APPENDIX B

Minimum Standards for
Surface Fault Rupture Hazard Studies

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

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1.0 INTRODUCTION

The Wasatch Fault Zone is a major tectonic feature of the intermountain region in the western United States. It extends from Fayette, Utah at the south to Malad, Idaho at the north, comprising about 230 miles. Surface faulting has occurred along the Wasatch Fault Zone in northern Utah throughout late Pleistocene and Holocene time. *"Surface faulting"* is a fault-related offset or displacement of the ground surface that may occur in an earthquake.

The Wasatch Fault Zone consists of a series of normal-slip fault segments where the earth experiences relative downward movement on the west side and upward movement on the east side. Ten major fault segments are recognized along the Wasatch Fault Zone, which are believed to be independent in regard to their potential for surface faulting. These segments have distinct geomorphic expression and are clearly visible on aerial photographs.

In the Salt Lake Valley, the Wasatch Fault Zone is represented by the Salt Lake City segment, which extends about 23 miles along the eastern edge of the valley. A portion of the Salt Lake City segment of the Wasatch Fault Zone is present in the foothills of FRUIT HEIGHTS CITY (the "*city*") on the eastern side of city. Documentation of repeated Holocene movements suggest that at least four major earthquake events have occurred in the last 6,000 years along Wasatch Boulevard near the mouth of Little Cottonwood Canyon.

In the event of an earthquake, a fault could break the ground surface below or near a structure and cause significant property damage, injuries and loss of life. In order to reduce risk from surface-fault-rupture hazards and to protect public health and safety, the city has defined a boundary for the sensitive lands that may have a heightened potential for surface fault ruptures and is requiring study for all new development or re-development within this area. Quaternary faults located within the Surface Fault Rupture Hazard Study Area should be considered active until proven otherwise.

The city requires a site specific geologic study for all properties that may be impacted by the Wasatch Fault Zone. The study must address the surface fault rupture potential and assess the suitability of the proposed development. In the event that a fault is discovered and deemed active (i.e., Holocene-age), appropriate building setbacks are required to minimize the potential damage during an earthquake.

The site-specific surface fault rupture hazard study requires a field investigation. This includes geologic documentation of an excavated trench or other pre-approved method of exploration and accompanying report that addresses the findings. The following information in this appendix describes the *minimum* standards required by the city for the surface fault rupture hazard study.

1.1 ***Purposes***.

(a) The purposes of establishing minimum standards for surface fault rupture hazard studies are to:

(i) Protect the health, safety, welfare, and property of the public by minimizing the potential adverse effects of surface fault ruptures and related hazards.

(ii) Provide guidance for property owners and land developers in performing reasonable and adequate studies of sensitive lands in the city.

(iii)Provide consulting engineering geologists with a common basis for preparing proposals, conducting investigations, and recommending setbacks.

(iv) Provide a consistent and objective framework for review of fault study reports.

(b) The procedures in this appendix are intended to provide the developer and consulting engineering geologist with an outline of appropriate exploration methods, standardized report information, and city expectations.

(c) These standards are the minimum level of effort required in conducting surface fault rupture hazard studies within the city. Considering the complexity of evaluating surface and near-surface faults, additional effort beyond the minimum standards may be required at some sites to adequately address the surface fault rupture hazard. The information presented in this appendix does not relieve the engineering geologist from his/her duty to perform additional geologic or engineering services he/she believes are necessary to assess the surface fault rupture potential at a site. In the interest of public safety, the city may, at any time, require additional information, studies, tests or other work that is not included in this appendix.

1.2 *Properties requiring a fault investigation*.

(a) Before approval of any land use, a fault study is required for properties within the surface fault rupture special study area that is located near the Wasatch Fault Zone, or any other property within the city that observes a fault trace during excavation. Appendix A of city code chapter 10.10A ("*chapter 10.10A*") contains the Surface Fault Rupture Hazard Study Area Map (Map 1) that identifies areas with known active faults in the city. Properties within this area must perform site-specific geologic investigations. Development of any parcel within the Surface Fault Rupture Hazard Study Area requires submittal and review of a site-specific fault study prior to receiving a land use or building permit from the city. It is the responsibility of the applicant to retain a *qualified* (as provided in chapter 10.10A) engineering geologist to perform the fault study.

(b) In addition, a fault study may be required if onsite or nearby fault-related features not shown on the Surface Fault Rupture Hazard Study Area Map are identified during the course of other geologic or geotechnical studies performed on or near the site or during construction.

1.3 *References and sources*.

(a) Guidelines for Evaluating Surface Fault Rupture Hazards in Utah (AEG, 1987).

(b) Guidelines to geologic and seismic reports, (CDMG, 1986a).

(c) Guidelines for preparing engineering geologic reports (CDMG, 1986b).

(d) Guidelines for Evaluating Potential Surface Fault Rupture/Land Subsidence Hazards in Nevada (Nevada Earthquake Safety Council, 1998)

(e) Fault Setback Requirements to Reduce Fault Rupture Hazards in Salt Lake County (Batatian and Nelson, 1999).

(f) Salt Lake County Geologic Hazards Ordinance (2002).

(g) Draper City Geologic Hazard Ordinance (2003).

(h) Guidelines for evaluating surface-fault-rupture hazards in Utah (Christenson and others, 2003).

2.0 MINIMUM STANDARDS FOR FAULT STUDIES

The following are the minimum standards for a comprehensive surface fault rupture study investigation.

2.1 *Scoping meeting*.

A scoping meeting with the DRC shall be scheduled by the consultant geologist. At this meeting, the developer, the city and the consultant will evaluate the fault investigation approach. The consultant should bring a site plan to the meeting that shows the following information:

(a) Proposed building locations (if known);

(b) Expected fault location(s) and orientation;

(c) Proposed trench locations, orientation, length, and depth (see Section 2.2, Fault

Investigation Method);

(d) Extent of impact to vegetation and trees; and

(e) Method of controlling erosion and managing storm water.

The investigative approach should allow for flexibility due to unexpected site conditions. The field findings may require modifications to the work plan.

2.2 ***Fault investigation method*****.** Inherent in fault study methods is the assumption that future faulting will recur along pre-existing faults and in a manner consistent with past displacement. The focus of fault studies is therefore to accurately locate existing faults. If faults are documented, the investigation shall also include (a) evaluation of the age of movement along the fault trace(s), and (b) estimation of amounts of past displacement, which is required in order to derive fault setbacks.

2.2.1 Previous studies and aerial photograph review. A fault study shall include review of available literature pertinent to the site and vicinity, including previous published and unpublished geologic/soils reports, and interpretation of available stereo-paired aerial photographs. The photographs reviewed should include more than one set and should include pre-urbanization aerial photographs, if available. Efforts must be made to accurately plot the locations of mapped or inferred fault traces on the property as shown by previous studies in the area.

2.2.2 Exploration methods. Subsurface trenching exploration is required. The engineering geologist shall clean and document ("*log*") trench exposures as described in Section 2.3.5. Existing faults may also be identified and mapped in the field by direct observation of young, fault-related geomorphic features, and by examination of aerial photographs. If trenching is not feasible due to the presence of shallow ground water or excessive fill, supplemental methods such as closely spaced Cone Penetration Test (CPT) soundings may be employed. Such supplemental methods must be discussed with the city prior to implementation and should be clearly described in the report.

(i) In lieu of conventional trenching or the CPT method, an alternative subsurface exploration program may be acceptable, depending upon site conditions. Such a program may consist of geophysical exploration techniques or a combination of other techniques.

(ii) When an alternative exploration program is proposed, a written description of the proposed exploration program along with an exploration plan should be submitted to the city for review and approval, prior to the exploration. The plan must include, at a minimum, a map of suitable scale showing the site limits, surface geologic conditions within several thousand feet of the site boundary, the location and type of the proposed alternative subsurface exploration, and the anticipated earth materials present at depth on the site.

(iii)The actual subsurface exploration program to be used on any specific parcel will be determined on an individual basis, considering the current state of technical knowledge about the fault zone and information gained from previous exploration on adjacent or nearby parcels. At all times, consideration must be given to safety, and trenching should comply with all applicable safety regulations.

2.2.3 Trench siting.

(i) Exploratory trenches must be oriented approximately perpendicular to the anticipated trend of known fault traces. The trenches shall provide the *minimum* footage of trenching necessary to explore the portion of the property situated in the surface fault rupture study area, such that the potential for surface fault rupture may be adequately assessed. When trenching to determine if faults might affect a proposed building site, the trench should extend beyond the building footprint at least the minimum setback distance for the building type (see Table A-1).

(ii) Test pits or potholes alone are neither adequate nor acceptable. In some instances more than one trench may be required to cover the entire building area, particularly if the proposed development involves more than one building. Where feasible, trenches shall be located outside the proposed building footprint, as the trench is generally backfilled without compaction, which could lead to differential settlement beneath the footings. Supplemental trenching may be required in order to:

A. Further refine fault locations (or the absence thereof);

B. Accurately define building restriction areas, and/or;

C. Provide additional exposures for evaluating the age of movement along fault traces.

2.2.4 Location determination. All trenches and fault locations must be surveyed by a registered professional land surveyor. Fault locations should be surveyed with an accuracy of 0.1 foot or better, so that structural setbacks can be developed. The fault locations (and all other features shown in the site plans) must be tied to a minimum of two Salt Lake County section corner monuments and the coordinate data shall be in US State Plane NAD83 (US Survey Feet). Other features in the site plan shall include property lines, building footprint, geologic features, utilities, existing structures, roadway, fences, etc. The location of all features, including the fault lines, shall be wet stamped and certified by the land surveyor.

