JENSEN HUGHES

April 7, 2023

Mr. Ryan Day
Senior Deputy District Attorney
Boulder County
1777 Sixth Street
Boulder, CO 80302

MARSHALL MESA TRAILHEAD FIRE INVESTIGATION REPORT

File Name:	Marshall Mesa Trailhead Fire
Date of Incident:	December 30, 2021
Location:	Intersection of Marshall Road (SH170), Eldorado Springs Drive, and Foothills Highway (SH93)
JH File Number:	1A3894001

Dear Mr. Day:

Jensen Hughes was retained to investigate the wildland fire that originated near the Marshall Trailhead on December 30, 2021. Jensen Hughes (JH) is an international engineering firm that specializes in fire protection engineering and fire investigation. My personal expertise includes wildland fire investigation involving electrical transmission and distribution systems. I have degrees in electrical engineering and forest resource management and nearly 30 years' experience investigating electrical fires. I have worked on many wildland fire investigations across the United States and have additional expertise in the field.

During my investigation I visited the area of the fire origin two times, examined the Xcel Energy electrical power distribution system from the ground and from an Xcel Energy bucket truck, examined the evidence recovered from the area of the fire origin, met with representatives from the Boulder County Sheriff's office on several occasions, met with representatives from Xcel Energy, reviewed documents provided to me, and prepared this report of my findings.

Special Agents with the United States Forest Service identified two general areas of origin ("GAO") for the Marshall Fire:

1. "GAO #1" was in the area of the property located at 5325 Eldorado Springs Drive. My understanding is that a group commonly referred to as "The Twelve Tribes" owned and managed this property.
2. "GAO #2" was in the area of a reported downed power line (later identified as a communication line) near Marshall Road (SH170) and Foothills Highway (SH93) and included the area of the intersection of Marshall Road (SH170) and Foothills Highway (SH93) and the Marshall Mesa trail area. Investigators further identified two Specific Areas of Origin (SAOs) within GAO#2 south of the Marshall Mesa trailhead. I will refer to those two areas as SAO #1 and SAO#2.

There are two documents that provide guidance for investigation of wildland fires: Neither of the two documents are definitive standards, rather they are guides only. Not all of the guidance in the documents are applicable to every fire and the investigator is not required to adhere to all sections of these documents. The two documents

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are the National Wildland Coordinating Group (NWCG) Handbook 1, PMS 412-1 and the National Fire Protection Association (NFPA) 921-2021, Guide for Fire and Explosion Investigations. NFPA 921 Chapter 27 deals specifically with wildland fire investigation.

NWCG PMS 412-1 handbook "provides instructions for identifying the point of origin of a wildland fire, protecting valuable evidence, and documenting and collecting that evidence, so the cause of the wildfire can be determined accurately."[1]

In order for a wildland fire to occur an ignition source must contact a susceptible fuel bed with enough energy to raise the fuel temperature to its ignition point. PMS 412-1 identifies the following ignition sources:

- Lightning
- Campfire
- Smoking
- Debris Burning
- Incendiary (Arson)
- Equipment Use
- Railroad
- Children
- Power lines
- Fireworks
- Cutting, welding, and grinding
- Firearms use
- Blasting
- Structures
- Glass refraction/magnification
- Spontaneous combustion
- Flare stack/pit fires

PMS 412-1 indicates that the investigator to consider all of the possible causes mentioned above and to attempt to eliminate them as possible causes of any particular fire.

NFPA 921 provides guidance on the investigative process and the Scientific Method that should be used during investigations. Refer to Figure 1. In general, NFPA 921 admonishes the investigator to diligently work to avoid several landmines that can be encountered.[2] Those landmines are:

1. Presumption: Until data have been collected, no specific hypothesis can be reasonable formed or tested.
2. Expectation bias: Expectation bias is a well-established phenomenon that occurs in scientific analysis when investigator(s) reach a premature conclusion without having examined or considered all of the relevant data.
3. Confirmation Bias: Different hypotheses may be compatible with the same data. When using the scientific method, testing of hypothesis should be designed to disprove a hypothesis (i.e., falsification of the hypothesis), rather than relying only on confirming data that support the hypothesis.

To summarize, the investigation should gather and consider all evidence and data, consider the veracity of the evidence and data, and then to develop a list of possible cause hypothesis of the fire. Each possible cause hypothesis should be tested using deductive reasoning and the investigator should attempt to eliminate the hypothesis as a possible cause of the fire. Hypothesis that can't be eliminated should be subjected to further analysis and testing to identify the fire cause.

[1] NWCG 412-1 page 1.
[2] Refer to NFPA 921-2021, Chapter 4.

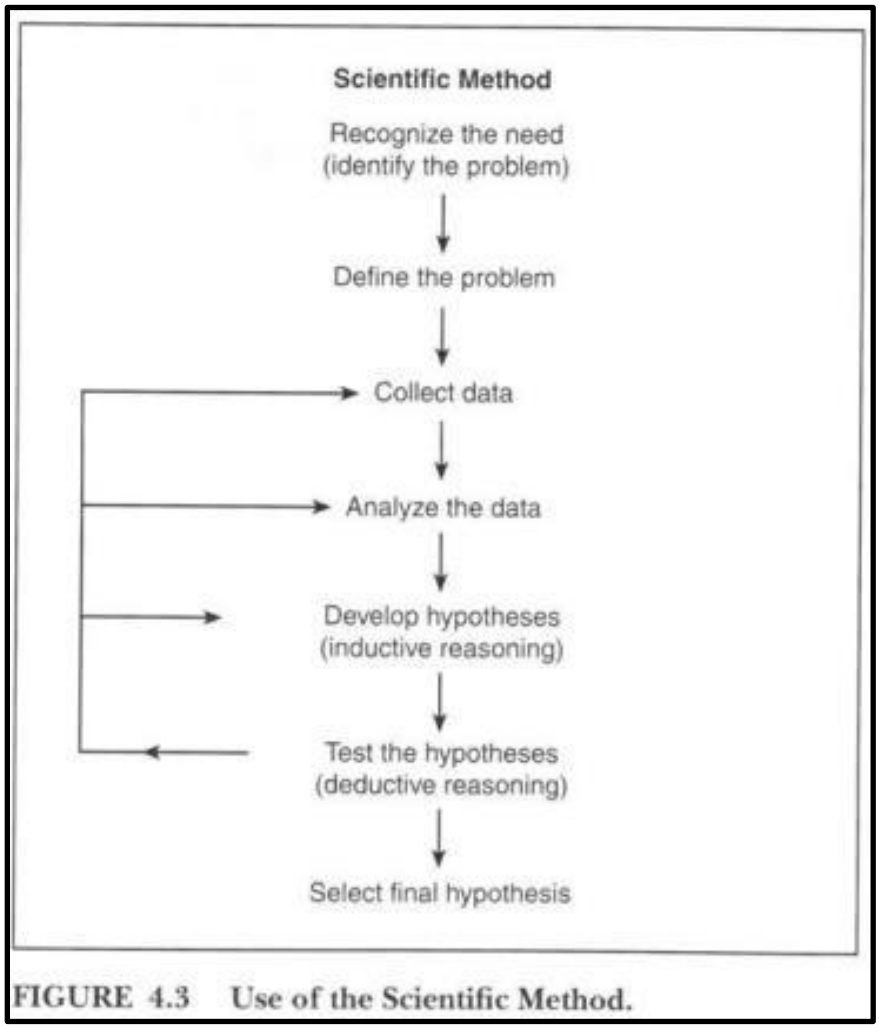


Figure 1. Figure 4.3 from NFPA 921, 2021 Edition.

