CENTER FOR
HERITAGE CONSERVATION

TEXAS A&M UNIVERSITY
College of Architecture

# Terrestrial Laser Scanning Survey of Haynes Engineering Building, Texas A&M University, College Station, Texas: Project Report II (CHC-2021-08-21)

Ben Baaske, Robert Warden, Kevin Glowacki, Sandra Hernandez-Mayen

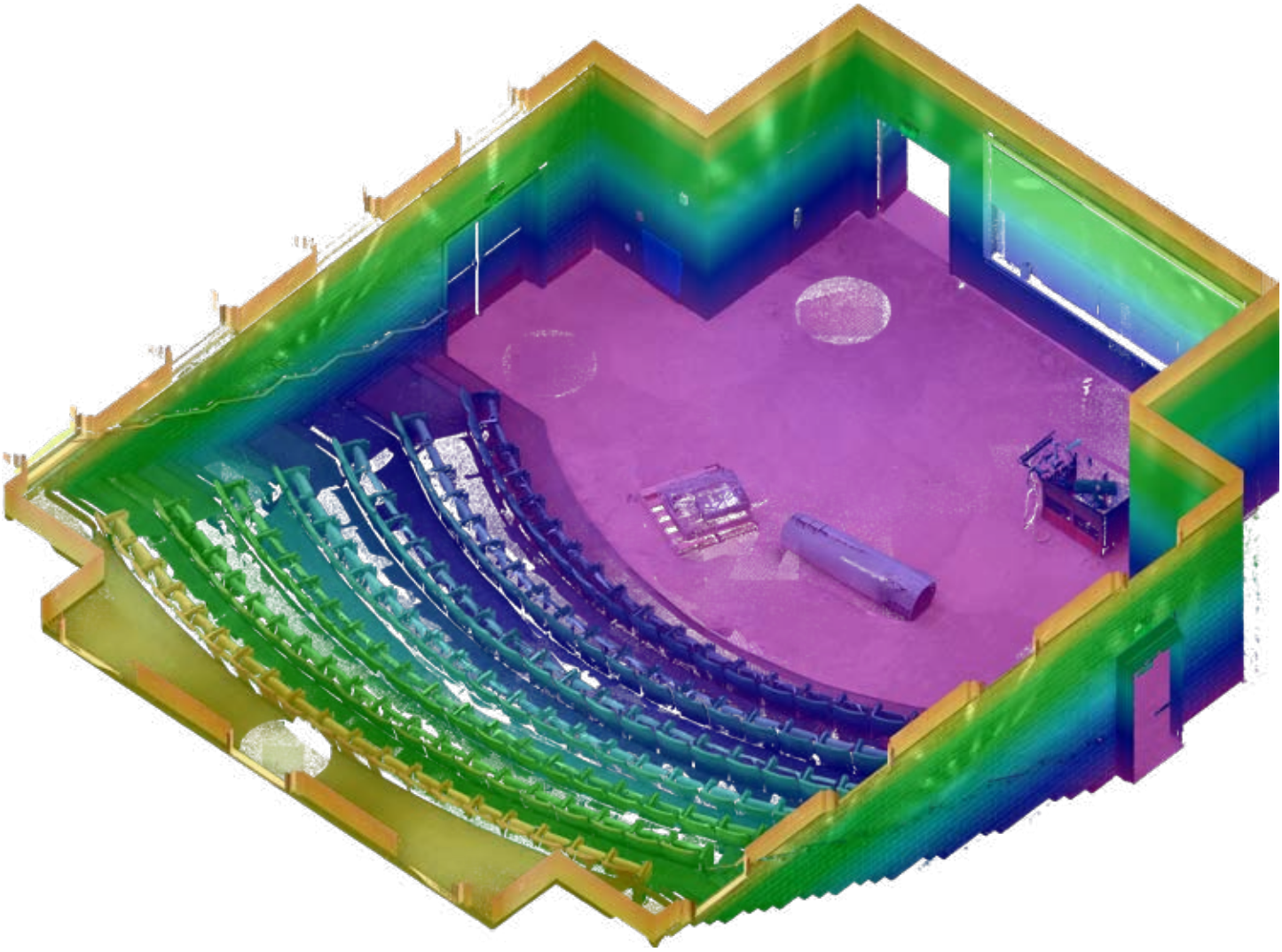


Figure 1: Aerial view showing location of Haynes Engineering Building in College Station, Brazos County, Texas. Google Earth.


Figure 2: Aerial view of Haynes Engineering Building. Google Earth.

## Introduction

The following is a report on the terrestrial laser scanning survey of the Haynes Engineering Building at Texas A&M University in College Station, Texas, conducted by the Center for Heritage Conservation at Texas A&M University on August 21, 2021.

The primary objectives of the scanning project were

1) to document the renovation of the auditorium prior to the planned study of material finishes;

2) to create preliminary orthographic images from the recorded point cloud data;

3) to prepare archival digital files ready for use in 3d modeling programs.

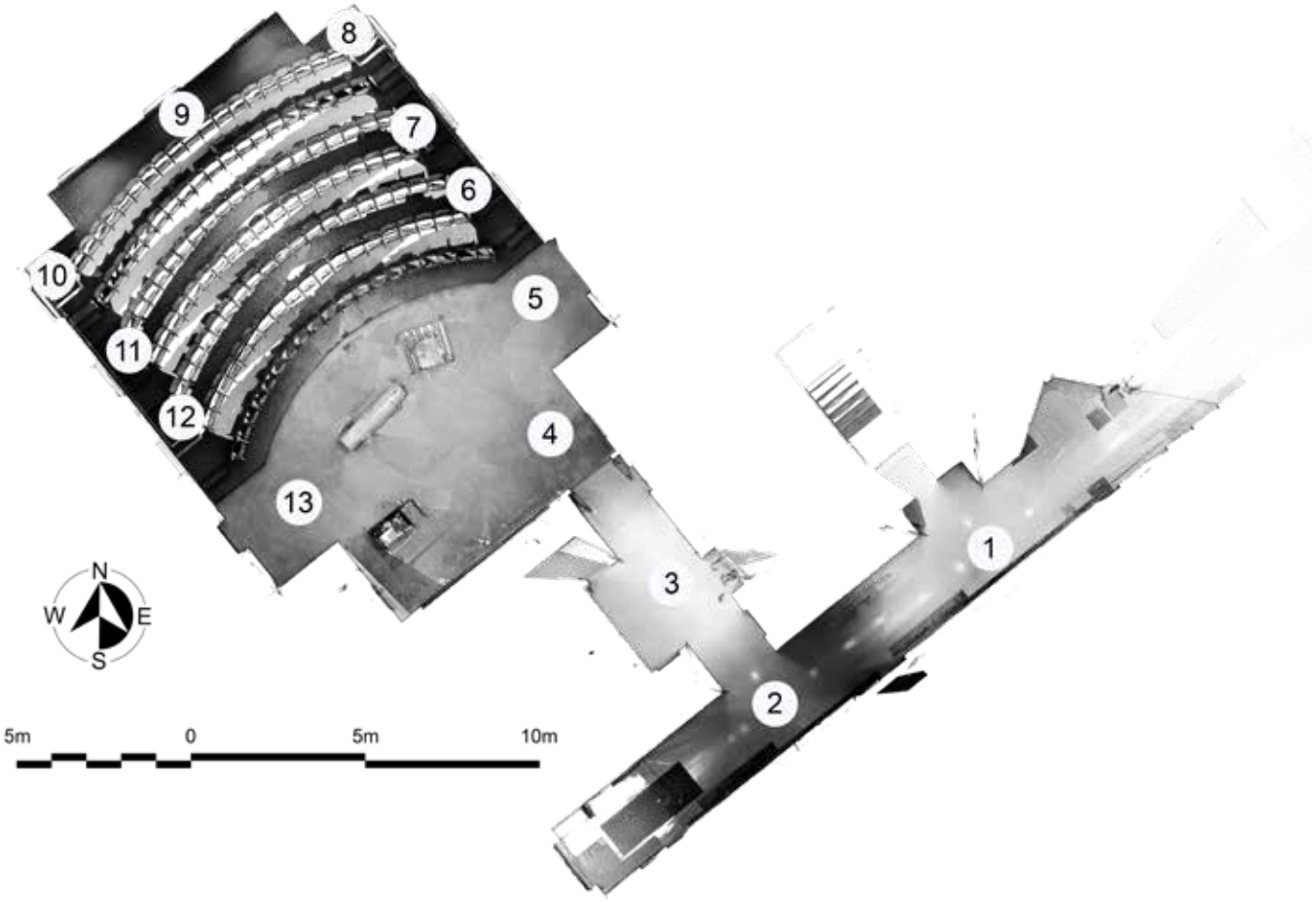
## The Terrestrial Laser Scanning Survey

The Center for Heritage Conservation (CHC) at Texas A&M University (TAMU) documented the auditorium renovation of the Haynes Engineering Building at Texas A&M University in College Station, Texas, using terrestrial laser scanning (TLS) technology on August 21, 2021.