2.2.5 Depth of excavation.

(i) The depth of the trenches will ultimately depend on the trench location, occurrence of ground water, stability of subsurface deposits, and the geologic age of the subsurface geologic units. As a minimum, however, trenches shall extend substantially below the A and B soil horizons and well into distinctly bedded Pleistocene-age materials, if possible. Where possible, the trenches should extend below Holocene deposits and should expose contacts between Holocene materials and the underlying older materials.

(ii) Appropriate safety measures pertaining to trench safety for ingress, egress, and working in or in the vicinity of the trench must be implemented and maintained. It is the responsibility of the person in the field directing trench excavation to ensure that fault trenches are excavated in compliance with current Occupational Safety and Health Administration excavation safety regulations.

(iii)Trench backfilling methods and procedures should be documented in order to establish whether additional corrective excavation, backfilling, and compaction should be performed at the time of site grading.

(iv)In cases where Holocene (i.e., active) faults may be present, but pre-Holocene deposits are below the practical limit of excavation, the trenches must extend at least through sediments that are clearly older than several fault recurrence intervals. The practical limitations of the trenching must be acknowledged in the report and recommendations must reflect resulting uncertainties.

2.2.6 Documenting trench exposures. Trench walls shall be cleaned of debris and backhoe smear prior to documentation. Trench logs shall be carefully drawn in the field at a minimum scale of 1-inch equals 5-feet (1:60) following standard and accepted fault trench investigation practices. Vertical and horizontal control must be used and shown on trench logs. Trench logs must document all significant geologic information from the trench and should graphically represent the geologic units observed; see Section 2.6.3(E). The strike, dip, and net vertical displacement (or minimum displacement) of faults must be noted.

2.2.7 Age dating.

(i) The engineering geologist shall interpret the ages of geologic units exposed in the trench. When necessary, radiocarbon or other age determinations methods shall be used. If evidence of faulting is documented, efforts shall be made to date the time of latest movement to determine whether recent (Holocene) displacement has occurred by using appropriate geologic and/or soil stratigraphic dating techniques. When necessary, obtain radiocarbon or other age determinations.

(ii) Many of the surficial deposits within Salt Lake Valley were deposited during the last pluvial lake cycle, referred to as the Bonneville lake cycle. Although late-stage Bonneville lake cycle sediments do not correspond to the Pleistocene-Holocene boundary (i.e., Bonneville lake cycle deposits are older than 10,000 years old), for purposes of evaluating fault activity, these deposits provide a useful regional datum, particularly when the entire Holocene sequence of sediments is not present.

(iii)For practical purposes, and due to documented Holocene displacement along the Salt Lake segment of the Wasatch fault, any fault which displaces late-stage Bonneville Lake Cycle deposits should be considered active unless the Bonneville deposits are overlain by clearly unfaulted *early* Holocene-age deposits. Conversely, the presence of demonstrably unbroken, undeformed, and stratigraphically continuous Bonneville sediments constitutes reasonable geologic evidence for the absence of active faulting.

2.3 ***Field review*.** A field review by the city's geologist is required during exploratory trenching. The applicant must provide a minimum of two business days notice to schedule the field review with the city. The trenches should be open, safe, cleaned, and a preliminary log completed at the time of the review. The field review allows the city to observe the subsurface data such as the age, type of sediments, and presence or absence of faulting with the consultant. Discussions about questionable features or an appropriate setback distance are encouraged, but the city will not help log the trench, explain the stratigraphy, or give verbal approval of the proposed development during the field review.

2.4 ***Recommendations for fault setbacks*.**

(a) To address wide discrepancies in fault setback recommendations, the city has adopted the fault setback calculation methodology for normal faults of Batatian and Nelson (1999) and Christenson and others (2003). The consultant should use this method to establish the recommended fault setback for critical facilities and structures designed for human occupancy. If another fault setback method is used, the consultant must provide justification in the report for the method used. Faults and fault setbacks must be clearly identified on site plans and maps.

(b) The minimum setbacks are based on the type and occupancy of the proposed structure as shown in Table A-1. The setbacks should be calculated using the following formulas presented below, and then compared to the minimum setback established in Table A-1. The greater of the two shall be used as the setback. Minimum setbacks apply to both the hanging wall and footwall blocks.

(c) Top of slope and/or toe of slope setbacks required by the local Building Code must also be considered; again, the greater setback must be used.

Downthrown Fault Block (Hanging Wall)
The fault setback for the downthrown block will be calculated using the following formula:
$S = U(2D + F/\tan\Theta)$ where:

S = Setback within which structures for human occupancy are not permitted;
U = Criticality Factor, based on the proposed occupancy of the structure (see Table A-1)
D = Expected fault displacement per event (assumed to be equal to the net vertical displacement measured for each past event)
F = Maximum depth of footing or subgrade portion of the building
Θ = Dip of the fault (degrees)

Upthrown Fault Block (Footwall)
The dip of the fault and depth of the subgrade portion of the structure are irrelevant in calculating the setback on the upthrown fault block. Therefore, the setback for the upthrown side of the fault will be calculated as:

$S = U \times 2D$

The setback is measured from the portion of the building closest to the fault, whether subgrade or above grade. Minimum setbacks apply as discussed above.

2.5 *Small displacement faults*.

(a) Small-displacement faults are not categorically exempt from setback requirements. Some faults having less than 4 inches (100 mm) of displacement ("*small displacement faults*") may be exempt from setback requirements.

(b) Specific structural risk-reduction options such as foundation reinforcement may be acceptable for some small-displacement faults in lieu of setbacks. Structural options must minimize structural damage.

(c) Fault studies must still identify faults and fault displacements (both net vertical displacements and horizontal extension across the fault or fault zone), and consider the possibility that future displacement amounts may exceed past amounts. If structural risk-reduction measures are proposed for small displacement faults, the following criteria must be addressed:

(i) Reasonable geologic data indicating that future surface displacement along the particular fault will not exceed 4 inches.

(ii) Specific structural mitigation to minimize structural damage.

(iii)A structural engineer must provide appropriate designs and the city shall review the designs.

2.6 *Required outline for surface fault rupture hazard studies*.

(a) The information described herein may be presented as a separate surface fault rupture hazard report or it may be incorporated within other geology or engineering reports that may be required for the property.

(b) The report shall contain a conclusion regarding the potential risk of surface fault rupture on the subject property and a statement addressing the suitability of the proposed development from a surface fault rupture hazard perspective. If exploration determines that there is a potential for surface rupture due to faulting, or if gradational contacts or other uncertainties associated with the exploration methods preclude the determination of absence of small fault offsets, the report should provide estimates of the amplitude of fault offsets that might affect habitable structures.

(c) Surface fault rupture hazard reports submitted to the city are expected to follow the outline and address the subjects presented below. However, variations in site conditions may require that additional items be addressed, or permit some of the subjects to be omitted (except as noted).

2.6.1 Report.

(i) *Statement of the purpose and scope of work*. The report shall contain a clear and concise statement of the purpose of the study and the scope of work performed for the study.

(ii) *Site description and conditions*. The report shall include information on geologic units, graded and filled areas, vegetation, geomorphic features, existing structures, and other factors that may affect site development, choice of investigative methods, and the interpretation of data.

(iii) *Geologic and tectonic setting*. The report shall contain a clear and concise statement of the general geologic and tectonic setting of the site and surrounding vicinity. This section should include a discussion of active faults in the area, paleoseismicity of the relevant fault system(s), and should reference relevant published and unpublished geologic literature.

(iv) *Methods of investigation*.

A. Review of published and unpublished maps, literature and records concerning geologic units, faults, surface and ground water, and other factors.

B. Stereoscopic interpretation of aerial photographs to detect fault-related topography, vegetation or soil contrasts, and other lineaments of possible fault origin. Reference the photograph source, date, flightline numbers, and scale. Salt Lake County has an excellent collection of stereoscopic aerial photographs dating back to 1937 (including 1937, 1940, 1958, 1964, and 1985).

C. Observations of surface features, both on-site and offsite, including mapping of geologic and soil units; geomorphic features such as scarps, springs, and seeps (aligned or not); faceted spurs, offset ridges or drainages; and geologic structures. Locations and relative ages of other possible earthquake-induced features such as sand blows, lateral spreads, liquefaction, and ground settlement should be mapped and described. Slope failures, although they may not be conclusively tied to earthquake causes, should also be noted.

D. The report shall include a description of the program of subsurface exploration, including trench logs, purpose of trench locations, and a summary of trenching or other detailed, direct observation of continuously exposed geologic units, soils, and geologic structures. All trench logs shall be at a scale of at least 1-inch is equal to five-feet.

E. The report must describe the criteria used to evaluate the ages of the deposits encountered in the trench, and clearly evaluate the presence or absence of active (Holocene) faulting.

(v) *Conclusions*.

A. Conclusions must be supported by adequate data and shall contain, at a minimum a summary of data upon which conclusions are based.

B. Location of active faults, including orientation and geometry of faults, amount of net slip along faults, anticipated future offset, and delineation of setback areas.

C. Degree of confidence in and limitations of data and conclusions.

(vi) *Recommendations*. Recommendations must be supported by adequate geologic data and appropriate reasoning behind each statement. Minimum recommendations shall include:

A. Recommended setback distances per Section 2.4. Supporting calculations must be included. Faults and setbacks must be shown on site maps and final recorded plat maps.

B. Other recommended building restrictions or use limitations (i.e., placement of detached garages, swimming pools, or other non-habitable structures).

C. Need for additional or future studies to confirm buildings are not sited across active faults, such as inspection of building footing or foundation excavations by the consultant.

2.6.2 Report references. Reports must include citations of literature and records used in the study, referenced aerial photographs or images interpreted (air-photo source, date and flight number, scale), and any other sources of data and information, including well logs, personal communications, etc.

2.6.3 Support information. At a *minimum*, each geologic report must include the following support information:

(i) *Location map*. A site location map depicting topographic and geographic features and other pertinent data. Generally a 1:24,000-scale USGS topographic base map will suffice.

