The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-9-2025
30th CIPA Symposium “Heritage Conservation from Bits:
From Digital Documentation to Data-driven Heritage Conservation”, 25–29 August 2025, Seoul, Republic of Korea

3D Laser Scanning for Historical Preservation and Archival Reconstruction Drawings

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Keywords: Architecture, Preservation, Cultural Heritage, Digital Documentation, Point Cloud, 3D Laser Scan.

Abstract

3D laser scanning technology has significantly transformed the fields of architecture and historic preservation by providing a precise, efficient, and non-invasive method for capturing complex three-dimensional spatial data. This technology facilitates comprehensive documentation of architectural and heritage sites, thereby advancing preservation, restoration, and maintenance efforts. This paper presents four case studies that illustrate the varied applications and efficacy of 3D laser scanning in archival documentation and historical reconstruction:

1. The second-century Roman bath and mosaic at Isthmia, Greece
2. The eighteenth-century Pancha Deval Hindu temples in Kathmandu, Nepal
3. The 1845 cabins at Cane River Creole National Historical Park in Natchitoches, Louisiana
4. The 1903 Galveston Historic Fire Station No. 3 in Galveston, Texas

Through these examples, this paper will demonstrate the long-term value of 3D laser scanning in preservation practice. Moreover, the integration of this technology into academic settings enhances experiential learning, allowing students and professionals to engage directly with real-world preservation challenges. By bridging digital innovation with traditional architectural methodologies, 3D laser scanning promotes interdisciplinary collaboration across architecture, landscape architecture, urban planning, and related fields.

1. CASE STUDY 1-The 2nd-Century Roman Bath and Nereid Mosaic in Isthmia, Greece

1.1 Historical Overview-Isthmia and Corinth

The second-century CE Roman Bath complex at Isthmia, Greece, was constructed within the Sanctuary of Poseidon, to whom the site was dedicated. The extant remains preserve a clearly defined outline of the original foundation stones in situ, although the superstructure—comprising brick masonry walls and vaulted roofing—no longer survives.

The significance of the Isthmian Bath lies in its socio-cultural, economic, and geographic context. Located near Corinth—one of the most commercially dominant poleis of the ancient Greek world—Isthmia occupied a strategic location along the Isthmus of Corinth, the narrow land bridge connecting the Peloponnese to mainland Greece (Jackson, 1980).

Isthmia’s prominence was reinforced by its role as the site of the Isthmian Games, one of the four major Panhellenic festivals. Held biennially at the Sanctuary of Poseidon, the games underscored the site's religious, cultural, and political relevance across the Hellenic world, second in prestige only to the Olympic Games (Hicky, 1914).

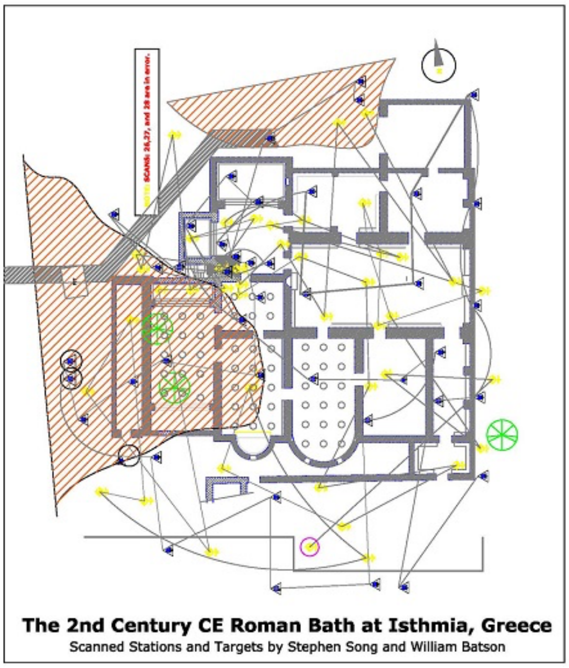

Figure 1. Station Map for scan station and targets.