Evidence that can and should be considered falls into the following categories:

- Witness interviews
- Photographs taken by witnesses and/or automated camera systems (game, trailhead, etc.)
- Video recordings
- Observations of the fire scene
- Fire patterns
- Location and types of ignition sources in the area
- Weather data

Site Description and Origin and Cause (O&C) Investigation

I was retained to investigate the possibility of an electrical cause of the fire and since GAO #1 did not include any electrical components it was outside the scope of my investigation. All investigators have agreed that GAO #1 does not involve electrical equipment. GAO #2 included the entire area between the intersection of Marshall Road (SH170) and Foothills Highway (SH93) and the area to south of the south of the Marshall Mesa trailhead. There was a downed communication line in the area that was part of a fiber optics and low-voltage network and carried no electrical energy capable of igniting a fire. Thus, JH focused our investigation on SAOs #1 and #2which were south of the Marshall Mesa trailhead.

Investigation into GAO #2, SAO #1, and SAO #2

On the day of the fire, high winds known as a "Mountain Wave" had developed in the area of Boulder, CO. The Mountain Wave produced an additional phenomenon known as a "Rotor." These winds achieved sustained speeds of 50 to 60 mph with gusts up to 80 to 100 mph.[3] The winds were blowing generally from the west to east.

GAO #2, as noted above, is located near the Marshall Mesa Trailhead. The trailhead, in turn, is situated south of the intersection of Marshall Road (SH170) and Foothills Highway (SH93). GAO #2 is bordered on the west by SH93. Between SH93 and GAO #2 there is an electrical distribution circuit owned that runs north-south on the east side of SH93 that is operated by Public Service Corporation, doing business as Xcel Energy.

The vegetation in the area of the Marshall Mesa Trailhead was mixed and varied. The lower areas around the trailhead were Western Great Plains Foothills and Piedmont Grassland and the higher elevations to the south and east were probably Southern Rocky Mountain ponderosa Pine Woodland & Savanna. In addition, it appears that revegetation of the mining area was done with an introduced smooth brome grassland mix. All of the available fuels were readily ignitable.

The USDA Forest Service "Wildland Fire Origin and Cause Supplemental Incident Report" (referred to as the FS O&C Report in this report) included a number of descriptive fire scene sketches on pages 16-20 which are included below as Figure 2 through Figure 5. The Marshall fire had three origin points. Referring to Figure 5 below, SAO #1 and SAO #2, were near and downwind from the Xcel Energy pole identified during preliminary investigation as "Pole MP2." Subsequent investigation revealed that "Pole MP2" was identified by Xcel Energy as Pole Number 432056196. For ease of reference, I will refer to the pole as Pole MP2.

The FS O&C Report examined all of the possible causes of the fire in the area of SAO #1 and #2. All possible causes (including ignition by the underground coal seam that was in the area) of the fire cause at those two SAOs were eliminated except for an electrical cause associated with the Xcel Energy power lines.

Investigation of Electrical Fire Causes

The electrical distribution circuit in the area of the Marshall Mesa Trailhead was identified by Xcel as the Eldorado 13.8kV circuit 1161. The Eldorado circuit 1161 was protected by two devices. The circuit breaker and associated relay that provided primary protection for the circuit was located in the Eldorado substation. The second circuit protection device was recloser 101-507 which was immediately adjacent to the area of the Marshall Mesa Trailhead (refer to Figure 4.)

The Eldorado circuit 1161 was protected by an ABB type MMCO Microprocessor Time Overcurrent Relay. This relay monitors the electrical conditions on the line being protected. The relay has two distinct components called "Instantaneous and time overcurrent" sensing. The instantaneous component is designed to sense high current, fast developing faults—like those that occur when two large conductors come into contact and then remain in contact. The time overcurrent component is designed to protect against overload due to excessive current demand.

Recloser 101-507 was the secondary protection for the Eldorado 1161 circuit. Reclosers are designed to operate if current in the line exceeds a selected level. Recloser 101-507 was set to trip at a minimum of 800 Amps of phase current, 650 Amps of ground current. This means that for the recloser to open at least 800 Amps of current would have been required to flow through line-to-line contact.

The MMCO relay would have been much more sensitive to line-to-line faults than Recloser 101-507.

The fire in the area of MP2 near the Marshall Mesa Trailhead, in its early, incipient stages, was recorded by video images captured on the Marshall Mesa Trailhead video camera (refer to Figure 8 through Figure 13). The images show that the fire in the area of MP2 began sometime between 12:17:05 pm. and 12:20:00 pm. A timeline of significant events is shown below:

[3] A Rotor is a horizontal roll of wind, oriented parallel to the foothills, where the wind flow direction reverses relative to the Mountain Wave wind direction.

09:24:58 am Recloser 101-507 tripped on overcurrent (clock on recloser was 30 min, 11 seconds fast)[4]
09:25:08 am Recloser 101-507 reset (closed)

09:25:38 am Circuit breaker 1161 recorded High limit 920 Amps

10:12:59 am Circuit breaker 1161 opened
10:13:55 am Circuit breaker 1161 closed

10:24:26 am Circuit breaker 1161 opened
10:24:34 am Circuit breaker 1161 closed

10:48:55 am Circuit breaker 1161 opened
10:48:57 am Circuit breaker 1161 closed

10:35:00 am The eastern conductor was in place on the crossarm of Pole MP2

11:10:34 am The eastern conductor was disconnected from its Pole MP2 insulator and was in contact with the push pole brace on the east side of Pole MP2

12:07:42 pm Circuit breaker 1161 opened
12:07:44 pm Circuit breaker 1161 closed

12:17:05 pm[5] Gate Camera Pics, no fire recorded. Refer to Figure 8and Figure 9
12:20:00 pm Gate Camera Pics smoke plume visible. Refer to Figure 10 through Figure 12
12:21 pm Mike Zoltowski video smoke plume present near MP2. Refer to Figure 14

12:42:56: pm Circuit breaker 1161 opened by ICCP

Circuit breaker 1161 opened and closed approximately 13 minutes before the smoke from the fire was first observed. The initial smoke plume and flames are in an area that matches the SAO #2 as shown in Figure 12 and Figure 13.