(ii) *Geologic map*. A regional-scale map (1:24,000 to 1:50,000 scale) is generally adequate. Depending on site complexity, a site-scale geologic map (minimum 1 inch= 200 ft or more detailed) may also be necessary. The map should show Quaternary and bedrock geologic units, faults, seeps or springs, soil or bedrock slumps, and other geologic and soil features existing on and adjacent to the project site. Geologic cross-sections may be included as needed to illustrate 3-dimensional relationships.

(iii)*Site plan and fault map*. A detailed survey-grade site plan is required. The site plan shall be prepared and certified by a licensed surveyor. The site plan should be at a minimum scale of at least 1 inch = 200 feet and should clearly show site boundaries, proposed building footprints, existing structures, streets, slopes, drainages, exploratory trenches, boreholes, test pits, geophysical traverses, utilities, property lines, fences, slopes, trees, retaining walls, adjacent structures and any other appurtenant features. The site plan shall include the locations of subsurface investigations and site-specific geologic mapping performed as part of the geologic investigation, including boundaries and features related to any geologic hazards, topography, and drainage. The site map must also show the surface fault rupture hazard study area within the subject site the locations of all faults identified during the investigation conducted for the subject site including inferred location of the faults between trenches and must show all recommended setbacks from identified faults and from the ends of trenches located within the surface fault rupture hazard study area. The site map must show the location of all proposed flexible expansion joints for utilities. Both buildable and non-buildable areas shall be clearly identified. All features on the map shall be tied to a minimum of two public survey monuments tied with bearings and distances. The datum shall be submitted in US State Plane NAD83 (US Survey Feet) and wet-stamped by a licensed surveyor. The site map should include a legend describing pertinent items shown on the map.

(iv)*Exploratory trench logs*. Trench logs are required for each trench excavated as part of the study, whether faults are encountered or not. Trench logs shall accurately depict all observed geologic features and conditions. Trench logs are hand- or computer-generated maps of excavation walls that show details of geologic units and structures. Logs must be submitted with a scale and not be generalized or diagrammatic. The minimum scale is 1 inch = 5 feet (1:60) with no vertical exaggeration. Trench logs must accurately reflect the features observed in the trench (see Section 2.3.6). Photographs shall not be used as a substitute for trench logs. However, it is recommended that a photographic log of the trench also be created.

(v) *Contents of trench logs*. Trench logs shall include orientation and indication of which trench wall was logged; trench top and bottom; stratigraphic contacts; stratigraphic unit descriptions including lithology, USCS soil classification, genesis (geologic origin), age, and contact descriptions; soil (pedogenic) horizons; marker beds; and deformation or offset of sediments, faults, and fissures. Other features of tectonic significance such as buried scarp free-faces, colluvial wedges, in-filled soil cracks, drag folds, rotated clasts, lineations, and liquefaction features including dikes, sand blows, etc. should also be shown. Interpretations of the age and origin of the deposits and any faulting or deformation must be included, based on depositional sequence. Fault orientation and geometry (strike and dip), and amount of net displacement must be measured and noted. Provide evidence for the age determination of geologic units. For suspected Holocene faults where unfaulted Holocene deposits are deeper than practical excavation depths, clearly state the study limitations

(vi)*Exploratory boreholes and CPT soundings*. If boreholes or CPT soundings are utilized as part of the investigation, reports shall include the logs of the borings/soundings. Borehole logs must include lithology descriptions, interpretations of geologic origin, USCS soil classification or other standardized engineering soil classification (include an explanation of the classification scheme), sample intervals, penetrative resistance values , static ground-water depths and dates measured, total depth of borehole, and identity of the person logging the borehole. Electronic copies of CPT data files should be provided to the city's reviewer, upon request. Since boreholes are typically multipurpose, borehole logs should contain standard geotechnical and geologic data such as lithology descriptions, soil class, sampled intervals, sample recovery, blow-count results, static ground-water depths with dates measured, total depth of boreholes, drilling and sampling methods, and identity of the person logging the borehole. In addition, borehole, geoprobe hole, and cone-penetrometer logs for fault studies should include the geologic interpretation of deposit genesis for all layers. Also include boring logs or logs from other exploration techniques, when applicable, prepared with standard geologic nomenclature.

(vii) *Geophysical data*. All geophysical data, showing stratigraphic interpretations and fault locations, must be included in the report, along with correlations to trench or borehole logs to confirm interpretations.

(viii) *Photographs*. Photographs of scarps, trench walls, or other features that enhance understanding of site conditions and fault-related conditions are not required but should be included when deemed appropriate. Composite, rectified digital photographs of trench walls may be used as background for trench logs, but features as outlined in section F above must still be delineated.

(ix)*Type and number of buildings*. A description of the location and size of site and proposed type and number of buildings (if known) planned for the site.

(x) *Specific recommendations*. Specific recommendations consistent with the purposes set forth in Chapter 10.10A, including a discussion of the evidence establishing the presence or absence of faulting including ages and geologic origin of faulted and unfaulted stratigraphic units and surfaces. The discussion shall include the location of faults, including orientation and geometry of faults, maximum amounts of vertical displacement on faults, anticipated future offsets, calculation of setbacks, and delineation of setback (non-buildable) areas if applicable. Recommendations must be supported with geologic evidence and appropriate reasoning that is supported by industry standards. Other recommended building restrictions, use limitations, or risk-reduction measures such as placement of detached garages, swimming pools, or other non-habitable structures in fault zones, or use of reinforced foundations for small-displacement faults.

(xi)*Support data*. All data upon which recommendations and conclusions are based shall be clearly stated in the report. This includes a complete citations of literature and records used in the study including personal communications, published and unpublished geologic literature with emphasis on current sources that discuss Quaternary faults in the area, historical seismicity (particularly earthquakes attributed to area faults), and geodetic measurements where pertinent. A listing of aerial photographs used and other supporting information, as applicable.

(xii) *Suitability of the development*. A statement shall be provided regarding the suitability of the proposed development from a geologic hazard perspective.

(xiv) *Flexible expansion joints*. All sewer and water lines that cross any fault on the subject site shall be equipped with flexible expansion joints to prevent rupture and consequential damage in the event of an earthquake.

(xv) *Foundation excavation inspection*. Recommended inspection of building foundation excavations during construction to confirm surface and subsurface investigations.

(xvi) *Current signature and seal*. A current signature and seal of the investigating, Utah-licensed professional geologist(s). Qualifications giving education and experience in engineering geology and fault studies can be presented through a CV or resume format in the appendix of the report.

(xvii) *Conclusions*. Conclusions that are clearly supported by adequate data included in the report, that summarize the characteristics of observed surface fault rupture hazards, and that address the potential effects of all identified faults on the proposed development, particularly in terms of risk and potential damage. All other geologic hazards identified during the investigation should be discussed. A discussion regarding the degree of confidence and/or limitations of the data should also be included. Supporting data relevant to the investigation not given in the text such as cross-sections, conceptual models, fence diagrams, survey data, water-well data, and qualifications statements. Specific recommendations for additional or more detailed studies, as may be required to understand or quantify all geologic hazards identified at the subject site.

Table A-1. Setback recommendations and criticality factors (U) for IBC occupancy classes (International Code Council).

Class (IBC)	**Occupancy group**	**Criticality**	**U**	**Minimum setback**
A	Assembly	2	2.0	25 feet
B	Business	2	2.0	20 feet
E	Educational	1	3.0	50 feet
F	Factory/Industrial	2	2.0	20 feet
H	High Hazard	1	3.0	50 feet
I	Institutional	1	3.0	50 feet
M	Mercantile	2	2.0	20 feet
R	Residential (R-1, R-2, R-4)	2	2.0	20 feet
R-3	Residential (R-3, includes Single Family Homes)	3	1.5	15 feet
S		-	1	0
U		-	1	0
		1	3.0	50 feet

Table A-2

Additional Structures Requiring Geologic Investigation

A. Buildings and other structures that represent a substantial hazard to human life in the event of failure, but not limited to:

1. Buildings and other structures where more than 300 people congregate in one area.
2. Buildings and other structures with elementary school, secondary school or day care facilities with occupancy greater than 250.
3. Buildings and other structures with occupancy greater than 500 for colleges or adult education facilities.
4. Health care facilities with occupancy greater than 50 or more resident patients but not having surgery or emergency treatment facilities.
5. Jails and detention facilities.
6. Any other occupancy with occupancy greater than 1000.
7. Power generating stations, water treatment or storage for potable water, waste water treatment facilities and other public utility facilities.
8. Buildings and other structures containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.

B. Buildings and other structures designed as essential facilities including, but not limited to:

1. Hospitals and other care facilities having surgery or emergency treatment facilities.
2. Fire, rescue and police stations and emergency vehicle garages and fueling facilities.
3. Designated emergency shelters.
4. Designated emergency preparedness, communications, and operation centers and other facilities required for emergency response.
5. Power-generating stations and other public utility facilities required as emergency backup facilities for facilities and structures included in this table.
6. Structures containing highly toxic materials as defined by the most recently adopted version of the IBC where the quantity of the material exceeds the maximum allowable quantities defined by the most recently adopted version of the IBC.
7. Aviation control towers, air traffic centers and emergency aircraft hangars.
8. Buildings and other structures having critical national defense functions.
9. Water treatment and storage facilities required to maintain water pressure for fire suppression.

APPENDIX C

Minimum Standards for Slope Stability Analyses

Sensitive Lands Evaluation & Development Standards (SLEDS)
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1.0 INTRODUCTION

The procedures outlined in this appendix are intended to provide consultants with a general outline for performing quantitative slope stability analyses and to clarify the expectations of the city of FRUIT HEIGHTS CITY (the "*city*"). These standards constitute the minimum level of effort required in conducting quantitative slope stability analyses in the city. Considering the complexity inherent in performing slope stability analyses, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address slope stability. The information presented herein does not relieve consultants of their duty to perform additional geologic or engineering analyses they believe are necessary to assess the stability of slopes at a site.

