UTAH GEOLOGICAL SURVEY
*a division of*
Utah Department of Natural Resources

# EXPLANATION

## Expansive Soil

$H_S$ **High Hazard** - Soils classified by the Natural Resources Conservation Service (NRCS) as having high hazard for volumetric change. These soils are typically clay rich and have a liquid limit (LL) ≥35, plasticity index (PI) ≥15, and/or swell/collapse test (SCT) values of ≥4 percent swell (Mortensen and others, 1977; Chen, 1988; Nelson and Miller, 1992). Soils having these characteristics are of limited aerial extent in the study area, and are typically associated with the Petrified Forest Member of the Chinle Formation and other clay-rich bedrock units.

$M_S$ **Moderate Hazard** - Soils classified by the NRCS as having moderate hazard for volumetric change (LL 25–55, PI 5–35). The LL and PI values in this category overlap at their upper ends with soils in the high-hazard category. Chen (1988) recognized that while PI is an indicator of expansive potential, other factors also exert an influence, and therefore reported a range of PI values when categorizing a soil's capacity to shrink or swell.

$L_S$ **Low Hazard** - Soils classified by the NRCS as having low hazard for volumetric change (LL 0–40, PI from nonplastic to 15). The LL and PI values in this category overlap at their upper ends with soils in the moderate-hazard category. However, the low-hazard category includes soils with highly variable potential for volumetric change that do not fit easily into the moderate or high categories.

## Expansive Rock

$H_R$ **High Hazard** - Bedrock units with high shrink/swell hazard, which include claystone horizons in the Virgin Limestone Member of the Moenkopi Formation, the Petrified Forest Member of the Chinle Formation, and the lower red beds of the Dinosaur Canyon Member and the Whitmore Point Member of the Moenave Formation. We include landslides mapped within these rock units in the high-hazard category because the landslides contain debris from high-hazard bedrock units. These bedrock units contain an abundance of expansive clay minerals and are commonly associated with expansive rock problems throughout southwestern Utah.

$M_R$ **Moderate Hazard** - Bedrock units with moderate shrink/swell hazard, which include the Shnabkaib and lower, middle, and upper red members of the Moenkopi Formation. These rock units are chiefly fine grained and contain alternating strata of shale, claystone, mudstone, siltstone, sandstone, and limestone. Not all or even the majority of these strata contain expansive clay minerals; however, past experience in southwestern Utah has shown that a sufficiently high percentage of strata do contain expansive clay that shrink/swell problems are often associated with these bedrock units. We include landslides mapped within moderate-hazard rock units in this category.

$L_R$ **Low Hazard** - Bedrock units with low shrink/swell hazard, which include the Timpoweap Member of the Moenkopi Formation and the Kayenta Formation. We consider these units to have a lower hazard than the bedrock units identified above however, low-hazard units contain some fine-grained, clay-rich strata that may cause shrink/swell problems locally.

## Concealed Highly Expansive Soil or Rock

C **Concealed** - Areas suspected of having highly expansive soil or rock (≥4 percent swell) in the shallow subsurface (≤20 feet), with little or no evidence of such materials at the ground surface. The likely presence of highly expansive materials in the shallow subsurface is based on the outcrop pattern of the Petrified Forest Member of the Chinle Formation, which indicates that the Petrified Forest Member likely underlies thin unconsolidated deposits in those areas. The Petrified Forest Member typically contains highly expansive shale and claystone, and past experience in southwestern Utah has shown that when wetted, highly expansive soil or rock can cause damaging differential displacements at the ground surface even when overlain by as much as 20 feet of nonexpansive material (Lund and others, 2008). Therefore, we consider areas where the Petrified Forest Member may be present in the shallow subsurface as having a potential for highly expansive soil and rock problems despite the lack of surface evidence for such materials.

