UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
National Park Service

SURFACE-FAULT-RUPTURE HAZARD ZION NATIONAL PARK GEOLOGIC-HAZARD STUDY AREA

By

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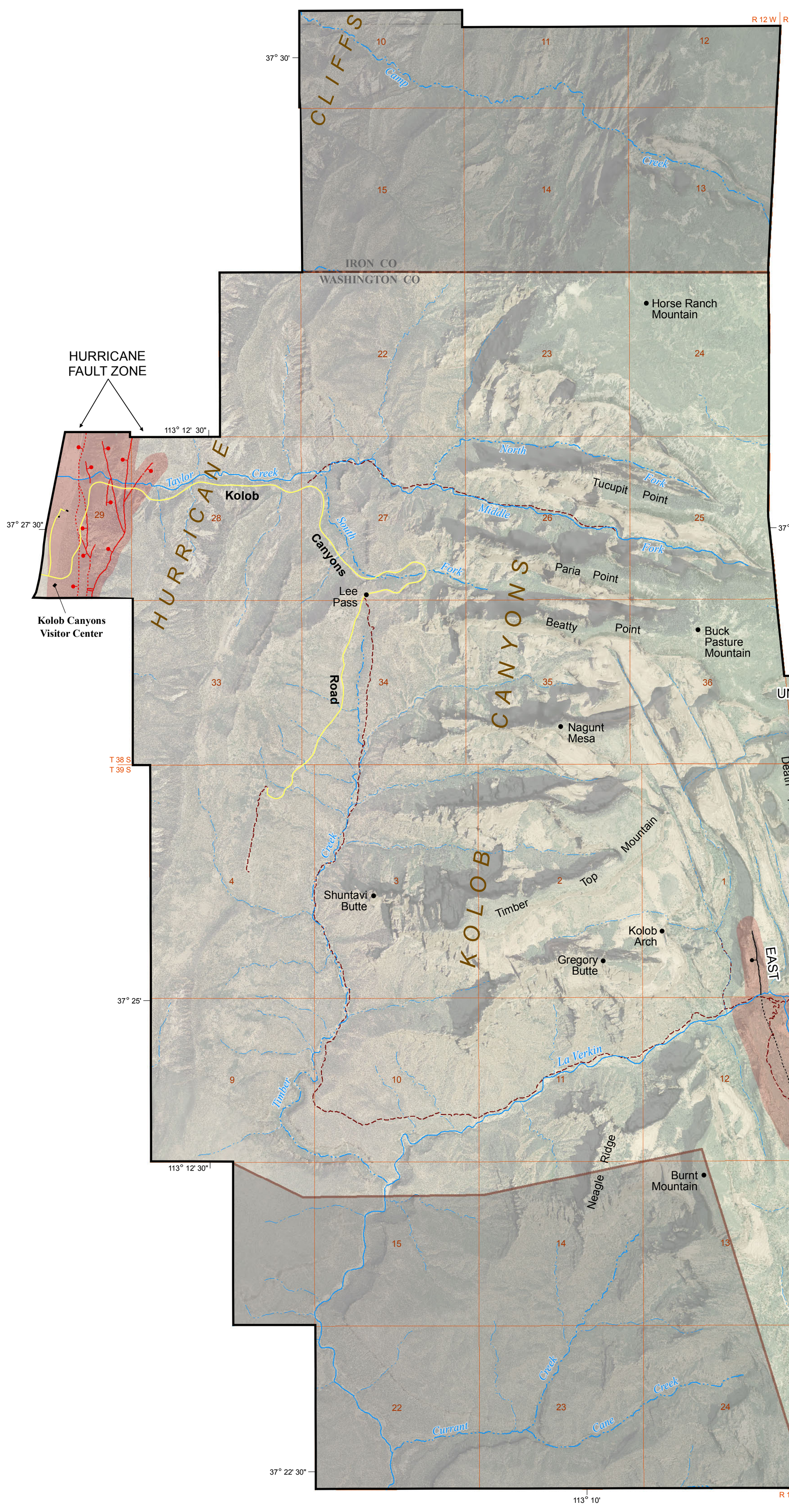

