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August 24, 2022,

FSE Project No. 52222-297

Tennessee Farmers Mutual Insurance Company
3930 Western Avenue
Knoxville, TN 37921

Re: Report of Geotechnical Assessment
The _____Residence
150 Meridian Way
Clinton, Tennessee 37716-6366
Claim No. 10000114982

On March 11, 2022, Forensic Subsurface Evaluations, LLC (FSE) was tasked by Tennessee Farmers Mutual Insurance Company (a.k.a. Farm Bureau) to conduct a geotechnical assessment at the _____residence to determine the cause of interior and exterior settlement-related distress, which based on our conversation with the insured's daughter, was first observed about three months prior to our assignment of this claim.

Specifically, FSE was tasked to determine if sinkhole activity was a cause of the described damages which prompted this claim. The following report presents the results of our findings.

Based on our findings, FSE was tasked by Farm Bureau to provide a detailed foundation repair plan. FSE consulted with American Foundation & Waterproofing who provided the requested repair scope and cost estimate for the necessary perimeter foundation and interior floor slab repair.

- A copy of the AFW foundation repair scope is included as **Attachment A** herein.

Sinkhole Activity Opinion Statement

Based on the information gathered during this study and in general accordance with Tennessee Code (Annotated) Title 56, Chapter 7, Part 1, (130) (d) (1) and (2), **it was FSE's opinion that the analysis conducted, as documented in this report, was of sufficient scope to have identified sinkhole activity as the cause of both the perimeter wall and interior floor slab settlement distress,** within a reasonable professional probability**.**

- *Sinkhole Activity* is defined in the above-referenced insurance statute as "settlement or systematic weakening of the earth supporting a covered structure, only if the settlement or systematic weakening results from the contemporaneous movement or raveling of soils, sediment, or rock materials into subterranean voids created by the effect of groundwater erosion on a limestone or similar rock formation."
- Based on the results of four (4) drill-rig-driven Standard Penetration Test (SPT) borings and one interior, hand-driven dynamic cone penetration (DCP) test, FSE identified a significantly deep (29-foot deep) cavernous zone in the carbonate (limestone) bedrock adjacent to the north foundation of the house near the joint between the house and the garage.
    - The cavernous zone was determined by FSE to be a paleokarst or relic-sinkhole which had been in-filled with alluvium (water transported soil deposits) which were very weak in consistency due to *sinkhole activity.*
    - The *sinkhole activity* extended to within the foundation bearing level where damages and topographic low areas on the floor slab(s) were identified.
- Within the interior core/DCP sounding, an inclined ledge associated with a disruption in weathered, friable, and weak limestone bedrock was discovered below the measured topographic low point on the kitchen floor slab.
    - Based on the radial crack pattern in the floor slab, and the weakened conditions below slab, s*inkhole activity* was also identified at this location by FSE.

A detailed analysis of the above-referenced conditions, as well as our opinions as to the causes of other distress in the home are presented in the ***Evaluations and Conclusions*** section in this report.

Property Location and Regional Description

The _____ residence is located at 150 Meridian Way in Clinton, Tennessee (Anderson County).

According to the Tennessee Assessor of Property (www.assessment.cot.tn.gov) the _____ residence was constructed in May 2007. Property records list the _____ the original owners. Other pertinent data presented on the property assessor database and/or observations included the following:

- The house is located at the cul-de-sac of Meridian Way and was constructed on a rural subdivision residential building lot encompassing approximately 0.47 acres.
- For purposes of this report the front of the residence is referenced to face west although the actual orientation is slightly south of west.
- The house can be described as a single family, single-story, wood-framed structure with the perimeter walls clad in brick veneer and vinyl siding.
    - A bonus room is located over a two-stall garage incorporated at the southwest corner of the house.
- The house living area measured 1947 square feet.
- The floor system is described as a conventional concrete slab-on-grade incorporating a continuous wall or "strip" perimeter foundation.
- The concrete driveway slab servicing the garage incorporated transverse concrete shrinkage control joints.

- A single, longitudinal concrete shrinkage control joint spanned the center of the garage from front to back.

- The home is serviced by municipal water and sewer services.

Land Topography Feature of Interest

The southeastern portion of the property extends onto the northwestern, steepened side slope of an isolated knoll or river bluff.

- The northeastern exposure of the bluff bounds the west cut-bank of an old-stage meander in the Clinch River.
  - The subject residence is positioned within 0.1-mile of the river.
- Based on our review of the United States Geologic Survey (USGS) 7.5-minute quadrangle topographic map, the vertical relief between the top of the bluff and the footprint of the home is about 40 feet.
  - Surface water runoff from the side slope of the bluff is directed toward the south foundation wall of the home.
  - A grassy drainage swale was installed between the toe of the bluff side slope and the _____ property to convey surface water runoff toward the Meridian Way stormwater collection and distribution system.
- Because of the adjacent side slope, a portion of the property appeared to have been terraced into the hillside to create a level building pad on which the home was constructed.
- The property was not located within any mapped FEMA flood zones.

A property plat location and aerial photograph depicting the property layout are shown below on composite **Figure 1**.