1.2 Digital Reconstruction Methodology – An Anastylosis-Based Approach

The reconstruction of the Isthmian Bath employed a digital anastylosis-based methodology, integrating 3D laser scanning, physical remains, and historical sources. The laser scanning process involved 40 scans and 45 target stations to capture the surviving foundations accurately, complemented by a detailed station map (see Figure 1). This method preserved the integrity of in-situ foundation stones while incorporating surviving structural fragments, such as an extant arch segment, to estimate features like barrel vaults and half domes.

Vitruvius’ De Architectura served as a foundational text for establishing proportional relationships and spatial hierarchies. His principles of symmetria, ordinatio, and proportio informed the layout and structural coherence of vaulted rooms within the

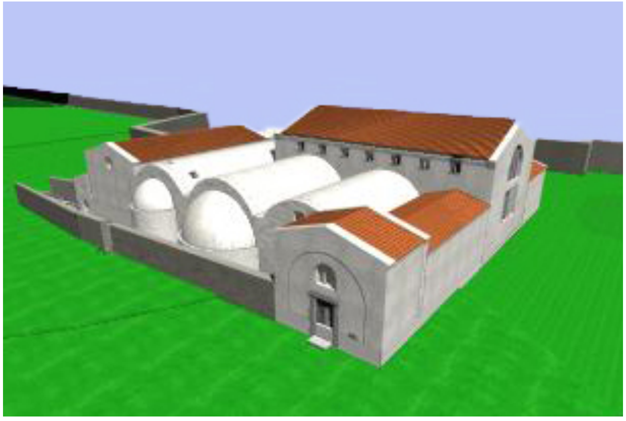

Figure 2. Roman bath vaulted caldarium and tepidarium.

Comparative analysis referred to well-documented Roman bath complexes to inform the reconstruction. The Stabian and Forum

1.4 Roman Bathing Culture and Spatial Arrangement

Public bathing was central to Roman social life, and the architectural sequence of these facilities—apodyterium, tepidarium, caldarium, and frigidarium—was replicated across the empire (Jones et al., 2019). Heated spaces employed hypocaust systems beneath the floors and embedded wall pipes for steam ventilation. These rituals often concluded with oil anointing and massage, reinforcing the baths’ role as a social and hygienic institution (Figure 3).At Isthmia, excavations revealed a

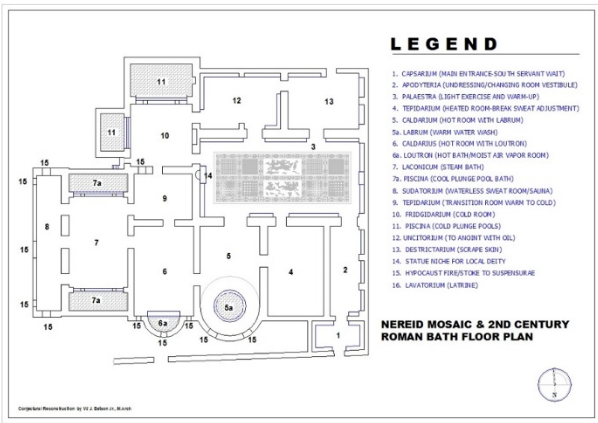

Figure 3. Roman bath organizational sequence plan.

pre-Roman pool, approximately one meter deep and lined with hydraulic cement, likely integrated into the later Roman complex. This suggests site-specific continuity and adaptation of earlier Greek water infrastructure.

1.5 Iconography of the Mosaic

The association between water and marine iconography was ubiquitous in Roman bath decoration. The Isthmian mosaic, located in the palaestra, reflects this tradition. It comprises a large rectangular field subdivided into a 6×2 grid of square modules The central panel features Greco-Roman marine imagery—

The fieldwork began with terrestrial laser scanning (TLS) of all five temples using twenty-two scan stations to collect dense point cloud data. The scanning campaign captured the exterior facades, interior volumes, and architectural details of the damaged structures without requiring direct contact. This was essential

reconstruction (Hicky, 1914). Notably, the dimensions of the caldarium and tepidarium followed Vitruvian ratios of 1:1, 1:1.5, and 2:3, depending on the room’s function and roofing system (Book V, Chapter 10) (Figure 2). Orientation adhered to Vitruvian solar guidance, maximizing morning light for thermal efficiency (Book I, Chapter 2).