At the time that the fire originated at around 12:20:00 pm the eastern conductor at Pole MP2 had come loose from its insulator and was not attached to its insulator. The conductor was found hanging down in contact with the push pole brace (refer to Figure 15). Lashing wire remains for the eastern conductor were found on the ground underneath the conductors near the base of pole MP2.[6]

The winds in the area of pole MP2 were extreme and the various photographs and video recordings show the conductors and communication lines moving in a very dramatic way. The eastern conduct came loose from its attachment to its insulator roughly 67 minutes before smoke from the fire near the Marshall Mesa trailhead was observed.

Xcel Energy Distribution Line Examination and Analysis

The Xcel Energy distribution line in the area of SAO #2 was supported by Pole MP2 (refer to Figure 16 through Figure 18.) The Xcel Energy system in the area was a three-phase, 33kV distribution line. Each conductor of the three-phase line was supported by a pin-type porcelain insulator and the conductors were lashed to the insulators with aluminum lashing wire (Figure 17 through Figure 20). The lashings from the east conductor that were found

[4] In electric power distribution, automatic circuit reclosers (ACRs) are devices designed for use on overhead electricity distribution networks to detect and interrupt momentary faults. Also known as reclosers or autoreclosers, ACRs are essentially high voltage rated circuit breakers with integrated current and voltage sensors and a protection relay. For overhead distribution networks, the majority of faults are transient, such as lightning strike, surges or foreign objects coming into contact with the exposed distribution lines such as tree branches or animals. By this logic, 80% of outages can be resolved by a simple close operation. Reclosers are designed to handle a short close-open duty cycle, where electrical engineers can optionally configure the number of attempted close operations prior to transitioning to a lockout stage where the device opens are locks open.

[5] 1 hour time offset due to daylight savings

[6] Lashing wire is used to attach conductors to insulators. Lashing wire is wrapped around the conductor and the insulator and allows a small amount of conductor movement. This may also be called “Tie wire.”

on the ground under the distribution line exhibited evidence of mechanical wear and electrical arcing (refer to Figure 21 and Figure 22).

The conductors were examined in the field and in the Jensen Hughes laboratory. All conductors exhibited evidence of electrical arcing (refer to Figure 26 through Figure 31). One area of the center conductor was missing a large (a few grams) particle of aluminum conductor (refer to Figure 28, Figure 30, and Figure 31). Furthermore, arc damage was observed on the lashing that had held the eastern conductor in place and the arcing would have contributed hot material to the hot particle production. Prior testing done by Jensen Hughes has shown that a hot particle with a mass of a few grams would have been large enough, hot enough, and near enough to a susceptible fuel bed to create ignition.

Ignition of wildland fire fuels by hot particles is dependent on a number of physical characteristics:

- Particle size
- Particle composition
- Particle temperature
- Moisture content of fuel bed
- Travel time of the particle

If the particle (molten aluminum in this case) is large enough, hot enough, and comes into contact with an ignitable fuel bed then ignition can occur. Assuming a wind speed of 100 mph and a particle travel distance of 100 feet the particle would only have taken ½ to ¾ second to reach the ground near the two SAOs. The particles that would have been produced on the center phase conductor and the lashing wire would have been sufficiently large to ignite wildland fuels in the area of two SAOs.

Comments on the Xcel Energy Presentation

Xcel Energy presented a summary of their position at meeting on October 11, 2022. In essence, their presentation concluded that their equipment in the area of Xcel Energy Pole MP2 did not ignite the fire in the area of SAO #2. Their reasoning for this conclusion was based on the behavior of recloser 101-507 and the lack of electrical arcing evidence on the eastern conductor supported by Pole MP2.

As discussed earlier in this report, recloser 101-507 opened and reclosed early in the day and the 1161 relay operated repeatedly in the minutes leading up to the fire which the Xcel position presentation ignored completely. Furthermore, the arcing between the eastern phase and center phase would have been result of intermittent lashing wire contact from the eastern phase to the center phase. There was distinctive evidence of electrical arcing on both the lashing wire and on the center conductor that the Xcel position presentation also ignored.

Recloser 101-507 was set to a minimum trip level of 800 Amps and was set to operate ten times to test to determine if any fault was permanent of if it was temporary.[7] This means that 800 Amps would have had to flow to a fault to cause recloser 101-507 to operate and the fault would have had to be present for 10 retry cycles. The arcing between the subject lashing wire and the center conductor would not have produced 800 Amps of fault current nor would it have been long enough to cause the recloser to lock out.

Furthermore, the recloser had the ability to use alternate settings. No alternate settings were used. This means that there were no settings enabled that would have caused the recloser to operate at lower than 800 Amps. Xcel could have enabled alternate settings to provide increased protection in unusual circumstances such as high wind and dry conditions. These alternate settings could have caused the recloser to act more quickly in response to small fault currents and may have reduced the probability that arcing would produce enough hot particles to ignite a fire. California utilities have adopted practices that include increasing recloser sensitivity and lockout after single operations. The California practices have not been adopted as “best practices” nationwide, however.

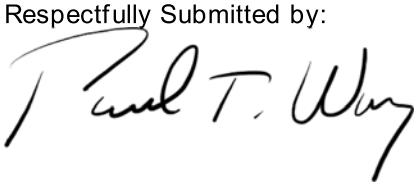
Conclusions

[7] This setting is called a “10 shot.” This means that the upon sensing a fault greater than 800 Amps the recloser would have opened, stayed open for a short time, then reclosed to test to see if the fault still existed. After 10 tests if the fault still existed the recloser would have then opened and locked open.

In light of my investigation and analysis, to a reasonable degree of scientific probability, I have reached the following conclusions:

1. The fire in the area of the Marshall Mesa trailhead was ignited by hot aluminum particles produced when the east phase of Xcel Energy circuit 1161 came loose from its insulator and the lashing wire of the east phase contacted the center phase. The evidence examined revealed that the east phase had become detached from its insulator and that there was electrical arcing on the center phase conductor and on the lashing that had held the east phase to its insulator. The arcing on the east phase lashing and on the center phase conductor is conclusive evidence that the two conductors came into contact with each other and produced hot particles.
2. Photographs and video of the eastern conductor show that it was bouncing and moving in a dramatic way.
3. Since Xcel apparently ignored the arcing evidence and the repeated operation of circuit breaker 1161, their conclusions are incorrect.
4. Xcel could have increased the sensitivity of recloser 101-507 by setting the recloser to operate one time instead of 10, and set it to lockout in the event of a fault. Xcel could also have set the trip level lower to increase the recloser sensitivity to faults. The setting revisions could have been changed during certain weather and fire hazard conditions. This temporary setting revision would have reduced the probability of ignition of the fire. These types of temporary setting revisions are conducted in California. Other states are considering recloser and circuit breaker revised settings during high-fire danger conditions but unified standard do not exist and no definitive guidance is available to help utilities develop recloser and circuit breaker protection strategies during high fire danger conditions.
5. No design, installation, or maintenance defects or deficiencies were identified on the Xcel Energy circuit 1161 in the area of the Marshall Mesa trailhead fire. Inspection of the electrical distribution system equipment in the area of the Marshall Mesa trailhead revealed that the poles, conductors, and insulators were in good condition. While the recloser and circuit breaker settings could have been revised during the high wind event on the day of the fire there is no “best practice” or engineering guidance for setting revisions.

