3 GEOLOGIC HAZARD

3.1 Geotechnical Setting

The downtown Anchorage study area is a geotechnically unstable area that underwent significant movement in the 1964 Alaska Earthquake. The area is underlain by a layer of gravel outwash approximately 50 feet thick, underlain by a layer of unstable Bootlegger Cove Clay, as shown in Figure 1.2. In a significant earthquake such as occurred in 1964, the unstable clay layer loses strength along a plane, and with each cycle of earthquake shaking the overlying block of soil moves towards the free surface (the bluff). In the volume behind the block of soil, the ground collapses into the void, forming a graben.

The evaluation described here was performed for seismic risk zones 1 (Lowest) through 5 (Very High), discussed in detail in the project memorandum defining seismic displacements for the project study area (dated June 12, 2009; see Appendix D). Figure 1.2 shows a cross section of Zone 5 including potential subsidence, block lateral movement, and pressure ridges. The seismic risk zones had been previously mapped in accordance with expected permanent ground deformation (PGD) in future earthquakes. The "Seismic Displacements" memorandum quantified the expected net displacement of soil on the surface in each zone by percentage, where the displacement was a vector combining horizontal and vertical movement. In most cases, the predominant movement is expected to be horizontal, but in the areas over the grabens, the predominant movement is expected to be subsidence, and over the pressure ridges, uplift. The methodology used in estimating the movements combined expected movements over the entire zone, and is presented as a percentage of the zone expecting the net movement. This displacement estimate serves as input into the building damage relationships and loss estimates in this memorandum.

The characterization of the magnitude and type of potential ground movement during major earthquakes in each of the four local ground failure hazard zones and its resulting impact on buildings and lifelines is an integral part of the seismic risk assessment for the Anchorage downtown area. This section describes the levels of potential seismic displacement used in the Downtown Anchorage Risk Assessment. Using a scenario consistent with the IBC design ground motions and the strength of materials derived from numerous sources, the probable range of seismic displacements have been developed.

3.2 Definition and Delineation of Slopes

The study area has been divided into five categories (Seismic Hazard Zones) based on seismic risk as outlined in the 1979 Harding Lawson study and shown in Figure 1.1.

- Zone 5 - Very High – Areas of previous seismically-induced landslides. Includes zones of tension cracks above the head wall scarp, toe bulge, and pressure ridge areas. Although portions of these previous slides may remain relatively undisturbed from future strong shaking, these slides will be the more likely site of future seismically-induced sliding.

- Zone 4 - High – Fine-grained, surficial and subsurface deposits within the vicinity of steep slopes; includes area above and below the slope. Highly susceptible to all types of seismically-induced ground failure, including liquefaction, translational sliding, lurching, land spreading, cracking, and subsidence.

- Zone 3 - Moderate – Fine-grained surficial and subsurface deposits, including the Bootlegger Cove Clay and other silt, clay, and peat deposits. May experience ground cracking and horizontal ground movement due to land spreading or lurching, and subsidence due to consolidation.

- Zone 2 - Moderate-Low – Mixed coarse and fine-grained glacial deposits in lowland areas, thick deposits of channel, terrace, flood plain, and fan alluvium. May have very low susceptibility; may experience minor ground cracking, localized settlement due to consolidation, and perhaps liquefaction or lurching of localized saturated zones of fine-grained material.

- Zone 1 - Lowest – Includes exposed bedrock, thin alluvium and colluvium over bedrock. May experience minor ground cracking and acceleration of normal mass wasting process in unconsolidated material such as rock falls and snow avalanches. (None in study area.)

The existing topography was provided by the Planning Department of the Municipality of Anchorage and was input into a Geographic Information System (GIS). The downtown area was then layered with the seismic zones described above. Four foot contours of the topography were used to describe slope geometries throughout the study area.

Twenty cross sections were drawn in the study area to characterize a representative range of the slopes found within each zone. An overlay of the study area with seismic zones and cross section lines is provided below in Figure 3.1.

