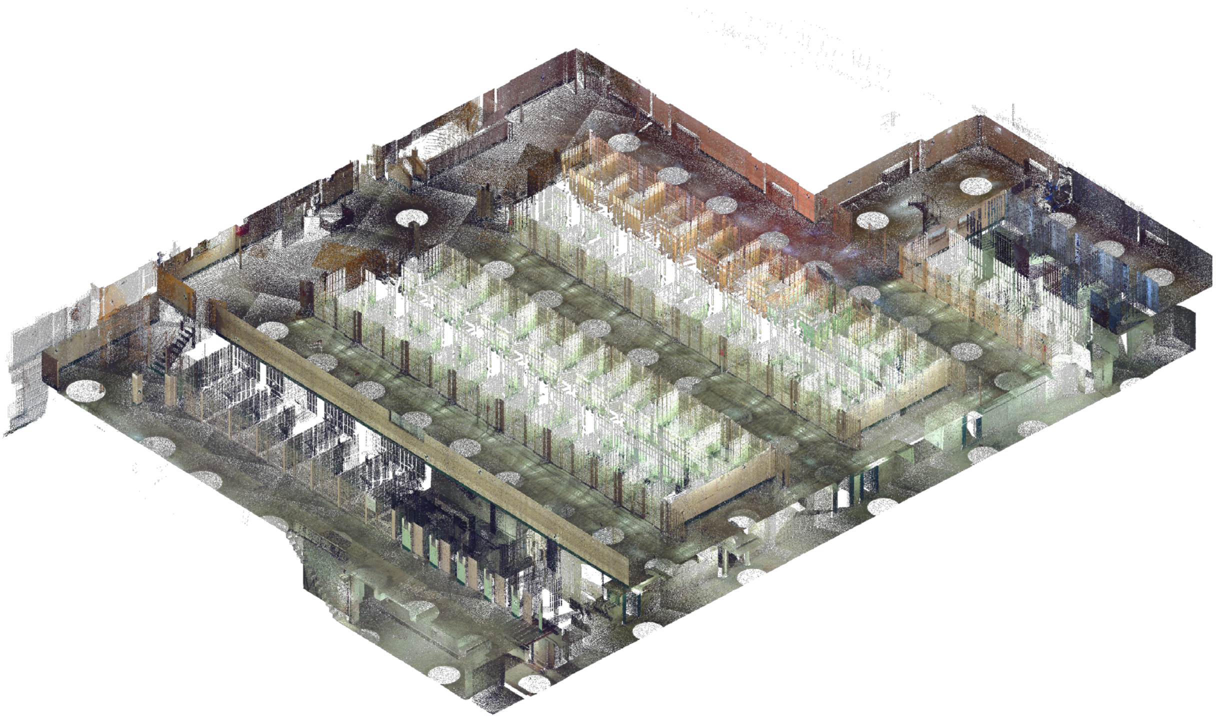
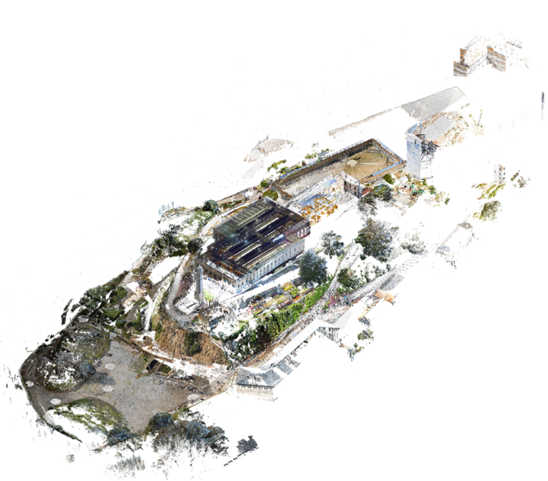
Center for Heritage Conservation



ALCATRAZ ISLAND | SCANNING & MODELING



PROCEDURAL REPORT

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31 AUGUST 2017

Table of Contents

1.	Introduction		3
2.	Laser Scanning		7
	2.1	Techniques & Procedure	8
	2.2	Data Files	10
3.	Scan Output		13
	3.1	Island Features	14
	3.2	Cellhouse	16
	3.3	Citadel	21
	3.4	Cellhouse - Citadel Relationship	22
4.	Point Cloud to Revit Model		29
5.	Conclusions		35

1. INTRODUCTION

Figure 1. Top View | Complete Point Cloud | 1:2000

1. Introduction

The Center for Heritage Conservation (CHC) from Texas A&M University (TAMU) conducted laser scanning studies at Alcatraz Island from 2011 to 2016. Survey consisted of two techniques: total station survey and 3D laser scanning. The survey produced raw scan data, which was processed into a 3D point cloud. From the point cloud, E57 and ASCII formats of the laser scans were exported. This point cloud data was then used to modify an existing Revit model into a more accurate preliminary BIM model, from which a BIM-ready model can be built.