Respectfully Submitted by:



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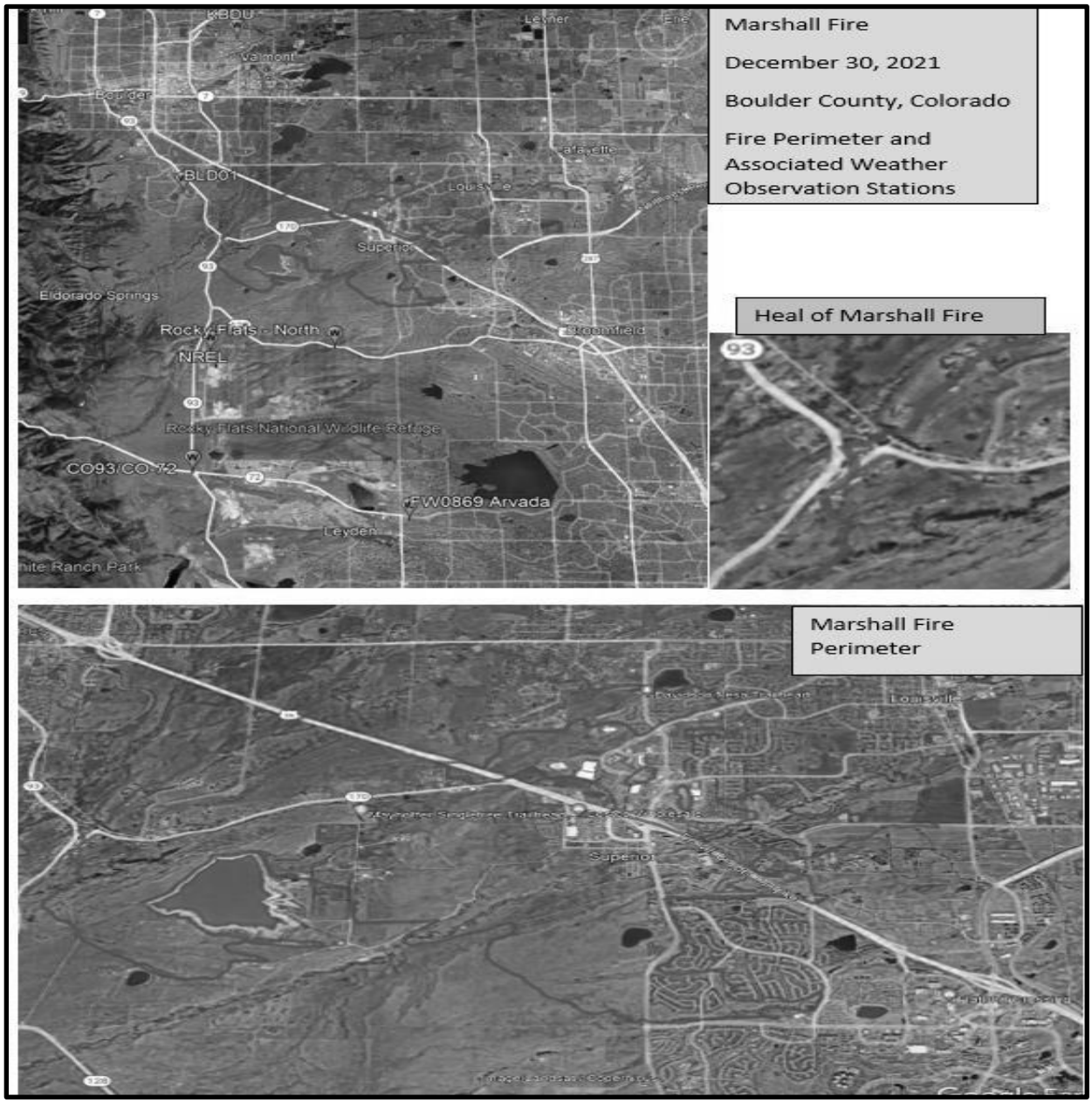

Figure 2. Excerpt from the Wildland Fire Origin and Cause Supplemental Incident Report, page 16.