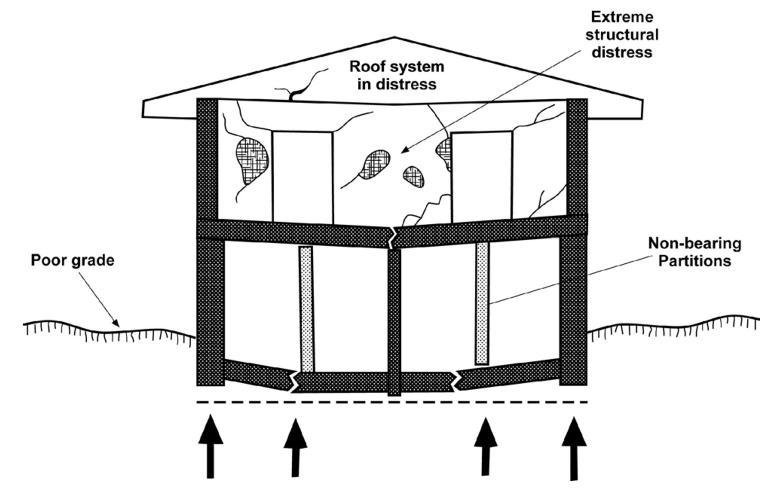


*Figure 1. Typical structural damage to a building from expansive soil (modified from Black and others, 1999).*

# INTRODUCTION

Expansive soil and rock increase in volume (swell) as they get wet, and decrease in volume (shrink) as they dry out. Expansive soil and rock contain a special type of clay minerals that can absorb water directly into their crystal structure when wetted. Some sodium-montmorillonite clay can swell as much as 2000 percent upon wetting (Costa and Baker, 1981). The resulting expansion forces can be greater than 20,000 pounds per square foot (Shelton and Prouty, 1979), and can easily exceed the loads imposed by most structures, resulting in cracked foundations and pavement, structural damage, and other building distress (figure 1).

# SOURCES OF INFORMATION

Sources of information used to evaluate expansive soil and rock in the State Route 9 Corridor Geologic-Hazard Study Area (SR-9 study area) include (1) 40 geotechnical reports on file with the National Park Service (NPS), the Utah Department of Transportation (UDOT), and the towns of Springdale and Virgin, (2) Natural Resources Conservation Service (NRCS) (formerly Soil Conservation Service) *Soil Survey of Washington County Area, Utah* (Mortensen and others, 1977), (3) the four Utah Geological Survey (UGS) 1:24,000-scale geologic quadrangle maps that cover the study area (Virgin [Hayden and Sable, 2008], Springdale West [Willis and others, 2002], Springdale East [Doelling and others, 2002], and Smithsonian Butte [Moore and Sable, 2001]), (4) *Engineering Geology of the St. George Area, Washington County, Utah* (Christenson and Deen, 1983), (5) "Geologic Hazards of the St. George Area, Washington County, Utah" (Christenson, 1992), (6) *Engineering Geologic Map Folio, Springdale, Washington County, Utah* (Solomon, 1996), (7) *Geologic Hazards and Adverse Construction Conditions, St. George–Hurricane Metropolitan Area, Washington County, Utah* (Lund and others, 2008), and (8) *Geologic Hazards of the Zion National Park Geologic-Hazard Study Area, Washington and Kane Counties, Utah* (Lund and others, 2010).

# DESCRIPTION

## Geologic Characteristics

Several bedrock formations in the SR-9 study area consist in whole or part of shale, claystone, or mudstone containing expansive clay minerals. These rock units and the expansive soils derived from them are capable of significant expansion and contraction when wetted and dried, causing structural damage to buildings (figure 2); cracked roads and driveways; damage to curbs, gutters, and sidewalks; and heaving of roads and canals. Expansive soils are chiefly derived from the weathering of clay-bearing rock formations (figure 3) and may be residual (formed in place) or transported (usually a short distance) and deposited in a new location. The principal transporting mechanisms are water or wind, but soil creep and mass-wasting processes may play important roles locally.

