Minimum Standards for Surface Fault Rupture Hazard Studies

SALT LAKE COUNTY GEOLOGIC HAZARDS ORDINANCE - CHAPTER 19.75 APPENDIX A

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1.0 INTRODUCTION

Salt Lake County lies adjacent to the active Wasatch Fault zone. *"Surface fault rupture"* is fault-related offset or displacement of the ground surface that may occur due to an earthquake. If a normal fault were to break the ground surface beneath a building, significant damage could occur, perhaps resulting in injuries or loss of life. To address the surface fault rupture hazard, Salt Lake County has defined Surface Fault Rupture Special Study Areas, within which site-specific investigations are required prior to development. To ensure that buildings are not sited across active faults, the Salt Lake County Geologic Hazards Ordinance (Chapter 19.75) requires a site-specific investigation to locate active faults and establish appropriate building setbacks prior to development of sites located within the Surface Fault Rupture Special Study Area. A site-specific surface fault rupture study includes a field investigation (usually by excavation and logging of a trench) and a fault rupture hazard report. This brochure describes the minimum standards that are required by Salt Lake County for these studies.

The purpose of establishing minimum standards for surface fault rupture hazard studies is to:

- Protect the health, safety, welfare, and property of the public by minimizing the potentially adverse effects of fault rupture and related hazards;
- Assist property owners and land developers within the Surface Fault Rupture Special Study Area in conducting reasonable and adequate studies;
- Provide consulting engineering geologists with a common basis for preparing proposals, conducting investigations, and recommending setbacks; and,
- Provide an objective framework for regulatory review of fault study reports.

The procedures outlined herein are intended to provide the developer and consulting engineering geologist with an outline of appropriate exploration methods, standardized report information (map and trench-log scales; setback recommendations, etc.) and expectations of the regulatory reviewer. These standards are intended to help minimize study costs and review time.

These standards constitute the *minimum* level of effort required in conducting surface fault rupture hazard special studies in Salt Lake County. Considering the complexity of evaluating surface and near surface faults, additional effort beyond the minimum standards may be required at some sites to adequately address the fault hazard.

1.1 Background

Little regard was given to fault hazards in Salt Lake County land-use planning before about 1970, when Woodward-Lundgren & Associates completed their Wasatch fault investigation and map (Cluff and others, 1970). This aerial-photo-based map presented the first detailed information on fault locations usable by local governments, and increased awareness of the hazard posed by the Wasatch fault. More recently, investigations by Black and others (1996) concluded that this fault has a late-Holocene average recurrence interval of surface-faulting earthquakes of 1,350 (±200) years, with the last major event approximately 1,300 years before present (ybp). McCalpin's (2002) megatrench study across the Wasatch fault near Little Cottonwood Canyon dated the last 6 events. The most recent earthquake on the West Valley Fault has been dated at approximately 2,220 years ago (UGS, 1998).

When Salt Lake County experienced a foothill-area residential building "boom" in the early 1970s, fault investigations were sometimes required for the new subdivisions. The Salt Lake County Planning Commission and Development Services staff relied heavily on the developer's consultant as the professional "expert" responsible for ensuring the fault rupture safety of the proposed development. Reports would sometimes be sent for review by the Utah Geological Survey.

This informal review process lasted until June 1985 when the Utah Geological Survey initiated the County Geologist program, funded through the U.S. Geological Survey's National Earthquake Hazards Reduction Program (NEHRP; Christenson, 1993). In 1988, Salt Lake County created a permanent County Geologist position on the Planning Department staff. The County Geologist is now in the Planning and Development Services Division, and is responsible for providing regulatory review for all fault hazard reports.

In May 1989, Salt Lake County enacted the Natural Hazards Ordinance (NHO). This ordinance adopted a series of geologic hazard special-study area maps that define areas where site-specific geologic hazard studies are required prior to approval of new development. Maps were adopted delineating surface fault rupture, liquefaction, and avalanche special study areas.

The Natural Hazards Ordinance was renamed the Geologic Hazards Ordinance and revised in 2002 to incorporate additional geologic hazards including landslide, debris flow, and rockfall. This document was incorporated as Appendix A to the Geologic Hazards Ordinance.

