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Re: Claim No.: Rimkus File: 100215553
TAI File: 3120801.0001
Incident: Hurricane Ridge Fire Origin and Cause | Electrical Evaluation
Subject: **Summary Report of Findings**

Dear Ms. Buechler and Ms. Lynch:

On May 7, 2023, a fire occurred to a two-story structure known as Hurricane Ridge Day Lodge located within Olympic National Park outside of Port Angeles, Washington. Port Angeles and Clallam County fire departments responded to and extinguished the fire.

On May 19, 2019, Rimkus and Talbott Associates, Inc. (TAI) were retained by Poole Fire Protection, Inc. under Indefinite Delivery, Indefinite Quantity Contract (IDIQ) Architect/Engineering (A/E) Fire Protection Engineering Contract (#140P2120D0006, Task Order #10) to determine the origin and cause of this fire.

During our investigation, we applied the methodology of fire investigation using the systematic approach, called the scientific method, as recommended in the current edition of the National Fire Protection Association's NFPA 921 - "Guide for Fire and Explosion Investigations" and in compliance with NFPA 1033 - "Standard for Professional Qualifications for Fire Investigator".

This summary report is based on information currently available and is subject to revision and expansion if additional data becomes available to TAI and Rimkus. The conclusions presented in this summary report are on a more probable than not basis. These probabilities are based upon application of engineering principles to the facts of the loss.

Selected photographs provided to us or taken during our investigation that are referenced in the report are included as figures. The remaining photographs will be provided in electronic format upon request.

1. CONCLUSIONS

1.1. A fire occurred at Hurricane Ridge Day Lodge (HRDL) between 9:06 a.m. and 10:41 a.m. on May 7, 2023. The fire was discovered that afternoon at approximately 4:30 p.m.

1.2. The fire most probably originated in the northeast portion of the main level of the lodge. See Figure 1.

Basis:

1.2.1. The oxidized metal roof panels observed were consistent with long burning fire within the defined area of fire origin.

1.2.2. The collapse and fire dynamics supported the initial burning within this region, followed by increased burning along the southern end of the lower level of the structure.

1.2.3. Evidence of electrical arcing was visible on multiple electrical panels and electrical conduits within the defined area of fire origin, consistent with fire attack while the conductors were energized. The electrical circuits providing power to these panels were later attacked by heat entering the lower level of the structure.

1.2.4. Determination of the area of fire origin was limited by the total burn time and the absence of passive fire protection (gypsum board) as part of the planned renovation. Gypsum board normally prevents or slows fire spread between different areas of a structure. However, the renovation of the HRDL meant that significant portions of the structure had the gypsum board removed at the time of the fire. This allowed the fire and heat to consume most of the available combustible materials.

Figure 1 – Area of Fire Origin – Pre-fire image.

1.3. The area of fire origin contained the ignition sources:

1.3.1.1. Makita brand lithium-ion batteries.

1.3.1.2. HILTI brand lithium-ion batteries.

1.3.1.3. Panel B (existing electrical panel in the theater area).

1.3.1.4. Failure of an unknown electrical hazard introduced by construction activity.

1.4. The specific cause of the fire could not be determined on a more probable than not basis. This was primarily due to the long burn time which destroyed vital fire patterns and induced failure of additional potential ignition sources. Additionally, the long burn time compromised the ability to conduct a complete failure analysis on the individual electrical products and components contained within the area of fire origin.

1.5. The last individuals, NPS Employee 1 and NPS Employee 2, as part of their duties to sample water in the restroom, entered the structure at approximately 8:36 a.m. on the morning of the fire and reported nothing unusual. It is unknown if they left light switches in the “on” position during their site visit to HRDL.

2. SCOPE OF INVESTIGATION

In the course of our work, we performed the following activities:

2.1. Performed an initial site inspection to determine the scope of work and site safety measures on July 12, 2023, and July 13, 2023. The following individuals attended the exam:

2.1.1. Taylor Bendt, Talbott Associates Inc, representing NPS

2.1.2. Chris Lyman, Rimkus, representing NPS

2.1.3. Amy Blades, ESi, representing JMG Constructors

2.1.4. Kari Myron, ALG, representing JMG Constructors

2.1.5. Scott Dau, FRT Investigation, representing JMG Constructors

2.1.6. Michael Fitz, ESi, representing JMG Constructors

2.1.7. Paul Josten, ESi, representing JMG Constructors

2.1.8. Derek Longeway, Firenze Engineering, representing Blue Mountain Electric

2.1.9. Steve Schrempp, NPS

2.1.10. John Spiegelberg, NEFCO, representing Pacific Northwest Environmental

2.1.11. Keith Robinson, NPS

2.1.12. Mickey Chisolm, NPS

2.1.13. Kevin Buckley, NPS

2.1.14. Doug Fields, Pacific Northwest Environmental

2.1.15. Jeff Granlee, JMG Constructors

2.1.16. Phil Fouts, The Fouts Group, representing Blue Mountain Electric

2.1.17. David Bridges, Meagher & Geer, representing Blue Mountain Electric

2.1.18. David Ahmuty, DMA, representing Pacific Northwest Environmental

2.1.19. Jeffrey Gonzales, Hi-Tech Electronics & Security

2.1.20. Stephanie Lynch, Department of the Interior, representing NPS

2.1.21. Lisa Buechler, Department of the Interior, representing, NPS

2.1.22. Sam Ellinger, JMG Constructors

2.2. Photographed, examined, and documented the extent of the fire damage to the structure.

2.3. Obtained and reviewed NPS drone documentation on August 3, 2023, and August 23, 2023.

2.4. Performed a destructive joint site examination on August 15, 2023, and August 16, 2023. The following individuals participated in the examination:

2.4.1. Taylor Bendt, Talbott Associates Inc, representing NPS

2.4.2. Chris Lyman, Rimkus, representing NPS

2.4.3. Scott Dau, FRT Investigation, representing JMG Constructors

2.4.4. Michael Fitz, ESi, representing JMG Constructors

2.4.5. Paul Josten, ESi, representing JMG Constructors

2.4.6. Tal Nagourney, ESi, representing JMG Constructors

2.4.7. Derek Longeway, Firenze Engineering, representing Blue Mountain Electric

2.4.8. Richard Jones, FIG, representing Blue Mountain Electric

2.4.9. John Spiegelberg, NEFCO, representing Pacific Northwest Environmental

2.4.10. Jeff Marsh, Jensen Hughes, representing Pacific Northwest Environmental

2.4.11. Omar Ortiz, NPS

2.4.12. Keith Robinson, NPS

2.4.13. David Bridges, Meagher & Geer, representing Blue Mountain Electric

2.4.14. Richard Martens, Martens Associates, representing NW Cascade

2.4.15. Andre Egel, Martens Associates, representing NW Cascade

2.4.16. Vytenis Babrauskas, Doctor Fire, representing NW Cascade

2.4.17. Pradeep Ramasubramanian, Exponent, representing HILTI

2.4.18. Shannon Ramey, Exponent, representing HILTI

2.4.19. Jeremiah Stepan, Exponent, representing HILTI

2.5. Interviewed various NPS employees with knowledge of the subject structure and the fire event.

2.6. Analyzed and reviewed the data listed below:

2.6.1. As built and construction submittal drawings.

2.6.2. Daily and weekly construction activity logs and photographs from the onsite contractors.

2.6.3. Reviewed webcam data obtained from NPS personnel.

2.6.4. Reviewed the Incident Management Analysis Reporting System (IMARS) reports received from NPS personnel.

3. BACKGROUND

3.1. The Hurricane Ridge Day Lodge (HRDL) was a two story, 12,200 square foot structure, constructed in 1952. The HRDL was built into a hill so that the main level was entered from the north at ground level. An additional lower floor could be entered from the south side of the building, down the slope. Figure 2 shows a side view of the lodge with entrances labeled. The structure was wood construction for the main floor with a concrete structure for the lower level. The structure had undergone numerous structural renovations in its lifetime. In particular, an additional roof was built above the original roof in the 1999 renovation. The 1999 renovation included use of glu-lam beams. Figure 3 shows the original lodge structure next to the structure at the time of the fire.

Figure 2 - HRDL Consruction - Entrances

Figure 3 - Original Lodge Structure (Left) and Stucture at time of the fire (Right)

3.2. The HRDL needed major updates to meet current structural, electrical, plumbing, mechanical, fire, and accessibility codes. In October 2022, JMG Constructors, LLC (JMG) was awarded the contract 140P2023C0024 to rehabilitate the HRDL. The scope of work included demolition and reconstruction of portions of the historic lodge. The first stages of construction involved mobilization, temporary power, temporary facilities, and demolition on all levels of the lodge.