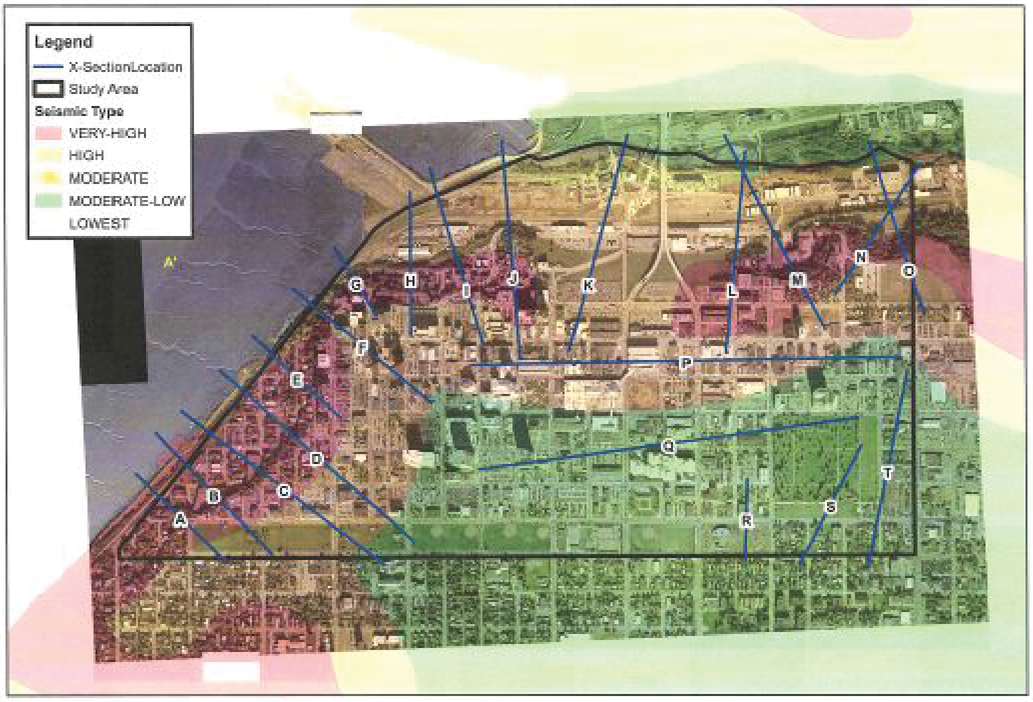

Figure 3.1 Overlay of Downtown Anchorage with Seismic Zones and Cross-Sectional Lines.

Each of the twenty cross sections was studied and 61 slopes within these cross sections were analyzed. The number of slopes analyzed within each of the zones was:

- Zone 5: 40 slopes
- Zone 4: 15 slopes
- Zone 3: 1 slope
- Zone 2: 5 slopes

As suggested in the descriptions of the zones above, Zones 4 and 5 are expected to produce the greatest number of slopes with large seismically-induced permanent displacements. These two zones also have the highest concentration of slopes within their boundaries. Zone 3 has only small acreage within the study area and is located in a flat plain. For this reason, only one slope was analyzed. Zone 2 is relatively flat with small, undulating hills.

3.3 Anticipated Slope Displacements Due to Seismic Shaking

In this study, the potential seismic displacement for each slope was estimated using the Bray and Travasarou (2007) simplified seismic slope displacement procedure. This procedure requires as input the slope geometry and soil properties to estimate the slope's characteristic dynamic resistance (i.e., its yield coefficient) and its dynamic response characteristics (i.e., the potential sliding block's fundamental period). The seismic demand was defined using the International Building Code (2006) for the likely level of earthquake shaking.

In many of the cross sections, multiple steep slopes that could produce shallow landslides existed within the mass of a potentially large translational slide. Given this complexity, all slopes, both shallow and translational, were independently evaluated to calculate anticipated displacements.

For each cross section, if the seismic displacements for the large translational slides were greater than the anticipated seismic displacements for the shallow slides located within the larger slide mass, the displacements for the larger slide were utilized in the subsequent analysis. The smaller slopes on the slide mass were assumed to essentially “go along for the ride.” Alternatively, if the large translational slide does not mobilize, it is probable that the shallower landslides will dominate the seismic displacements, and the shallower slides were thus utilized.

The slopes and their calculated seismic displacements were then placed on the Harding Lawson maps. Using engineering judgment, the plan view square footage for the potential displacements was calculated for each seismic region. The results of the seismic slope displacement analyses are presented in Figure 3.2.

Zone 5 is the region for which the largest potential seismic displacements are predicted. Over 80% of the area of Zone 5 would likely experience more than eight feet of seismic slope displacement during the design level of earthquake shaking in Anchorage. These large, translational slides are typically through the Bootlegger Cove Clay. Shallower slopes, mainly comprised of 30 to 50 feet of sands and gravels, are expected to “go along for the ride” within the larger sliding mass. However, there are areas within Zone 5 which may have 6 to 12 inches or less displacement, or even negligible estimated seismic displacement. This suggests that some refinement of the generalized seismic zonation of the 1979 Harding Lawson maps may be possible.

Zone 4 has the largest square footage in comparison to the other zones. Results for Zone 4 show that calculated seismic displacements can be large with almost 20 percent of the region possibly displacing more than four feet for the design earthquake scenario. These slides are large, translational slides within the Bootlegger Cove Clay and are without a toe berm or pressure ridge. Shallower potential slope failures comprised of the sands and gravels within the larger sliding mass are expected to “go along for the ride” within the larger sliding mass. Approximately 3 percent of Zone 4 will likely displace between 6 and 12 inches for the design event. These areas are generally directly behind Zone 5. A movement of about 6 inches is commensurate with observations of movement behind the scarps from the 1964 earthquake (Long, 1973; Hansen, 1965). However, a considerable percentage of the Zone 4 is more stable within areas significantly behind Zone 5 or within the areas of the toe berm/pressure ridge.

