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**Pre- and Post-Harvest Activity Assessment using the
U.S. Forest Service Forest Soil Disturbance Monitoring
Protocol (FSDMP), Mark Twain National Forest,
Missouri (2021-2022)**

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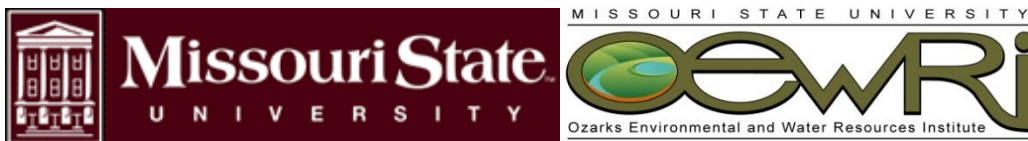
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TABLE OF CONTENTS

TABLE OF CONTENTS.....	2
LIST OF TABLES.....	3
LIST OF FIGURES.....	3
LIST OF PHOTOS.....	4
PURPOSE AND SCOPE.....	5
STUDY AREA.....	5
METHODS.....	6
Geospatial Methods.....	6
Field Methods.....	6
Data Storage and Visualization.....	7
ASSESSMENT RESULTS.....	7
Site Descriptions (Years 1-2).....	7
Fox Hollow.....	7
Monterey.....	8
Sterling Hollow.....	8
Swayback.....	8
Warthog.....	8
Wild Coyote.....	9
Site Descriptions (Year 3).....	9
Hellroaring Springs.....	9
Huckleberry Ridge.....	9
Garner Hollow.....	9
Site Description (Year 4).....	10
Tabor Cave.....	10
Pre-Activity Evaluation (2018-2019).....	10
Pre-Activity Evaluation (2021).....	12
Pre-Activity Evaluation (2022).....	13
Post-Activity Evaluation I (<1-year from harvest).....	13
Post-Activity Evaluation II (>1-year from harvest).....	16
Post Activity Evaluation III (>2-years from harvest).....	18
OBSERVATIONS AND RECOMMENDATIONS.....	20
Pre-Activity Assessment.....	20
Post-Activity I Assessment.....	20
Post-Activity II Assessment.....	22
Post-Activity III Assessment.....	22
CONCLUSIONS.....	23

Year 1	23
Year 2	23
Year 3	24
Year 4	24
REFERENCES	25
TABLES.....	26
FIGURES.....	31
PHOTOS.....	44
APPENDIX A - TIMBER SALE MAPS.....	56
APPENDIX B – ARCMAP GEODATABASE HTML POPUP TOOL.....	66
APPENDIX C – SOIL SERIES BY SALE SITE	68

LIST OF TABLES

Table 1. Summary of sites evaluated for this project.....	26
Table 2. Pre-Activity Forest Floor Depth and Percentage of Observations.....	27
Table 3. Initial Post-Activity Survey Results (<1-year since harvest).....	28
Table 4. Number of Post-Activity I Sample Points Evaluated at each Site by Disturbance Class.	28
Table 5. Post-Activity II Survey Results (>1-year since harvest).	29
Table 6. Number of Post-Activity II Sample Points Evaluated at each Site by Disturbance Class.	29

LIST OF FIGURES

Figure 1. Mark Twain National Forest (MTNF) Ranger Districts in Southern Missouri.	31
Figure 2. Fox Hollow Site Map.	32
Figure 3. Monterey Site Map.	33
Figure 4. Sterling Hollow Site Map.....	34
Figure 5. Swayback Site Map.	35
Figure 6. Warthog Site Map.....	36
Figure 7. Wild Coyote Site Map.	37
Figure 8. Hellroaring Springs Site Map.	38
Figure 9. Huckleberry Ridge Site Map.....	39
Figure 10. Garner Hollow Site Map.....	40
Figure 11. Tabor Cave Site Map.....	41
Figure 12. Observed temporal changes in site characteristics since 2018.....	42

LIST OF PHOTOS

Photo 1. Using GPS navigation to locate pre-selected pit locations (Swayback: Sept. 26, 2018).	44
Photo 2. Pit location and ring where forest floor is evaluated prior to digging a pit (Monterey: May 11, 2018).	44
Photo 3. Measuring forest floor depth (Sterling Hollow: July 31, 2018).	45
Photo 4. Pits are dug to a depth of 15-30 cm (Warthog: April 5, 2018).	45
Photo 5. Measuring pit depth (Coyote: Sept. 27, 2018).	46
Photo 6. IPADs are used to enter data to FSDMP datasheet (Coyote: Sept. 27, 2018).	46
Photo 7. Using an example of platy structure to help field workers identify it in the field (Monterey: May 11, 2018).	47
Photo 8. Wind damage was observed at some of the sites (Fox Hollow: August 2, 2018).	47
Photo 9. Tree throw was common at most sampling sites (Fox Hollow: August 2, 2018).	48
Photo 10. ATV trail located within the monitoring site (Monterey: May 11, 2018).	48
Photo 11. Very rocky conditions were observed at some sites (Warthog: April 5, 2018).	49
Photo 12. Rocky colluvium material above loamy A horizon (Warthog: April 5, 2018).	49
Photo 13. Stream channels were located within some of the sites (Warthog April 5, 2018).	50
Photo 14. Loess parent material (Wild Coyote: Sept. 27, 2018) NOTE: Horizontal lines are not platy structure but are from scraping with a soil knife.	50
Photo 15. Weathered loess parent material (Wild Coyote: Sept. 27, 2018).	51
Photo 16. Main haul road within the sale site (Fox Hollow: November 14, 2019).	51
Photo 17. Sample pit with an example of compaction (Fox Hollow: November 15, 2019).	52
Photo 18. Sample points located in dense brush left over from harvest (Sterling Hollow: December 11, 2019).	52
Photo 19. Rutting observed along the main haul road (Swayback: December 5, 2019).	53
Photo 20. Large amount of slash left on site significantly increases woody debris observations during post-activity evaluation (Warthog: December 16, 2019).	53
Photo 21. Steep sites tend to have high rock at the surface (Warthog: December 18, 2019). ..	54
Photo 22. Main haul road along the ridge line (Warthog: December 16, 2019).	54
Photo 23. Example of a soil sampling point with no "O" horizon present (Fox Hollow: November 14, 2019).	55
Photo 24. Example of a soil sampling point with the "O" horizon present (Wild Coyote: December 6, 2019).	55

PURPOSE AND SCOPE

The United States Forest Service (USFS) has contracted the Ozarks Environmental and Water Resources Institute (OEWRI) to perform the Forest Soil Disturbance Monitoring Protocol (FSDMP) within the Mark Twain National Forest (MTNF) in southern Missouri. The FSDMP is a national monitoring program designed to assess the extent of ground disturbance during timber harvest activity and to quantify changes to the landscape that may affect long-term sustainability of the site (Page-Dumroese et al. 2009¹). This is the first time this type of monitoring has been performed within the MTNF and results of this study will be used to refine the FSDMP to adequately assess the impact of timber harvest on variable Ozarks landscapes. The overall goal of this project is to use the FSDMP to monitor different areas within the MTNF and assess the effectiveness of the FSDMP as a monitoring tool.

This report covers the results from Year 4 monitoring activities that includes both pre- and post-harvest assessments. Results from Years 1-3 are also included to analyze the temporal trends. Specific objectives of Year 4 monitoring activities are:

1. Implement FSDMP on MTNF lands based on forest management units selected by MTNF soils program manager.
2. Complete post-harvest activity data collection at **nine** timber sale sites in 2021-2022.
3. Enter pre- and post-activity data into FSDMP database and provide a quality control review.
4. Provide a photo location representative for each transect line and spatial data associated with transects and points along transects.
5. Summarize findings, results, and analysis.

STUDY AREA

The MTNF consists of six ranger districts in southern Missouri (Figure 1). For the first two years of this program three districts were chosen for this project: Doniphan/Eleven Point, Ava/Cassville/Willow Springs, and the Poplar Bluff Districts. Two sites were assessed within each district and range from 5.7-38.6 ha in size (Table 1). The Warthog and Monterey sites are located in the Doniphan/Eleven Point Ranger District in Carter and Oregon Counties. The Sterling Hollow and Fox Hollow sites are located in the Ava/Cassville/Willow Springs Ranger

District in Howell and Douglas Counties. Finally, the Swayback and Coyote sites are located in the Poplar Bluff Ranger District in Butler and Wayne Counties. For year three, Hellroaring Springs, Huckleberry Ridge, and Garner Hollow were added from the Ava/Cassville/Willow Springs Ranger District. Tabor Cave was added in year four and is within the Ava/Cassville/Willow Springs Ranger District in Howell County.

The MTNF is located in the southern Missouri Ozarks region that is characterized by a dissected plain grading from broad, gently rolling uplands to steep, highly dissected hillslopes when closer to major river valleys (USDA 2006). In general, the region is underlain by soluble Ordovician and Mississippian age cherty limestone and dolomite, with remnant Pennsylvanian age sandstone and shale along ridgetops (Adamski et al. 1995). The area is a karst landscape where sinkholes, losing streams, and springs are common. Upland soils are formed from cherty residuum and colluvium capped by a thin layer of loess, fragipans are common on the broad, flat divides (USDA 2006). The forest is dominated by Oak and Oak-mixed hardwood forest communities with smaller areas of native shortleaf pines (Nigh and Schroeder 2002).

METHODS

Geospatial Methods

USFS staff selected sites for the FSDMP and provided maps highlighting several payment units at each site (Appendix A). The maps were rectified in ArcGIS and each payment unit was digitized to create polygon areas of each unit. For each unit, a best-fit “zig-zag” transect including 68 total sampling points at equally spaced intervals was created by visual judgement to cover all areas of the payment unit (see layout patterns of sampling points in Figures 2-11). The uniform use of 68 total sampling points at each site, regardless of differences in payment unit area, is based on criteria to collect the maximum number of points needed to quantify the maximum variability at the 90% confidence limit with a margin of error at +/- 10% (Page-Dumroese et al. 2009²). These points were transferred to a Trimble 7x global positioning system (GPS) unit for navigation in the field (Photo 1).

Field Methods

Each transect was sampled by starting at monitoring point #1 and performing the FSDMP at every other sample point (odd numbers). This resulted in a minimum of 34 monitoring points being sampled across the entire unit. As data were entered into the Excel based FSDMP datasheet, site variability is updated continuously by the software. The FSDMP spreadsheet specifies the minimum number of points to be evaluated based on the chosen confidence interval. For this project a 90% confidence limit with a margin of error at +/- 10% was chosen.

Therefore, if there was low variability in the data, a total of 30 locations would be enough to satisfy the minimum number of pits needed per the assessment. Alternatively, if the unit was highly variable, a total of 68 pits would be needed to satisfy the chosen confidence interval. If this occurred, the evaluators would backtrack along the transect and fill in with more sampling pits at the even numbered monitoring points to meet the requirement. For this project, a minimum of 34 points were evaluated, which exceeds the minimum required, to make sure the entire site was assessed.

At each pit location, a 6" ring was laid down at the predetermined location and a photo was taken to capture the condition of the forest floor to include the surrounding landscape (Photo 2). Forest floor depth was measured using a folding ruler and any notes of surrounding vegetation, woody debris, surface rocks, or bare earth were also recorded (Photo 3). A pit was then dug to a depth of 6-12" (15-30 cm) (Photos 4 and 5). The exposed soil was then evaluated using the FSDMP protocol using visual indicators in the soil such as rutting, compaction and platy, massive, or puddled structure (Photo 6). Results of the assessment were entered into the Excel spreadsheet on site using an iPad (Appendix B, Photo 7). Finally, a photo of the pit was taken for later reference.

Data Storage and Visualization

All photos and datasheets were joined with each soil pit location and stored in an ArcGIS Geodatabase. These data can then be brought into ArcMap and the photo, and the data collected at the individual pits can be observed by using the HTML Popup Tool to click on each point on the screen (Appendix C).

ASSESSMENT RESULTS

Site Descriptions (Years 1-2)

There was a total of six payment unit sites identified for assessment for the first two years of this project. The location, sampling layout, and brief description of the soils with each site are given below.

Fox Hollow

The Fox Hollow site (38.6 ha) is located within the Ava/Cassville/Willow Springs Ranger District in Douglas County. The total length of the transect line is 3,276 m and points are spaced 49 m apart along the summit and upper side slope of a narrow ridgetop (Figure 2). The soil series mapped along the ridgetop is the Scholten-Tonti (3-8% slope), Scholten-Poynor (3-8% slope), and the Scholten-Poynor (8-15% slope). The Scholten and Tonti soil series have fragipans and

all three series have between 15-40% rock fragments in the upper soil. Moving downhill to the steeper side slope the soils are mapped as the Poynor extremely gravelly silt loam (8-15% slope) and Coulstone-Bender complex (3-8% slope). The Poynor soil series is formed in colluvium with 15-40% chert fragments in the upper portions of the profile.

Monterey

The Monterey site (28 ha) is located within the Doniphan/Eleven Point Ranger District in Oregon County. The transect is 2,493 m in length with points spaced 37 m apart along the summit and shoulder of a broad upland landscape (Figure 3). The soil series mapped along the summit is the Macedonia silt loam (3-8% slope) with smaller areas of Coulstone gravelly sandy loam (3-8% slopes) and Poynor very gravelly silt loam (1-8% slopes). The Macedonia soil series is formed from residuum of the underlying bedrock and capped by a thin layer of loess with 2-6% chert fragments in the upper 35 cm of the profile. Moving downslope, the Clarksville very gravelly silt loam 8-15% is mapped on the side slope with 20-30% rock fragments in the upper 30 cm of the profile.

Sterling Hollow

The Sterling Hollow site (7.9 ha) is located within the Ava/Cassville/Willow Springs Ranger District in Howell County. The length of the transect is 1,218 m and points spaced 18 m apart along the summit and side slope of a relatively narrow ridgetop (Figure 4). The soil series mapped along the ridgetop is the Tick very gravelly silt loam (3-5% slope). Moving downhill to the steep side slope, the soils are mapped as the Tick extremely gravelly silt loam (15-50% slope). The Tick soil series is formed in gravelly colluvium and the underlying mudstone with 15-35% chert fragments in the upper 25 cm. At the base of the slope there is a small area of Cedargap very gravelly silt loam (0-3% slope) mapped near the drainage way.

Swayback

The Swayback site (5.8 ha) is located within the Poplar Bluff Ranger District in Douglas County. The transect line is 1,557 m in length with points spaced 23 m apart along the summit and shoulder of a ridge (Figure 5). The soil series mapped along the ridgetop is the Captina-Scholten complex (3-8% slope) and the Clarksville-Scholten complex (15-45% slope) mapped along the side slope. The Captina soil series has a fragipan and is typically free of rock fragments in the upper 30 cm of the profile.

Warthog

The Warthog site (22 ha) is located within the Doniphan/Eleven Point Ranger District in Carter County. The transect line length is 2,066 m and points are spaced 31 m apart along the summit and steep side slope of a narrow ridge (Figure 6). The Coulstone gravelly sandy loam (3-8%

slope) is mapped on the ridgetop and Coulstone sandy loam (15-35% slopes) is mapped on the side slope (USDA 2018a). Coulstone is formed from colluvium and sandstone residuum with 40-50% rock fragments in the upper 28 cm of the soil profile (USDA 2018b). There is also a small area of Midco very gravelly loam mapped at the base of the slope.

Wild Coyote

The Wild Coyote site (6.4 ha) is in the Poplar Bluff Ranger District in Wayne County. The transect line is 1,082 m long and points are spaced 16 m apart along a side slope below the summit of a ridge and includes a headwater drainage (Figure 7). The soil series mapped along the ridgetop is the Captina silt loam (3-8% slope) and the Yelton-Scholten (8-15% slope) was mapped further downhill along the side slope. The Yelton soil series has a fragipan and the upper soil is generally rock-free. At the base of the slope there is a small area of the Tilk-Secesh complex mapped which is formed in alluvium along floodplains, terraces, and alluvial fans.

Site Descriptions (Year 3)

The Forest Service added three additional sites for evaluation in 2020-2021, Hellroaring Springs, Huckleberry Ridge, and Garner Hollow. These sites were evaluated in February – March 2021.

Hellroaring Springs

The Hellroaring Springs site (5.2 ha) is in the Willow Springs Ranger District in Douglas County. The transect line is 685 m long and points are spread 10.2 m apart along a north facing slope (Figure 8). Six soil series compose the Hellroaring Spring site. The Scholten-Tonti Complex (3–8% slope) compose the ridge on the eastern side of the site. The hillslopes are composed of the Gatewood-Moko Complex (3-15% slope), the Poynor Extremely Gravelly Silt Loam (8-15% slope), and the Coulstone-Bender Complex (15-50% slope). Two soil series create interfluves on the site, the Tonti Silt Loam (1-3% slope) and the Mano-Ocie Complex (1-8% slope).

Huckleberry Ridge

The Huckleberry Ridge site (9.7 ha) is in the Cassville Ranger District in Barry County. The transect line is 1,858 m long and points are spread 27.7 m apart along a ridgetop that is oriented North to South (Figure 9). Three soil series compose the Huckleberry Ridge site, all are very to extremely gravelly silt loams. The Clarksville-Noark complex (3-15% slope) creates the ridge crest, while the Rueter-Hailey (35-60% slope) and Hailey-Nixa (3-15% slope) Complexes compose the back and side slopes.

Garner Hollow

The Garner Hollow site (7.2 ha) is in the Cassville Ranger District in Barry County. The transect line is 1,464 m long and points are spread 22 m apart along a ridge and southern facing hillslope

(Figure 10). Two soil series compose the Garner Hollow site, both are very to extremely gravelly silt loams. The Rueter-Hailey Complex (35-60% slope) and Hailey-Nixa Complex (3-15% slope) both compose back and side slopes at the site.

Site Description (Year 4)

One additional site, Tabor Cave, was added by the Forest Service for evaluation in Year 4 (2021-2022). This site was added since Huckleberry Ridge was not harvested after the pre-activity assessment was conducted in Year 3. This site was evaluated in February of 2022.

Tabor Cave

The Tabor Cave site (16.6 ha) is in the Willow Springs Ranger District in Howell County. The transect line is 1,911 m long and sample points are spread 28.1 m apart along a ridgetop oriented East to West (Figure 11). There are three soil series mapped within the Tabor Cave site. The Scholten-Poynor complex (8-15% slopes) is found along the ridgetop, the Coulstone-Bender-Gatewood complex (15-60% slopes) down the hillslope, and the Topazmill loam (3-8% slopes) along the footslopes near the west boundary of the site.

Pre-Activity Evaluation (2018-2019)

Five pre-activity sites were assessed between April 5th and September 27th, 2018, and Monterey was assessed on December 16, 2019. The results of the pre-activity assessment are given below.

Fox Hollow

The Fox Hollow site had signs of storm damage with several trees laying on the ground either by snapping near the base or from tree throw. Forest floor depth ranged from 0.0-6.0 cm and averaged 3.0 cm (Table 2). There was a relatively high number of sampling points (6%) with bare ground noted within the sampling ring compared to the other sites evaluated. Also, there was a number of trees that were laying on the ground from storm damage at this site, but the amount of coarse and fine woody debris observed was less than at Sterling Hollow (Photo 8 and 9). Overall, the Fox Hollow site was given a soil disturbance class of "0" for no impact observed using the FSDMP protocol.