The team utilized a FARO Focus3D X330, a phase-based laser scanning system. The scan data were initially processed with FARO Scene 2019.0 software.

The scan project resulted in 13 usable scan positions, with each scan duration being 6 minutes and 37 seconds. A scan resolution of ¼ was set; this results in an average point spacing of 6mm at a distance of 10m. The scan quality was set to 3x; this number pertains to the number of measurements of a collected data point. A full 360-degree capture was obtained at each scan position, with a vertical declination range of -60-degree to 90-degrees. Light metering was set to even-weighted and the high dynamic range (HDR) setting was not used for images.

Figure 3. Site Plan. Orthophoto of point cloud export from FARO Scene showing scan positions.



## Processing & Registration

The most effective means of aligning adjacent scans correctly proved to be automatic alignment using the combined top view and cloud-to-cloud registration. The resulting cluster was then optimized using cloud-to-cloud registration. Using automatic registration with the combined top view and cloud-to-cloud registration of Scene resulted in the following scan point statistics: a mean point error of 0.9mm, a maximum point error of 1.6mm, and a minimum overlap of 17.0%.

Once registered, the project point cloud was created; this allowed for export of orthophotos and the project point cloud itself (in various file formats). The auditorium of the Haynes Engineering Building project point cloud consists of 279,059,390 data points.

Figure 4: Plan view. Screenshot of point cloud in visual registration view from FARO Scene.

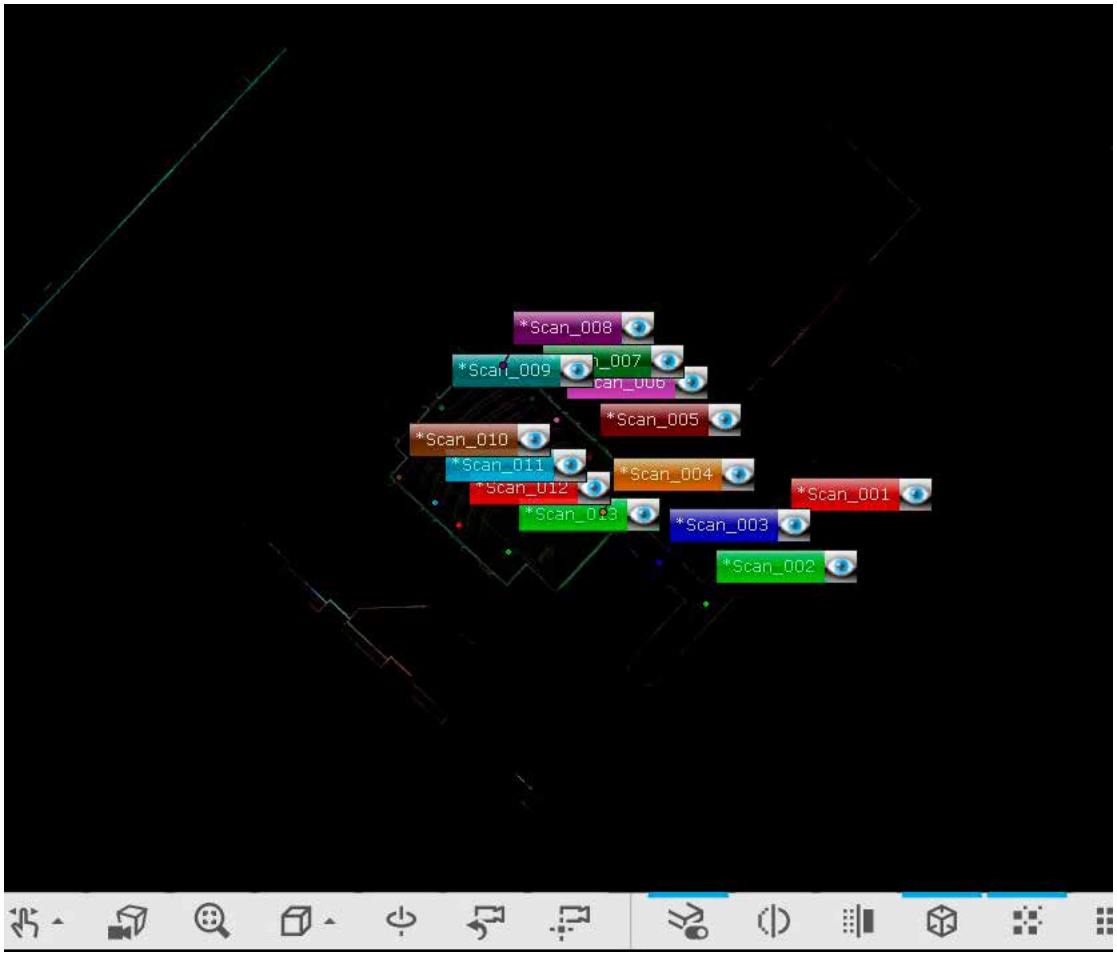
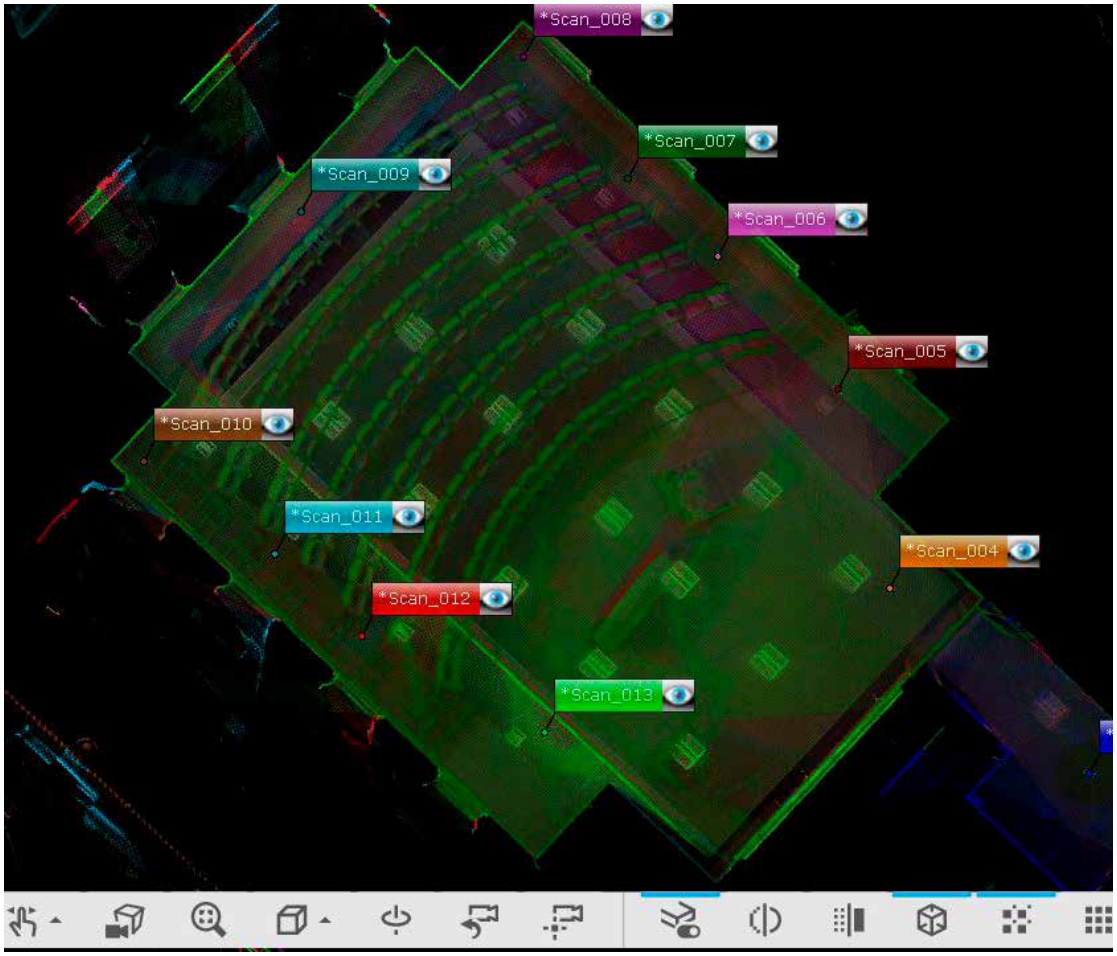



