Draper City

Geotechnical Engineering Standards

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1.0 INTRODUCTION

These Standards present the requirements for geotechnical engineering reports performed in Draper City (the City). Civil engineering projects requiring geotechnical engineering studies (or a "soils report") are stipulated in Titles 9, 10, 11, 17, and 18 of the Draper City Municipal Code. When a geotechnical engineering report is required, the geotechnical engineering report shall be submitted to the City Building Division.

The applicant and their consultants shall present the results of geotechnical engineering studies in compliance with these Standards. The standards outlined herein constitute the minimum level of effort required in conducting geotechnical engineering studies in the City.

Considering the complexity inherent in evaluating geotechnical engineering parameters at a property, additional effort beyond the minimum standards presented herein may be required at some sites. The information presented herein does not relieve consultants of their responsibility to perform additional geotechnical engineering analyses they believe are necessary to assess the geotechnical engineering parameters at a site. It is not the intent of these Standards to supplant the judgment of the geotechnical engineer. In addition, these Standards shall not supersede other more stringent requirements that may be required by other regulatory agencies or the City.

Non-compliance with these Standards may lengthen the geotechnical engineering review process and delay project approval. The purpose of establishing minimum standards for performing geotechnical engineering studies and preparing geotechnical engineering study reports is to:

1. Provide consulting geotechnical engineers with a common basis for preparing proposals, conducting studies, and preparing geotechnical engineering reports, including conclusions and recommendations.

2. Provide an objective framework for the City review of geotechnical engineering study reports.

The City policies, standards, and municipal codes are subject to periodic revision and the most current versions may not be represented in this document. Consequently, these Standards may be periodically updated. The City Building Division may notify consultants of substantive changes via direct mail, or publication in local society newsletters (e.g., American Society of Civil Engineers, Earthquake Engineering Research Institute). If questions arise, it is recommended geotechnical engineering consultants contact the City directly for clarification.

2.0 DEFINITIONS

As used in these Standards:

Acceptable and reasonable risk means no loss of life or significant injury to occupants, no release of hazardous or toxic substances, and structural damage following an earthquake, rockfall, debris flow, or other natural hazard that retains a margin against the onset of partial or total collapse.

Active Fault means a fault displaying evidence of displacement along one or more of its traces during the past 4,000 radiocarbon years before present or 4,500 calibrated calendar years before present (about three times the closed mean recurrence interval between surface faulting earthquakes along the Salt Lake City and Provo segments of the Wasatch fault zone.

For any other Draper City faults not associated with the WFZ, Active Fault means a fault displaying evidence of displacement along one or more of its traces during the Holocene epoch of geologic time (past 10,000 radiocarbon years before present or about 11,700 calibrated calendar years before present).

Bedrock means solid, consolidated, and indurated rock underlying soil and/or other unconsolidated and/or alluvial materials (modified after AGI, 2011).

Buildable area means:

1. The part of a site that may be developed after required setbacks have been deducted and open space requirements of Title 9 of the Draper City Municipal Code have been met, and;

2. If applicable, based on an accepted geologic hazards report, the part of a site not impacted by geologic hazards, or the part of a site where the identified geologic hazards can be mitigated to an acceptable risk.

City means the City Council, Mayor, City Manager, Public Works Director, City Engineer, Community Development Director, Planning Manager, Building Official, or other City employee.

City Council means the city council of Draper City.

Critical facilities mean essential, hazardous, special occupancy facilities, and Risk Categories III and IV as defined in the currently adopted International Building Code, and lifelines such as major utility, transportation, and communication facilities and their connections to critical facilities.

Critical Failure Surface means the surface in a slope stability analyses with a factor of safety greater than or equal to 1.5 under static conditions and greater than or equal to 1.0 under seismic conditions.

Development means all critical facilities, subdivisions, single- and multi-family dwellings, commercial and industrial buildings, retaining walls, and public right-of-way improvements, also additions to or intensification of existing buildings, storage facilities, pipelines, and utility conveyances, and other land uses.

Engineering geologist means a Utah-licensed geologist, who, through education, training, and experience, is competent in applying geologic data, techniques, and principles, such that geologic conditions and factors affecting engineered works are recognized, adequately interpreted, and clearly presented for use in engineering practice, land-use planning, and the protection of the public, safety, and welfare.

The individual must meet the following qualifications:

1. An undergraduate or graduate degree in geology, engineering geology, or geological engineering, or closely related field, from an accredited college or university;

2. Five full years of experience in a responsible position in the field of engineering geology in Utah, or in a state with similar geologic hazards and regulatory environments.

Engineering geology means geologic work relevant to engineering and environmental concerns, and public health, safety, welfare, and property. Engineering geology is the application of geological data, principles, and interpretation so geological factors affecting planning, design, construction, and maintenance of engineered works, land use planning, and groundwater resources are adequately recognized and properly interpreted for use in engineering, land-use planning, and related practice.

Essential facility means buildings and other structures intended to remain operational in the event of an adverse geologic event, including all structures defined in Section 10-7-160 of the City geologic hazards ordinance.

Fault means a fracture in the earth's crust forming a boundary between rock or soil masses that have moved relative to each other.

Fault plane means the plane that represents the rupture surface of a fault.

Fault setback means an area on either side of a fault within which structures for human occupancy or critical facilities or their structural supports are not permitted.

Fault scarp means a steep slope or cliff formed by movement along a fault.

Fault trace means the intersection of a fault plane with the ground surface, often present as a fault scarp, or detected as a lineament on aerial photographs or other imagery such as lidar.

Fault zone means a corridor of variable width along one or more fault traces, within which deformation has occurred.

Geologic hazard means a surface fault rupture, liquefaction, slope stability, landslide, debris flow, and rockfall that may present a risk to life or property.

Geologic hazards study report means a report containing the results of the geologic hazards study including maps, figures, data, and calculations that substantiate all conclusions and recommendations.

Geotechnical engineer means a Utah-licensed civil engineer who, through education, training, and experience, is competent in the field of geotechnical engineering for use in engineering practice, land use planning, and the protection of the public, safety, and welfare.

The individual must meet the following qualifications:

1. A graduate degree in civil engineering, with an emphasis in geotechnical engineering; or an undergraduate degree in civil engineering with twelve (12) semester hours of graduate level education in geotechnical engineering, or course content related to evaluation of geologic hazards, from an accredited college or university.

2. Five (5) full years of experience in a responsible position in the field of geotechnical engineering in Utah, or in a state with similar geologic hazards and regulatory environment, and experience demonstrating the engineer's knowledge and application of appropriate techniques in participating in geologic hazards studies, including slope stability analyses.

Geotechnical engineering means the study and engineering evaluation of earth materials including soil, rock, and man-made materials and their interaction with earth retention systems, foundations, and other civil engineering works. The practice involves the fields of soil mechanics, rock mechanics, and earth sciences and requires knowledge of engineering laws, formulas, construction techniques, and performance evaluation of engineering.

Geotechnical engineering report means reports prepared to provide data on the physical properties of surface and subsurface soil conditions for the development of a property that contain the findings of field studies, including maps, plans, figures, data, calculations, etc. necessary to substantiate all geotechnical engineering conclusions and recommendations.

Governing body means the city council or a designee of the city council.

Holocene epoch means the period of time between about 10,000 radiocarbon years before present (or about 11,700 calibrated calendar years before the present).

Landslide means the downslope movement of a mass of soil, surficial deposits, or bedrock, including a continuum of processes between landslides, earth-flows, debris flows, debris avalanches, and rockfalls.

Liquefaction means a process by which certain water-saturated soils lose bearing strength because of earthquake-related ground shaking and subsequent increase of groundwater pore pressure.

Life safety means the damage state following a natural hazard (i.e., earthquake, flood, rockfall, debris flow, etc.), in which a structure has damaged components but retains a margin against the onset of partial or total collapse (to preserve the lives of the occupants). The goal of designing for life safety is to only protect public health and safety.

Public infrastructure means wastewater sewer collection systems, drinking water systems, storm-water drainage systems, utility extensions, telecommunications lines, streets, roads, and bridges, etc., owned and operated by municipalities and governments; includes any infrastructure within public rights-of-way.

Responsible charge, Geologist means the independent control and direction by use of initiative, skill, and independent judgment of geological work or the supervision of the work.

Responsible charge, geotechnical engineer means the independent control and direction by use of initiative, skill, and independent judgment of geotechnical engineering work or the supervision of the work.

Rockfall means a rock or mass of rock, newly detached from a cliff or other steep slope which moves downslope by falling, rolling, toppling, or bouncing; includes rockslides, rockfall avalanches, and talus.

Setback means an area subject to risk from a geologic hazard, within construction of critical facilities and structures designed for human occupancy are not permitted.

Slope stability means the resistance of a natural or artificial slope or other inclined surfaces to failure by landsliding, usually assessed under both static and dynamic (earthquake-induced) conditions.

Slope stability analysis means the analysis of the static and seismic stability of engineered and natural slopes of soil and rock.

Structure designed for human occupancy means any building or structure containing a habitable space, or classified as an assembly, business, educational, factory and industrial, institutional, mercantile, or residential occupancy classification under the adopted International Building Code and/or any residential dwelling or any other structure containing a habitable space used or intended for supporting or sheltering any use or occupancy, which is expected to have an occupancy rate of at least 2000 person-hours per year but does not include an accessory building.

Surface faulting means the fault-related displacement of the ground surface that occurs during an earthquake.

3.0 MINIMUM QUALIFICATIONS

Slope stability analyses must be performed by qualified engineering geologists and geotechnical engineers as defined in Section 2.0 of these Standards, and Sections 10-7-050, *Minimum Qualifications of the Geologist*, and 10-7-060, *Minimum Qualifications of the Geotechnical Engineer*, in the City geologic hazards ordinance.

4.0 GENERAL

All geotechnical engineering studies must consider the need for geological information. If geological data is required, the geotechnical engineering study work plan shall include a geologic component to supplement the geotechnical engineering study. Geology shall be performed by a geologist who meets the minimum qualifications stipulated in Section 2.0 of these Standards, and Section 10-7-050 of the City geologic hazards ordinance.

For projects in the City Geologic Hazard Special Study Areas (see the City geologic hazards ordinance), the geotechnical engineering report shall comply with the City geologic-hazards ordinance. Geotechnical engineering reports must include supporting data for all recommendations and conclusions (i.e., laboratory test data, boring/test pit logs, engineering calculations, etc.).

5.0 SCOPING MEETING

Scoping meetings are only required for projects in the City Geologic Hazards Special Study Areas (see Section 10-7-070(A) of the City geologic hazards ordinance). For all other geotechnical engineering studies, a scoping meeting may be scheduled at the request of the applicant or, if deemed appropriate, by the City. The purpose of scoping meetings is to review the geotechnical engineer's investigative approach before the commencement of the geotechnical engineering study.

6.0 LAND DISTURBANCE PERMIT

Geotechnical engineering studies within geologic hazard special study areas require a land disturbance permit before the commencement of any subsurface exploration. As required by Title 18 of the current edition of the Draper City Municipal Code and except as otherwise noted therein, in City Geologic Hazards Special Study Areas, no person shall commence or perform any land disturbance, grading, relocation of earth, or any other land disturbance activity, without first obtaining a land disturbance permit.

7.0 SUBSURFACE EXPLORATION

All subsurface exploration programs must first consider the need for geological information. If geological subsurface data is required, the subsurface exploration program must be coordinated with a geologist who meets the minimum qualifications stipulated in Section 2.0 of these Standards, and Section 10-7-050 of the City geologic hazards ordinance. Both the geologist and geotechnical engineer must agree as to the extent of the program.

If geological information is not required, the geotechnical engineer must determine the exploration required to determine the site will be suitable for development from a geotechnical engineering perspective, consistent with concerns for public health, safety, and welfare; the requirements of the City Geotechnical Engineering Standards, and; the provisions of the current edition of the Draper City Municipal Code and City geologic hazards ordinance.

The number of exploratory borings, test pits, trenches, Cone Penetration Tests, etc., shall be based on obtaining representative subsurface data consistent with the geotechnical engineering requirements of the project, the type of structures, the topography, and the geology. At a minimum:

1. One exploration per 3,000 square feet of building area for single-lot residential dwelling projects.

2. One exploration per acre of buildable area for single-family residential subdivision projects.

3. One exploration per 5,000 square feet of building area for multi-family residential projects.

4. Two explorations beneath small commercial structure projects (up to 6,000 square feet of building area).

5. One exploration per 6,000 square feet of building area for large commercial projects, greater than 6,000 square feet of building area.

The depth of the study shall extend at least to the depth of the zone of influence below footings from structural loads or refusal on bedrock.

Sampling intervals shall be at vertical intervals of no greater than 3 feet within 15 feet of the ground surface. Below a depth of 15 feet, sampling shall be performed at vertical intervals of no more than 5 feet or at significant stratigraphic changes, whichever results in more sampling.

Subsurface conditions observed in the subsurface explorations must be carefully documented (“logged”) at the time of exploration by the geotechnical engineer or geologist or by field personnel under the direct supervision of the geotechnical engineer or geologist. A description of the field exploration program and the logs of the subsurface explorations must be included with the project geotechnical engineering study report.

Relatively undisturbed and bulk samples of representative subsurface materials shall be obtained from the subsurface explorations for laboratory testing and visual classification.

When encountered in subsurface explorations, depth to groundwater shall be measured on the day of the study and at least 5 days after completion of the subsurface study.

8.0 LABORATORY TESTING

Geotechnical engineering studies shall include sufficient in-situ and/or laboratory testing data to characterize the geotechnical engineering parameters of subsurface material(s) and to substantiate calculations from which conclusions and recommendations are derived. An adequate number of soil index tests (e.g., grain size, Atterberg Limits, dry density, and moisture content) shall be performed to characterize the physical parameters of the subsurface material.

Consolidation tests shall be completed to evaluate soil compressibility, expansion, and collapse potential in cohesive soils.

Evaluation of hydro-consolidation must extend to depths below the zone of influence from the stress of the footings or fill, and tests shall be performed at pressures typical of the magnitude to be encountered under design conditions. Sample disturbance will not be accepted as a reason to dismiss data showing significant hydro-consolidation potential without supporting data.

Unconfined compression, triaxial shear, direct shear, vane shear testing shall be completed for the analysis of allowable bearing capacity and lateral loading recommendations. Chemical tests to provide a preliminary evaluation of the chemical properties of soils having a deleterious effect on building materials will be contingent on the geotechnical engineer and the geotechnical engineering requirements of the project. These tests include, but are not limited to pH, chloride and sulfate content, and resistivity.

Tests to determine the California Bearing Ratio (CBR) value of subgrade materials:

1. Must be performed when providing pavements sections for public roads or roads to be dedicated to the City. A CBR test shall be completed on each soil type that will be used for roadway support.

2. Is not required for private streets or driveways.

Classification testing shall accompany consolidation tests, shear tests (direct/triaxial) and CBR tests.

9.0 GEOTECHNICAL ENGINEERING STUDY REPORTS REQUIRED

The applicant shall submit one electronic copy and two paper copies of the geotechnical engineering study report to the City. Only electronic copies of geotechnical engineering study reports are retained by the City. Hard copies of geotechnical engineering study reports are only provided for use by the City geotechnical engineering consultant to facilitate the review process.

All geotechnical engineering study reports shall include the original or electronic signature and professional seal of the Utah-licensed civil engineer meeting the qualifications of a geotechnical engineer as defined herein, and who is responsible for the preparation of the report. When applicable, the report shall also contain the original or electronic signature and professional seal of the Utah-licensed geologist meeting the qualifications of an engineering geologist as defined herein, and who is responsible for co-preparation of the geotechnical engineering study report.