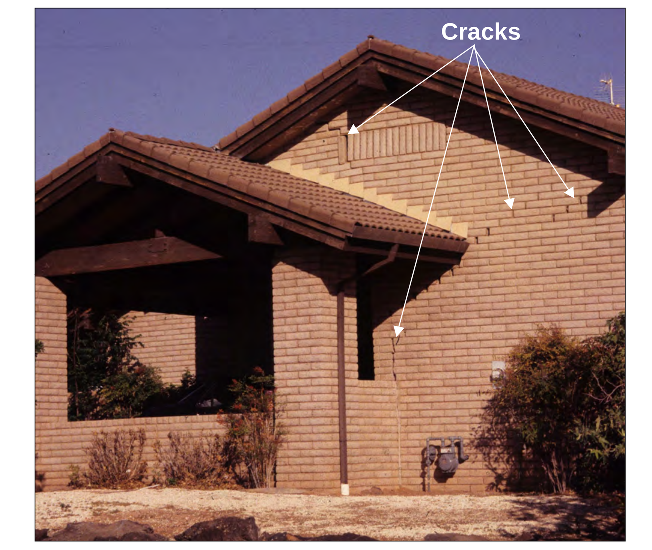


*Figure 2. Home in southwestern Utah damaged by expansive soil/rock. Photo date: June 2005.*


*Figure 3. Outcrop of the clay-rich Petrified Forest Member of the Chinle Formation in Springdale. Photo date: February 2011.*

## Geotechnical Data Evaluation

Data on expansive soils in the SR-9 study area are limited. The geotechnical database compiled for this study (see Sources of Information section) includes laboratory test data for soil samples collected from test pits and exploratory boreholes in and near the study area. The database includes 65 samples with liquid limit (LL) and plasticity index (PI) data, and 90 samples with swell/collapse test (SCT) data. Swell/collapse test results are the most reliable indicator of a soil's capacity to shrink or swell. An SCT value of ≥4 percent swell under a 60 pounds per square foot (psf) surcharge is generally considered the lower bound (table 1) of problematic swell-susceptible soils in southwestern Utah (David Black, Rosenberg Associates, written communication 2012). Plasticity index, LL, and expansion index data are sometimes used as qualitative indicators of shrink/swell potential (table 2) (Chen, 1988; International Code Council, 2009a) either in the absence of SCT data or to assist in selecting samples for swell/collapse testing. The *International Building Code* (IBC) states (Section 1803.5.3; International Code Council, 2009a) that a soil meeting the following four provisions shall be considered expansive: (1) PI ≥15, determined in accordance with ASTM D 4318, (2) >10 percent of soil particles pass the No. 200 sieve (0.075 mm), determined in accordance with ASTM D 422, (3) >10 percent of the soil particles are less than 5 micrometers (0.005 mm) in size, determined in accordance with ASTM D 422, and (4) expansion index >20 determined in accordance with ASTM D 4829.

***Table 1.** Soil swell hazard rating (modified from Southern Nevada Building Officials, 2010).*

| Swell Hazard | Percent Swell Under 60 psf Surcharge |
|---|---|
| Low | >0 to <4 |
| Moderate | ≥4 to <8 |
| High | ≥8 to <12 |
| Critical | ≥12 |

***Table 2.** Correlation of soil swelling potential with plasticity index (from Chen, 1988).*

| Swelling Potential | Plasticity Index |
|---|---|
| Low | 0–15 |
| Medium | 10–35 |
| High | 20–55 |
| Very High | 35 and above |

Table 3 shows the relation between ASTM Unified Soil Classification System (USCS) soil types and SCT test results in the geotechnical database. Of the 90 SCT values in the database, 11 (12%) exhibited ≥4 percent swell, and therefore fall into the problematic-swell category. Problematic-swell values are associated with three types of material: CH soil (high-plasticity inorganic clays), CL soil (low- to medium-plasticity inorganic clays), and clay-rich bedrock. Eighty percent of the CH clays and fine-grained bedrock samples tested reported values ≥4 percent swell, while a much smaller percentage of CL clays (8%) showed ≥4 percent swell. Note that for all three material types, a relatively small number of the total available samples were tested: 38 percent of CH clays, 19 percent of CL clays, and 24 percent of fine-grained bedrock.