For the present project, the CHC and National Park Service (NPS) have agreed upon the production and delivery of specific data sets by the CHC:

1. 3D point cloud
    a. RAW, unprocessed scan data
    b. Registered, Autodesk Recap project
    c. Registered, gridded E57 file
    d. Control data, ASCII format
    e. Relevant metadata forms, registration diagnostics, and report
2. 3D Autodesk Revit model
3. Scanning & Modeling Procedural Report

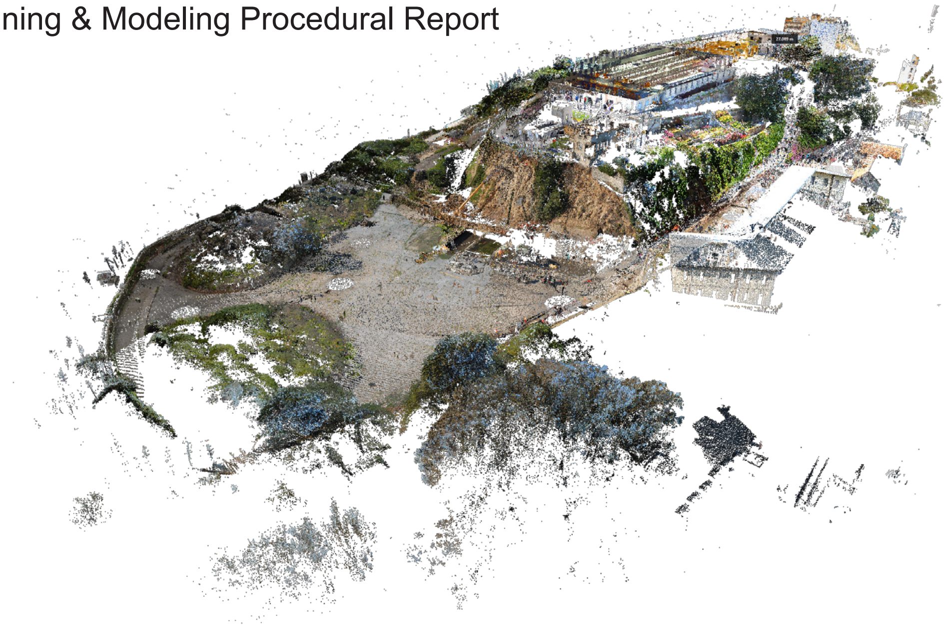


Figure 2: Bird's Eye Perspective View [From Southeast looking Northwest] | Complete Point Cloud

The registered point cloud data was used to provide a high resolution digital model. The digital model provides the necessary data to extract desired architectural views in orthographic and perspective formats. This extraction enables the viewing and interpretation of relationships between built and natural elements on the island.

CHC-led survey teams worked to laser scan the East Staircase in the fall of 2011, the Recreation Yard and West Road in the summer of 2012, the Parade Ground in the spring of 2013, and the Cellhouse and Citadel in the summer of 2016. While a HABS (Historic American Buildings Survey) team scanned the Citadel comprehensively, the CHC-led team conducted scanning specifically to visualize the relationship between the Citadel and Cellhouse. (The model produced by the CHC does not include the HABS scans).

Figure 3. West Elevation | 1:2000

Figure 4. East Elevation | 1:2000

2. LASER SCANNING

The CHC survey team used total station survey and 3D laser scanning techniques in documenting Alcatraz Island. Total station survey served to establish a coordinate system, ensuring accurate positioning and orientation of individual laser scans between field seasons.

Documentation of Alcatraz Island by the CHC began in the summer of 2011. A small team scanned the staircase on the east side of the island. In the summer of 2012, a larger team returned to document the Recreation Yard, the Westside Road, and the same east side staircase. The CHC survey team laser scanned the Recreation Yard, and a team from Geophysics at Texas A&M collected data using ground-penetrating radar (GPR) [the model produced by the CHC does not contain this GPR data].

In the summer of 2016, work continued at Alcatraz Island with laser scanning and GPR of the island Cellhouse and Citadel. One faculty member and a student, both from geophysics, conducted GPR. One faculty member, one volunteer, and five students (four in historic preservation and architecture, and one in geophysics) conducted laser scanning. Students conducting laser scanning were part of TAMU's Recording Historical Buildings course (Architecture 647), working in conjunction with the CHC.