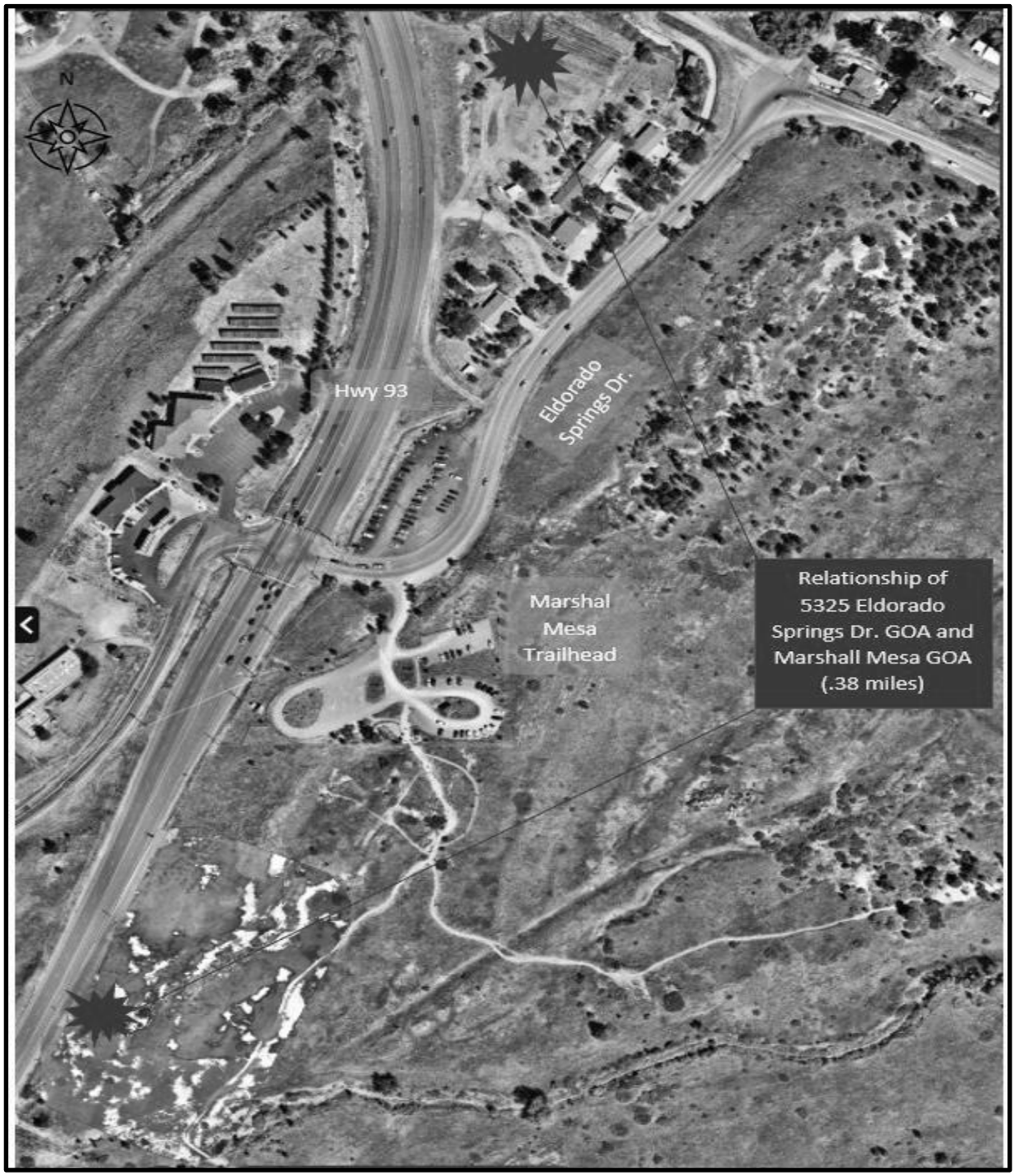

Figure 3. Excerpt from the Wildland Fire Origin and Cause Supplemental Incident Report, page 17.

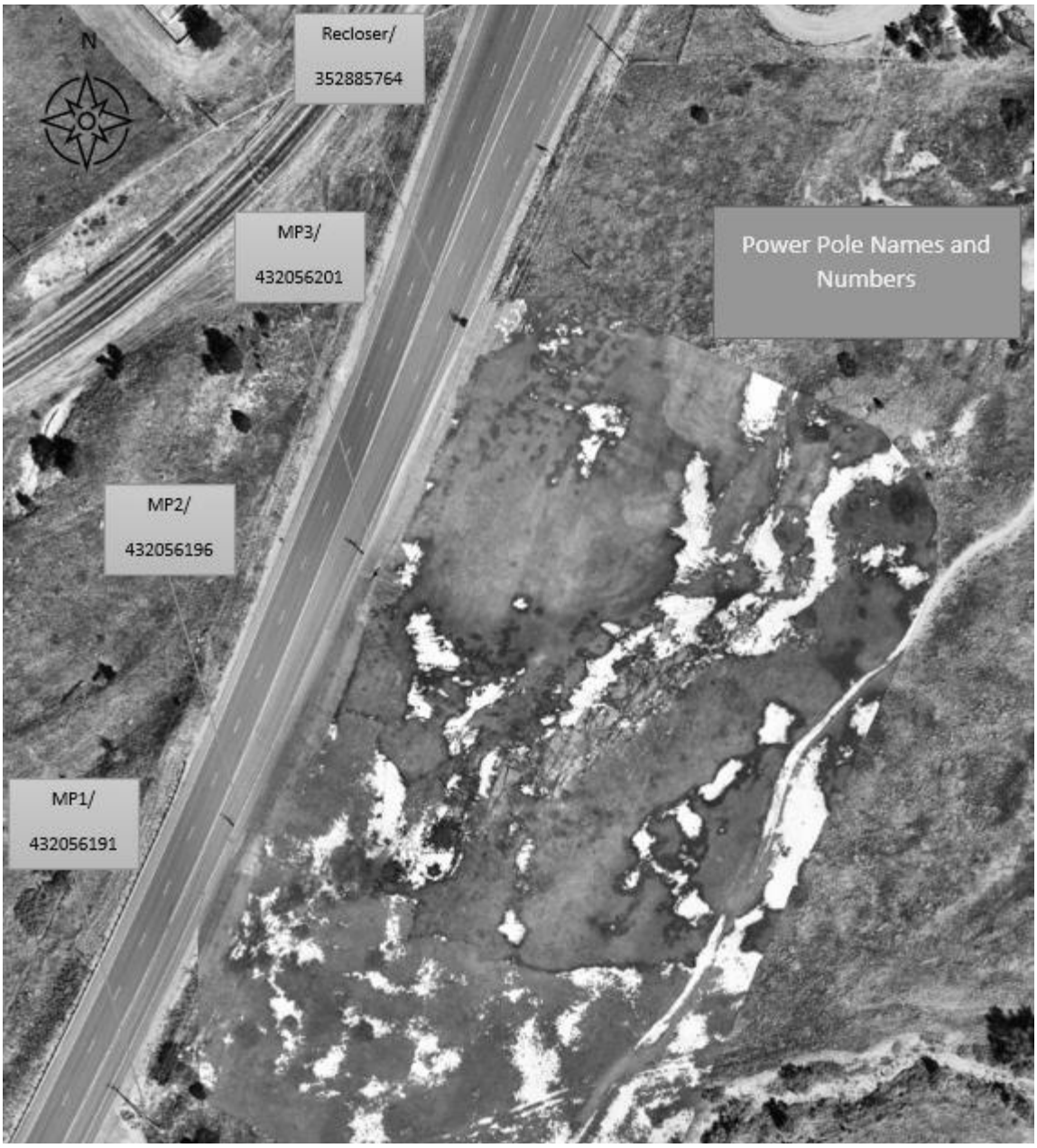

Figure 4. Excerpt from the Wildland Fire Origin and Cause Supplemental Incident Report, page 20.

Figure 5. Excerpt from the Wildland Fire Origin and Cause Supplemental Incident Report, page 20.

Figure 6. Google Earth image of the area of the Marshal Mesa Trailhead.

Figure 7. Google Earth image of the area of the Marshal Mesa Trailhead.

Figure 8. Gate Camera Pics 0810

Figure 9. Gate Camera Pics 0873. Time is actually 12:17:05pm

Figure 10. Gate Camera Pics 0874. Time is actually 12:20:00 pm.

Figure 11. Gate Camera Pics 0877. Time is actually 12:20:03 pm.

Figure 12. Gate Camera Pics 0877 enlarged. Note the tree indicated by the red circle.

Figure 13. Gate Camera Pics 0815 enlarged and lightened. Note the tree shown in Figure 12 is also circled in red. Also, Xcel Energy pole MP2 is indicated by the red arrow.

Figure 14. 12:21 pm Mike Zolowski video smoke plume present near MP2.

Figure 15.Gate camera folder 101RECNX, IMG_0815, cropped and enlarged.

Figure 16. Area of Xcel Energy pole MP2 image facing southeast.

Figure 17. Top of pole MP2 that shows the three phase conductors mounted to the top of the crossarm and supported by pin type insulators. Pin insulators are designed to support conductors on their top surfaces. This image was taken facing southwest.