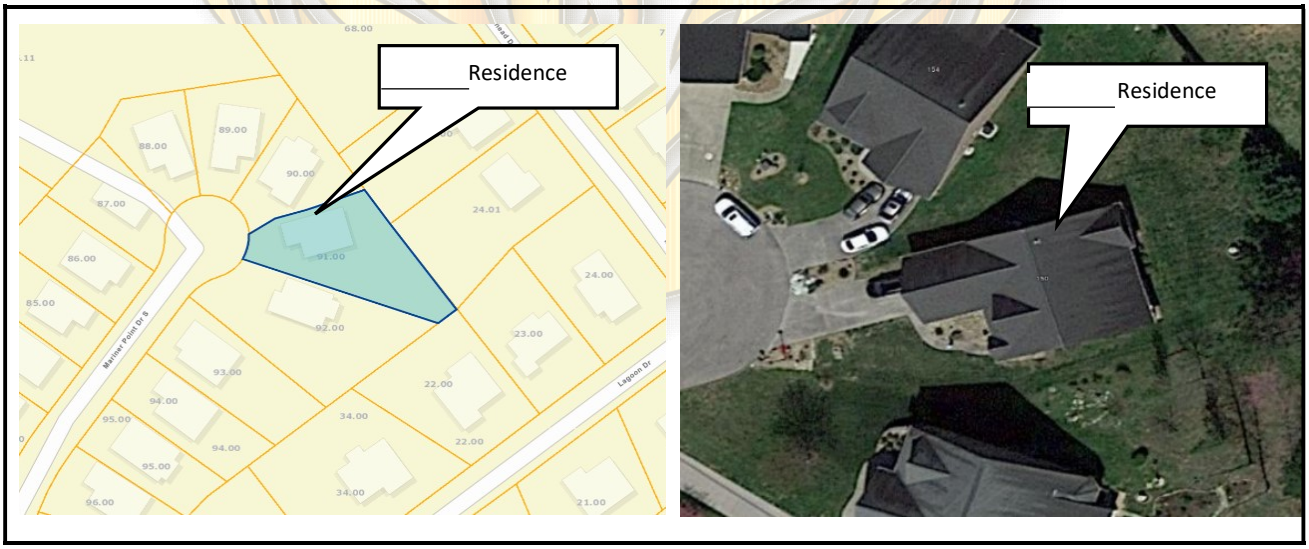

Figure 1: Composite Property Location Map (GoogleEarth™).

Site Visit and Insured Pertinent Statements

Mr. Bernd T. Rindermann, P.G., a state licensed professional geologist and owner/proprietor of FSE, initially visited the subject property on March 18, 2022. _____
Mr. Rindermann spoke to the _____who relayed the following:

- For purposes of this report the front of the house is referenced to face west although the actual orientation is slightly south of west.
- The home was reportedly constructed in 2006 and the _____are the original owners.
- The damages in the home were reported to have first been noticed around the beginning of the year (January 2022), following a prolonged rainfall event.
    - Initially it was observed that the kitchen windows along the rear wall (east side) became difficult to open and shut.
    - Progressively, interior drywall cracks which were concentrated about the west-central area and southwest quadrant of the house also developed and according to _____ worsened in the past three months.
    - Perimeter cracks in the brick veneer also became a concern. FSE notes that none of the cracks had been previously patched and that based on sharp jagged edges, that the cracks appeared relatively new.
    - Finally, it was reported that the neighboring house to the west had the elevated front porch retaining wall stabilized due to settlement and failure of the wall blocks and that the retaining wall had recently repaired by a foundation contractor.

Distress Observations

Interior Distress

During our site inspection, it was readily apparent that the central area of the interior floor slab had settled.

- Up to 1-inch-wide separations between the baseboard and hardwood floor covering were observed in the west central hallway/corridor servicing the kitchen, north side bathrooms and northeast quadrant master bedroom.
- Racked (visually distorted) door openings and doorways associated with radiating diagonal cracks at the upper corners were observed in the garage personnel door opening header wall, northwest quadrant laundry room and centrally located kitchen entryway.
    - The principal crack of concern at the upper corner of the kitchen entryway measured 3/8-inch wide.
    - The kitchen entryway measured 1-inch out-of-square whereas the laundry room door opening was 1/2-inch out-of-square.
    - A laterally extensive ceiling /wall joint separation and drywall corner bead separations occurred commensurate with this entryway damage.

Concrete Slab Distress

In the garage, we observed a previously patched, 3/8-inch-wide floor slab crack trending parallel to, but at times crossing, the longitudinal concrete shrinkage control joint spanning the center of the floor slab.

- The crack had a hairline (less than 1/32-inch) to 1/16-inch vertical offset suggesting the northern portion of the slab had settled resulting in cantilever-type uplift along the crack edge.

A 1/16-inch-wide transverse crack was present in the concrete slab of the front porch.

- There were no control joints present in this porch slab.
- There was no vertical offset along the crack edge.

Randomly oriented, 1/16-inch wide to 3/8-inch-wide cracks were present in the concrete driveway slab.

- The 16-foot-wide driveway only incorporated transverse concrete shrinkage control joints.

A section of the front concrete sidewalk was vertically offset one inch along a shrinkage control joint.

- The control joint sawcut appeared to have extended all the way through the concrete thus isolating one segment of the sidewalk from another.
- The sidewalk did not appear to be listing or leaning as would be expected from differential settlement.
    - One segment of the sidewalk had lifted relative to the adjacent segment.

Perimeter Wall Distress

The observed perimeter wall distress cracking was minor, generally consisting of widespread (not localized) hairline to 1/16-inch-wide cracks trending the masonry course joint lines in the brick veneer.

- Masking tape strips were present on the brick joints on the exterior walls.
- According to _____, the masking tape strips were recently placed on the walls by Master Services, a foundation repair contractor who inspected the residence for settlement on March 22, 2022. Further discussion on the work performed by Master Services is included in the **Foundation Repair** portion of this report.

Photographs of our observations or other pertinent property features are included as **Attachment B** herein.

Relative Elevation Floor Survey

During our March 18, 2022, FSE performed a relative elevation floor survey within the living area of the home and attached garage. This survey was performed in order to quantify the degree of differential floor slab and perimeter foundation wall deflection which may have occurred in the structure.

- The floor survey was performed using a ZipLevel Pro 2000 gas altimeter level.
- Initially, FSE created a scaled, hand-drawn floor plan of the main living area and garage on which we notated our floor topography elevation measurements.
- Measurements were made across these floor surfaces on an approximate 5 to 6-foot spaced grid pattern.