***Table 3.** Relation of high swell test values (>4%) from SCT testing to USCS soil types in the geotechnical database.*

| USCS Soil Type | Total Samples in Database | Samples Tested (number) | Samples Tested (percent) | Samples Having Swell ≥4% (number) | Samples Having Swell ≥4% (percent) |
|---|---|---|---|---|---|
| **SM** | 223 | 31 | 14 | 0 | 0 |
| **SC** | 35 | 5 | 14 | 0 | 4 |
| **SM/SP** | 30 | 4 | 13 | 0 | 4 |
| **SP** | 19 | 1 | 5 | 0 | 4 |
| **CH** | 13 | 5 | 38 | 4 | 80 |
| **ML** | 27 | 3 | 11 | 0 | 0 |
| **CL** | 189 | 36 | 19 | 3 | 8 |
| **Bedrock** | 21 | 5 | 24 | 4 | 80 |
| **Total** | 557 | 90 | 16 | 11 | 12 |

# HAZARD CLASSIFICATION

## Soil

We grouped soils into three shrink/swell-hazard categories on the basis of their expansive characteristics and potential for volumetric change. The principal sources of information regarding expansive soil characteristics in the study area are the "Estimated Soil Properties of Significance to Engineering" and "Interpretation of Engineering Test Data" tables in the NRCS *Soil Survey of Washington County Area, Utah* (Mortensen and others, 1977). We compared the ratings and data presented in those tables with the limited laboratory test results in our geotechnical database. The correlation between the NRCS information and the geotechnical test data is generally good, with a few local discrepancies. The discrepancies are not unexpected given the generalized nature of the NRCS information and the susceptibility of soil characteristics to local influences, such as adjacent or underlying bedrock, depositional process and history, effects of soil-forming processes, and limited depth of characterization (upper 60 inches of the soil column) of the NRCS data.

Details of our geotechnical data analysis are presented in the Geotechnical Data Evaluation section. Information from UGS geologic maps (see Sources of Information section) was used to estimate shrink/swell hazard beyond the boundaries of the NRCS mapping and geotechnical database coverage.

The expansive-soil-hazard categories are described in the Explanation section.

## Rock

We also grouped bedrock units in the study area into three shrink/swell-hazard categories on the basis of relative abundance of expansive clay minerals, abundance and thickness of fine-grained strata in mixed bedrock units, and past experience with expansive rock units in southwestern Utah (Lund and others, 2008). We did not classify bedrock formations possessing little or no potential for volumetric change.

The expansive-rock-hazard categories are described in the Explanation section.

## Areas of Concealed Highly Expansive Soil or Rock

This map shows several locations where highly expansive soil or rock may be present in the shallow subsurface (<20 feet), with little or no evidence of such materials at the ground surface. The likely presence of highly expansive materials in the shallow subsurface is based on the outcrop pattern of the Petrified Forest Member of the Chinle Formation, which indicates that the Petrified Forest Member likely underlies thin unconsolidated deposits in those areas. The Petrified Forest Member typically contains highly expansive shale and claystone, and past experience in southwestern Utah has shown that when wetted, highly expansive soil or rock can cause damaging differential displacements at the ground surface even when overlain by as much as 20 feet of nonexpansive material (Lund and others, 2008). Therefore, we consider areas where the Petrified Forest Member may be present in the shallow subsurface as having a potential for highly expansive soil and rock problems despite the lack of surface evidence of such materials.

The areas of concealed highly expansive soil or rock are characterized in the Explanation section.

# USING THIS MAP

This map shows the location of known or suspected expansive soil and rock in the SR-9 study area. The map is intended for general planning and design purposes to indicate where expansive soil and rock may exist and special investigations should be required. Site-specific investigations can resolve uncertainties inherent in generalized mapping and help identify the need for special foundation designs, site grading and soil placement, or mitigation techniques. The presence and severity of expansive soil and rock, along with other geologic hazards should be addressed in these investigations. If expansive soil or rock is present at a site, appropriate design and construction recommendations should be provided.

# HAZARD REDUCTION

Although costly when not recognized and properly accommodated in project design and construction, problems associated with expansive soil and rock rarely are life threatening. As with most geologic hazards, early recognition and avoidance are the most effective ways to mitigate potential problems. However, expansive soil and rock are present in some of the most heavily developed parts of the study area, and avoidance may not always be a viable or cost-effective option.