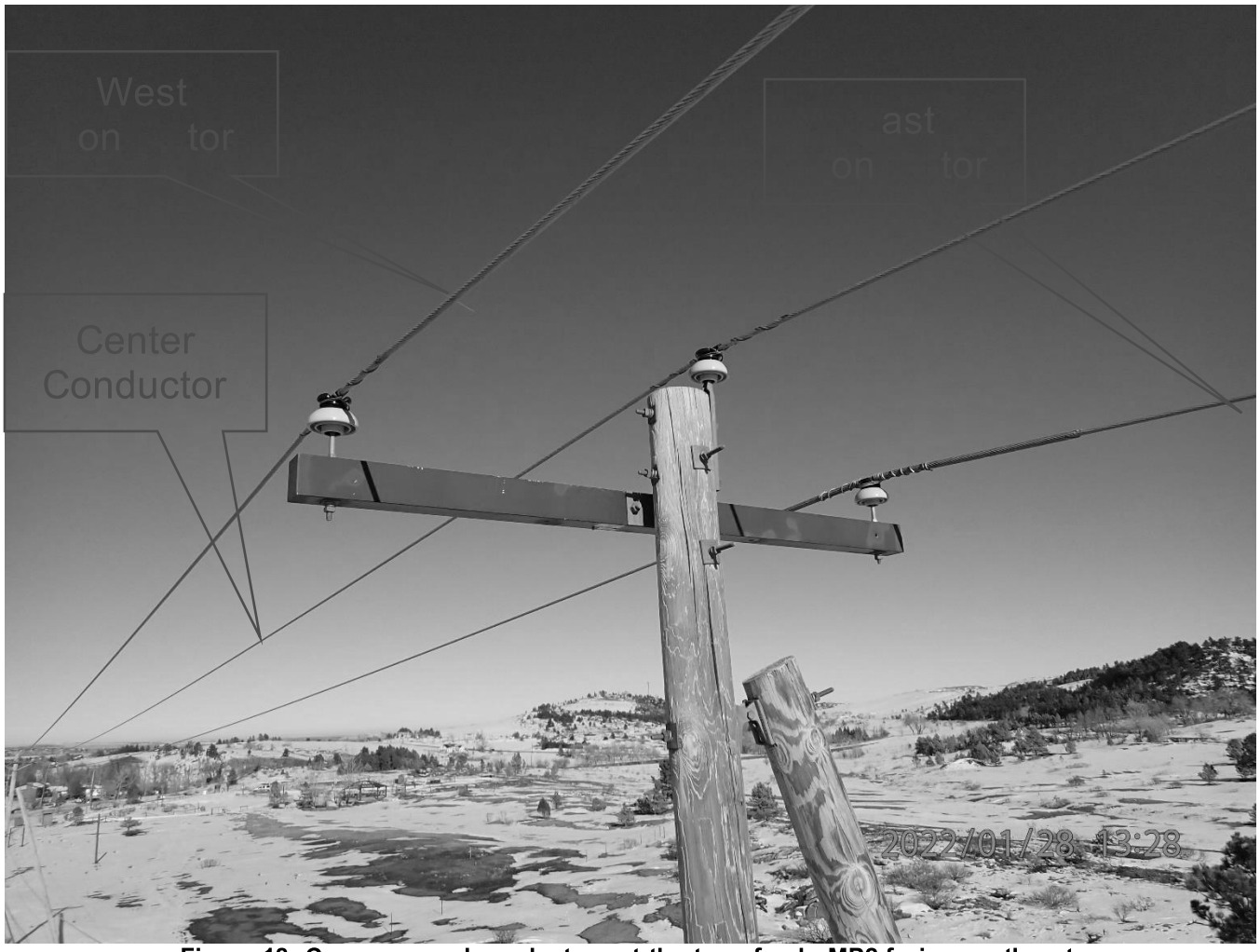

Figure 18. Crossarm and conductors at the top of pole MP2 facing northeast.

Figure 19. West phase pin insulator.

Figure 20. East phase conductor. Note that the lashing on this conductor had degraded and failed at the time of the fire and allowed the conductor to become displaced from the insulator. The lashing on the conductor was replaced after the fire.

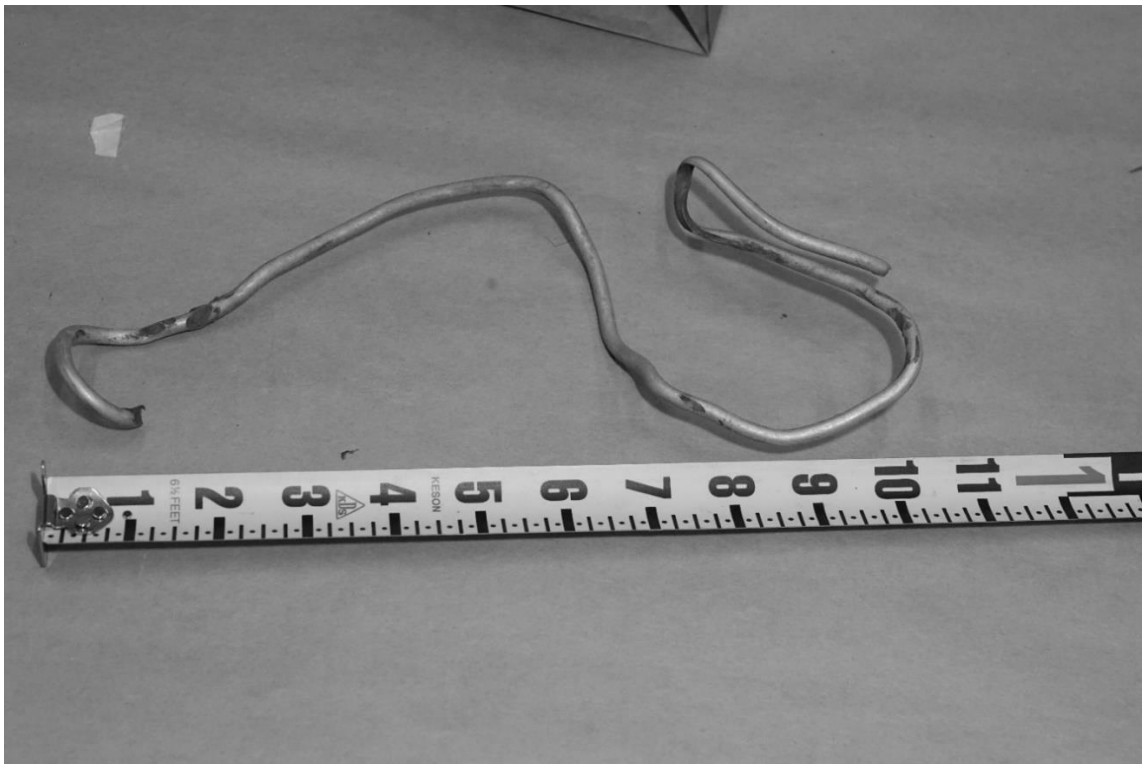

Figure 21. Failed lashing from the east conductor with evidence of wear and electrical arcing.