1.3 Comparative Precedents: Pompeii & Leptis Magna

Baths at Pompeii demonstrated early imperial spatial sequencing and gender segregation, with centralized praefurnia supplying heat to multiple rooms.

The Hunting Baths at Leptis Magna in Libya provided critical insight into Roman vaulting techniques. Its preserved concrete barrel vaults offered direct precedent for hypothesizing the roofing system at Isthmia, aligning with Vitruvius’ preference for vaulted ceilings in baths (Hicky, 1914). Additional comparative studies of baths in Syria, Turkey, and Portugal strengthened interpretive assumptions by confirming recurring typologies and identifying regional variants (Brown & Taylor, 2021).

interpreted as nereids or sea deities—surrounded by geometric ornamentation, designed to be viewed from the north.

1.6 Conclusion

The reconstruction of the Isthmian Bath complex exemplifies the potential of integrated digital heritage methodologies. By synthesizing Vitruvian theory, physical remains, and comparative architectural analysis, this project produced a plausible and instructive reconstruction. The study not only enhances understanding of Roman architectural engineering but also illustrates the social rituals embedded within bath architecture. The use of 3D laser scanning proved vital in preserving and interpreting the site's architectural heritage.

2. CASE STUDY 2-The 18th-Century Pancha Deval Hindu Temples in Kathmandu, Nepal

2.1 Historical Overview – UNESCO Nepal

Nepal is internationally recognized for its rich cultural heritage and distinctive Newar architecture. It contains one of the highest concentrations of UNESCO World Heritage Sites globally, with many structures dating from the 13th to 17th centuries. In April 2015, the Gorkha earthquake struck central Nepal, causing widespread destruction. Nearly 9,000 people lost their lives, and over 500,000 homes and historic structures were damaged or destroyed. This disaster was the most severe to affect the region since the 1934 Nepal–Bihar earthquake (U.S. National Park Service, 2015).

Due to Nepal’s high seismic activity, the preservation of its built heritage requires sustained documentation and restoration efforts (Bilham, 2004). In this context, our University, in collaboration with UNESCO Nepal, carried out a 3D laser scanning survey of the Pancha Deval Temple Complex in Kathmandu. The complex, comprising five temples located within one of the three Durbar Squares of the Kathmandu Valley, is part of the UNESCO World Heritage designation (UNESCO World Heritage Centre, 2024).
given the instability and partial collapse of several temple components. The collected data was processed to generate accurate as-built documentation, including elevation and section drawings using AutoCAD. In total, twenty digital reconstruction

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVIII-M-9-2025-1401-2025

drawings and a 3D model were produced and presented to UNESCO Nepal (Figure 4).

Figure 4. 3D Model creation by ReCap and Rhino softwares.

The integration of laser scanning and digital drawing production provided both a detailed record of the site's existing conditions and a valuable tool for future conservation planning. This methodology demonstrates the applicability of TLS in heritage preservation projects in seismically vulnerable regions, particularly where historical documentation is limited or nonexistent.

2.2 Overview of the 3D Laser Scanning Process

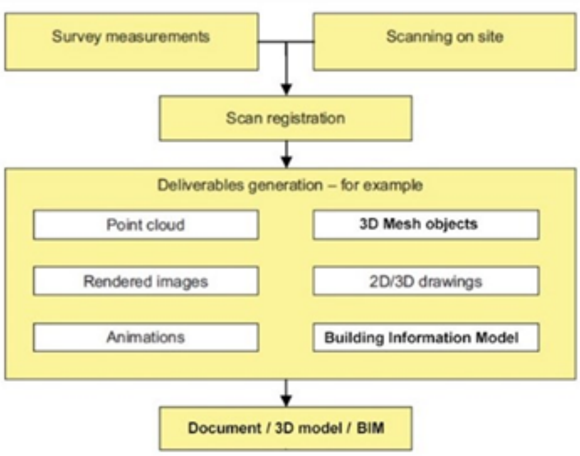

Figure 5. 3D Laser scanning workflow.