Figure 5: Plan view. Screenshot of point cloud in visual registration view from FARO Scene.



# Registration Report

## Color Coding

| | | |
|---|---|---|
| Point Error | < 8 mm | > 20 mm |
| Overlap | > 25.0 % | < 10.0 % |

## Overview

### Scan Point Statistics

| | |
|---|---|
| Maximum Point Error | 1.6 mm |
| Mean Point Error | 0.9 mm |
| Minimum Overlap | 17.0 % |

## Scan Errors

### Scan Point Statistics

| Cluster/Scan | Connections | Max. Point Error [mm] | Mean Point Error [mm] | Min. Overlap |
|---|---|---|---|---|
| Haynes02_Scan_001 | 1 | 0.8 | 0.8 | 72.1 % |
| Haynes02_Scan_002 | 3 | 1.4 | 1.0 | 17.0 % |
| Haynes02_Scan_003 | 3 | 1.4 | 1.0 | 31.7 % |
| Haynes02_Scan_004 | 4 | 1.6 | 1.3 | 17.0 % |
| Haynes02_Scan_005 | 9 | 1.4 | 1.0 | 49.9 % |
| Haynes02_Scan_006 | 9 | 1.4 | 0.9 | 31.7 % |
| Haynes02_Scan_007 | 8 | 1.0 | 0.8 | 43.9 % |
| Haynes02_Scan_008 | 8 | 1.1 | 0.9 | 53.1 % |
| Haynes02_Scan_009 | 8 | 1.0 | 0.8 | 42.6 % |
| Haynes02_Scan_010 | 8 | 1.1 | 0.9 | 49.9 % |
| Haynes02_Scan_011 | 8 | 1.0 | 0.8 | 42.6 % |
| Haynes02_Scan_012 | 8 | 1.0 | 0.9 | 56.6 % |
| Haynes02_Scan_013 | 9 | 1.6 | 1.1 | 71.3 % |

Table 1. Scan point statistics from FARO Scene registration report.

Table 2. Detailed errors of scan point statistics from FARO Scene registration report.

# Detailed Errors

## Scan Point Statistics

| Cluster/Scan 1 | Cluster/Scan 2 | Point Error [mm] | Overlap |
|---|---|---|---|
| Haynes02_Scan_002 | Haynes02_Scan_001 | 0.8 | 72.1 % |
| Haynes02_Scan_002 | Haynes02_Scan_003 | 0.7 | 67.1 % |
| Haynes02_Scan_002 | Haynes02_Scan_004 | 1.4 | 17.0 % |
| Haynes02_Scan_004 | Haynes02_Scan_003 | 0.9 | 72.2 % |
| Haynes02_Scan_005 | Haynes02_Scan_004 | 1.4 | 82.9 % |
| Haynes02_Scan_005 | Haynes02_Scan_006 | 0.8 | 86.7 % |
| Haynes02_Scan_005 | Haynes02_Scan_009 | 0.9 | 50.4 % |
| Haynes02_Scan_005 | Haynes02_Scan_011 | 0.9 | 77.2 % |
| Haynes02_Scan_005 | Haynes02_Scan_013 | 1.0 | 81.3 % |
| Haynes02_Scan_006 | Haynes02_Scan_003 | 1.4 | 31.7 % |
| Haynes02_Scan_007 | Haynes02_Scan_005 | 0.8 | 81.8 % |
| Haynes02_Scan_007 | Haynes02_Scan_006 | 0.6 | 87.6 % |
| Haynes02_Scan_007 | Haynes02_Scan_009 | 0.7 | 43.9 % |
| Haynes02_Scan_007 | Haynes02_Scan_011 | 0.8 | 74.1 % |
| Haynes02_Scan_007 | Haynes02_Scan_012 | 0.9 | 75.8 % |
| Haynes02_Scan_007 | Haynes02_Scan_013 | 1.0 | 75.6 % |
| Haynes02_Scan_008 | Haynes02_Scan_005 | 0.9 | 60.3 % |
| Haynes02_Scan_008 | Haynes02_Scan_006 | 0.7 | 64.2 % |
| Haynes02_Scan_008 | Haynes02_Scan_007 | 0.7 | 66.3 % |
| Haynes02_Scan_008 | Haynes02_Scan_009 | 0.8 | 66.8 % |
| Haynes02_Scan_008 | Haynes02_Scan_012 | 1.0 | 56.6 % |
| Haynes02_Scan_008 | Haynes02_Scan_011 | 1.0 | 57.2 % |
| Haynes02_Scan_008 | Haynes02_Scan_013 | 1.1 | 71.3 % |
| Haynes02_Scan_009 | Haynes02_Scan_006 | 0.7 | 46.5 % |
| Haynes02_Scan_009 | Haynes02_Scan_011 | 0.8 | 42.6 % |
| Haynes02_Scan_010 | Haynes02_Scan_005 | 1.0 | 49.9 % |
| Haynes02_Scan_010 | Haynes02_Scan_006 | 0.9 | 52.3 % |
| Haynes02_Scan_010 | Haynes02_Scan_007 | 0.8 | 51.8 % |
| Haynes02_Scan_010 | Haynes02_Scan_008 | 1.1 | 53.1 % |
| Haynes02_Scan_010 | Haynes02_Scan_009 | 0.8 | 60.1 % |
| Haynes02_Scan_010 | Haynes02_Scan_012 | 0.8 | 57.7 % |
| Haynes02_Scan_010 | Haynes02_Scan_011 | 0.8 | 61.5 % |
| Haynes02_Scan_010 | Haynes02_Scan_013 | 1.0 | 79.1 % |
| Haynes02_Scan_011 | Haynes02_Scan_006 | 0.9 | 76.4 % |
| Haynes02_Scan_012 | Haynes02_Scan_005 | 0.9 | 76.1 % |
| Haynes02_Scan_012 | Haynes02_Scan_006 | 1.0 | 77.2 % |
| Haynes02_Scan_012 | Haynes02_Scan_009 | 0.8 | 76.5 % |
| Haynes02_Scan_012 | Haynes02_Scan_011 | 0.7 | 90.9 % |
| Haynes02_Scan_012 | Haynes02_Scan_013 | 0.9 | 88.5 % |
| Haynes02_Scan_013 | Haynes02_Scan_004 | 1.6 | 79.2 % |
| Haynes02_Scan_013 | Haynes02_Scan_006 | 1.0 | 78.7 % |
| Haynes02_Scan_013 | Haynes02_Scan_009 | 1.0 | 74.2 % |
| Haynes02_Scan_013 | Haynes02_Scan_011 | 0.9 | 86.1 % |

## Inclinometer Mismatches

| Cluster/Scan | Scan | Mismatch [deg] |
|---|---|---|
| Haynes02_Scan_010 | Haynes02_Scan_010 | 0.0085 |
| Haynes02_Scan_008 | Haynes02_Scan_008 | 0.0151 |
| Haynes02_Scan_007 | Haynes02_Scan_007 | 0.0193 |
| Haynes02_Scan_012 | Haynes02_Scan_012 | 0.0043 |
| Haynes02_Scan_005 | Haynes02_Scan_005 | 0.0177 |
| Haynes02_Scan_002 | Haynes02_Scan_002 | 0.0337 |
| Haynes02_Scan_013 | Haynes02_Scan_013 | 0.0490 |
| Haynes02_Scan_009 | Haynes02_Scan_009 | 0.0134 |
| Haynes02_Scan_011 | Haynes02_Scan_011 | 0.0109 |
| Haynes02_Scan_001 | Haynes02_Scan_001 | 0.0249 |
| Haynes02_Scan_006 | Haynes02_Scan_006 | 0.0219 |
| Haynes02_Scan_004 | Haynes02_Scan_004 | 0.1908 |
| Haynes02_Scan_003 | Haynes02_Scan_003 | 0.0361 |

Table 3. Inclinometer mismatches from FARO Scene registration report.