The evaluation of landslides generally requires quantitative slope stability analyses. Therefore, the standards presented herein are directly applicable to landslide investigation, and also constitute the *minimum* level of effort when performing landslide investigations. This appendix does not address debris flows (*see* Appendix E) or rock falls (*see* Appendix F).

1.1 ***Purposes*****.** The purposes for establishing minimum standards for slope stability analyses are to:

(a) Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of unstable slopes and related hazards;

(b) Assist property owners and land developers in conducting reasonable and adequate slope stability studies;

(c) Provide consulting engineering geologists and geotechnical engineers with a common basis for preparing proposals, conducting investigations, and designing and implementing mitigation; and

(d) Provide an objective framework for regulatory review of slope stability reports.

1.2 ***References and Sources*****.** The minimum standards presented in this appendix were developed, in part, from the following sources:

(a) Guidelines for Evaluating Landslide Hazards in Utah (Hylland, 1996).

(b) Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California (Blake et al., 2002).

(c) CDMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California.

(d) Salt Lake County Geologic Hazards Ordinance (2002).

(e) FRUIT HEIGHTS CITY, Utah Code of Ordinances (2005).

(f) City of Draper, Utah, Title 9, Land Use and Development Code for Draper City, Chapter 9-19, Geologic Hazards Ordinance, December 11, 2007.

1.3 ***Areas Requiring Slope Stability Analyses*****.**

(a) Slope stability analyses shall be performed for all sites located within the Slope Stability Study Area Map and for all slopes that may be affected by the proposed development which meet the following criteria:

(i) Cut and/or fill slopes steeper than about 2 horizontal (h) to 1 vertical (v).

(ii) Natural slopes steeper than or equal to 3 horizontal (h) to 1 vertical (v).

(iii)Natural and cut slopes with potentially adverse geologic conditions (e.g. bedding, foliation, or other structural features that are potentially adverse to the stability of the slope).

(iv)Natural and cut slopes which include a geologic hazard such as a landslide, irrespective of the slope height or slope gradient.

(v) Buttresses and stability fills.

(vi)Cut, fill, or natural slopes of water-retention basins or flood-control channels.

(b) In hillside areas, investigations shall address the potential for surficial instability, debris/mudflows (see Appendix E), rock falls (see Appendix F), and soil creep on all slopes that may affect the proposed development or be affected by the proposed development.

(c) When evaluating site conditions to determine the need for slope stability analyses, off-property conditions shall be considered (both up-slope to the top(s) of adjacent ascending slopes and down-slope to and beyond the toe(s) of adjacent descending slopes). Also, the consultant shall demonstrate that the proposed hillside development will not affect adjacent sites or limit adjacent property owners' ability to develop their sites.

1.4 ***Roles of Engineering Geologist and Engineering*.**

The investigation of the static and seismic stability of slopes is an interdisciplinary practice. To provide greater assurance that the hazards are properly identified, assessed, and mitigated, involvement of both an engineering geologist and geotechnical engineer is required. Analyses shall be performed only by or under the direct supervision of licensed professionals, qualified and competent in their respective area of practice. An engineering geologist shall provide appropriate input to the geotechnical engineer with respect to the potential impact of the geology, stratigraphy, and hydrologic conditions on the stability of the slope. The shear strength and other geotechnical earth material properties shall be evaluated by the geotechnical engineer. All slope stability should be performed by a qualified and licensed engineer or under the purview of a licensed engineer. Ground motion parameters for use in seismic stability analysis may be provided by either the engineering geologist or geotechnical engineer.

2.0 GENERAL REQUIREMENTS

Except for the derivation of the input ground motion for pseudostatic and seismic deformation analyses (see Section 12), slope stability analyses and evaluations should be performed in general accordance with the latest version of Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Landslide Hazards in California (Blake et al., 2002). Procedures for developing input ground motions to be used in the city are described in Section 12.1.

3.0 SUBMITTALS

(a) Submittals for review shall include boring logs; geologic cross sections; trench and test pit logs; laboratory data (particularly shear strength test results, including individual stress-deformation plots from direct shear tests); discussions pertaining to how idealized subsurface conditions and shear strength parameters used for analyses were developed; analytical results, and summaries of the slope stability analyses and conclusions regarding slope stability.

(b) Subsurface geologic and groundwater conditions must be illustrated on geologic cross sections and must be utilized by the geotechnical engineer for the slope stability analyses. If on-site sewage or storm water disposal exists or is proposed, the slope stability analyses shall include the effects of the effluent plume on slope stability.

(c) The results of any slope stability analyses must be submitted with pertinent backup documentation (i.e., calculations, computer output, etc.). Printouts of input data, output data (if requested), and graphical plots must be submitted for each computer-aided slope stability analysis.

4.0 FACTORS OF SAFETY

The minimum acceptable static factor of safety is 1.5 for both gross and surficial slope stability. The minimum acceptable factor of safety for a *calibrated pseudostatic analysis* is 1.0 using the method of Stewart et al. (2003) (see Section 12.2).

5.0 LANDSLIDES

The evaluation of landslides generally requires quantitative slope stability analyses. Therefore, the standards presented herein are directly applicable to landslide investigation, and also constitute the minimum level of effort when performing landslide investigations. Evaluation of landslides shall be performed in the preliminary phase of hillside developments. Where landslides are present or suspected, sufficient subsurface exploration will be required to determine the basic geometry and stability of the landslide mass and the required stabilization measures. The depth of geologic exploration shall consider the regional geologic structure, the likely failure mode of the suspected failure, and past geomorphic conditions.

6.0 SITE INVESTIGATION AND GEOLOGIC STUDIES

(a) Adequate evaluation of slope stability for a given site requires thorough and comprehensive geologic and geotechnical engineering studies. These studies are a crucial component in the evaluation of slope stability. Geologic mapping and subsurface exploration are normal parts of field investigation. Samples of earth materials are routinely obtained during subsurface exploration for geotechnical testing in the laboratory to determine the shear strength parameters and other pertinent engineering properties.

(b) In general, geologic studies for slope stability consist of the following fundamental phases:

(i) Study and review of published and unpublished geologic information (both regional and site specific).

(ii) Review and interpretation of available stereoscopic and oblique aerial photographs, DEMs, and LiDAR data.

(iii) Geologic field mapping, including, but not necessarily limited to, measurement of bedding, foliation, fracture, and fault attitudes and other parameters.

(iv) Documentation and evaluation of subsurface groundwater conditions (including effects of seasonal and longer-term natural fluctuations as well as landscape irrigation), surface water, on-site sewage disposal, and/or storm water disposal.

(v) Subsurface exploration.

(vi) Analysis of the geologic failure mechanisms that could occur at the site (e.g., mode of failure and construction of the critical geologic cross sections).

(vii) Presentation and analysis of the data, including an evaluation of the potential impact of geologic conditions on the project.

(c) Geologic/geotechnical reports shall demonstrate that each of the phases described in subsection 6.0(b) has been adequately performed and that the information obtained has been considered and logically evaluated. Minimum criteria for the performance of each phase are described and discussed in Blake et al. (2002).

7.0 SUBSURFACE EXPLORATION

The purpose of subsurface exploration is to identify potentially significant geologic materials and structures at a site and to provide samples for detailed laboratory characterization of materials from potentially critical zones. Subsurface exploration is almost always required and may be performed by a number of widely known techniques such as bucket-auger borings, conventional small-diameter borings, cone penetration testing (CPT), test pits, trenches, and/or geophysical techniques (see section 4.2 of Blake et al., 2002). In general, subsurface explorations should extend to a minimum depth of the anticipated failure planes or 2/3 the maximum height of the slope, whichever is greater. A discussion of the applicability of some subsurface exploration techniques follows.

7.1 ***Trenching*****.** Subsurface exploration consisting of trenching has proven, in some cases, to be necessary when uncertainty exists regarding whether or not a particular landform is a landslide. Care must be exercised with this exploration method because landslides characteristically contain relatively large blocks of intact geologic units, which in a trench exposure could give the false impression that the geologic unit is "in-place." Although limited to a depth of about 15 feet below existing grades, trenching has also proven to be a useful technique for verifying margins of landslides, although the geometry of a landslide can generally be readily determined from evaluation of stereoscopic aerial photographs. Once a landslide is identified, conventional subsurface exploration drilling techniques will be required (see Section 7.2 and 7.3). Slope stability analyses based solely on data obtained from trenches will not be accepted.

7.2 ***Methods for Bedded Formations*****.**

(a) Conventional subsurface exploration techniques involving continuous core drilling with an oriented core barrel, test pits, and deep bucket-auger borings may be used to assess the subsurface soil and geologic conditions, particularly for geologic units with inclined bedding that includes weak layers.

(b) Particular attention must be paid to the presence or absence of weak layers (e.g.., clay, claystone, silt, shale, or siltstone units) during the exploration. Unless adequately demonstrated (through comprehensive and detailed subsurface exploration) that weak (clay, claystone, silt, shale, or siltstone) layers (even as thin as 1/16-inch or less) are not present, a weak layer shall be assumed to possibly occur anywhere in the stratigraphic profile (i.e., ubiquitous weak clay beds).

(c) The depth of the subsurface exploration must be sufficient to assess the conditions at or below the level of the deepest potential failure surface possessing a factor of 1.5 or less. A preliminary slope stability analysis may need to be performed to assist in the planning of the subsurface exploration program.