- The measured data was normalized to reflect a "zero" elevation benchmark which represents the highest measured elevation in these areas.
    - All other respective measurements made throughout the survey areas were normalized and set to a negative elevation relative to the benchmark.
- In data post processing at our office, and as shown below on **Figure 2**, FSE utilized the Golden Software™ Surfer generated Kriging method, and produced a colored contour map with contour intervals in 0.25-inch increments.

Results of Floor Survey

Within the main living area, and as shown on **Figure 2** below, our measurements revealed an overall topographic elevation change of 3.1 inches across the surface of the floor.

Within the main living area, the highest elevations were measured near the southeast corner by the fireplace, whereas secondary higher elevations generally occurred along the south perimeter wall.

- The lowest elevations were measured in the centrally located kitchen area, from where forth an elongate topographic low trend spanned in an east-west direction in the northern portion of the house.
- The overall downward, south to north global trend in elevation change suggests that the house northern portions of the perimeter wall, as well as the northern half of the interior floor slab had uniformly settled downward in the northerly direction.
    - Interior living area floor slabs typically incorporate some sort of structural connection (angled rebar) with the perimeter wall, meaning that if one component moves, the other joined component will respond similarly.

Within the garage, and unusual by construction standards, the highest elevation was measured at the southwest corner, near the vehicle door opening.

- Also unusual, the lowest elevation was measured near the southeast corner of the garage near the personnel door opening servicing the residence.
- The overall elevation change from the front of the garage toward the rear was 2.5 inches.
- As within the house living area, the contoured data revealed an unusual, linear, trough-like pattern spanning diagonally across the garage floor.

Garage floor slabs and other concrete slab appurtenances adjoining the structure, are typically cast, and finished to incorporate an inclined surface to shed water away from the structure, should these surfaces become wet.

- In this case, the measured topography doesn't represent typical construction intent.
- It is our opinion that the anomalous measured topography on the garage floor slab surface represent poorly controlled construction and concrete finishing practices, combined with settlement in the central to northern portions of the garage slab.

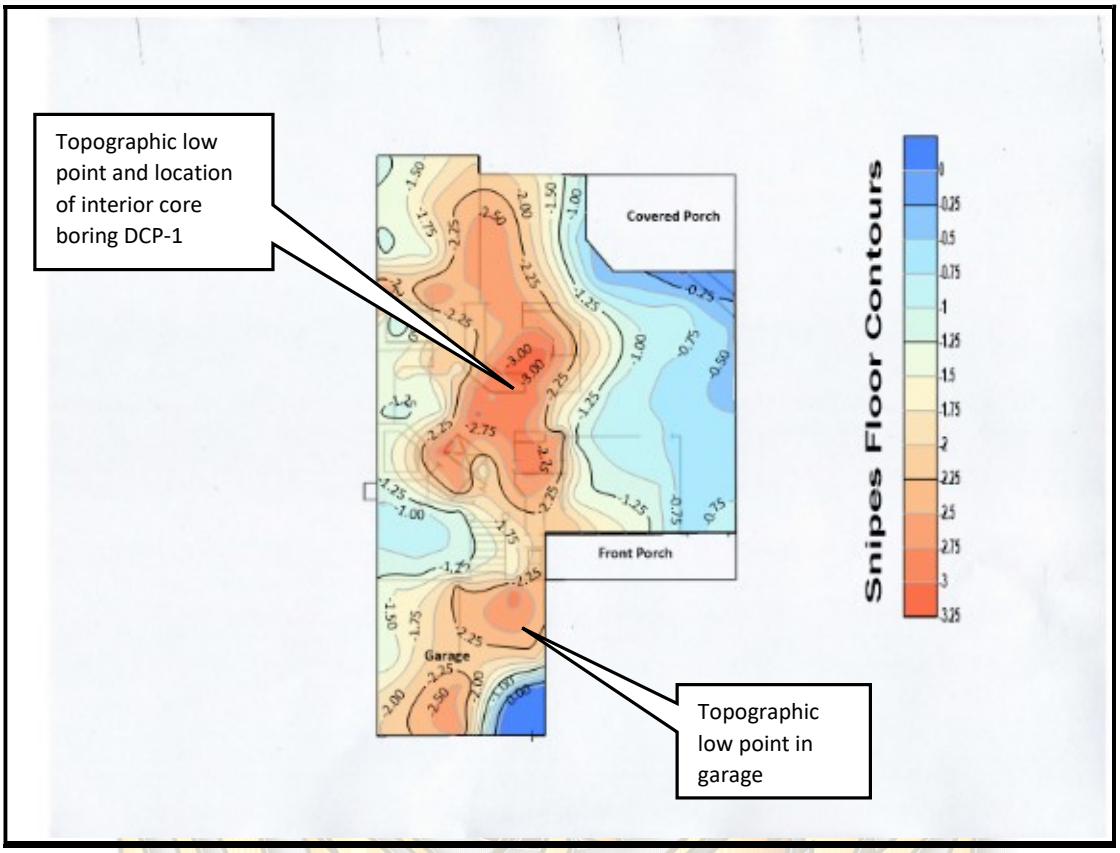

Figure 2: Relative Elevation Floor Contour Map.

Regional Geologic Setting

FSE relies on readily available public information published by the United States Geologic Survey (USGS) for pertinent and regionally specific geologic information, and how this information relates to the site-specific conditions. The following summarizes our review of the USGS documents.

Physiographic Province

The _____ residence is located midway along the southwest to northeast trending Valley and Ridge Physiographic Province (valley and ridge), this being a landform characterized by valleys and high elevation mountain ridges that span along the eastern seaboard from central Alabama into the middle of New York State.

- The valley and ridge were formed in the geologic past from tectonic mountain building forces.
    - The various carbonate, shale, sandstone or conglomeritic lithologic units of the valley and ridge are highly folded and faulted.
- The valleys are typically underlain by carbonate bedrock (limestone or dolostone) which is more susceptible to physical weathering, erosion, and chemical dissolution.
    - Erosion and alluvial transport of soil by rivers and streams have carved the valleys.
- Because shale, sandstone or conglomerate are harder than limestone, the peaks or higher elevations of the valley and ridge are capped by these more resistive lithologic units.