10.0 GEOTECHNICAL ENGINEERING STUDY REPORTS

All geotechnical engineering study reports shall include, but not necessarily be limited to the following items (as applicable):

1. A title page indicating the name and location of the project and who the report was prepared for.

2. The purpose of the geotechnical engineering study.

3. A discussion of the proposed development, including the type and size of structures and proposed grading.

4. A vicinity map, with a north arrow and bar scale, depicting major streets, roadways, geographic features, and other pertinent data to locate and orient the site.

5. A description of the site, including at a minimum, location, size, topography, drainage, geologic hazards, adjacent properties, existing and adjacent structures, subterranean structures, and on-site and adjacent slopes that may affect the proposed development.

6. A site plan at a scale of at least 1 inch = 200 feet (or more detailed), with a north arrow and bar scale, depicting:

a. Site boundaries.
b. Proposed buildable area(s).
c. Existing and adjacent structures.
d. On-site and adjacent slopes.
e. Topography/contours labeled at a minimum of 10-foot intervals.
f. Subsurface explorations.
g. Other data pertinent to depict site condition/development.

7. A regional geologic map at a scale of about 1 inch = 2,400 feet with a north arrow, bar scale, contours, and the site labeled.

8. A discussion of the field exploration program, which shall include, at a minimum:

    a. Methods of subsurface exploration.
    b. Methods and type of sampling.
    c. Exploration logs.
    d. Date(s) of exploration.
    e. The materials documented during the subsurface exploration.
    f. Depth below existing ground surface to groundwater.

9. A discussion of the geotechnical engineering study laboratory testing program, referencing applicable American Standard of Testing Materials (ASTM) or American Association of State Highway and Transportation Officials (AASHTO) procedures.

10. Numerical and graphical results of the following laboratory tests (as applicable):

    a. In-situ dry density.
    b. In-situ moisture content.
    c. Atterberg Limits.
    d. Grain size analysis (sieve and hydrometer).
    e. Unconfined Compression Tests. Dry density, moisture content, percent saturation, and Atterberg limits shall be reported with the unconfined compression test result of each sample.
    f. Consolidation tests with the following shown: Pre-consolidation Pressure (Pc), Initial Effective Overburden Pressure (Po), Compression Index (Cc), and Swell or Rebound Index (Cr). Index testing shall be performed on consolidation test samples.
    g. Direct shear tests with plots of normal stress versus shear resistance (failure envelope) and shear resistance versus displacement. If the shear test samples are soaked before testing and the rate of shear displacement exceeds 0.005

inches per minute, the Consultant shall provide data to demonstrate the rate of shear displacement was sufficient for drained conditions. Index testing shall be performed on shear test samples.

h. Triaxial shear tests with plots of normal stress versus shear resistance (failure envelope) and shear resistance versus axial strain. Index testing shall be performed on shear test samples.
i. Proctor tests showing maximum dry density, optimum moisture content, gradation, Atterberg limits, and rock correction, as applicable.
j. California Bearing Ration (CBR) tests with gradation and Atterberg limits as applicable.

11. A discussion of the effect of groundwater on the project including:

    a. Depth to groundwater table from existing grade, if encountered, at the time of drilling and at least 5 days after drilling.
    b. Historical high groundwater elevation.

12. Recommendations for footing design (allowable bearing capacity). Calculations used in the engineering analyses shall be provided in an appendix. Variables used in the calculations shall be substantiated.

13. Anticipated total and differential settlement beneath structures and public utilities. Analysis of secondary consolidation shall be provided for normally consolidated clays and when proposed loading exceeds existing overburden pressures.

14. Mitigation recommendations for settlement of buildings and public utilities constructed over fill areas.

15. Foundation setbacks from top and bottom of slopes if less than minimum building code requirements.

16. Depth of removal of soils not acceptable for support of proposed structure(s). The aerial limits of removal of soils not acceptable for support of proposed structure(s) shall be depicted on a site plan. Soils not acceptable for support of proposed structure(s) must be defined.

17. A recommendation whether perimeter foundation drains will be required, based on site-specific subsurface conditions.

18. Site class for seismic analysis, Site Modified Peak Ground Acceleration (PGA_M), spectral response acceleration parameter at a short period of 0.2 seconds, (S_{DS}), and spectral response acceleration parameter at 1.0 seconds, (S_{D1}), shall be clearly stated in the report. Values shall be based on the current American Society of Civil Engineers (ASCE)-7 (presently ASCE, 2016) for structural design. For commercial sites requiring a site-specific ground-motion-hazard analysis, the geotechnical engineer shall contact the structural engineer to verify whether a site-specific ground-motion-hazard analysis is required. If required, the site-specific ground-motion-hazard analysis shall be completed in accordance with the current ASCE 7 (ASCE, 2016).

19. Output files for seismic analyses shall be included in an appendix.

20. Site earthwork recommendations with testing frequencies.

21. Retaining wall design recommendations (if applicable), with shear strength and/or equivalent fluid weight recommendations based on a laboratory shear test with test.

22. Input and output files, calculations sheets, and associated laboratory test results for slope stability and/or liquefaction analyses (as applicable), provided in an appendix.

23. Pavement design and pavement construction recommendations for public streets. Pavement recommendations shall reference the City minimum pavement thickness standards based on street classification and the California Bearing Ration (CBR) test for the site.

24. Citations of literature and records used in the study, referenced aerial photographs, lidar images, and any other sources of data and information, including water-well logs, personal communications, etc.

25. A statement the site is suitable for the proposed development from a geotechnical engineering perspective, consistent with concerns for public health, safety, and welfare; the requirements of the City Geotechnical Engineering Standards, and; the provisions of the current edition of the Draper City Municipal Code.

11.0 AMENDED AND UPDATED GEOTECHNICAL ENGINEERING STUDY REPORTS

Update geotechnical engineering study reports may be required from applicants when:

1. The scope of the project changes after the initial geotechnical engineering study report was submitted to the City.

2. Geotechnical reports shall be valid and applicable in the City for two years. After two years, the applicant shall submit a letter from the geotechnical engineer stating:

    a. the scope of the project as stated in the initial geotechnical engineering report has remained unchanged.
    b. the professional registration of the consultant has not expired.
    c. site conditions have not changed.
    d. the report meets the requirements of the City Geotechnical Engineering Standards and the provisions of the current edition of the Draper City Municipal Code.

3. Site conditions change.

If an updated geotechnical engineering study report is required, the report must include at a minimum:

1. The purpose of the updated report.

2. A description of the proposed development.

3. A site reconnaissance by the geotechnical engineer of record for the project.

4. A statement addressing whether the recommendations of the prior report(s) remain valid and applicable.

5. Revised recommendations, as appropriate.

12.0 DRAPER CITY REVIEW

All geotechnical engineering study and geologic hazards study reports performed in the City will be reviewed by the City's retained consultants and permanently filed with the City. The City's retained geotechnical engineering and geologic consultants will evaluate geotechnical engineering reports for conformance with the City Geotechnical Engineering Standards and advise the City regarding the conformance of geotechnical engineering study or geologic hazards study reports with the City Geotechnical Engineering Standards. These minimum standards thus serve as the basis for the review of geotechnical engineering study and/or geologic hazards study reports.

When geotechnical engineering study and geologic hazards study reports comply with the City Geotechnical Engineering Standards, the City geotechnical engineering and geologic reviewers will prepare a report to the City recommending the City consider the geotechnical engineering study and geologic hazards report complete from a geotechnical engineering or geologic perspective.

When geotechnical engineering study and geologic hazards study reports do not comply with the City Geotechnical Engineering Standards, the City geotechnical engineer and geologic consultant will prepare a report to the City recommending the City consider the geotechnical engineering study and geologic hazards study report incomplete. The reviewer's report(s) shall list where the consultant's geotechnical engineering study and geologic hazards reports are not in compliance with the City's Geotechnical Engineering Standards.

13.0 CHANGE OF CONSULTANT LETTER

Written notification will be required if a change in geotechnical engineering or engineering geologist consultants occurs after the review process has been initiated or ownership of the property has changed. The letter must state that the new geotechnical engineering and/or engineering geologist consultant has reviewed the work performed by the previous geotechnical engineering and/or engineering geologist consultant, concurs with the recommendations and conclusions of the previous geotechnical engineering consultant, and agrees to assume responsibility as geotechnical engineering and/or engineering geologist consultant of record from “this point forward.”

If the new geotechnical engineering and/or engineering geologist consultant does not concur with the previous geotechnical engineering and/or engineering geologist consultant’s conclusions and recommendations or does not agree to assume responsibility as geotechnical engineering and/or engineering geologist consultants of record from “this point forward,” the new geotechnical engineering and/or engineering geologist consultant shall perform the necessary supplemental geotechnical engineering and/or geologic studies, in accordance with these Standards, necessary to assume responsibility as geotechnical engineering and/or engineering geologist consultants of record from “this point forward.”

The applicant shall submit one electronic copy and one paper copy of the Change of Consultant letter, with the original or electronic signature and professional seal of the Utah-licensed civil engineer meeting the qualifications of a geotechnical engineer, as defined herein, and who will assume responsibility as geotechnical engineering consultants of record from “this point forward” and/or Utah-licensed geologist meeting the qualifications of an engineering geologist as defined herein and who will assume responsibility as engineering geologist of record "from this point forward.

No new permits shall be issued for a project, and all previously permitted work shall stop until the City is officially notified of the name, address, and telephone number of the new project geotechnical engineer and/or engineering geologist (as applicable), or as otherwise approved by the City Building Official.

14.0 REFERENCES

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APPENDIX A - MINIMUM STANDARDS FOR FAULT ACTIVITY INVESTIGATIONS

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1.0 INTRODUCTION

This Appendix presents the minimum standards and methods for performing fault activity investigations in Draper City (the City) and preparing geologic hazards study reports for fault activity investigations. These standards constitute the minimum level of effort required in conducting fault activity investigations in the City.

Considering the complexity of evaluating the timing of the last surface rupture earthquake along a fault (fault activity), additional effort beyond the minimum standards presented herein may be required at some sites to adequately address fault activity.

The information presented herein does not relieve consultants of their responsibility to perform additional geologic or engineering studies they believe are necessary to assess fault activity at a site. The purpose of establishing minimum standards for fault activity investigations is to:

1. Protect the health, safety, welfare, and property of the public by minimizing the potential adverse effects of active faulting and related hazards.

2. Assist property owners and Applicants with property in Fault Activity Study Areas in conducting reasonable and adequate fault activity investigations.

3. Provide consultants with a common basis for preparing proposals, conducting Fault Activity Study Areas investigations, and recommending mitigation.

4. Provide an objective framework for the City review of geologic hazards study reports for Fault-Activity-Study-Area investigations.

2.0 ACTIVE FAULT

The City defines an active fault as a fault displaying evidence of displacement along one or more of its traces during the past 4,000 radiocarbon years before present [14C yr. B.P.] or about 4,500 calibrated years before present [cal yr. B.P.] (about three times the closed mean recurrence interval between surface faulting earthquakes along the Salt Lake City and Provo segments of the Wasatch Fault Zone (WFZ)) (WGUEP, 2016).

For any other City fault not directly associated with the WFZ, active fault means a fault displaying evidence of displacement along one or more of its traces during the past 10,000 14C yr. B.P. or about 11,700 cal yr. B.P.

3.0 WASATCH FAULT ZONE

The WFZ is a major tectonic feature in the western United States, extending for about 230 miles from near Fayette, Utah in the south to near Malad, Idaho in the north. Surface faulting has occurred along the WFZ in northern Utah throughout late Pleistocene and Holocene time (WGUEP, 2016).

The WFZ consists of a series of normal-slip faults with relative movement down to the west and up to the east (WGUEP, 2016; DuRoss and Hylland, 2015). In Salt Lake Valley, the WFZ is represented by the Salt Lake City segment which extends for 23± miles along the eastern edge of the valley (WGUEP, 2016). In Utah Valley, the WFZ is represented by the Provo segment which extends for 59± miles along the eastern edge of Utah Valley (WGUEP, 2016). Repeated Holocene normal-slip movement has been well documented along the Salt Lake City and Provo segments of the WFZ (WGUEP, 2016; DuRoss and Hylland, 2015; Olig, 2011).

4.0 MINIMUM QUALIFICATIONS OF INVESTIGATORS

Site-specific fault activity investigation in the City must be performed by qualified engineering geologists as defined in Section 2.0 of these Standards, and in Section 10-7-050 of the City geologic hazards ordinance.

5.0 PARCELS REQUIRING A FAULT-ACTIVITY INVESTIGATION

The City has delineated Fault Activity Study Areas bracketing faults considered active until proven otherwise. Geologic hazards special study area maps reflecting geological concerns pertaining to development within the City may be viewed at the City online map portal via the geologic information application. A site-specific fault activity investigation for the part of the property in the Fault Activity Study Area is required before receiving a land use approval or building permit from the City.

The City Fault Activity Study Areas generally extend horizontally 300 feet on the downthrown side and 150 feet on the upthrown side of mapped fault traces For fault zones; Fault Activity Study Areas extend from the outermost faults in the fault zone.

A site-specific fault activity investigation may also be required if onsite or nearby fault-related features, not shown on the City Fault Activity Study Areas Map, are identified during other geologic or geotechnical engineering studies performed on or near the site or during construction.

Development of any parcel of land in a fault activity study area requires submittal and the City review of a geologic hazards study report for a site-specific fault activity investigation before receiving a land-use or building permit from the City. It is the responsibility of the applicant to retain a qualified geologist to perform the fault activity investigation (see Section 2.0 of these Standards, and Section 10-7-050 of the City geologic hazards ordinance). The purpose of fault-activity investigations is to accurately locate active faults. When faults are identified, fault-activity investigations shall:

1. Evaluate the age of the last surface-faulting earthquake along the fault trace(s).

2. Document the physical characteristics of the fault, e.g., amount of past fault displacement, bearing (strike) of fault, and inclination (dip) of fault.

A site-specific surface fault rupture hazard study includes a field investigation (usually involving the excavation and geologic documentation of a trench) and a geologic hazards study report. This Appendix describes the minimum standards required by the City for surface-fault-rupture-hazard studies.

6.0 SCOPING MEETING

The applicant or consultant shall schedule a scoping meeting with the City to evaluate the engineering geologist's/geotechnical engineer's investigative approach (see Section 10-7-070 of the City geologic hazards ordinance).

7.0 FAULT-ACTIVITY INVESTIGATIONS

The part of the property in a Fault Activity Study Area must be evaluated for the presence of active faults. At a minimum, the fault-activity investigation shall consist of the following tasks:

7.1 Review of Available Literature, Evaluation of Aerial Photographs and Lidar Imagery

The initial task in a fault-activity investigation shall consist of:

1. Review of available published geologic/geotechnical engineering reports pertinent to the site and vicinity, including previous unpublished fault-activity investigations.

2. Interpretation of available stereo-paired aerial photographs, and evaluation of lidar imagery for geomorphic features (such as scarps, springs, and seeps; faceted spurs, offset ridges or drainages; geologic structures, etc.), and lineaments indicative of surface fault rupture. Aerial photographs reviewed shall include more than one set

and shall include pre-urbanization aerial photographs. The locations of geomorphic features and lineaments identified from aerial photographs and lidar imagery shall be presented in the geologic hazards study report for the fault-activity investigation as a lineament map.

7.2 Geologic Reconnaissance and Fault Mapping

The second task of the fault-activity investigation shall consist of performing a geologic reconnaissance and site-specific fault mapping (Lund and others, 2020).

1. Geologic reconnaissance of the property shall be performed to assess the origin of the geomorphic features and lineaments identified from the evaluation of stereo-paired aerial photographs, and lidar imagery and whether the features are associated with surface-fault-rupture.

2. Detailed fault and surficial geologic mapping of the property shall be performed to:

   a. Document on a site map the site-specific geologic deposits. The site map shall be at a scale of at least 1 inch = 200 feet (or more detailed), with a north arrow and bar scale, and clearly depicted site boundaries.
   b. Identify fault scarps and other fault-related features such as sag ponds, springs, aligned or disrupted drainages, faceted spurs, grabens, and displaced landforms (e.g., terraces, shorelines).
   c. Ascertain the location and age of faults.
   d. Identify trench locations.