In Utah, soil-test requirements are specified in chapter 18 (Soils and Foundations) of the 2009 IBC (International Code Council, 2009a) and chapter 4 (Foundations) of the 2009 *International Residential Code for One- and Two-Family Dwellings* (IRC) (International Code Council, 2009b), which are adopted statewide. IBC Section 1803.3 and IRC Section R401.4 contain requirements for soil investigations in areas where expansive soil may be present. Where the presence of expansive soil or rock is confirmed, possible mitigation techniques include soil removal and replacement with non-expansive, compacted backfill; use of special foundation designs such as drilled pier deep foundations; moisture barriers; chemical stabilization of expansive clays; and careful site landscape and drainage design to keep moisture away from buildings and expansive soils (Nelson and Miller, 1992; Keller and Blodgett, 2006).

# MAP LIMITATIONS

This map is based on limited geologic and geotechnical data; site-specific investigations are required to produce more detailed geotechnical information. The map also depends on the quality of those data, which may vary throughout the study area. The mapped boundaries between hazard categories are approximate and subject to change as new information becomes available. The hazard from expansive soil and rock may be different than shown at any particular site because of variations in the physical properties of geologic deposits within a map unit, gradational and approximate map-unit boundaries, and the small map scale. The map is not intended for use at scales other than the published scale, and is designed for use in general planning and design to indicate the need for site-specific investigations.

# REFERENCES

Black, B.D., Solomon, B.J., and Harty, K.M., 1999, Geology and geologic hazards of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah: Utah Geological Survey Special Study 96, 65 p.

Chen, F.H., 1988, Foundations on expansive soils: Amsterdam, Elsevier, 463 p.

Christenson, G.E., 1992, Geologic hazards of the St. George area, Washington County, Utah, *in* Harty, K.M., editor, Engineering and environmental geology of southwestern Utah: Utah Geological Association Publication 21, p. 99–108.

Christenson, G.E., and Deen, R.D., 1983, Engineering geology of the St. George area, Washington County, Utah: Utah Geological and Mineral Survey Special Studies 58, 32 p.

Costa, J.E., and Baker, V.R., 1981, Surficial geology, building with the earth: New York, John Wiley & Sons, 498 p.

Doelling, H.H., Willis, G.C., Solomon, B.J., Sable, E.G., Hamilton, W.L., and Naylor, L.P., II, 2002, Interim geologic map of the Springdale East quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report 393, 19 p., scale 1:24,000.

Hayden, J.M., and Sable, E.G., 2008, Geologic map of the Virgin quadrangle, Washington County, Utah: Utah Geological Survey Map 231, 2 plates, scale 1:24,000, CD.

International Code Council, 2009a, International building code: Country Club Hills, Illinois, 678 p.

International Code Council, 2009b, International residential code for one- and two-family dwellings: Country Club Hills, Illinois, 870 p.

Keller, E.A., and Blodgett, R.H., 2006, Natural hazards—Earth's processes as hazards, disasters, and catastrophes: Upper Saddle River, New Jersey, Pearson Prentice Hall, 395 p.

Lund, W.R., Knudsen, T.R., and Sharrow, D.L., 2010, Geologic hazards of the Zion National Park geologic-hazard study area, Washington and Kane Counties, Utah: Utah Geological Survey Special Study 133, 95 p., 9 plates, GIS data, DVD.

Lund, W.R., Knudsen, T.R., Vice, G.S., and Shaw, L., 2008, Geologic hazards and adverse construction conditions, St. George–Hurricane metropolitan area, Washington County, Utah: Utah Geological Survey Special Study 127, 105 p., DVD.

Moore, D.W., and Sable, E.G., 2001, Geologic map of the Smithsonian Butte quadrangle, Washington County, Utah: Utah Geological Survey Miscellaneous Publication 01-1, 30 p., scale 1:24,000.