Figure 6. Auditorium, Floor Plan. Orthophoto of point cloud export from FARO Scene.

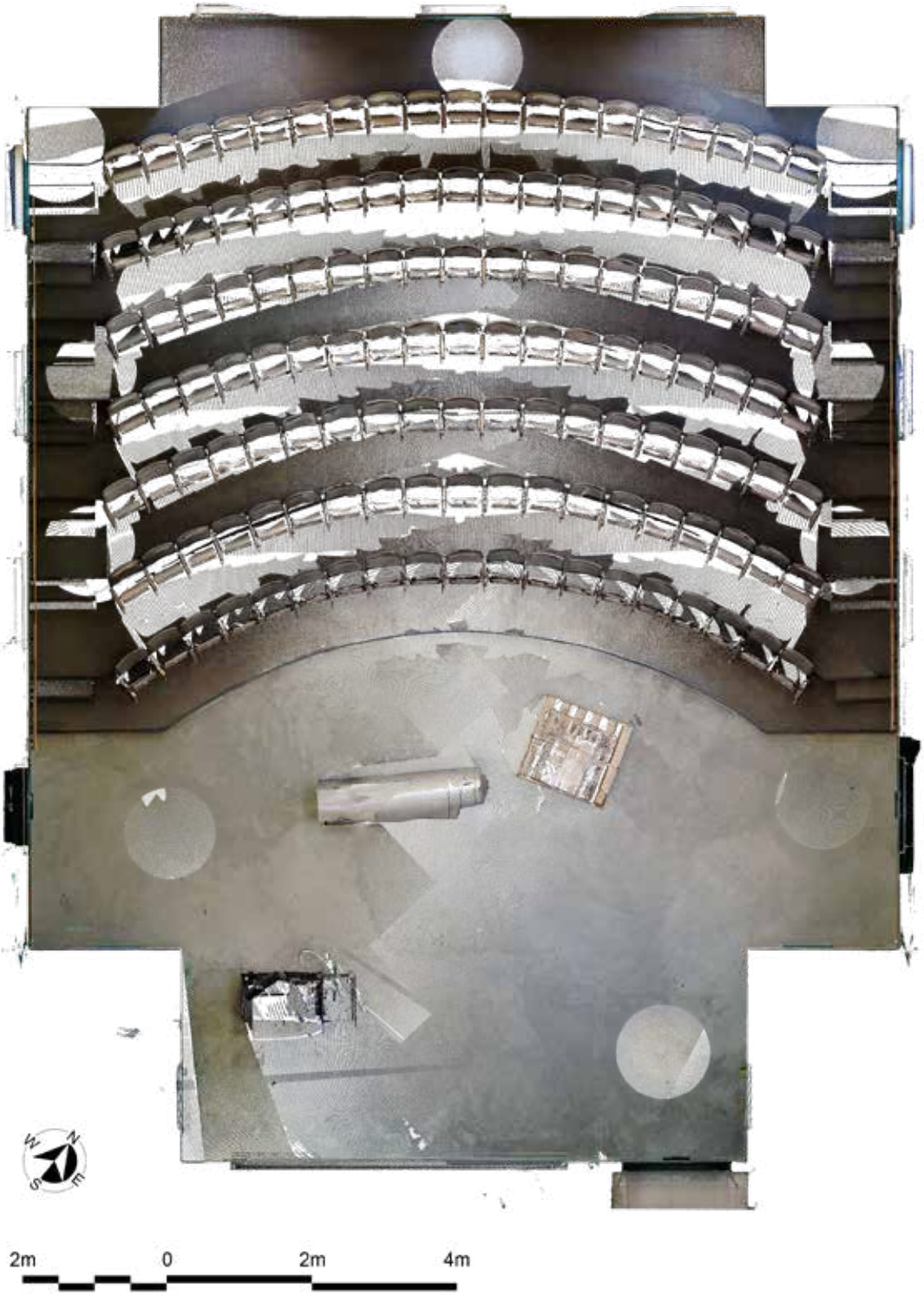


Figure 7. Auditorium, Reflected Ceiling Plan. Orthophoto of point cloud export from FARO Scene.