Mapped Geologic Units

According to the USGS, in their regional geologic unit Google Earth™ overlay maps (, The regional geology consists of the named Chickamauga Group, which includes the upper part of the grouping consisting of Reedsville Shale and an unnamed limestone formation that may be 600 feet thick.

- The limestone member of this grouping is described as consisting of medium-grained, fossiliferous, gray limestone.
- The middle and lower sections of the grouping consist mostly of layered shale and limestone.
- Combined, but generally further south from the residence, this geologic grouping may be as thick as 2000, or more, as the formation reportedly thickens from north to south.

Mapped Soil Units

FSE reviewed the United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS; formerly known as the Soil Conservation Services) publication entitled Soil Survey of Anderson County, Tennessee, dated 1978. • This publication is useful in providing depositional origin and physical properties of the soil. The NRCS publication detailed the following:

- The footprint of the home and immediate surrounding perimeter is located within the mapped boundary of the Colbert-Lyerly-Rock outcrop complex; 5 to 20 percent slopes.
    - Closely associated with the Collegedale soil type, and as presented in *Table 13: Engineering Index Properties*, this soil is reported to have moderate to high shrink-swell potential.
    - Below 6 inches deep in the native soil profile (excluding imported fill or regraded soil), cited plasticity indices ranging from 18 to 46 with corresponding liquid limits ranging from 41 to 80 percent.
        - Soils having a shrink-swell potential are deemed to be "plastic", deforming volumetrically in response to seasonal or cyclical changes in soil moisture content.
        - Plastic soils shrink when dry and swell when wet.
        - The cyclical actions of soil shrink-swell behavior can cause foundation displacement (settlement and/or uplift), in some cases severe (see **Expansive Soil** discussion herein).
    - Bedrock generally occurs less than 3 feet deep.

Karst Topography

Carbonate or limestone formations are soluble by the chemical actions of ground water, sometimes resulting in the formations of sinkholes and/or mapped, closed circular topographic low-lying areas (karst topography).

- Examples of karst topography can include features such as visible "cover-collapse" sinkholes, or barely discernable troughs or swales in the land surface caused by "cover-subsidence" sinkholes, as the land surface begins to sag downward into underlying zones of dissolutioning (caves, vugs, voids, enlarged joints or fractures etc.…) in the underlying bedrock, caused by sinkhole activity.
    - Often these depressional features intersect the surficial water table causing them to become permanently, cyclically, or seasonally infilled with ground water.

- Sometimes, when features as these have subsurface connectivity with other, similar dissolution features, particularly if geographically clustered such as within the boundaries of a watershed, these land surface karst features can play important roles for stormwater management and flood control.

- As shown on **Figure 3** below, two (2) mapped topographic low lying depressional features, suspected to have been formed by the dissolutioning of the surface of the underlying carbonate bedrock, occurred within one-quarter mile of the _____ residence.

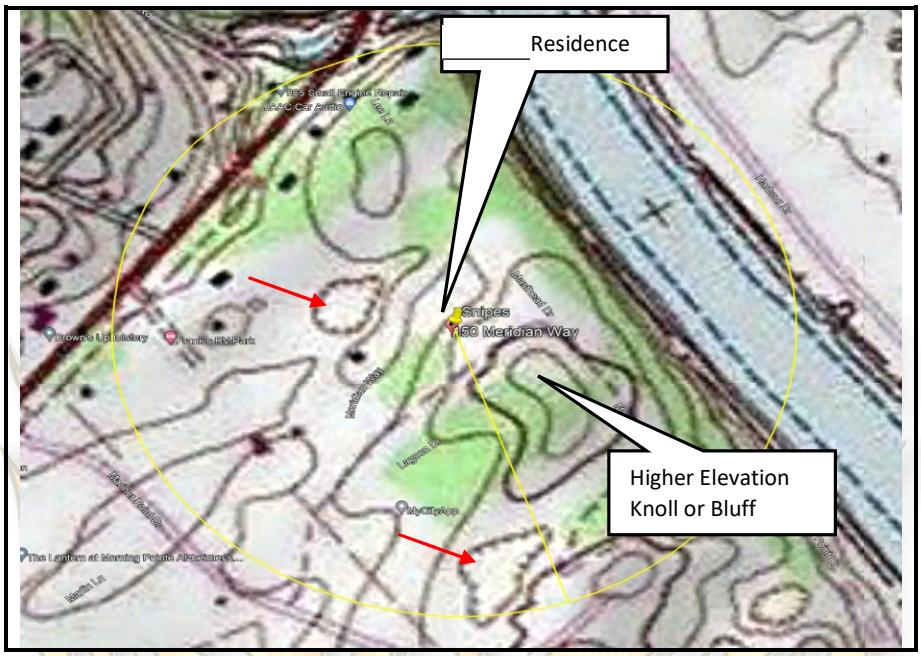

Figure 3: Mapped Closed-Circular Depressional Features Within ¼-Mile of the _____ Residence.

Precipitation Data

Due to the insureds concern regarding the sudden onset of the damages in the home, and that the damages appeared to have worsened following recent, prolonged rainfall events, FSE reviewed the National Weather Service (NWS; www.weather.gov) published historic precipitation records from the nearby Oak Ridge monitoring station.

- This geographic area of the state received 5.87 inches of precipitation in the month of January 2022.
  - The average precipitation amount for the month of January over a 9-year span (1991-2020) was reported to be 5.07 inches.
    - In January 2022, the average rainfall amount for the area was exceeded by 0.8 inches.
- For the month of February 2022, NWS reported 9.76 inches of precipitation in the area.
  - The published 9-year average 5.59-inch rainfall amount for the month of February was exceeded by 4.17 inches.