3.3. On Sunday, May 7, 2023, a fire occurred at HRDL. The fire was discovered by two NPS rangers at approximately 4:30 p.m. Fire suppression personnel from Port Angeles and Clallam County fire departments responded and attempted to suppress the fire with limited water supply. Fire suppression personnel focused on preventing the spread of the fire until the fire decayed. Photographs reviewed of early firefighting efforts indicated the structure sustained significant structural collapse prior totheir arrival. See Figure 4. It is unknown when the fire started due to the fog level and elevation of the loss location concealing the fire. The fire alarm system at the HRDL was not monitored by a third-party fire alarm company. The fire alarm system was a local alarm system only.

Figure 4 - Fire Fighters at HRDL on May 7, 2023.

3.4. At the time of the fire, the structure was supplied with 240-Volt electrical service. There were no natural gas or other combustion fuel sources used in the structure. The demolition project began in the first phases of the rehabilitation project led by JMG personnel. JMG had two primary sub-contractors performing the demolition leading up to the fire:

3.4.1. Blue Mountain Electric (BME), an electrical contractor. Their scope of work included locking out electrical circuits, demolishing, and performing work on electrical circuits.

3.4.2. Pacific Northwest Environmental (PNE), a demolition contractor. Their scope of work included the removal of the interior wood paneling, ceiling tiles, and deconstructing portions of the structure per the scope of work.

3.5. In the winter of 2022, the structures boiler reportedly failed, and heat was temporarily being supplied to the structure with portable radiator style heaters. See Figure 5. The heaters were initially installed by NPS employees and were taken out of service as the demolition process progressed. At the time of the fire, a few radiant heaters were observed being utilized in bathrooms within the structure.

Figure 5 - Radiant Heaters utilized at HRDL. (April 19, 2023)

3.6. Work on the HRDL was still in the early stages. The JMG construction management trailer was located along the northwest exterior corner of the structure. At the time of the fire, the trailer did not have power supplied to it. Webcam data supports that work performed by the contractors ended on Thursday, May 4, 2023 at approximately 5:20 p.m.. At this time, all JMG, BME, and PNE employees departed the site for the weekend.

3.7. Two webcams were affixed to the structure which updated approximately every five minutes. The north webcam captured a portion of the parking lot looking northeast. The south webcam captured views of Mt. Olympus to the southwest.

3.8. On May 7, 2023, between 8:36 a.m. and 9:06 a.m., the day of the fire event, two individuals were observed on the north exterior webcam. See Figure 6. Both individuals were identified as NPS employees; NPS Employee 1 and NPS Employee 2.

3.8.1. NPS Employee 1 was onsite performing water residual testing as part of his normal work duties. NPS Employee 1 reported that everything seemed normal at the time of his visit. He reported looking around in the main level lobby but did not venture into the structure. NPS Employee 1 reported no unusual sounds or smells during that time.

3.8.2. NPS Employee 2 was changing out the toilet paper rolls for larger rolls in the temporary restrooms in preparation for the opening of the park in the near future. NPS Employee 2 reportedly walked around the interior of the lodge on both levels of the structure out of curiosity of the recent demolition work conducted. He stated the interior walls and ceiling spaces were exposed and in a “demolished state”. He did not observe anything out of the ordinary. NPS Employee 2 recalled walking through the theater area and the gift shop. NPS

Employee 2did not recall anything specific except that he noticed the presence of Makita power tools. At the time, NPS Employee 2 was looking to purchase new portable tools and was interested in the Makita brand. NPS Employee 2 reported that he may have turned on light switches out of habit, but most of the switches did not operate the lights. He did not recall if he turned the light switches to the "off" position or not. NPS Employee 2 did not notice any smells or sounds which would have indicated a fire event at that time.

3.9. At approximately 8:51 a.m., NPS Employee 1 and NPS Employee 2 relocated their truck along the east side exterior of the subject structure to the location of the portable bathroom trailers to prepare for opening of the park. At approximately 9:06 a.m., their truck was no longer captured by the webcam surveillance video.

Figure 6 - North webcam - 8:36 a.m. and 9:06 a.m. May 7, 2023.

3.10. Following their duties, NPS Employee 1 and NPS Employee 2 traveled down the mountain together and did not report any other vehicle passing them. NPS Employee 1 reported that the gate was closed and locked and they did not have any unexpected traffic during their visit.

3.11. At approximately 10:41 a.m., the north webcam stopped updating. No unusual activity or indication of fire was captured by the webcam surveillance video between 9:06 a.m. and 10:41 a.m. Refer to the final webcam images in Figure 7. All the north webcam images from May 7, 2023 are included at Appendix A to show all activity in this time frame.

Figure 7 - Final HRDL Webcam Images. 10:41 a.m. (left) and 10:36 a.m. (right).

3.12. At approximately 10:41 a.m., NPS personnel were alerted that HRDL lost communications with their information technology (IT) and webcam system. NPS personnel reported this was not an unusual occurrence as the internet for the webcams at the lodge were unreliable and frequently went down. The southern webcam stopped updating at approximately 10:37 a.m. No indication of fire was observed by the south webcam surveillance video prior to losing communications. All the southern webcam images for May 7, 2023 are included as Appendix B. About the same time communications were lost, IMARS reports indicated that NPS personnel reported the radio system was not functioning. Both the radio and IT systems were controlled through the same network cabinet housed in the attic on the east end of the HRDL.

3.13. At approximately 4:30 p.m., Ranger 1 and Ranger 2 arrived onsite and observed the HRDL structure mostly burned to the ground, with only the masonry chimneys intact. They observed spot fires in the lower level of the structure and miscellaneous contractor combustible materials on fire along the north side main level of the structure.

3.14. The IMARS incident reports indicated the fire was still burning primarily in the lower levels of the structure in the area of the western elevator shaft, western stairwell, and restrooms when fire suppression efforts were abandoned due to a lack of a water supply.

3.15. The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) performed an initial, nondestructive examination with NPS personnel present. ATF personnel reportedly did not enter the structure to conduct an origin and cause investigation. ATF personnel performed interviews of individuals involved with HRDL. TAI and Rimkus have not had the opportunity to review the ATF reports or documents from their investigation. However, ATF declared to NPS personnel there was no indication of criminal activity.

3.16. Poole Fire, Rimkus, and Talbott Associates were engaged by NPS to conduct a fire origin and cause investigation and electrical evaluation of the subject structure.

4. DATA AND OBSERVATIONS

The following data and observations were documented throughout the course of the investigation and are organized herein to illustrate their connections. This is not a chronological presentation of the facts as they were observed.

4.1. The subject structure was constructed primarily of large dimensional lumber, glue laminated timber (glulam), and finished with wood paneling. See Figure 8.

Figure 8 - Prefire photograph of the lounge and exhibits area (Google Maps).

4.2. During the renovation project, significant portions of the wood paneling, ceiling, gypsum board, and other materials were removed prior to the fire. Prior to the fire event, weekly and daily activity logs and photographs show exposed wood structural members throughout most of the interior of the structure. Figure 9, Figure 10, Figure 11, and Figure 12 show examples of the state of the lodge during the demolition progression. Each figure shows a map with a blue circle denoting the approximate position of the photographer and a triangle showing the direction and field of view.

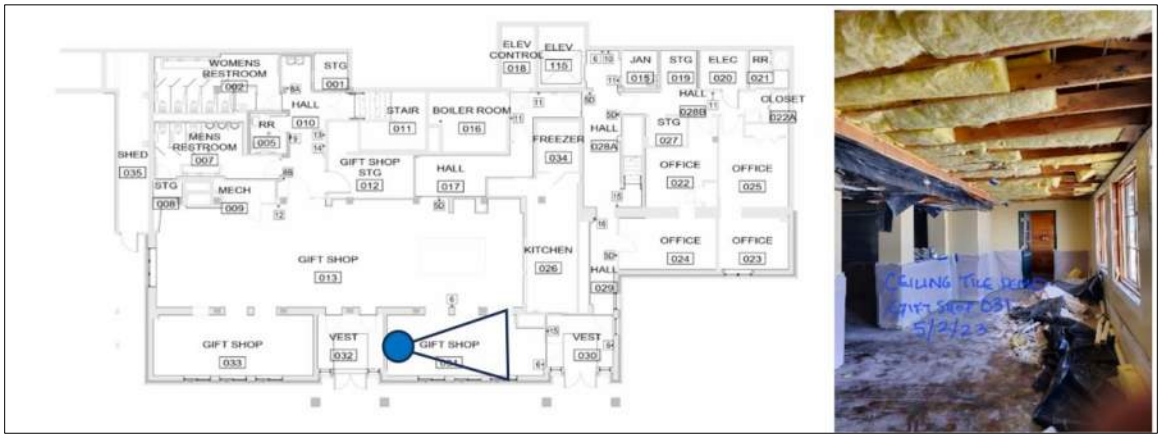

Figure 9- Exposed wood beams in the Gift Shop (Lower level, facing east, May 2, 2023).