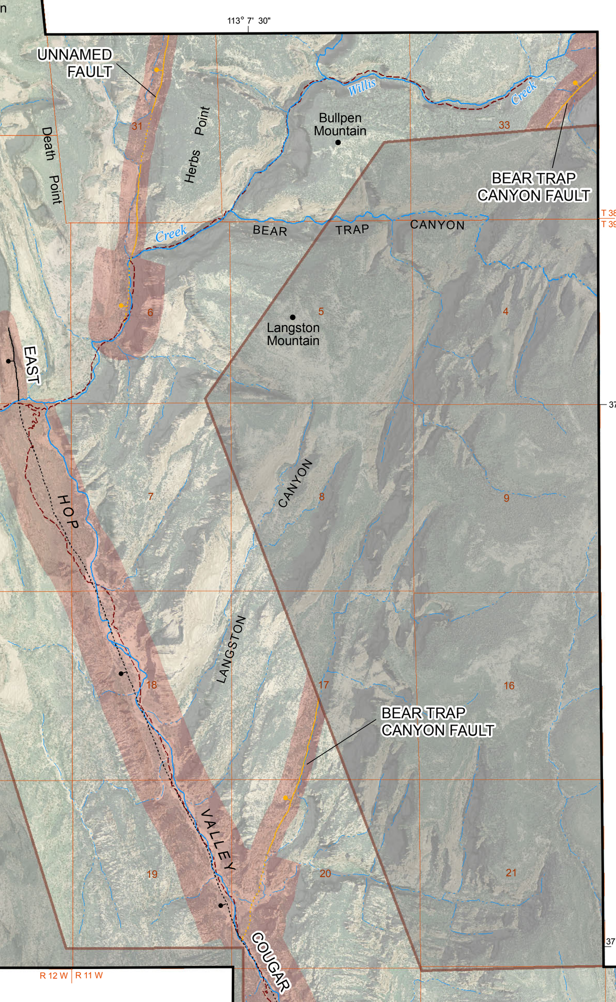

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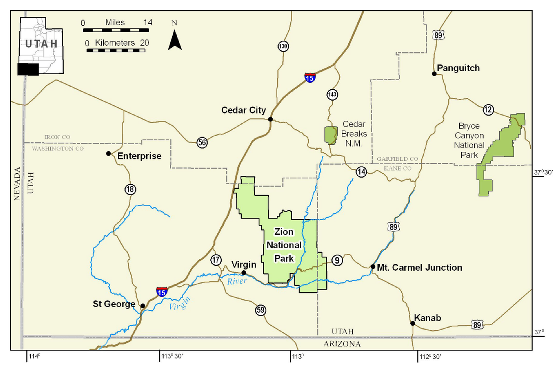
Base map consists of U.S. Department of Agriculture 2006 National Agricultural Imagery Program natural color aerial photography and shaded relief generated from digital elevation data acquired from the Utah Automated Geographic Reference Center.

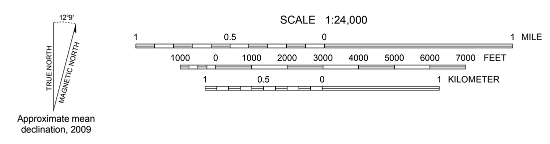
Universal Transverse Mercator Projection, zone 12
North American Datum of 1983

SYMBOLS

- Zion National Park Geologic-Hazard Study Area boundary
- Zion National Park boundary
- County boundary
- State highway
- Minor road
- Foot trail
- Existing park structure
- Area not studied
- Fault - see Explanation for description of color codes; ball and bar on downthrown side of fault