The unusually high rainfall amount in the month prior to the insured failing the claim would create wet weather springs as described herein, particularly within the discovered sinkhole activity zones resulting in inundation and weakening of the foundation/floor slab supporting soils, and as reported, the sudden onset of damages in the structure.

Subsurface Exploration and Results

Discussion of Soil Morphology

In central and eastern Tennessee, the native or undisturbed soils are typically termed "residuum", this being a soil comprised of various percentages of silt and clay weathered and eroded from parent carbonate bedrock (i.e., limestone).

- The soil can be formed in situ (in place weathering) or has been transported some distance from the parent material via the actions of water (alluvium) or wind (aeolian).

Standard Penetration Test Borings

FSE returned to the subject property on April 28, 2022, to perform drill-rig driven subsurface exploration Standard Penetration Test (SPT) borings. The SPT drilling methods and procedure generally follow the guidelines published by American Society for Testing and Materials; ASTM-D1586. The method periodically provides a recovery of a soil/bedrock sample between standardized sample depth intervals.

- SPT 'N' values, the indicator for soil strength, carries different nomenclature when discussing granular soils and their 'relative densities' versus 'soil consistency' in cohesive soil, the latter more applicable in this geographic area of the state.
- The drilling was performed with a limited access, track-mounted drilling rig using the hollow stem auger method to advance the borehole.
- FSE senior geologist Mr. Bernd T. Rindermann, P.G. logged the soil borings and classified the recovered soil and bedrock samples in the field.
    - If necessary, select soil samples can be collected and sealed in properly annotated sample jars or bags and transported to an offsite testing laboratory facility to determine the soil physical properties.
    - Based on the encountered subsurface conditions and our review of the NRCS published soil physical property data, none of the recovered soil samples from our borings performed at the Snipes residence were deemed by our geologist to require additional laboratory analysis.

Boring Location Site Plan

At the locations shown below on **Figure 4**, FSE performed four (4) drill-rig driven subsurface exploration test borings (Borings B-1 through B-4), with each boring positioned near the exterior perimeter walls where either damage was observed or where downward trends in the measured floor topography occurred near the perimeter walls.

Figure 4: SPT Boring Location Map

Boring Results

Based on the SPT borings performed on the property, the following conditions were encountered:

Boring B-1

In boring B-1, we initially encountered about 3 feet of heterogenous (mixed), reworked or imported clayey fill soil with entrained chert fragments. The upper 18 inches were cleared with a hand auger to check for buried obstructions.

- Based on an SPT 'N' = 7 in the 18-inch to 3-foot depth interval, the soil was medium firm or stiff in consistency. However, individual seating drives remained soft.

Below 3 feet deep, a more native, undisturbed soil profile of chert-bearing, uniform-colored, reddish brown silty clay continued to a depth of 7 feet.

- As above and based on an SPT 'N'=6, the soil was medium firm to stiff in consistency. Individual seating drives remained soft.

Very hard limestone was encountered at a depth of 7 feet below grade. Once encountered, the rotary auger drill could not advance beyond this depth. The SPT 'N' =25 blows/0" advancement indicated technical refusal, and the boring was terminated.

Boring B-2

During hand clearing the borehole with a hand auger, limestone bedrock was encountered at a depth of 18 inches.

- The recovered soil in the upper 18 inches was reworked, heterogenous chert-bearing silty clay.
- The auger stem was positioned over the borehole, but the auger was not able to penetrate any further.
    - Based on 25 blows of the hammer with no advancement of the tooling recorded, the boring was terminated in hard limestone.

Boring B-3

The upper 2 feet of the borehole were cleared with a hand auger. The recovered material was heterogenous, chert-bearing clayey fill or reworked soil.

- In the 2 to 4-foot depth interval, we encountered a thin limestone ledge or "cap rock" layer at a depth of 2-1/2 feet deep.
    - Based on the strokes of the hammer on the drill stem and split spoon sampler, this limestone layer was easily breached.
    - The SPT 'N' value was artificially inflated due to the presence of the limestone and our efforts to break through it.
- Below 2-1/2 feet deep, a thickened sequence of silt and clay varying in texture, color and consistency continued to a depth of 29 feet deep.
    - The color of the soil ranged from reddish brown to greenish gray, with inclusions of black organic staining and rounded pebble present in the upper 10 feet.
- Below 10 feet deep, a zone of saturation was encountered. The soils were wet.
- From 3 feet deep to 29 feet deep, the SPT 'N' value distribution ranged from 'N'=3 to 'N'=14. Particularly in the upper 20 feet, these soils were soft or very soft in consistency. Numerous seating intervals of no resistance to advancement of the tooling were encountered throughout (weight-of-hammer/weight-of-rod).
- Very hard limestone bedrock was encountered at a depth of 29 feet deep, and the boring was terminated.

Boring B-4

The upper 2 feet of the borehole were cleared with a hand auger. The recovered material was heterogenous, chert-bearing clayey fill or reworked soil.

- Considering the 2 to 4-foot sample depth interval, the initial seating drive was soft.
- The penetration resistance increased below a depth of 2-1.2 feet due to the inclusions of limestone or lime rock (fill material).
    - The SPT 'N' = 22 indicated the resistance of the reworked soil to be very stiff.
- Auger refusal, followed by technical refusal occurred at a depth of 4 feet and the boring was terminated.

Dynamic Cone Penetration Test

As shown on **Figure 2** herein, FSE performed a manually driven dynamic cone penetration (DCP) test accompanied by a hand auger to evaluate the density, consistency, or hardness of the recovered materials present below the kitchen floor slab, where the lowest floor survey elevations were measured. The method and procedure generally followed the guidelines published in ASTM D-6951; procedures for light duty DCP soundings.

The DCP utilizes a 15-pound sliding weight falling 20 inches to drive a rod with a cone point through the undisturbed soils at the base of the hand auger boring increment.