Scanning of the Cellhouse and the Citadel were executed using a FARO Focus scanner, a Riegl scanner, and a FARO Freestyle scanner, in conjunction with Leica Total Station. The Total Station Survey served to place scans in a geocoordinate system established by the CHC in 2011. This coordinate system allows for scans to be accurately registered across multiple project years.

The FARO Freestyle was used only as an experiment in work flow. This hald-held scanner is best equipped for small-scale scans and performed well in the documentation of an individual cell in A Block. While it may be advantageous in some situations to use the FARO Freestyle in coordination with the FARO Focus to better resolve scan data for each individual cell, the automation and consistant work flow of the FARO Focus renders the Freestyle scanner unnecessary. The Freestyle better serves to produce small, quick scan patches, which can be aligned with primary scan data.

The Riegl laser scanner was used primarily for exterior scans (in projects from 2011 to 2013). In 2016, the Riegl scanner executed 12 laser scans, focusing on the adjoining corridors at each end of the Cellhouse. The scanner was also used to scan the Mess Hall on the north end of the Cellhouse. Due to its overall greater range, the Riegl optimized scan distance, gathering necessary data on the high ceilings. These scans served as an overall reference base for the FARO Focus scans. The final point cloud data in ReCap and FARO Scene do not contain these interior scans. The final point cloud data consists of interior scans by the FARO Focus scanner (2016) with exterior scans by the Riegl scanner (2011-13).

The FARO Focus scans were concentrated at regular intervals down each cell block, their intersecting corridors, as well as the adjoining corridors. It is important to note that these scans were performed only on the ground floor of the Cellhouse. In the future, additional scans could also be produced of each individual cell, on each remaining level above the ground floor, and potentially in the cavity space between cell blocks. Recommendations for building on the current scan data for a more highly-resolved digital model will be discussed in the conclusions, along with other avenues to expand documentation of the island.

2.1 Techniques & Procedures

Figure 5: Leica Total Station

Figure 6: Riegl Scanner (above)
Figure 7: FARO Scanner (below)

Cell Block A

	mean target distance error [mm]	mean target angle error [°]
Position 1	5.30	0.000
Position 2	5.13	0.000
Position 3	5.42	0.000
Position 4	6.96	0.001
Position 5	6.67	0.001
Position 6	5.40	0.000
Position 7	5.65	0.000
Position 8	5.34	0.000
Position 9	5.53	0.000
Position 10	3.99	0.000
Position 11	3.51	0.000

Cell Block B
(in scan cluster with Cell Block Iso: scans 1-10)

	mean target distance error [mm]	mean target angle error [°]
Position 11	4.26	0.000
Position 12	4.65	0.000
Position 13	5.43	0.000
Position 14	6.65	0.000
Position 15	6.00	0.000
Position 16	5.75	0.000
Position 17	6.05	0.000
Position 18	7.53	0.000
Position 19	5.67	0.000
Position 20	5.95	0.000
Position 21	6.02	0.000
Cluster 22-28	4.92	0.000
Position 22	5.87	0.001
Position 23	5.34	0.001
Position 24	5.49	0.001
Position 25	5.35	0.001
Position 26	4.02	0.001
Position 27	5.58	0.001
Position 28	6.70	0.001

The raw Riegl scans were processed using RiScan Pro, while FARO scans were processed using Scene software. These processed scans were imported into Autodesk ReCap and registered together. From ReCap, a gridded E57 file was created. The E57 file was brought into Cloud Compare and exported into their corresponding ASCII files: the overall island (that is, all exterior scans), the Cellhouse, and the Citadel.

Scans of the interiors of the Cellhouse and Citadel were completed in 2016, while all exterior scans were performed between 2011 and 2013.

What follows are detailed registration data from the 2016 laser scans using the FARO Focus laser scanner. These data indicate the level of precision and consistency executed using the current laser scanning methods. This format serves a tentative, baseline-standard of data analysis moving forward by which accuracy can be closely monitored over multiple field seasons.

Cell Block C

	mean target distance error [mm]	mean target angle error [°]
Position 1	11.18	0.000
Position 2	4.59	0.000
Position 3	5.72	0.000
Position 4	4.86	0.000
Position 5	5.03	0.000
Position 6	5.08	0.000
Position 7	5.83	0.000
Position 8	4.98	0.000
Position 9	4.60	0.000
Position 10	4.54	0.000
Position 11	5.19	0.000
Position 12	6.56	0.000
Position 13	5.72	0.000
Position 14	7.14	0.000
Position 15	6.42	0.000
Position 16	8.70	0.000