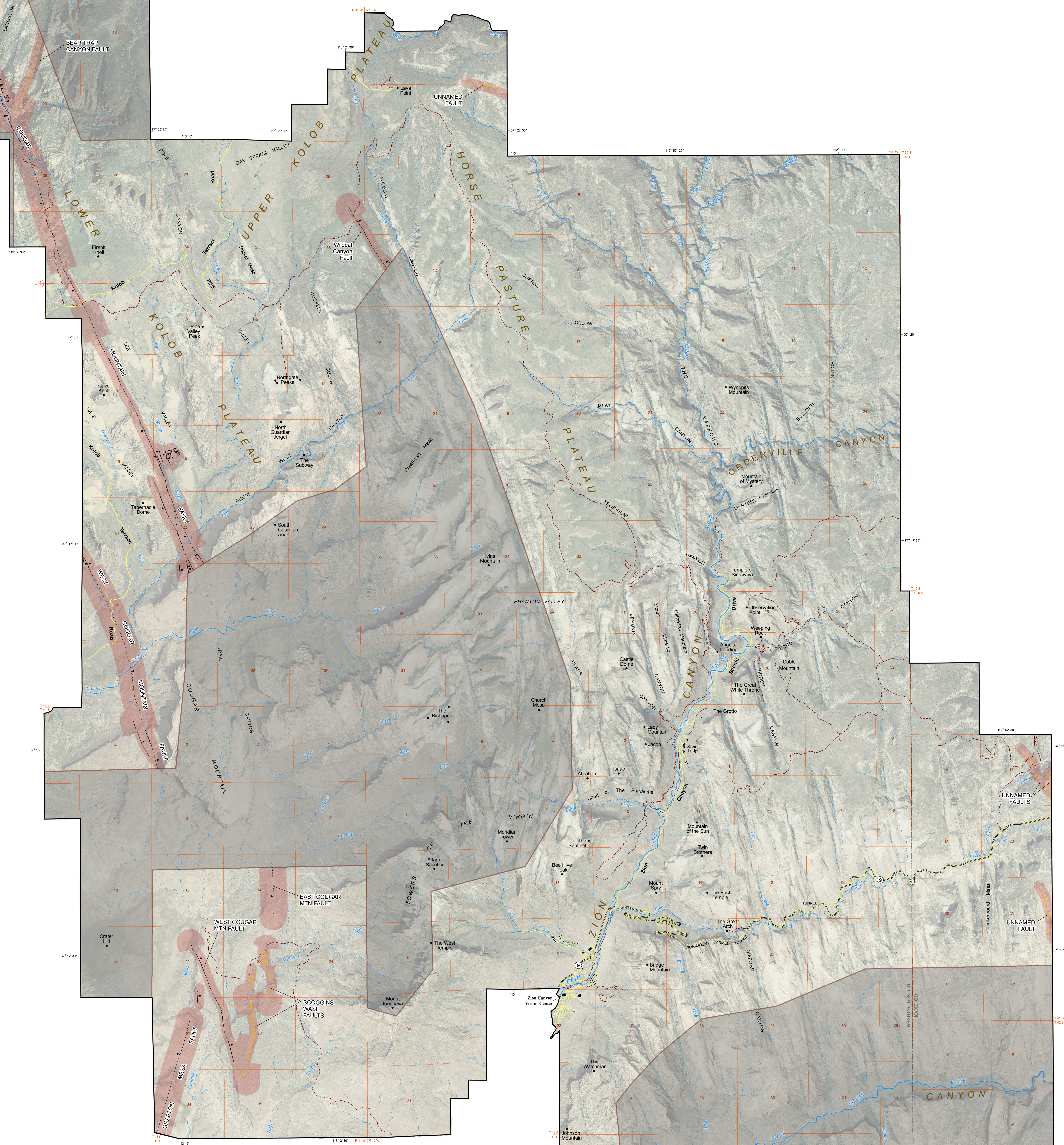
Map Location

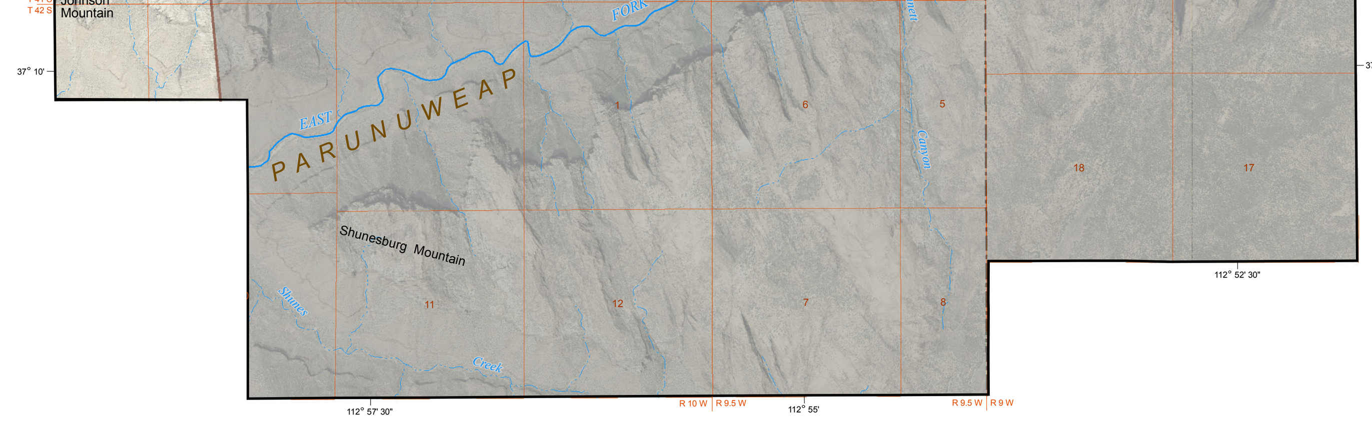




EXPLANATION

- Well-defined Holocene-active (movement within the past 10,000 years [11,500 cal yr B.P.]) or suspected Holocene-active fault: surface-fault-rupture-hazard investigation recommended for all IBC Occupancy Category II, III, and IV buildings and other structures (International Code Council, 2009a).
- Buried or approximately located Holocene-active or suspected Holocene-active fault: surface-fault-rupture-hazard investigation recommended for all IBC Occupancy Category II, III, and IV buildings and other structures (International Code Council, 2009a).
- Well-defined fault with unknown activity level: paleoseismic data are lacking, recommend treating as a Holocene-active fault until proven otherwise.
- Buried or approximately located fault with unknown activity level: paleoseismic data are lacking, recommend treating as a Holocene-active fault until proven otherwise.
- Well-defined suspected late-Quaternary- or Quaternary-active fault: normal fault related to the current regional extensional tectonic regime overlain by an unfaulted mid- or late-Quaternary basalt flow ≥ 100,000 years old; the most recent surface-faulting earthquake is older than the age of the overlying basalt, but how much older is unknown. Surface-fault-rupture-hazard investigation recommended for IBC Occupancy Category III and IV buildings and other structures (International Code Council, 2009a). Studies for other structures designed for human occupancy remain prudent for faults demonstrated to be late-Quaternary active (movement within the past 130,000 years), but should be based on an assessment of whether risk-reduction measures are justified by weighing the probability of occurrence against the risk to lives and potential economic loss. Studies for other structures intended for human occupancy for faults demonstrated to be Quaternary active (movement within the past 1,800,000 years) are optional because of the low likelihood of surface faulting, although surface rupture along the fault is still possible.