Monterey

There was evidence of past disturbance at the Monterey site, but overall the site was classified as undisturbed. There were signs of recent prescribed fire in the area with charred pieces of woody debris present across the site. However, the forest floor depth still ranged from 1.0-8.0 cm and averaged 4.0 cm at this site (Table 2). The Monterey site also had the highest number of live plants of all sites (35% of the sampling points). A sampling point did land on an ATV trail

and one shallow rut point was recorded, however, there was no evidence of compaction or platy structure (Photo 10). Overall, the Monterey site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Sterling Hollow

The Sterling Hollow site was rocky with forest floor depths ranging from 0.05-6.0 cm with an average of 3.0 cm (Table 2). Around 20% of the sampling points had coarse and fine woody debris identified within the sampling ring, as there was evidence of storm damage that toppled several trees within the site. Additionally, around 6% of sampling points had at least some bare ground within the sampling ring. Overall, the Sterling Hollow site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Swayback

The soils within the Swayback site were less rocky than the other sites that could make the unit more susceptible to disturbance impacts during timber harvest due to lower substrate support compared to the rockier sites. Forest floor depth was 0.5-3.0 cm and averaged 2.0 cm (Table 2). This site had the lowest occurrences of live plants, woody debris, and bare soil among the six evaluated. While there were some pits that contained a few rocks within the upper profile, the majority of the pits evaluated at this site had a relatively thick layer of rock-free loess. This rock-free loess material may be more susceptible to compaction during timber harvest as compared to the rocky soils at the other sites. Overall, the Swayback site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Warthog

There were no disturbance indicators recorded at this site using the FSDMP protocol. The forest floor depth at this site ranged from 1.0-12 cm and averaged 4.9 cm (Table 2). The site was fairly rocky with almost a quarter of the sampling points having a rock identified on the surface (Photos 11 and 12). There was an old road along the top of the ridge, but our preselected site locations did not fall on the road. An intermittent stream was also noted during the assessment (Photo 13). Overall, the Warthog site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Wild Coyote

Similar to the Swayback Site, the Wild Coyote site was less rocky than the other sites, which could make the unit more susceptible to disturbance impact during timber harvest. Forest floor depth was 0.5-3.0 cm and averaged 2.0 cm (Table 2). About 10% of the pits evaluated at this site had live plants and 6% had fine woody debris. There was no coarse woody, bare earth, or rock observed at the surface of any of the pit locations at this site. In addition, pits evaluated at

this site had a relatively thick layer of rock-free loess in the upper part of the soil profile (Photos 14 and 15). As with the Swayback site, this material may be more susceptible to compaction during timber harvest as compared to the rocky soils at the other sites. Overall, the Wild Coyote site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Pre-Activity Evaluation (2021)

Hellroaring Springs

There were no disturbance indicators recorded at this site using the FSDMP protocol. Forest floor depth ranged from 4 to 10 cm and averaged 5 cm (Table 2). About 74% of the evaluated pits had live plants, 100% had fine woody debris, and 18% had coarse woody debris. Bare earth and rock were not observed at this site. Gravel content within the pits tended to increase with location downslope. Overall, the Hellroaring Springs site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Huckleberry Ridge

The majority of this site was undisturbed with the exception of an existing road that runs along the ridge. Forest floor depth ranged from 1 to 15 cm with an average of 7 cm (Table 2). About 85% of the evaluated pits had live plants, 91% had fine woody debris, and 21% had coarse woody debris. Soils were extremely gravelly, especially within the Rueter-Hailey complex along the northern portion of the payment unit. Shallow rutting (<5 cm) and shallow compaction (0-10 cm) were observed within one pit, where the sample point was located on an existing dirt road, running along the length of the ridge. Overall, the Hellroaring Springs site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Garner Hollow

There were no disturbance indicators recorded at this site using the FSDMP protocol. Forest floor depth ranged from 1 to 10 cm and averaged 6.3 cm (Table 2). All of the evaluated pits had live plants present, 91% had fine woody debris, and 35% had coarse woody debris. Bare earth and rock were not observed in the sample pits. Soils contained large amounts of gravel and had a clayey subsoil. The Garner Hollow site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Pre-Activity Evaluation (2022)

Tabor Cave

There were no disturbance indicators recorded at this site using the FSDMP protocol. However, there is an existing forest service trail extending northwest from the end of the main access road (center of the site) downslope towards Tabor Creek. Forest floor depth ranged from 2 to 8 cm and averaged at 4.1 cm (Table 2). Live plants were present at 91% of the sample pits. Fine woody debris was present at 97% of sample pits and coarse woody debris was present at 26% of the sample pits (Table 2). Bare earth and rock were not observed at the sample points. Soils contained large amounts of gravel especially on hillslopes. Overall, the Tabor Cave site was given a soil disturbance class of “0” for no impact observed using the FSDMP protocol.

Post-Activity Evaluation I (<1-year from harvest)

The six pre-activity sites were reassessed between November 14th and December 16th, 2019, after harvest activities were completed for five of the six sites. The exception was the Monterey site that was not harvested as of December 16, 2019. However, the site was still reevaluated. For the remaining five sites, the post-activity assessments occurred 3-12 months after harvest was completed. Results of the post-activity assessment are given below.

Fox Hollow

The most disturbance identified during the post-activity assessment was found at the Fox Hollow payment unit that was mostly due to the amount of compaction observed at the site. The post-activity assessment was conducted about 2 months after harvest on November 14, 2019. The average forest floor depth was similar during both assessment periods, while the number of sample points with live plants and woody debris was significantly higher during the post-activity assessment (Table 3). The increase in woody debris in the post-activity assessment is likely due to the amount of slash being left on the ground post-harvest. The amount of disturbance observed at the site ranged from shallow rutting with little forest floor impact, to large ruts with no forest floor and significant compaction in the upper 30 cm of the soil profile (Photos 16 and 17). Of the 52 points sampled, 10 were in disturbance class “1”, 3 in disturbance class “2”, and 1 in disturbance class “3” (Table 4).

The amount of disturbance observed at this site is at least somewhat influenced by the size and shape of the payment unit. Fox Hollow is the largest site evaluated and it's situated along a ridge in a “horseshoe” around a small stream valley. The main haul road is relatively long as it is situated generally along the crest of the ridgeline. Therefore, it is likely this road also had to be traversed multiple times to move all of the harvested timber off the site. This suggests the

size of the site, and perhaps the shape of the site, can impact the amount of disturbance observed within a payment unit.

Monterey

The initial post activity evaluation for Monterey was conducted on December 16, 2020. Forest floor depth ranged from 0 – 8 cm and averaged at 2.6 cm (Table 3). Live plants, coarse, and fine woody debris presence in the sample points increased from the previous post-activity harvest in 2019. Rock presence in the observed sample points decreased while the presence of bare soil increased. Rutting was observed in 47% of the observed sample points and compaction was observed in 21%. The increase in rutting and compaction can be explained because at the time of the previous post-activity evaluation the site had not yet been harvested. Of the 53 sample points, 27 were class “0”, 12 were class “1”, 14 were class “2”, and 0 were class “3” (Table 4).

Sterling Hollow

The post-activity assessment at Sterling Hollow showed only light disturbance that was likely due to the main haul road being located outside the payment unit boundary. The post-activity assessment was conducted about 2.5 months after harvest on December 11, 2019.

Average forest floor depths were 3.0 cm during both assessment periods, while the number of live plants, woody debris, and rock at the surface was higher in the post-activity assessment (Table 3). The increase in woody debris in the post-activity assessment is likely due to the amount of slash being left on the ground post-harvest (Photo 18). There was some evidence of light disturbance with shallow rutting observed in 3 of the 30 sampling points, but they were all within the disturbance class “1”. However, it was noted that the main haul road was not located within the payment unit. Generally, the most disturbance observed at a site is typically along the main haul road.

Swayback

Swayback is one of the more disturbed sites evaluated during the post-harvest activity period, despite being one of the smaller sites. The post-activity assessment was conducted about 7 months after harvest on December 5, 2019. Average forest floor depths were 2.0 cm during both assessment periods, while the number of live plants, woody debris, rock, and bare soil at the surface was significantly higher in the post-activity assessment (Table 3). A total of 60 sampling points were evaluated at this site, with 14 being classified as disturbance class “1” or “2” (Table 3). There was evidence of rutting observed in 33% of the sampling points, but compaction was only detected at 6.7% of the sampling points. While this site is relatively small, the main haul road was within the payment unit and the most disturbance observed at a site is typically along the main haul road (Photo 19).

Warthog

This site was slightly disturbed according to the protocol, however there was considerable disturbance noted along the major haul road at the top of the ridge and a large amount of slash left on the site. The post-disturbance evaluation was performed on December 16, 2019, which was about one year after harvest on December 28, 2018 (Figure 1). The average forest floor depth at this site during the post-activity assessment was 5.4 cm, which was similar to the pre-activity average forest floor depth (Table 3). There were more live plants, woody debris and less rock at the surface noted in the post-activity assessment. Some of this is because of the large amount of slash left on the site, but it may also be due to the interpretation of how a sample point is evaluated (Photo 20). The site was very rocky in the upper 10 cm of the majority of the pits to be colluvial that was also noted in the pre-harvest assessment (Photos 21). There was an old road along the top of the ridge that was noted in the pre-activity assessment, but the preselected site locations did not fall on the road during either assessment period. This road appears to have been used as the major haul road for the site where rutting, soil erosion, and soil displacement were observed off the transect line (Photo 22).

Wild Coyote

Wild Coyote was very similar to the Sterling Hollow site where there was very little post-harvest disturbance observed within the payment unit. The post-activity assessment was conducted about 3 months after harvest on December 11, 2019. Average forest floor depths were 2.0 cm during both assessment periods, while the number of live plants, woody debris, and bare soil at the surface was higher in the post-activity assessment (Table 3). There was some evidence of light disturbance with shallow rutting observed in only 2 of the 34 sampling points, but they were all within the disturbance class "1" (Table 4). However, the main haul road was not located within the payment unit. Generally, the most disturbance observed at a sight is typically along the main haul road. Additionally, the number of trees harvested per acre appeared low at this site compared to the other sites that may be reason so little disturbance was noted.

Hellroaring Springs

The post activity I survey was conducted about 3 months after harvest on November 9, 2021. Average forest floor depth decreased from the pre-harvest survey to 4 cm (Table 3). Coarse and fine wood presence at the sample points increased, with fine wood present at 100% of the sample points and coarse wood present at 48.6% of the points. Rutting was observed in 7 of the sample points and compaction was observed in 3. Bare soil was also observed in 2 of sample points. Overall, 30 sample points were class "0" for minimal to no disturbance, 4 points were class "1" where rutting was observed, and 3 points were class "2" where the soil O horizon was

displaced (Table 4). Compaction was generally shallow with no points compacted over 30 cm. Post-harvest disturbance was minimal at this site.

Garner Hollow

The post-harvest survey was conducted on November 30, 2021. While we were unable to confirm the exact date, the assessment likely took place immediately after the site was harvested. Average forest floor depth decreased from the pre-harvest survey to 4.6 cm (Table 3). Live plants were found at 73.8% of sample points, decreasing from the pre-harvest survey. Fine wood was present at 97.6% of the points. Coarse wood was present at 42.9% of points. Rutting was observed at 9 points (21.4%) and compaction was observed at 3 points (7.1%). Of the 42 observed sample points, 33 were class “0”, 4 were class “1”, 5 were class “2” and none of the points were class “3” (Table 4). Disturbance was mainly focused along the main haul road, FR1006, otherwise disturbance was minimal.

Post-Activity Evaluation II (>1-year from harvest)

Post activity evaluation II surveys for Fox Hollow, Sterling Hollow, Swayback, Warthog, and Wild Coyote were conducted in November and December of 2020, approximately one year after the initial post-harvest activity evaluation in 2019 and >1-year after harvest.

Fox Hollow

The post-activity evaluation II for Fox Hollow was conducted on November 5, 2020. The average forest floor depth was 2.4 cm and was similar to the last post-activity assessment I (Table 5, Figure 12). Live plants, coarse, and fine woody debris presence in the sample points all increased from the previous survey. However, between the two assessments a storm caused considerable damage toppling many of the standing trees in the payment unit. There was a reduction in the number of sample points that had rock, bare soil, and compaction between post-activity assessment I and II. There was an increase in the amount of rutting observed at the site, but it appears there were firewood cutters that came through the unit after the storm. Of the 40 sample points, 29 were disturbance class “0”, 5 were disturbance class “1”, 5 were disturbance class “2”, and 1 was disturbance class “3” (Table 6).

Sterling Hollow

The post activity evaluation II for Sterling Hollow was conducted on November 12, 2020. Forest floor depth averaged at 3.2 cm and has been consistent since prior to harvest (Table 5, Figure 12). The number of sample points with live plants has increased during both post-activity assessments while the amount with coarse and fine wood has remained consistent after harvest. No rock or bare soil was observed in the sample points in the post-activity II evaluation, but there were only a few observations during the previous assessments. Shallow

rutting and compaction increased slightly from the post-activity I evaluation but is only about 10% different suggesting some variability between evaluators point locations. Of the 40 sample points, 33 were class “0”, 5 were class “1”, 2 were class “2”, and 0 were class “3” (Table 6).

Swayback

The post-activity evaluation II for Swayback was conducted on December 15, 2020. Average forest floor depth was 2.3 cm and has been similar during all evaluation periods (Table 5, Figure 12). Live plants presence in the observed sample points increased slightly from the post-activity I evaluation, but coarse and fine woody debris observed at sample points was similar. There was also a lower number of sample points with rock, bare soil, rutting, and compaction compared to the previous assessment. This may indicate that the forest floor is recovering from the timber harvest. Of the 34 observed sample points, 29 were class “0”, 3 were class “1”, 2 were class “2” and 0 were class “3” (Table 6). Most of the disturbance was located along the main haul road. Also, at the time of the assessment Timber Stand Improvement (TSI) had just been performed at the site.

Warthog

The post activity evaluation II for Warthog was conducted on December 15, 2020. The forest floor depth decreased considerably from the post-activity I assessment going from around 5 cm to 2.3 cm (Table 5, Figure 12). There was an increase in the presence of live plants, while there was a decrease in the presence of coarse and slight decrease in fine woody debris. The amount of rock observed at the surface was lower than previous assessments and the number of sample points with bare soil was similar. There was also a reduction in the amount of rutting and compaction observed at the site. This is an indication the forest floor is recovering from the timber harvest. Of the 34 observed sample points, 32 were class “0”, 2 were class “2”, and 0 were class “3” or “4” (Table 6).

Wild Coyote

The post activity evaluation II for Wild Coyote was conducted on December 16, 2020. Average forest floor depth was 3.5 cm, which is a 1.5 cm increase from the previous evaluations (Table 5, Figure 12). The number of live plants and the amount of fine wood increased compared to the previous assessment, while observations of coarse wood decreased. No rock or compaction was observed at this site, which has been the case with previous assessments. The amount of shallow rutting and base soil has decreased slightly since the previous assessment. This may indicate that the forest floor is recovering from timber harvesting activities. Of the 34 observed sample points, 31 were classified as disturbance class “0”, and 3 were disturbance class “1”, no points were classified as “2” or “3” (Table 6).

Monterey

The post-activity evaluation II for Monterey was conducted on December 22, 2021. Average forest floor depth was 1.6 cm, a decrease from the previous post activity survey (Table 5). However, there was evidence of prescribed burning throughout the site that may account for the reduction. Live plants presence increased from the previous survey to 88%. Coarse woody debris and fine woody presence remained similar to the previous post-harvest survey. The presence of rutting and compaction also decreased from the previous survey to 12% and 6% of the sample points. Of the 34 observed sample points, 30 were class “0”, with minimal disturbance, 2 were class “1”, and 2 were class “2” (Table 6). The decrease in disturbance indicators (rutting and compaction), may indicate that the forest floor is recovering from timber harvesting activities.

Post Activity Evaluation III (>2-years from harvest)

Fox Hollow

The post-activity III survey for Fox Hollow was conducted on November 4, 2021, two years after the initial harvest date (Table 6). Average floor depth was 2.8 cm, remaining similar to the previous survey. Live plants were present at 94.6% of the sample points, an increase from the previous post-harvest survey. Coarse woody debris and fine woody debris presence at sample points remained similar to the previous survey at 43.2% and 91.9%. Rutting and compaction presence at the sample points decreased to 8.1% from 27.5% and 10% respectively. This may indicate that the forest floor is recovering from the timber harvest. Of the 37 observed sample points, 34 were disturbance class “0”, none were class “1”, 3 were class “2”, and none were class “3” (Table 7).

Sterling Hollow

The post-activity III evaluation for Sterling Hollow was conducted on October 26, 2021. Average forest floor depth was 3.1 cm, remaining the same as the previous survey (Table 6). Live plants were present at 97.1% of the sample points, increasing from the previous survey. Coarse and fine woody debris presence at the sample points remained the same as the previous survey at 61.8% and 97.1% respectively. Rutting and compaction were not observed at the sample points during the post-activity III evaluation. In the post-activity II evaluation 8 sample points had rutting and 3 points were compacted. All 34 of the observed sample points during the post-activity III evaluation were in disturbance class “0” (Table 7). Therefore, this site appears to have recovered to pre-activity conditions three years after harvest.

Swayback

Swayback's post-activity evaluation III was conducted on December 21, 2021 (Table 6). Average forest floor depth was 2.3 cm remaining the same as the post-activity II evaluation. Live plants increased from 76.5% of the sampling points in the previous survey, to 100%. Fine woody debris presence (76.5%) remained similar to the previous survey. Coarse woody debris was observed at less sample points (35.3%) than the post-activity II evaluation. Rutting was observed at 1 sample point and compaction was observed at 2 sample points, decreasing from the previous survey. Of the 34 observed sample points, 33 were disturbance class "0" and 1 sample point was class "1", no points were disturbance class "2" or "3" (Table 7).

Warthog

The post-activity III evaluation for Warthog was conducted on December 22, 2021 (Table 6). Average floor depth remained similar to the post-activity II evaluation (2.9 cm). Live plants were observed at all the sample points (increasing from the previous evaluation). Coarse and fine woody debris presence was similar to the previous survey at 55.9% and 97.1% of the sample points respectively. Rutting was observed at 5.9% (2) of sample points, the same as the previous survey. Compaction was observed in 8.8% (3) of points, an increase from the previous evaluation. The increase in compaction is the result of variability in GPS locations when returning to a site, which are likely around 1-2 m depending on satellite alignment, terrain, and overhead canopy cover. Soils can be compacted at an area of rutting and unaffected less than 1 m away. However, disturbance was minimal at this site. Of the 34 observed sample points, 32 were disturbance class "0", 2 were class "1", and no points were in disturbance class "2" or "3" (Table 7).

Wild Coyote

Wild Coyote was evaluated for the post-activity III survey on December 21, 2021 (Table 6). Average forest floor depth (2.7 cm) was similar to the previous survey. Live plant presence increased by over 70% since the previous survey with live plants observed in 97.1% of the sampling points. Coarse woody debris and fine woody debris were observed in 32.4% and 100% of the sample points, a slight increase in both categories from the previous survey. Rutting was observed at 1 sample point and compaction was observed in 2 sample points. Compared to the post-activity II survey rutting decreased. However, compaction which was not observed in the post-activity II evaluation, was observed in 2 points in the post-activity III survey. Again, this is likely due to GPS variability during the evaluation period. Still, disturbance was minimal at this site. Of the 34 observed sample points, 33 were disturbance class "0", 1 point was class "1", none of the observed sample points were in disturbance classes "2" or "3" (Table 7).