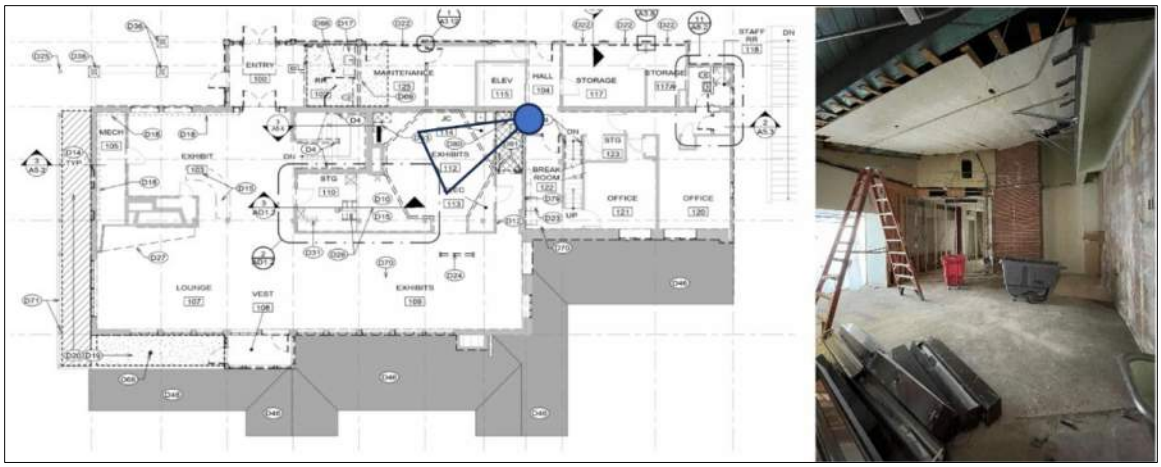

Figure 10 - Exposed wood structure near the "Theater" Area (Main level, facing west, April 27, 2023).

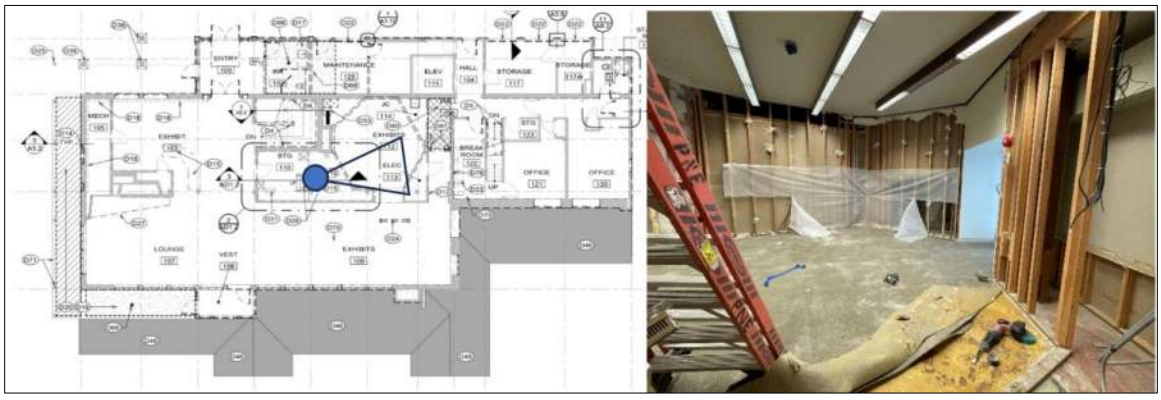

Figure 11- Exposed wood structure near the "Theater" Area (Main level, facing east, April 25, 2023)

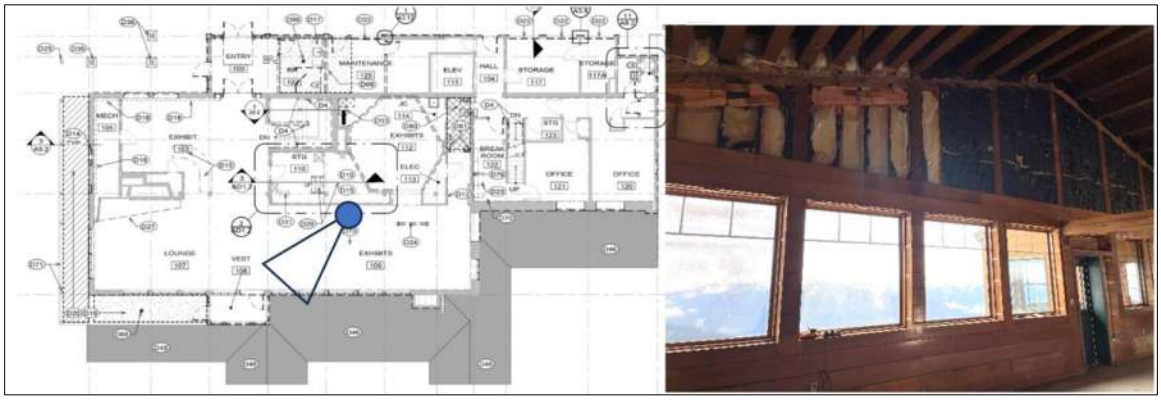

Figure 12 - Exposed wood structure in the Lounge Area (Main level, facing southwest, May 4, 2023).

4.3. Following the fire event, substantial fire and heat damage to the main level was evident from the complete consumption of the major structural elements. Nearly all the glulam beams and wood framing components were consumed by fire and heat.

4.4. Drone images showed metal roof panels with intense oxidation along the northern region of the peak near the upper main roof structure. This region is shown in Figure 13 with a dashed yellow circle.

4.5. Drone images indicated the southern half of the roof collapsed toward the south. Arrows are included in Figure 13 to show the shifted direction of the metal roof materials. The northern portion of the roof collapsed directly down onto the main level of the structure.

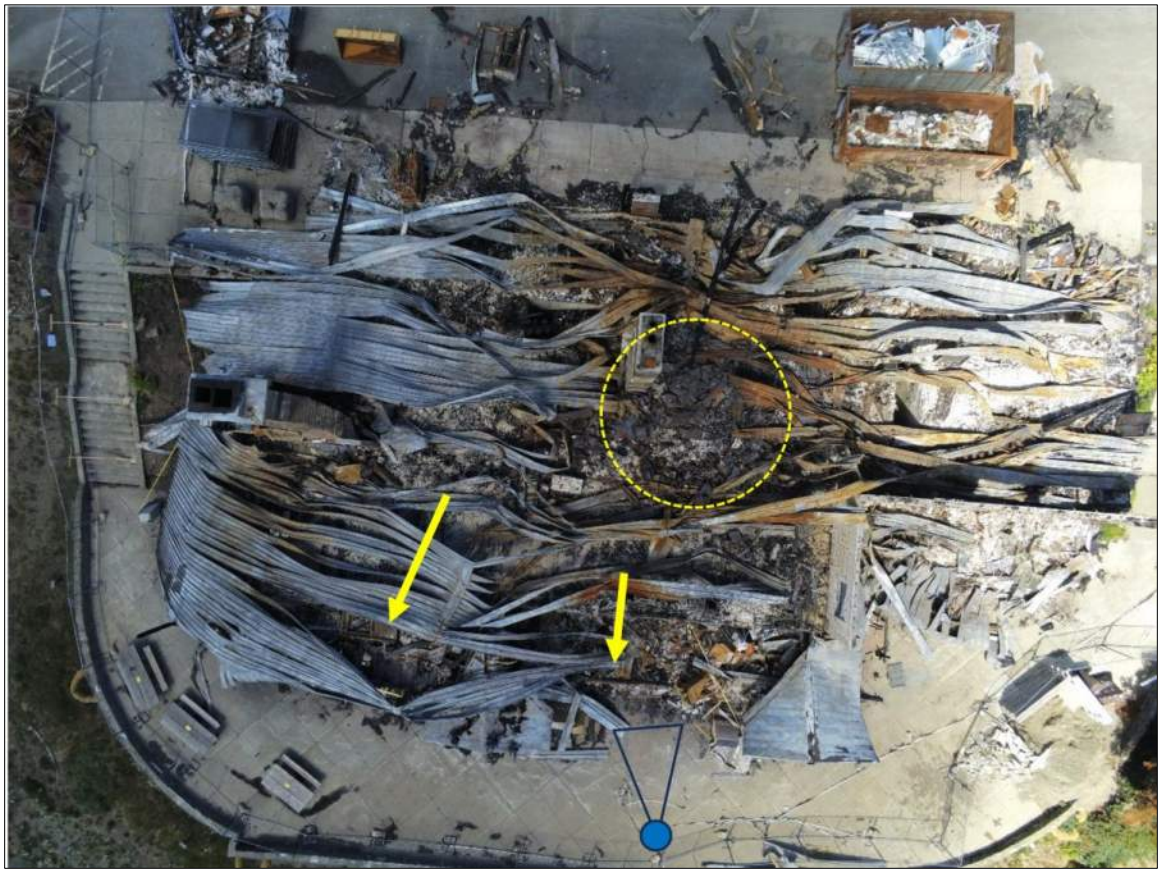

Figure 13 – NPS Drone Image – Roof Details - August 8, 2023.