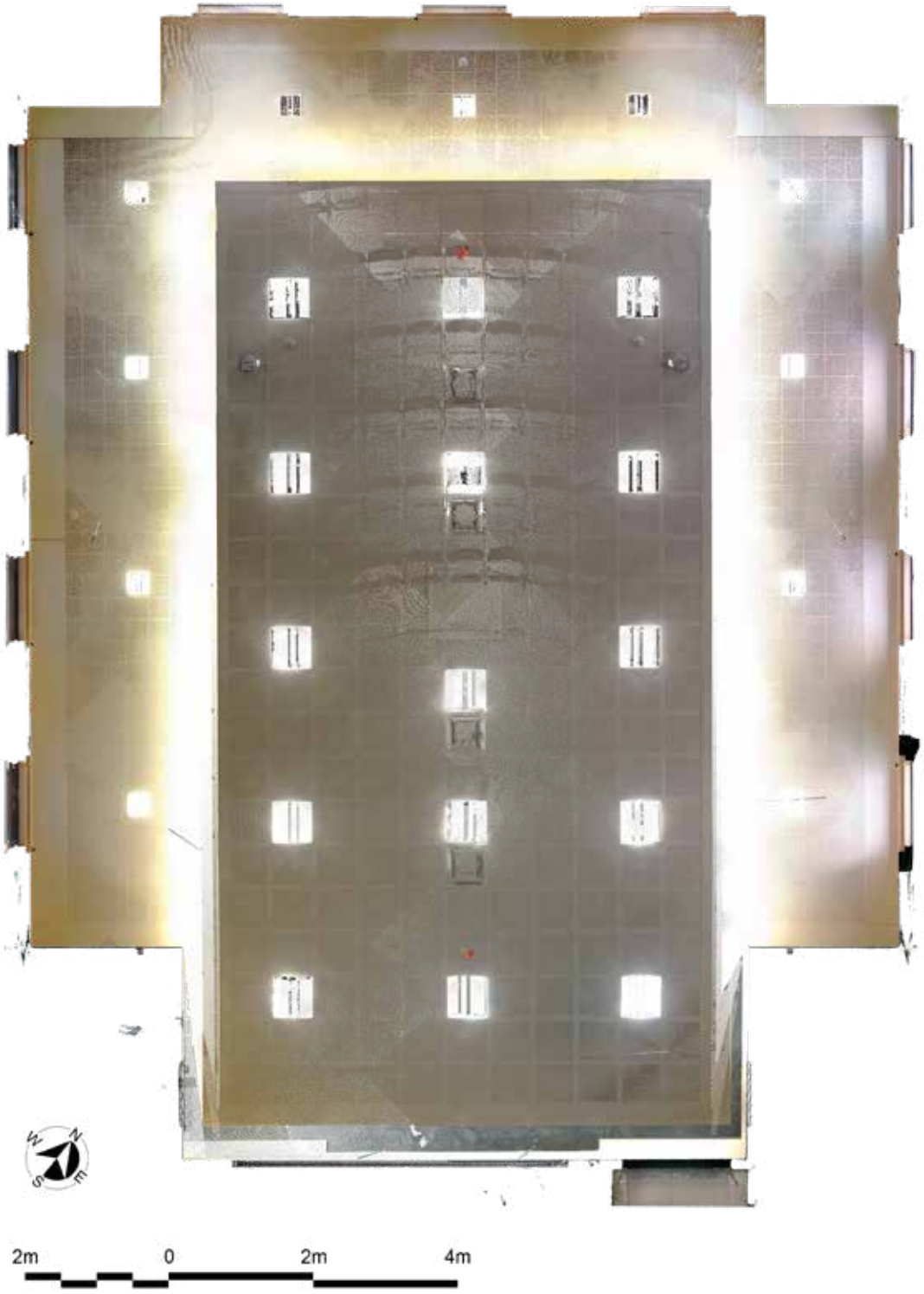
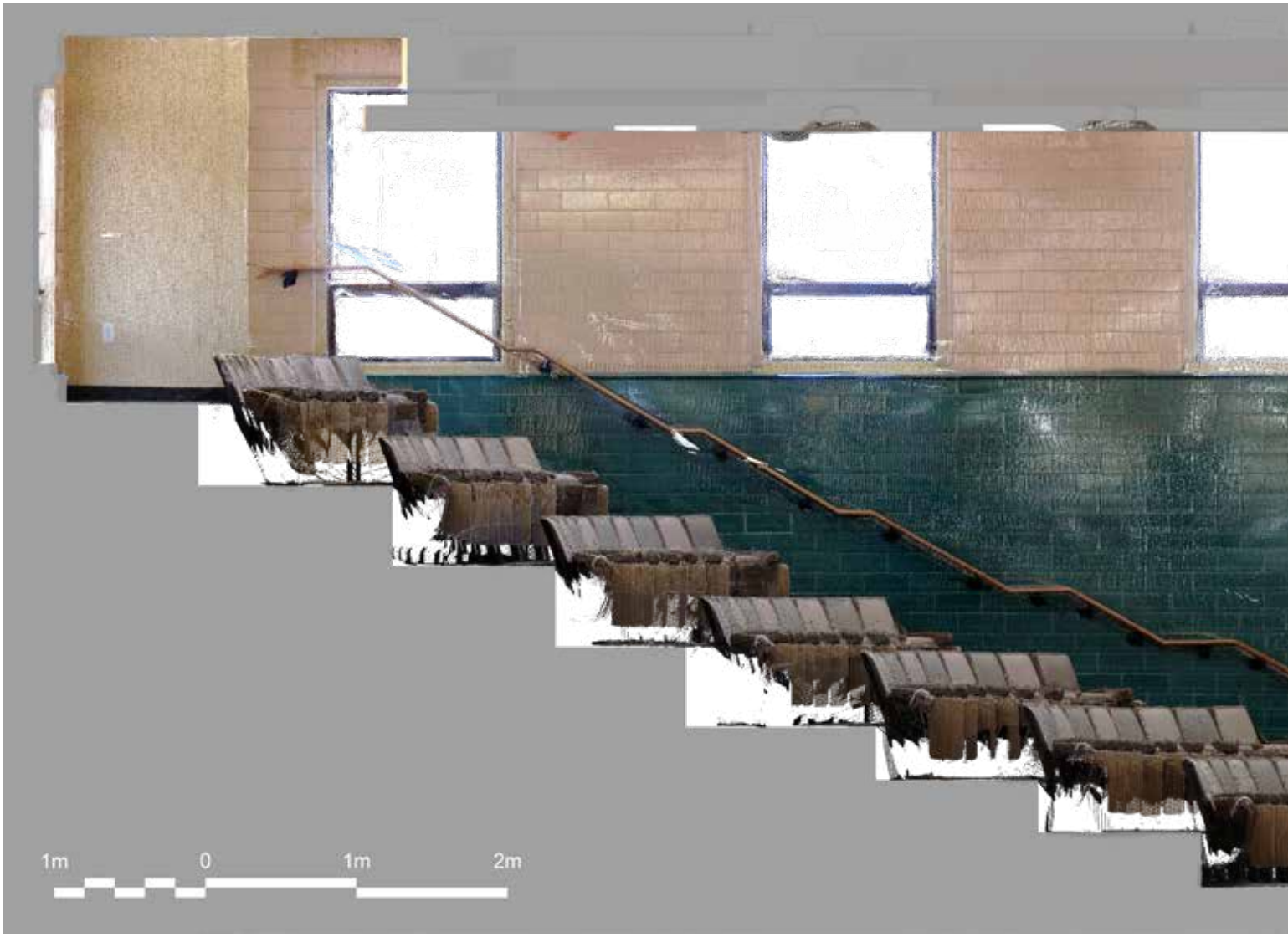


Figure 8.
Auditorium Longitudinal Section (Northwest-Southeast Axis, looking Northeast). Orthophoto of point cloud export from FARO Scene.