Site Survey and Setup
The process begins with planning the scan layout, positioning the 3D laser scanner and targets, and configuring the scanner for optimal data capture.

On-Site 3D Laser Scanning
Using the Leica ScanStation P40, the building and surrounding site are scanned to collect comprehensive spatial data.

Data Registration with Cyclone Software
Raw scan data is imported into a project database using Cyclone. The software aligns and merges individual scans into a unified 3D point cloud of the entire structure.

Reconstruction Drawings in AutoCAD
The point cloud is imported into AutoCAD via CloudWorx, enabling the creation of detailed floor plans, elevations, and section drawings in 3D space.

3D Model Creation and Fabrication
The point cloud is converted into a mesh model to generate a 3D representation using Scene, Autodesk ReCap, and Rhino software. This model is then fabricated into a physical form using 3D printing technology (Figure 5).

2.3 Fabrication Process

Our University is equipped to produce both large-scale architectural models and intricate details. The process begins with creating a 3D digital model using software such as AutoCAD (Figure 6), Revit, SketchUp, or Rhino. For this project, the model was printed using the Stratasys F370, a high-performance FDM (Fused Deposition Modeling) 3D printer known for its speed and quality. The temple model was divided into three sections and printed at a resolution of 1/1000 inch per layer.

One of the limitations of the laser scanner is that it is not accessible to all building areas. The added use of a drone enables laser scanning technology to scan places that are inaccessible or dangerous. The drone improves safety and saves time by accurately measuring blind views and roof structures from a bird's-eye perspective. After the laser scanning work is complete, part of our objective is to help determine the best means of reconstruction to prevent future failure or collapse. Some traditional methodologies may require enhancement or modification to ensure the long-term viability of the structure (Brown & Taylor, 2021).

Our University faculty and students traveled to Kathmandu, Nepal, to present to UNESCO the as-built reconstruction

Figure 6. AutoCAD precision Temple elevation drawing.

drawings of the Pancha Deval Hindu Temple Complex. This collaborative initiative with UNESCO Nepal catalyzed our current and future preservation projects. One important outcome is the engagement and training of students at Nepalese universities in 3D laser scanning and digital documentation, empowering them to become active stakeholders in their local heritage preservation.

3D Laser scanning is the first step. The interpretation of the data and informed decision-making is crucial. The preservation process must embrace appropriate technologies and, pragmatic materials and strategies to ensure that Nepal's architectural legacy endures.

2.4 Conclusion

Our University is dedicated to advancing architectural education through research-driven, experiential learning. Faculty and students engage in preservation and documentation initiatives that employ 3D laser scanning to explore the educational, scientific, and cultural significance of historic structures.

These efforts support broader goals of digital conservation, education, and reconstruction. The program emphasizes hands-on training and the development of technical competencies essential for contemporary preservation practices. In addition, our institution actively promotes global and interdisciplinary partnerships to advance the stewardship of architectural heritage worldwide.

3. CASE STUDY 3-The 1845 Cabins at Cane River Creole National Park in Natchitoches

3.1 Historical Overview – Magnolia Plantation

The Magnolia Plantation, established in 1835 by Ambrose LeComte II and Julia Buard, traces its origins to colonial Louisiana, beginning with a French land grant issued in the 1750s. Initially developed for the cultivation of cash crops such as indigo, cotton, and sugarcane, the plantation had become, by 1860, the largest cotton-producing estate in the parish. By the mid-19th century, it encompassed over 6,000 acres and ranked among the largest cotton plantations in the region. At that time, it was operated by 235 enslaved individuals who resided in seventy cabins, including twenty-four two-room brick structures measuring approximately 16 by 17 feet (Figure 7). A center wall with a fireplace for each cabin divided each space, creating a room for two separate families, each with access to a central fireplace, with up to ten family members sharing this space (Figure 8).