   The area mapped must extend beyond parcel boundaries as necessary to locate and evaluate evidence of other faults projecting towards or into the site (Lund and others, 2020).

7.3 Subsurface Exploration

The third task is subsurface exploration consisting of exploratory trenching to directly identify faults:

1. If buildable areas are known, subsurface exploration must provide the minimum footage of trenching necessary to explore proposed buildable areas plus a distance beyond proposed buildable areas equal to at least the minimum fault setback distance for proposed structure types (see Fault Setback Table for IBC Risk Categories, Section 8.1) (e.g., generally about 50 ft.).

2. If buildable areas are not known, the entire part of the property in the fault-activity-study area must be investigated by trenching.

Trench backfilling methods and procedures must be documented in the geologic hazards study report for the fault-activity investigations in order to determine whether additional corrective excavation, backfilling, and compaction shall be required at the time of construction and/or site grading.

7.3.1 Trench Siting

Exploratory trenches must be oriented as perpendicular to the anticipated trend of identified active fault traces as possible and provide continuous coverage across the part of the site investigated (one trench or overlapping trenches). When a fault is identified, additional trenches will be required to:

1. Accurately determine the trend and location of the fault as it crosses the property.

2. Provide a comprehensive characterization of faulting at a site, and/or;

3. Characterize variability along the trend of the fault.

Ground deformation resulting from past surface faulting on normal faults in Utah is highly variable and may change significantly over short distances along the trend of the fault (Lund and others, 2020). Consequently, the City requires subsurface data not to be extrapolated more than 300 feet without additional subsurface information (i.e., trenches).

Complex fault zones may require closer trench spacing. When it is necessary to offset trenches to accommodate site conditions, at least 25 feet of overlap must be provided to avoid gaps in trench coverage. Care must be taken not to offset trenches at a common surficial feature potentially associated with past surface faulting (e.g., a change in surface slope across the site). Test pits or potholes alone are not an acceptable alternative to trenches for evaluating surface rupture.

7.3.2 Trench Safety

Appropriate trench safety measures regarding ingress, egress, and working in or in the vicinity of the trench must be implemented and maintained at all times. It is the responsibility of the consultant to ensure fault trenches are excavated in compliance with all applicable federal and state safety regulations.

7.3.3 Depth of Trench Excavation

The depth of a trench will ultimately depend on the presence of groundwater, stability of subsurface deposits, and the geologic age of the subsurface geologic units. At a minimum, trenches shall be deep enough to:

1. Extend into sediments at least 4,000 14C yr B.P. or to the base of Holocene deposits and into the underlying older materials.

2. Evidence of the most recent surface faulting.

3. Record all relevant aspects of fault geometry when a fault is identified (strike, dip, displacement of the fault(s); width of fault and deformation zones, including grabens and subsidiary hanging-wall and footwall faults, etc.).

When site conditions preclude exploratory trenching (i.e. the presence of shallow groundwater; excessive thickness of fill; inability to extending into sediments at least 4,000 14C yr B.P. or to the base of Holocene deposits and into the underlying older materials), alternative subsurface exploration programs must be implemented. Benching, shoring, and any other means to safely increase trench depth must be utilized before abandoning exploratory trenching.

Alternative subsurface exploration programs:

1. May consist of closely spaced Cone Penetration Test (CPT) soundings, borings, geophysical exploration techniques, or a combination of techniques. 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 the previous exploration on adjacent or nearby parcels.

2. Must be discussed with the City, at a project scoping meeting before implementation, and shall be clearly described in a consultant work plan. At the project scoping meeting, the consultant’s work plan shall include a written description of the proposed exploration program along with an exploration site plan. The site plan shall be at a scale of at least 1 inch = 200 feet (or more detailed), with a north arrow and bar scale, clearly depicting site boundaries, anticipated or published surface geologic conditions within several thousand feet of the site, the location and type of the proposed alternative subsurface exploration, and the anticipated earth materials present at depth on the site.

Should all applicable subsurface explorations techniques prove insufficient to adequately characterize past fault activity, and a potentially active fault may be concealed by unfaulted younger deposits:

1. The practical limitations of trenching must be acknowledged and explained in the geologic hazards study report.

2. The resulting uncertainties of the trench depth and unfaulted deposits must be acknowledged in the geologic hazards study report, and recommendations must reflect the resulting uncertainties of the trench depth and unfaulted deposits.

3. The uncertainty in fault location shall be discussed with the City and addressed by increasing fault setback distances along the projected fault trace (see Section 8.1, Requirements for Fault Setbacks).

7.3.4 Documenting Trench Exposures

Trench walls shall be cleaned of debris and backhoe smear before documentation. Trench logs shall be carefully drawn in the field at a minimum scale of 1 inch = 5 feet, with no vertical exaggeration. Vertical control must be used and shown on each end of trench logs. Horizontal control must be used and shown on the base of trench logs.

Trench logs shall not be generalized or diagrammatic and must graphically represent the geologic units and geologic structures observed and all other significant geologic information from the trench (see Section 9.0(9)(g)). Interpretations of the age and origin of the deposits, faulting, and/or deformation must also be included. The strike, dip, and net vertical displacement of faults must be noted. Clearly annotated field logs are acceptable for the geologic hazards study report for the fault activity investigation.

7.3.5 Fault Displacement

In general, one surface-faulting earthquake is not sufficient to characterize surface-faulting displacements associated with an active fault. Consequently, whenever possible, ground displacements assigned to an active fault should be based on a minimum of two surface-faulting earthquakes at the site of interest.

If an active fault is identified and surface-faulting displacements cannot be measured at the site, the maximum surface-faulting displacements based on paleoseismic data from nearby paleoseismic investigations on the Salt Lake City and Provo segments shall be used (Lund and others, 2020). In the absence of nearby data, consult WGUEP (2016), or the most current paleoseismic literature, for the range of surface-faulting displacements measured on the Salt Lake City and Provo segments of the WFZ.

7.3.6 Geochronology

The engineering geologist shall interpret the ages of geologic units exposed in the trench. When faulting is identified, efforts must be made to determine the time of the latest surface-faulting displacement along the fault using appropriate geologic and/or relative soil stratigraphic age-dating techniques, such as radiocarbon dating, optically stimulated luminescence (OSL) signals from quartz sand grains, relative, etc. If relative soil profile development is used to estimate the age of sediments, the experience of the geologist in soil profile development dating must be provided at the scoping meeting.

Many of the surficial deposits in the Salt Lake and Provo valleys were deposited during the Pleistocene epoch and are referred to as Bonneville lake-cycle sediments. 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 14C yr B.P.), for purposes of evaluating fault activity, these deposits provide a useful regional datum.

For practical purposes, and due to documented Holocene displacement along the Salt Lake and Provo segments of the WFZ, any fault which displaces late-stage Bonneville lake-cycle deposits shall be considered active unless the Bonneville deposits are overlain by clearly un-faulted Holocene-age deposits greater than 4,000 years old. Conversely, the presence of demonstrably unbroken, undeformed, and stratigraphically continuous Bonneville sediments constitutes reasonable geologic evidence for the absence of younger age faulting.

7.3.7 Documenting Trenches and Faults

All trenches and faults in trenches must be surveyed by a Utah licensed professional land surveyor. Faults in trenches must be surveyed with an accuracy of about 0.1 feet. Survey data shall be included in the geologic hazards study report for the fault-activity investigation as an appendix. Trenches and faults surveyed by hand-held GPS devices will not be accepted.

7.4 Field Review

A field review by the City is required during exploratory trenching. The applicant must provide a minimum of 48 hours' notice to schedule the field review with the City. The trenches shall be open, safe, cleaned, and a preliminary log completed at the time of the review. Field reviews allow the City to evaluate the subsurface data (i.e., age and type of sediments; presence/absence of faulting, etc.) with the consultant. Discussions about questionable features or mitigation measures 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.

7.5 Geologic-Restricted Areas

When the entire part of a property situated in the fault activity study area is not assessed for surface-fault rupture, the areas not assessed shall be designated as a geologic-restricted area. A fault activity investigation must be performed before the development and/or issuance of building permits for habitable structures in Geologic-Restricted Areas. Geologic-Restricted Areas must be shown on all site maps and final recorded plat maps.

8.0 SURFACE-FAULTING MITIGATION

In the City, two methods are available to mitigate an active fault.

1. Active fault mitigation by fault avoidance, and/or;

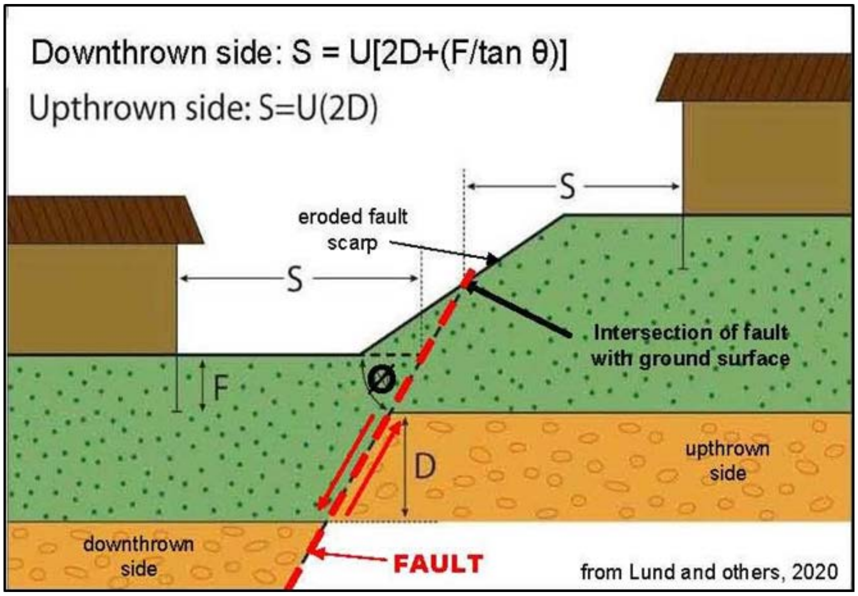
2. Active fault mitigation by engineering design.

8.1 Active Fault Mitigation by Fault Avoidance and Fault Setback

To address wide discrepancies in fault setback recommendations, the City has adopted the fault setback calculation methodology for normal faults of Lund and others (2020). The consultant shall use this method to establish the minimum fault setbacks for critical facilities and structures designed for human occupancy. Should a consultant want to use a different fault setback method, the consultant must obtain prior approval from the City and justify the method used in the geologic hazards study report. Faults and fault setbacks must be clearly identified on all pertinent site maps.

Minimum fault setbacks are based on the type and criticality of the proposed structures as defined by the International Building Code (IBC) (see Fault Setback Table for IBC Risk Categories). A fault setback shall be calculated using the formulas presented herein and then compared to the minimum fault setback established in the Fault Setback Table for IBC Risk Categories. *The greater of the two shall be used as the fault setback*. Minimum fault setback distances apply to both the downthrown and upthrown sides of the fault (hanging wall and footwall blocks, respectively).

Top-of-slope and/or toe-of-slope setbacks required by the City Municipal Code must also be considered; the greater setback must be used.



8.1.1 Downthrown Side of Fault (hanging wall block)

The fault setback for the downthrown side of the fault shall be calculated using the following formula:

$S= U (2D + F/\tan \theta)$,

where:

S = Setback in which critical and essential facilities and structures for human occupancy are not permitted.

U = Criticality Factor, based on the proposed occupancy of the structure (see Fault Setback Table for IBC Risk Categories).

D = Expected fault displacement per surface faulting earthquake (assumed to be equal to the net vertical displacement measured for each past surface faulting earthquake); If earthquake displacements cannot be measured, the maximum displacement based on paleoseismic data from nearby paleoseismic investigations on the Salt Lake City and Provo segments (as applicable), of the WFZ may be used

(Lund and others, 2020). In the absence of nearby data, consult WGUEP (2016), or the most current paleoseismic literature, for the range of displacements measured on the Salt Lake City and Provo segments of the WFZ.

F = Maximum depth of footing or subgrade part of the building.

ϴ = Dip of the fault (degrees).

8.1.2 Upthrown Side of Fault (footwall block)

The dip of the fault and depth of the subgrade part of the structure is not relevant in calculating the fault setback on the upthrown side of the fault. Consequently, the fault setback for the upthrown side of the fault shall be calculated as:

$S = U \times 2D$

The fault setback is measured from the part of the structure closest to the fault, whether subgrade or above grade. Minimum fault setbacks apply as defined above.

8.1.3 Fault Setback Table for IBC Risk Categories

Fault setback recommendations and criticality factors (U) for modified IBC risk category of buildings and other structures (modified from 2024 Table 1604.5 (ICC, 2024)).[1]

IBC Risk Category[2]	Criticality[3]	U4	Minimum Setback (feet)[4]
I - Buildings and other structures that represent a low hazard to human life in the event of failure	4	--	--
II(a) - Single-family dwellings.	3	1.5	15
II(b) - Buildings and other structures except those listed in Risk Categories I, II(a), III, and IV	2	2	20
III Buildings and other structures that represent a substantial hazard to human lives in the event of failure	1	3	50
IV - Buildings and other structures designated as essential facilities	1	3	50

[1] See ICC (2024) chapter 3, Use and Occupancy Classification (p. 45) and chapter 16, Structural Design, table 1604.5 (p. 364) for a complete list of structures/facilities included in each IBC Risk Category. Check table 1604.5 if a question exists regarding which Risk Category a structure falls under.

[2] *Risk Category I* - includes but is not limited to agricultural facilities, certain temporary facilities, and minor storage facilities.
Risk Category II – includes subcategories II(a) and II(b) to reflect the lower hazard associated with single-family dwellings and apartment complexes and condominiums with <10 dwelling units.

1. Risk Category II(a) - single-family dwellings.

2. Risk Category II(b) - buildings and other structures except those listed in Risk Categories I, II(a), III, and IV; includes but not limited to:

    a. many businesses, factory/industrial, and mercantile facilities.
    b. public assembly facilities with an occupant load ≤ 300 (e.g., theaters, concert halls, banquet halls, restaurants, community halls).
    c. adult education facilities such as colleges and universities with an occupant load ≤ 500.
    d. other residential facilities (e.g., boarding houses, hotels, motels, care facilities, dormitories with >10 dwelling units).

3. *Risk Category III*—includes but not limited to:

    a. public assembly facilities with an occupant load > 300, schools (elementary, secondary, daycare).
    b. adult education facilities such as colleges and universities with an occupant load > 500.
    c. Group I-2 occupancies (medical facilities without surgery or emergency treatment facilities) with an occupant load >50.
    d. Group I-3 occupancies (detention facilities for example jails, prisons, reformatories, detention facilities) with an occupant load >5.
    e. any other occupancy with an occupant load >5000.
    f. power-generating stations, water-treatment plants, wastewater treatment facilities, and other public utility functions not included in risk category IV.

g. buildings and other structures not included in risk category IV that contain quantities of toxic or explosive materials.

4. *Risk Category IV*—includes but is not limited to:

a. Group I-2 occupancies having surgery or emergency treatment facilities.
b. fire, rescue, ambulance, and police stations, and emergency vehicle garages.
c. designated emergency shelters: emergency preparedness, communication, and operations centers and other facilities required for emergency response.
d. power-generating stations and other public utility facilities are required as emergency backup facilities for Risk Category IV structures.
e. buildings and other structures containing quantities of highly toxic materials.
f. aviation control towers, air traffic control centers, and emergency aircraft hangars.
g. buildings and other structures having critical national defense functions.
h. water-storage facilities and pump structures required to maintain water pressure for fire suppression.