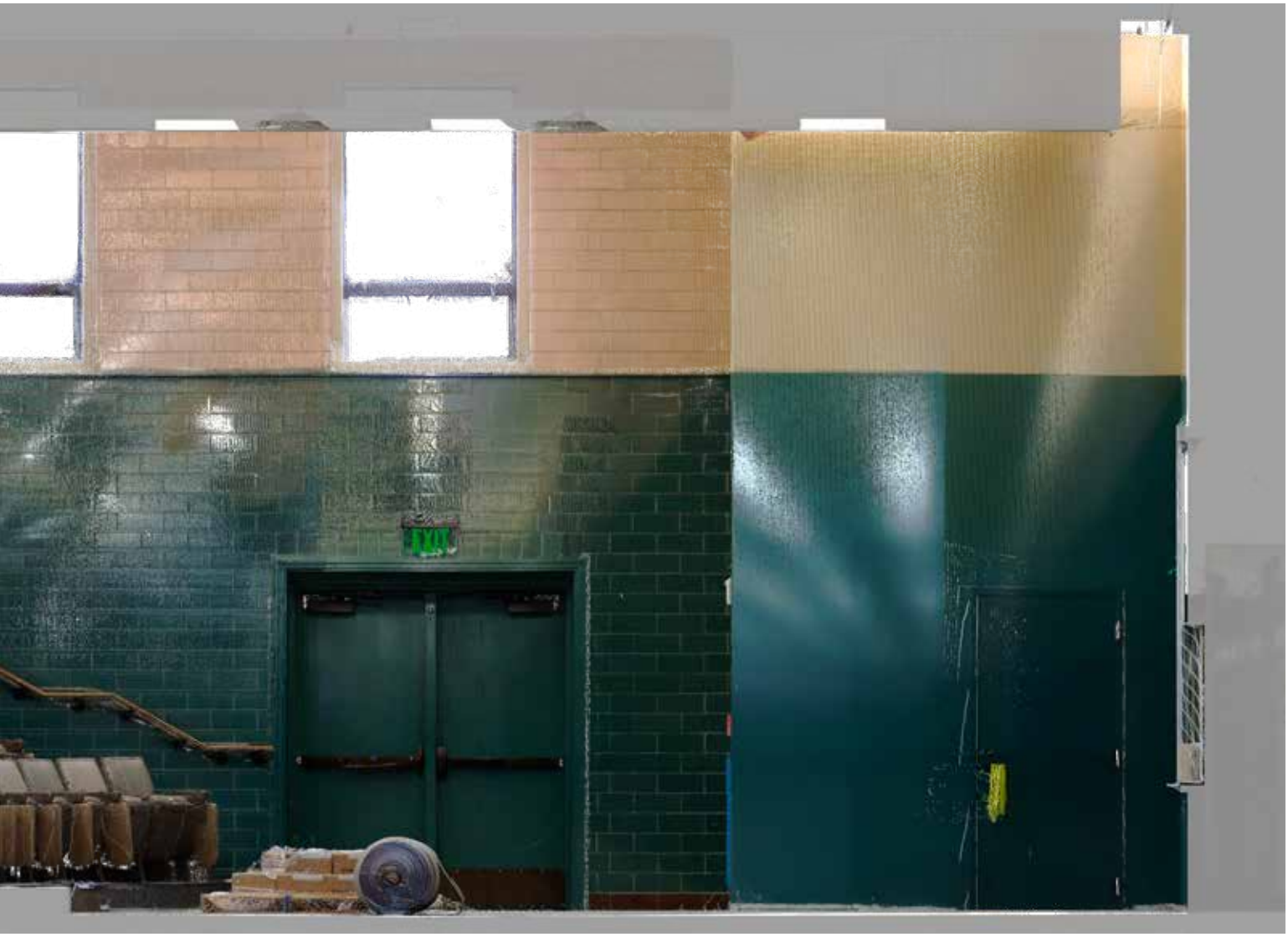

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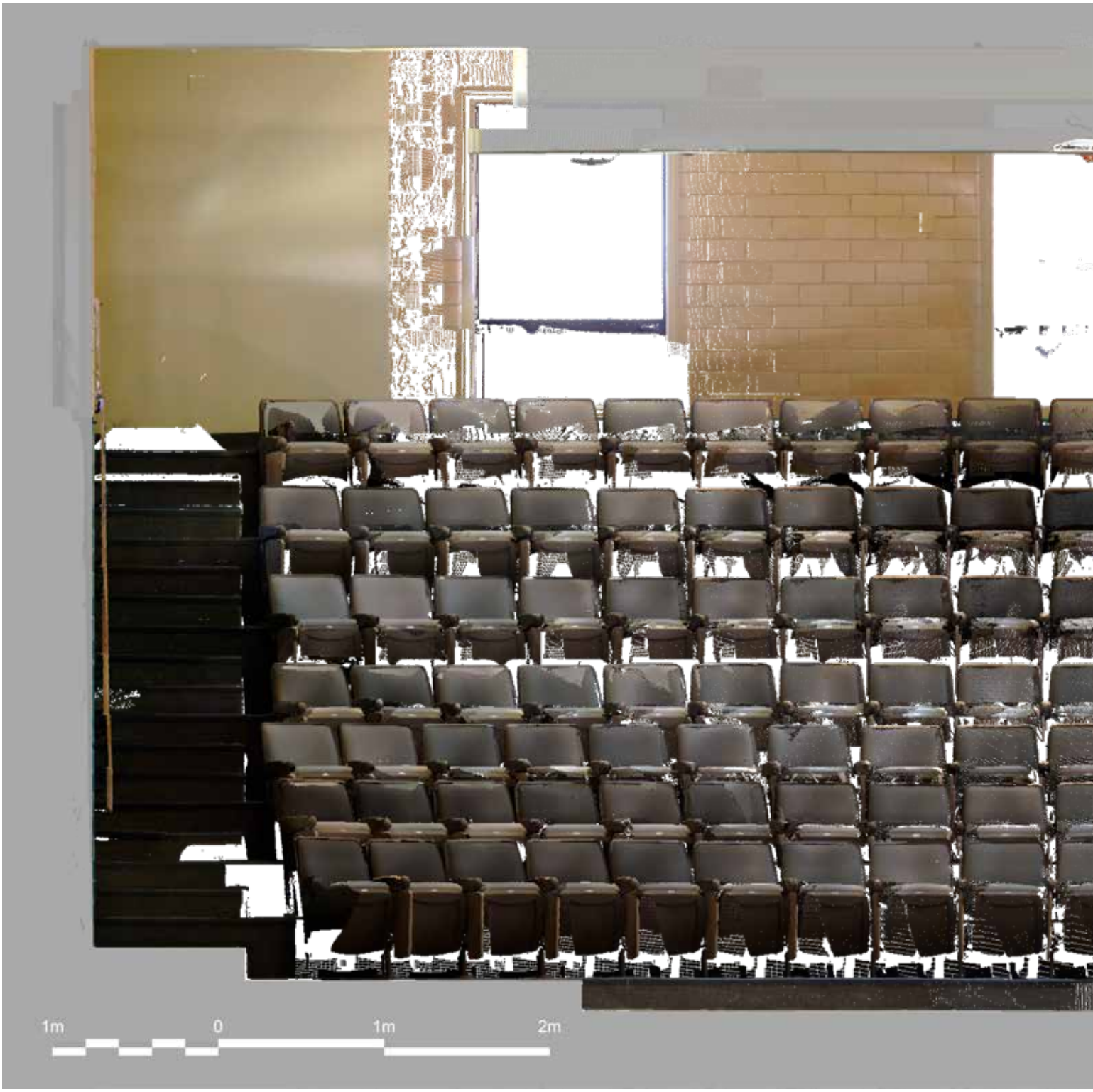
Figure 9. AuditoriumTransverse Section (Southwest-Northeast Axis, looking Northwest). Orthophoto of point cloud export from FARO Scene.



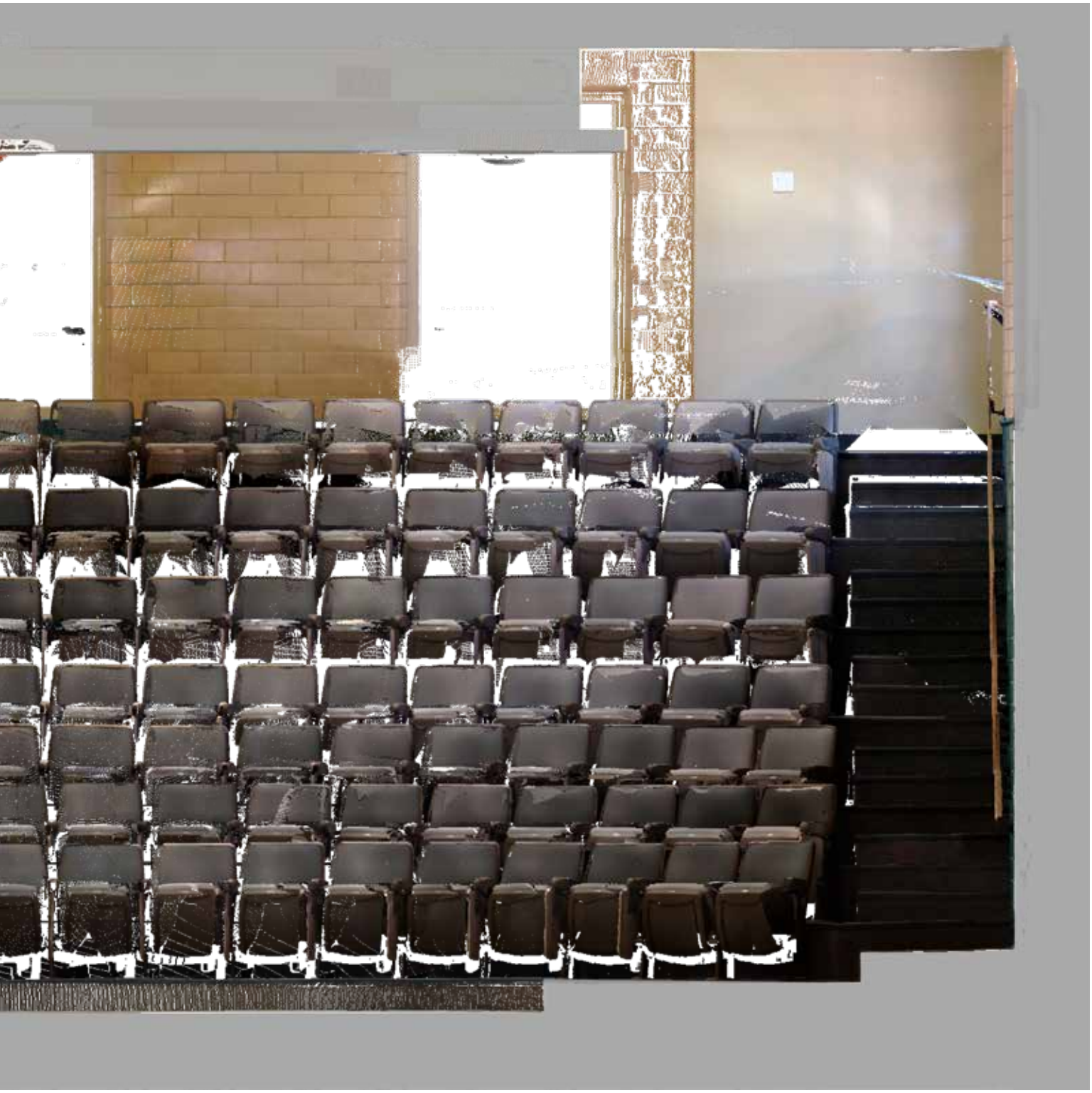


Figure 10. Isometric view (from South looking North). Image export from Autodesk ReCap.