Mortensen, V.L., Carley, J.A., Crandall, G.C., Donaldson, K.M., Jr., and Leishman, G.W., 1977, Soil survey of Washington County area, Utah: U.S. Department of Agriculture Soil Conservation Service and U.S. Department of the Interior Bureau of Land Management and National Park Service, 139 p., 95 plates, scale 1:24,000.

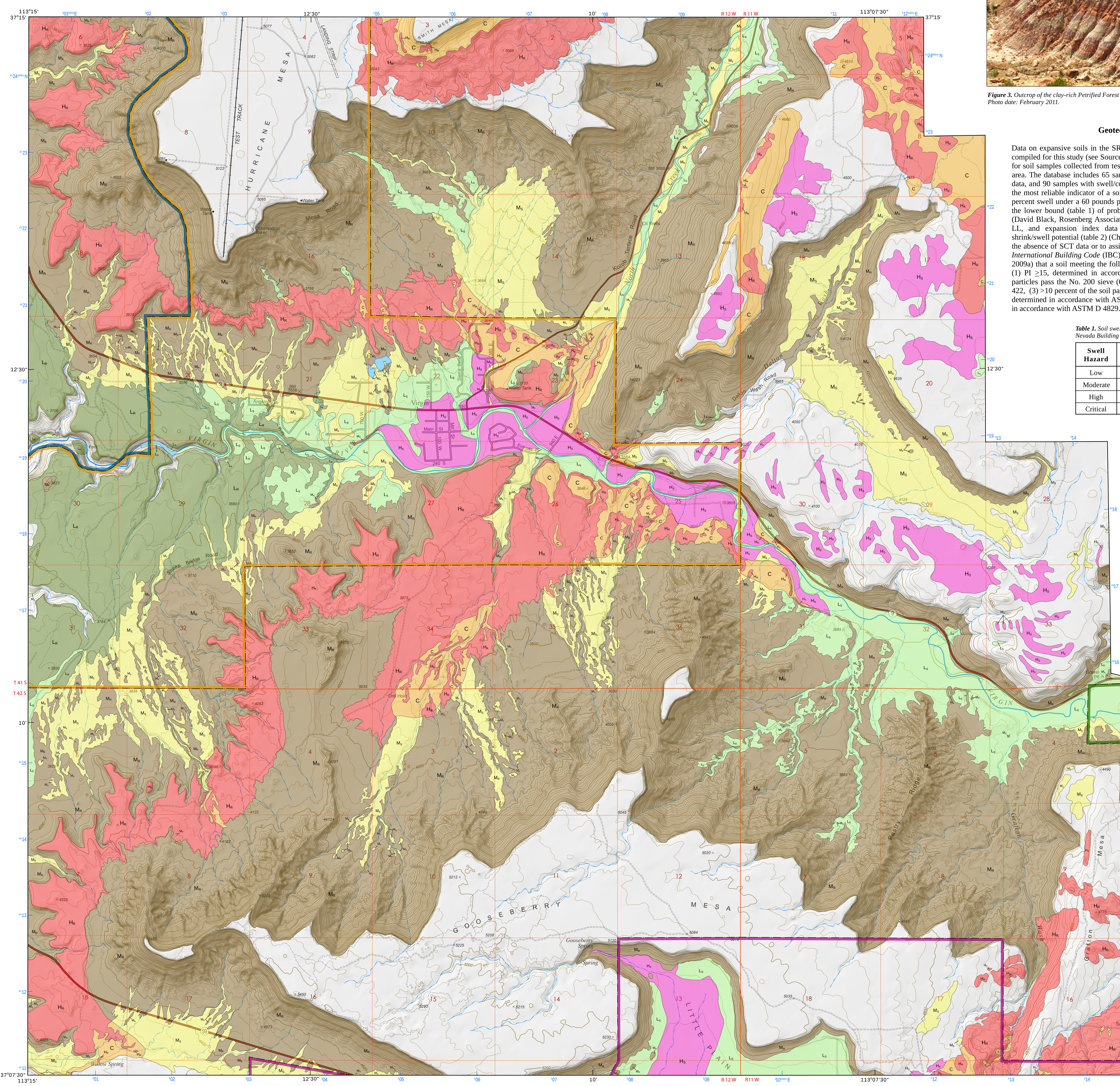
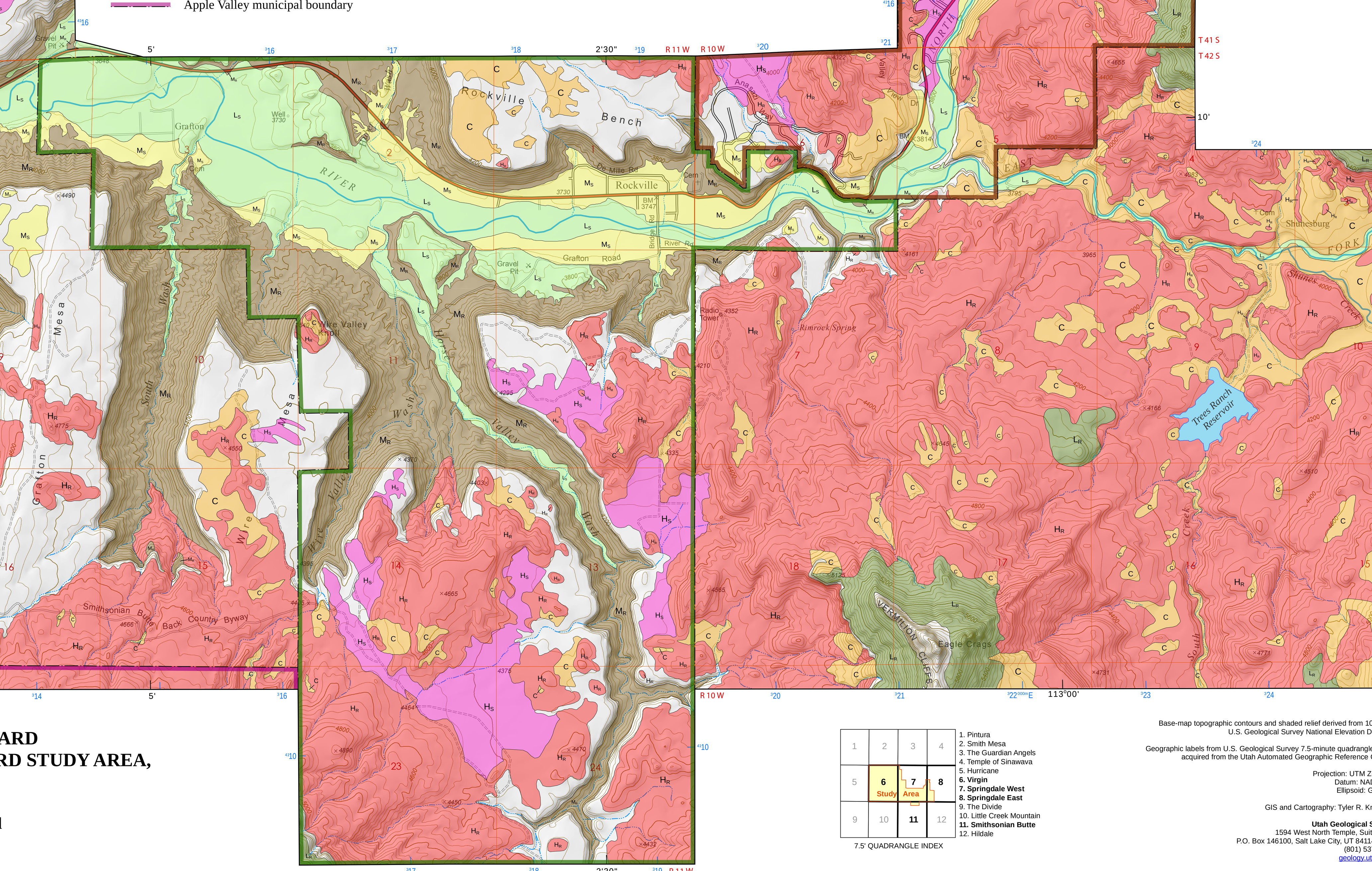
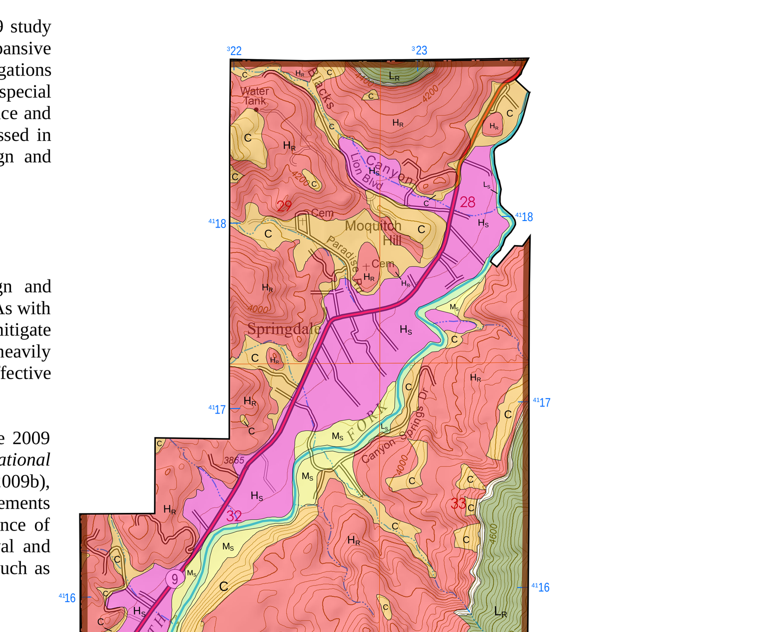
Nelson, J.D., and Miller, D.J., 1992, Expansive soils, problems and practice in foundation and pavement engineering: New York, John Wiley & Sons, 259 p.