4.6. The southern edge of the concrete structure sustained substantial fire and heat damage on the lower level. Figure 14 shows this area as photographed from the position shown in Figure 13.

4.7. Metal brackets used to anchor large wooden columns to the surface of the concrete were bent to the south, consistent with structural collapse of an intact southern portion of the structure. See Figure 15.

Figure 14 - South side of the concrete structure (looking north, August 17, 2023, TJB).

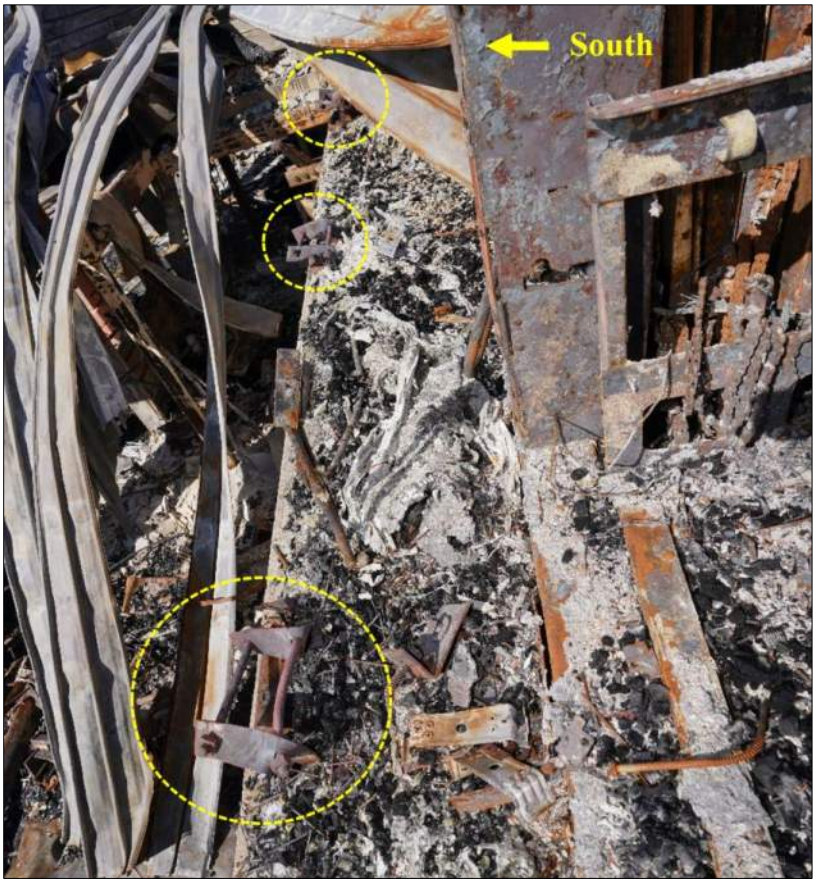

Figure 15 - Column brackets bent toward the southern exterior of the structure. (August 16, 2023, TJB)

4.8. Looking in the area directly below the damaged column brackets indicated significant spalling damage to the concrete ceiling of what was the concessions area. See Figure 16.

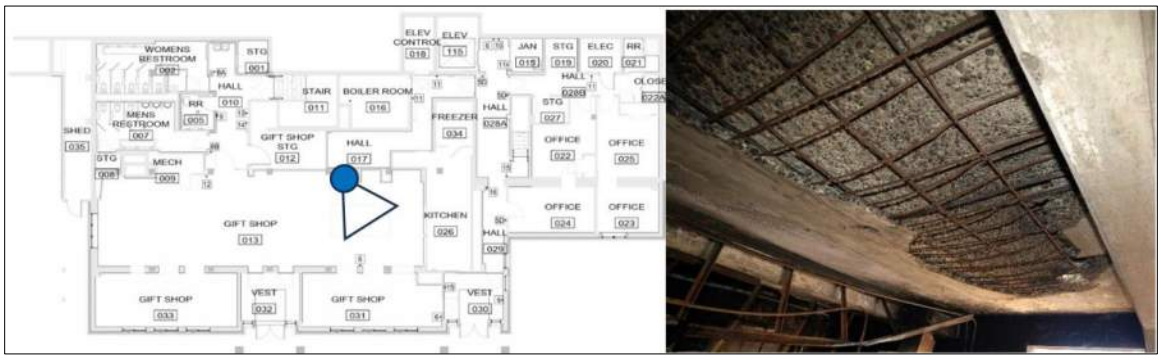

Figure 16 - Concession area spalling (Lower level - South end, August 15, 2023, TJB).

4.9. Looking northeast into the hallway between the kitchen and freezer on the lower level. The fire and heat damage indicated vertical fire travel from the concessions area laterally toward and vertically up the eastern stairwell. See Figure 17.

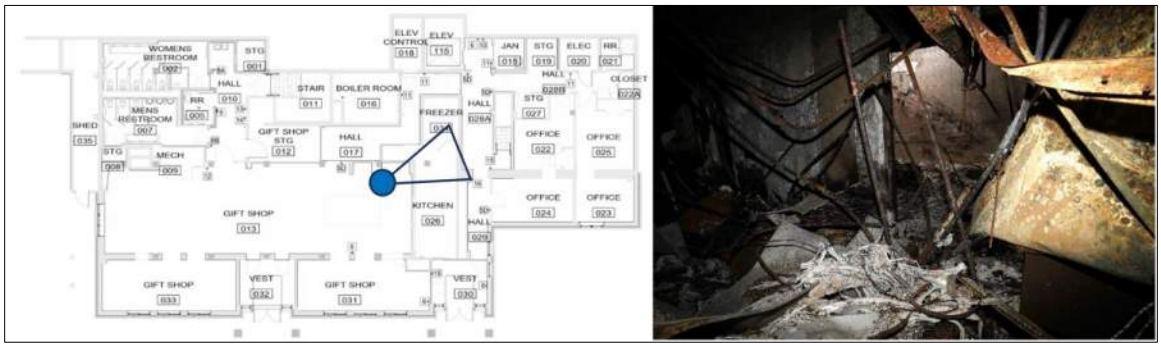

Figure 17 - Damage to kitchen and stairwell (Lower Level, July 12, 2023, TJB).

4.10. The northeastern area of the lower level had decreased fire and heat damage when compared to the other portions of the structure. Multiple wood doors and frames were intact with minimal heat damage observed to the electrical components. See Figure 18.

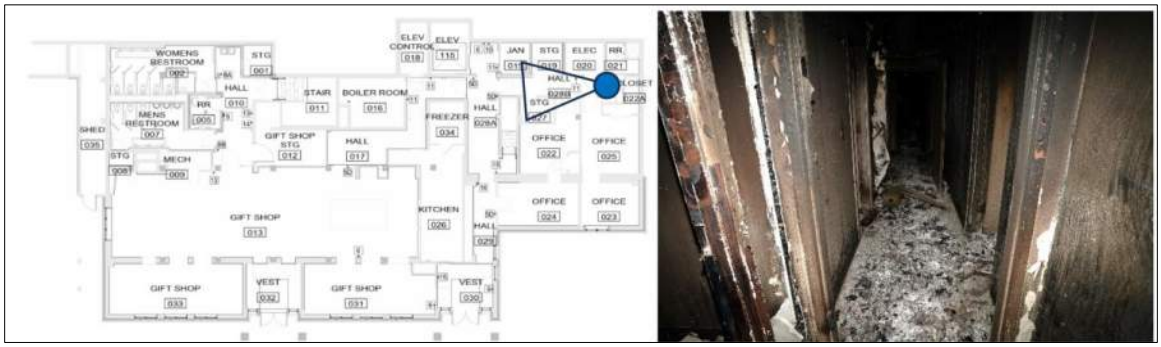

Figure 18 - Northeast hallway (Lower Level, July 12, 2023, TJB).