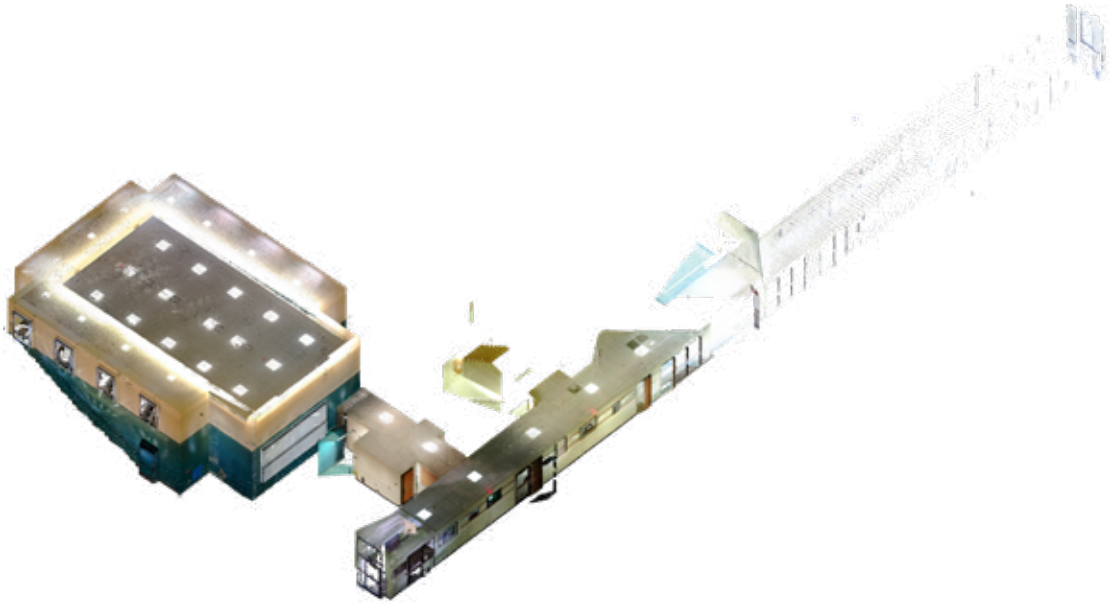
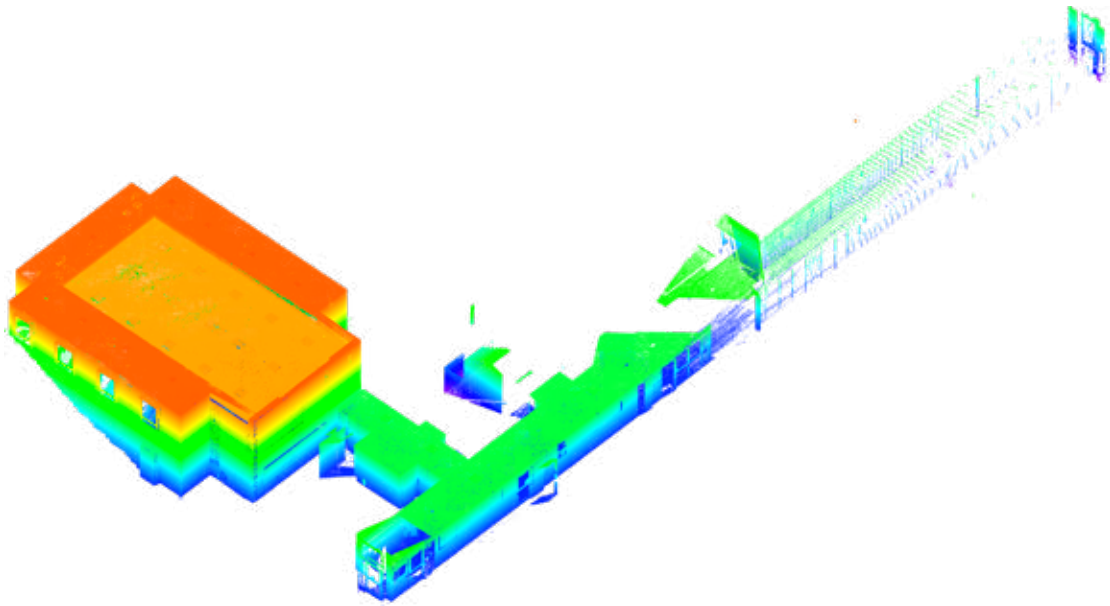


Figure 11. Isometric view (from South looking North). Image export from Autodesk ReCap ("heat map" filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

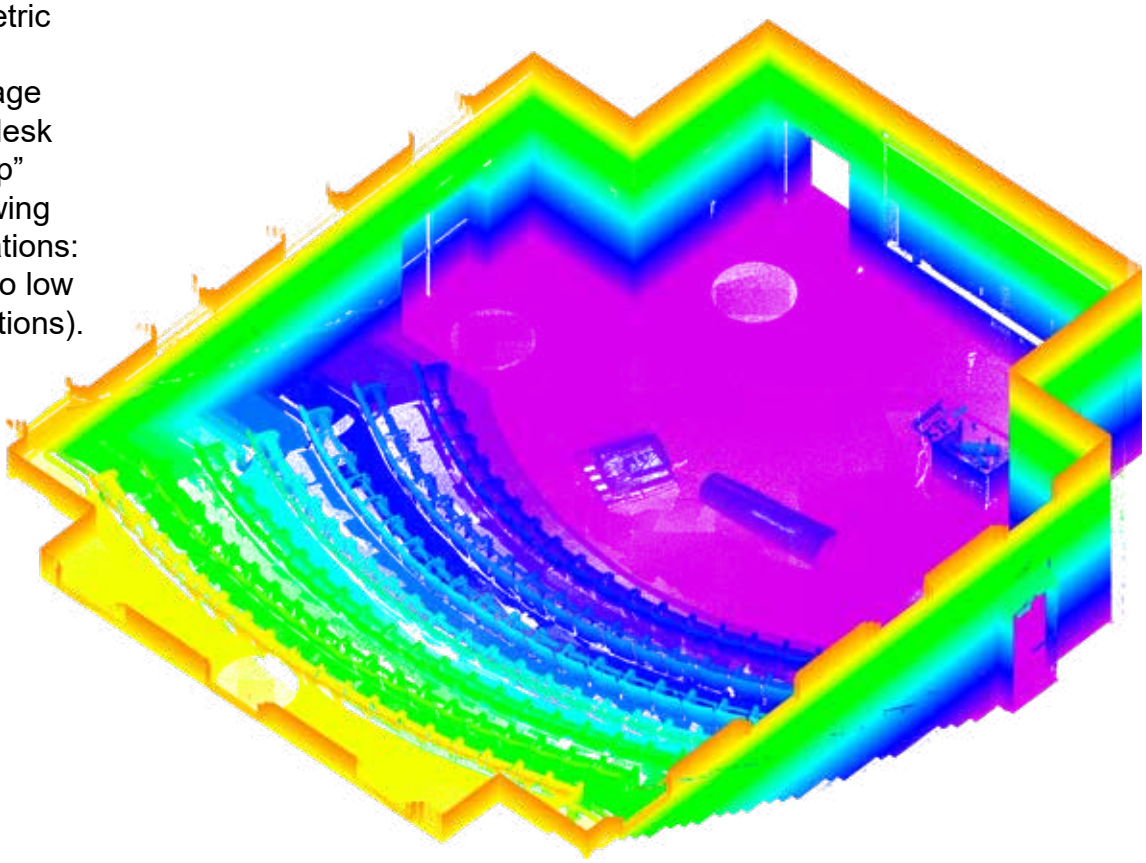


## Post Processing & Modeling

Once registered, the data was exported to various general formats and brought into secondary software for editing. The project point cloud was exported to E57 and PTS file formats, since either of these formats can be brought into a variety of useful secondary software (e.g., Autodesk ReCap Pro, CloudCompare, Rhinoceros 6, etc.). The scan project was also exported as an Autodesk ReCap Pro project, directly from FARO Scene. In the context of this project, this was done in order to take advantage of that software's "heat map" filter and preset isometric view settings (for image export). This ReCap point cloud can also be linked to AutoCAD and Revit for further modeling, if necessary.