Salt Lake County's primary objective is to protect life safety in the event of an earthquake. Earthquakes can cause structural failures due to ground shaking, liquefaction, and surface fault rupture effects. Ground-shaking hazards are addressed through seismic requirements included in the local Building Code, while liquefaction-related problems are addressed by conducting a liquefaction analysis as per the requirements of the Geologic Hazards Ordinance (see Appendix B, “Liquefaction: A Guide to Land Use Planning, Salt Lake County, 2001).

An earthquake along the Salt Lake City segment of the Wasatch Fault could result in as much as 8 feet of displacement of the ground surface. To address surface fault rupture hazards, the Geologic Hazards Ordinance (Section 19.75.080) prohibits construction of habitable structures and critical facilities across an active fault (defined as having greater than four inches of displacement along one or more traces during Holocene time- about 10,000 years ago to the present).

For most geologic hazards, engineering controls can be implemented to mitigate or minimize damage. However, it is generally impractical from an economic, engineering, and architectural point of view to design a typical structure to withstand the serious damage that significant surface fault rupture can cause. Mitigation of the fault-rupture hazard thus requires relocating the structure. The purpose of the fault study is to evaluate the presence or absence of the fault, and, if necessary, establish an appropriate building setback.

1.2 References and Sources

The minimum standards presented herein were developed from the following sources:

- Utah Section of the Association of Engineering Geologists (AEG) *Guidelines for Evaluating Surface Fault Rupture Hazards in Utah* (AEG, 1987).
- California Division of Mines & Geology publications (CDMG, 1986a, b).
- Nevada Earthquake Safety Council, 1998.
- Batatian, L.D., and Nelson, C.V., 1999.

1.3 When Is a Fault Study Required?

A fault study is required prior to approval of any land use at sites that lie within a fault study area, as shown on the Surface Fault Rupture Special Study Area Map published by Salt Lake County Planning and Development Services Division (1995). This map identifies known active faults in Salt Lake County, and defines special study areas along the faults within which site-specific investigations are required. Development of any parcel within the Surface Fault Rupture Special Study Area requires submittal and review of a site-specific fault study prior to receiving a land use or building permit from Salt Lake County Planning and Development Services. The developer must retain a qualified engineering geology consultant to perform the fault study.

1.4 Selecting a Consultant

Fault investigations must be performed by a consulting engineering geologist specifically trained and experienced in completing fault investigations *(see Section 2.1, “Minimum Qualifications of the Preparer” below).* Qualifications and experience deserve significant consideration along with cost. An experienced consultant will understand the scope of the project, be familiar with the type of soils expected, know how to log the trench and interpret the stratigraphy, and prepare a report with appropriate recommendations that will receive prompt regulatory approval. Their expertise will ultimately save both time and money.

Engineering geologists preparing surface fault rupture special studies are ethically bound first and foremost to protect public safety and property in their investigations, and as such must adhere to the highest ethical and professional standards. The engineering geologist's conclusions, drawn from any given set of geologic data, must be consistent and unbiased. Information gained during a study may not be withheld.

2.0 MINIMUM STANDARDS FOR FAULT STUDIES

Following are the minimum standards for a comprehensive fault investigation. Fault investigations may be reported in conjunction with other geological and geotechnical investigations, or may be submitted separately.

2.1 Minimum Qualifications of the Preparer

Fault hazard evaluation is a specialized discipline within the practice of engineering geology requiring technical expertise and knowledge of techniques not commonly used in other geologic or geotechnical investigations. Therefore, a surface fault rupture special study will only be accepted when conducted and signed by a *qualified engineering geologist*. Minimum qualifications of the engineering geologist who performs a fault study are herein defined as:

- An undergraduate or graduate degree in geology, engineering geology, geological engineering, or a related field with a strong emphasis on geologic coursework, from an accredited college or university; and,
- Three 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 environment. This experience must demonstrate the engineering geologist's knowledge and application of appropriate techniques in performing surface fault rupture hazard studies; and,
- Effective January 1, 2003, per State law, a Utah State Professional Geologist's license is required to practice geology before the public.

As stated in Section 19.75.060(A) of the Geologic Hazards Ordinance, and in Section 2.9.5, below, all surface fault rupture hazard reports shall be prepared, signed and stamped by a licensed professional geologist, and shall include the qualifications of the preparer (such as their training and experience conducting similar studies).

Under the direct supervision of a qualified engineering geologist, a less-qualified engineering geologist may participate in the study for training and to gain experience.