4.11. The fire patterns in the lower level indicated fire travel from the southern windows of the structure in a northeasterly direction. Protected and damaged areas are shown in Figure 19. Green blocks indicate less burned areas with no visible low burn to the walls. The red area represents increased burn patterns from a south to north direction. Solid red arrows show a path of increased fire damage from the kitchen and freezer area on the lower level toward the eastern stairwell.

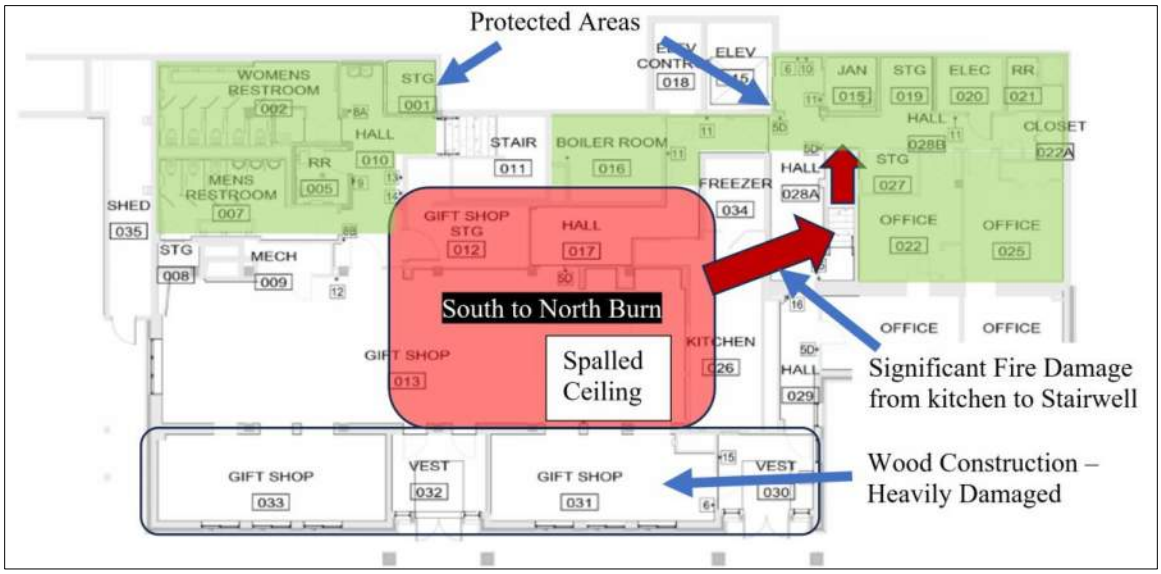

Figure 19 – Lower-Level relative damage map.

4.12. Between August 15 and 16, 2023, the processing of the main level consisted of the use of an excavator to remove fire-damaged metal roofing and debris from the surface to examine the area. This area was examined and processed with hand tools. Drone photographs taken on August 22, 2023, show the extent of the processing conducted at the loss location. See Figure 20.

***Figure 20 – NPS Drone Image - August 22, 2023*.**

4.13. The tool batteries owned by JMG, PNE and BME were identified within the processed areas. These areas are shown on Figure 21. Ownership of the tools was based upon the reported storage locations from representatives for each party present at the time of the examination.

4.13.1. JMG tools were observed along the western end of the structure near the main entry on the main level of the structure. JMG personnel reported using DeWalt brand tools. The battery cell strapping, and the circuit boards were consistent with DeWalt lithium-ion batteries. These tools were located as shown by the blue dot on Figure 21. See Figure 22.

4.13.2. BME tools were observed along the north (centrally located) area of the structure as shown in Figure 21. This was within the area of fire origin determined during this investigation. BME did not report which brand of tools they used. The strapping and circuit boards on the tool batteries were consistent with a Makita brand lithium-ion batteries. See Figure 23.

4.13.3. PNE tools were observed along the north northeastern interior on the main level of the structure as shown in Figure 21. This was within the area of fire origin determined during this investigation. PNE reported using HILTI brand tools. The tool battery strapping was consistent with HILTI lithium-ion batteries. See Figure 24.

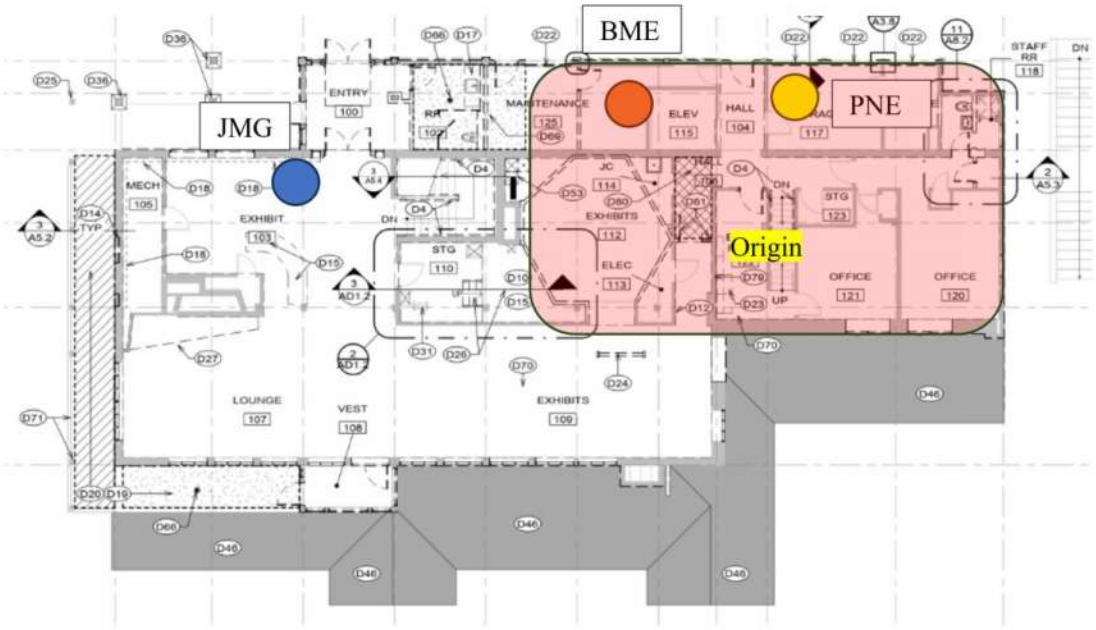

Figure 21 - Approximate tool battery locations.

Figure 22 - JMG - DeWalt battery. (August 17, 2023, TJB)

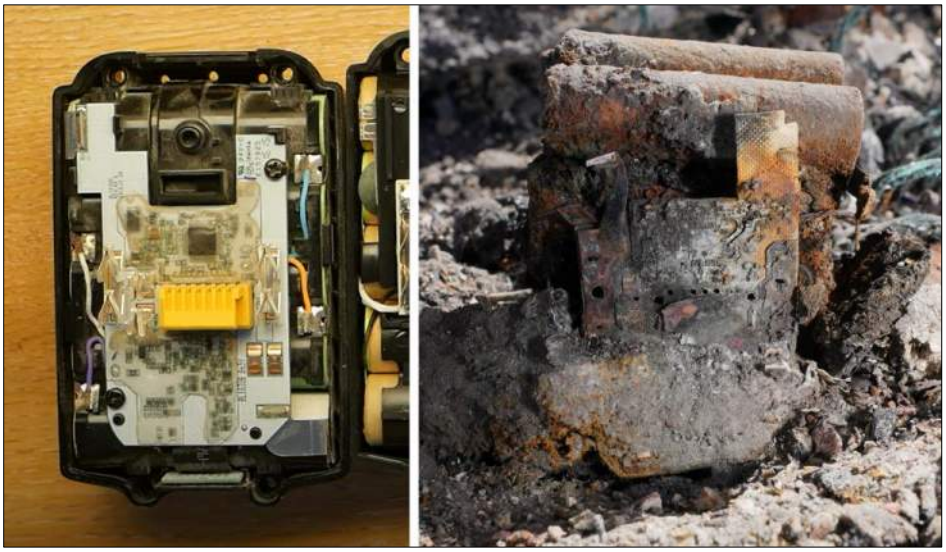

Figure 23 - BME - Makita battery. (August 16, 2023, TJB)

Figure 24 - PNE - HILTI battery. (August 16, 2023, TJB)

4.14. Electrical distribution (breaker) panels were located in two regions of the HRDL. A one-line diagram indicates the following panels in the structure. See Figure 25:

4.14.1. Panel A: Lower level
4.14.2. Panel K: Lower level
4.14.3. Panel B: Main level
4.14.4. Panel XA: Fed from generator transfer switch.
4.14.5. Panel XB: Fed from generator transfer switch.