2.2 Data Files

Cell Block D

	mean target distance error [mm]	mean target angle error [°]	mean scan point distance error [mm]
Position 1	4.69	0.027	1.62
Position 2	4.14	0.027	2.78
Position 3	4.89	0.016	1.59
Position 4	4.78	0.017	1.55
Position 5	4.77	0.014	1.51
Position 6	5.69	0.013	2.21
Position 7	5.50	0.014	2.25
Position 8	6.18	0.030	2.98
Position 9	6.00	0.013	2.17
Position 10	6.46	0.020	2.22
Position 11	6.19	0.013	2.28
Position 12	5.93	0.012	1.96
Position 13	5.66	0.013	1.73
Position 14	8.39	0.011	1.77
Position 15	6.31	0.013	3.18
Position 16	9.34	0.020	4.62
Position 17	5.85	0.015	5.12
Position 18	-	0.012	7.92

Cell Block Isolation
(in scan cluster with Cell Block B: scans 11-28)

	mean target distance error [mm]	mean target angle error [°]
Position 1	5.02	0.000
Position 2	5.10	0.000
Position 3	4.08	0.000
Position 4	4.73	0.000
Position 5	4.85	0.000
Position 6	4.57	0.001
Position 7	4.07	0.000
Position 8	3.73	0.000
Position 9	4.11	0.000
Position 10	4.36	0.000

Citadel

	reference position	mean scan point tension [mm]	<4 mm [%]	overlap [%]	used points	mean scan point distance error [mm]
Position 1	2	1.305	89.6	24.8	12,994	1.74
Position 2	-	-	-	-	-	1.31
Position 3	2	1.316	91.4	33.0	25,054	2.02
Position 4	3	1.600	85.0	64.9	77,242	1.60
Position 5	3	3.156	55.0	54.0	29,401	2.72
Position 6	5	2.287	77.0	66.9	36,240	2.56
Position 7	6	2.825	58.3	51.4	57,065	6.14
Position 8	7	9.448	39.1	30.4	19,055	5.25
Position 9	8	1.460	89.5	35.0	30,295	1.76
Position 10	9	2.069	73.4	66.8	77,947	2.15
Position 11	10	2.226	74.3	45.4	19,180	2.41
Position 12	11	2.596	64.1	41.8	40,792	2.91
Position 13	12	3.221	58.9	47.3	71,857	2.62
Position 14	13	2.027	79.5	46.7	23,122	2.26
Position 15	14	2.493	68.8	38.8	12,793	2.49
Position 19	8	4.828	44.9	42.1	33,378	4.83
Cluster 16-18	1	2.177	79.7	33.9	17,689	2.18
Position 16	17	0.900	95.2	11.5	1,194	0.90
Position 17	-	-	-	-	-	1.80
Position 18	17	2.702	70.4	59.1	26,678	2.70
Overall Citadel	-	2.8147	70.5	-	-	-
Overall 16-18	-	1.8011	82.8	-	-	-