2.4 Scoping Meeting

The developer or consultant will schedule a scoping meeting with the County Geologist to evaluate the fault investigation approach. At this meeting, the consultant should present a site plan that includes: proposed building locations; expected fault location(s) and orientation; and the proposed trench locations, orientation, length, and depth (see *Fault Investigation Method*, below). The investigation approach should allow for flexibility due to unexpected site conditions; field findings may require modifications to the work plan.

If the project is relatively straightforward, the site plan can be faxed to the County Geologist and the scoping meeting can be completed via telephone. The developer and consultant need to clarify who will be responsible for contacting the County Geologist during the project.

2.5 Fault Investigation Method

Inherent in fault study methods is the assumption that future faulting will recur along pre-existing faults (Bonilla, 1970 p. 68; McCalpin 1987), and in a manner consistent with past displacement. The focus of fault investigations is therefore to 1) accurately locate existing faults, 2) evaluate the recency of their activity, and 3) estimate amounts of past displacement to derive recommended fault setbacks.

The most direct method of locating existing faults and evaluating the history of fault activity is to excavate exploratory trenches using a backhoe or trackhoe. The engineering geologist will clean and log the trench as described below. Existing faults may also be identified and mapped in the field by direct observation of young, fault-related geomorphic features, or by examination of aerial photographs. These and other methods are discussed in: McCalpin (1996; 1987); Slemmons and dePolo (1992); AEG (1987); Bonilla (1982); Hatheway and Leighton (1979); Slemmons (1977), Wallace (1977); Sherard and others (1974), and Taylor and Cluff (1973). Trenching is required; additional methods used should be clearly described in the report.

Trench Siting. The exploratory trench must be oriented perpendicular to the fault trace, and of adequate length to explore the proposed building site(s) plus any potential setback. The trench(es) must therefore extend beyond the building footprint at least the minimum setback distance for the building type (see Table A-1). Test pits or potholes are not adequate. Sometimes more than one trench is required to cover the entire building area, particularly if the proposed development involves more than one building. It is recommended that the trench be located outside the proposed building footprint, as the trench is generally backfilled without compaction, which could lead to differential settlement beneath the footings. Additional trenches may be necessary to accurately determine the trend of the fault as it crosses the property. It is strongly recommended that trench(es) and fault location(s) are surveyed by a registered professional land surveyor.

Depth of Excavation. A frequently-asked question is "How deep must the trench be?" The trench must be deep enough to extend below Holocene deposits (see below)- generally in the 8-12-foot range, but sometimes deeper. Please see the note below about practical limits of excavation. *It is the responsibility of the person in the field directing the excavation to ensure that fault trenches are excavated in compliance with current Occupational Safety and Health Administration excavation safety regulations (OSHA 1989).*

Logging the Trench. The engineering geologist will clean debris and backhoe smear off one or both of the trench walls, and carefully log the trench at a minimum scale of 1-inch equals 5-feet (1:60) following accepted fault trench investigation practices (McCalpin, 1996). Some form of vertical and horizontal logging control must be used and shown on the log. The log must document all significant information from the trench; see Section 2.9.3(E).

The engineering geologist will interpret the ages of sediments exposed in the trench, or, when necessary, obtain radiocarbon or other age determinations, to constrain the age of most recent fault movement to determine whether recent (Holocene) displacement has occurred. In Salt Lake County, stratigraphic and facies analysis of Pleistocene Lake Bonneville sediments are used to infer relative ages of sediments, and thus estimate ages of surface-faulting events. An excellent and well-documented stratigraphic lacustrine record exists from both transgressive and regressive stages, including the Bonneville highstand (approxmately 16,000 ybp); the catastrophic Lake Bonneville flood (14,400 ybp), and subsequent regressions below the Provo highstand (approx. 13,000 ybp) and Gilbert level (10,000 - 10,500 ybp; Personius and Scott, 1992; also see Oviatt and Thompson, 2002). The presence of unfaulted Lake Bonneville sediments (or other deposits shown to be older than 10,000 years in age) in a trench therefore provides reasonable evidence that Holocene faulting has not occurred at that site.

