403.1.9 are not satisfied.

c. There is evidence of past slope instability on the property or on properties with similar topographic and geologic conditions in the vicinity of the development.

d. Other conditions exist or are proposed that may present a slope hazard, as determined by BDS.

The evaluation of general slope stability must include an analysis of arcs, planes and other irregular surfaces considered most appropriate for the site topographic and geologic conditions. The potential failure surface search limits must be sufficiently broad to adequately consider potential failure surfaces that may encompass, intersect or otherwise affect the development and/or adjacent properties. Where critical failure surfaces pass near the model boundary, the model boundaries must be expanded and additional failure surfaces analyzed.

The proposed final development conditions must have a minimum factor of safety of 1.5 with subsurface water conditions commensurate with the predicted mean annual high groundwater conditions.

Surcharge loads from traffic loading or other live loads must be included in the static slope stability analyses unless they contribute a stabilizing force. Residual soil strength values must be used for analysis of existing landslide features.

Exceptions:

When approved by BDS:

i. Quantitative analysis is not required where subsurface evidence demonstrates the presence of geologic conditions with low susceptibility to instability (i.e. shallow hard rock).

ii. Factors of safety lower than those prescribed above may be accepted where special circumstances exist. Special circumstances might include stabilization of existing unstable slopes, repair of structures damaged by slope instability, or where extensive investigation and testing provides a high degree of confidence in the subsurface conditions and model parameters.

3. Seismic Slope Stability

Seismic slope hazards must be evaluated when a general slope stability analysis is required as described in section B.2.

Seismic slope stability analyses must be evaluated for ground motions consistent with the maximum considered earthquake (MCE) hazard. The analysis must consider the earthquake sources with significant contribution to the hazard. The significant earthquake sources, magnitudes and distances should be obtained from the USGS Interactive Deaggregation [http://geohazards.usgs.gov/deaggint/2008/].

In the Portland area, the deaggregation will typically result in the need to evaluate two sources: (1) a local crustal earthquake of approximate magnitude (M_w) 6.8 and (2) a subduction zone earthquake of approximate magnitude (M_w) 9.0.

A pseudo-static screening analysis may be conducted initially. The pseudo-static earthquake coefficient (k_h) must be a percentage of the maximum horizontal earthquake acceleration associated with the significant sources contributing to the MCE hazard. The method(s) must consider earthquake magnitude or duration and acceptable displacement in determining an appropriate value of k_h. An acceptable method is described by Blake, et al. (2002), in which the maximum horizontal earthquake acceleration is multiplied by the value f_{eq}. The value of f_{eq} must be determined for a threshold displacement of 2 inches (5 cm). If the pseudo-static factor of safety is less than 1.0, a displacement based analysis must be conducted.

Displacement based slope stability analysis may be performed using simplified charts or equations, or rigorous analysis (i.e. Newmark cumulative displacement analysis) of appropriately selected and scaled earthquake time-histories. Simplified methods include Makdisi and Seed (1978), Bray et al. (1998) and Saygili and Rathje (2008). Other appropriate simplified methods may be permitted when approved by BDS.

Acceptable displacement must be determined based on the target performance level of the building or slope. For example, Risk Category I and II structures have a target performance level of *Collapse Prevention*. Acceptable displacement for Risk Category III and IV structures must be developed on a project specific basis considering the target performance level of the project.

Subsurface water conditions used in seismic slope stability analysis must be commensurate with mean wet season conditions.

4. Pre-Historic and Historic Deep-Seated Landslides

The stability of pre-historic and historic deep-seated landslides must be evaluated where any portion of a proposed development property is located on or within a pre-historic or historic deep-seated landslide mapped by the Oregon Department of Geology and Mineral Industries [http://www.oregongeology.org/sub/slido/index.htm], a registered design professional or other authoritative source.

The analysis must include a numerical stability analysis of the mapped landslide. Requirements described in sections B.2 and B.3 apply to pre-historic and historic landslides.

Where any portion of a proposed development property is located near the head scarp of a pre-historic or historic deep-seated landslide, the potential for retrogression of the head scarp shall be evaluated.

Exceptions:

When approved by BDS:

i. Quantitative analysis of mapped pre-historic and historic deep-seated landslides may be waived where studies have determined the landslide to be incorrectly mapped based on thorough subsurface investigation.

ii. Quantitative analysis of mapped pre-historic and historic landslides may be waived where adequate slope stabilization measures have been effectively implemented for the slope failure mode requiring evaluation.

iii. Quantitative analysis of mapped pre-historic and historic deep-seated landslides may be waived where all of the following conditions are met:

- *The proposed development satisfies the requirements of sections B.1 through B.3 for local and/or shallow-seated slope stability.*
- *A qualitative evaluation of the deep-seated landslide performed by a certified engineering geologist determines:*
  - *The proposed development will have no adverse impact to the stability of the pre-historic or historic deep-seated landslide.*
  - *The probable character of deep-seated slope movement is unlikely to result in a life safety risk to the occupants of the development.*
  - *The property owner(s) sign a Potential Landslide Hazard Area Covenant Running with the Land with Acknowledgement and Acceptance of Risk, Duty to Inform, Need for Insurance, Indemnity, and Waiver approved by BDS and record the covenant with the county recorder.*

5. Soil Creep

   The potential for soil creep must be evaluated for proposed development with foundations located on or within a horizontal distance of 10 feet from slopes of 3H:1V or steeper. Soil creep may be addressed by removing creep-prone soils from the foundation area, embedding foundations below creep-prone soils and designing the foundations to resist soil creep forces acting on the foundations and/or designing foundations to accommodate the cumulative displacement resulting from soil creep.