[3] *Criticality:* a factor based on relative importance and risk posed by a building; lower numbers indicate more critical facilities. Criticality is included in fault-setback equations by the factor U, which is inversely proportional to criticality to increase fault setbacks for more critical facilities.
[4] *Minimum setback*: Use minimum fault setback or the calculated fault setback, whichever is greater

8.2 Active Fault Mitigation by Engineering Design

Performance-based engineering building design as used herein means an approach to the design of a structure to meet certain measurable or predictable performance seismic load and vertical and horizontal displacement requirements, for structures built astride active faults without a specifically prescribed method by which to attain those requirements. This contrasts with traditional prescribed building codes, which mandate specific construction practices, such as stud size and distance between studs in wooden frame construction, etc.

Performance-based engineering building design:

1. Does not apply to critical and essential facilities, defined as IBC Category III and IV structures (see Fault Setback Table for IBC Risk Categories, Section 8.1.3).

2. Is intended to provide life safety protection to the inhabitants of the structure in the event of a surface-faulting earthquake beneath the structure.

Performance-based engineering building design will be permitted in the City on sites where the Applicant has submitted:

1. The required geologic hazards study report, prepared by a qualified geologist, containing all items in Section 9.0, including:

   a. age and origin of geologic units.
   b. fault type and location(s).
   c. all relevant aspects of fault geometry (the strike, dip, and the width of the fault and deformation zones, including grabens and subsidiary hanging-wall and footwall faults, etc.).
   d. evidence of the most recent surface faulting.
   e. fault recurrence interval (if known).
   f. ground displacement per surface-faulting earthquake.

2. A geotechnical engineering report from a Utah licensed geotechnical engineer performed in accordance with these Standards, including the potential maximum cantilever, free span, and tilt of the foundation at the location of the active fault(s).

3. A structural engineering report from a Utah licensed structural engineer presenting the structural design for the residential dwelling meeting all required building code and seismic requirements. The structural engineering report shall confirm:

   a. The geologic hazards study and geotechnical engineering reports have been received and reviewed.
   b. Structures have been designed in accordance with the recommendations in the geologic hazards study and geotechnical engineering reports.
   c. Structures have been designed to account for the identified hazards in accordance with the City municipal code and the International Building Code standards.

The structural design shall be reviewed by:

1. An internal City Staff review committee consisting of the City Engineer and Chief Building Official; the committee shall utilize the City geologic hazard ordinance, the International Building Code, and other applicable City regulations to evaluate the structural design.

2. The City consulting structural engineer, in accordance with the standards established by the City Building Official, the International Building Code, the City Municipal Code, and the City geologic hazard ordinance.

8.3 Small-Displacement Faults

Small-displacement faults are defined herein as faults having less than 4 inches of displacement. Small-displacement faults are not categorically exempt from mitigation requirements. Fault activity investigations must consider whether possible future displacements may exceed past amounts.

Specific structural risk-reduction options such as foundation reinforcement shall be acceptable for small-displacement faults if structural risk-reduction mitigation protects life safety and minimizes structural damage. If structural risk-reduction measures are proposed for small-displacement faults, the criteria in Section 8.2 (Engineering Design for Surface-Fault Mitigation) must be fulfilled.

9.0 GEOLOGIC HAZARD REPORTS FOR FAULT ACTIVITY INVESTIGATIONS

Geologic hazards study reports for fault activity investigations shall be prepared in accordance with the City geologic hazards ordinance. If the geologic hazards study report contains geotechnical engineering recommendations, the geotechnical engineering part of the geologic hazards study report must be prepared in accordance with the City Geotechnical Engineering Standards.

Geologic hazards study reports for fault activity investigations submitted to the City are expected to follow the outline and address the subjects presented herein. Variations in site conditions may require additional items to be addressed or permit some items to be omitted (except as noted).

Geologic hazards study reports for fault activity investigations shall include, at a minimum:

1. *Purpose and scope of work*: The geologic hazards study report shall contain a clear and concise statement of the purpose of, and the scope of work performed for the investigation.

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

geologic literature.

3. *Site description and conditions*: The geologic hazards study report shall include information on geologic units, graded and filled areas, vegetation, existing structures, and other factors affecting site development, choice of investigative methods, and the interpretation of data.

4. *Methods of investigation*: The geologic hazards study report shall include the following information:

   a. Review of published and unpublished maps, literature, and records concerning geologic units, faults, surface and groundwater, and other factors.
   b. Stereoscopic interpretation of aerial photographs and examination of lidar imagery, both on-site and off-site, to detect fault-related topography, vegetation or soil contrasts, and other lineaments of possible fault origin. The photograph's source, date, flightline numbers, and scale must be referenced.
   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.
   d. Locations and relative ages of other possible earthquake-induced features, both on-site and off-site, such as sand blows, lateral spreads, liquefaction, and ground settlement shall be mapped and described. Slope failures, although they may not be conclusively tied to earthquake causes, shall also be noted.

5. *Subsurface investigations*: The geologic hazards study report shall include:

   a. A description of the program of subsurface exploration,
   b. The purpose of each trench and trench location,
   c. A summary of trenching.
   d. All trench logs (see Section 9.0[9]g).

   e. The criteria used to evaluate the ages of the deposits documented in subsurface explorations and shall demonstrate the presence or absence of faulting.
   f. Exploratory borehole and cone penetration testlogs (see Item 9h).
   g. The purpose of each trench and trench location.

6. *Conclusions*: Conclusions must be supported by adequate data and shall contain, at a minimum:

   a. The data upon which conclusions are based, which shall include, at a minimum, a discussion of the consultant's findings regarding:

i. Interpretation of stereoscopic aerial photographs, evaluation of lidar imagery, and other remote sensing tools.
ii. Review of published and unpublished maps, literature, and records concerning geologic units, faults, surface, and groundwater.
iii. Observations of surface features, both on-site and offsite, including mapping of geologic and soil units; geomorphic features such as lineaments; scarps, springs, and seeps (aligned or not); faceted spurs, offset ridges or drainages, etc.

b. The location of active faults, including orientation and geometry of faults, amount of net slip along faults, anticipated future offset.
c. The method to mitigate active faulting.
d. The delineation of fault setback areas if mitigation method is fault avoidance by fault setback.
e. All factors stipulated in Section 8.2, Surface-Fault Mitigation by Engineering Design if engineering design mitigation is chosen.
f. The degree of confidence in, and limitations of, the data and conclusions.
g. A conclusion regarding the potential risk of active faulting at the subject property.
h. A statement of whether the proposed development and buildable area depicted on the site plan meet the requirements of the City geologic hazards ordinance.

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

   a. Recommended fault setback distances per Section 8.1, if the proposed fault activity mitigation method is fault avoidance by fault setback. Supporting calculations must be included. Faults and fault setbacks must be shown on all site maps and final recorded plat maps.
   b. The required geologic information stipulated in Section 8.2 if performance-based engineering building design of structures is the proposed fault activity mitigation method.
   c. Geologic-Restricted Areas as stipulated in Section 7.5, Geologic-Restricted Areas. Geologic-Restricted Areas must be shown on all site maps and final recorded plat maps.
   d. Other recommended building restrictions or use limitations (i.e., placement of detached garages, swimming pools, or other non-habitable structures).

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

8. *References*: Geologic hazards study reports for fault activity investigations must include citations of literature and records used in the investigation, referenced aerial photographs or images interpreted (air-photo source, date and flight number, scale), and any other sources of data and information, including lidar images, well logs, personal communications, etc.

9. *Illustrations*: At a minimum, the geologic hazards study report must include the following:

a. *Vicinity map*, with north arrow and bar scale, depicting major streets, roadways, geographic features, and other pertinent data to locate and orient the site.
b. *Site plan*, with north arrow and bar scale, at a scale of at least 1 inch = 200 feet (or more detailed), clearly depicting site boundaries, proposed buildable area, existing structures, streets, slopes, drainages, subsurface explorations, geophysical traverses, etc., and all other pertinent data.
c. *Regional geologic map*, with a north arrow, bar scale, contours, and citation, depicting the general surface geology (landslides, alluvial fans, etc.), bedrock geology where exposed, bedding attitudes, faults, and other geologic structural features near the site (generally a published 1:24,000 scale geologic map is adequate); geologic cross-sections may be included as deemed appropriate to illustrate three-dimensional relationships.
d. *Site-specific geologic map* of the subject area, with north arrow and bar scale, at a scale equal to or more detailed than 1 inch = 200 feet, depicting at a minimum:

i. location and boundaries of the property.
ii. proposed buildable areas, if known.
iii. topographic contours labeled at a minimum of 10-foot intervals labeled at a minimum of 10-foot intervals.
iv. the locations of subsurface investigation explorations.
v. topography, and drainage.
vi. site-specific geologic mapping performed by the consultant as part of the geologic hazard investigation.
vii. boundaries and features related to all geologic hazards.
viii. delineation of any recommended building setback distances from hazards.
ix. Geologic restricted areas.
x. recommended locations for structures.

xi. Buildable and non-buildable areas, clearly identified with distance from property corners.
xii. all bedding, jointing, and other geologic structures following Federal Geographic Data Committee (FGDC) Standard Geologic Map Symbolization (FGDC, 2020).
xiii. a legend defining all items noted on the map.

e. *Site-specific fault map*, with north arrow and bar scale, when faulting is identified at the site. The fault map shall be at a scale of at least 1 inch = 200 feet and must depict, at a minimum:

i. location and boundaries of the property.
ii. proposed buildable areas, if known.
iii. topographic contours labeled at a minimum of 10-foot intervals.
iv. surveyed locations of trenches (and any other exploratory techniques).
v. surveyed location(s) of faults identified in the trenches.
vi. inferred location of the faults between trenches.
vii. recommended fault setback distance on each side of the faults.
viii. geologic-restricted areas.
ix. a legend defining all items noted on the map.

f. *Lineament map* of the subject area, with north arrow and bar scale, at a scale equal to or more detailed than 1 inch = 500 feet, depicting lineaments and other geomorphic features identified from the interpretation of stereoscopic aerial photographs, evaluation of lidar imagery, and other remote sensing tools.
g. *Trench logs* for each trench excavated as part of the investigation. Graphical trench logs shall be carefully drawn in the field at a minimum scale of 1 inch = 5 feet, with no vertical exaggeration. Vertical control must be used and shown on each end of trench logs. Horizontal control must be used and shown along the base of trench logs. At a minimum, trench logs shall include (as applicable):

i. trench orientation and an indication of the trench wall logged.
ii. trench top and bottom.
iii. sample locations.
iv. geologic units and geologic structures observed and all other significant geologic information from the trench.
v. interpretations of the age and origin of the deposits, faulting, and/or deformation.
vi. stratigraphic contacts.
vii. detailed stratigraphic unit lithology descriptions.

viii. USCS soil classification of unconsolidated/non-lithified trench units.
ix. geologic origin and age of geologic units.
x. contact descriptions.
xi. pedogenic horizons.
xii. marker beds.
xiii. fault orientation and geometry (strike and dip), and amount of net displacement.
xiv. deformation or offset of sediments, faults, and fissures, buried scarp-free faces, and colluvial wedges.
xv. in-filled fractures.
xvi. drag folds.
xvii. rotated clasts.
xviii. lineations.
xix. liquefaction features including dikes, sand blows, etc.

h. *Exploratory boreholes and cone penetration testlogs* when utilized as a part of the investigation shall be included in the geologic hazards study report and must include (as applicable):

i. lithologic descriptions.
ii. geologic origin and age of geologic units.
iii. USCS soil classification or other standardized engineering soil classification (an explanation of the classification scheme must be included).
iv. sample intervals.
v. penetrative resistance values.
vi. static ground-water depths and dates measured.
vii. total depth of the borehole.
viii. identity of the person logging the borehole.
ix. electronic copies of CPT data files (in an appendix).

i. *Geophysical data* must be included in geologic hazards study reports for fault activity investigations and shall depict stratigraphic interpretations and fault locations, along with correlations to trench or borehole logs to confirm interpretations.

j. *Photographs* of scarps, trench walls, or other features to enhance the understanding of site conditions and fault-related conditions are not required but shall be included when deemed appropriate. Composited, rectified digital photographs of trench walls may be used as background for trench logs, but all geologic features and conditions observed in the trench must still be depicted.

10.0 DISCLOSURE OF GEOLOGIC HAZARDS STUDY REPORT

The owner of the parcel must record a notice running with the land disclosing the geologic hazards study report for the property; see Section 10-7-120 of the City geologic hazards ordinance. The disclosure of the geologic hazards report must be completed before the approval of any development or subdivision of such parcel.

APPENDIX B - MINIMUM STANDARDS FOR SLOPE STABILITY ANALYSES

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1.0 INTRODUCTION

The purpose of this Appendix to the Draper City Geotechnical Engineering Manual is to protect the health, safety, welfare, and property of the citizens of Draper City (the City), protect the City's infrastructure and financial health, and minimize adverse effects of geologic hazards to public health, safety, welfare, and property by encouraging wise land use.

This Appendix presents the minimum standards and methods for performing quantitative slope-stability investigations in the City and preparing geologic-hazards study reports for quantitative slope-stability investigations. The standards presented herein are directly applicable to landslide investigations and constitute the minimum standards and methods when evaluating the stability of landslides.

Considering the complexity inherent in performing quantitative slope stability investigations, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address the stability of a property. The minimum standards presented herein do not relieve consultants of their professional responsibility to perform additional geologic and/or geotechnical engineering analyses they believe are necessary to assess the stability of a site.

The purposes for establishing minimum quantitative standards for slope stability analyses are to:

1. Protect the health, safety, welfare, and property of the public by minimizing the potential adverse effects of unstable slopes and related hazards.

2. Assist property owners and Applicants in conducting reasonable and adequate studies.

3. Provide consultants with a common basis for preparing proposals, conducting investigations, and formulating mitigation measures.

4. Provide an objective framework for municipal review of geologic-hazards study reports for slope stability investigations.

1.1 Areas Requiring Slope Stability Investigations

Slope stability investigations shall be performed for all sites located within slope stability study areas as designated on the City online map portal via the geologic information application, that are affected by proposed developments meeting the following criteria:

1. Cut and/or fill slopes steeper than are at gradient of about 2 horizontal (h) to 1 vertical (v).

2. Natural slopes with gradients steeper than or equal to 3h:1v.

3. 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 a slope).

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

5. Buttresses and stability fills.

6. Cut, fill, or natural slopes of water-retention basins or flood-control channels.

When evaluating site conditions to determine the need for slope stability analyses, off-property conditions shall be included The consultant shall demonstrate that the proposed hillside development will not affect or limit the development of adjacent sites.

1.2 Roles of Engineering Geologist and Geotechnical Engineer

The investigation of the static and seismic stability of slopes is an interdisciplinary practice. The 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, competent in their respective areas of practice, and meeting the qualifications stipulated in the City geologic hazards ordinance.

An engineering geologist shall provide appropriate input to the geotechnical engineer concerning the potential impact of the geology, stratigraphy, and hydrologic conditions on the stability of slopes. The shear strength and other geotechnical engineering earth material properties shall be evaluated by the geotechnical engineer. Qualified engineering geologists and geotechnical engineers may assess and quantitatively evaluate slope stability. However, the geotechnical engineer shall perform all design stability calculations. Ground motion parameters for use in seismic stability analysis may be provided by either the engineering geologist or geotechnical engineer.

1.3 Minimum Qualifications of the Licensed Professionals

Slope stability analyses must be performed by qualified engineering geologists and geotechnical engineers as defined in Section 2.0 of these Standards, and Sections 10-7-050, Minimum Qualifications of the Geologist, and 10-7-060, Minimum Qualifications of the Geotechnical Engineer, in the City geologic hazards ordinance.

2.0 SCOPING MEETING

The Applicant must schedule a scoping meeting with the City. A work plan prepared by the Applicant's geologic and geotechnical engineering consultants, outlining the consultant's investigative approach, shall be provided to the City before the scheduled scoping meeting. At scoping meetings, the City reviews the consultant's work plan with the Applicant and the Applicant's consultants. The work plan should allow for flexibility due to unexpected site conditions. The City understands field findings may require modifications to the work plan. Upon completion of a successful scoping meeting, and acceptance of the consultant work plan, a work plan approval letter will be issued by the City (see Section 10-7-070, Preliminary Activities, of the City geologic hazards ordinance).