OBSERVATIONS AND RECOMMENDATIONS

Pre-Activity Assessment

Overall the FSDMP protocol was easy to understand and implement for the pre-activity portion of this project. Sampling bias and errors associated with in-the-field judgements during point selection were likely reduced by pre-determining sampling locations and using objective GPS locations to locate sampling points. Additionally, using georeferenced photos at each sampling point to log the conditions at the time of the assessment is a good way to catalog temporal changes at each site. Furthermore, this allows other Forest Service personnel not present at the time of the assessment to visualize the site conditions. However, the applicability of the protocol cannot be fully evaluated until the post-activity assessment is completed.

Digging a 15-30 cm pit at each sampling point adds significantly more time to the overall assessment process. Perhaps it would be more efficient to only dig pits where there is an indicator of disturbance. Within the protocol the evaluator looks for indicators of disturbance such as skid trails, ruts, and other signs of activity. Therefore, an excavated pit may not be needed if the sample point does not show an indication of disturbance. Limiting pit sampling to disturbed points would allow more sites to be included in the program or more sampling points to be assessed at a site with improved confidence.

Another drawback is that sometimes the points do not land on a disturbance indicator, such as a road, which has been observed by the evaluator. Such conditions could necessitate additional pits to be evaluated that are effected by the disturbance. Therefore, if the predetermined points do not land on a disturbance indicator, additional pits should be added, and the soil evaluated in these areas. Furthermore, it may also be beneficial to identify sensitive areas that are found within the unit, such as streams, and use photos to document any changes that may occur post-harvest. Possibly, adding a site mapping component to the assessment which locates pre-activity disturbance areas (i.e., roads) or excluded areas from sampling (i.e., streams) may help to focus sampling to better evaluate recent activity effects while maintaining sampling confidence requirements.

Post-Activity I Assessment

There are five main observations and/or recommendations after the post-activity assessment period conducted in the fall of 2019:

1. Assessments were conducted in the late fall during leaf-off conditions. Leaf-off conditions allow evaluators more visibility to be able to access forest conditions more effectively. Another aspect of performing the FSDMP during this part of the year is that the antecedent

soil moisture conditions are relatively wet at undisturbed sites. This actually helps the evaluator detect compacted soils that will often be hard and dry since they do not allow water to infiltrate. In contrast, antecedent soil moisture conditions during the summer are relatively dry and soils naturally can be dry and hard therefore making it more difficult to identify compaction in those conditions.

2. Size of the payment unit may have an influence on the amount of disturbance found in the payment unit. For two of the three sites less than 10 ha, the main haul road was located outside the unit perimeter. As a result, very little disturbance was detected at these two sites. Additionally, if the site is very large, like Fox Hollow, the main haul road tends to be longer and likely must be used more to pull the larger number of logs off the site thereby increasing the amount of disturbance. The type of equipment used to harvest logs and the number of trees removed per acre can also influence the amount of disturbance identified at these sites. These factors should be explored further.
3. The presence of the “O” horizon, or “duff” layer on the surface was a key indicator of the severity of disturbance at each sampling point for sites evaluated for this project. Generally, if the surface “O” horizon is missing, the soils at that sampling point show at least some degree of disturbance (Photo 23). However, if the “O” horizon remains intact, despite evidence of shallow rutting, the soil typically shows little or no signs of compaction (Photo 24).
4. High rock content in the surface layers may negate some of the compaction observed in less rocky soils. The amount of rock, and the size of the rock fragments, in the soil profile can make detecting compaction difficult. Just digging a 30 cm pit in very rocky soils can distort the soil profile. However, less disturbance was detected in the soil profile at sites selected for this project with high rock content despite having surficial evidence of disturbance.
5. A preliminary flow chart was developed to help describe the typical disturbance conditions that were observed at each site and how the disturbance classes were assigned for this project (Figure 13). This chart reflects the observations made at the six sites evaluated for this project and can be revised as needed. The first thing is to determine if there is evidence of rutting, or if machinery has moved over the area. If there was no evidence of rutting, the sample point was designated as disturbance class 0. The next step was to determine if the “O” horizon was still present. If “O” horizon was present and there was surficial evidence of rutting, generally there was little to no compaction, and the sampling point was designated as disturbance class 1. If there was no “O” horizon present and compaction was identified in the soil profile to a depth of <30 cm the sample point was

designated as disturbance class 2. Finally, if there was no “O” horizon present and compaction was identified in the soil profile to a depth of >30 cm, the sample point was designated as disturbance class 3.

Post-Activity II Assessment

There are three main observations after the pre- and post-activity assessments conducted in 2020-2021:

1. Three new, pre-activity sites were evaluated with no disturbance detected within the payment unit. This brings the total number of sites evaluated for this project to nine across southern Missouri.
2. Post-harvest activities such as TSI, storm damage, and firewood gathering can influence the outcome of the protocol by increasing the observed disturbances within a pay unit. This is especially true at Fox Hollow, where there were signs of disturbance that were due to storm damage that occurred at the site. However, these post-harvest activities are not associated with timber harvest but may prolong the recovery period at this location.
3. Significant forest floor recovery was observed in three of the five sites evaluated for this project with greater than one-year of recovery time since timber harvest activities. Sites at Warthog, Swayback, and Wild Coyote all had less observed rutting and compaction compared to the previous post-activity evaluation.

Post-Activity III Assessment

There are three main observations after the pre- and post- activity evaluations conducted in 2021-2022.

1. One new pre-activity site, Tabor Cave, was added with no disturbance indicators detected within the payment unit. This site was added since the Huckleberry Ridge unit had not been harvested since the pre-activity assessment. This brings the total number of evaluated sites to ten across southern Missouri.
2. Significant forest floor recovery was observed at all five of the post-activity III survey sites. Of the 173 observed sample points (across the five sites), 4 points were disturbance class “1” and 3 were disturbance class “2”. All points at Sterling Hollow were disturbance class “0”, and less than two points were disturbance class “1” at each of the following sites Wild Coyote, Warthog, and Swayback, with all other sample points’ class “0”.

3. After 2-years post-harvest, forest floor disturbance becomes greatly reduced. Areas that were not disturbed in the post-activity I evaluation remain undisturbed in the following post-activity II and III evaluations. The main haul roads and landings are the only areas with disturbance indicators remaining. Delineating and re-evaluating these areas may be more beneficial in understanding timber harvest activities on the forest floor than re-evaluating undisturbed sample points.

CONCLUSIONS

Year 1

OEWRI implemented the USFS FSDMP at six pre-harvest activity payment units within the MTNF in southern Missouri. For this protocol, sampling locations were determined using a systematic, spatially-scaled, “zig-zag” transect method with a total of 68 equally spaced pit locations created in ArcGIS prior to going into the field. Transect length and the pit spacing were based on the size of the payment unit that ranged from 5.8-38.6 ha for the six sites evaluated for this study. These data were uploaded to a GPS that was used to navigate to the pit locations in the field. At each site the ground surface was evaluated prior to digging a 15-30 cm pit to assess the soil for signs of compaction. Ultimately, none of the sites evaluated using this protocol were considered impacted prior to timber harvest or other disturbances. However, in some cases the predetermined sample pit locations did not land on disturbance indicators (like a road). Therefore, additional points may need to be collected in future assessments to more effectively evaluate observed disturbances that were under-sampled. Finally, this report addresses the results and observations of the pre-activity portion of the protocol and cannot be fully evaluated until the post-activity assessment is completed.

Year 2

OEWRI implemented the USFS FSDMP at six post-harvest activity payment units within the MTNF in southern Missouri in November and December of 2019 during leaf-off conditions. These sites were evaluated about 3-12 months after harvest activities had concluded. For the post-harvest activity monitoring period, the same 68 sampling locations identified in the pre-harvest activity evaluations performed in 2018 were used and reevaluated. Post-harvest activity results showed increases in the amount of woody debris, rutting, and compaction at the harvested sites. The severity of the disturbance appears to be due to several factors including the size of the payment unit, the presence of a main haul road within the payment unit, and the amount of rock content within the soil profile. A preliminary flowchart was developed to better understand the three specific disturbance indicators identified at these six sites and how these

indicators were used to assign disturbance class values. These disturbance indicators are: 1) the presence of rutting at the surface; 2) the presence of the “O” horizon at the surface; and 3) the depth of compaction in the soil profile. These indicators were identified as the most important for these six sites, however, these can be revised as needed.

Year 3

OEWRI implemented the USFS FSDMP at six post-activity and three pre-activity payment units within the MTNF in southern Missouri in 2020-2021 during leaf-off conditions. Sites at Swayback, Warthog, Sterling Hollow, Fox Hollow, and Wild Coyote were evaluated over 1-year since timber harvest activities had concluded. Significant forest floor recovery was observed in three of the five sites evaluated for this project with greater than one-year of recovery time since timber harvest activities. Sites at Warthog, Swayback, and Wild Coyote all had less observed rutting and compaction compared to the previous post-activity evaluation. Post-harvest activities such as TSI, storm damage, and firewood gathering can influence the outcome of the protocol by increasing the observed disturbances within a pay unit. This is especially true at Fox Hollow, where there were signs of disturbance that were due to storm damage that occurred at the site. However, these post-harvest activities are not associated with timber harvest but may prolong the recovery period at this location. The site at Monterey was evaluated less than one year since timber harvest activity. Sites at Huckleberry Ridge, Hellroaring Springs, and Garner Hollow were all pre-activity evaluations. The three new, pre-activity sites were evaluated with no disturbance detected within the payment unit.

Year 4

OEWRI implemented the USFS FSDMP at eight post-activity and one pre-activity payment units within the MTNF in southern Missouri in 2021-2022 during leaf-off conditions. Sites at Swayback, Warthog, Sterling Hollow, Fox Hollow, and Wild Coyote were evaluated over 2-years after timber harvest activities. Significant forest floor recovery was observed at all of these sites with only 7 of the evaluated points greater than disturbance class “0”. Generally, rutting and compaction decreased at these sites and at Monterey. At the two new post-activity I sites, Garner Hollow and Hellroaring Springs, disturbance indicators were mainly found along the main haul roads and otherwise disturbances across the sites were low. The pre-activity survey of Tabor Cave found no disturbance indicators present within the payment unit.

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TABLES

Table 1. Summary of sites evaluated for this project.

Site	MTNF District	County	Area (ha)	Pre-Activity Date	Harvest Date	Post-I Date	Post-II Date	Post-III Date
Fox Hollow	Ava/Cassville/Willow Springs	Douglas	38.6	Aug. 2, 2018	Sept. 9, 2019	Nov. 14, 2019	Nov. 5, 2020	Nov. 4, 2021
Monterey	Doniphan/Eleven Point	Oregon	27.8	Dec. 16, 2019	Dec. 9, 2020	Dec. 16, 2020	Dec. 22, 2021	NA
Sterling Hollow	Ava/Cassville/Willow Springs	Howell	7.9	July 31, 2018	Sept. 23, 2019	Dec. 11, 2019	Nov. 12, 2020	Oct. 26, 2021
Swayback	Poplar Bluff	Butler	5.8	Sept. 26, 2018	April 25, 2019	Dec. 5, 2019	Dec. 15, 2020	Dec. 21, 2021
Warthog	Doniphan/Eleven Point	Carter	22.3	April 5, 2018	Dec. 28, 2018	Dec. 16, 2018	Dec. 15, 2020	Dec. 22, 2021
Wild Coyote	Poplar Bluff	Wayne	6.4	Sept. 27, 2018	Aug. 20, 2019	Dec. 4, 2019	Dec. 16, 2020	Dec. 21, 2021
Hellroaring Spring	Ava/Cassville/Willow Springs	Douglas	5.2	Feb. 3, 2021	Aug. 16, 2021	Nov. 9, 2021	NA	NA
Huckleberry Ridge	Ava/Cassville/Willow Springs	Barry	9.7	March 4, 2021	NA	NA	NA	NA
Garner Hollow	Ava/Cassville/Willow Springs	Barry	7.2	March 24, 2021	Sept. 30, 2021	Nov. 30, 2021	NA	NA
Tabor Cave	Ava/Cassville/Willow Springs	Howell	16.6	Feb. 10, 2022	NA	NA	NA	NA

Table 2. Pre-Activity Forest Floor Depth and Percentage of Observations

Site	Avg. Forest Floor Depth (cm)	Pre-Activity Survey				
		Live Plants	Present in Sample Point Observations (%)		Rock	Bare Soil
			Coarse Woody Debris (>7 cm Dia.)	Fine Woody Debris (<7 cm Dia.)		
Fox Hollow	3.0	5.9	11.8	5.9	0.0	5.9
Monterey	4.0	35.3	5.9	5.9	17.6	0.0
Sterling Hollow	3.0	8.8	20.6	20.6	2.9	5.9
Swayback	2.0	2.9	0.0	2.9	2.9	0.0
Warthog	4.9	8.8	8.8	14.7	23.5	2.9
Wild Coyote	2.0	9.1	0.0	6.1	0.0	0.0
Hellroaring Springs	5.3	73.5	17.6	100	0.0	0.0
Huckleberry Ridge	7.1	85.3	20.6	91.2	0.0	0.0
Garner Hollow	6.3	100	35.3	91.2	0.0	0.0
Tabor Cave	4.1	91.2	26.5	97.1	0.0	0.0

Table 3. Initial Post-Activity Survey Results (<1-year since harvest).

Site	Avg. Forest Floor Depth (cm)	Present in Sample Point Observations (%)						
		Live Plants	Coarse Woody Debris (>7 cm Dia.)	Fine Woody Debris (<7 cm Dia.)	Rock	Bare Soil	Rutting	Compaction
Fox Hollow	2.5	26.9	34.6	76.9	1.9	5.8	15.4	17.3
Monterey	2.6	75.5	45.3	100	0.0	17.0	47.2	20.8
Sterling Hollow	3.0	26.5	61.8	97.1	11.8	2.9	8.8	0.0
Swayback	2.0	65.0	46.7	81.7	8.3	8.3	33.3	6.7
Warthog	5.4	37.5	57.5	100	5.0	2.5	17.5	2.5
Wild Coyote	2.0	20.6	44.1	47.1	0.0	5.9	8.8	0.0
Garner Hollow	4.6	73.8	42.9	97.6	0.0	0.0	21.4	7.1
Hellroaring Springs	4.0	100	48.6	100	0.0	5.4	18.9	8.1

Table 4. Number of Post-Activity I Sample Points Evaluated at each Site by Disturbance Class.

Site	Total	Class 0		Class 1		Class 2		Class 3	
Fox Hollow	52	38	73%	10	19%	3	6%	1	2%
Monterey	53	27	51%	12	23%	14	26%	0	0%
Sterling Hollow	34	31	91%	3	9%	0	0	0	0
Swayback	60	46	77%	10	17%	4	7%	0	0
Warthog	40	32	80%	8	20%	0	0	0	0
Wild Coyote	34	32	94%	2	6%	0	0	0	0
Garner Hollow	42	33	79%	4	10%	5	12%	0	0
Hellroaring Springs	37	30	81%	4	11%	3	8%	0	0

Table 5. Post-Activity II Survey Results (>1-year since harvest).

Site	Avg. Forest Floor Depth (cm)	Present in Sample Point Observations (%)						
		Live Plants	Coarse Woody Debris (>7 cm Dia.)	Fine Woody Debris (<7 cm Dia.)	Rock	Bare Soil	Rutting	Compaction
Fox Hollow	2.4	62.5	47.5	87.5	0.0	0.0	27.5	10.0
Sterling Hollow	3.2	82.5	62.5	97.5	0.0	0.0	20.0	7.5
Swayback	2.3	76.5	47.1	82.4	0.0	0.0	14.7	2.9
Warthog	2.3	70.6	41.2	97.1	0.0	2.9	5.9	0.0
Wild Coyote	3.5	23.5	14.7	88.2	0.0	0.0	5.9	0.0
Monterey	1.6	88.0	53.0	94.0	0.0	0.0	12.0	6.0

Table 6. Number of Post-Activity II Sample Points Evaluated at each Site by Disturbance Class.

Site	Total	Class 0		Class 1		Class 2		Class 3	
Fox Hollow	40	29	73%	5	13%	5	13%	1	3%
Sterling Hollow	40	33	83%	5	13%	2	5%	0	0%
Swayback	34	29	85%	3	9%	2	6%	0	0%
Warthog	34	32	94%	2	6%	0	0%	0	0%
Wild Coyote	34	31	91%	3	9%	0	0%	0	0%
Monterey	34	30	88%	2	6%	2	6%	0	0%

Table 6. Post-Activity III Survey Results (>2-years since harvest).

Site	Avg. Forest Floor Depth (cm)	Present in Sample Point Observations (%)						
		Live Plants	Coarse Woody Debris (>7 cm Dia.)	Fine Woody Debris (<7 cm Dia.)	Rock	Bare Soil	Rutting	Compaction
Fox Hollow	2.8	94.6	43.2	91.9	0.0	0.0	8.1	8.1
Sterling Hollow	3.1	97.1	61.8	97.1	0.0	0.0	0.0	0.0
Swayback	2.3	100	35.3	76.5	0.0	0.0	2.9	5.9
Warthog	2.9	100	55.9	97.1	26.5	0.0	5.9	8.8
Wild Coyote	2.7	97.1	32.4	100	5.9	0.0	2.9	5.9

Table 7. Number of Post-Activity III Sample Points Evaluated at each Site by Disturbance Class.