The enslaved African laborers at Magnolia Plantation possessed a broad range of specialized skills. In addition to their roles as agricultural workers and harvesters, they served as weavers, shoemakers, painters, carpenters, brick masons, and cotton ginners. Notably, they produced the bricks used in the construction of their own dwellings, underscoring their technical expertise and contributions to the built environment of the plantation (National Park Services, 2025).

After the Civil War, the plantation transitioned to a system of sharecropping. The sharecropping arrangement changed the cabin plans from two to one to provide more room for families. The cabins became single-family homes with gardens and livestock, and community life included music, games, and sports. With agricultural and mechanization innovations that began in the 1930s, sharecropping proved all but obsolete, and the last laborers left the cabins in the 1970s. In 1997, the National Park Service acquired the outbuildings, which are now open for public tours.

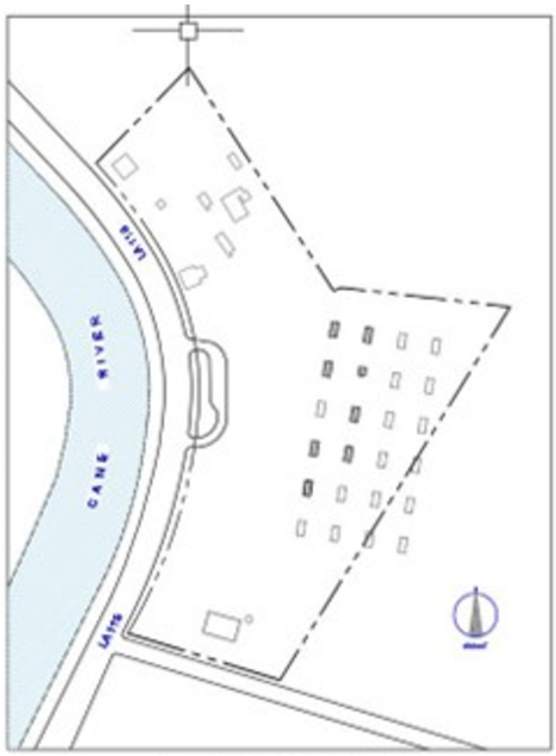

Figure 7. Site of original twenty-four cabins.

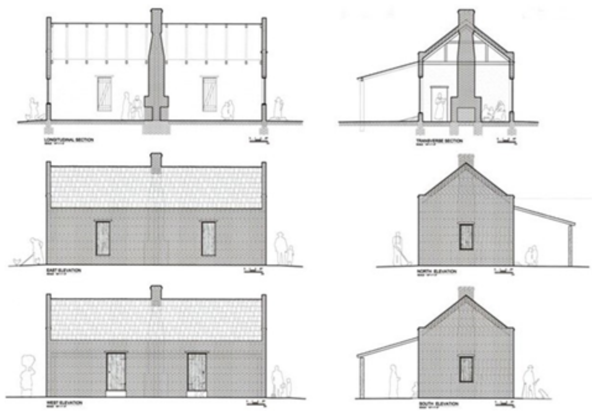

Figure 8. Cabin 16 X 17 floor plan with fireplace.

3.2 Reconstruction Process – Intact Structural and Architectural Reconstruction

Our University was invited by the administrators of Cane River Creole National Historical Park to produce as-built and archival drawings of the eight surviving slave cabins, as no original plans or architectural documentation existed. Due to the absence of established precedents for slave cabin design constructed by French planters, the university was specifically requested to develop digital reconstructions that reflect the cabins' condition prior to hurricane damage.