3. SCAN OUTPUT

Figure 8: South Elevation | 1:2000

Figure 9: North Elevation | 1:2000

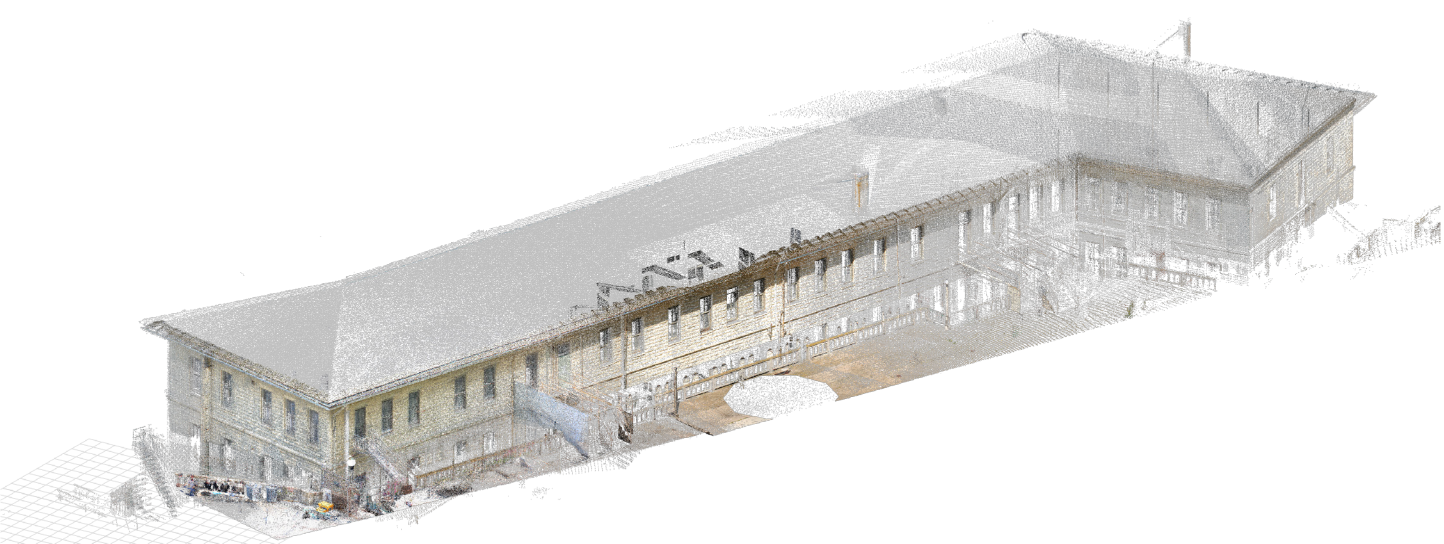


Figure 10: Building 64, Isometric View [From Northwest looking Southeast]

3.1 Island Features

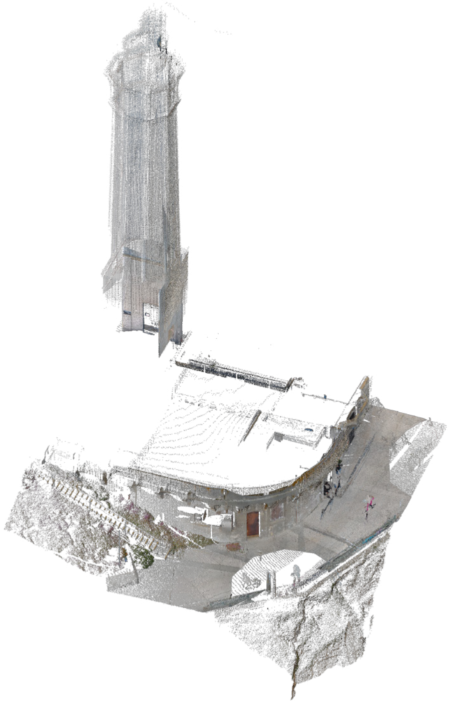


Figure 11: Lighthouse, Isometric View [From Southwest looking Northeast]

Figure 12: Warden’s House, Isometric View [From Northwest looking Southeast]

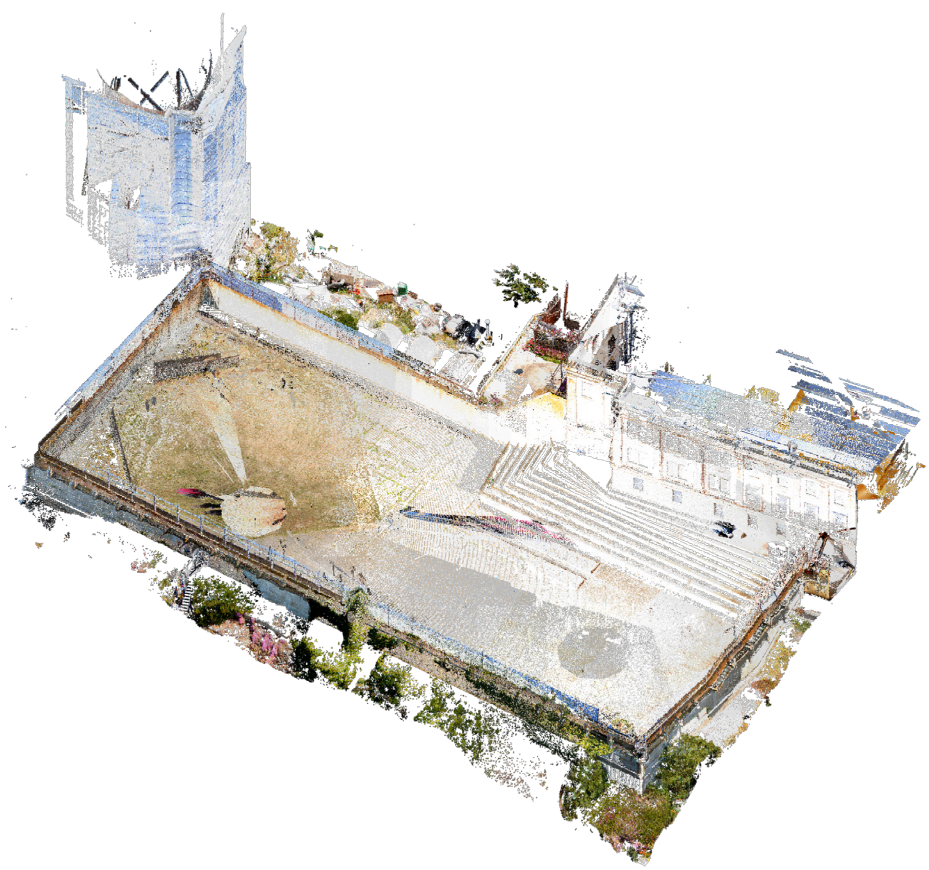


Figure 13: Recreation Yard, Isometric View [From Southwest looking Northeast]