Site	Total	Class 0		Class 1		Class 2		Class 3	
Fox Hollow	37	34	92%	0	0%	3	8%	0	0%
Sterling Hollow	34	34	100%	0	0%	0	0%	0	0%
Swayback	34	33	97%	1	3%	0	0%	0	0%
Warthog	34	32	94%	2	6%	0	0%	0	0%
Wild Coyote	34	33	97%	1	3%	0	0%	0	0%

FIGURES

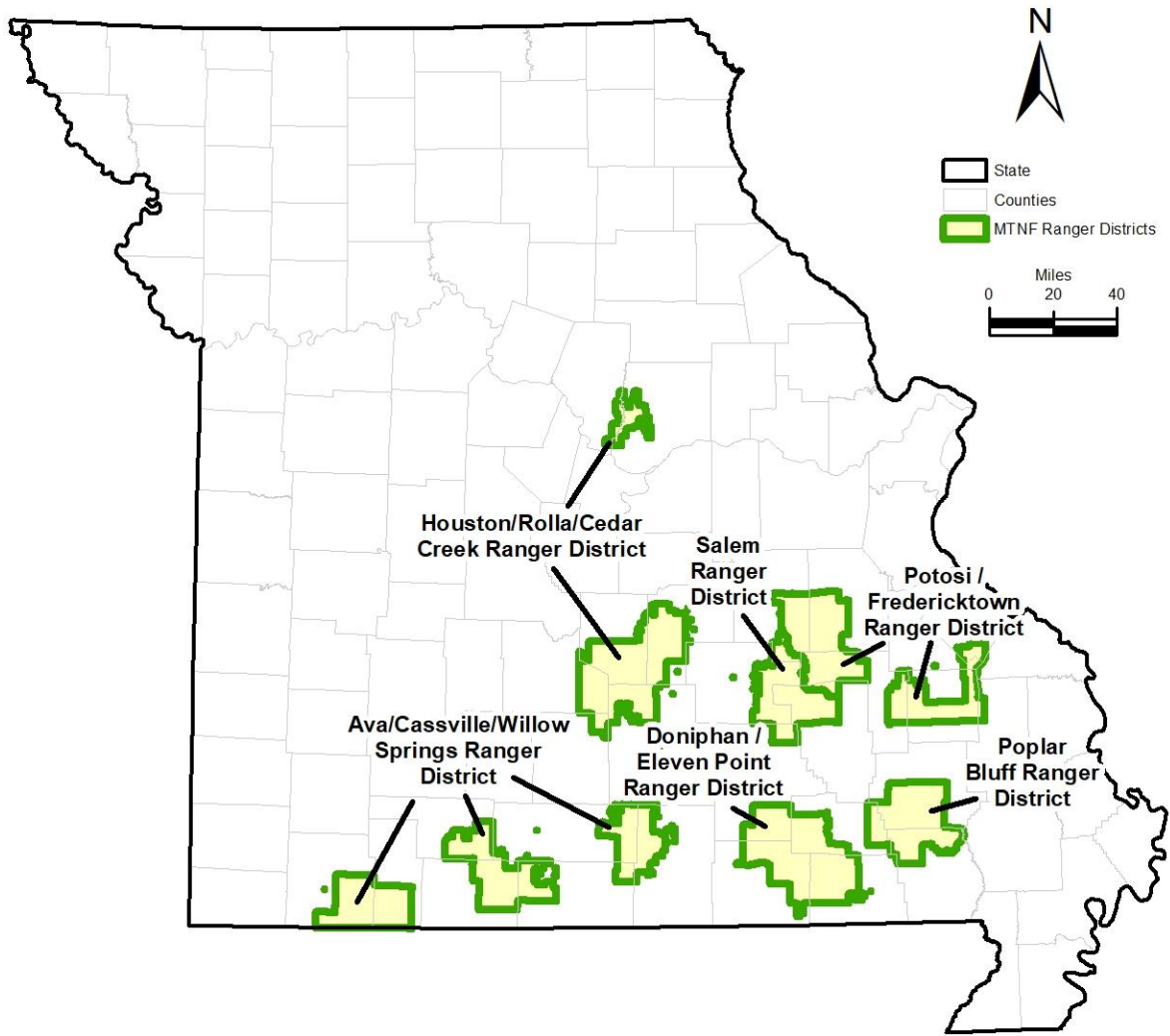


Figure 1. Mark Twain National Forest (MTNF) Ranger Districts in Southern Missouri.

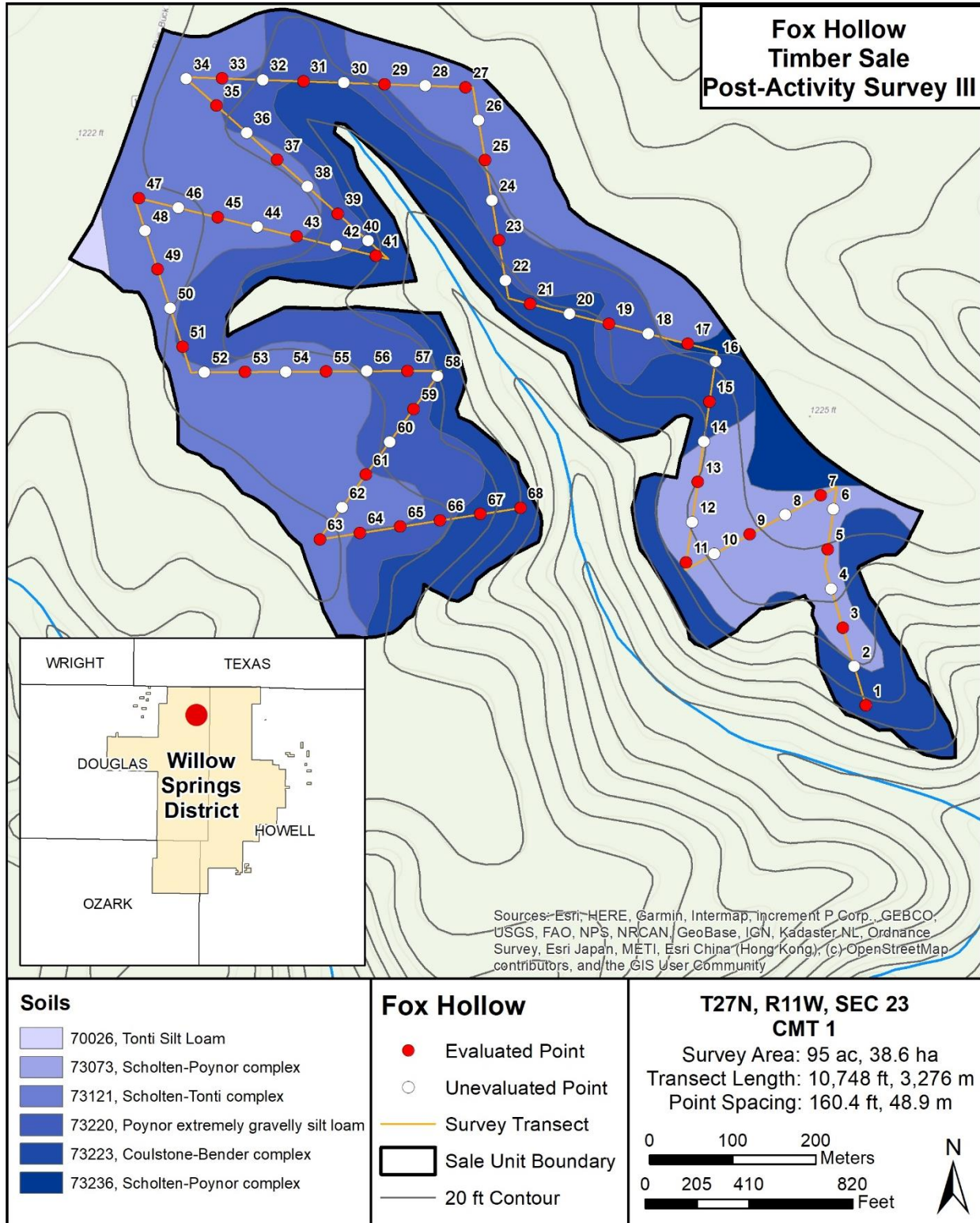


Figure 2. Fox Hollow Site Map.

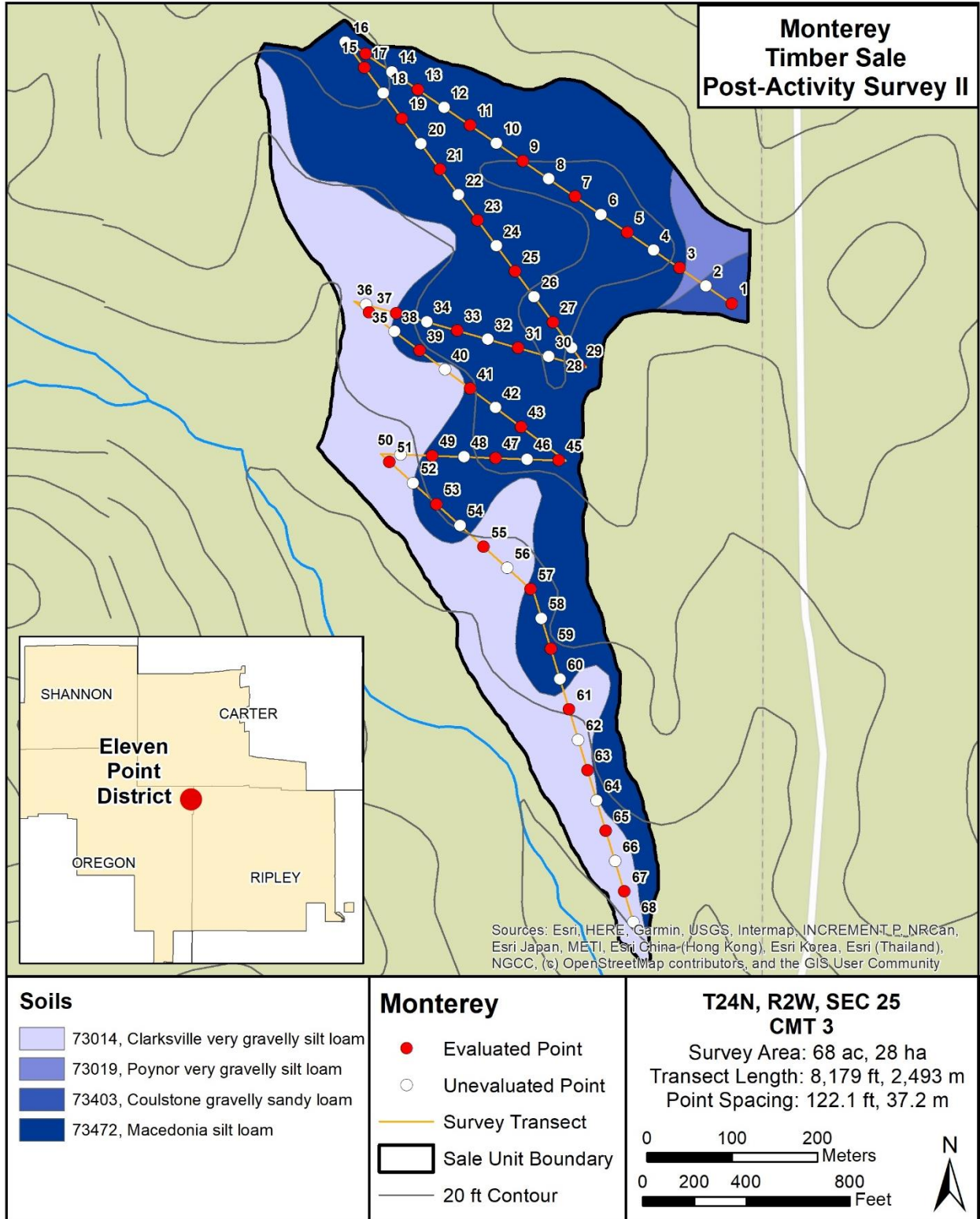


Figure 3. Monterey Site Map.

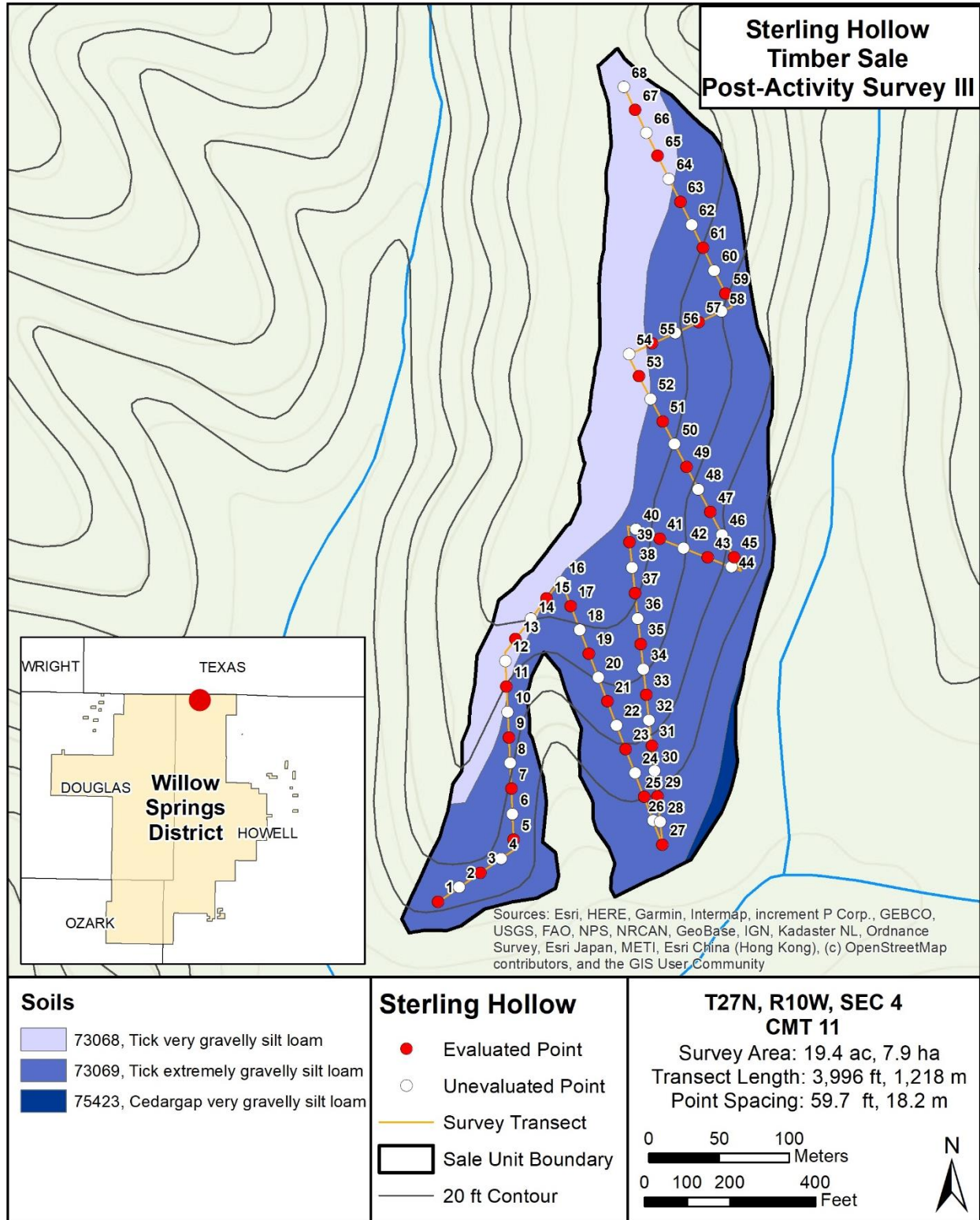


Figure 4. Sterling Hollow Site Map.

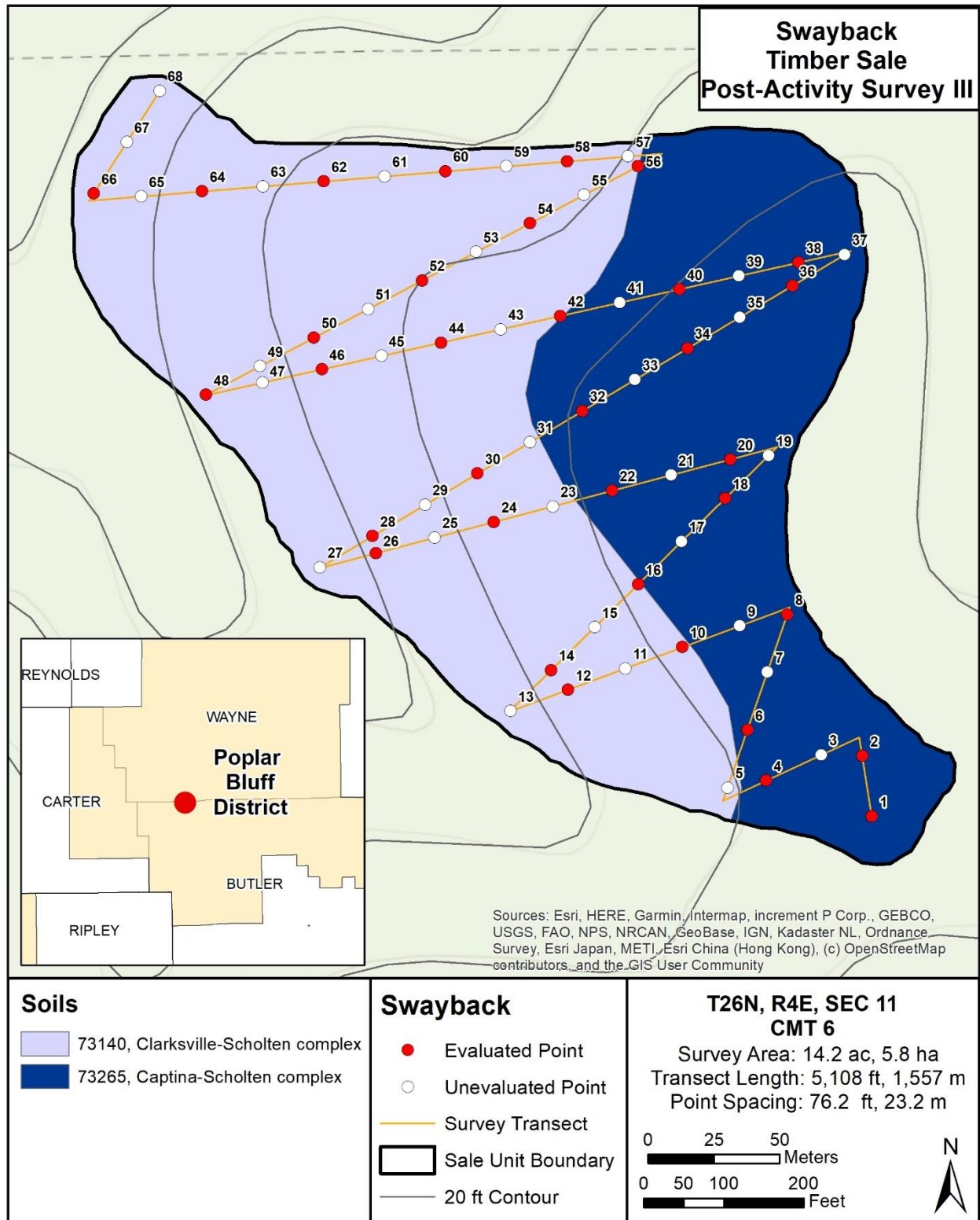


Figure 5. Swayback Site Map.