- Buried or approximately located suspected late-Quaternary- or Quaternary-active fault: normal fault related to the current regional extensional tectonic regime overlain by an unfaulted mid- or late-Quaternary basalt flow ≥ 100,000 years old; the most recent surface-faulting earthquake is older than the age of the overlying basalt, but how much older is unknown. Surface-fault-rupture-hazard investigation recommended for IBC Occupancy Category III and IV buildings and other structures (International Code Council, 2009a). Studies for other structures designed for human occupancy remain prudent for faults demonstrated to be late-Quaternary active (movement within the past 130,000 years), but should be based on an assessment of whether risk-reduction measures are justified by weighing the probability of occurrence against the risk to lives and potential economic loss. Studies for other structures intended for human occupancy for faults demonstrated to be Quaternary active (movement within the past 1,800,000 years) are optional because of the low likelihood of surface faulting, although surface rupture along the fault is still possible.
- Surface-fault-rupture-hazard special-study area. The special-study areas established for well-defined faults extend for 500 feet on the downthrown side and 250 feet on the upthrown side of each fault. We classified normal faults as well defined if UGS 1:24,000-scale mapping shows them as solid lines, indicating that they are recognizable as faults at the ground surface. Because their location is uncertain, the surface-fault-rupture-hazard special-study areas around buried or approximately located faults are broader, extending 1000 feet on each side of the suspected trace of the faults.