Shelton, D.C., and Prouty, D., 1979, Nature's building codes: Colorado Geological Survey Special Publication 12, p. 37–40.

Solomon, B.J., 1996, Engineering geologic map folio, Springdale, Washington County, Utah: Utah Geological Survey Open-File Report 340, 6 plates, scale 1:14,400.

Southern Nevada Building Officials, 2010, Southern Nevada amendments to the 2009 International Building Code: City of Las Vegas Building and Safety Department, 74 p.

Willis, G.C., Doelling, H.H., Solomon, B.J., and Sable, E.G., 2002, Interim geologic map of the Springdale West quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report 394, 20 p., scale 1:24,000.

## MAP SYMBOLS

- State highway
- Primary paved road
- Secondary paved road
- Improved road
- Unimproved road
- Trail
- Springdale municipal boundary
- Rockville municipal boundary
- Virgin municipal boundary
- La Verkin municipal boundary
- Apple Valley municipal boundary



APPROXIMATE MEAN DECLINATION, 2013

SCALE 1:24,000
CONTOUR INTERVAL 40 FEET

MAP LOCATION

# EXPANSIVE-SOIL-AND-ROCK HAZARD
# STATE ROUTE 9 CORRIDOR GEOLOGIC-HAZARD STUDY AREA, WASHINGTON COUNTY, UTAH

by
Tyler R. Knudsen and William R. Lund

2013

7.5' QUADRANGLE INDEX
1. Pintura
2. Smith Mesa
3. The Guardian Angels
4. Temple of Sinawava
5. Hurricane
6. Virgin
7. Springdale West
8. Springdale East
9. The Divide
10. Little Creek Mountain
11. Smithsonian Butte
12. Hildale

Base-map topographic contours and shaded relief derived from 10-meter U.S. Geological Survey National Elevation Dataset.
Geographic labels from U.S. Geological Survey 7.5-minute quadrangle maps acquired from the Utah Automated Geographic Reference Center.
Projection: UTM Zone 12
Datum: NAD 1983
Ellipsoid: GRS 80
GIS and Cartography: Tyler R. Knudsen
Utah Geological Survey
1594 West North Temple, Suite 3110
P.O. Box 146100, Salt Lake City, UT 84114-6100
(801) 537-3300
geology.utah.gov