A comprehensive 3D laser scan was conducted to document the existing conditions of the cabins, capturing structural deformations and surface textures in detail. This survey included all seven fully intact cabins as well as the remaining half of an eighth cabin that had suffered significant hurricane damage. High-resolution photographs were also taken to refine architectural details and enhance the precision of foundation measurements (Jones, Patel, & Wang, 2019; Smith, Johnson, & Kim, 2020).

To facilitate accurate restoration, a range of 3D modeling software—including AutoCAD, Rhino, Revit, and SketchUp—was employed to produce digital models of the cabins in both their current and pre-disaster states. These models provided the precise dimensions necessary for reconstruction and enabled the creation of complete working and archival drawings for long-term preservation and future reference (Brown & Taylor, 2021).

3.3 Conclusion

The reconstruction of the 1845 slave cabins at Magnolia Plantation, conducted by our University, represents a significant intersection of historical preservation, technological innovation, and cultural remembrance. Through a rigorous field methodology—including 3D laser scanning, photogrammetry, and manual measurement—faculty, students, and IT staff documented the architectural and material details of the eight remaining brick cabins with high precision.

These efforts resulted in the production of accurate digital models and architectural drawings that reflect the cabins in their pre-disaster condition. This undertaking was more than a technical or academic exercise; it served as a tribute to the enslaved and tenant-farming families who once inhabited these structures. By producing detailed digital records and archival drawings, the project preserves the physical remnants of the cabins and the lived experiences they embody.

These cabins were homes—spaces of survival, resistance, and community—and their documentation extends the memory of the individuals and cultures that shaped them into a permanent, accessible visual record. The reconstructions now function as both educational resources and historical records, ensuring that the narratives embedded within these structures are not forgotten. In doing so, the project contributes to a more comprehensive and inclusive understanding of American history and stands as a testament to the role of architectural technology in preserving memory, fostering empathy, and inspiring future generations.

4. CASE STUDY 4-The 1903 Galveston Historic Fire Station No. 3

4.1 Historical Overview

The original firehouse, known as Star State Company No. 3, was initially located at 2512 Church Street and later moved to 2828 Market Street. Established prior to the Civil War as a volunteer fire department, it was created in response to Galveston's growing need for fire protection during a period of rapid population growth. In 1885, the city's volunteer fire companies were consolidated into a paid municipal fire department. Notably, Star State Company No. 3 became the first racially integrated fire company in Galveston.

The original structure was destroyed in the 1900 Galveston hurricane. This hurricane destroyed more than 7,000 buildings in

Figure 9. Fire Station No.3 damaged by Hurricane Ike in 2008.

Galveston. The current fire station, constructed in 1903 on the original site (Figure 9), sustained additional damage from Hurricane Ike in 2008, with sustained winds of 110 mph and a storm surge of approximately 15 feet. Despite these setbacks, the 1903 structure remains standing, symbolizing Galveston’s resilience and its enduring commitment to public safety and community service (WF History Timeline – Fire, U.S. National Park Service).

4.2 Preservation and Restoration Assessment

Fire Station No. 3 sustained extensive damage, including the complete destruction of its roof and the collapse of approximately thirty-five percent of the exterior brick veneer. In subsequent years, the building underwent multiple renovations aimed at preserving its appearance and ensuring continued structural integrity. In 1960 it was abandoned and subsequently left to deteriorate. Over the ensuing decades, the building underwent significant exterior alterations, including the removal of original decorative elements and the application of stucco over the historic brick façade.

Fire Station No. 3 represents a rare surviving example of Victorian-era civic architecture on Galveston Island. The building’s original design incorporated red brick arranged in polychromatic bands, cast concrete decorative elements, and a prominent second-story multi-light window framed by a distinctive projecting balcony—colloquially referred to as a “Rapunzel porch.” These elements collectively embody the ornamental richness and expressive formal language that typify late 19th-century municipal architecture.