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

2.6 Field Review

A field review by the County Geologist is required during the exploratory trenching. The Project Manager (consultant or developer) must provide a minimum of 48-hours notice to schedule the field review with the County Geologist. The trench(es) should be open and a preliminary log completed at the time of the review. The field review allows the County Geologist to evaluate the subsurface data (i.e., age and type of sediments; presence/absence of faulting, etc.) with the consultant, and determine whether the investigation is adequate. Discussions about questionable features or an appropriate setback distance are encouraged, but the County

Geologist will not help log the trench, explain the stratigraphy, or give verbal approval (or disapproval) of the proposed development during the field review.

The Utah Geological Survey (UGS) is interested in collecting age-dating samples or other information from exploratory trenches in Salt Lake County. To help achieve this goal, consultants are requested to inform the UGS about trenching activities (contact Gary Christenson, (801) 537-3304).

2.7 Recommendations for Fault Setbacks

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

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

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

<u>Downthrown Fault Block (Hanging Wall)</u>
The fault setback for the downthrown block will be calculated using the following formula:

$$S = U\,(2D + F/\tan 0)$$ where:

S = Setback within which structures for human occupancy are not permitted;

U = Criticality Factor, based on the proposed occupancy of the structure (see Table A-1)

D = Expected fault displacement per event (assumed to be equal to the net vertical displacement measured for each past event)

F = Maximum depth of footing or subgrade portion of the building

0 = Dip of the fault (degrees)

All units are in feet. Variables used in the equation are presented graphically in Figure A-1.

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

$$S = U \times 2D$$

The setback is measured from the portion of the building closest to the fault, whether subgrade or above grade. Minimum setbacks apply as discussed above. Figure A-1 shows the variables used.

2.8 Regulatory Review

All fault investigation reports conducted in Salt Lake County will be reviewed by, and permanently filed with, the County Geologist. The County Geologist will evaluate the adequacy of the investigation, report, and setbacks, and advise the Planning and Development Services Staff and/or Planning Commission regarding the suitability of the proposed development. These minimum standards thus serve as the basis for the review and approval of fault study reports and the associated land use permits.

2.9 Required Outline for Surface Fault Rupture Hazard Studies

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

Two (2) signed original copies must be submitted to the County Geologist for review, prior to approval of any development where a fault study is required.

2.9.1. Required Text

A. Purpose and scope of investigation

B. Geologic and tectonic setting, including active faults in the area and paleoseismicity, reference relevant published and unpublished geologic literature.

C. Site description and conditions. Include information on geologic units, graded and filled areas, vegetation, existing structures, and other factors that may affect the site development plan, choice of investigative methods, and the interpretation of data.

D. Methods of investigation:
1. Review of published and unpublished maps, literature and records concerning geologic units, faults, surface and ground water, and other factors.

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

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

4. Subsurface investigations:
a. Summary of trenching or other detailed, direct observation of continuously exposed geologic units, soils and geologic structures. Trenching must be of adequate length and depth, and be carefully logged, as described in Section 2.5 and 2.9.3.(E). The strike, dip, and net vertical displacement (or minimum displacement) of faults must be noted.

The report must describe the criteria used to evaluate the ages of the deposits encountered in the trench, and clearly evaluate the presence or absence of active (Holocene) faulting. As described in Section 2.5, unfaulted Lake Bonneville sediments (or deposits shown to be older than 10,000 years in age) provide reasonable evidence that recent faulting has not occurred at the site. See page 4 for a discussion of the practical limits of excavation.

5. Other methods might be included when special conditions permit, or requirements for critical structures demand a more intensive investigation. These may include the following methods.

a. Test pits, boreholes, or cone-penetrometer soundings to collect data on geologic units and ground water at specific locations. The number and spacing of data points must be sufficient to permit valid correlations and interpretations.

b. Geophysical investigations. These are indirect methods that require knowledge of the geology (Chase and Chapman, 1976) and of specific geologic conditions for reliable interpretation. However, geophysical methods alone cannot prove the absence of a fault nor identify the recency of activity. Types of equipment and techniques may include seismic reflection, seismic refraction, ground-penetrating radar, or other methods (e.g., magnetic intensity, electrical resistivity, or gravity).

c. Age-dating techniques. These may include: isotopic (radiocarbon, cosmogenic nuclide) and radiogenic (thermoluminescence or TML)methods, particularly of colluvial wedges and soil horizons; soil-profile development; stratigraphic correlation (fossils, lithologic provenance); and other methods to date faulted and unfaulted units or surfaces (Noller and others, 2000).