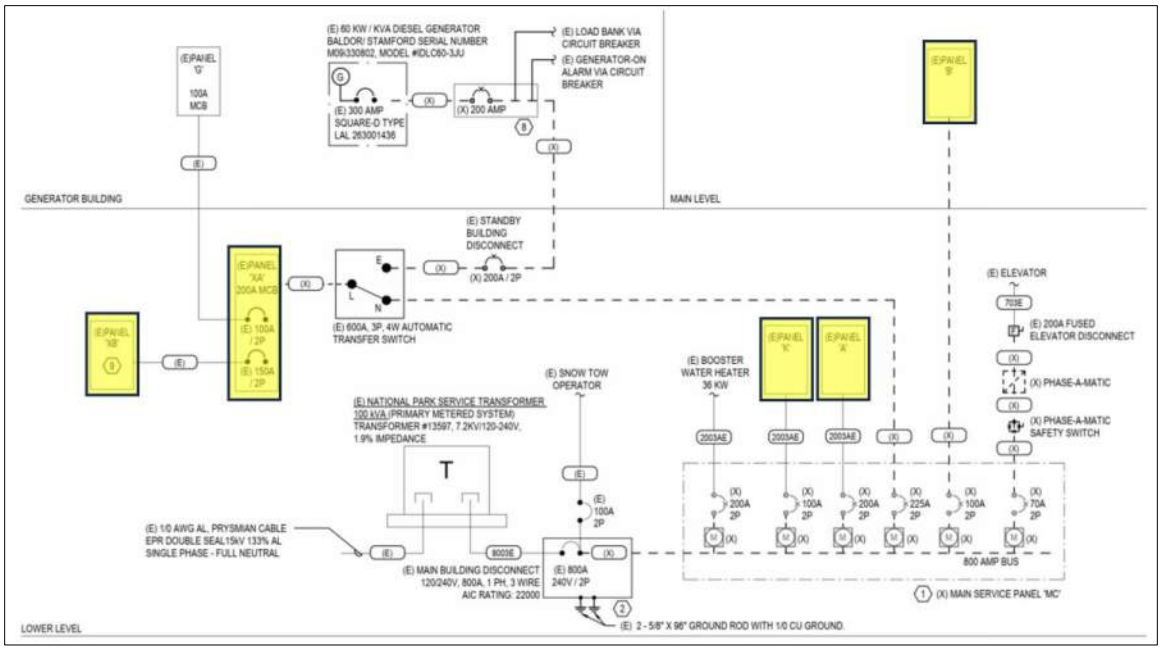

Figure 25 - Existing One-line with electrical panel highlights.

4.15. The electrical panel locations are shown in Figure 26. This figure has each panel labeled with a single or double letter designation. Additionally, the service entrance (metering room) is labeled as “M”.

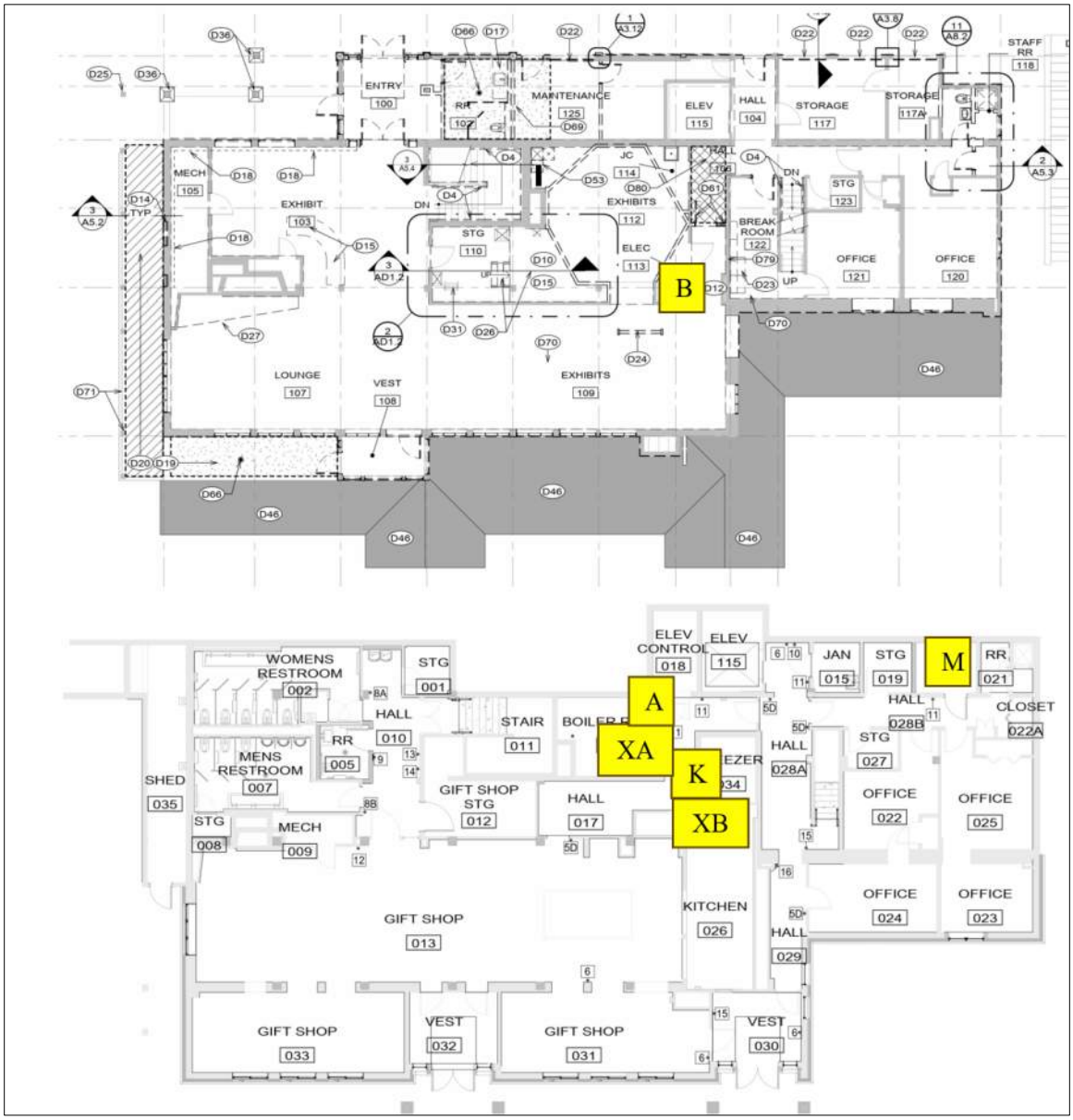

Figure 26 - Panel locations (Main and Lower Levels).

4.16. The service entrance, or metering gear, was located along the northeast corner of the lower level as shown in Figure 26. This area was minimally damaged by the fire and showed minimal heat exposure. See Figure 27.

4.17. Six circuit breakers in the metering gear were found in the “tripped” position at the time of the inspection. This indicated there was an electrical short circuit downstream of each breaker.

4.18. The fire alarm panel sustained minimal heat and soot deposition to the conductors and housing. The panel was a Pyrotronics System-3 controller which did not log the

date, the time, or record alarms. The alarm panel was not monitored at a third-party company. See Figure 28.

Figure 27 - Service entrance metering gear. (August 15, 2023, TJB)

Figure 28 - Pyrotronics System-3 Fire Alarm Panel. (August 15, 2023, TJB)

4.19. Electrical panels identified as panel A and XA both exhibited minimal heat exposure but were otherwise undamaged by fire. They showed intact insulation and undamaged circuit breakers. Panel A is shown in Figure 29 for comparison of fire exposure to panels K and XB.

4.20. Panel A showed evidence of lockout devices on the circuit breakers.

4.21. Panel A showed evidence of pre-existing water penetration and corrosion.

4.22. Panels K and XB were located past a metal door directly to the south of panels A and XA as shown in Figure 26. These panels showed increased fire damage compared to other panels on the lower level. See Figure 30.