Where landslides are present:

1. The proposed subsurface exploration program shall include borings (see Section 5.0).

2. For the scoping meeting, the consultant shall perform a preliminary slope stability analysis to assist in the planning of the depth of the borings and intervals for obtaining samples, particularly for obtaining samples at potential landslide slip surfaces[1] with the lowest factors of safety.

3. The following soil properties shall be used for preliminary slope stability analyses:

---

[1] Landslide slip surface(s): the surface along which the displaced material within a landslide moves.

a. For material above and below the potential landslide slip surface:

   i. Friction Angle = 30 degrees
   ii. Cohesion = 100 pounds per square foot
   iii. Soil Unit Weight = 135 pounds per cubic foot
   iv. No water table.

b. For the landslide slip surface material:

   i. Friction Angle = 11 degrees
   ii. Cohesion = 0 pounds per square foot
   iii. Soil Unit Weight = 135 pounds per cubic foot
   iv. No water table.

3.0 SLOPE STABILITY INVESTIGATIONS

The analysis of the stability of slopes and landslides requires a comprehensive understanding of the geologic and geotechnical engineering parameters of the particular property. Consequently, geologic, and geotechnical engineering parameters are crucial components in slope stability investigations.

Slope stability investigations shall consist, at a minimum, of the following fundamental phases:

1. Review of available published geologic/soils reports pertinent to the site and vicinity, including previous unpublished surface-fault-rupture investigations available from the City upon request[2].

2. Review and interpretation of available stereoscopic and oblique aerial photographs, DEMs, and lidar imagery.[3]

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[2] The Utah Geological Survey Geodata Archive website contains a collection of consultant geologic and geotechnical engineering reports (UGS, 2025a).

[3] The Utah Geological Survey Geodata Archive website contains a collection of stereoscopic aerial photographs dating back to 1937 (UGS, 2025b). OpenTopography provides online access earth science-oriented, lidar imagery, and topography data acquired with lidar and other technologies (OpenTopograhy, 2025).

3. Geologic field mapping, including, but not necessarily limited to, identification and documentation of geologic units and measurement of the bearing (strike) and inclination (dip) of bedding, foliation, fractures, jointing, faults, particularly geologic structures oriented such that the geologic structures adversely impact the stability of slopes (i.e., adverse geologic conditions).

4. 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 stormwater disposal.

5. Subsurface exploration and sampling of earth materials for geotechnical engineering testing in the laboratory; testing to include determination of shear strength parameters and other pertinent geotechnical engineering properties.

6. Construction of geologic cross-sections for all slope stability analyses.

7. Where landslides are present, analysis of the geologic mode of failure, depicted on a geologic cross-section.

8. Evaluation of data obtained from the investigation and presentation of findings and recommendations in a geologic-hazards study report.

Geologic-hazards study reports for slope-stability investigations shall demonstrate each of these phases has been adequately performed and the information obtained has been considered and logically evaluated (see Section 13.0).

4.0 FACTORS OF SAFETY

The factor of safety for slope stability means the ratio of resisting forces or moments (i.e., shear strength of the soils and rock along a failure plane), to the driving forces such as gravity loads of the hillside mass, plus any loading from structures, plus live loads (e.g., traffic), and/or earthquake/seismic loads.

The City minimum required factors of safety follow:

1. Static and surficial slope stability analyses: 1.5 (see Sections 8.0 Static Slope Stability Analysis and 9.0 Surficial Stability of Slopes). If the factor of safety is less than 1.5:

    a. mitigation is required to achieve a minimum factor of safety to 1.5.

   b. the project must be designed to achieve a minimum factor of safety of 1.5.

2. Calibrated pseudostatic slope stability analyses: 1.0 (see Section 10.0, Seismic Stability of Slopes). If the factor of safety is less than 1.0, the slope is susceptible to movement from ground shaking associated with an earthquake, and a deformation analysis must be performed to estimate the amount of slope movement during an earthquake).

3. Temporary excavations and slopes: 1.3. Mitigation measures must be recommended as necessary to maintain a minimum factor of safety of 1.3 during construction.

5.0 SUBSURFACE EXPLORATION

The purpose of subsurface exploration is to identify and document the geologic materials and structures at a site, to provide data to evaluate geotechnical engineering parameters, 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 several techniques, the applicability of which is discussed herein.

Where landslides are not present or suspected, subsurface exploration must be performed to provide data to evaluate geotechnical engineering parameters and to assess the potential impact of the geology, stratigraphy, and hydrologic conditions on the stability of the slope. The program of subsurface exploration must include obtaining samples of representative subsurface materials for appropriate laboratory testing.

Where landslides are present or suspected, subsurface exploration must be performed to determine the type, controlling geologic conditions, geometry, and depth of the landslide; the stability of the landslide, and the necessary mitigation to achieve the required factors of safety for landslide stability. The depth of geologic exploration must consider the regional geologic structure and the likely failure mode of the landslide (Cornforth, 2005).

5.1 Trenching

Subsurface exploration consisting of trenching has proven, in some cases, to be useful:

1. To evaluate subsurface conditions and potential adverse geologic conditions to depths of about 15 feet.

2. When uncertainty exists regarding whether a particular landform is a landslide, although a landslide can generally be identified from evaluation of stereoscopic aerial photographs and lidar imagery.

3. For verifying margins of landslides, although the geometry of a landslide can typically be determined from evaluation of stereoscopic aerial photographs and lidar imagery.

Care must be exercised when trenching within a landslide. Landslides characteristically contain relatively large blocks of intact geologic units, which, in trench exposures, can give the false impression the geologic unit has not been displaced by landslide movement. *Slope stability analyses for landslides, based solely on data obtained from trenches, will not be accepted unless the trenches extend to depths representative of probable landslide slip surfaces determined by the preliminary slope analyses*.

Exposures in trenches shall be documented on a trench log. Trench logs shall be carefully drawn in the field at a minimum scale of 1 inch = 5 feet. Vertical control must be used and shown on each end of trench logs. Horizontal control must be used and shown along the base of trench logs. Trench logs must document all geologic information from the trench and must graphically represent the geologic units and geologic structures observed.

Trench logs shall include, at a minimum:

1. Date of excavation.

2. Type and size of equipment used for excavation of the trench.

3. Name of person(s) responsible for logging the trench.

4. Relative location of the trench to nearest landmark or common property corner and associated accuracy in location.

5. Trench orientation.

6. An indication of the trench wall was logged.

7. Trench top and bottom.

8. Stratigraphic contacts.

9. Stratigraphic unit descriptions including lithology, prepared with standard geologic nomenclature (FGDC, 2020).

10. Geologic origin and age of the deposits.

11. USCS soil classification.

12. Contact descriptions.

13. Pedogenic horizons.

14. Marker beds.

13. Deformation or offset of sediments, faults, and fissures.

14. Location and type of soil/bedrock samples.

15. Groundwater when documented in the trench.

5.2 Drilling

When the trench technique will not extend to depths representative of probable landslide slip surfaces determined by the preliminary slope analyses, drilling must be used for:

1. Locating basal and internal landslide slip surfaces.

2. Documenting the subsurface soil and geologic conditions, particularly for geologic units with inclined bedding that includes weak layers (i.e., claystone, shale, siltstone, etc.).

3. Obtaining soil samples within the range of probable landslide slip surfaces.

Conventional subsurface exploration techniques involving continuous core drilling with an oriented core barrel, angle drilling, and auger borings are useful techniques to assess and document subsurface soil and geologic conditions.

Although not commonly used in Utah, a 24-inch-diameter bucket-auger-boring with down-hole logging can provide valuable data (provided the consultant has determined the drill hole is safe to enter). The evaluation of the safety of the proposed subsurface exploration program is the responsibility of the consultant.

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 safety factor of 1.5 or less under static conditions and 1.0 or less under seismic conditions.

Boring logs must be included with all geologic-hazards study reports and shall include, at a minimum:

1. Date of drilling.
2. Type and size of drill rig used.
3. Name of person that logged the boring.
4. Relative location of boring to nearest landmark or common property corner and associated accuracy in location.
5. Stratigraphic contacts.
6. Stratigraphic unit descriptions including lithology, prepared with standard geologic nomenclature (FGDC, 2020).
7. Geologic origin and age of the deposits.
8. USCS soil classification.
9. Contact descriptions.
10. Marker beds.
11. Location and type of soil/bedrock samples.
12. Groundwater elevation, if encountered, on the day of drilling and at least 5 days after drilling is complete.

5.3 Geologic Units

Particular attention must be given to the presence or absence of weak layers during subsurface exploration (i.e., claystone, shale, siltstone, etc.). Unless demonstrably proven (through comprehensive and detailed subsurface exploration), subsurface geological weak layers, even as thin as 1/16-inch or less, are not present, a weak layer shall be assumed to occur anywhere in the stratigraphic profile (i.e., ubiquitous weak clay beds) when performing slope stability analyses.

For unconsolidated alluvium, fill materials, or other soil units not containing weak interbeds, other exploration methods such as small-diameter borings (i.e., rotary wash or hollow-stem-auger) or Cone Penetration Testing (CPT) are acceptable. When CPT soundings are used, at a minimum, one boring used for sampling and laboratory testing shall be performed next to one of the CPT soundings to verify CPT-soil behavior type interpretations.

6.0 FIELD REVIEW

A field review by the City is required during exploratory trenching. The applicant must provide a minimum of 48-hours' notice to schedule the field review with the City. The trenches shall be open, safe, cleaned, and a preliminary log completed at the time of the review. Field reviews allow the City to evaluate the subsurface data (i.e., age and type of sediments; presence/absence of faulting, etc.) 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.

7.0 SOIL PARAMETERS

Soil properties, including unit weight and shear strength parameters (i.e., cohesion and friction angle), can be based on conventional field and laboratory tests as well as in-field performance tests., Laboratory tests for saturated, residual shear strengths of the weakest material along bedding or the landslide slip surface material must be performed. Strength parameters derived solely from CPT data are not appropriate for slope-stability analysis, particularly for strengths along existing landslide slip surfaces where residual strengths have developed.

Should all applicable subsurface exploration techniques prove unsuccessful in adequately documenting and sampling the weakest material along bedding and/or the landslide slip surface:

1. The weakest material present, consistent with site geologic conditions may be used if substantiated.

2. The practical limitations of subsurface exploration techniques must be acknowledged and explained in the geologic-hazards study report.

The resulting uncertainties of the subsurface exploration techniques must be acknowledged in the geologic-hazards study report, and recommendations must reflect the resulting uncertainties of the depth of subsurface exploration and deposits not documented and sampled.

7.1 Residual Shear Strength Parameters

Residual strength parameters shall be determined using either the direct shear or ring shear testing apparatus; however, ring shear tests are preferred. Soil specimens must be subjected to the necessary number of shearing cycles in the direct shear test or the necessary amount of rotation in the ring shear test to assure residual strength has developed.

In the direct-shear and ring-shear tests, the stress-deformation curves should be used to determine when the necessary number of shear cycles has been achieved. When the stress-deformation curves indicate no further decreases in shear strength with additional shearing cycles or shearing rotations, the necessary number of shear cycles has been achieved.

7.2 Interpretation of Shear Strength Parameters

The geotechnical engineer should use 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.

The stress-deformation curves obtained during shear tests must be submitted with the other laboratory test results. It shall be recognized 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 must be discounted in the interpretation of the strength parameters. Scatter plots of shear strength data should be presented to show idealized parameters. The geologic-hazards study report shall summarize shear strength parameters used for slope stability analyses and describe the methodology used to interpret test results and estimate shear strength parameters.

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

Shear strengths used in slope stability analyses shall be evaluated considering the natural variability of engineering characteristics inherent in earth materials. Shear tests on each earth material identified at a site may be required.

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 shall be performed to verify tested shear strength parameters (e.g., Stark and others, 2005). Strength values used in analyses that exceed those obtained by the correlation must be justified.

Shear strengths of fill materials for proposed fill slopes shall be evaluated using samples mixed and remolded to represent anticipated field conditions. Confirming shear strength testing of fill materials shall be completed during grading. In situations where strength degradations are not expected to occur, peak shear strengths may be used to represent across-bedding failure surfaces or compacted fill. Fully softened (or lower) strengths shall be used for saturated colluvial materials having the potential for soil creep.

When there has not been past landslide deformation, ultimate shear strength parameters shall be used in static slope stability analyses. When there has been past landslide deformation, residual shear strength parameters shall be used in static slope stability analyses.

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 and others (2005).

7.3 Default Soil Parameters

In the Traverse Mountain area, landslide slip surfaces for known landslides commonly occur in the Tertiary-age volcanic deposits. The landslide slip surfaces typically are along clay layers formed by the in-situ alterations of tuff layers. In cases when landslide slip surfaces have been sampled and tested, relatively low residual-shear-strength values of cohesion equal 0 psf and friction angles equal 11 to 12 degrees have been reported. Similar values have been reported from the Springhill landslide in North Salt Lake, occurring in a similar Tertiary-age tuffaceous volcanic formation .

Based on existing shear strength parameters of the Tertiary-age volcanics at Traverse Mountain, the following shear strength parameters for landslide slip surfaces and weak layers in the Tertiary volcanics shall be used (unless demonstrated otherwise):

1. Cohesion = 0 psf.

2. Friction angle = 11 degrees.

If site-specific testing produces lower residual shear strength parameters than the default values, the site-specific test results should be used. If site-specific testing produces higher values, documentation must be provided to demonstrate:

1. The weakest materials were retrieved and tested.

2. The materials retrieved represent the basal landslide slip surface.

8.0 STATIC SLOPE STABILITY ANALYSIS

The following guidelines must be followed when evaluating static slope stability for slopes, landslides, and temporary stability of excavations:

1. Static slope stability shall be analyzed along cross-sections depicting the most adverse conditions (e.g., highest slope, steepest slope, most adverse bedding planes, shallowest likely groundwater table, etc.). Often several analyses are required to characterize different site conditions and several cross-sections to demonstrate the most adverse site condition.

2. When evaluating the static stability of an existing landslide, slope stability analyses must also address the potential for partial reactivation. Inclinometers can be used to determine critical landslide slip surfaces and, along with high-resolution GPS, the rate of movement of existing landslides. Critical slip surfaces shall be depicted on the slope stability cross-sections.

3. 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 5.0, Subsurface Exploration.

4. Where back-calculation is appropriate for landslide analyses, shear strengths used for design shall be no higher than the lowest strength computed using back-calculation (see Cornforth, 2005). Justification shall be required to use shear strength values higher than back-calculated shear strength values. Assumptions used in back-calculations regarding pre-sliding topography and groundwater conditions at failure must be substantiated in the geologic-hazards study report.

5. Shear strength values higher than those obtained through site-specific laboratory tests shall not be accepted.

6. 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 is consistent with the practice of rock mechanics.

7. 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.

8. Stability analyses shall include the effect of expected maximum moisture conditions on soil unit weight.

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

10. 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.

11. Anticipated surcharge loads, as well as external boundary pressures from water, shall be included in slope stability analyses, as deemed appropriate.

12. Analytical chart solutions may be used provided the analytical charts were developed for similar site conditions. Otherwise, computer-aided search techniques shall be used to locate the potential failure surface with the lowest factor of safety. Substantiation of the analytical results must be provided in the geologic-hazards study report.

Both the lowest factor of safety and the critical failure surface shall be documented. The critical potential failure surface determined from slope stability analyses may be composed of circles, wedges, planes, or other shapes that could potentially 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.

9.0 SURFICIAL STABILITY OF SLOPES

Slopes must be analyzed for surficial stability to a depth of 4 ft. The slumping and sliding of near-surface sediments are most critical during the seasonal snowmelt, periods of heavy prolonged perception, or when excessive landscape water is applied.