7.3 ***Other Geologic Units*****.** For alluvium, fill materials, or other soil units that do not contain weak interbeds, other exploration methods such as small-diameter borings (e.g., rotary wash or hollow-stem-auger) or cone penetration testing may be suitable.

8.0 SOIL PARAMETERS

Soil properties, including unit weight and shear strength parameters (cohesion and friction angle), may be based on conventional field and laboratory tests as well as on field performance. Where appropriate (i.e., for landslide slip surfaces, along bedding planes, for surficial stability analyses, etc.), laboratory tests for saturated, residual shear strengths must be performed. Estimation of the shear resistance along bedding (or landslide) planes normally requires an evaluation of saturated residual along-bedding-strength values of the weakest interbedded (or slide-plane) material encountered during the subsurface exploration, or in the absence of sufficient exploration, the weakest material that may be present, consistent with site geologic conditions. Strength parameters derived solely from CPT data may not be appropriate for slope-stability analysis in some cases, particularly for strengths along existing slip surfaces where residual strengths have developed. Additional guidance on the selection of strength parameters for slope stability analyses is contained in Blake et al. (2002).

8.1 ***Residual Shear Strength Parameters*****.** Residual strength parameters may be determined using the direct shear or ring shear testing apparatus; however, ring shear tests are preferred. If performed properly, direct shear test results may approach ring-shear test results. The soil specimen must be subjected to a sufficient amount of deformation (e.g., a significant number of shearing cycles in the direct shear test or a significant amount of rotation in the ring shear test) to assure that residual strength has been developed. In the direct-shear and ring-shear tests, stress-deformation curves can be used to determine when a sufficient number of cycles of shearing have been performed by showing that no further significant drop in shear strength results with the addition of more cycles or more rotation. The stress-deformation curves obtained during the shear tests must be submitted with the other laboratory test results. It shall be recognized that for most clayey soils, the residual shear strength envelope is curved and passes through the origin (i.e., at zero normal stress there is zero shear strength). Any "apparent shear strength" increases resulting from a non-horizontal shear surface (i.e., ramping) or "bulldozing" in residual direct shear tests shall be discounted in the interpretation of the strength parameters.

8.2 ***Interpretation*****.**

(a) The engineer will need to use considerable judgment in the selection of appropriate shear test methods and in the interpretation of the results to develop shear strength parameters commensurate with slope stability conditions to be evaluated. Scatter plots of shear strength data may need to be presented to allow for assessment of idealized parameters. The report shall summarize shear strength parameters used for slope stability analyses and describe the methodology used to interpret test results and estimate those parameters.

(b) Peak shear strengths may be used to represent across-bedding failure surfaces or compacted fill, in situations where strength degradations are not expected to occur (see guidelines in Blake et al., 2002). Where peak strengths cannot be relied upon, fully softened (or lower) strengths shall be used.

(c) Ultimate shear strength parameters shall be used in static slope stability analyses when there has *not* been past deformation. Residual shear strength parameters shall be used in static slope stability analyses when there has been past deformation.

(d) Averaged strength parameters may be appropriate for some across-bedding conditions, if sufficient representative samples have been carefully tested. Analyses for along-bedding or along-existing-landslide slip surfaces shall be based on lower-bound interpretations of residual shear strength parameters and comparison of those results to correlations, such as those of Stark et al. (2005).

9.0 SOIL CREEP

(a) The potential effects of soil creep shall be addressed where any proposed structure is planned in close proximity to an existing fill slope or natural slope. The potential effects on the proposed development shall be evaluated and mitigation measures proposed, including appropriate setback recommendations. Setback recommendations shall consider the potential affects of creep forces.

(b) All reports in hillside areas shall address the potential for surficial instability, debris/mudflow (Appendix E), rock falls (Appendix F), and soil creep on all slopes that may affect the proposed development or be affected by the proposed development. Stability of slopes along access roads shall be addressed.

10.0 GROSS STATIC STABILITY

Gross stability includes rotational and translational deep-seated failures of slopes or portions of slopes existing within or outside of but potentially affecting the proposed development. The following guidelines, in addition to those in Blake et al. (2002), shall be followed when evaluating slope stability:

(a) Stability shall be analyzed along cross sections depicting the most adverse conditions (e.g., highest slope, most adverse bedding planes, shallowest likely ground water table, and steepest slope). Often analyses are required for different conditions and for more than one cross section to demonstrate which condition is most adverse. When evaluating the stability of an existing landslide, analyses must also address the potential for partial reactivation. Inclinometers may be used to help determine critical failure surfaces and, along with high-resolution GPS, the state of activity of existing landslides. The critical failure surfaces on each cross-section shall be identified, evaluated, and plotted on the large-scale cross section.

(b) If the long-term, static factor of safety is less than 1.5, mitigation measures will be required to bring the factor of safety up to the required level or the project may be redesigned to achieve a minimum factor of safety of 1.5.

(c) The temporary stability of excavations shall be evaluated and mitigation measures shall be recommended as necessary to obtain a minimum factor of safety of 1.3.

(d) Long-term stability shall be analyzed using the highest known or anticipated groundwater level based upon a groundwater assessment performed under the requirements of Section 6.0.

(e) Where back-calculation is appropriate, shear strengths utilized for design shall be no higher than the lowest strength computed using back calculation. If a consultant proposes to use shear strengths higher than the lowest back-calculated value, justification shall be required. Assumptions used in back-calculations regarding pre-sliding topography and groundwater conditions at failure must be discussed and justified.

(f) Reports shall describe how the shear strength testing methods used are appropriate in modeling field conditions and long-term performance of the subject slope. The utilized design shear strength values shall be justified with laboratory test data and geologic descriptions and history, along with past performance history, if known, of similar materials.

(g) Reports shall include shear strength test plots consisting of normal stress versus shear resistance (failure envelope). Plots of shear resistance versus displacement shall be provided for all residual and fully softened (ultimate) shear tests.

(h) The degree of saturation for all test specimens shall be reported. Direct shear tests on partially saturated samples may grossly overestimate the cohesion that can be mobilized when the material becomes saturated in the field. This potential shall be considered when selecting shear strength parameters. If the rate of shear displacement exceeds 0.005 inches per minute, the consultant shall provide data to demonstrate that the rate is sufficiently slow for drained conditions.

(i) Shear strength values higher than those obtained through site-specific laboratory tests generally will not be accepted.

(j) If direct shear or triaxial shear testing is not appropriate to model the strength of highly jointed and fractured rock masses, the design strengths shall be evaluated in a manner that considers overall rock mass quality and be consistent with rock mechanics practice.

(k) Shear strengths used in slope stability analyses shall be evaluated considering the natural variability of engineering characteristics inherent in earth materials. Multiple shear tests on each site material will typically to be required.

(l) Direct shear tests do not always provide realistic strength values (Watry and Lade, 2000). Correlations between liquid limit, percent clay fraction, and strength (fully softened and residual) with published data (e.g., Stark and McCone, 2002) shall be performed to verify tested shear strength parameters. Strength values used in analyses that exceed those obtained by the correlation must be appropriately justified.

(m) Shear strengths for proposed fill slopes shall be evaluated using samples mixed and remolded to represent anticipated field conditions. Confirming strength testing may be required during grading.

(n) Where bedding planes are laterally unsupported on slopes, potential failures along the unsupported bedding planes shall be analyzed. Similarly, stability analyses shall be performed where bedding planes form a dip-slope or near-dip-slope using composite potential failure surfaces that consist of potential slip surfaces along bedding planes in the upper portions of the slope in combination with slip surfaces across bedding planes in the lower portions of the slope.

(o) The stability analysis shall include the effect of expected maximum moisture conditions on soil unit weight.

(p) For effective stress analyses, measured groundwater conditions adjusted to consider likely unfavorable conditions with respect to anticipated future groundwater levels, seepage, or pore pressure shall be included in the slope stability analyses.

(q) Tension crack development shall be considered in the analyses of potential failure surfaces. The height and location of the tension crack shall be determined by searching.

(r) Anticipated surcharge loads as well as external boundary pressures from water shall be included in the slope stability evaluations, as deemed appropriate.

(s) Analytical chart solutions may be used provided they were developed for conditions similar to those being analyzed. Generally though, computer-aided searching techniques shall be used, so that the potential failure surface with the lowest factor of safety can be located. Examples of typical searching techniques are illustrated on figures 9.1(a) through 9.1(f) in Blake et al. (2002). However, verification of the reasonableness of the analytical results is the responsibility of the geotechnical engineer and/or engineering geologist.

(t) The critical potential failure surface used in the analysis may be composed of circles, wedges, planes, or other shapes considered designed to yield the minimum factor of safety most appropriate for the geologic site conditions. The critical potential failure surface having the lowest factor of safety with respect to shearing resistance must be sought. Both the lowest factor of safety and the critical failure surface shall be documented.

11.0 SURFICIAL STABILITY OF SLOPES

Surficial slope stability refers to slumping and sliding of near-surface sediments and is most critical during the snowmelt and rainy season or when excessive landscape water is applied. The assessment of surficial slope stability shall be based on analysis procedures for stability of an infinite slope with seepage parallel to the slope surface or an alternate failure mode that would produce the minimum factor of safety. The minimum acceptable depth of saturation for surficial stability evaluation shall be four feet.

11.1 ***Applicability and Procedures*.**

(a) Conclusions shall be substantiated with appropriate data and analyses. Residual shear strengths comparable to actual field conditions shall be used in completing surficial stability analyses. Surficial stability analyses shall be performed under rapid draw-down conditions where appropriate (e.g., for debris and detention basins).

(b) Where 2:1 or steeper slopes have soil conditions that can result in the development of an infinite slope with parallel seepage, calculations shall be performed to demonstrate that the slope has a minimum static factor of safety of 1.5, assuming a fully saturated 4-foot thickness. If conditions will not allow the development of a slope with parallel seepage, surficial slope stability analyses may not be required (provided the geologic/geotechnical reviewer concurs).