6. Soil/Debris Flow Inundation

   The potential for soil/debris flow inundation must be evaluated for development located on or within a horizontal distance of 100 feet of debris flow or fan deposits mapped by the Oregon Department of Geology and Mineral Industries (e.g. Oregon HazVu: Statewide Geohazards Viewer), a registered design

professional or other authoritative source; or when there is evidence of soil/debris flow hazards that may affect the development.

Buildings must be located outside areas subject to soil/debris flow inundation. Where there is insufficient buildable area not subject to soil/debris flow inundation, mitigation must be provided such that the hazard is unlikely to result in a life safety risk to the occupants of the development.

Mitigation measures which divert soil/debris onto adjacent properties or right-of-way are not permitted unless appropriate easements and permits are acquired and recorded in the property records. Mitigation measures which require maintenance are not permitted unless maintenance agreements are signed and recorded in the property records.

7. Temporary Excavation Slopes

   Temporary excavation slopes near adjacent properties or structures must be protective of those features and have a minimum factor of safety of 1.25 for the worst case conditions anticipated during construction. If dry season conditions are assumed in the analysis, the construction plans and permit conditions must include restrictions, consistent with the analysis assumptions, on the time of year during which excavations may be unsupported. Use of soil cohesion must be supported with laboratory test data or well established local correlations, unless otherwise approved by BDS.

C. Reporting

Slope hazard reports must be prepared in general accordance with the applicable sections of the *Guidelines for Preparing Engineering Geologic Reports in Oregon* prepared by the Oregon State Board of Geologist Examiners, the minimum requirements of OSSC 1803 and PCC 24.70. In addition, slope hazard investigations and reports must include:

1. A site reconnaissance conducted by a Certified Engineering Geologist where deep-seated pre-historic and historic landslides are required to be evaluated.
2. Subsurface investigations which extend below possible failure surfaces anticipated to have a factor of safety of less than 1.5 under static loading or 1.0 under seismic loading.
3. Investigation to determine the location of groundwater within the area of interest.
4. Strength testing of the soils of interest; either in-situ testing, laboratory testing, or both. Strength correlations for in-situ testing shall be well documented.
5. Geologic cross sections for the critical slope sections analyzed, including assumed piezometric surfaces.
6. Detailed descriptions of the analysis methods used and assumptions made in the numerical modeling.

7. Recommendations for temporary and permanent surface and subsurface drainage elements.
8. Discussion of the effects of on-site effluent disposal and stormwater disposal systems, existing or proposed, on slope stability.
9. Detailed laboratory testing results attached within a report appendix.
10. Detailed subsurface investigation results attached within a report appendix.
11. Geotechnical recommendations for site development, grading, and construction.
12. Recommendations for site development and mitigation measures required to achieve the minimum allowable factors of safety against slope instability.
13. Recommendations for temporary and permanent erosion control.
14. A statement of understanding of the performance criteria and expected displacements under seismic loading conditions.
15. A statement that the construction plans have been reviewed by the project geotechnical engineer for conformance with the recommendations of the slope hazard evaluation and geotechnical engineering report. The date listed on the reviewed plans should be stated.

D. References

Blake, T. F., R. A. Hollingsworth, and J. P. Stewart, editors. 2002. *Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California*. Southern California Earthquake Center, University of Southern California, Los Angeles, California.

Bray, J. D., E. M. Rathje, A. J. Augello, and S. M. Merry. 1998. “Simplified Seismic Design Procedure for Geosynthetic-Lined, Solid-Waste Landfills,” *Geosynthetics International*, 5(1-2).

Campbell, R.H. 1975. *Soil Slips, Debris Flows and Rainstorms in the Santa Monica Mountains and Vicinity, Southern California*. U.S. Geological Survey Professional Paper 851.

Building Seismic Safety Council (BSSC). 2009. *NEHRP Recommended Provisions for Seismic Regulation of Buildings and Other Structure*, FEMA P750, Part 3, Resource Paper 12, Evaluation of Geologic Hazards and Determination of Seismic Lateral Earth Pressures. Federal Emergency Management Agency, Washington, D.C., USA.

Makdisi, F. T., and H. B. Seed. 1978. “Simplified Procedure for Estimating Dam and Embankment Earthquake-Induced Deformations.” ASCE/SEI *Journal of Geotechnical Engineering*, 104(GT7).

Oregon Board of Geologist Examiners. 1990. *Guidelines for Preparing Engineering Geologic Reports in Oregon*.

Saygili, G., and E. M. Rathje. 2008. “Empirical Predictive Models for Earthquake-Induced Sliding Displacements of Slopes,” ASCE/SEI *Journal of Geotechnical and Geoenvironmental Engineering*, 134(6).

New: _____, 2016