The assessment of surficial slope stability shall be based on analysis procedures for the 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 4 feet.

Soil creep as used herein means the steady downhill movement of material at an imperceptible rate (e.g., deformation continuing under constant stress) (Cruden and Varnes, 1996). All geologic-hazards study reports in hillside areas shall address the potential for soil creep. If identified, the potential effects of soil creep shall be addressed where any proposed structure is planned within 10 feet to an existing natural slope, by either infinite or translational stability analyses. The potential effects on the proposed development shall be evaluated and mitigation measures proposed as deemed appropriate, including setback recommendations.

9.1 Applicability and Procedures

Conclusions must be substantiated with appropriate data and analyses in the geologic-hazards study report. 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).

Where 2:1 (horizontal: vertical) 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 City geologic/geotechnical engineer consultants concur).

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.

9.2 Soil Properties

Soil properties used in surficial stability analyses shall be determined as noted in Section 7.0, Soil Parameters. Residual shear strength parameters for surficial slope stability analyses shall be used for soil creep analysis. Softened soil strengths shall be used for all other surficial stability analyses developed for a stress range consistent with the near-surface conditions being modeled.

9.3 Seepage Pressure

The minimum acceptable vertical depth for which saturation parallel to the slope shall be applied is 4 feet for natural and man-made slopes. The vertical depth of saturation should be increased to the depth of loose fill placed on the surface of the slope or loose surficial material if greater than 4 feet. The seepage pressure to be added in the global stability analyses of a detention or retention pond shall be determined through a flow net analysis, finite element numerical analysis, or the seepage pressure can be modeled using pore water pressure as a piezometric line.

10.0 SEISMIC SLOPE STABILITY ANALYSIS

When the factor of safety for calibrated pseudostatic stability analyses is less than 1.0, a deformation analysis must be performed to estimate the amount of slope movement from ground shaking during an earthquake. The method used for performing the deformation analysis must be described in the geologic-hazards study report. All variables used in the deformation analysis must be substantiated.

10.1 Ground Motion for Pseudostatic and Seismic Deformation Analyses

The controlling faults for the City are the Salt Lake City, Fort Canyon, and Provo segments of the Wasatch fault zone (WFZ). Repeated Holocene normal-slip movement has been well documented along the segments (WGUEP, 2016; DuRoss and Hylland, 2015).

For determining the minimum design loads and associated criteria for buildings and other structures, the City uses the most current version of the American Society of Civil Engineers (ASCE)-7 (presently ASCE, 2016). In regard to design ground accelerations for seismic slope-stability analyses, ASCE-7 allows either a probabilistic or deterministic approach to determining the likelihood of different levels of ground motion that will be exceeded at a particular site within a given time period. To remain consistent with the current International Building Code (ICC, 2017) and ASCE-7 documents, slope stability analyses shall be based on the modified peak acceleration (PGA_M) with a 2 percent probability of exceedance in 50 years (2,500-year return period).

Modified peak bedrock ground motions can be obtained via the internet from the ASCE[4] or from the California's Office of Statewide Health Planning and Development (OSHPD) website[5]. Site-specific response analysis may also be used to develop PGA values as long as the procedures are in accordance with the current ASCE-7, input data are provided, and results are documented in the geologic-hazards study report.

10.2 Seismic (Pseudostatic) Slope Stability Evaluations

Pseudostatic analysis for evaluating seismic slope stability is acceptable as long as the minimum factor of safety is met. Pseudostatic seismic slope stability analyses should be performed using a seismic coefficient (kh) equal to ½ the PGAM (see Section 10.1). If the

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[4] http:\asce.org

[5] http:\seismicmap.org

City mandated factor of safety of 1.0 or greater is not met, a deformation analysis must be performed to estimate the amount of slope movement from ground shaking during an earthquake (see Section 10.3).

10.3 Permanent Seismic Slope Deformation Analyses

The method used for performing deformation analyses to estimate the amount of slope movement from ground shaking during an earthquake must be described in the geologic-hazards study report. Bray and Travasarou (2009), or the most current version thereof, is currently the City's preferred method. For deformation analyses, calculated seismic displacements shall be 5 cm or less, or mitigation measures must be recommended to constrain calculated displacements to 5 cm or less. Should the City's preferred method for performing deformation analyses change, the Applicant and the Applicant's consultants will be notified at the project scoping meeting.

If using Bray and Travasarou (2009):

1. The input for the Moment Magnitude for sites within the City shall be 7.1.

2. The probable deformation shall not be less than the displacement calculated for a probability of exceedance of 50%.

3. The spectral acceleration at 1.5 times the fundamental period of the slope shall be taken from the spectral acceleration curve based on the 2% probability of exceedance in 50 years adjusted for the appropriate site class.

4. The printout of the pseudostatic analysis used to determine the yield coefficient (ky) as well as the displacement calculations must be submitted with the geologic-hazards study report.

For specific projects, different levels of tolerable displacement may be possible, however the following site-specific conditions must be considered:

1. The extent to which the displacements are localized or broadly distributed: broadly distributed shear deformations would generally be less damaging, potentially allowing larger displacements

2. The displacement tolerance of the foundation system: stiff, well-reinforced foundations with lateral continuity of vertical support elements are generally more

resistant to damage than typical slabs-on-grade type with individual spread footings, consequently, possibly allowing greater displacements.

3. Foundations placed on slopes composed of soils are likely to experience strain-softening which could involve very large displacements following strain-softening if peak strengths are used in the evaluation of ky.

   Foundations placed on slopes composed of 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.

To consider a threshold larger than 5 cm, the project consultant must provide prior, acceptable justification to the City and obtain the City's approval. Such justification must demonstrate, to the satisfaction of the City, the proposed project can be developed to an acceptable and reasonable risk as defined in the City geologic hazards ordinance.

11.0 WATER RETENTION BASINS AND FLOOD CONTROL CHANNELS

Static and seismic slope stability analyses shall be performed for cut, fill, and/or natural slopes associated with water-retention basins and flood-control channels. The slope stability analyses shall include the effects of rapid drawdown (if applicable).

12.0 MITIGATION

When unstable slopes and/or landslides are determined to exist on a property, mitigation measures resulting in factors of safety in excess of 1.5 for the static slope stability analyses and acceptable seismic displacement estimates shall be implemented such that the property can be developed to an acceptable and reasonable risk as defined in the City geologic hazards ordinance.

Mitigation measures intended to add stabilizing forces to slopes should include strain compatibility as follows:

1. The amount of deformation needed to mobilize the recommended shear strength in buttresses proposed to stabilize laterally unsupported bedding or a landslide. The amount of deformation must be included in the analyses to confirm buttresses will not allow adverse movements of the upslope bedding or landslide deposits.

2. Soldier pile deformations resulting from movements needed to mobilize the soil's shear strength when drilled soldier piles are proposed to support a potentially unstable slope. If residential structures are to be directly or indirectly supported by the solder piles, pile deformations must be compared to tolerable deflections in the supported structures.

13.0 REPORT SUBMITTALS

Geologic-hazards study reports for slope stability investigations shall be prepared in accordance with the City geologic hazards ordinance. If the geologic-hazards study report contains geotechnical engineering recommendations, the geotechnical engineering part of the geologic-hazards study report must be prepared in accordance with these Standards.

Geologic-hazards study reports for slope stability investigations submitted to the City are expected to follow the outline and address the subjects presented herein. Variations in site conditions may require additional items to be addressed or permit some items to be omitted (except as noted).

Geologic-hazards study reports for slope stability investigations shall include, at a minimum:

1. All items required in Section 10-7-100(I), Geologic Hazards Study Reports, of the City geologic hazards ordinance.

2. Boring, trench, and test pit logs.

3. Analytical results, including computer output files.

4. Summaries of the slope stability analyses and conclusions regarding slope stability.

5. A discussion of:

   a. The development of idealized subsurface conditions and the shear strength parameters used in the slope stability analyses.
   b. The engineering analysis.
   c. The slope stability analyses.

6. Laboratory data (particularly shear strength test results, including individual stress-deformation plots from direct shear tests).

7. A description of the appropriateness of the shear strength testing methods used in modeling field conditions and the long-term performance of the subject slope. Design shear strength values used shall be justified with laboratory test data and geologic descriptions and history, along with past performance history, if known, of similar materials.

8. 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.

9. An evaluation of whether mitigation measures are required, including an evaluation of multiple mitigation options. (See Section 10-7-100(I)(14) of the City geologic hazards ordinance.)

10. Specific recommendations for mitigation of the effects of identified hazards, consistent with the purposes set forth in Section 10-7-010, of the City geologic hazards ordinance, including design or performance criteria for engineered mitigation measures, including all supporting calculations, analyses, modeling, or other methods, and assumptions. Final design plans and specifications for engineered mitigation must be signed and sealed in blue ink by a qualified geotechnical and civil and/or structural engineer, as appropriate. (See Section 10-7-100(I)(15) of the City geologic hazards ordinance.) Mitigation measures must be reasonable and practical to implement especially if the mitigation measures require ongoing maintenance by property owners. (See Section 10-7-110(F)(9) of the City geologic hazards ordinance.)

11. Subsurface geologic and groundwater conditions illustrated on geologic cross-section(s) prepared by the qualified engineering geologist. The geologic cross-section must be used by the geotechnical engineer for slope stability analyses. When on-site sewage or stormwater disposal exists or is proposed, the slope stability analyses shall include the effects of the effluent plume on the stability of the slope.

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

stability analysis. In addition, input data files, recorded on diskettes, CDs, or other electronic media may be requested by the City to facilitate the City's review.

13. A statement addressing potential impacts of the geology, stratigraphy, and hydrologic conditions on the stability of slopes.

14. A conclusion regarding the stability of slopes and impacts of geologic hazards on the development of the site.

15. A statement the proposed development and buildable area depicted on the site plan meet the requirements of the City geologic hazards ordinance.

16. Recommendations for development and mitigation of the property.

14.0 DRAPER CITY REVIEW

All geologic-hazards study reports for slope stability investigations performed in the City will be reviewed by the City's retained reviewers and permanently filed with the City. The City's reviewers will evaluate geologic-hazards study investigations and geologic-hazards study reports for conformance with the City geologic hazards ordinance and applicable City codes and advise the City regarding the conformance of the consultant geologic-hazards study investigation and geologic-hazards study reports with the City geologic hazards ordinance and applicable City codes (see Section 10-7-110, Review of Geologic Hazards Study Reports, of the City geologic hazards ordinance).

When a geologic-hazards investigation and geologic-hazards study report comply with the City geologic hazards ordinance and applicable City codes, the City reviewers will prepare a report to the City recommending the City consider the geologic-hazards investigation and geologic-hazards study report *complete*.

When the geologic-hazards study investigation and geologic-hazards study report is not performed in compliance with the City geologic hazards ordinance and applicable City codes, the City reviewers will prepare a report to the City recommending the City consider the geologic-hazards study investigation and geologic-hazards study submittal report incomplete. The reviewer's report(s) shall list/explain the parts of the consultant's geologic-hazards study investigation and geologic-hazards study report not in compliance with the City geologic hazards ordinance and/or applicable City codes.

The City reviewers do not approve consultant documents or the supporting data in consultant documents. The City reviewers recommend the City either consider a consultant submittal complete or incomplete in accordance with applicable City codes and ordinances.

15.0 DISCLOSURE OF GEOLOGIC HAZARDS STUDY REPORTS

Whenever a geologic-hazards study report is required, the owner of the parcel must record a notice running with the land in a form satisfactory to the City before the approval of any development or subdivision of such parcel (see Section 10-7-120 of the City geologic hazards ordinance). Disclosure shall include signing a Disclosure and Acknowledgment Form provided by the City, which includes:

1. Notice the parcel is located within a City geologic-hazard-study area as shown on the Draper City webpage geologic information application or as otherwise defined herein.

2. Notice a geologic-hazards study report was prepared and is available for public inspection in the City's files.

Where geologic hazards and related setbacks are delineated in a subdivision, the Applicant shall also place an additional notification on the City plat map stating the above information.

16.0 NOTICE OF GEOLOGIC HAZARDS 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 partial mitigation, but not totally eliminated.

In addition, the owner shall assume all risks, waive all claims against the City and its consultants, and indemnify and hold the City and its consultants harmless from any and all claims arising from the partial mitigation of the seismic displacement hazard.

APPENDIX C - MINIMUM STANDARDS FOR LIQUEFACTION INVESTIGATIONS

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1.0 INTRODUCTION

This Appendix presents the minimum standards and methods for performing liquefaction investigations in the City and preparing geologic-hazards study reports for liquefaction hazard investigations. These standards constitute the minimum standards and methods required when conducting liquefaction investigations in the City.

Considering the complexity inherent in performing liquefaction investigations, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address the liquefaction potential of a property. The minimum standards presented herein do not relieve consultants of their professional responsibility to perform additional geologic or geotechnical engineering analyses they believe are necessary to adequately assess the liquefaction potential at a site.

The purpose of establishing minimum standards for liquefaction investigations is to:

1. Protect the health, safety, welfare, and property of the public by minimizing the potential adverse effects of liquefaction and related hazards.

2. Assist property owners and land developers in conducting reasonable and adequate studies.

3. Provide consultants with a common basis for preparing proposals, conducting investigations, and formulating mitigation measures.

4. Provide an objective framework for municipal review of geologic-hazards study reports liquefaction investigations.

1.2 Liquefaction Factor of Safety

The factor of safety for liquefaction resistance is defined as the cyclic stress ratio required (CRR) to generate liquefaction divided by the cyclic stress ratio (CSR) generated by the anticipated earthquake ground motions at the site:

Factor of Safety = CRR/CSR

Acceptable factors of safety for liquefaction studies in the City are shown in the table in Section 1.3.

1.3 Properties Requiring Liquefaction Analyses

The Liquefaction Potential Geologic Overlay Map, may be viewed at the City online map portal via the geologic information application, depicts generalized liquefaction susceptibility areas for the City and shall be used to determine whether or not a site-specific liquefaction assessment is required for a particular property.

Site-specific liquefaction investigations required in the City geologic hazards ordinance are based on modified IBC risk category of buildings and other structures (modified from 2018 Table 1604.5 (ICC, 2017)[1]:

IBC Risk Category[2]	Liquefaction Study Required	Required Safety Factor
I - Buildings and other structures that represent a low hazard to human life in the event of failure	No	not applicable
II(a) - Single-family dwellings.	See Section 1.4	1.25
II(b) - Buildings and other structures except those listed in Risk Categories I, II(a), III, and IV	Yes	1.25
III Buildings and other structures that represent a substantial hazard to human lives in the event of failure	Yes	1.3
IV - Buildings and other structures designated as essential facilities	Yes	1.3

[1] See ICC (2024) chapter 3, Use and Occupancy Classification (p. 45) and chapter 16, Structural Design, table 1604.5 (p. 364) for a complete list of structures/facilities included in each IBC Risk Category. Check table 1604.5 if a question exists regarding which Risk Category a structure falls under.

[2] *Risk Category I* - includes but is not limited to agricultural facilities, certain temporary facilities, and minor storage facilities.
Risk Category II – includes subcategories II(a) and II(b) to reflect the lower hazard associated with single-family dwellings and apartment complexes and condominiums with <10 dwelling units.

1. Risk Category II(a) - single-family dwellings.

2. Risk Category II(b) - buildings and other structures except those listed in Risk Categories I, II(a), III, and IV; includes but not limited to:

   a. many businesses, factory/industrial, and mercantile facilities.
   b. public assembly facilities with an occupant load ≤ 300 (e.g., theaters, concert halls, banquet halls, restaurants, community halls).
   c. adult education facilities such as colleges and universities with an occupant load ≤ 500.
   d. other residential facilities (e.g., boarding houses, hotels, motels, care facilities, dormitories with >10 dwelling units).