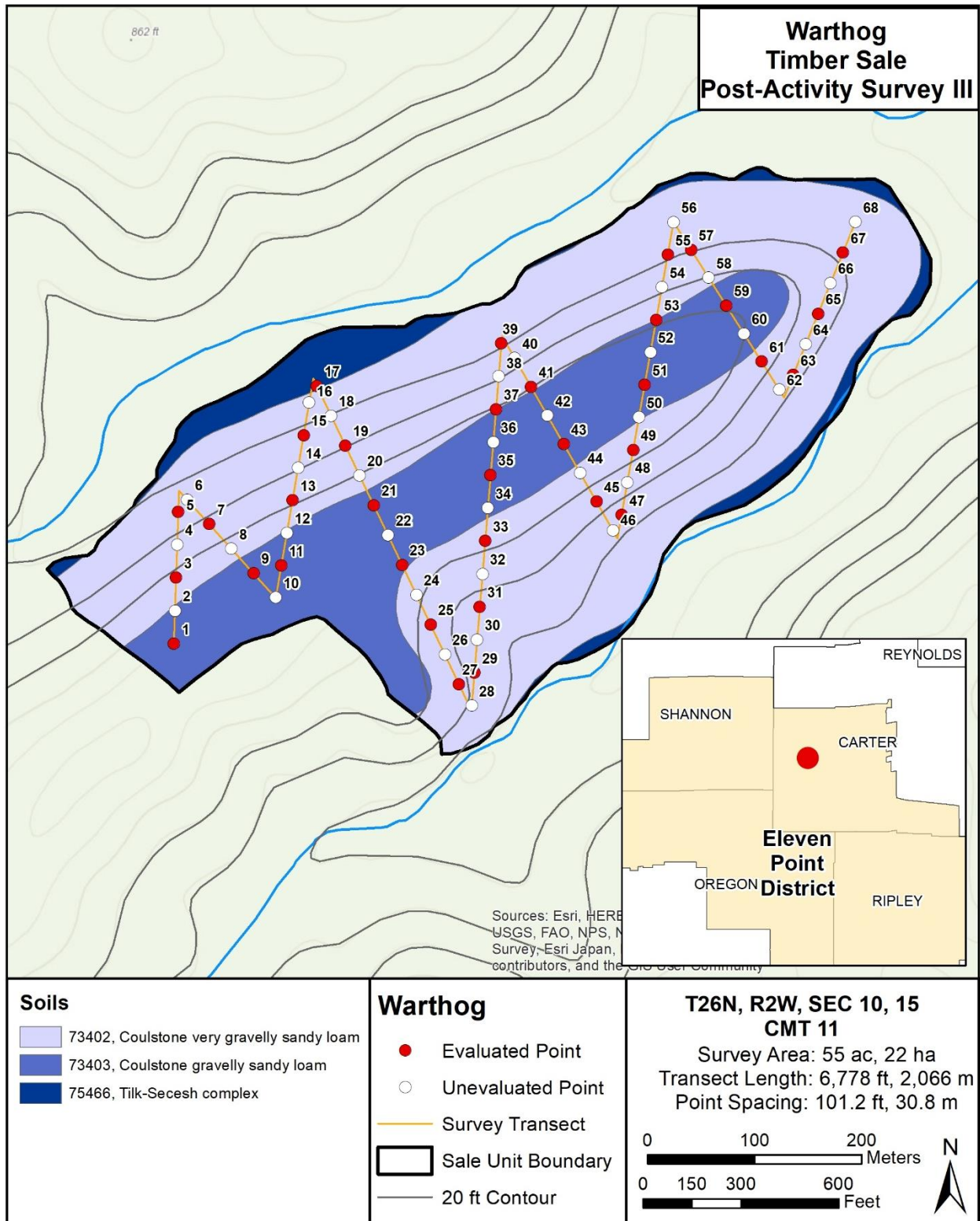


Figure 6. Warthog Site Map.

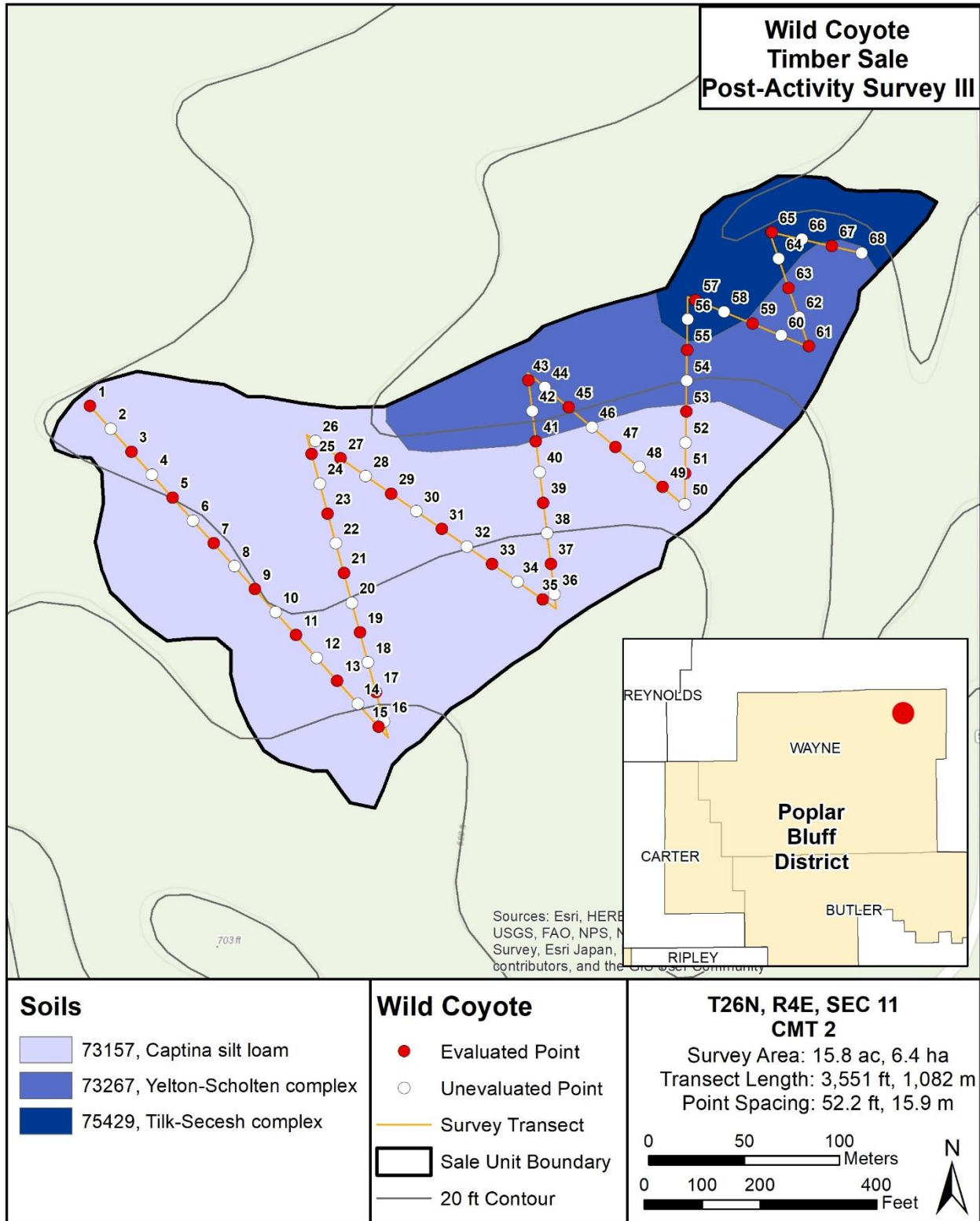


Figure 7. Wild Coyote Site Map.

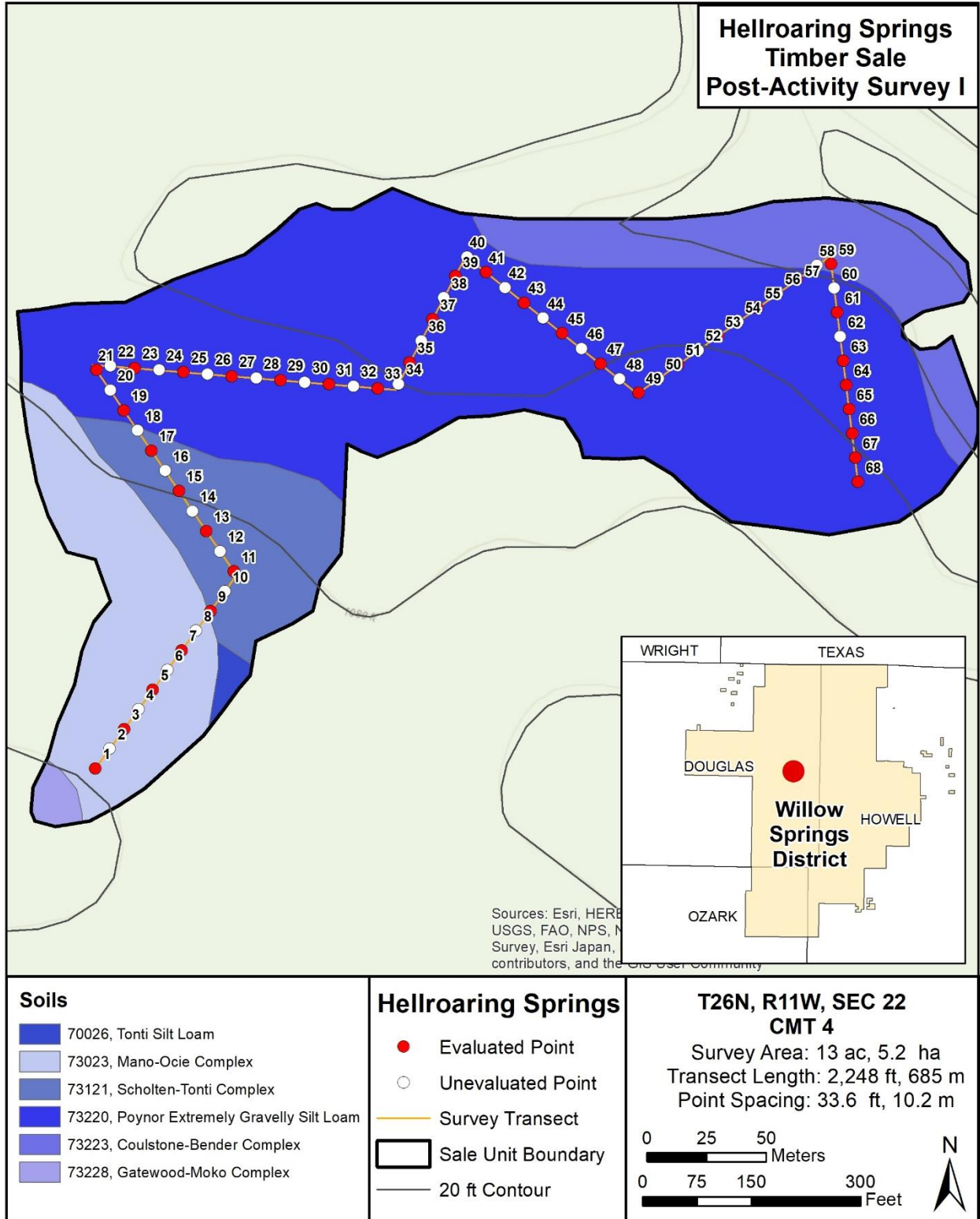


Figure 8. Hellroaring Springs Site Map.

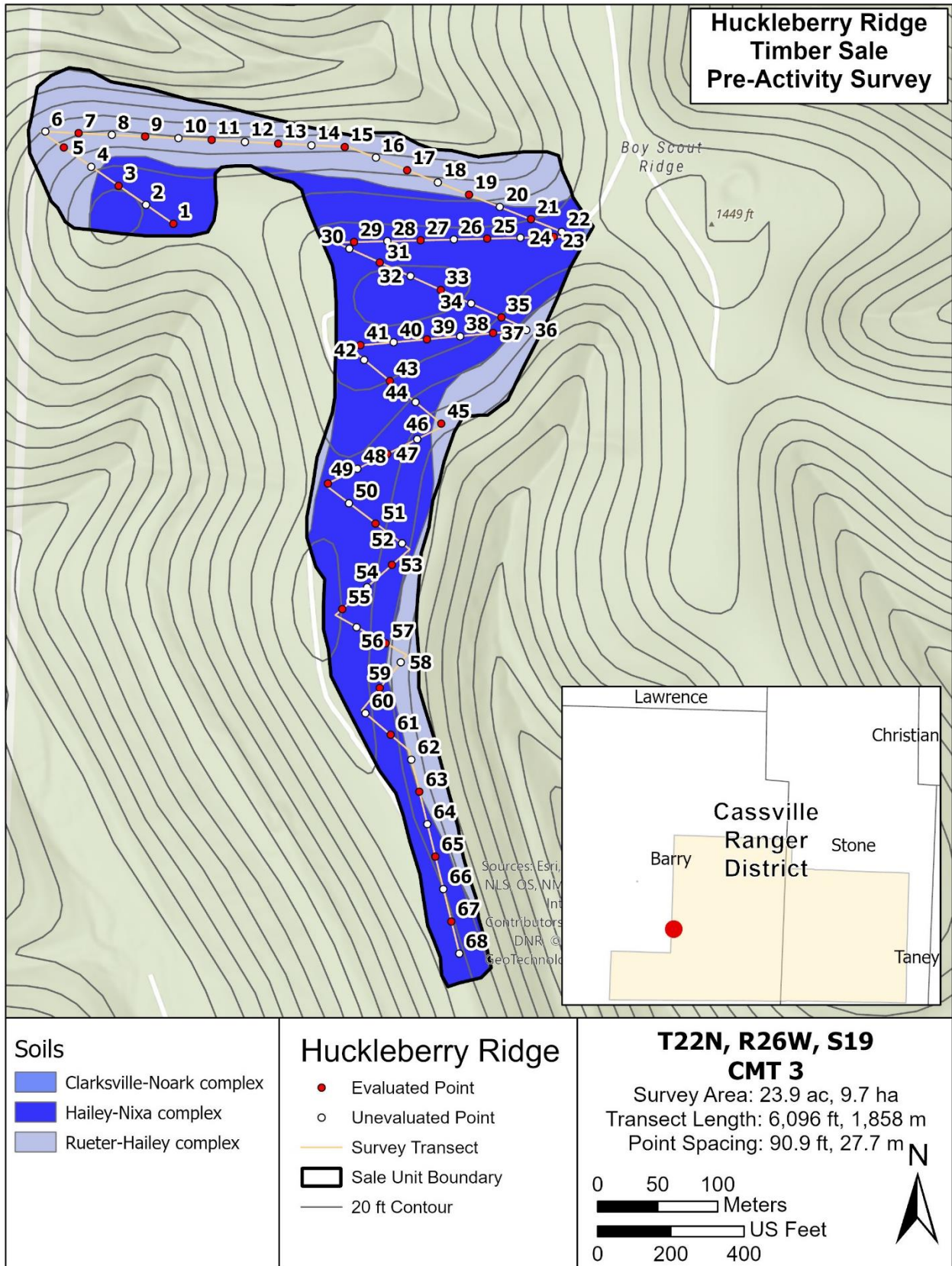


Figure 9. Huckleberry Ridge Site Map.

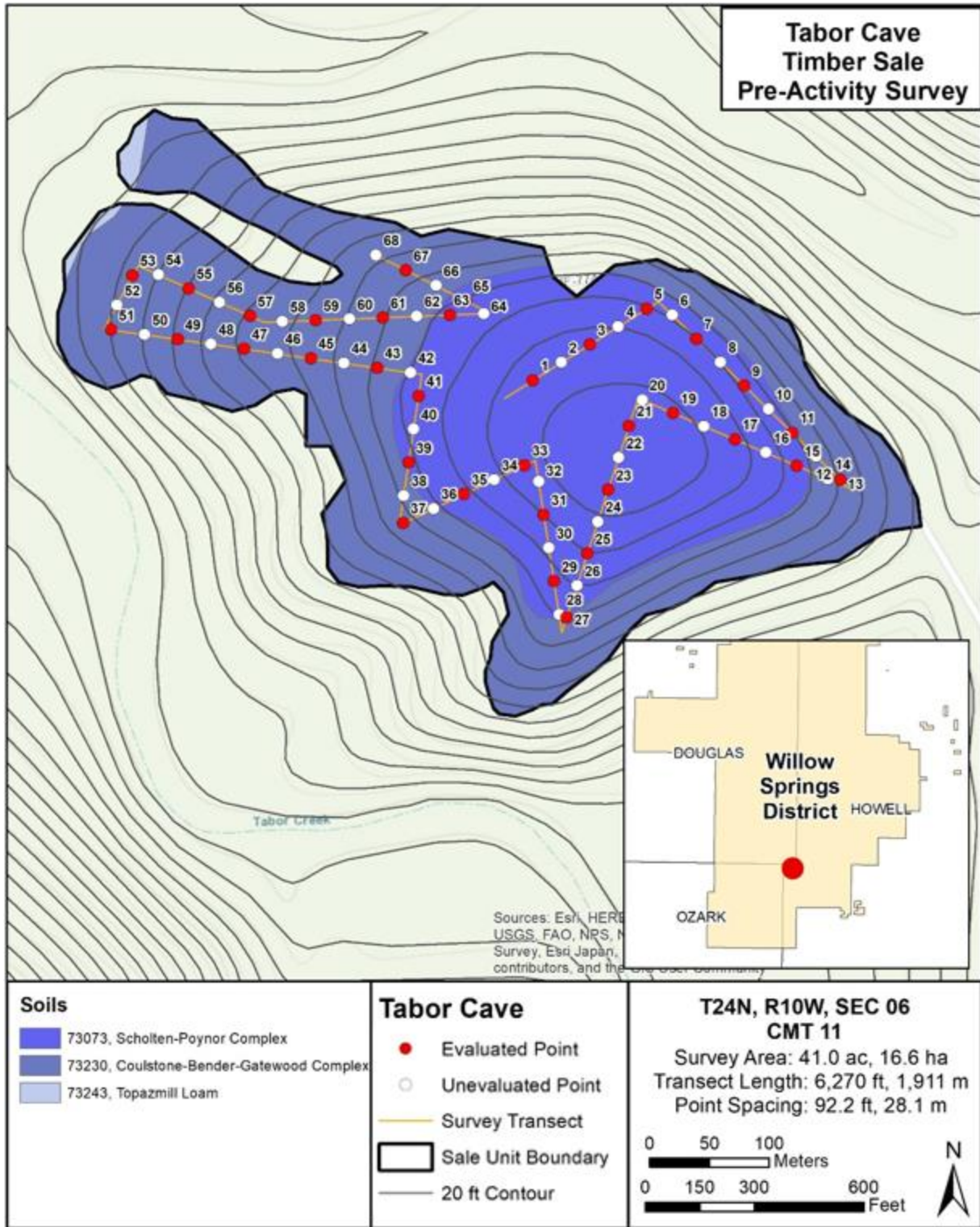


Figure 11. Tabor Cave Site Map.