Figure 12. Auditorium, Isometric view (from West looking East). Image export from Autodesk ReCap.

Figure 13. Auditorium, Isometric view (from West looking East). Image export from Autodesk ReCap (“heat map” [above] filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).



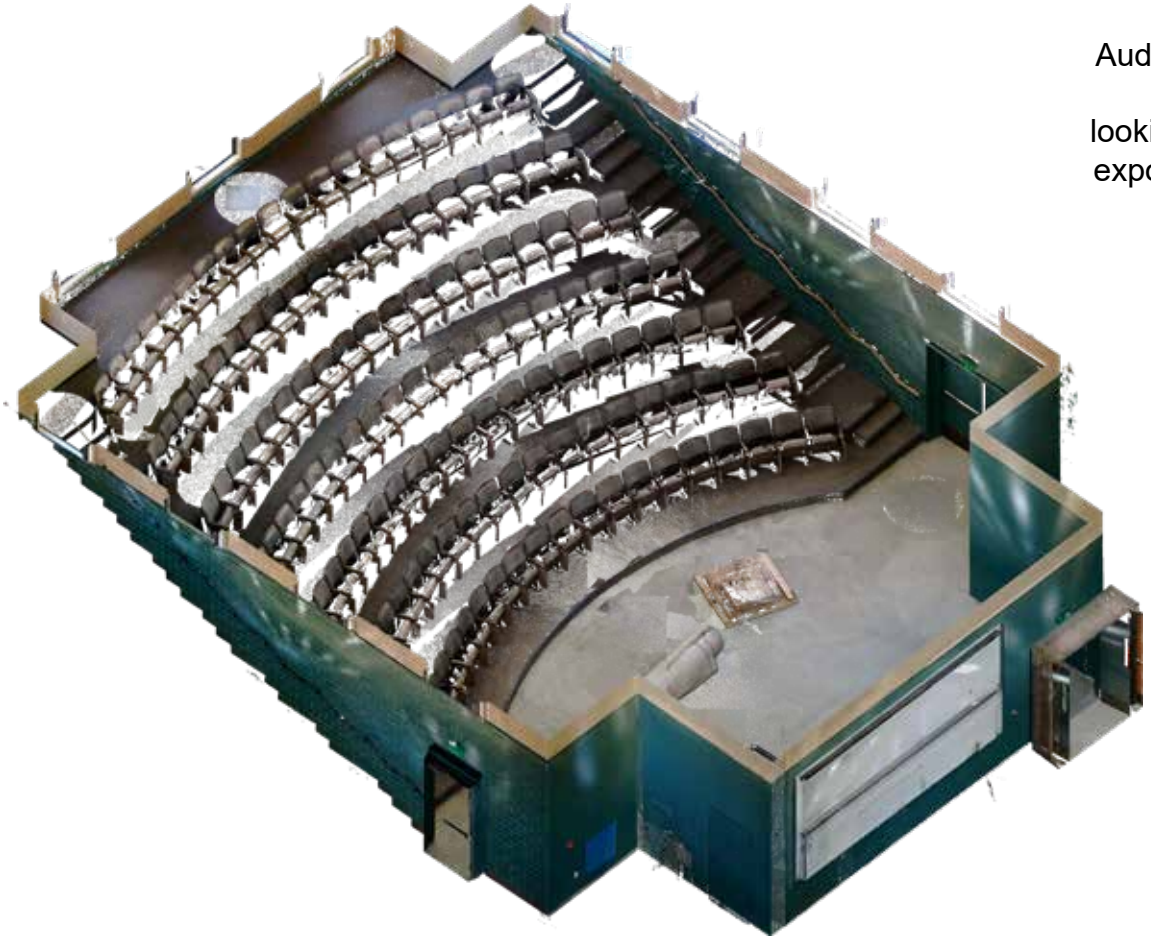


Figure 14. Auditorium, Isometric view (from South looking North). Image export from Autodesk ReCap.

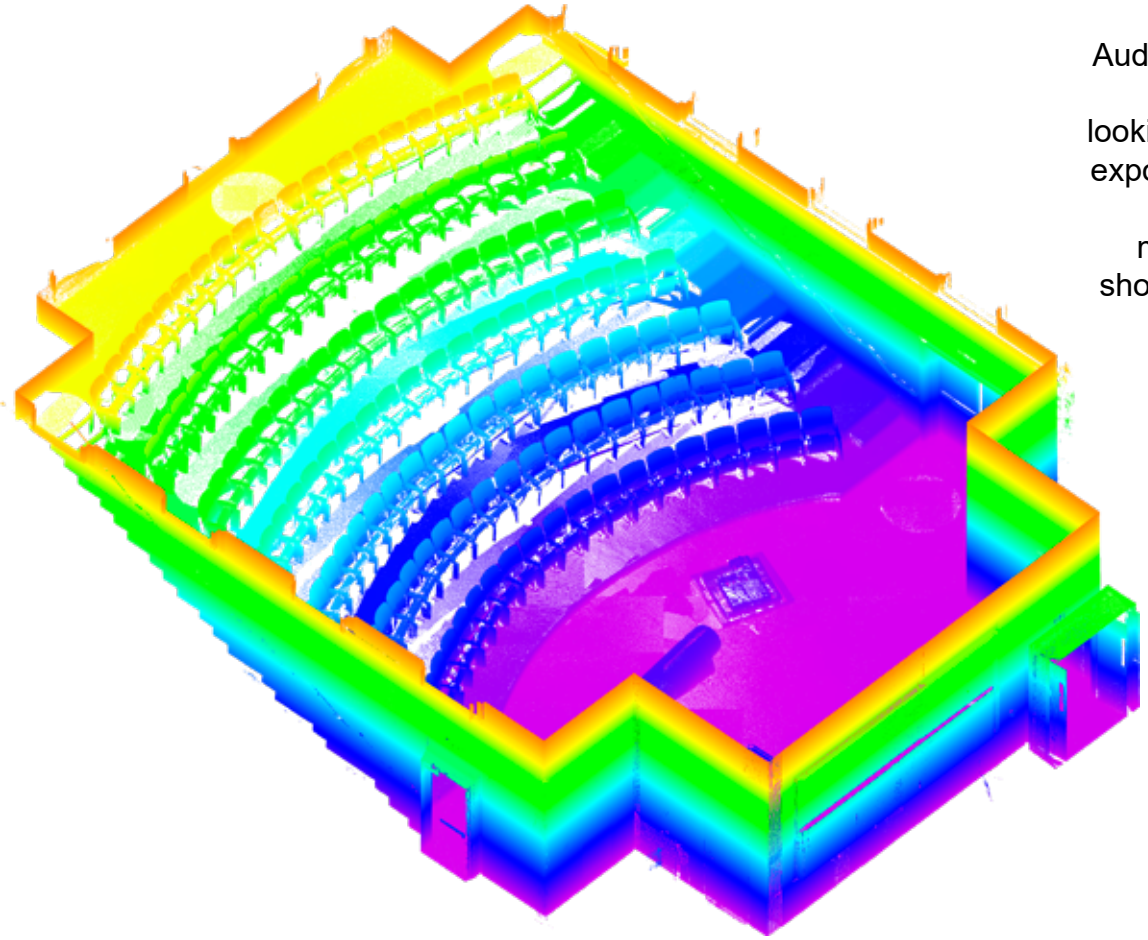


Figure 15. Auditorium, Isometric view (from South looking North). Image export from Autodesk ReCap ("heat map" [above] filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).