3. *Risk Category III*—includes but not limited to:

   a. public assembly facilities with an occupant load > 300, schools (elementary, secondary, daycare).
   b. adult education facilities such as colleges and universities with an occupant load > 500.
   c. Group I-2 occupancies (medical facilities without surgery or emergency treatment facilities) with an occupant load >50.
   d. Group I-3 occupancies (detention facilities for example jails, prisons, reformatories, detention facilities) with an occupant load >5.
   e. any other occupancy with an occupant load >5000.
   f. power-generating stations, water-treatment plants, wastewater treatment facilities, and other public utility functions not included in risk category IV.
   g. buildings and other structures not included in risk category IV that contain quantities of toxic or explosive materials.

4. *Risk Category IV*—includes but is not limited to:

   a. Group I-2 occupancies having surgery or emergency treatment facilities.
   b. fire, rescue, ambulance, police stations, and emergency vehicle garages.
   c. designated emergency shelters: emergency preparedness, communication, and operations centers and other facilities required for emergency response.

d. power-generating stations and other public utility facilities are required as emergency backup facilities for Risk Category IV structures.
e. buildings and other structures containing quantities of highly toxic materials.
f. aviation control towers, air traffic control centers, and emergency aircraft hangars.
g. buildings and other structures that have critical national defense functions.
h. water-storage facilities and pump structures that are required to maintain water pressure for fire suppression.

1.4 Liquefaction Hazard Assessment Wavier – Residential Dwellings

A liquefaction investigation will be waived for wood framed residential structures if:

1. Liquefaction hazard reduction measures are to be included in the design and construction of the structures.

2. A Utah licensed structural engineer prepares a signed and sealed letter demonstrating the proposed design measures and the expected behavior of the structure should liquefaction occur, do not need to be implemented because the residential structure(s) has been designed to withstand at least 4 to 12 inches of vertical and horizontal liquefaction induced ground displacements[1] with respect to life safety.

   Risk to the occupants and potential damage to the structure must be addressed, and the structural engineer must demonstrate the life safety of occupants will be preserved should liquefaction occur. The letter must explain what hazard reduction measures are included in the design of the structure, or explain why none should be required.

   If such a letter cannot be obtained from a Utah licensed structural engineer, a liquefaction hazard investigation must be performed per this appendix. If a structural engineer has not been retained by the applicant, as may be case for residential subdivision sites, then the liquefaction hazard investigation may be waived for Plat approval at the discretion of the City building official if the geotechnical engineer indicates the liquefaction hazard will not prevent

[1] see Figure 8-1, p. 20, Figure 8-2, p. 21, and Figure 8-7, p. 27, in Bartlett and others, 2007.

development of the property. The letter from the structural engineer or a site specific liquefaction analysis will be required for the building permit application.

A disclosure notice referencing the letter from the Utah licensed structural engineer will be required to be completed by the applicant and filed with the City prior to issuing a building permit.

1.5 Roles of Engineering Geology and Geotechnical Engineering

The investigation of liquefaction hazards 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 engineering geologist or geotechnical engineer, also competent in the field of seismic hazard evaluation and mitigation.

Because of the different expertise and abilities of qualified engineering geologists and geotechnical engineers, the scope of the site investigation report for the project may require that both professionals prepare and review the report, each practicing in the area of their expertise. The involvement of both a qualified engineering geologist and geotechnical engineer is not required but will generally provide greater assurance that the hazard is properly identified, assessed, and mitigated.

Liquefaction analyses are the responsibility of the geotechnical engineer, although the engineering geologist should be involved in the application of screening criteria (see Section 3.0, steps 1 and 2) and general geologic site evaluation (see Section 4.1) to map the likely extent of liquefiable deposits and shallow groundwater. Geotechnical engineers shall:

1. Evaluate the engineering properties of subsurface earth material.

2. Perform the quantitative liquefaction analysis resulting in a numerical factor of safety and quantitative assessment of settlement and liquefaction-induced permanent ground displacement.

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 geotechnical engineer.

1.6 Minimum Qualifications of the Licensed Professional

Liquefaction analyses in the City must be performed by qualified engineering geologists and qualified geotechnical engineers as defined in Section 2.0 of these Standards, and Sections 10-7-050 and 10-7-060 of the City geologic hazards oridinace.

2.0 GENERAL REQUIREMENTS

Except for the derivation of ground motion parameters for use in quantitative liquefaction analyses (see Section 6.0), liquefaction investigations should be performed in general accordance with the latest version of Recommended Procedures for Implementation of California Division of Mines and Geology Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California (Martin and Lew, 1999). Additional protocol for liquefaction investigations is provided in Youd and Idriss (1997). See the City geologic hazard ordinance for supplemental requirements.

3.0 SCOPING MEETING

The applicant must schedule a scoping meeting with the City. A work plan prepared by the applicant's geologic and geotechnical engineering consultants, outlining the consultant's investigative approach, shall be provided to the City before the scheduled scoping meeting. All work plans shall include the original or electronic signature and professional seal, in blue ink, of the qualified professional(s) responsible for the work. At scoping meetings, the City reviews the consultant's work plan with the Applicant and the Applicant's consultants.

The work plan should allow for flexibility due to unexpected site conditions. The City understands field findings may require modifications to the work plan. Upon completion of a successful scoping meeting, and acceptance of the consultant work plan, a work plan approval letter will be issued by the City (see Section 10-7-070, Preliminary Activities, of the City geologic hazard ordinance).

4.0 PRELIMINARY SCREENING FOR LIQUEFACTION

The Liquefaction Special Study Area map is based on broad regional studies and does not replace site-specific studies. The presence of a site in a designated potential liquefaction area does not automatically indicate a liquefaction hazard exists; it only indicates that a liquefaction hazard investigation must be performed to determine whether a liquefaction hazard may be present.

Soil liquefaction is caused by strong seismic ground shaking where saturated, cohesionless, granular soil undergoes a 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, and sandy silt, non-plastic silts, and gravelly soils (Youd and Gilstrap, 1996; Boulanger and Idriss, 2004; Bray and Sancio, 2006). All of the following conditions *must* be present for liquefaction to occur:

1. Soils *must be* submerged below the water table.

2. Soils *must be* loose to moderately dense.

3. The intensity and duration of ground shaking *must be* sufficient for the soils to generate seismically-induced excess pore water pressure and lose shearing resistance.

The following criteria may be used to assess when a quantitative evaluation of potential liquefaction hazard may not be necessary:

1. When the estimated maximum historical, present, and/or future groundwater levels are determined to be deeper than 50 feet below the existing ground surface or proposed finished grade (whichever is greater.

2. When “bedrock” or similar solid, lithified, very dense, and very hard formational material underlies the site.

3. If the corrected standard penetration blow count, $(N1)_{60}$, is greater than or equal to 33 *in all samples*.

During a quantitative evaluation of a potential liquefaction hazard the following subsurface soils may be considered non-liquefiable:

1. When samples with corrected standard penetration blow count, (N1)60, ≥33.

2. The corrected cone penetration test tip resistance, qc1N, in cone penetration test hat are ≥180.

3. The plastic soils (i.e., Plastic Limits ≥20).

5.0 FIELD INVESTIGATIONS

5.1 Geologic Reconnaissance

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 describe the formations present at the site that includes the nature, thickness, and origin and age of deposits with liquefaction potential.

There also should be an analysis of current groundwater conditions at the site, the highest historical water levels, and the estimated highest water level likely to occur under the most adverse foreseeable conditions in the future.

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.

Shallow groundwater conditions 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 drainage canals, lakes, reservoirs, and detention basins may create a shallow groundwater table in previously unsaturated sediments.

5.2 Subsurface Explorations

Subsurface explorations may consist of drilled-borings and/or cone penetration tests.

The exploration program shall be planned to determine the soil stratigraphy, groundwater level, and subsurface soil indices required to evaluate the liquefaction potential by either geotechnical engineering in situ and/or laboratory testing of soil samples. Borings and CPT soundings must penetrate a minimum of:

1. Fifty (50) feet below final ground surface for native and proposed fill sites.

For saturated cohesionless soils where the SPT $(N1)_{60}$ values are less than 15, or where cone penetration test tip resistances are below 60 tons per square foot (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. These same tests shall be performed on saturated cohesionless soils with SPT $(N1)_{60}$ values between 15 and 30 to further evaluate the potential for liquefaction-induced settlement.

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 below the lowest expected foundation level (e.g., caisson bottom or pile tip) or 50 feet below the existing ground surface or lowest proposed finished grade, whichever is deeper.

During a liquefaction investigation, if the liquefaction indices indicate that the liquefaction potential may extend below those depths, the exploration should be continued until a thickness of at least 10 feet of non-liquefiable soils are documented.

5.3 Spatial Frequency of Tests

At a minimum, standard penetration tests for liquefaction analyses shall be performed at intervals no more than 2.5 feet. Cone penetration tests for liquefaction should be continuous.

For parcels ≤1-acre, one liquefaction boring will be sufficient. For larger parcels, the horizontal spacing between borings for liquefaction analyses:

1. Shall depend on the specific project, but must not exceed 500 feet.

2. Will be reviewed and modified, if deemed appropriate, during the project scoping meeting.

6.0 GROUND MOTION FOR LIQUEFACTION ANALYSES

The two controlling faults most impacting 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 (DuRoss and Hyland, 2015).

For determining the minimum design loads and associated criteria for building and other structures, the City uses the most current version of the American Society of Civil Engineers (ASCE)-7 (presently 2016). In regard to design ground accelerations for liquefaction analyses, ASCE-7 allows either a probabilistic or deterministic approach to determining the likelihood of different levels of ground motion that will be exceeded at a particular site within a given time period. To be consistent with current IBC and ASCE-7 documents, liquefaction analyses shall be based on the modified peak acceleration (PGA_M) with a 2 percent probability of exceedance in 50 years (2,500-year return period).

Modified peak bedrock ground motions can be obtained via the internet from the ASCE or from California's Office of Statewide Health Planning and Development (OSHPD) website, seismicmaps.org which is based on Petersen and others (2014)[2]. 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 in accordance with the current ASCE-7.

7.0. EVALUATION OF LATERAL SPREAD IN LIQUEFACTION-PRONE SOILS

Estimates of the amount of lateral spread, and measures to mitigate the hazard must be provided if liquefaction-prone soils are identified. The methodology used tp eva;iate the lateral spread hazared at the property must be from a published document and cited for review. The method should be discussed at the City scoping meeting.

Generally lateral spread occurs in cohesionless sands and gravels. A site must meet the following criteria for lateral spread to occur:

1. The lateral spread susceptible layers should be relatively continuous.

[2] http://Seismicmap.org

2. The free face ratio[3] should be between 1 and 20 percent.

3. The ground slope should be between 0.1 and 6 percent.

4. The lateral spread susceptible layers should be at least about 3 feet (1 m) thick but no greater than about 50 feet (15 m) thick.

5. The depth to the top of lateral spread zone or layers should be less than about 35 feet (10 m).

8.0 SUBMITTALS

Submittals for review shall include:

1. Boring/CPT logs.

2. The methodology used, with complete citation.

3. Laboratory data.

4. Subsurface conditions and parameters used for analyses.

5. Liquefaction calculations, submitted with pertinent backup documentation (i.e., calculations, computer output, etc.).

6. Estimates of ground settlement, lateral spread, and measures to mitigate the hazard if liquefaction-prone soils are identified.

7. A signed and sealed letter from a Utah licensed structural engineer acknowledging receipt of the liquefaction investigation report, stating the proposed liquefaction-hazard reduction design measures, and the expected behavior of the structure during an earthquake with respect to life safety.

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.

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[3] Free face ratio means the height of the free face divided by the distance of the site behind the free face times 100.

9.0 DISCLOSURE OF GEOLOGIC HAZARD REPORT

The owner of the parcel must record a notice running with the land disclosing the geologic hazards study report for the property; see Section 10-7-120 of the City geologic hazards ordinance. The disclosure of the geologic hazards report must be completed before the approval of any development or subdivision of such parcel.

APPENDIX D - MINIMUM STANDARDS FOR DEBRIS FLOW INVESTIGATIONS

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1.0 INTRODUCTION

The procedures outlined herein are intended to provide consultants with a general outline for performing uniform debris flow hazard investigations on alluvial fans and engineering measures to mitigate the debris flow hazards in Draper City, Utah. These standards constitute the minimum level of effort required in conducting debris flow hazard investigations in Draper City.

Debris flows are fast moving, flow-type landslides composed of a slurry of rock, mud, organic matter, and water that move down drainage basin channels onto alluvial fans. In addition to threatening lives, debris flows can damage structures and infrastructure by sediment burial, erosion, direct impact, and associated water flooding.

Debris flow investigations are required for:

1. Areas depicted in the City Debris Flow Special Study Area Map; the City Debris Flow Special Study Area Map may be viewed at the City online map portal via the geologic information application.

2. Other environmentally sensitive areas that the City Planning Commission and the City Council finds to be of significance to the health, safety, welfare, and property of the citizens of the Draper City; and

3. All properties on or adjacent to alluvial fans and drainage channels subject to flash flooding and debris-flow deposition.

Section 10-7-100 of the City geologic hazards ordinance requires a geologic hazards study report for sites depicted in the City Debris Flow Special Study Area Map.

2.0 MINIMUM QUALIFICATIONS OF INVESTIGATORS

Debris flow related geologic hazard investigations/assessments in the City must be performed by qualified engineering geologists as defined in Section 2.0 of these Standards, and Section 10-7-050 of the City geologic hazards ordinance, with at least five years of previous experience performing debris-flow hazard investigations in Utah or another state with similar geologic conditions.

Often debris-flow geologic hazard investigations are interdisciplinary, requiring assistance from a professional engineer, the engineering must be performed by a Utah licensed civil with at least five years of previous experience performing debris-flow hazard investigations in Utah or another state with similar geologic conditions.

3.0 INVESTIGATIVE METHODS

Considering the complexity of evaluating debris-flow hazards, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address the hazard. The information presented herein does not relieve the geologist/engineer of their responsibility to perform additional geologic and/or engineering analyses they believe are necessary to assess debris flow hazards at a site.

Debris flow hazard investigations shall include, when appropriate, evaluation of the drainage basin and channel independently of the alluvial fan evaluation, particularly for estimating erodible sediment volume available for debris flow bulking (see Section 6.0) and the probability of post-wildfire debris flows (i.e., see Cannon, 2001; Giraud and McDonald, 2007; Cannon and others, 2010).

Debris-flow hazard investigations and reports shall conform with:

1. The most current Utah Geological Survey Guidelines for the Geologic Investigation of Debris-Flow Hazards on Alluvial Fans in Utah (presently, Giraud, 2020). The methodology presented in Giraud (2020), is not summarize herein.

2. Section 10-7-100 of the City geologic hazards ordinance.

4.0 SCOPING MEETINGS

The applicant or consultant shall schedule a scoping meeting with the City to evaluate the engineering geologist's/geotechnical engineer's investigative approach (see Section 10-7-070 of the City geologic hazards ordinance). For debris flow hazard investigations the investigative approach shall include proposed cross-channel profiles to estimate the erodible sediment volume available for debris flow bulking.

5.0 SUBSURFACE EXPLORATIONS

Exposures in trenches/test pits shall be documented on a trench/test pit log. Trench/test pit logs shall be carefully drawn in the field at a minimum scale of 1-inch equals 5-feet (1:60).

Vertical control must be used and shown on each end of the trench/test pit log. Horizontal control must be used and shown along the base of the trench/test pit log.

Trench/test pit logs must document all significant geologic information from the trench/test pit and shall graphically represent the geologic units and geologic structures observed.

Trench/test pit logs shall include, at a minimum, trench orientation and an indication of which trench/test pit wall was logged; trench/test pit top and bottom; stratigraphic contacts; stratigraphic unit descriptions including lithology, Unified Soil Classification System soil classification, geologic origin and age of the deposits, and contact descriptions; soil (pedogenic) horizons; marker beds, and; deformation or offset of sediments, faults, and fissures.