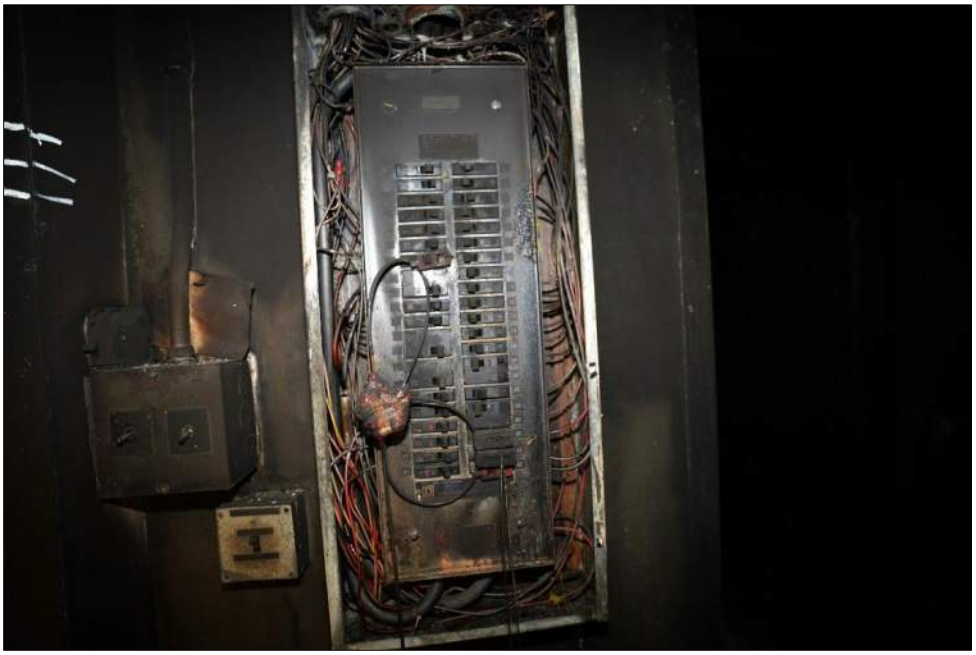

Figure 29 - Panel A (August 15, 2023, TJB)

Figure 30 - Panel K (Left) and XB (Right). (August 16, 2023, TJB)

4.23. Panel XB supplied power to a small distribution panel on the main level which indicated evidence of arcing on the supply conduits. See Figure 31.

Figure 31 - Arced conduits from the main level (Fed from XB). (August 16, 2023, TJB)

4.24. Panel B was located in the heavily demolished theater area on the main level of the structure. See Figure 26 for panel location. The conditions of this room are shown in Figure 10 and Figure 11. This panel had evidence of electrical arcing through the steel enclosure. See Figure 32.

Figure 32 - Panel B (August 16, 2023, TJB)

4.25. Indications of electrical arcing were observed in the areas near the JMG, BME, and PNE tools, as well as panel B. This indicated power was still available to the main level at the time of fire attack.

4.26. Evidence of electrical arcing was observed on electrical conductors which fell into the western stairwell.

4.27. The IT/Network cabinet was located along the northeast area on the main level, as shown in Figure 33.

4.28. The IT/Network cabinet was located in the attic above the eastern stairwell. This attic was enclosed with fire blocking and was not scheduled to have any walls demolished during the renovation project.

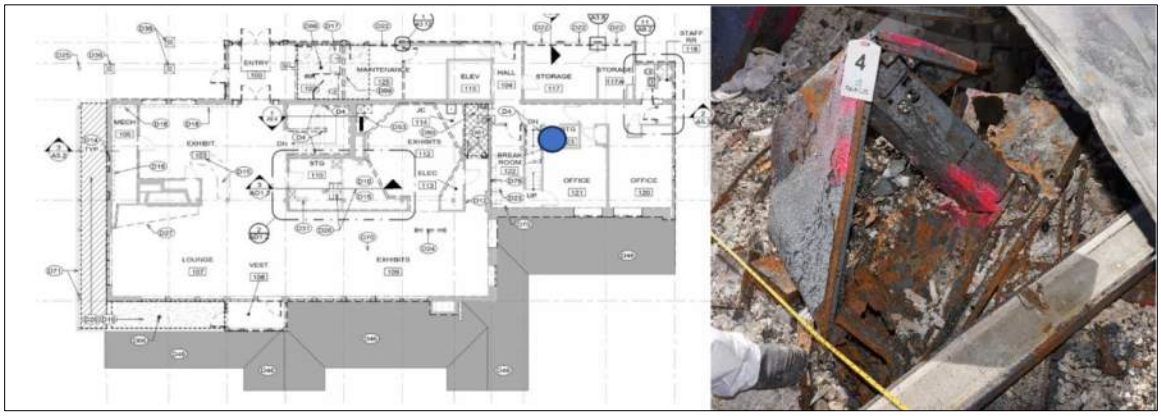

Figure 33 - IT/Network Cabinet. (August 16, 2023, TJB)

4.29. A radiant heater was observed along the northeast portion of the structure. The heater most likely was used to prevent freezing of the bathroom plumbing. See Figure 34. This was not the bathroom used for water sampling by NPS Employee 1.

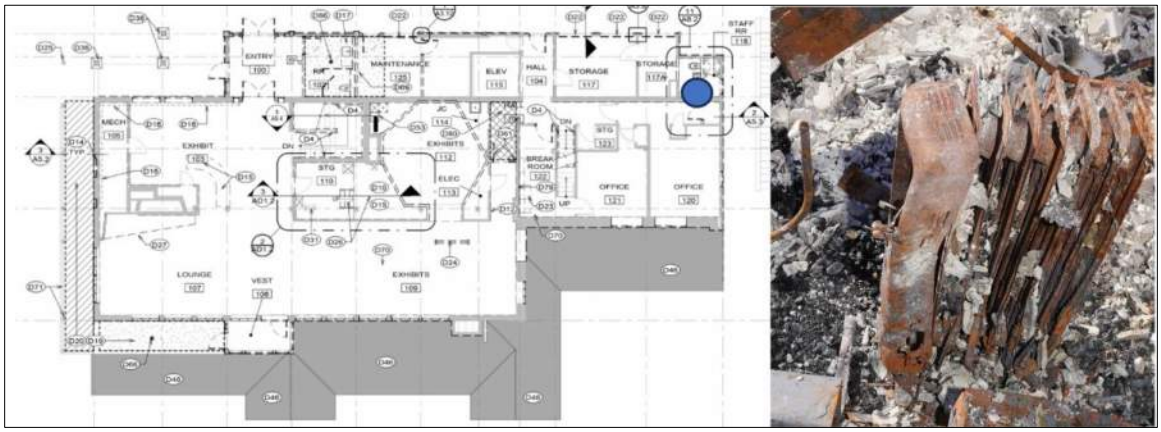

Figure 34 - Radiant heater observed along the northeast area on the main level. (August 16, 2023, TJB)

4.30. Miscellaneous tools, batteries, and fire-damaged equipment were observed on both levels of the structure. Photographs are available upon request.

5. ANALYSIS AND DISCUSSION

5.1. The fire origin and fire dynamics analysis was conducted by J. Christopher Lyman, IAAI-CFI (V), Fire Practice Leader:

5.1.1. Based upon the analysis of the available evidence and as discussed in this section, the fire most likely originated on the main level of the structure in the area shown on Figure 1. This section discusses the basis of this conclusion using observations from the least damaged area to the most fire-damaged area (the area of origin).

5.1.2. The last areas witnessed as burning, by the fire department, were the restrooms on the lower level of the structure.

5.1.3. The damage within the lower level of the structure was consistent with fire primarily burning from gift shop area, on the south end of the lower level, and following the natural vertical chimney of the eastern stairwell. For this to be an effective chimney, the main floor of the structure would need to have already been compromised by the fire. This supports that the fire did spread on the lower level until the roof above the eastern stairwell had been compromised.

5.1.4. The metal roof panels observed along the southern exterior side of the structure fell outwards indicating fire direction and spread. In order for the southern portion of the structure to collapse to the south, the roof structure to the north was compromised by the fire. This enabled the south end to freely fall toward the south. This was consistent with the heavy oxidation and damage observed to the metal roof panels and remaining fire debris shown in Figure 13.

5.1.5. Figure 35 shows two roof levels on the sloped portion of the structure. Each of these would need to be compromised in order to allow the entire southern end of the structure to collapse in the manner it did. This analysis indicates the fire most likely occurred in the area under the lower roof of the structure.

5.1.6. If the fire originated in the attic (with the network/IT equipment) or the interstitial space between the two roofs, shown in green in Figure 35, then the main roof would have collapsed onto the lower roof structure. This would have resulted in the entire roof structure being pulled to the south when the structure collapsed to the south. However, the north portions of the roof collapsed directly downward and did not shift to the south. Thus, the fire most probably did not originate in the attic.

5.1.7. The metal roofing material of theold roof peak, circled in green on Figure 35 did not exhibit increased oxidation or damage when compared to the new roof peak materials, circled in red. This observation supports the fire originating to

the east of the masonry chimney shown in Figure 35. The chimney, boxed in blue, and stairwell most likely provided a fire block which partially isolated the western side of the structure from the incipient stages of the fire. If the fire had originated to the west of the chimney then greater oxidation would be observed at the peak of the old roof.