- The cone point is initially driven 2 inches to ensure the tip is completely embedded into the soil. Blow counts (the number of times the weight is dropped 20 inches) are then recorded and averaged for two consecutive 1-3/4- inch intervals.
- The readings obtained using the DCP were correlated to SPT "N-values" using known ratios compiled within ASTM STP 399 Figure 3 – Penetration Relationships.
- DCP soundings were incrementally recorded while the bore hole was cleared with a hand auger.

Given the consent of the insured, FSE removed four (4) ceramic floor tiles in the kitchen to allow access for the sub-slab testing.

- By doing this, we discovered that a thickened thinset mortar base was required in this area to maintain levelness for the tile installation (see discussion herein).
- FSE also observed the presence of a radial crack in the floor slab which had been covered with a slip sheet fiber tape membrane (see discussion herein).

FSE utilized a 4-inch diameter water-cooled concrete drill to perforate the floor slab to gain access to the soils beneath.

- Upon completion of the boring and backfilling of the borehole, the concrete core removed from the slab was replaced and re-cemented into place.
- Replacement tiles stored in the homeowner's garage were also put back in place, being installed by the traditional methods by our experienced staff.

Results of DCP Soundings

The following presents the results of our interior DCP test and findings thereof:

- The concrete floor slab measured 3-1/2 inches thick.
    - The interior floor slab at this location was somewhat thinner than the nominal 4-inch-thick concrete usually maintained during the construction of the slab.
    - The slab did not incorporate any wire mesh, nor was fiber mesh reinforcement observed.
    - The slab was underlain with a plastic vapor retardant barrier which was repaired when sealing the borehole hole.
    - The slab was underlain by 12 inches of 3/4-inch diameter gravel subgrade.

- Due to the gravel, the DCP procedure began at a depth of 12 inches below top of slab.
    - Once the gravel subgrade subgrade was cleared, the penetration resistance in the underlying silty clay was very soft (adjusted 'N'=2) to a depth of 19 inches below the slab.
    - Very soft to soft penetration resistance continued to a depth of 30 inches below the floor slab in native, undisturbed silty clay.
        - The corrected 'N' values were N=3 in both the 19 to 24 and 24 to 27-inch depth intervals.
    - Limestone bedrock was initially encountered at a depth of 27 inches below slab.
- At a depth of 27 inches, the DCP hand tool deflected sideways into a slot, or other type of lateral discontinuity in the bedrock.
    - FSE continued to drive the DCP tooling into the recess in the bedrock.
        - The corrected 'N' value was 'N'=6. This was representative of weak, highly weathered, and corroded bedrock.
    - Access constraints from operating within a core hole prevented proper clearing of the discovered angled recess in the bedrock below a depth of 27 inches.
        - A follow-up "seating" drive of the DCP revealed a modified 'N' value of 8.5, this also being indicative of highly weathered limestone.
- The DCP sounding/had auger boring was backfilled with the extracted soil cuttings and gravel.
    - Once backfilled the concrete core was replaced into the core hole and cemented into place.
    - As leftover ceramic floor tile was available, the tiles were reinstalled to match the levelness of the surrounding tiles.
        - As stated above, an unusual amount of thinset mortar was required to bring the replacement tiles to matching elevation with those of the surrounding tiles.
    - Once sufficient setup of the tile mortar bed had occurred, the joint spaces between the tiles were grouted with color-matched grout.

<u>DCP Analysis</u>

Below 12 inches, the slab supporting soils were very soft or soft in consistency.

- The DCP boring was terminated in weak, friable limestone bedrock, the top of which was encountered around a depth of 27 inches below grade.
- FSE encountered an angled recess/lateral discontinuity in the surface of the bedrock.
    - Upon further assessment with the hand tooling, it was revealed that the limestone bedrock was highly weathered and corroded.
    - The vertical extent of this weakened zone within the bedrock was undetermined.

Based on the evidence that weakening of the limestone had occurred within a recess or lateral discontinuity in the bedrock, and that the soils near the limestone interface, as well as the soil supporting the gravel

underlayment and floor were excessively soft in consistency, it was our opinion that the identified subsurface conditions were consistent with those of emerging *sinkhole activity*.

Discussion of Expansive Soils

Expansive silty clay soil was identified on the property. Because of the soil physical properties, these soils expand when moist and shrink when dry. The shrink-swell behavior of plastic soil can result in differential foundation movement causing distress cracks, sometimes severe.

- If the soil moisture exceeds the soil liquid limit, the soil grains may dissociate due to a loss of internal friction/cohesion; (Rahn, Perry; Engineering Geology, 1986).
- Due to the buoyancy effect of the increased soil pore pressure accompanied with dissociation of soil grains, the soil weakens and diminishes in bearing capacity.
- Applied loads on water-saturated soils can cause particle re-orientation (compression) and expulsion of water from the soil pore spaces resulting in squeezing (consolidation) of the soil and a loss of volume reduction also resulting in foundation settlement.

Evaluations and Conclusions

Based on the results of four (4) drill-rig-driven Standard Penetration Test (SPT) borings and one interior, hand-driven dynamic cone penetration (DCP) test, FSE identified a significantly deep (29-foot deep) cavernous zone in the carbonate (limestone) bedrock adjacent to the north foundation of the house near the joint between the house and the garage.

- The cavernous zone was determined by FSE to be a paleokarst or *relic-sinkhole* which had been in-filled with alluvium (water transported soil deposits) over geologic time.
- The origin of these soils appears related to a former flow path of the Clinch River which is currently located about 0.1 mile northeast the residence.
    - Our boring data revealed the infilled soils within the relic-sinkhole to be very weak in consistency within 20 feet of the ground surface.
    - The weak soil underlay the north foundation and garage slab area of the house.

FSE attributes the weakened soils conditions within the sinkhole to be caused by ongoing *sinkhole activity*, which had resulted in downward migration of the soil column into underlying, or deeper-seated dissolutioning zones within the bedrock.