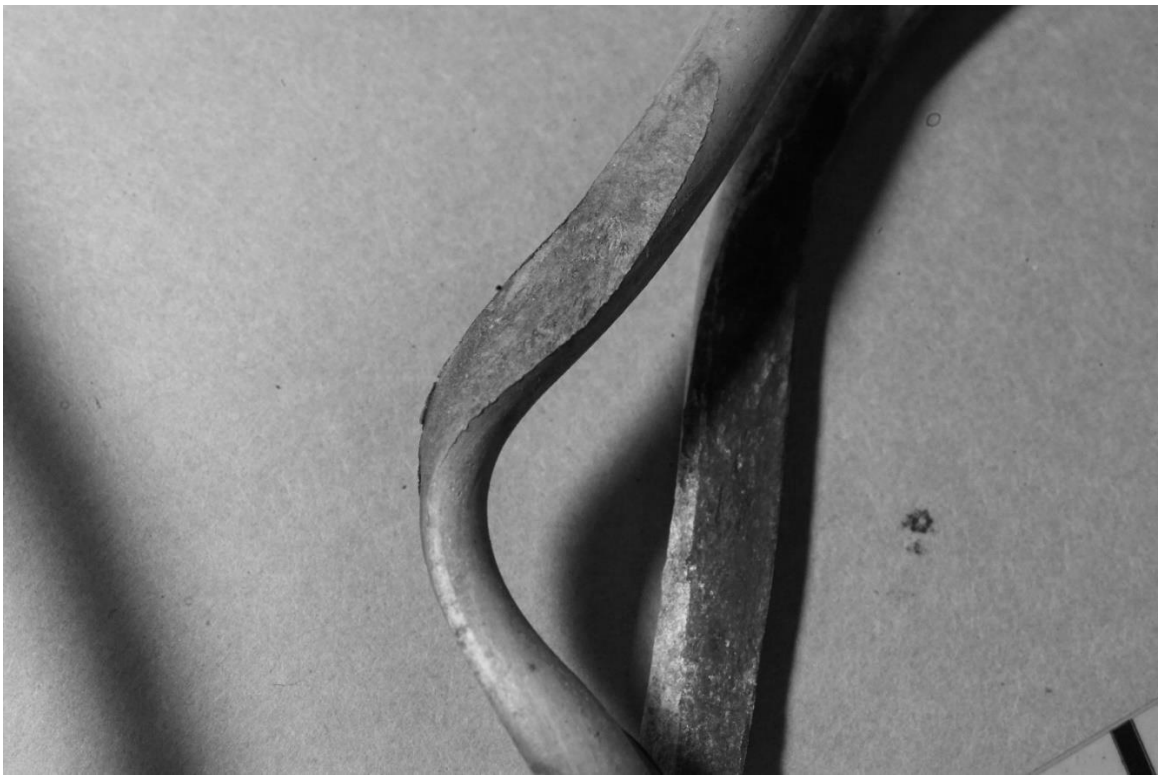

Figure 22. Failed lashing from the east conductor with evidence of wear and electrical arcing.

Figure 23. Evidence of electrical on the failed lashing.