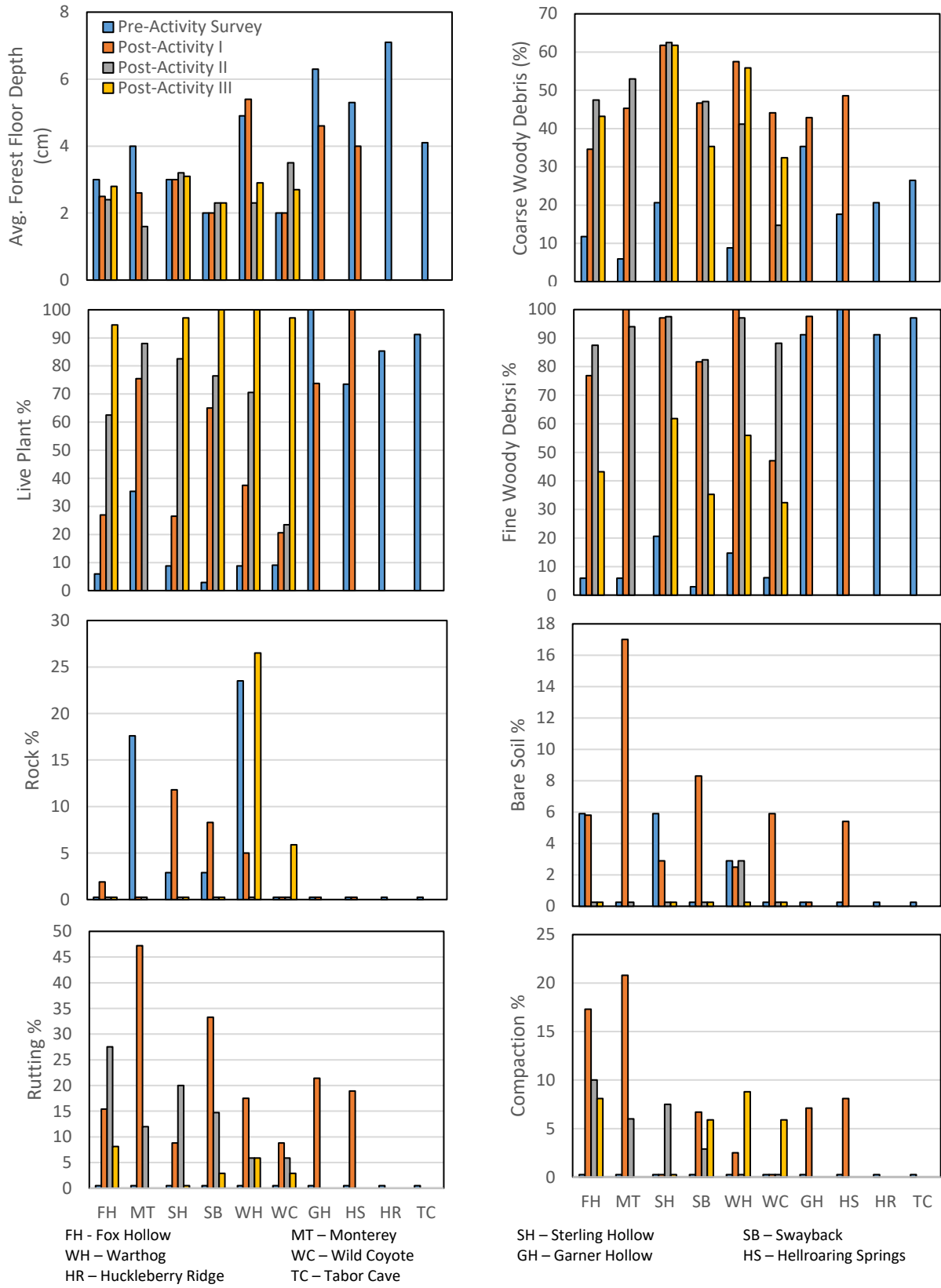


Figure 12. Observed temporal changes in site characteristics since 2018

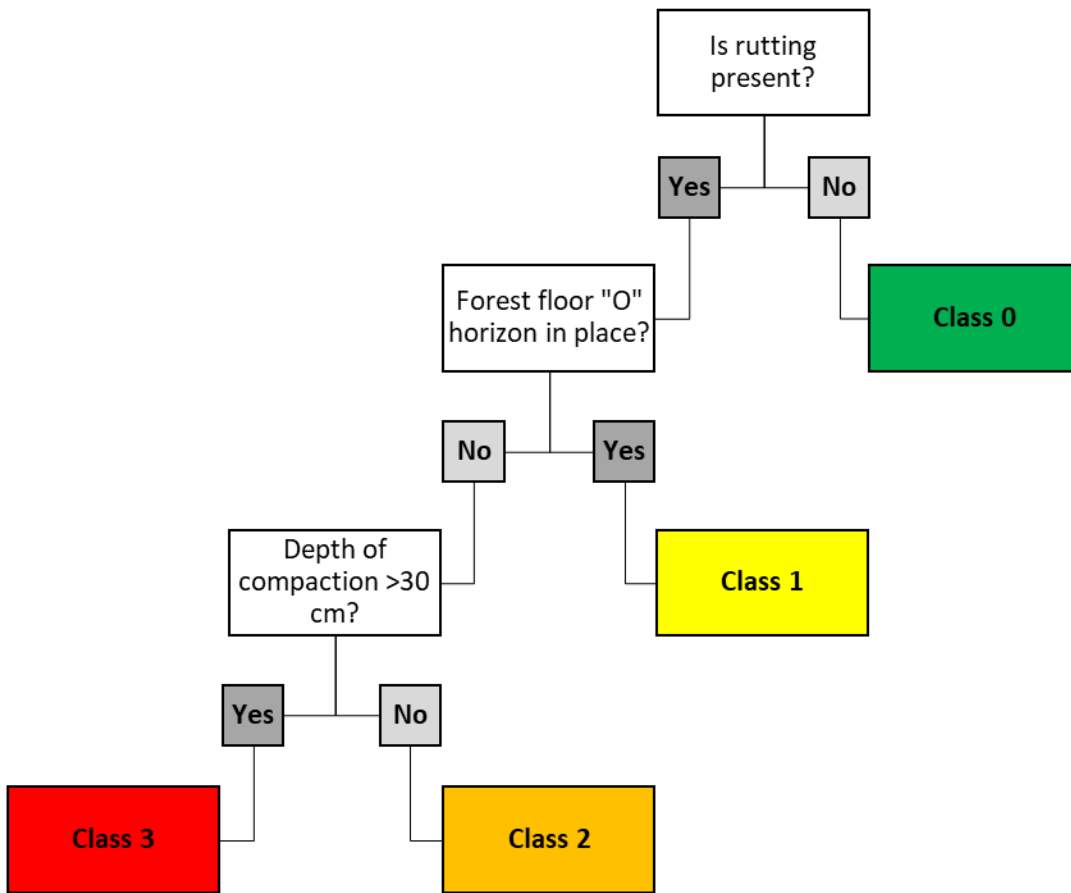


Figure 13. Preliminary flow chart showing typical disturbances found in the post-activity monitoring period and how disturbance class values were designated at the six sites selected for this project.

PHOTOS



Photo 1. Using GPS navigation to locate pre-selected pit locations (Swayback: Sept. 26, 2018).



Photo 2. Pit location and ring where forest floor is evaluated prior to digging a pit (Monterey: May 11, 2018).



Photo 3. Measuring forest floor depth (Sterling Hollow: July 31, 2018).



Photo 4. Pits are dug to a depth of 15-30 cm (Warthog: April 5, 2018).



Photo 5. Measuring pit depth (Coyote: Sept. 27, 2018).



Photo 6. IPADs are used to enter data to FSDMP datasheet (Coyote: Sept. 27, 2018).



Photo 7. Using an example of platy structure to help field workers identify it in the field (Monterey: May 11, 2018).



Photo 8. Wind damage was observed at some of the sites (Fox Hollow: August 2, 2018).



Photo 9. Tree throw was common at most sampling sites (Fox Hollow: August 2, 2018).



Photo 10. ATV trail located within the monitoring site (Monterey: May 11, 2018).



Photo 11. Very rocky conditions were observed at some sites (Warthog: April 5, 2018).



Photo 12. Rocky colluvium material above loamy A horizon (Warthog: April 5, 2018).



Photo 13. Stream channels were located within some of the sites (Warthog April 5, 2018).



Photo 14. Loess parent material (Wild Coyote: Sept. 27, 2018) NOTE: Horizontal lines are not platy structure but are from scraping with a soil knife.



Photo 15. Weathered loess parent material (Wild Coyote: Sept. 27, 2018).



Photo 16. Main haul road within the sale site (Fox Hollow: November 14, 2019).



Photo 17. Sample pit with an example of compaction (Fox Hollow: November 15, 2019).



Photo 18. Sample points located in dense brush left over from harvest (Sterling Hollow: December 11, 2019).



Photo 19. Rutting observed along the main haul road (Swayback: December 5, 2019).



Photo 20. Large amount of slash left on site significantly increases woody debris observations during post-activity evaluation (Warthog: December 16, 2019).



Photo 21. Steep sites tend to have high rock at the surface (Warthog: December 18, 2019).



Photo 22. Main haul road along the ridge line (Warthog: December 16, 2019).



Photo 23. Example of a soil sampling point with no “O” horizon present (Fox Hollow: November 14, 2019).



Photo 24. Example of a soil sampling point with the “O” horizon present (Wild Coyote: December 6, 2019).

APPENDIX A - TIMBER SALE MAPS

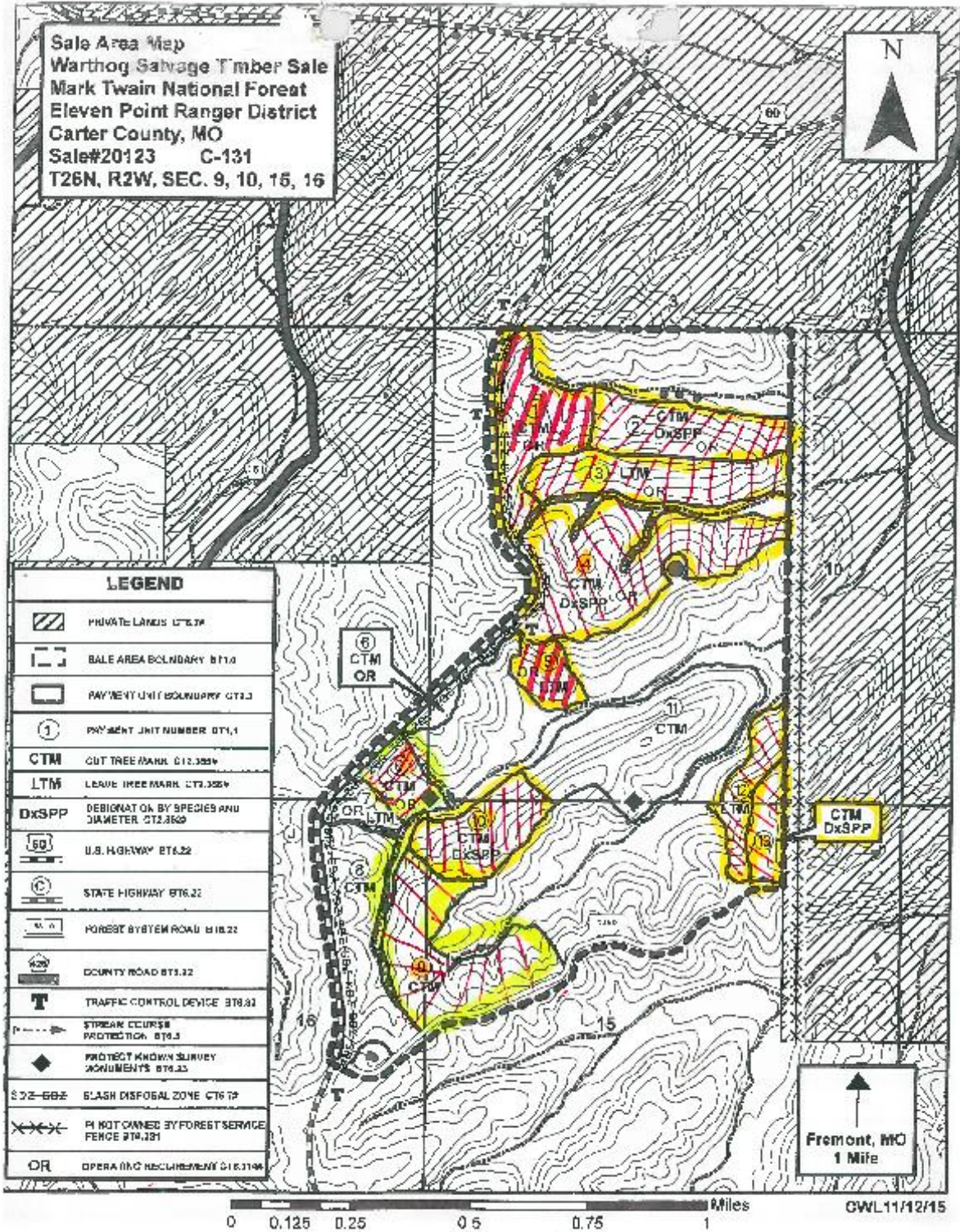


Figure 14. Warthog Timber Sale Map.

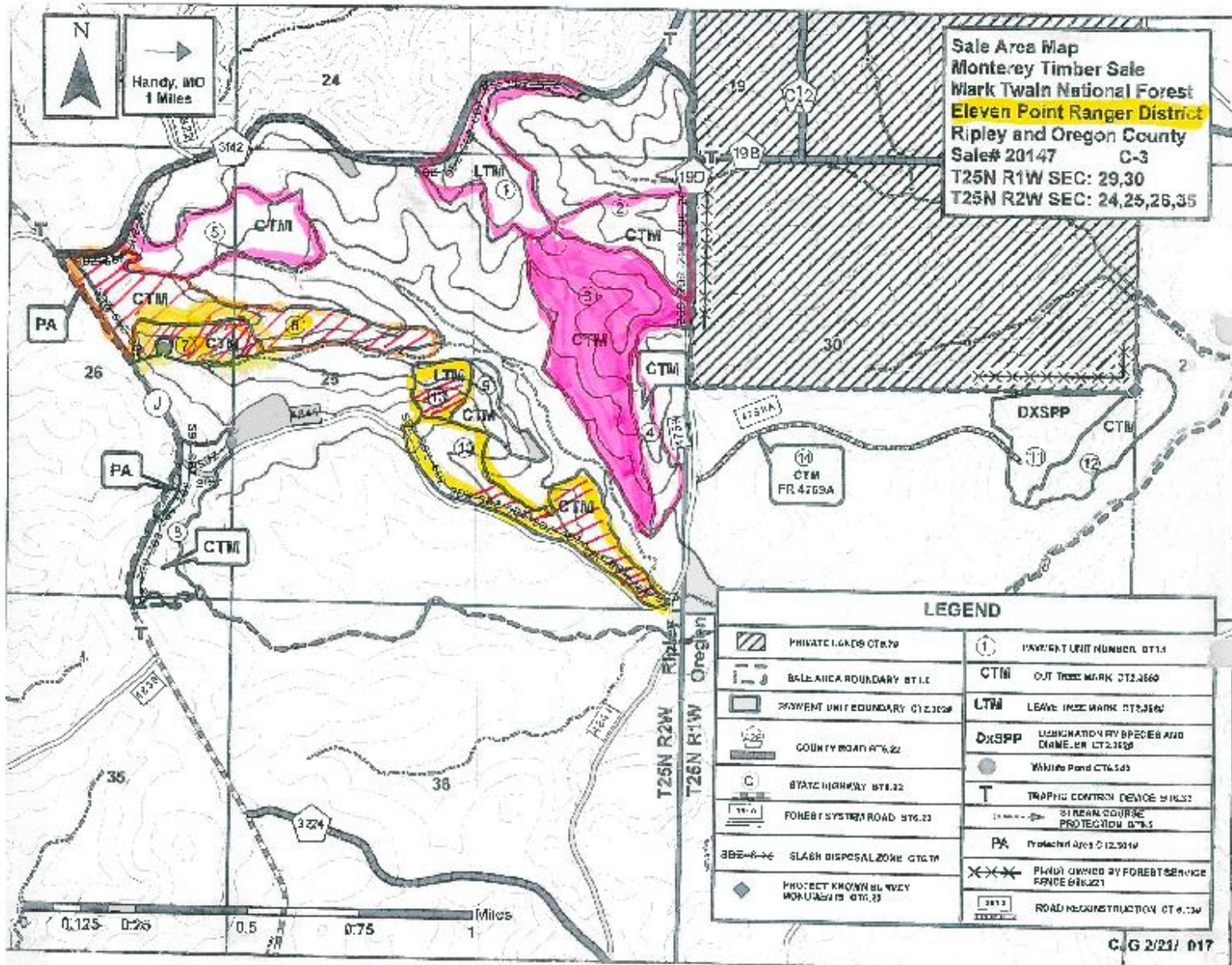


Figure 15. Monterey Timber Sale Map.

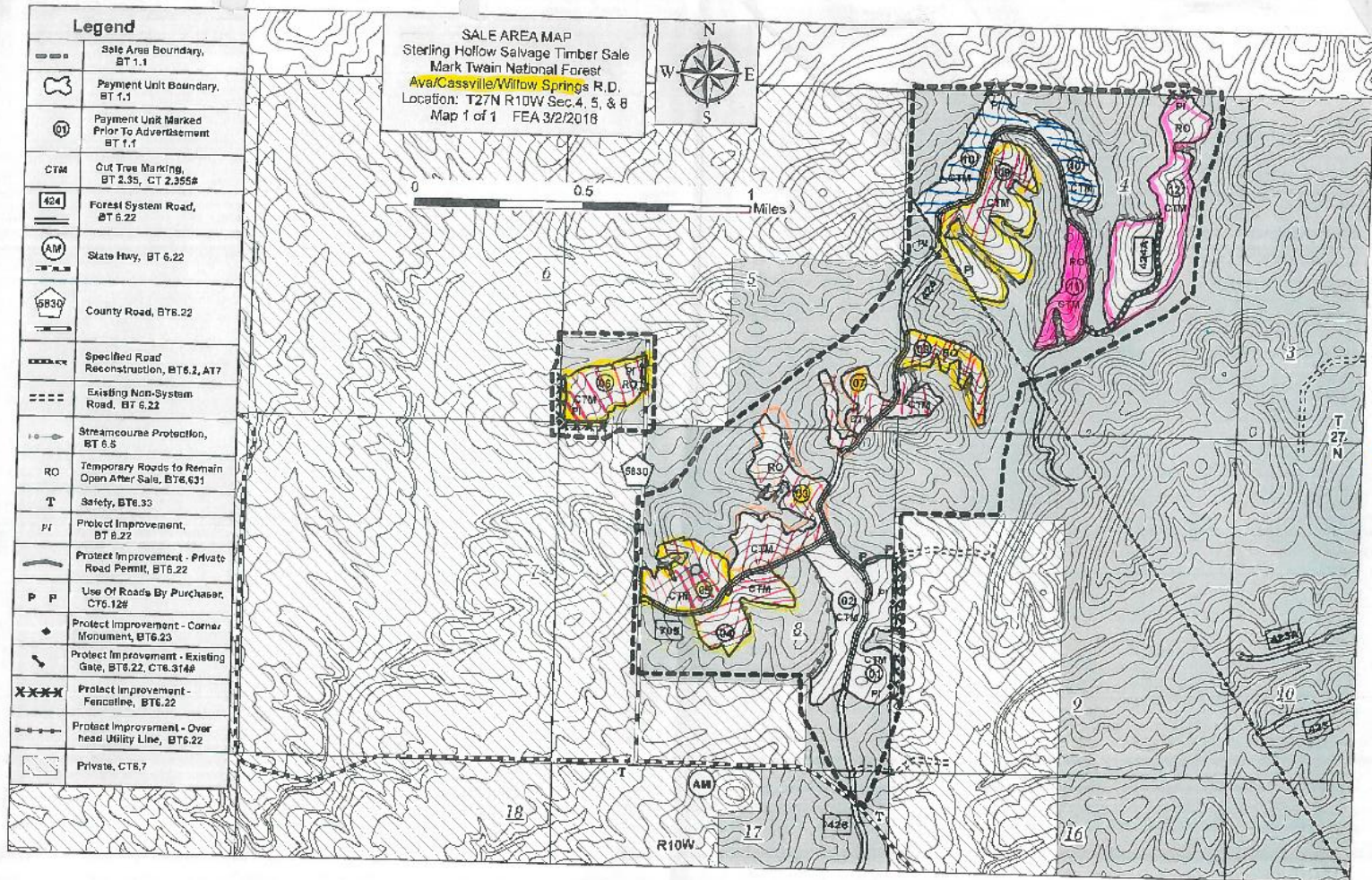


Figure 16. Sterling Hollow Timber Sale Map.