- Based on our review of GoogleEarth™ published available aerial photographs dating back to 1985, which through 2007 depict the lot as heavily treed, there was no evidence of a visible sinkhole being present on the property.
- By September 2008, the subject residence had been constructed.
- Sometimes, sinkholes on site development projects are covered over by earth moving equipment during grading and re-shaping of the terrain, prior to construction of the home.

To a lesser degree and extent, and within the interior core/DCP sounding performed by FSE, we discovered an inclined ledge on the surface of the bedrock which we encountered about 2-1/2 feet below the floor slab.

- This ledge resulted in sideways deflection of the hand tooling, as well as the tooling being able to penetrate deeper (about 4 feet deep) into a pocket, or dissolution feature within the bedrock.
- This feature was associated with structurally significant downward defection of the interior floor slab which had settled 3.1 inches local to the west-central portion of the home.
    - Prior to coring, and after having removed about 6 square feet of floor tiles in the kitchen, we discovered that a circular or arc-shaped crack had been covered with a fiber tap "slip sheet" membrane prior to the installation of the tiles.
        - Once the slip sheet tape (used to cover a preexisting crack in the floor slab, thus preventing telegraphing of the slab crack through the surface of the tile) was removed, this arc-shaped floor slab crack, measured 1/16-inch in width.
        - Based on the curvature of the arc-shaped crack, we inferred that a 10-foot wide depressional feature underlay the slab.

Because of the documented topography on the floor slab, and in consideration of our core boring/DCP sounding data, **it was our opinion that another sinkhole underlay this area of the interior floor slab**.

Supporting Data

The United States Geologic Survey (USGS) has mapped several "closed circular depressions" occurring within one-half mile of the subject residence.

- Such mapped features represent karst topography, this being a landform shaped by the dissolution of limestone.
- These features are suspected to be sinkholes.

Based on our review of the published historic precipitation data, higher than normal rainfall amounts were recorded in the area in the months preceding the reported date of loss for this claim.

In this case, and common near the toes of hillside slopes, infiltrated ground water flowing through preferential flow paths in the bedrock (i.e., cracks, fissures, joints etc.,) will enlarge such features over geologic time.

- Sometimes, and under the conditions of an increase in hydrostatic pressure during seasonal or cyclical increases in rainfall, the ground water entrained within the bedrock can "upwell" and breach the land surface.
    - When ground water seeps out of the ground at the toe of a slope during the wet weather months, it is commonly referred to as a "wet weather spring".
    - As applicable in this case, and due to the soil plastic physical properties, upwelling of ground water would result in weakening of the foundation supporting soils (see discussion on expansive soil herein).

Accordingly, based on the identified subsurface conditions, and the known/mapped geologic hazards in the area, it was our opinion that *sinkhole activity,* as defined in the herein-referenced statute was met in two (2) of the borings performed by FSE on the subject property.

Further, it was our opinion that *sinkhole activity* has caused localized settlement damage in the foundation and that *sinkhole activity* was the cause of the interior floor slab settlement which resulted in the other ceiling and wall distress in the home.

Other Causes of Damage

The cracks in the driveway and garage concrete slab were consistent with those originating from concrete shrinkage. Concrete shrinkage is a well understood material property of concrete as it cures and ages.

- The 16-foot-wide section of damaged driveway only incorporated transverse concrete shrinkage control joints. The distribution of control joint spacing and/or the absence of a longitudinal control joint did not meet published criteria or reference standards set forth by the American Concrete Institute (ACI) in their publication entitled Guide for Concrete Floor and Slab Construction (ACI 302.1R-04).
- The lack of and/or improperly spaced concrete shrinkage control joints was determined to be a cause of damage in the driveway and front porch concrete slabs.
    - The front porch slab did not incorporate any shrinkage control joints.

The herein described vertically offset crack in the garage slab was also initially caused by concrete shrinkage. The garage slab only included the centrally aligned longitudinal shrinkage control joint.

- The crack in the garage slab was wider than that typically associated with concrete shrinkage.
- Based on the previous application of elastomeric caulk in the crack, the crack was a long-term and pre-existing recognized condition.

According to ACI, the depth of the control joint cut should not exceed 30 percent of the thickness of the concrete. If cut too deep, the remaining concrete beneath the cut can crack, particularly under the applied loads of a vehicle or by differential slab movement (settlement and/or uplift).

- The vertical offset along the crack edge indicated that the crack extended through the entire thickness of the slab. This essentially bisected the slab into two slab segments, each capable of independent movement.
- The crack continued to worsen over time by the combination of applied vehicle loads and differential settlement of the “free floating” slab along the northern perimeter.

Removal of some of the kitchen floor tiles exposed a pre-existing arc-shaped crack in the underlying concrete slab which was covered with a fiber-tape slip-sheet membrane.

- As the floor tiles in the kitchen were reported to be original to the house, it was our opinion that the crack in the floor slab existed prior to the installation of the tile.
- The exposed arc of what through visual interpolation appeared to form a 10-foot diameter circular depressional area in the kitchen, was caused by tensional stress as the slab had settled during the construction of the home.
    - Concrete performs better under compression and is very weak under tension, thus the incorporation of wire mesh or fiber mesh in a conventional concrete slab, should minor tensional displacement of the slab occur.

- To maintain levelness of the floor tile installation, additional thinset mortar was applied at the base of the tiles local to the measured topographic low point in the kitchen.
    - The tile thinset mortar bed was almost one inch thick along the edge of the kitchen counter, requiring additional effort in removal of the tile.

The one-inch vertical offset which occurred along a control joint in the front concrete sidewalk was caused by the control joint having been cut too deep (see preceding discussion) coupled with plastic deformation or expansion of expansive clay soil on which the sidewalk was constructed.

- Expansive soils having a low to moderate shrink-swell potential were present on the subject property.
- Due to grading or general yard topography, preferential flow paths developed for surface water runoff to be directed toward the sidewalk.
    - The increased frequency of saturation or inundation of the soils beneath the displaced sidewalk section relative to other portions of the sidewalk, resulted in swelling of the expansive soils causing the observed, localized distress in the sidewalk.