(c) Surficial slope stability analyses shall be performed for fill, cut, and natural slopes assuming an infinite slope with seepage parallel to the slope surface or other failure mode that would yield the minimum factor of safety against failure. A suggested procedure for evaluating surficial slope stability is presented in Blake et al. (2002).

11.2 ***Soil Properties*****.** Soil properties used in surficial stability analyses shall be determined as noted in Section 8.1. For sites with deep slip surfaces, the guidelines given by Blake et al. (2002) should be followed.

11.3 ***Seepage Conditions*****.** The minimum acceptable vertical depth for which seepage is parallel to the slope shall be applied is four feet for cut or fill slopes. Greater depths may be necessary when analyzing natural slopes that have significant thicknesses of loose surficial material.

12.0 SEISMIC SLOPE STABILITY

In addition to static slope stability analyses, slopes shall be evaluated for seismic slope stability as well. Acceptable methods for evaluating seismic slope stability using calibrated pseudo-static limit-equilibrium procedures and simplified methods (e.g., those based on Newmark, 1965) to estimate permanent seismic slope movements are summarized in Blake et al. (2002). Nonlinear, dynamic finite element/finite difference numerical methods also may be used to evaluate slope movements resulting from seismic events as long as the procedures, input data, and results are thoroughly documented, and deemed acceptable by the city.

12.1 ***Ground Motion for Pseudo-static and Seismic Deformation Analyses*****.**

(a) The controlling fault that would most affect the city is the Salt Lake City segment of the Wasatch fault zone (WFZ). Repeated Holocene movement has been well documented along this segment (Black et al., 2003). Studies along the Salt Lake City segment of the WFZ indicate a recurrence interval of about 1,300 years and the most recent event being about 1,300 years ago (Lund, 2005). Based on the paleoseismic record of the Salt Lake City segment and assuming a time-dependent model, McCalpin (2002) estimates a conditional probability (using a log-normal renewal model) of 16.5% in the next 100 years (8.25% in the next 50 years) for a M>7 surface-faulting earthquake. Therefore, using a time-dependent rather than Poisson or random model for earthquake recurrence, the likelihood of a large surface-faulting earthquake on the Salt Lake City segment of the WFZ is relatively high and therefore the Salt Lake City segment is considered the primary controlling fault for deterministic analyses.

(b) Regarding design ground accelerations for seismic slope-stability analyses, the city prefers a probabilistic approach to determining the likelihood that different levels of ground motion will be exceeded at a particular site within a given time period. In order to more closely represent the seismic characteristics of the WFZ and better capture this possible high likelihood of a surface-faulting earthquake on the Salt Lake City segment, design ground motion parameters for seismic slope stability analyses shall be based on the peak accelerations with a 2.0 percent probability in 50 years (2,500-year return period). Peak bedrock ground motions can be readily obtained via the internet from the United States Geological Survey (USGS) National Seismic Hazard Maps, Data and Documentation web page (USGS, 2002), which is based on Frankel et al., 2002. PGAs obtained from the USGS (2002) web page should be adjusted for effects of soil/rock (site-class) conditions in accordance with Seed et al. (2001). Site specific response analysis may also be used to develop PGA values as long as the procedures, input data, and results are thoroughly documented, and deemed acceptable by the city.

12.2 *Pseudo-Static Evaluations*.

(a) Pseudo-static methods for evaluating seismic slope stability are acceptable as long as minimum factors of safety are satisfied, and appropriate consideration is given in the selection of the seismic coefficient, kh, reduction in material shear strengths, and the factor of safety for pseudo-static conditions.

(b) Pseudo-static seismic slope stability analyses can be performed using the “screening analysis” procedure described in Blake et al. (2002). For that procedure a kh-value is selected from seismic source characteristics (modal magnitude, modal distance, and firm rock peak ground acceleration) and an acceptable level of deformation is specified. For this procedure, a factor of safety of 1.0 or greater is considered acceptable; otherwise, an analysis of permanent seismic slope deformation shall be performed.

12.3 *Permanent Seismic Slope Deformation*.

(a) For seismic slope stability analyses, estimates of permanent seismic displacement are preferred and may be performed using the procedures outlined in Blake et al. (2002). It should be noted that Bray and Rathje (1998), referenced in Blake et al. (2002), has been updated and superseded by Bray and Travasarou (2007), which is the city’s currently preferred method. For these analyses, calculated seismic displacements shall be 15 cm or less, or mitigation measures shall be proposed to limit calculated displacements to 15 cm or less.

(b) For specific projects, different levels of tolerable displacement may be possible, but site-specific conditions, which shall include the following, must be considered:

(i) The extent to which the displacements are localized or broadly distributed – broadly distributed shear deformations would generally be less damaging and more displacement could be allowed.

(ii) The displacement tolerance of the foundation system – stiff, well-reinforced foundations with lateral continuity of vertical support elements would be more resistant to damage (and hence could potentially tolerate larger displacements) than typical slabs-on-grade or foundation systems with individual spread footings.

(iii)The potential of the foundation soils to experience strain softening – slopes composed of soils likely to experience strain softening should be designed for relatively low displacements if peak strengths are used in the evaluation of *ky* due to the potential for progressive failure, which could involve very large displacements following strain softening.

(c) In order to consider a threshold larger than 15 cm, the project consultant shall provide prior, acceptable justification to the city and obtain the city’s approval. Such justification shall demonstrate, to the city’s satisfaction, that the proposed project will achieve acceptable performance.

13.0 WATER RETENTION BASINS AND FLOOD CONTROL CHANNELS

For cut, fill, or natural slopes of water-retention basins or flood-control channels, slope stability analyses shall be performed. In addition to analyzing typical static and seismic slope stability, those analyses shall consider the effects of rapid drawdown, if such a condition could develop. All proposed structures should be permitted under Utah Dam Safety rules, as applicable.

14.0 MITIGATION

(a) When slope stability hazards are determined to exist on a project, measures to mitigate impacts from those hazards shall be implemented. Some guidance regarding mitigation measures is provided in Blake et al. (2002). Slope stability mitigation methods include:

(i) hazard avoidance,
(ii) grading to improve slope stability,
(iii)reinforcement of the slope or improvement of the soil within the slope, and
(iv)reinforcement of the structure built on the slope to tolerate anticipated slope displacements.

(b) Where mitigation measures that are intended to add stabilizing forces to the slope are to be implemented, consideration should be given to strain compatibility.

14.1 ***Full Mitigation*****.** Full mitigation of slope stability hazards shall be performed for developments in the city. Remedial measures that produce static factors of safety in excess of 1.5 and acceptable seismic displacement estimates shall be implemented as needed.

14.2 ***Partial Mitigation for Seismic Displacement Hazards*****.** On some projects, or portions thereof (such as small structural additions, residential "infill projects", non-habitable structures, and non-structural natural-slope areas), full mitigation of seismic slope displacements may not be possible, due to physical or economic constraints. In those cases, partial mitigation, to the extent that it prevents structural collapse, injury, and loss of life, may be possible if it can be provided consistent with IBC philosophies, and if it is approved by the city. The applicability of partial mitigations to specific projects will be evaluated on a case-by-case basis.

15.0 NOTICE OF GEOLOGIC HAZARD AND WAIVER OF LIABILITY.

For developments where full mitigation of seismic slope displacements is not implemented, a Notice of Geologic Hazard shall be recorded with the proposed development describing the displacement hazard at issue and the partial mitigation employed. The Notice shall clearly state that the seismic displacement hazard at the site has been reduced by the partial mitigation, but not totally eliminated. The Notice also shall provide that the owner assumes all risks, waives all claims against the city and its consultants, and indemnifies and holds the city and its consultants harmless from any and all claims arising from the partial mitigation of the seismic displacement hazard.

APPENDIX C - REFERENCES

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APPENDIX D

Minimum Standards for Liquefaction Investigations and Evaluations

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

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1.0 INTRODUCTION

The procedures outlined in this Appendix D are intended to provide consultants with a general outline for performing liquefaction studies and to specify the city's expectations concerning such studies. These standards constitute the ***minimum*** level of effort required in conducting liquefaction studies in the city. Considering the complexity inherent in performing liquefaction studies, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address the liquefaction potential at the site. The information presented in this Appendix D does not relieve consultants of their duty to perform additional geologic or geotechnical engineering analyses that is required by the city or otherwise reasonably necessary to adequately assess the liquefaction potential at a site.

1.1 ***Purposes*.** The purposes of establishing minimum standards for liquefaction investigations in the city are to:

(a) Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of liquefaction and related hazards;

(b) Assist property owners and land developers in conducting reasonable and adequate studies;

(c) Provide consulting engineering geologists and geotechnical engineers with a common basis for preparing proposals, conducting studies, and mitigation; and

(d) Provide an objective framework for regulatory review of liquefaction study reports.

1.2 ***References and Sources***. The minimum standards presented herein were developed, in part, from the following sources:

(a) CDMG Special Publication 117, Guidelines for evaluating and mitigating seismic hazards in California (1997).

(b) Recommended procedures for implementation of DMG special publication 117, guidelines for analyzing and mitigating liquefaction hazards in California (Martin and Lew, 1999).

(c) Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Technical Report NCEER-97-0022 (Youd and Idriss, 1997).

(d) Liquefaction Resistance of Soils: Summary Report from the 1996 and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, Journal of Geotechnical and Environmental Engineering, (Youd et al., 2001).

(e) Salt Lake County geologic hazards ordinance (2002).

(f) Southern California Earthquake Center (1999), Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for analyzing and mitigating liquefaction in California.

1.3 ***Properties Requiring Liquefaction Analyses***. The Liquefaction Hazard Study Area Map (Map 3 in Appendix A of Chapter 10.10A of this code) depicts generalized liquefaction susceptibility for the city, and shall be used to determine whether or not a site-specific liquefaction assessment is required for a particular project.