Figure 14: A Block [From South end looking North]

3.2 Cellhouse

Figure 15: B Block [From block center looking North]

Figure 16: C Block [From block center looking North]

3.2 Cellhouse

Figure 17: D Block [From South end looking North]

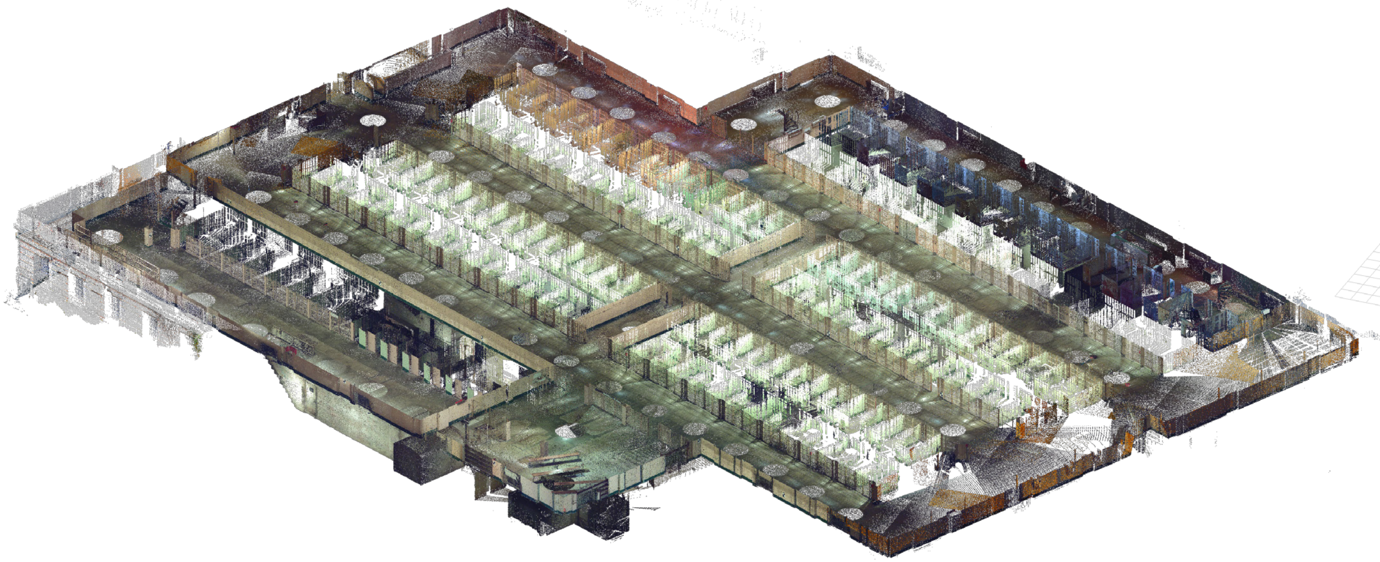


Figure 18: Plan-Section Isometric View, through Solitary Block [From Southwest looking Northeast]