4.3 Reconstruction Process – Photographic Model Reconstruction

Our University was commissioned by the Galveston Historical Center to produce as-built drawings documenting the existing conditions and to conduct a structural integrity assessment of the 122-year-old Galveston Fire Station No. 3. Designated a Galveston City Landmark in 2007 and acquired by the Galveston Historical Foundation (GHF) in 2017, the building was found to be structurally unstable. In response, the GHF adopted a reconstruction strategy aimed at preserving the original Victorian-era brick façade. This approach prioritized the use of salvaged materials and historical photographs from the early 20th century to guide the rebuilding process in a manner consistent with the architectural heritage (Doe, Smith, & Lee, 2022).

Our engineering team conducted a structural integrity assessment and concluded that the original roof architecture could not be replicated due to its compromised condition. As a result, the building was reclassified for adaptive reuse. To support the restoration process, a 3D laser scan was performed to document the existing conditions and enable the digital reconstruction of the original 1903 fire station façade. The original façade of the building was obscured by stucco, leaving only historical photographs as a reference for reconstruction. To accurately recreate the structure, a multi-step digital modeling process was employed:

Archival Research & 3D Laser Scanning:
Historical photographs were analyzed in conjunction with existing architectural decorations, and a comprehensive 3D laser scan of the existing structure was performed, generating a high-resolution model that captured the building's architecture and geometry (Figure 10).

Digital Modeling:
Using archival photographs as reference, a digital reconstruction of the original structure was constructed. The accuracy of this model relied upon both the quality and the number of available historical images.

Image Assignment & Corrections:
To address photographic distortion and ensure spatial accuracy, the historical images were overlaid onto the 3D point cloud using AutoCAD. Adobe Photoshop was then employed to refine the alignment, allowing architectural details captured in the photographs to correspond accurately with the scanned geometry

Structural Analysis:
Our faculty civil engineer conducted a structural assessment of the roof system to inform the reconstruction of roof elements.

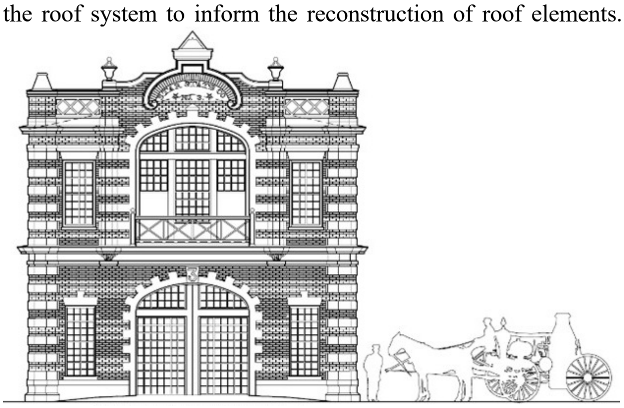

Figure 10. 1900 Fire Station No. 3 reconstruction drawing.

4.4 Conclusion

The Galveston Fire Station No. 3 serves as a significant symbol of the city's architectural heritage and civic development, as well as a living monument to its evolving social fabric. Its history embodies broader themes such as disaster recovery, integration, and historic preservation. Over the past sixty years, the Galveston Historical Foundation (GHF) has broadened its mission beyond traditional preservation to include community redevelopment, maritime heritage, coastal resiliency, and the stewardship of historic properties.

GHF's approach integrates advances in environmental and natural sciences, recognizing the intersection of historic architecture with ecological systems and coastal life (Bilham, 2004). In collaboration with our University, GHF has undertaken the preservation of Fire Station No. 3—an exceptional and rare example of a surviving civic firehouse from the late 19th and early 20th centuries in the Victorian style. This joint effort reflects a commitment to maintaining a unique architectural heritage and preserving the timeless historical narratives it represents (Brown & Taylor, 2021).

Acknowledgments

Special thanks to our student workers and scholars: Ernesto Alviso, Chelsea Chavez, Jovany De Los Santos, Yessenia Davila, Nancy Guerrero, Rodrigo Salvador, Armony Panighello, Juan Rojas, Julian Degraft-Johnson and Dr. Doeun Choe.

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