Master Services Foundation Repair Estimate

Master Services Optical Survey

Masking tape strips were present at unevenly spaced distances on each perimeter wall. The tape marks were recently placed on the walls by Master Services, a foundation repair contractor based out of Knoxville. The tape was used as optical survey markers to establish the horizontal alignments of the brick joints. Based on their work sheet dated March 7, 2022, the following was presented:

- Strictly based on their optical survey, Master Services recommended the installation of 20 foundation underpins to be installed beneath the perimeter walls, with this foundation repair plan specifically targeting the north, east, south, and west foundations local the the northeast and southwest quadrants of the house.
- No other work appeared to have been performed by Master Services to aid in their foundation repair design plan.

FSE Review of Master Services Worksheet

Master Services did not perform a geotechnical assessment of the soil or bedrock conditions on the property, nor did they take into consideration the possible deleterious impacts on underpin stability, nor the effectiveness of their foundation repair plan, considering the discovered *sinkhole activity* identified by FSE beneath the north foundation and interior floor slab in the home.

Master Services did not perform any level measurements across the interior living area floor slab surface, nor were plumb measurements taken along the current highly distressed door frames in the central area of the house.

- No floor slab settlement problems were documented nor recognized by Master Services; at the time the foundation repair estimate was prepared.

- The worksheet did not furnish any design plans for the foundation repair, which in our experience would typically include details of the proposed foundation repair including a discussion as to type of underpin (i.e., helical pier, push pin, etc.…) being recommended, and why; a breakdown of material and labor unit rates, contractor mobilization costs, permitting fees, contingency fees for unexpected depths to bedrock, removal/replacement of concrete slab appurtenances, concrete saw cuts, electrical systems, incidental collateral property impacts/damages etc.…,

It was our opinion that any foundation repair plan should include some type of assessment of the foundation bearing soil.

- Soil types, soil strength and various soil physical properties (i.e., expansive clay soil) could impact foundation repair deigns.
  - For instance, a helical pier should not be seated in expansive clay soil, which as in this case have a moderate to high shrink-well potential.
- The foundation repair specialist should be interested in depths to bedrock.
- As in this case, and commonplace in geographic areas known for karst topography, the depths to bedrock can vary significantly, even across individual building plots which may include the locations of the proposed underpin installations.
  - FSE and others have previously assessed other structures where after foundation repairs, claim filings pertained to ongoing settlement damages were re-assessed, sometimes requiring a follow-up program of subsurface exploration.

Post-foundation repair damages can be caused by a variety of contractor deficiency conditions including but not limited to: The type of underpin being used (i.e., helical pier, push pier, drilled pier, injection pier, etc.); inadequate depths of underpin installations, terminating pressures erroneously relied upon as being representative of bedrock; underpin spacing, lack of connector rods (i.e. grade beams), non-uniform load distributions (not notching strip footings), etc., have all been reported by engineers as common causes of continued foundation settlement.

- Poor engineering practices (i.e., insufficient testing, lack of due-diligence, absence of soils laboratory testing, etc.) would result in “blind” drilling advancement of the underpins, which as stated above could result in the underpins to be improperly installed.

AFW Foundation Repair Estimate

Based on our findings and conclusions presented herein, Farm Bureau asked FSE to solicit a more detailed and comprehensive foundation and interior floor slab repair scope, this to include a detailed line itemization of anticipated labor and material costs, including contingency fees if the proposed work scope was altered due to unforeseen conditions.

- FSE contacted Mr. Darle Canova, President of American Foundation & Waterproofing (AFW) based out of Maryville, Tennessee to provide the above-requested scope of services and fee schedules.

- Mr. Canova visited the _____ property on June 2, 2022, to personally view the damages in the home. FSE had provided draft documentation to AFW which included the results of our testing; this information being pertinent for AFW to produce a repair scope.
- As also included in **Attachment A**, AFW recommended the following:

Foundation and Floor Slab Underpinning

As detailed in their estimate, 23 drilled piers are to be installed around the perimeter foundation of the home.

- An additional 17 drilled piers are to be installed beneath interior load bearing walls local to the documented floor slab settlement.
    - As needed (i.e., to span the width of door opening, etc.…), steel spreader beams were to be installed between piers to provide uniform load distribution.
- The depth of underpin installation was estimated to be 30 feet deep, with each drilled pier seated some distance into competent bedrock.
- Based on site conditions, AFW pre-drills the underpin locations to clear potentially stiff or hard consistency clay zones on which potentially erroneous refusal to further advancement of the underpins could occur and to ensure that limestone was encountered at the termination depth of each underpin.

Chemical Grouting

To address the interior floor slab settlement, AFW recommended the injection of polyurethane (poly) grout, sometimes referred to as “slab jacking”, to be performed beneath the principal area of the documented interior floor slab settlement.

- The poly injection will be performed through 3/4-inch diameter drill holes in the concrete, each fitted with injection nozzles to pump the grout underneath the slab.
- Injection spacing should occur along a grid pattern with injection points spacing of 3 to 4-feet.
- 300 pounds per square inch (psi) terminating pressures were established for each poly injection point to ensure that sufficient lift of the slab would occur at each injection point.
- Complete releveling of the floor slab to a pre-settlement condition is not to be expected, as significant collateral damages to sensitive interior drywall finishes could occur.
- Saw cuts, drill holes and worker or equipment-related efforts are anticipated to cause additional damages to the floor covering throughout the workspace area, including those pathways used as ingress and egress pathways to the interior of the home.

AFW allocated line-item fee schedules for pre-construction inspection of the house plumbing system, use of specialty equipment and engineering oversight for a licensed and qualified engineer to issue a certified foundation repair closure letter, should such documentation be requested by a third party like a mortgage provider, sometime in the future.