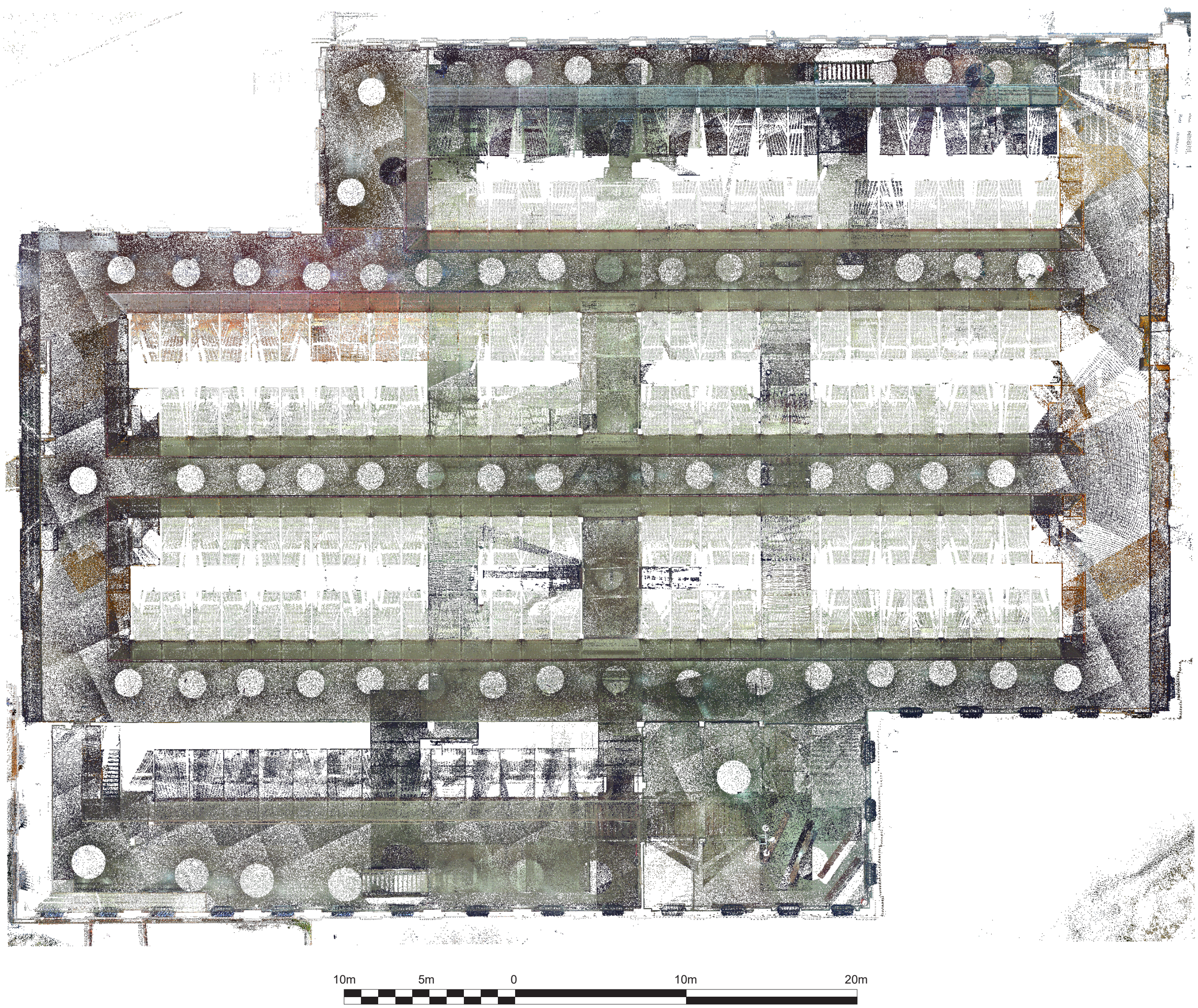


Figure 19: Cellhouse Floor Plan | 1:400

3.3 Citadel

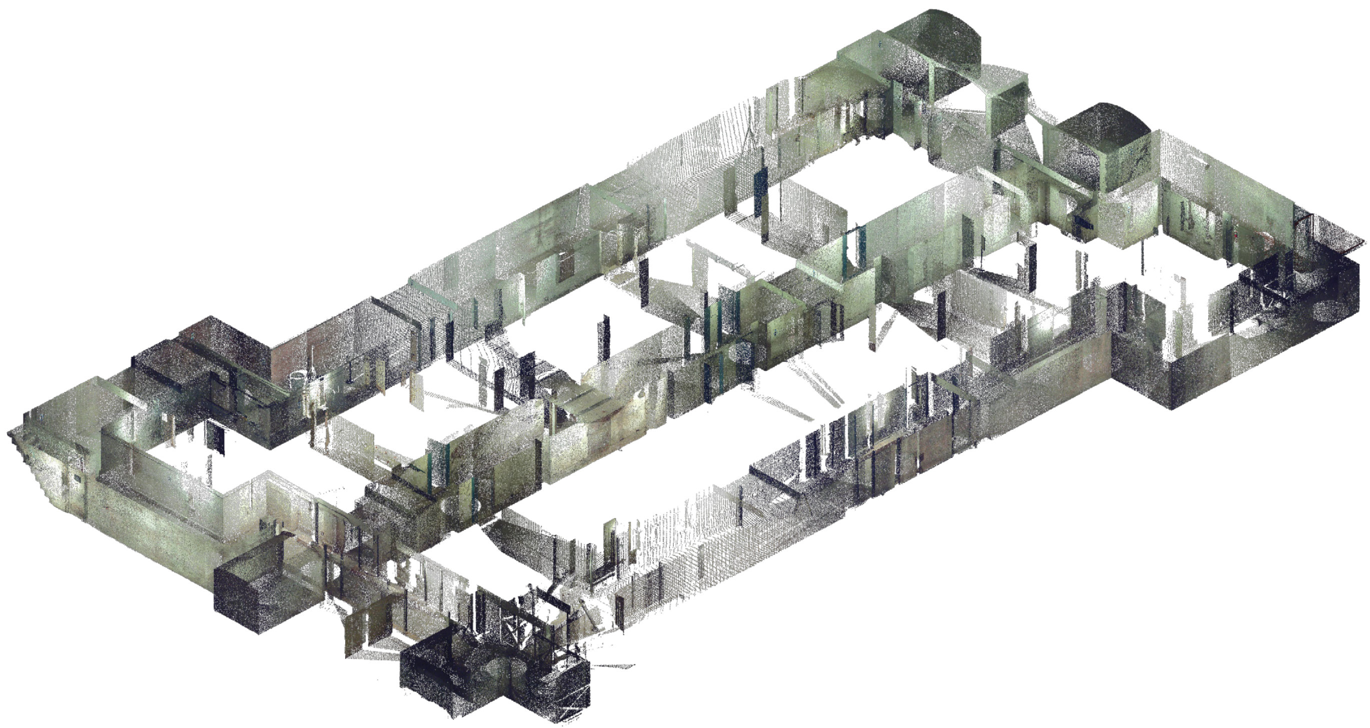