(a) The Liquefaction Hazard Study Area Map is based on a regional-scale investigation of Salt Lake County; therefore, the liquefaction potential at a specific site may be different (higher or lower) than the liquefaction potential suggested by the map. Such map may not identify all areas that have potential for liquefaction; a site located outside of an area of required study is not necessarily free from liquefaction hazard, and the study areas do not always include lateral spread run-out areas. The Liquefaction Hazard Study Area Map is available from the city's planning department.

(b) Chapter 10.10A requires a site-specific liquefaction study to be performed prior to approval of a project based on the liquefaction potential. The liquefaction potential for each individual soil layer in a CPT sounding or at the sampling frequency interval in a boring should be assessed. If the factor of safety for liquefaction is less than 1, then an estimate of the settlement for each layer should be completed. The total anticipated settlement should be defined in the analysis and report. All liquefaction analyses should be completed in accordance with DMG Special Publication 117 (1999), as amended or superceded.

1.4 ***Roles of Engineering Geology and Geotechnical Engineering***.

(a) The study of liquefaction hazard is an interdisciplinary practice. The site investigation report must be prepared by a qualified engineering geologist or geotechnical engineer, who must have competence in the field of seismic hazard evaluation and mitigation, and be reviewed by a qualified geotechnical engineer, also competent in the field of seismic hazard evaluation and mitigation.

(b) Because of the differing expertise and abilities of qualified engineering geologists and geotechnical engineers, the scope of the site investigation report for the project may require that both types of professionals prepare and review the report, each practicing in the area of their expertise. Involvement of both a qualified engineering geologist and geotechnical engineer will generally provide greater assurance that the hazard is properly identified, assessed, and mitigated.

(c) Liquefaction analyses are the responsibility of the geotechnical engineer, although the engineering geologist should be involved in the application of screening criteria (section 3.0, steps 1 and 2) and general geologic site evaluation (section 4.1) to map the likely extent of liquefiable deposits and shallow groundwater. Engineering properties of earth material shall be evaluated by the geotechnical engineer. The performance of the quantitative liquefaction analysis resulting in a numerical factor of safety and quantitative assessment of settlement and liquefaction-induced permanent ground displacement shall be performed by geotechnical engineers. The geotechnical and civil engineers shall develop all mitigation and design recommendations. Ground motion parameters for use in quantitative liquefaction analyses may be provided by either the engineering geologist or the geotechnical engineer.

1.5 ***Minimum Qualifications of the Licensed Professional***. Liquefaction analyses must be performed by engineering geologists and geotechnical engineers, qualified as provided in Chapter 10.10A.

2.0 GENERAL REQUIREMENTS

Except for the derivation of input ground motion (see Section 5.0, below), liquefaction studies should be performed in general accordance with the latest version of Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California (Martin and Lew, 1999). Additional protocol for liquefaction studies is provided in Youd and Idriss (1997), cited above.

3.0 PRELIMINARY SCREENING FOR LIQUEFACTION

(a) The Liquefaction Hazard Study Area Map is based on broad regional studies and does not replace site-specific studies. The fact that a site is located within a Liquefaction Hazard Study Area does not mean that there is a significant liquefaction potential at the site, only that a study shall be performed to determine if such potential is present.

(b) Soil liquefaction is caused by strong seismic ground shaking where saturated, cohesionless, granular soil undergoes a significant loss in shear strength that can result in settlement and permanent ground displacement. Surface effects of liquefaction include settlement, bearing capacity failure, ground oscillations, lateral spread and flow failure. It has been well documented that soil liquefaction may occur in clean sands, silty sands, sandy silt, non-plastic silts and gravelly soils. Research shows that the following conditions must be present for liquefaction to occur:

(i) Soils *must be* submerged below the water table;
(ii) Soils *must be* loose to moderately dense;
(iii) Ground shaking *must be* relatively intense; and
(iv) The duration of ground shaking *must be* sufficient for the soils to generate seismically-induced excess pore water pressure and lose their shearing resistance.

(c) The following screening criteria may be applied to determine if further quantitative evaluation of liquefaction hazard is required:

(i) If the estimated maximum past, current, and future groundwater levels (i.e., the highest groundwater level applicable for liquefaction analyses) are determined to be deeper than 50 feet below the existing ground surface or proposed finished grade (whichever is deeper), liquefaction studies are not required. For soil materials that are located above the level of the groundwater, a quantitative assessment of seismically induced settlement is required.

(ii) If "bedrock" or similar lithified formational material underlies the site, those materials need not be considered liquefiable and no analysis of their liquefaction potential is necessary.

(iii) If the corrected standard penetration blow count, (N1)60, is greater than or equal to 33 in all samples with a sufficient number of tests, liquefaction assessments are not required. If cone penetration test soundings are made, the corrected cone penetration test tip resistance, qc1N, should be greater than or equal to 180 tsf in all soundings in sand materials, otherwise liquefaction assessments are needed.

(d) If plastic soil (PI $\geq$ 20) materials are encountered during site exploration, those materials may be considered non-liquefiable. Additional acceptable screening criteria regarding the effects of plasticity on liquefaction susceptibility are presented in Boulanger and Idriss (2004), Bray and Sancio (2006), and Seed and others (2003).

(e) If the screening investigation clearly demonstrates the absence of liquefaction hazards at a project site and the City concurs, the screening investigation will satisfy the site study report requirement for liquefaction hazards. If not, a quantitative evaluation is required to assess the liquefaction hazards.

(f) An important part of a liquefaction analysis is the potential for lateral spreading. Any open face and/or sloped sites should be assessed for the potential for lateral spreading. Mitigation measures should be provided in the analysis and report with respect to this hazard.

4.0 FIELD INVESTIGATIONS

Geotechnical field investigations are routinely performed for new projects as part of the normal development and design process. Geologic reconnaissance and subsurface explorations are normally performed as part of the field exploration program even when liquefaction does not need to be investigated.

4.1 ***Geologic Reconnaissance***.

(a) Geologic research and reconnaissance are important to provide information to define the extent of unconsolidated deposits that may be prone to liquefaction. Such information should be presented on geologic maps and cross sections and provide a description of the formations present at the site that includes the nature, thickness, and origin of Quaternary deposits with liquefaction potential. There also should be an analysis of groundwater conditions at the site that includes the highest recorded water level and the highest water level likely to occur under the most adverse foreseeable conditions in the future.

(b) During the field investigation, the engineering geologist should map the limits of unconsolidated deposits with liquefaction potential. Liquefaction typically occurs in cohesionless silt, sand, and fine-grained gravel deposits of Holocene to late Pleistocene age in areas where the groundwater is shallower than about 50 feet.

(c) Shallow groundwater may exist for a variety of reasons, some of which are of natural and or manmade origin. Landscape irrigation, on-site sewage disposal, and unlined manmade lakes reservoirs, and storm-water detention basins may create a shallow groundwater table in sediments that were previously unsaturated.

4.2 ***Subsurface Explorations***.

(a) Subsurface exploratins shall consist of drilled-borings and/or cone penetration tests (CPTs). The exploration program shall be planned to determine the soil stratigraphy, groundwater level, and indices that could be used to evaluate the potential for liquefaction by either in situ testing or by laboratory testing of soil samples. Borings and CPT soundings must penetrate a minimum of 50 feet below final ground surface.

(b) For saturated cohesionless soils where the SPT (N1)60 values are less than 15, or where CPT tip resistances are below 60 tsf, grain-size analyses, hydrometers tests, and Atterberg Limits tests shall be performed on these soils to further evaluate their potential for permanent ground displacement (Youd et al., 2002) and other forms of liquefaction-induced ground failure and settlement. In addition, it is also recommended that these same tests be performed on saturated cohesionless soils with SPT (N1)60 values between 15 and 30 to further evaluate the potential for liquefaction-induced settlement.

(c) Where a structure may have subterranean construction or deep foundations (e.g., caissons or piles), the depth of investigation should extend to a depth that is a minimum of 20 feet (6 m) below the lowest expected foundation level (e.g., caisson bottom or pile tip) or 50 feet (15 m) below the existing ground surface or lowest proposed finished grade, whichever is deeper. If, during the study, the indices to evaluate liquefaction indicate that the liquefaction potential may extend below that depth, the exploration should be continued until a significant thickness (at least 10 feet or 3 m, to the extent possible) of nonliquefiable soils are encountered.

5.0 GROUND MOTION FOR LIQUEFACTION SUSCEPTIBILITY AND GROUND DEFORMATION ANALYSES

(a) The two controlling faults that would most affect the city are the Salt Lake City and Provo segments of the Wasatch Fault Zone (WFZ). Repeated Holocene movement has been well documented along both segments (Black and others, 2003). Studies along the Provo segment of the WFZ indicate a recurrence interval of about 1150 years (Olig, and others, 2006; later revised, Olig, 2007) and the most recent event being about 500 to 650 years ago (Black and others, 2003; Olig, and others, 2006). Studies along the Salt Lake City segment of the WFZ indicate a recurrence interval of about 1300 years and the most recent event being about 1300 years ago (Lund, 2005). Based on the paleoseismic record of the Salt Lake City segment and assuming a time-dependent model, McCalpin (2002) estimates a conditional probability (using a log-normal renewal model) of 16.5% in the next 100 years (8.25% in the next 50 years) for a M>7 surface-faulting earthquake. Therefore, using a time-dependent rather than Poisson or random model for earthquake recurrence, the likelihood of a large surface-faulting earthquake on the Salt Lake City segment of the WFZ is relatively high and therefore the Salt Lake City segment is considered the primary controlling fault for deterministic analyses.