DISCUSSION

Earthquakes occur without warning and can cause injury and death, major economic loss, and social disruption (Utah Seismic Safety Commission, 1995). An earthquake is the abrupt, rapid shaking of the ground caused by sudden slippage of rocks deep beneath the Earth's surface. The rocks break and slip when the accumulated stress exceeds the rock's strength. The surface along which the rocks slip is called a fault. Large earthquakes (>M 6.5) are commonly accompanied by surface faulting. The rupture may affect a zone tens to hundreds of feet wide and tens of miles long. Surface faulting on normal faults produces ground cracking and typically one or more "fault scarps." When originally formed, fault scarps have near-vertical slopes and, depending on the size of the earthquake, can range from a few inches to many feet high. Local ground tilting and graben formation by secondary (antithetic) faulting may accompany surface faulting, resulting in a zone of deformation along the fault trace tens to hundreds of feet wide. Surface faulting, while of limited aerial extent when compared to other earthquake-related hazards such as ground shaking and liquefaction, can have serious consequences for structures or other facilities that lie along or cross the fault rupture path (Bonilla, 1970). Buildings, bridges, dams, tunnels, canals, and pipelines have all been severely damaged by surface faulting (see, for example, Lawson, 1908; Ambraseys, 1960, 1963; Duke, 1960; California Department of Water Resources, 1967; Christenson and Bryant, 1998; USGS, 2000).

The hazard due to surface faulting is directly related to the activity of the fault—that is, how often the fault ruptures the ground surface and how likely it is to rupture in the future (Christenson and Bryant, 1998). Because designing a structure to withstand surface faulting is generally considered impractical from an economic, engineering, and architectural standpoint for most structures (Christenson and others, 2003; Bryant and Hart, 2007), avoiding active fault traces is the recommended approach for mitigating surface-faulting hazards. Effectively avoiding surface faulting requires conducting a site-specific investigation to (1) identify all potentially active faults at a site, (2) assess the level of activity of the faults, and (3) establish appropriate setback distances from the fault(s).

ACTIVITY CLASSES

In California, the Alquist-Priolo Earthquake Fault Zoning Act (Bryant and Hart, 2007), which regulates development along known active faults, defines an "active" fault as one that has had "surface displacement within Holocene time (about the past 11,000 years)." Because California has a well-recognized earthquake hazard and was the first state to implement regulations designed to mitigate those hazards, the California "Holocene" standard has found its way into many regulations in other parts of the country, even in areas where the Holocene is not the best time frame against which to measure surface-faulting recurrence. dePolo and Slemmons (1998) argued that in the Basin and Range Province, a time period longer than the Holocene is more appropriate for defining active faults, because most faults there have surface-faulting recurrence intervals (average repeat times) that approach or exceed 10,000 years. They advocate a late Pleistocene age criterion, specifically 130,000 years, to define active faults in the Basin and Range Province. They base their recommendation on the observation that six to eight (>50%) of the 11 historical surface-faulting earthquakes in that region were on faults that lacked evidence of Holocene activity but had evidence of late Pleistocene activity.

Because of the difficulties in using a single "active" fault definition, the Western States Seismic Policy Council (WSSPC) has defined the following fault activity classes (WSSPC Policy Recommendation 08-2, 2008; first adopted in 1997 as WSSPC Policy Recommendation 97-1, and revised and readopted in 2002, 2005, and 2008 [WSSPC, 2008]):

Holocene fault – a fault that has moved within the past 10,000 years (11,500 cal yr B.P.) and has been large enough to break the ground surface.

Late Quaternary fault – a fault that has moved within the past 130,000 years and has been large enough to break the ground surface.

Quaternary fault – a fault that has moved within the past 1,800,000 years and has been large enough to break the ground surface.

Christenson and Bryant (1998) and Christenson and others (2003) recommended adopting the WSSPC fault activity-class definitions in Utah, and we follow that recommendation in this study.

For additional information about surface faulting and other earthquake-related hazards in the Zion National Park Geologic-Hazard Study Area, refer to the Earthquake Hazards chapter in this report.

USING THIS MAP

This map shows potentially active faults along which surface faulting may occur. A special-study area is shown around each fault, within which we recommend that a site-specific, surface-fault-rupture-hazard investigation be performed prior to construction. These investigations can resolve uncertainties inherent in generalized hazard mapping and help ensure safety by identifying the need for setbacks from the fault.