A field review by the City is required at the completion of consultant's exploratory excavations. The applicant must provide a minimum of 48-hours' notice to schedule the field review with the City. The excavations must be open, safe, cleaned, and a preliminary log completed at the time of the review. The field review allows the City to evaluate the subsurface data with the consultant. Discussions about questionable features are encouraged, but the City will not help log the trench/test pit, explain the stratigraphy, or give verbal approval of the proposed development during the field review.

6.0 CHANNEL SEDIMENT BULKING AND FLOW-VOLUME ESTIMATION

Channel sediment-bulking and flow-volume estimates must not rely solely on empirical methods alone. Empirical methods are only approximate and have low reliability (see Giraud, 2020). Cross-channel profiles to estimate the erodible depth of channel sediment is necessary to estimate the sediment volume available for bulking. This may be accomplished by either:

1. Cross-channel profiles generated from high-resolution lidar (i.e., ≤1 meter), or;

2. Estimating potential sediment-bulking rates of the material likely to be mobilized via field inspection of the drainage channels and field generated cross-channel profiles (Giraud, 2020).

The number of cross-channel profiles to estimate the erodible sediment volume available for debris flow bulking shall be based on the dimensional uniformity of the channel, supported by adequate data, and consisting of at least one profile at each end of the channel and one in the center of the drainage. A variant of more than 10 percent in either the channel width or depth would be considered dimensional non-uniformity.

7.0 DEBRIS-FLOW HAZARDS REPORT

In addition to items listed in Section 10-7-100 of the City geologic hazards ordinance, debris flow geologic hazards study reports shall contain at a minimum:

1. Recommendations and conclusions supported by satisfactory data, presented clearly and concisely.

2. The probability of debris-flow occurrence (if possible), estimates of debris-flow volume, a map showing hazard areas, and a discussion on the likely effects of debris flows on the proposed development.

3. The degree of confidence in, and limitations of, the data and conclusions.

4. Recommendations to define buildable and non-buildable areas (if appropriate) and design risk-reduction measures.

5. Geologic and/or engineering analyses necessary to assess the debris-flow hazards at a site.

6. The area of the drainage basin, shown on a site plan.

7. Calculations to support the 100-year storm event with estimated flow rates.

8. The erodible sediment volume available for debris flow bulking.

9. Probability of non-fire-related debris flows.

10. Probability of post-wildfire debris flows.

11. The volume of debris flows based on non-fire related flows and post wildfire flows.

12. Alluvial fan evaluation (Giraud, 2020, p. 89).

13. Drainage basin and channel evaluation (Giraud, 2020, p. 89).

14. The across-fan and down fan extent of individual debris flows.

15. Cross-sections of the debris flow channel used to estimate debris-flow volumes.

16. Calculations to substantiate debris-flow-volume estimates, stream gradients, sediment bulking, etc.

8.0 RISK REDUCTION MEASURES

Holocene-age sediments were generally deposited under climatic conditions similar to the present. Consequently, the Utah Geological Survey considers Holocene-age debris-flow deposits on an alluvial fan as sufficient evidence of a potential hazard to warrant site-specific debris-flow-hazard studies and implementation of risk-reduction measures as appropriate (unless geologic and topographic conditions on the alluvial fan have changed) (Giraud, 2020).

Risk-reduction measures shall reduce the level of risk such that there are no impacts to properties from potential debris flow events. If risk-reduction measures are included in the report, the following shall be addressed in the report (Giraud, 2020):

1. A discussion of the implications of risk-reduction measures on adjacent properties, and the need for long-term maintenance.

2. Calculation of debris flow impact forces if recommendations are provided for debris flow-deflection structures or debris-flow-resistant construction (reinforcement of foundations, flood-proofing), hydraulic modeling of debris flow discharge, run-up, and runout. Specific information on flow type(s), deposit distribution and thickness, flow velocity, peak flow, and runout is necessary to calibrate models.

3. A discussion of the residual risk to development (if appropriate) after risk-reduction measures are in place.

9.0 DISCLOSURE OF GEOLOGIC HAZARD REPORT

The owner of the parcel must record a notice running with the land disclosing the geologic hazards study report for the property; see Section 10-7-120 of the City geologic hazards ordinance. The disclosure of the geologic hazards report must be completed before the approval of any development or subdivision of such parcel.

APPENDIX E - MINIMUM STANDARDS FOR ROCKFALL HAZARD INVESTIGATIONS

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1.0 INTRODUCTION

The procedures outlined herein are intended to provide consultants with a general outline for performing uniform rockfall-hazard investigations and engineering measures to mitigate the rockfall hazards in Draper City, Utah (the City). These Standards constitute the minimum level of effort required in conducting rockfall hazard investigations in the City.

Considering the complexity inherent in performing rockfall-hazard investigations, additional effort beyond the minimum standards presented herein may be required at some sites to adequately address rockfall hazards. The information presented herein does not relieve consultants of their duty to perform additional geologic or geotechnical engineering analyses that they believe are necessary to assess the rockfall hazard at a site.

2.0 SCOPING MEETINGS

The applicant or consultant shall schedule a scoping meeting with the City to evaluate the engineering geologist's/geotechnical engineer's investigative approach (see Section 10-7-070 of the City geologic hazards ordinance).

3.0 ROCKFALL-HAZARD SPECIAL STUDY AREAS

Rockfall hazard is based on several factors including geology, topography, and climate. Rockfall sources include bedrock outcrops or boulders on steep mountainsides or near the edges of escarpments such as cliffs, bluffs, and terraces. Talus cones and scree-covered slopes are indicators of a rockfall hazard, but other less obvious areas may also be vulnerable to rockfall.

Rockfalls are initiated by freeze/thaw action, rainfall, weathering, and erosion of the rock and/or surrounding material, and root growth. Rockfall is also the most common type of slope failure caused by earthquakes (Lund and Knudsen, 2020).

The following three components must be considered when evaluating the rockfall-hazard susceptibility of a property:

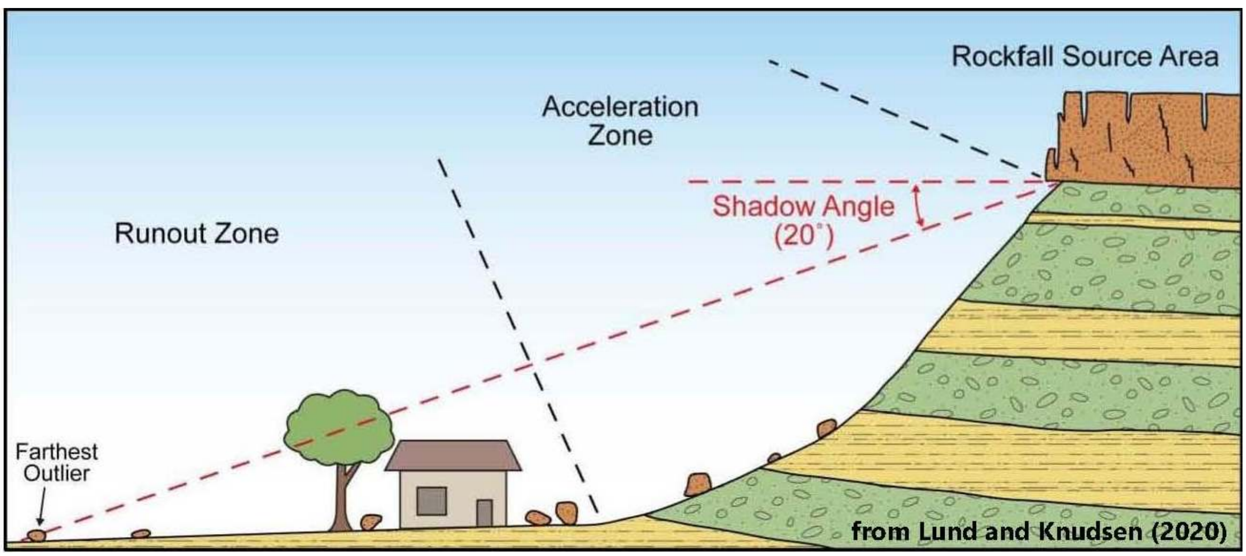
1. A rock source, in general, defined by bedrock geologic units that exhibit relatively consistent patterns of rockfall susceptibility throughout the study area;

2. An acceleration zone, where rockfall debris detached from the source gain momentum as the rock debris travels downslope. The acceleration zone often

includes a talus slope, which becomes less apparent with decreasing relative hazard and is typically absent where the hazard is low, and;

3. A runout zone (rockfall shadow zone), which includes gentler slopes where rock debris (i.e., cobbles and boulders), have rolled or bounced beyond the base of the acceleration zone (see Rockfall Component Figure, from Lund and Knudsen, 2020). The boundary of the rockfall shadow zone is established using the shadow angle (Lund and Knudsen, 2020), which is the angle formed by a horizontal line and a line extending from the base of the rock source and the outer limit of the runout zone (see the following figure). Shadow angles vary based on rock type, boulder shape, slope steepness, slope composition, and rock source height.

Rockfall Component Schematic



Rock fall investigations are required for:

1. Areas depicted in the City Rockfall Special Study Area Map; the City Rockfall Special Study Area Map may be viewed at the City online map portal via the geologic information application.

2. Environmentally sensitive areas that the City Council finds to be of significance to the health, safety, and welfare of the citizens of the City

3. Locations at the base of rock and talus slopes that are susceptible to rockfall; evidence of past rockfalls being the primary indictor. For the City, a rockfall hazard area is

defined by the following:

a. The presence of a rock source area;
b. The presence of rock debris in the acceleration and runout zones, and;
c. Whether the size of rock debris in the acceleration and runout zones and associated rock debris velocities pose a life safety issue to existing and/or proposed structures.

5.0 MINIMUM QUALIFICATIONS OF INVESTIGATORS

Rockfall related geologic hazard investigations/assessments in the City must be performed by qualified engineering geologists as defined in Section 2.0 of these Standards, and in Section 10-7-050 of the City geologic hazards ordinance, with at least five years of previous experience performing rockfall hazard investigations in Utah or another state with similar geologic conditions.

Often rockfall hazard investigations are interdisciplinary, requiring assistance from a professional engineer. When interdisciplinary, must be performed by qualified geotechnical as defined in Section 2.0 of these Standards, and in Section 10-7-060 of the City geologic hazards ordinance, with at least five years of previous experience performing rockfall hazard investigations in Utah or another state with similar geologic conditions.

6.0 ROCKFALL HAZARD STUDY ASSESSMENT

The rockfall-hazard assessment should commence with an assessment of whether the conditions for rockfall are present at or near the site of interest by documentation of the following:

1. A rock source;

2. An acceleration zone;

3. A runout zone (rockfall shadow zone).

If either a rock source or a slope steep enough to permit rockfall debris to move rapidly downslope is absent, or there is no rock debris on the site, there is no rockfall hazard. The determination of whether a rockfall hazard is present or not can often be made quickly from analysis of aerial photographs or other remote sensing data, or from a brief site reconnaissance (Lund and Knudsen, 2020). Rockfall-hazard investigations should include (see Lund and Knudsen, 2020):

1. Interpretation of stereoscopic aerial photographs (from multiple years if available), evidence of rockfalls subsequently obscured by development or other ground disturbance.

2. Analysis of available lidar imagery and other remotely sensed data for evidence of rockfall sources and past rockfall activity.

3. Review of topographic maps (from multiple years if available), for indications of talus and near-vertical slopes.

4. Mapping susceptible geologic units, talus slopes, and topographic features that may affect rockfall hazards.

    a. In acceleration zones, the following must be recorded:
        i. slope angle.
        ii. aspect (compass direction of the slope face).
        iii. substrate (defined in rockfall simulation program).
        iv. surface roughness (defined in rockfall simulation program).
        v. vegetation.
        vi. geomorphic or topographic features that could deflect the path of a rockfall.
        vii. abrupt changes in slope potentially causing rockfall debris to become airborne (“launch points”).

    b. In runout zones, the following must be recorded:
        i. distribution of rockfall debris.
        ii. rockfall debris rock sizes.
        iii. amount/extent of rockfall debris embedment.
        iv. weathering of rockfall debris as an indicator of rockfall age.

5. Rockfall sources must be evaluated for:

    a. rock type/lithology.
    b. weathering.
    c. discontinuities (bedding, joints, faults, shear zones, foliation, schistosity, veins, etc.).
    d. potential rockfall rock sizes.

6. The presence of discontinuities in the bedrock source, which could potentially provide additional detachment surfaces for blocks and/or wedge failures, and control the size and shape of rockfall debris; important properties of discontinuities include:

    a. Orientation.
    b. Spacing.
    c. Persistence.
    d. Roughness.
    e. Weathering.
    f. aperture width and filling.
    g. seepage.

    Discontinuity spacing and other rock mass data can be obtained from a rock outcrop scanline survey or rock cores.

7. Investigation of groundwater conditions, both current and historical.

8. The use of a 2-D or 3-D rockfall simulation programs (i.e., Higgins and others, 2000; CRSP, 2000; Rocscience, 2015) to:

    a. predict rockfall trajectories, characteristics, and runout limits.

    b. provide a basis for the analyses and specifications for rockfall-hazard mitigation measures (see Turner and Duffy, 2012, for a discussion of 2-D rockfall simulation programs).

    Many of the parameters listed in Items 4a and 4b are required input for rockfall simulation programs.

7.0 ROCKFALL HAZARD INVESTIGATION REPORTS

Rockfall hazard investigation geologic hazard reports shall conform with Section 10-7-100 of the City geologic hazards ordinance. The rockfall hazard investigation geologic hazard reports shall also include, but are not limited to:

1. Calculations to substantiate rockfall impact energies.

2. Input/output files for computer rockfall simulation programs.

3. Sufficient data to support all conclusions and recommendations.

4. Recommendations for rockfall-hazard mitigation, when required.

8.0 ROCKFALL HAZARD MITIGATION REQUIREMENTS

When a rockfall hazard is present, avoidance is the most effective and pragmatic means of mitigating the hazard. When avoidance is not a viable or cost-effective hazard-reduction option i.e., (existing developments), the engineering geologic/geotechnical engineering consultants should:

1. Propose design measures and/or define the boundary beyond which siting of a structure will minimize the risk from future rockfall, with respect to life safety and rockfall debris penetrating exterior walls of proposed structures.

2. Provide the parameters required for a qualified Utah licensed structural engineer to determine and design an engineering technique to mitigate the hazard (i.e., rock stabilization, engineered structures, or modification of at-risk structures or facilities, etc.).

3. Provide, at a minimum, the following parameters: rock size(s), rock trajectories, rock velocities, rock impact energies, rock bounce heights, rock runout distances, which in turn form a basis for the selection of designs for rockfall hazard mitigation.

4. Employ a 2-D or 3-D rockfall simulation program to predict rockfall trajectories, characteristics, rock velocities, energy, bounce heights, runout limits, etc., and to provide a basis for the analyses and design of rockfall hazard mitigation measures (Higgins and others, 2000; CRSP, 2000; Rocscience, 2015).

9.0 LETTER FROM STRUCTURAL ENGINEER

A stamped letter is required from a Utah licensed structural engineer acknowledging receipt of the rockfall hazard report and addressing the proposed design measures and the expected behavior of the structure during the design rockfall event. The letter must demonstrate:

1. The life safety of occupants will be preserved should a rockfall event occur.

2. Potential damage to the structure should a rockfall event occur.

3. Rockfall debris will not penetrate the exterior walls of the structure.

10.0 DISCLOSURE OF GEOLOGIC-HAZARD REPORT

The owner of the parcel must record a notice running with the land disclosing the geologic hazards study report for the property; see Section 10-7-120 of the City geologic hazards ordinance. The disclosure of the geologic hazards report must be completed before the approval of any development or subdivision of such parcel.