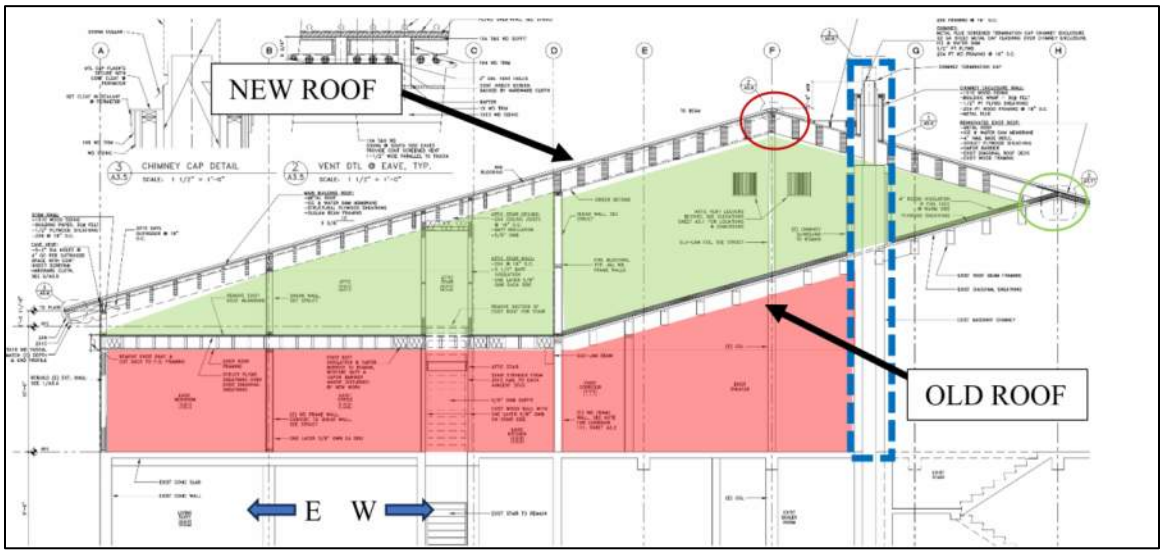

Figure 35 - Profile view - roof structure from 1999 submittal.

5.1.8. The totality of paragraphs 5.1.1to 5.1.7 support on a more probable than not basis, that the fire originated on the main level in the northeast area of the structure. See Figure 1. The fire damage in the lower level, dynamics of building collapse, and location of oxidized metal roof materials do not support any other origin interior or exterior to the HRDL.

5.2. The electrical fire analysis was conducted by Taylor Bendt, M.S., P.E.:

5.2.1. The evidence of electrical arcing was visible on the subpanel conduits shown in Figure 31 which support the fire attack on the main level prior to significant burning in the kitchen area on the lower level. The feeder to the subpanel was routed from the kitchen to the main level. The fire attacked the feeder breaker shown in Figure 30. Arc mapping indicated the fire originated on the main level prior to the lower level of the structure. Arc mapping is the analysis of the physical locations of electrical arcing to assist in determining the origin of a fire. The presence of electrical arcing requires that electrical panels and circuits be energized at the time of fire attack. In this case, evidence of arcing on the main level required that the fire spread on the main level prior to compromising the circuits in the lower level.

5.2.2. Multiple portable tool lithium-ion batteries were identified on the main level of the structure. The Makita and HILTI brand lithium-ion batteries were

within the area of the fire origin. Each of the sets of the lithium-ion batteries (examples shown in Figure 23 and Figure 24) had evidence of a thermal runaway. Thermal runaway is the process in which a lithium-ion battery undergoes a chemical reaction which results in rapid heating of the cell. This reaction can result in venting, explosion, or jets of flame from the cells involved. Thermal runaway can be induced by heating of lithium-ion cells, and therefore can propagate from battery cell to battery cell once the reaction has begun. The use of this observation was limited due to the nature of lithium-ion batteries in fires. Current research indicates the remains of fire damaged lithium-ion batteries have no reliable physical attributes which differentiate between thermal runaway induced by internal cell failure and fire attack.[1]

5.2.3. The smaller electrical panels, conduit, and other components in the area of origin showed additional evidence of arcing which was likely due to fire attack. It was unlikely that a failure in any of these components would have had sufficient fuel to escape the metal conduit or enclosure.

5.2.4. Panel B was supplied directly from the metering section on the lower level of the structure. This meant the panel had significantly more fault capacity than the other smaller components in the area. If the electrical panel was compromised by recent work, performed by BME, then the panel may have failed with adequate energy to ignite nearby combustible materials. However, due to the presence of significant electrical activity across the area of fire origin, it is likely the evidence of arcing in the electrical panel was due to fire attack.

5.2.5. Damage to the IT network cabinet in the attic above the main level ceiling was most likely caused by fire attack. This area of the structure was largely undisturbed and was not part of the major demolition scope of work. Furthermore, the dynamics of the structure collapse do not support the failure of the network cabinet as a likely cause of this fire. Alternatively, the network cabinet power circuitry may have been damaged in the early stages of the fire. The webcams most likely stopped updating due to heat penetrating the attic during the incipient stage of the fire.

5.2.6. The failure of a portable radiant heater could have occurred. However, fuel packages in most of the construction areas appeared to be relatively sparse. Additionally, the radiant heaters were being used in bathrooms which were mostly covered with tile and gypsum board. Additionally, if these heaters were beginning to fail, one of the NPS employees who visited the structure prior to

[1] Nagourney, T., Jordan, J., Marsh, L. et al. The Implications of Post-Fire Physical Features of Cylindrical 18650 Lithium-Ion Battery Cells. Fire Technol 57, 1707–1722 (2021). https://doi.org/10.1007/s10694-020-01077-8

the fire most likely would have noticed a smell, visual or malfunction (room too hot, too cold, or an indication of smoke).

5.3. Electrical discussion conducted by Taylor Bendt, M.S., P.E.

5.3.1. The final person to enter the structure, NPS Employee 2, reported that light switches were not operating during his walk around. If an electrical circuit was not safely locked out, there would be a possibility that NPS Employee 2 unintentionally energized an electrical hazard within the structure. However, evidence on the intact electrical panels indicated that BME had been appropriately locking out energy sources during demolition process.

5.3.2. Additionally, there were indications the electrical panels may have been exposed to water and corrosion prior to the fire event. This could have potentially led to an electrical panel failure. However, if the panels were hazardous then BME would have been expected to identify this and disconnected the unsafe circuits.

5.3.3. Lithium-ion tools utilized from each of the contractors appeared to be stored in a similar manner. Miscellaneous lithium-ion batteries were charging, and some were stored in boxes, toolboxes, or in the portable tools themselves. All the portable tools appeared to be stored in areas designated for contractor storage. A lithium-ion battery pack can experience a thermal runaway while charging, under load, or in storage as long as the battery is sufficiently charged (above 50% depending on cell and battery pack). Because of this, most of the batteries would exhibit fire damage which could have either been caused by a lithium-ion battery failure or as a result of the fire.

5.3.4. Modern lithium-ion batteries and their chargers, such as those observed at the HRDL, are commonly left unattended and connected for extended periods of time. Because of this, manufacturers such as DeWalt, HILTI, and Makita incorporate protection circuits into both the chargers and battery packs. This design prevents overcharging, charging when too hot or cold, as well as over discharge. There are no warnings or standards which prohibit charging tool batteries in unsupervised spaces.

5.3.5. Based on the scientific limitations of assessing lithium-ion batteries, neither the Makita nor HILTI battery packs could be ruled out as the cause of this fire.

5.3.6. The electrical system in the area of fire origin had either been stable for a long period of time, or directly worked on by the contractors during the demolition work. Because of this, any electrical failure in the origin was most likely a result of construction activities or due to fire attack. While a specific failure was not identified, it cannot be ruled out as a cause of this fire.

5.3.7. The presence of significant electrical activity on Panel B indicated it could not be ruled out as a cause of this fire.

5.3.8. Due to the remoteness of the site and the unmonitored fire alarm system, the fire burned unmitigated for approximately six hours prior to being discovered. As a result, much of the electrical activity observed was most likely due to fire impingement and cannot be differentiated from the cause of the fire.

5.3.9. Due to the challenges presented by the physical evidence, the cause of the fire cannot be determined on a more probable than not basis. The following list of ignition sources could not be eliminated based on the totality of the evidence:

5.3.9.1. Failure of the Makita lithium-ion batteries.

5.3.9.2. Failure of the HILTI lithium-ion batteries.

5.3.9.3. Failure of Panel B

5.3.9.4. Failure of an unknown electrical hazard.

5.3.10. Due to the number and nature of potential ignition sources, further examination would not contribute to a scientifically valid cause of this fire. Thus, a destructive evidence examination has not been conducted to date.

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