The UGS *Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah* (Christenson and others, 2003) include a detailed rationale for performing surface-fault-rupture-hazard investigations, minimum technical requirements for conducting and reporting those studies, recommendations regarding when surface-fault-rupture-hazard investigations should be conducted based on fault activity class and the type of facility proposed, and procedures for establishing safe setback distances from active faults. Zion National Park staff and others should refer to the UGS guidelines regarding the details of conducting and reviewing surface-fault-rupture-hazard investigations.

For well-defined faults color-coded red and black (Holocene and Suspected Quaternary, respectively), we recommend that surface-fault-rupture-hazard investigations be performed in accordance with the UGS guidelines. Because paleoseismic data are lacking for the orange-coded faults (fault activity class unknown), we recommend that those faults be considered Holocene active until paleoseismic studies demonstrate otherwise.

Because approximately located and buried faults lack a clearly identifiable surface trace, they are not amenable to trenching, which is the standard surface-fault-rupture-hazard investigation technique used to study well-defined faults (McCalpin, 2009). Where development is proposed in a special-study area for a buried or approximately located fault, we recommend that, at a minimum, the following tasks be performed to better define the surface-fault-rupture hazard in those areas:

1. Review of published and unpublished maps, literature, and records concerning geologic units, faults, surface and ground water, previous subsurface investigations, previous geotechnical and geophysical investigations, and other relevant factors.
2. Stereoscopic interpretation of aerial photographs to detect any subtle fault-related features expressed in the site topography, vegetation or soil contrasts, and any lineaments of possible fault origin.
3. Field evaluation of the proposed site and surrounding area to observe pertinent surface evidence for faulting, including mapping of geologic units as necessary to define critical geologic relations; evaluation of geomorphic features such as springs or seeps (aligned or not), sand blows or lateral spreads, or other evidence of earthquake-induced features; and excavation of test pits to evaluate the age of the deposits onsite to constrain the time of most recent surface faulting.

If the results of these investigations reveal evidence of possible surface-faulting-related features, those features should be trenched in accordance with the UGS guidelines for evaluating surface-fault-rupture hazards in Utah (Christenson and others, 2003). Following the above-recommended studies, if no evidence of surface faulting is found, development at the site can proceed as planned. However, we recommend that construction excavations and cut slopes be carefully examined for evidence of faulting as development proceeds.

MAP LIMITATIONS

This map is based on 1:24,000-scale geologic mapping, and the inventory of potentially active faults obtained from that mapping and shown on this map reflects that level of detail. Some smaller faults may not have been detected during the mapping or faults may be concealed beneath young geologic deposits. Additionally, approximately located and buried faults by definition lack a clearly identifiable surface trace, and therefore their location is less well known. Site-specific fault-trenching investigations should be preceded by a careful field evaluation of the site to identify the surface trace of the fault, other faults not evident at 1:24,000-scale, or other fault-related features at a site-specific scale.

HAZARD REDUCTION

Because surface faulting is typically confined to relatively narrow zones along the surface trace of a fault, early recognition and avoidance are the most effective strategies for mitigating this hazard. Once the activity class of the fault is determined (see Activity Classes section above), we recommend that setbacks from the fault trace and any associated zone of deformation be established in accordance with UGS guidelines for evaluating surface-fault-rupture hazards in Utah (Christenson and others, 2003). Carefully locating all potentially active fault traces at a site, assessing their level of activity and amount of displacement, establishing an appropriate setback distance from the fault, and proper facility and site design remain the most reliable procedures for mitigating damage and injury due to surface faulting. Considering the proximity of the Kolob Entrance Station and associated buildings to the surface trace of the Hurricane fault, we recommend that a reconnaissance surface-fault-rupture-hazard investigation be conducted for those facilities. If the reconnaissance shows that a surface-rupture hazard may exist, we recommend a follow-up trenching investigation to fully assess the hazard.

In Utah, earthquake-resistant design requirements for construction are specified in the seismic provisions of the IBC (International Code Council, 2009a) and IRC (International Code Council, 2009b), which are adopted statewide. IBC Section 1803.5.11 requires that an investigation be conducted for all structures in Seismic Design Categories C, D, E, or F (see the Earthquake Ground-Shaking Hazard section in chapter 5) to evaluate the potential for surface rupture due to faulting.

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