E. Conclusions
1. Summary of evidence establishing whether faulting is or is not present, and is active or inactive, including ages of faulted and unfaulted stratigraphic units and surfaces.

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

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

F. Recommendations.
Recommendations must be supported with geologic evidence and appropriate reasoning behind each statement.

1. Recommended setback distances per Section 2.7. Supporting calculations must be included. Faults and setbacks must be shown on site maps and final recorded plat maps.

2. Other recommended building restrictions or use limitations (i.e., placement of detached garages, swimming pools, or other non-habitable structures).
3. Need for additional or future studies to confirm buildings are not sited across active faults, such as inspection of building footing or foundation excavations by the consultant.

2.9.2. References

A. Complete citations of literature and records used in the study.

B. Aerial photographs or images interpreted (air photo source, date and flight number, scale).

C. Other sources of data and information, including well logs, personal communications, etc.

2.9.3. Illustrations

A. Location Map. The site location, topographic and geographic features, and other pertinent data should be identified; generally on a 1:24,000-scale USGS topographic base map (may combine with item B).

B. Geologic Map. A regional-scale map (1:24,000 to 1:50,000 scale) is generally used. Personius and Scott, 1992 is usually appropriate. Depending on site complexity, a site-scale geologic map (1:1,200 or 1 inch= 100 ft) may also be necessary. The map should show Quaternary and bedrock geologic units, faults, seeps or springs, soil or bedrock slumps, and other geologic and soil features existing on and adjacent to the project site.

Geologic cross-sections may be included as needed to illustrate 3-dimensional relationships.

C. Site Plan. The site boundaries, proposed building footprints, existing structures, streets, slopes, drainages, exploratory trenches, boreholes, test pits, geophysical traverses, and other data should be shown on a map scaled 1 inch = 100 feet, or smaller. May be combined with item (D)

D. Site Plan and Fault Map. Include the surveyed locations of trenches or boreholes, location(s) of faults encountered in the trenches, inferred location of the faults between trenches, recommended fault setback distance on each side of the faults, topographic contours, and proposed building locations. Scale will vary depending on the size of the site and area covered by the study; recommended scale is 1 inch = 100 feet, or smallerr.

E. Exploratory Trench Log(s): These are <u>required</u> for <u>each</u> trench excavated as part of the study. Trench logs are hand- or computer-generated logs of the trench wall that show details of observed features and conditions. Trench logs shall <u>not</u> be generalized or diagrammatic. The minimum scale is 1 inch = 5 feet (1:60) with no vertical exaggeration. Trench logs must accurately reflect the features observed in the trench, as noted below and in Section 2.5.

Details logged shall include: trench orientation and indication of which trench wall was logged; trench top and bottom; stratigraphic contacts; stratigraphic unit descriptions including lithology, engineering soil classification, and contact descriptions; soil (pedogenic) horizons; marker beds; deformation or offset of sediments, and faults and fissures. Other features of tectonic significance such as buried scarp free faces, colluvial wedges, in-filled soil cracks, drag folds, rotated clasts, lineations, and liquefaction features including dikes, sand blows, etc. should also be shown. Interpretations of the age and origin of the deposits and any faulting or deformation must be included, based on depositional sequence. Fault orientation and geometry (strike and dip), and amount of net displacement must be measured and noted.

Excavations must penetrate through the entire Holocene sequence to prove the absence of active faulting in a trench. Evidence for the age determination of the sediments must be provided in the text. See page 4 for a discussion of practical limits of excavation.

F. Exploratory boreholes. Borehole logs must include lithology descriptions, USCS soil classification or other standardized engineering soil classification (include an explanation of the classification scheme), sampled intervals, blow count results, static ground water depths and dates measured, total depth of boreholes, and identity of the person logging the borehole. Minimum scale: 1 inch = 5 feet.

H. Geophysical data and associated interpretations.

I. Photographs of scarps, trench walls, or other features that enhance understanding of site conditions and fault-related conditions.

2.9.4. Appendices.
Include any other supporting data relevant to the investigation (e.g., aerial photograph interpretations, cross sections or fence diagrams, survey data, water well data, laboratory soils test results, etc.)

2.9.5. Authentication
Include the signature, Utah State Professional Geologists stamp, and qualifications of the investigating engineering geologist.