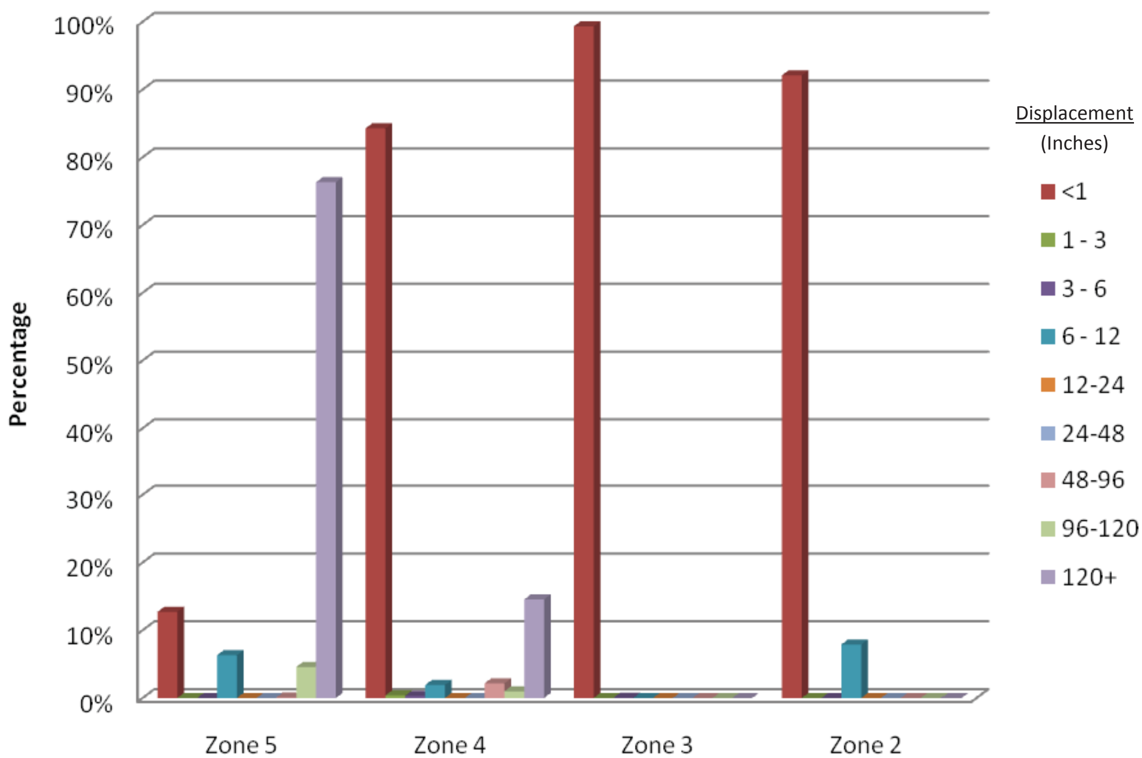

Figure 3.2 Displacements by Percentage of Area within each Zone.

Zone 3 has only one gentle slope within the study area. It is anticipated that this slope will displace less than 1 inch during the design event. Additionally, this shallow slide is less than 1 percent of the plan area of Zone 3 within the study area. Thus, Zone 3 does not present a significant seismic slope displacement hazard within the study area.

Zone 2 is characterized by large square footage and does not contain significant open faces or steep slopes. The relatively few slopes in this area are moderate and may move on the order of 6 to 12 inches during the design event. These slopes represent less than 10 percent of the land mass of Zone 2 within the study area.

The Figure 3.2 results are probability based. That is, they include percentages of the areas where grabens and pressure ridges form as well as areas where little or no movement occurs. For example, in Hazard Zone 5, a building could be subjected to less than one inch of movement, or, it could experience greater than 10 feet of movement. The location of graben and pressure ridge formation in future earthquakes is unknown, so it is assumed they could occur anywhere within Hazard Zone 5, or to a lesser degree within Hazard Zone 4.

The orientations of the calculated seismic displacements are aligned roughly with the slope topography. Gentle slopes that displace on a horizontal base sliding plane will displace largely horizontally. Steep slopes on inclined base sliding planes may displace vertically as much as they displace horizontally. Intermediate cases will include both horizontal and vertical components of displacement.

In addition to using slope topography to estimate the likely orientation of the calculated seismic displacement vector, observations of slope movements in the study area during the 1964 Alaska earthquake were considered. For example, the L Street Slide moved 14 feet horizontally and 10 feet vertically (about a 1.5H:1V ratio). The 4th Avenue slide moved between 19 feet to 11 feet horizontally and 10 feet vertically, or approximately a 2H:1V to 1H:1V ratio of displacements. Based on a comparison with existing topography and these observations of past performance, these relationships may provide some insight into potential relative amounts of horizontal and vertical movements within each zone:

- Zone 5 with an open face: 1.5H : 1V
- Zone 4 with an open face: 1.5H : 1V
- Zone 4 without an open face: 3H : 1V
- Zone 3: primarily horizontal movement with minor vertical movement
- Zone 2: primarily horizontal movement with minor vertical movement

The displacements developed in this section are then used to estimate prototypical building damage in the scenario earthquake.