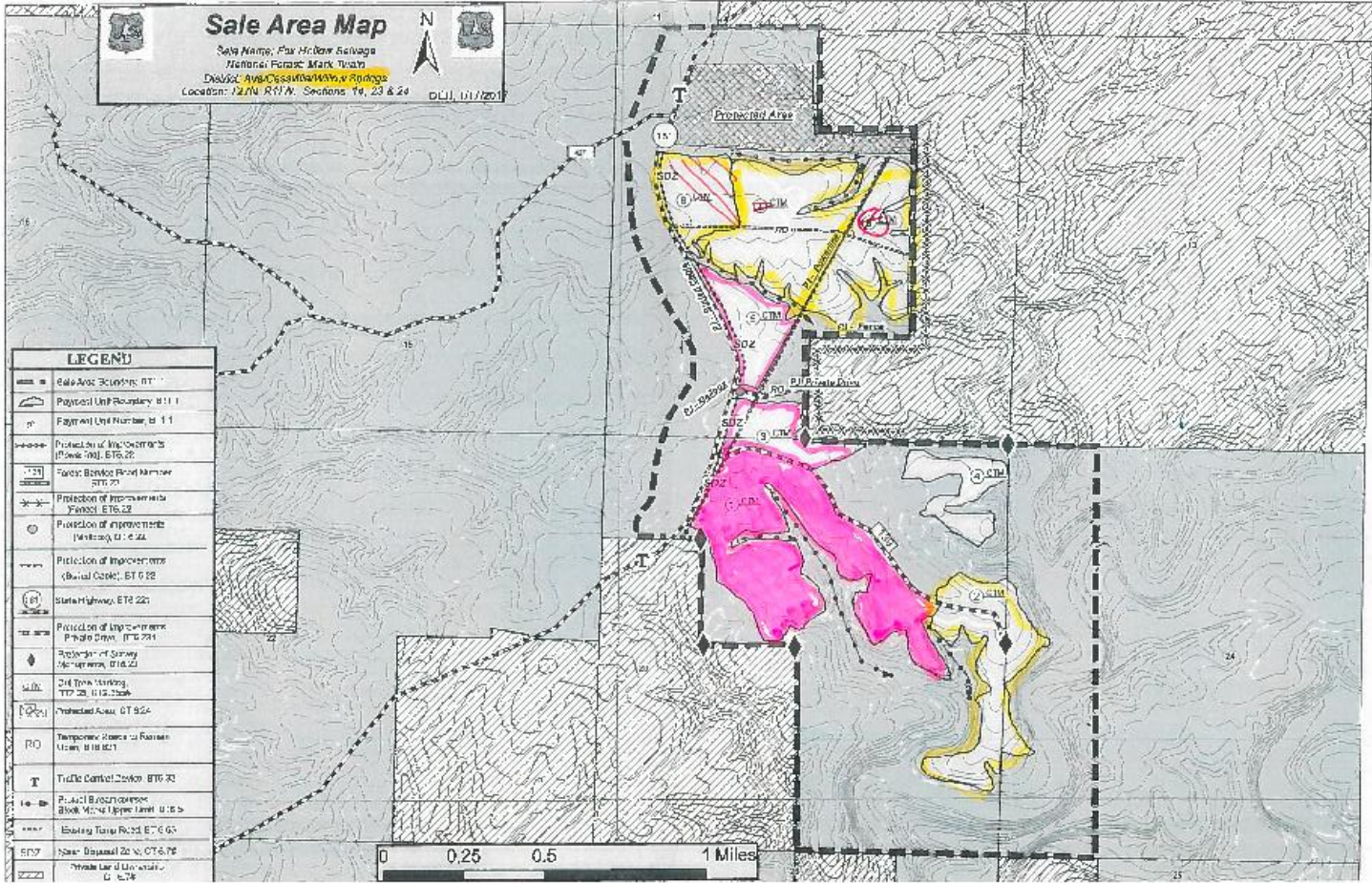


Figure 17. Fox Hollow Timber Sale Map.

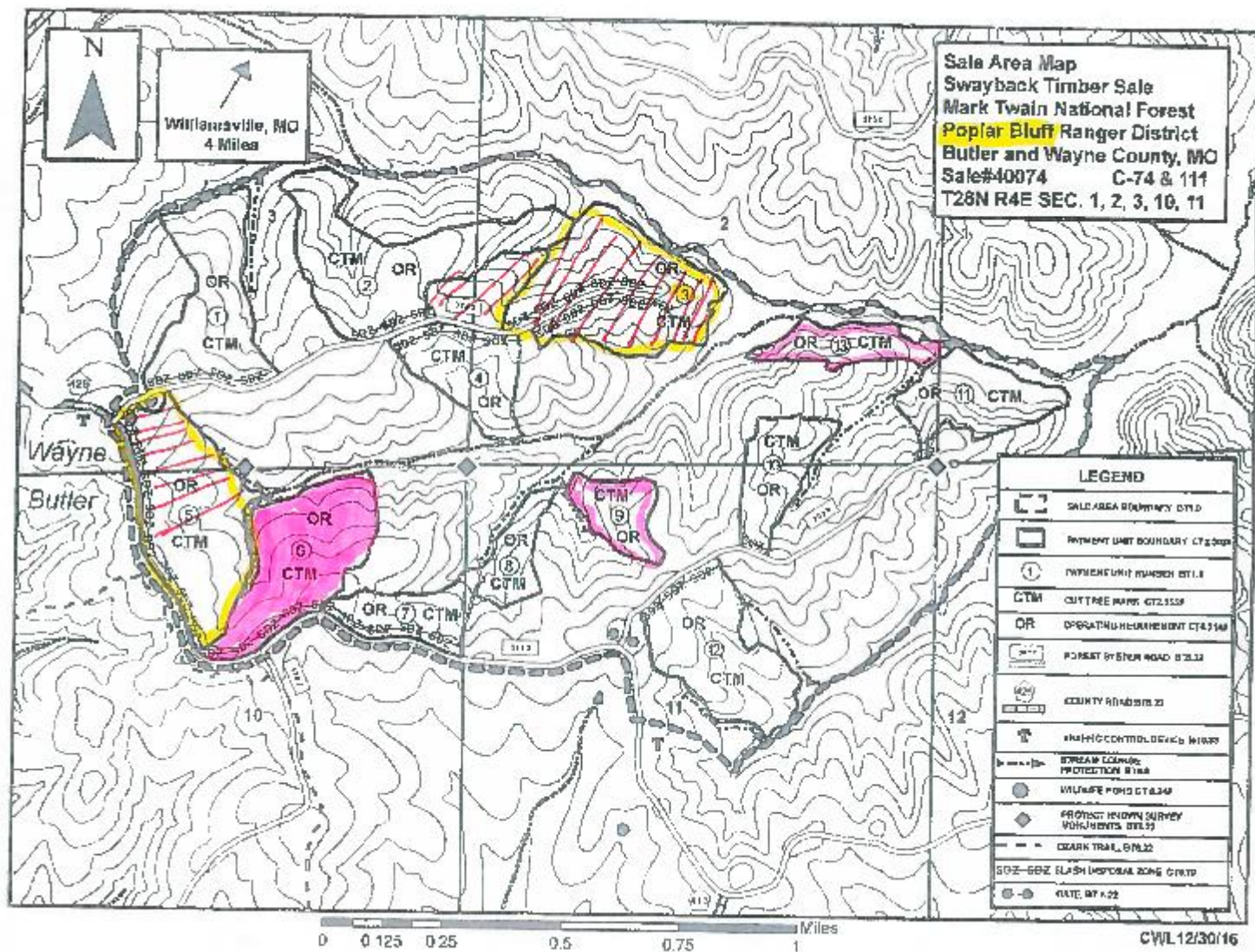


Figure 18. Swayback Timber Sale Map.

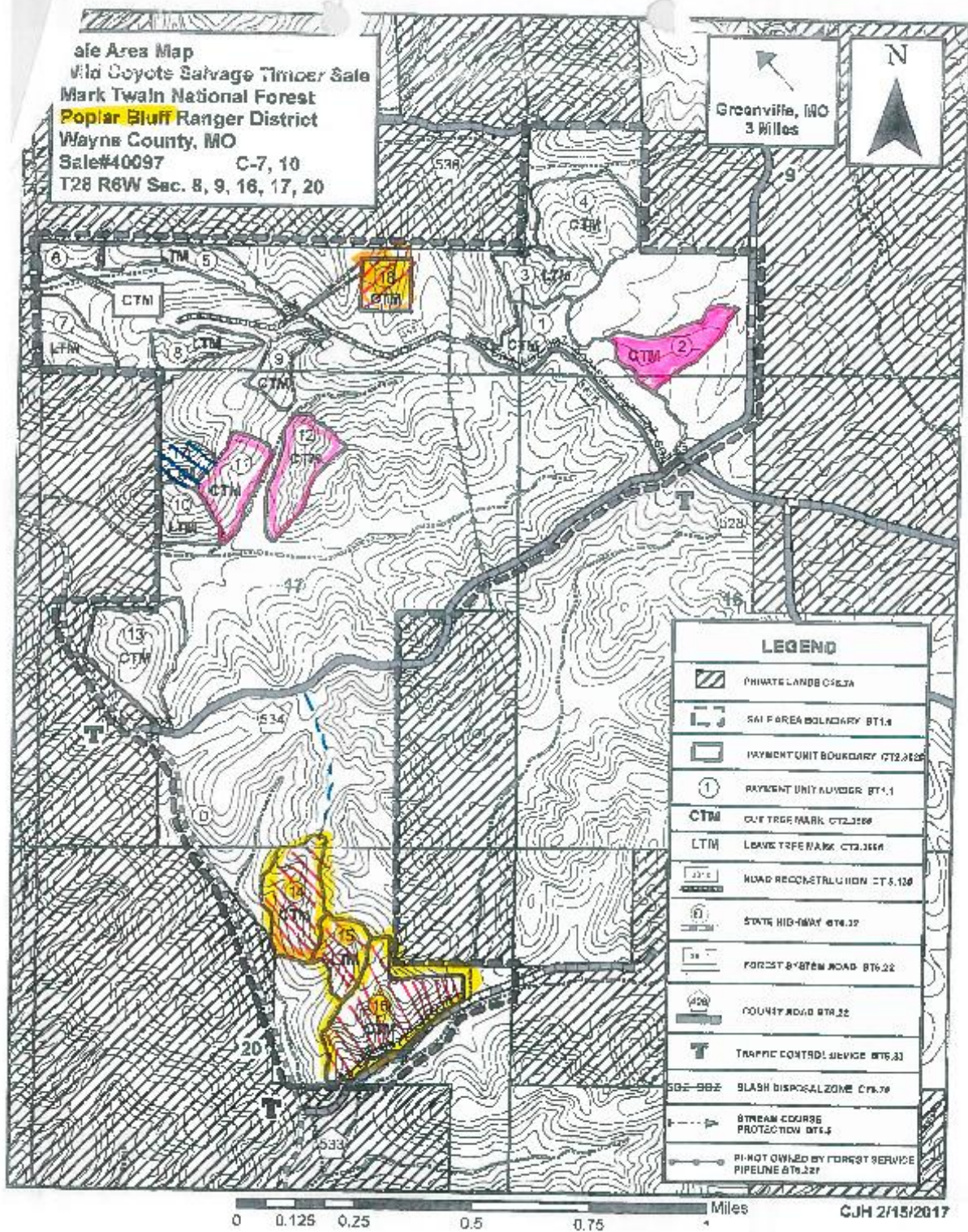
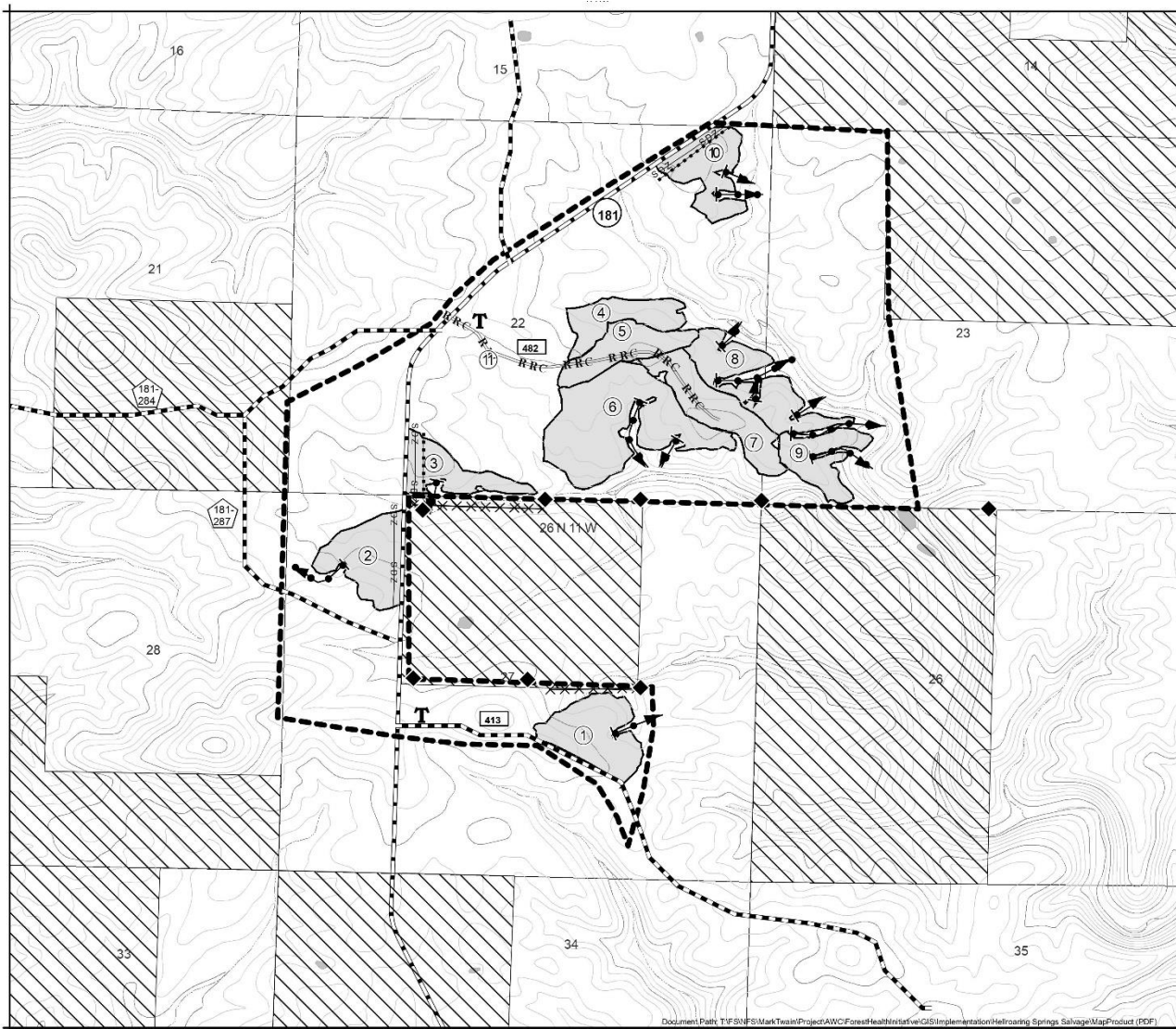
















Figure 19. Coyote Timber Sale Map.



**Sale Area Map
Hellroaring Springs Salvage**

USDA **Ava/Cassville/Willow Springs
Mark Twain National Forest** 
Douglas County

Legend	
	Sale Area Boundary, BT1.1
	Payment Unit Boundary, BT1.1
	Payment Unit Number, BT1.1
	Protection of Improvements, Fence BT6.22
	Forest Service Road, BT6.22
	Protection of Improvements, Burned Cable BT6.22
	State Highway, BT6.221
	County Road, BT6.221
	Road Reconstruction-482 AT7,BT5.2,BT6.222
	Protection of Survey Monuments, BT6.23
	Traffic Control Device,BT6.33
	Protect Stream Courses, BT6.5
	Private Land Ownership,BT6.7#
	Slash Disposal Zone,CT6.7#

Unit Number	Contractual Requirements
1-11	CTM: BT2.35, CT2.355#



The USDA Forest Service uses the most current and complete data available. GIS data and product accuracy may vary. Using GIS products for purposes other than those for which they were intended may yield inaccurate or misleading results. The USDA Forest Service reserves the right to correct, update, modify, or replace GIS products without notification.



DEH Date: 11/22/2019

Figure 20. Hellroaring Springs Timber Sale Map.

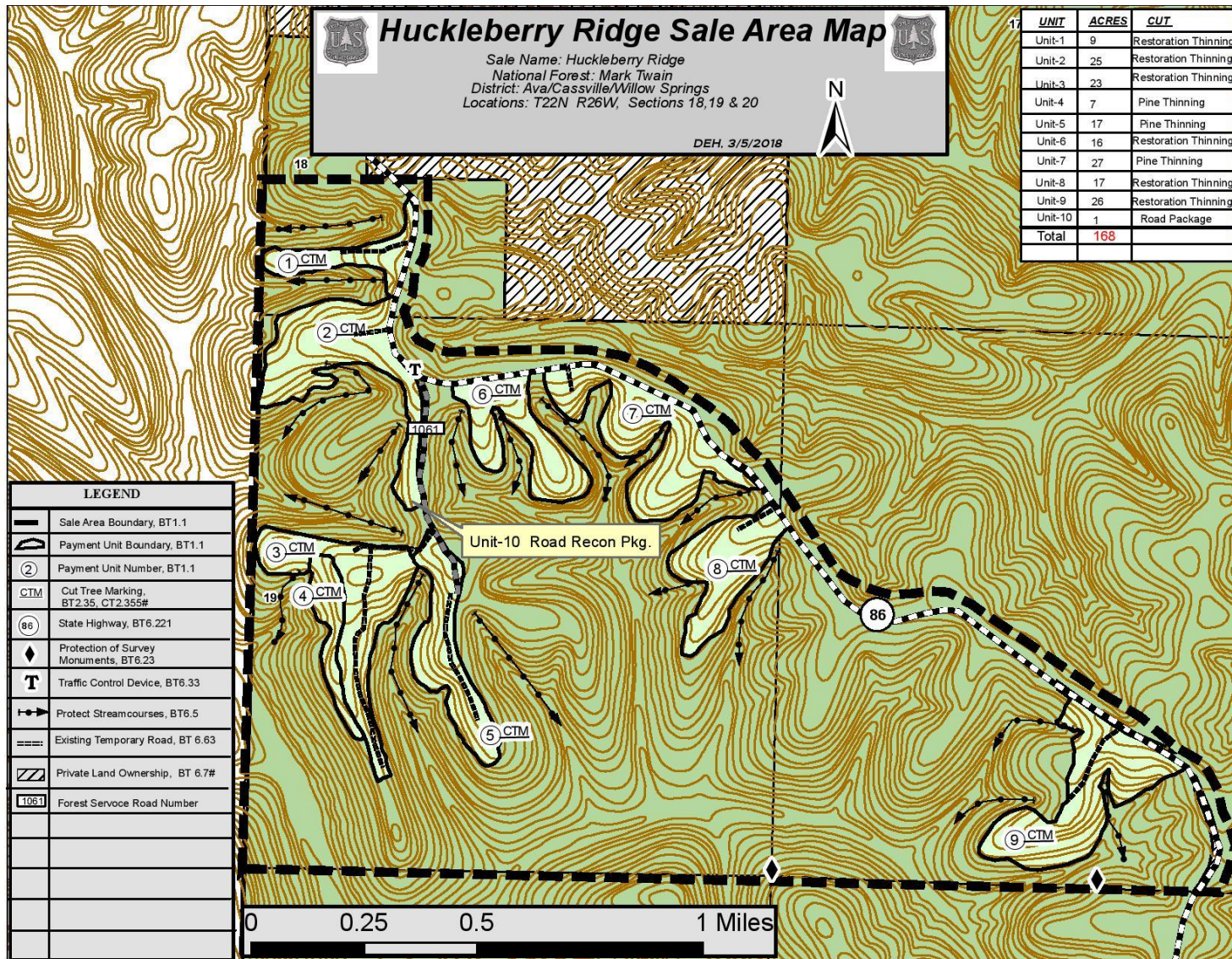


Figure 21. Huckleberry Ridge Timber Sale Map.