3.0 APPLICABLE AND CITED REFERENCES

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Table A-1. Setback recommendations and criticality factors (U) for IBC occupancy classes (International Code Council, 2000).

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

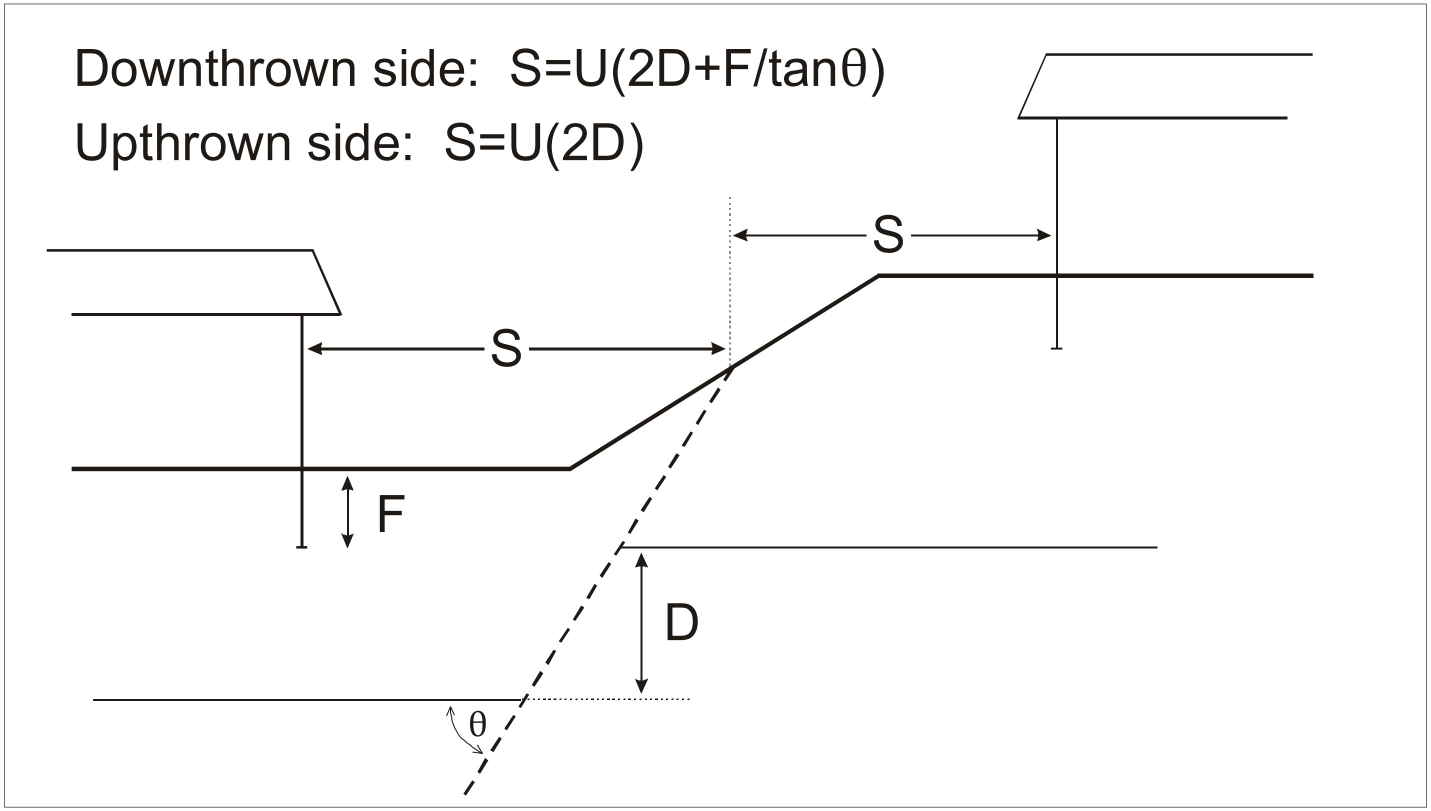

Figure A-1. Setback variables for the downthrown fault block (hanging wall) and upthrown fault block (footwall). S= Setback; U=Criticality Factor; D= Expected fault displacement (based on past events); F= Maximum depth of footing or subgrade portion of the structure; 0= Dip of fault.