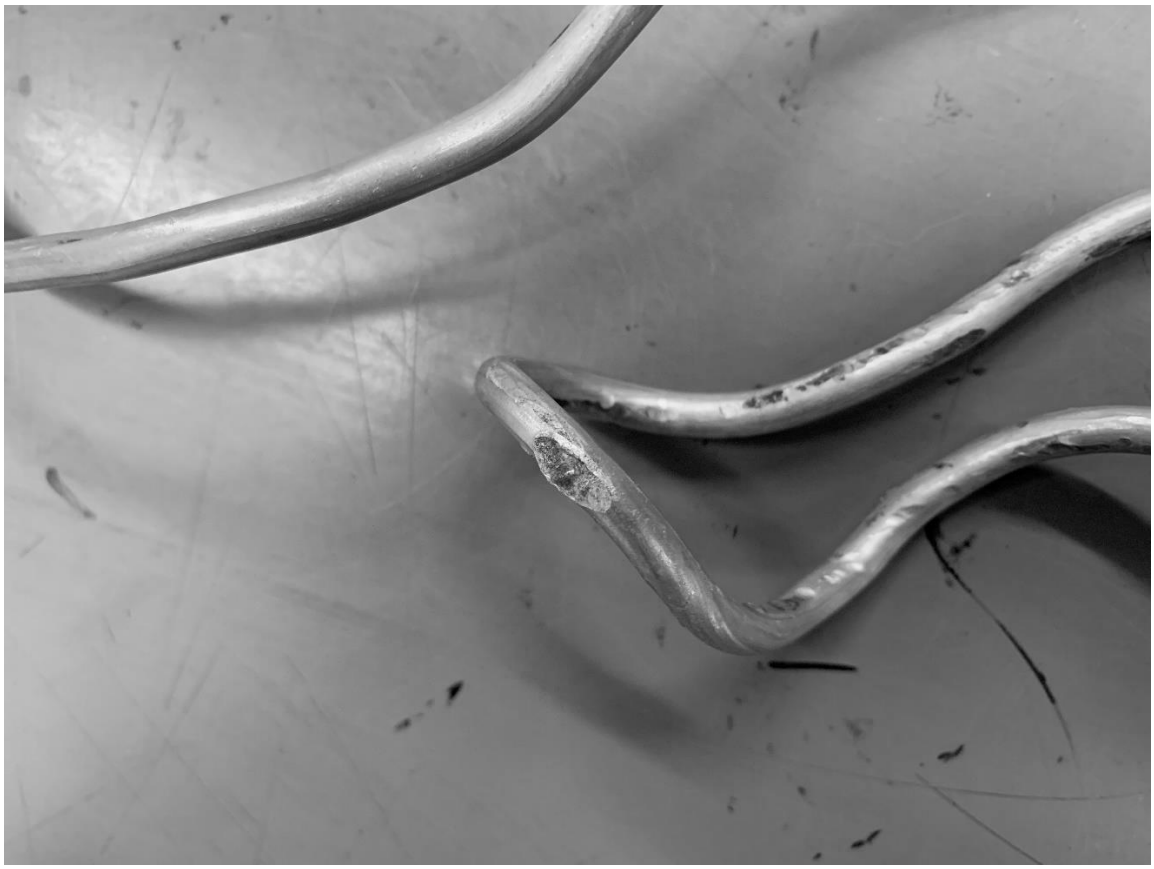

Figure 24. Evidence of electrical on the failed lashing

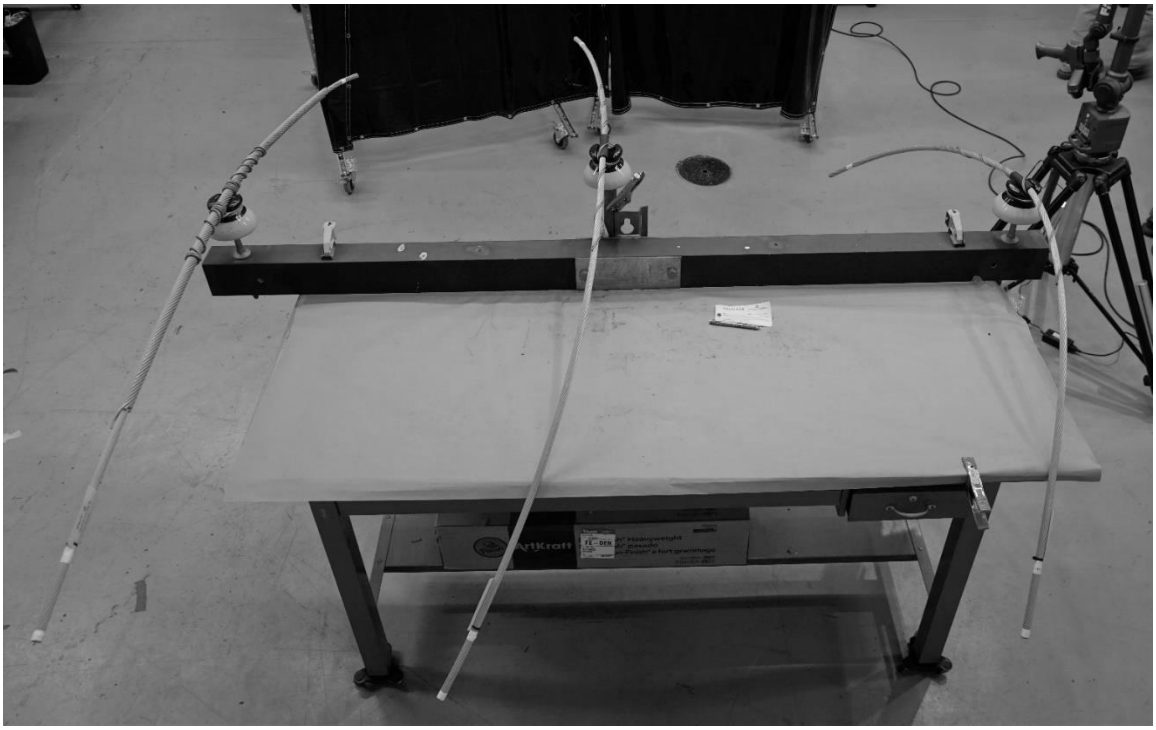

Figure 25. Crossarm and conductors reconstructed in the laboratory.

Figure 26. West phase insulator. Note evidence of electrical arcing on the lashing.

Figure 27. West Phase conductor with arc damage.

Figure 28. Center phase conductor

Figure 29. Arc evidence on the center phase conductor.

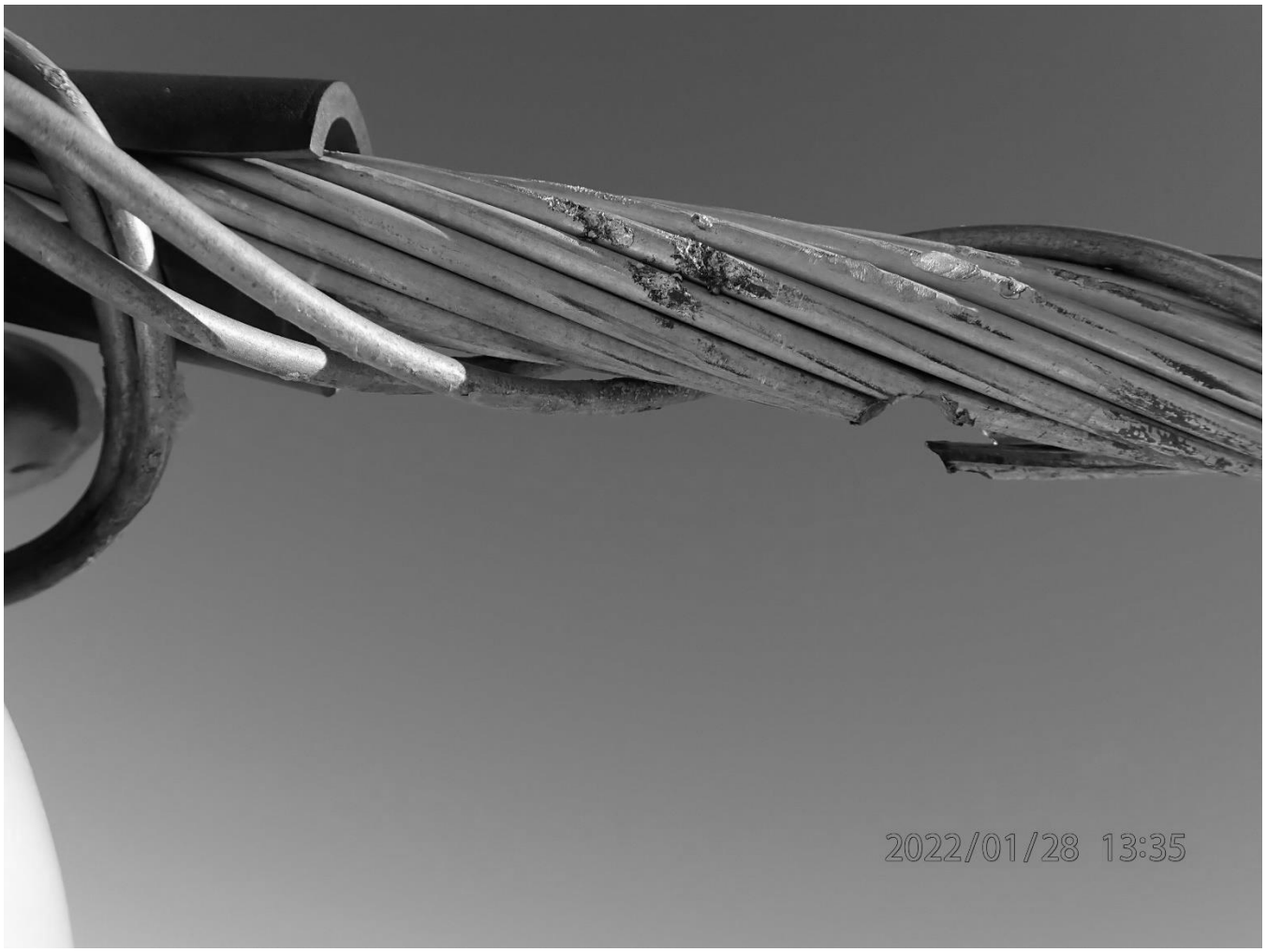

Figure 30. Arc evidence on the center phase conductor.

Figure 31. Electrical arcing on the center phase conductor.