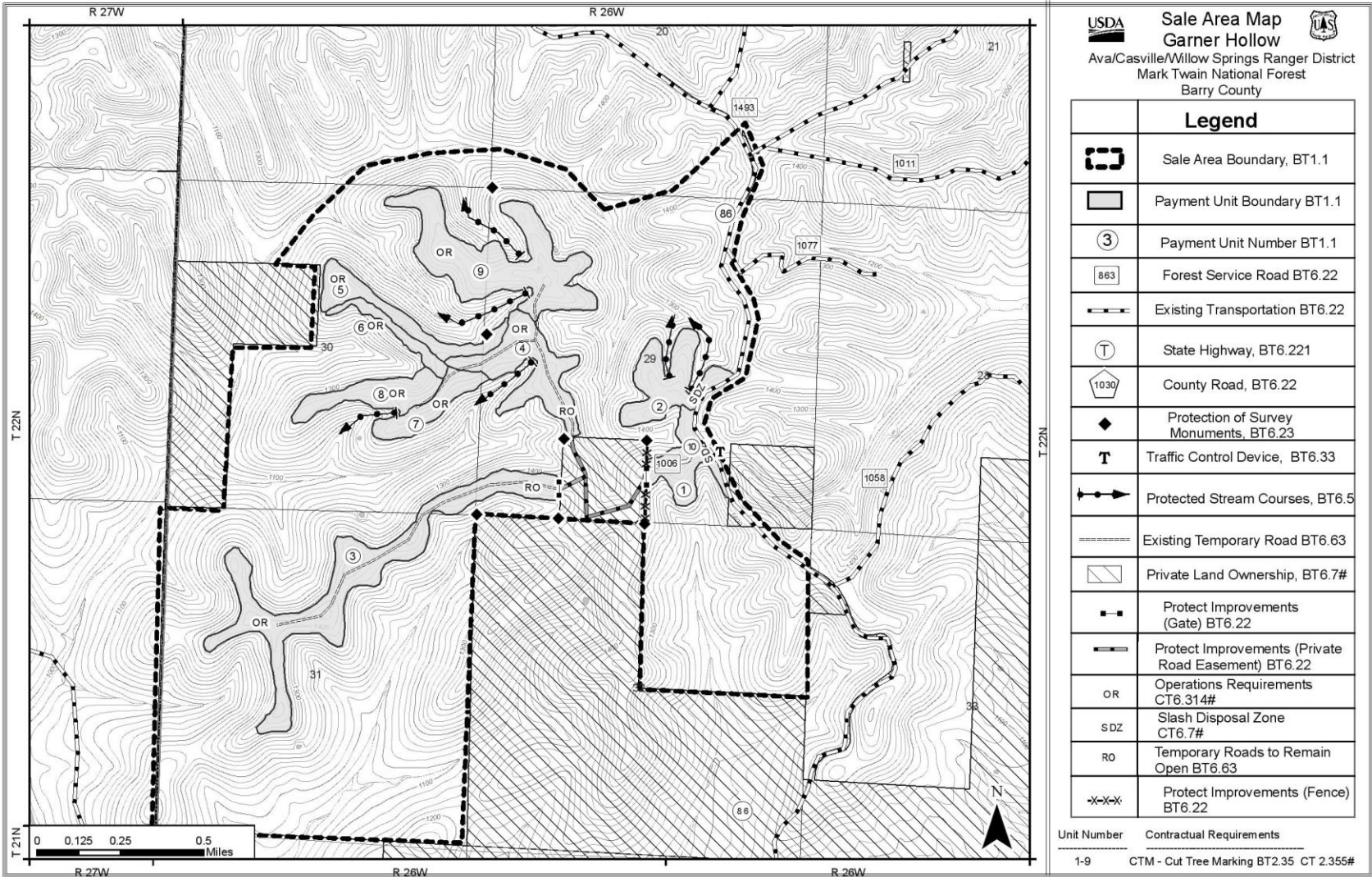


Figure 22. Garner Hollow Timber Sale Map.

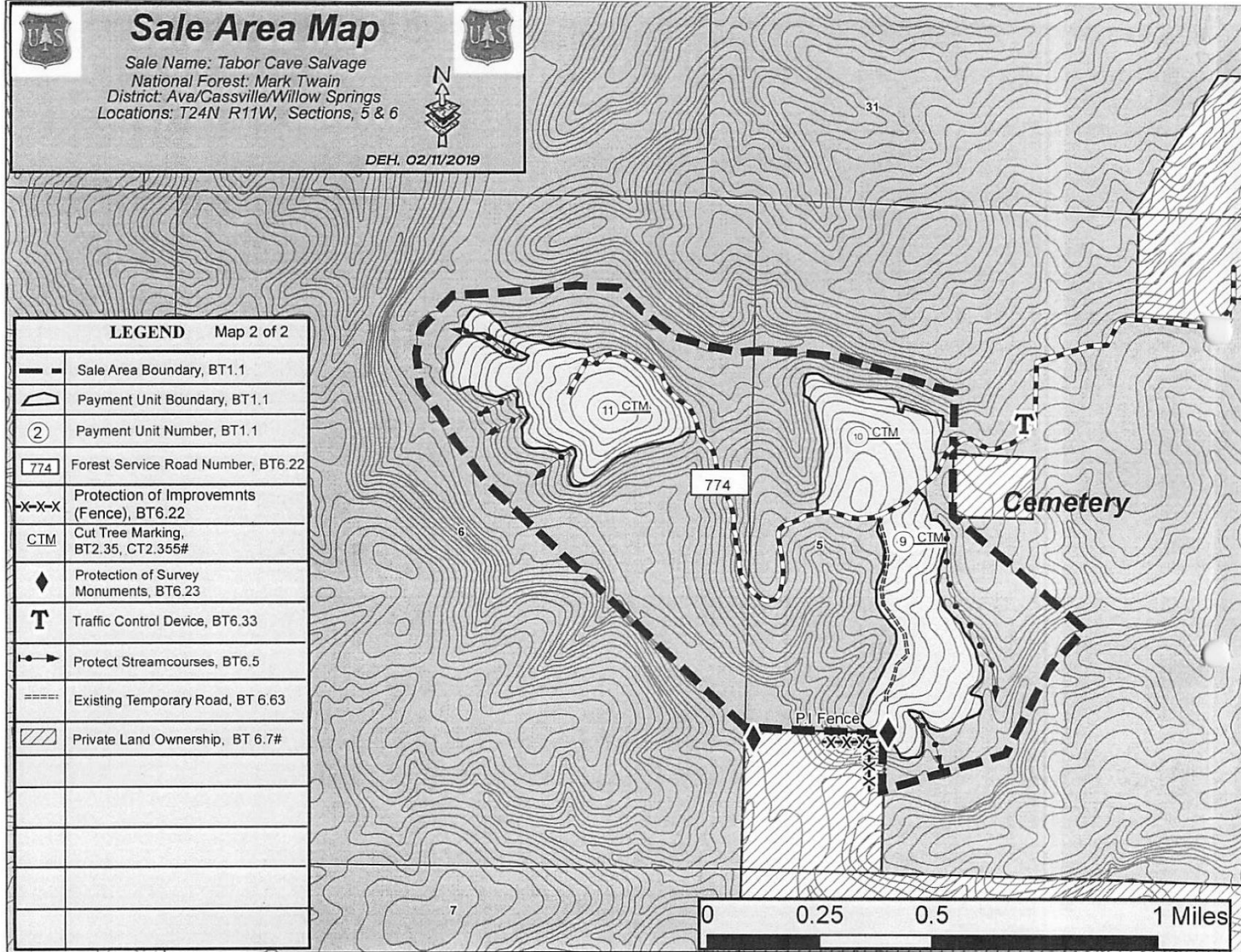


Figure 23. Tabor Cave Timber Sale Map

APPENDIX B – ARCMAP GEODATABASE HTML POPUP TOOL

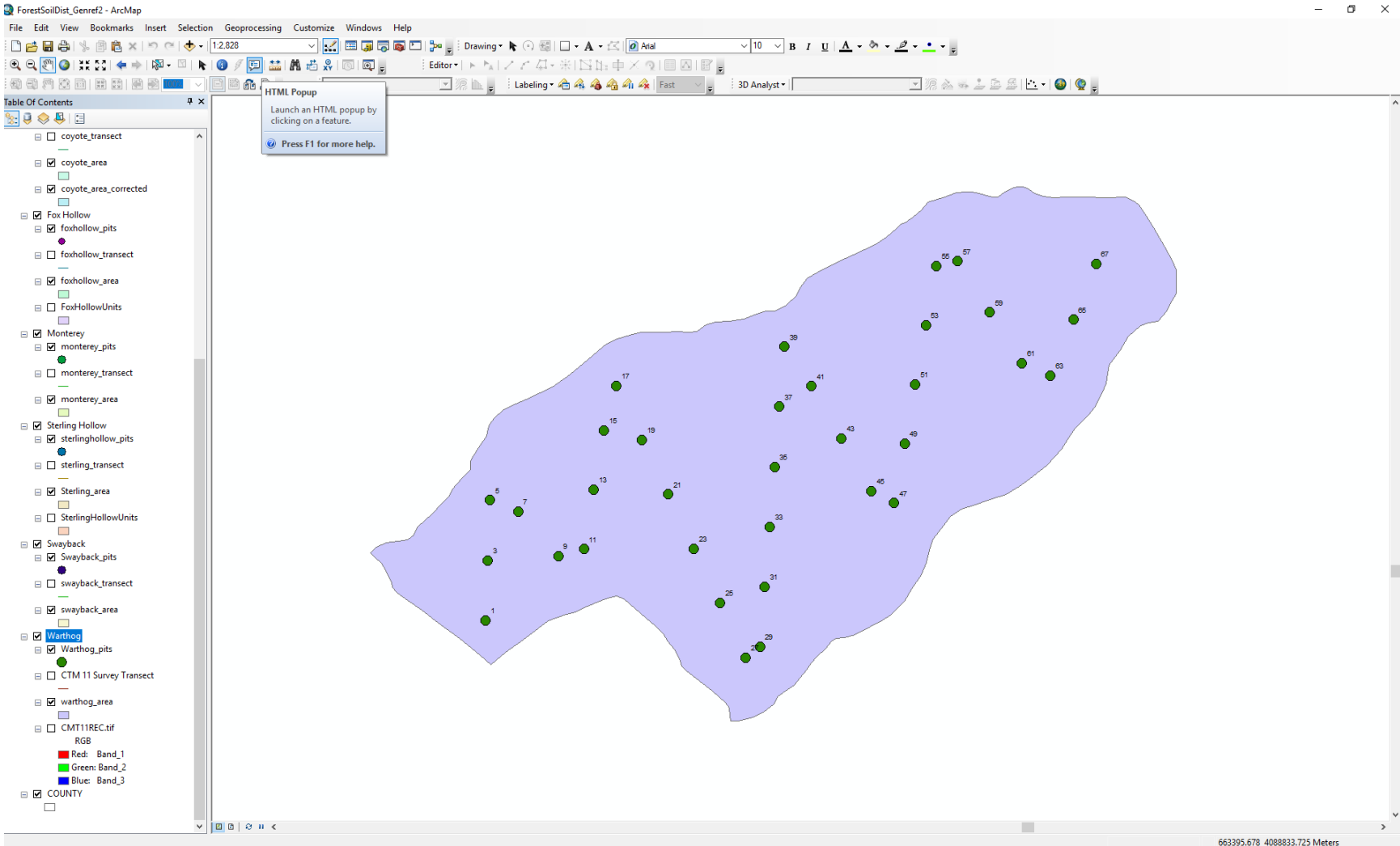


Figure 24. Select the HTML Popup Tool.

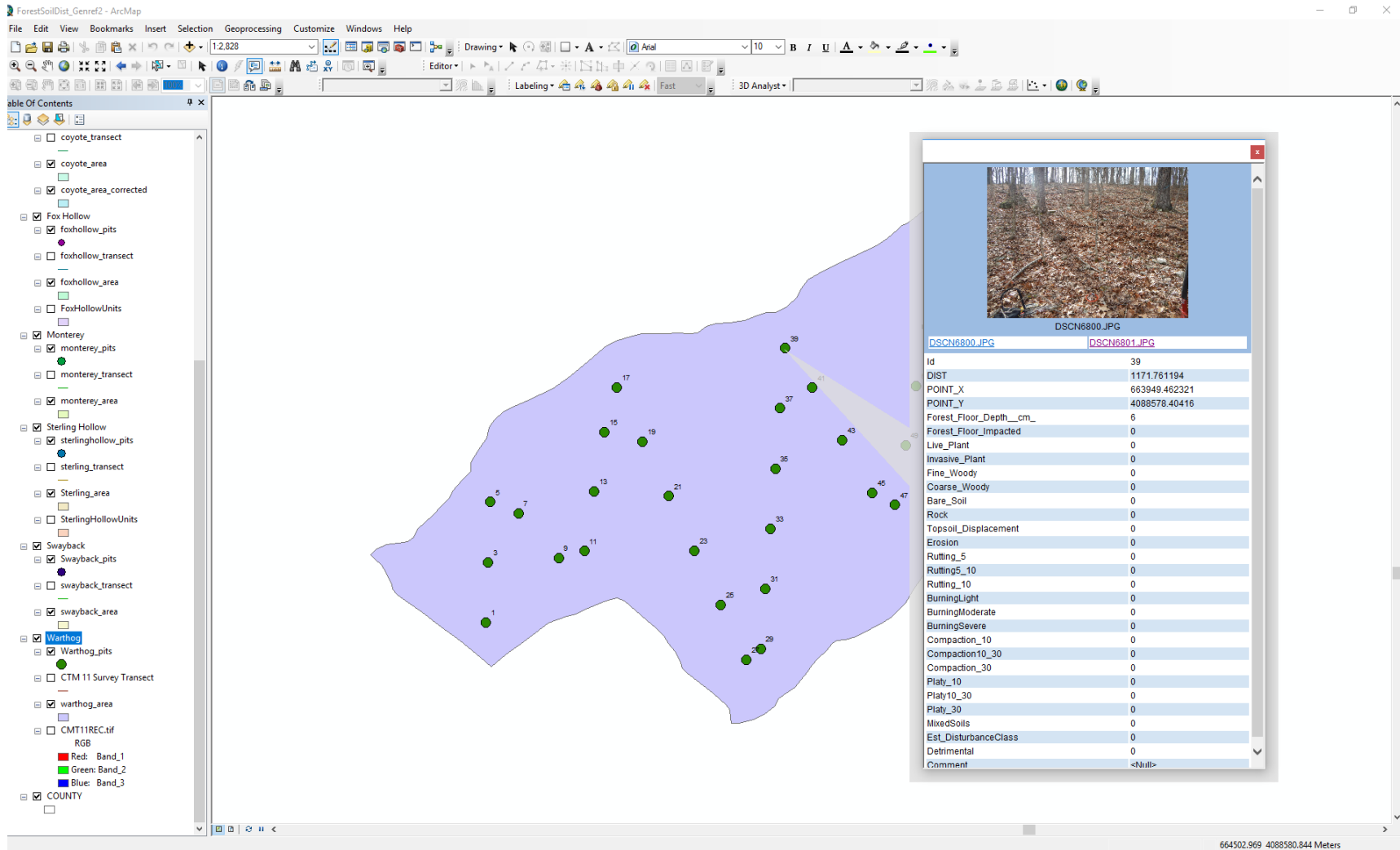


Figure 25. Click on the points using the HTML Popup Tool to see the photos and data collected at each pit.

APPENDIX C – SOIL SERIES BY SALE SITE

MU	Acres	% Area	Series Name	Landform	Slope % Range
<u>Fox Hollow</u>					
70026	0.5	0.5	Tonti silt loam	Uplands	1-3
73073	10.1	10.6	Scholten-Poynor complex	Uplands	8-15
73121	34.5	36.2	Scholten-Tonti complex	Uplands	3-8
73220	21.6	22.6	Poynor extremely gravelly silt loam	Uplands	8-15
73223	26.4	27.7	Coulstone-Bender complex	Uplands	15-50
73236	2.4	2.5	Scholten-Poynor complex	Uplands	3-8
<u>Garner Hollow</u>					
73119	7.0	39.2	Rueter-Hailey Complex	Uplands	35-60
73452	10.8	60.8	Hailey-Nixa Complex	Uplands	3-15
<u>Hellroaring Springs</u>					
70026	0.1	0.5	Tonti silt loam	Interflueve	1-3
73023	1.9	14.5	Mano-Ocie Complex	Interflueve	1-8
73121	1.3	10.3	Scholten-Tonti Complex	Upland	3-8
73220	8.0	62.1	Poynor Extremely Gravelly Silt Loam	Upland	8-15
73223	1.5	11.7	Coulstone-Bender Complex	Upland	15-50
73228	0.1	0.8	Gatewood-Moko Complex	Upland	3-15
<u>Huckleberry Ridge</u>					
70076	0.2	0.8	Clarksville-Noark Complex	Uplands	3-15
73119	8.4	35.0	Rueter-Hailey Complex	Uplands	35-60
73452	15.4	64.2	Hailey-Nixa Complex	Uplands	3-15
<u>Monterey</u>					
73014	22.6	32.9	Clarksville very gravelly silt loam	Uplands	8-15
73019	1.5	2.2	Poynor very gravelly silt loam	Uplands	1-8
73403	1.1	1.6	Coulstone gravelly sandy loam	Uplands	3-8
73472	43.5	63.2	Macedonia silt loam	Uplands	3-8
<u>Sterling Hollow</u>					
73068	4.3	22.2	Tick very gravelly silt loam	Uplands	3-15
73069	14.8	76.2	Tick extremely gravelly silt loam	Uplands	15-50
75423	0.3	1.6	Cedargap very gravelly silt loam	Floodplains	1-3
<u>Swayback</u>					
73140	8.7	61.4	Clarksville-Scholten complex	Uplands	15-45
73265	5.5	38.6	Captina-Scholten complex	Uplands	3-8
<u>Tabor Cave</u>					
73073	16.7	40.8	Scholten-Poynor Complex	Uplands	8-15
73230	23.9	58.4	Coullstone-Bender-Gatewood Complex	Uplands	15-60
73243	0.3	0.7	Topazmill Loam	Uplands	3-8
<u>Warthog</u>					
73402	37.3	67.2	Coulstone very gravelly sandy loam	Uplands	15-30
73403	14.4	26.0	Coulstone gravelly sandy loam	Uplands	3-8

MU	Acres	% Area	Series Name	Landform	Slope % Range
76051	3.8	6.8	Tilk-Secesh complex	Floodplains	1-3
<u>Wild Coyote</u>					
73157	11.1	70.4	Captina silt loam	Uplands	3-8
73267	3.1	19.9	Yelton-Scholten complex	Uplands	8-15
75429	1.5	9.7	Tilk-Secesh complex	Floodplains	0-3