(b) Concerning design ground accelerations for liquefaction analyses, the city prefers a probabilistic approach to determining the likelihood that different levels of ground motion will be exceeded at a particular site within a given time period. In order to more closely represent the seismic characteristics of the WFZ and to better capture this possible high likelihood of a surface-faulting earthquake on the Salt Lake City segment, design ground motion parameters for liquefaction analyses shall be based on the peak accelerations with a 2.0 percent probability in 50 years (2,500-year return period). Peak bedrock ground motions can be readily obtained via the internet from the United States Geological Survey (USGS) National Seismic Hazard Maps, Data and Documentation web page (USGS, 2002), which is based on Frankel and others (2002). PGAs obtained from the USGS (2002) web page should be adjusted for effects of soil/rock (site-class) conditions in accordance with Seed and others (2001) or other appropriate methods that consider the site-specific soil conditions and their potential for amplification/ deamplification of the high frequency strong motion.

6.0 REMEDIAL DESIGN

Sites, facilities, buildings, structures and utilities that are founded on or traverse liquefiable soils may require further remedial design and/or relocation to avoid liquefaction-induced damage. These should be investigated and evaluated on a site-specific basis with sufficient geologic and geotechnical evaluations to support the remedial design and/or mitigative plan. This design or plan may include changes/modifications to the soil, foundation system, structural frame or support of the building, etc. and should be reviewed and approved by the city.

7.0 SUBMITTALS

(a) Submittals for review shall include boring logs; geologic cross-sections; laboratory data; discussions pertaining to how idealized subsurface conditions and parameters used for analyses were developed; analytical results, including computer output files (on request); and summaries of the liquefaction analyses and conclusions regarding liquefaction potential and likely types and amounts of ground failure.

(b) Subsurface geologic and groundwater conditions must be illustrated on geologic cross-sections and must be utilized by the geotechnical engineer for the liquefaction analyses. If on-site sewage or storm-water disposal exists or is proposed, the liquefaction analyses shall include the effects of the effluent plume on liquefaction potential.

(c) The results of any liquefaction analyses must be submitted with pertinent backup documentation (i.e., calculations, computer output, etc.). Printouts of input data, output data (on request), and graphical plots must be submitted for each computer-aided liquefaction analysis. In addition, input data files, recorded on diskettes, CDs, or other electronic media, may be requested to facilitate the city's review.

APPENDIX E

Minimum Standards for Debris Flow Hazard Studies

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

Debris-flow reports shall follow general guidance contained in "Guidelines for the geologic evaluation of debris-flow hazards on alluvial fans in Utah," Utah Geological Survey Miscellaneous Publication 05-6. Debris-flow hazard analyses and mitigation measures may require contributions from hydrologists as well as qualified engineering geologists and geotechnical engineers.

APPENDIX F

Minimum Standards for Rock Fall Hazard Studies

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

Useful methods to evaluate rock-fall hazards are outlined in: Evans, S.G., and Hungr, O., 1993, The assessment of rockfall hazard at the base of talus slopes: Canadian Geotechnical Journal, v. 30, p. 620-636; Jones, C.L., Higgins, J.D., and Andrew, R.D., 2000, Colorado rockfall simulation program, version 4.0: Report prepared for the Colorado Department of Transportation, 127 p.; and Wieczorek, G.F., Morrissey, M.M., Iovine, G., and Godt, J., 1998, Rock-fall hazards in the Yosemite Valley: U.S. Geological Survey Open-File Report 98-467, 7 p., 1 pl., scale 1:12,000. Rock-fall studies shall be prepared by a qualified engineering geologist and may require contributions from a qualified geotechnical engineer, particularly in the design of mitigation measures.

APPENDIX G

Groundwater Source Protection

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

Groundwater source protection requirements in the city are contained in Chapter 17.30, FRUIT HEIGHTS CITY CODE OF ORDINANCES.

APPENDIX H

Foundation Excavation Observation Standards

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

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1.0 INTRODUCTION

1.1 ***Introduction***. The procedures contained in this appendix are intended to provide consultants with a general outline for performing quantitative foundation excavation observation studies and reports for the development of structures within FRUIT HEIGHTS CITY (the "*city*"). These standards constitute the minimum level of effort required in conducting these studies. The information presented herein does not relieve consultants of their duty to identify and perform additional geologic or engineering analyses they believe are necessary to assess the suitability of development at a site.

1.2 ***Purposes***. The purposes for establishing minimum standards for foundation excavation observation studies are to:

(a) Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of development on unsuitable soils and/or high groundwater;

(b) Assist property owners, contractors and land developers in conducting reasonable and adequate foundation excavation observation studies; and

(c) Ensure that the recommendations from the subdivision's geotechnical soils investigation are followed. If no report exists, ensure that a licensed engineer observes the foundation excavation and performs any necessary analyses to determine the suitability of the soils for the proposed building. The engineer shall report that the site is suitable for the proposed structure and that all recommended mitigation has been performed to render the site buildable.

1.3 ***Areas requiring foundation excavation observation reports*.** A foundation excavation observation report shall be performed for all proposed development or redevelopment within the city.

1.4 ***Roles of professionals*.** Analyses of soils that shall support a structure shall be performed only by or under the direct supervision of licensed professionals, qualified and competent in their respective area of practice.

2.0 GENERAL REQUIREMENTS

The expertise of qualified professional engineers, retained at the developer's cost, is required to verify the suitability of the soil for the construction of a proposed structure and ensure that the actual *in-situ* soil material is consistent with previous reports and ensure that the recommendations from those reports have been followed. If no previous reports have been prepared, an engineer shall make appropriate analyses of the *in-situ* material to determine the suitability of the site for construction and report that all necessary mitigation measures have been performed.

3.0 SUBMITTALS

3.1 ***Explanatory letter***. A letter that states that the site is suitable for development shall be accompanied by an appendix with all pertinent data that was used to determine the suitability of the site for development, include boring logs; geologic cross sections; trench and test pit logs; laboratory data (Atterberg limits, plasticity, soil classification, soil bearing capacity, shear strength test results, density test results etc.); and a discussion regarding the suitability of the site for development. The appendix will contain recommendations for the footings and foundation of the structure such as backfill requirements, additional compaction, drainage, elevation, pilings, bedrock, or any other mitigation measure to meet current building codes, ensure adequate soil bearing capacity, prevent flooding or other adverse factors.

3.2 ***Subsurface conditions***. Subsurface groundwater conditions must be considered and must include an estimate of the maximum anticipated groundwater elevation. If the site contains sewage or storm water infrastructure or is proposed, the recommendations shall reflect the potential impact from a 10-year and 100- year storm event.

3.3 ***Background documentation***. The results of any foundation excavation observation study must be submitted with pertinent backup documentation such as soil logs, laboratory test data, calculations, photographs, measurements and other pertinent data.

4.0 SITE INVESTIGATION AND SOIL INVESTIGATION STUDIES

Adequate evaluation and comprehensive geotechnical engineering studies shall be used to evaluate the suitability of the soil to support the proposed building structure. As directed by the engineer, adequate soil sampling of the subsurface material may be necessary to perform geotechnical testing to determine the soil bearing capacity and other strength parameters to determine the suitability of the soil. In general, the foundation observation evaluation shall follow the following phases:

4.1 ***Review***. Review the soils report or geotechnical investigation that has been performed for the subject site. Understand all relevant geotechnical features related to the property, including groundwater, soil bearing capacity, soil type, drainage, proximity to a flood zone, and all other pertinent geologic factors.

4.2 ***Excavation*****.** Conduct a foundation excavation inspection prior to the placement of footings. Assess the potential for groundwater below the proposed footings as necessary.

4.3 ***Observation and assessment***. Observe that all of the recommendations from the previous reports have been implemented. Observe that the soil properties are consistent with the findings and assumptions in the report. Assess the groundwater potential and observe that the elevation and drainage is suitable for the proposed structure.

4.4 ***Documentation and evaluation*****.** Documentation and evaluation of subsurface groundwater conditions (including effects of seasonal and longer-term natural fluctuations as well as landscape irrigation), surface water, on-site sewage disposal, and/or storm water disposal.

4.5 ***Additional suitability analysis*****.** If no previous geotechnical report has been performed, the licensed engineer shall perform whatever work is deemed necessary to evaluate the suitability of the site for development.

4.6 ***Report***. Prepare a signed and wet stamped letter to the city that the site has been observed and has been deemed suitable for the proposed development. Once this letter has been received and accepted by the city, the placement of footings may commence.

5.0 MITIGATION

If *in-situ* soil conditions are inconsistent with previous reports and recommendations, a qualified engineer shall perform whatever tests are necessary to assess if the site is suitable for development. If the site is not suitable for development, an engineer may develop mitigation measures and shall report that these measures have been met in a signed and wet stamped letter to the city prior to the construction of footings.

6.0 NOTICE OF GEOLOGIC HAZARD AND WAIVER OF LIABILITY

For developments where full mitigation of recommended measures is not implemented, a notice of geotechnical hazard acceptable to the city shall be recorded with the proposed development describing the hazard at issue and the partial mitigation employed. The notice shall clearly state that the hazard at the site has been reduced by the partial mitigation, but not totally eliminated. In addition, the owner shall (a) be deemed to have assumed all risks and waived all claims against the city and its officers, employees, agents, contractors, consultants and other related parties consultants, and (b) indemnify and hold the city and such related parties harmless from any and all claims arising from the partial mitigation of the seismic displacement hazard.

APPENDIX I

Riparian Corridor and Watershed Protection

Sensitive Lands Evaluation & Development Standards (SLEDS)
Chapter 10.10A, FRUIT HEIGHTS CITY CODE OF ORDINANCES

Riparian corridor and watershed protection requirements in the city are contained in Chapter 17.31, FRUIT HEIGHTS CITY CODE OF ORDINANCES.