Figure 20: Citadel Plan Isometric View [From Southwest looking Northeast]

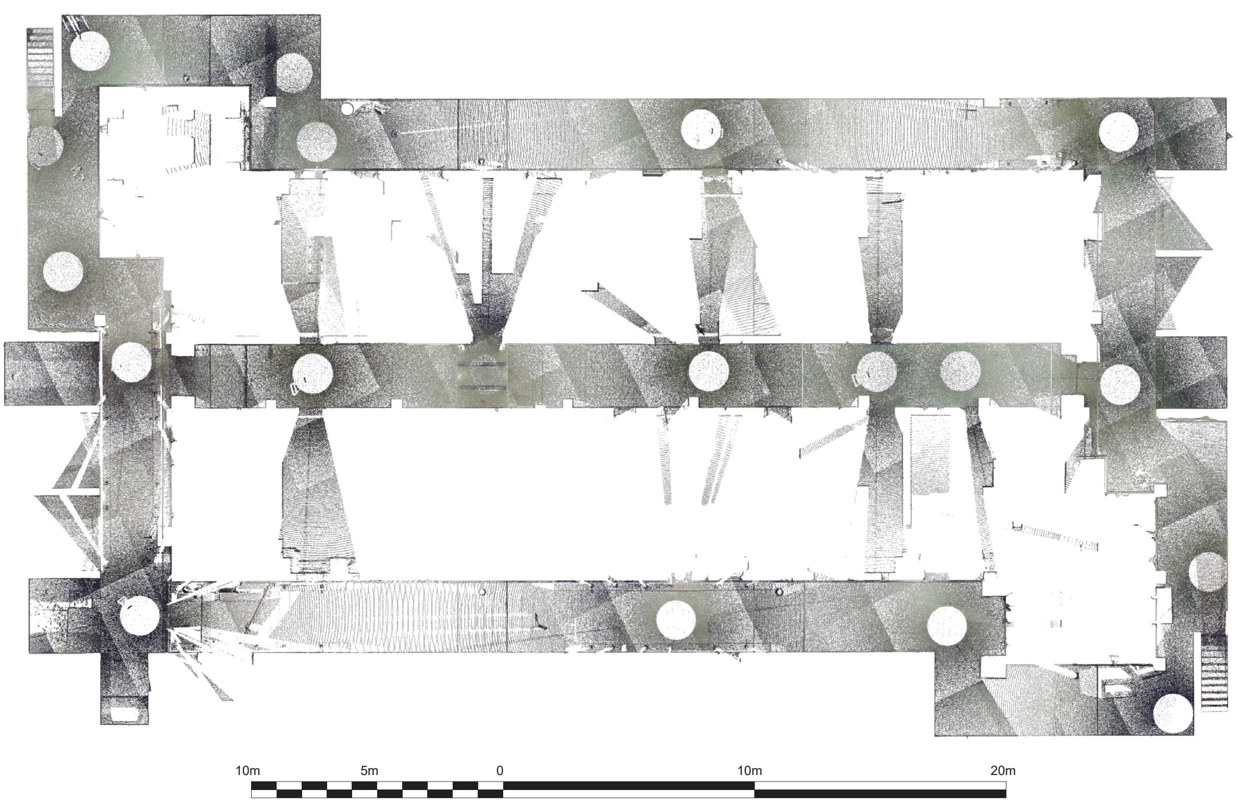


Figure 21: Citadel Floor Plan | 1:300

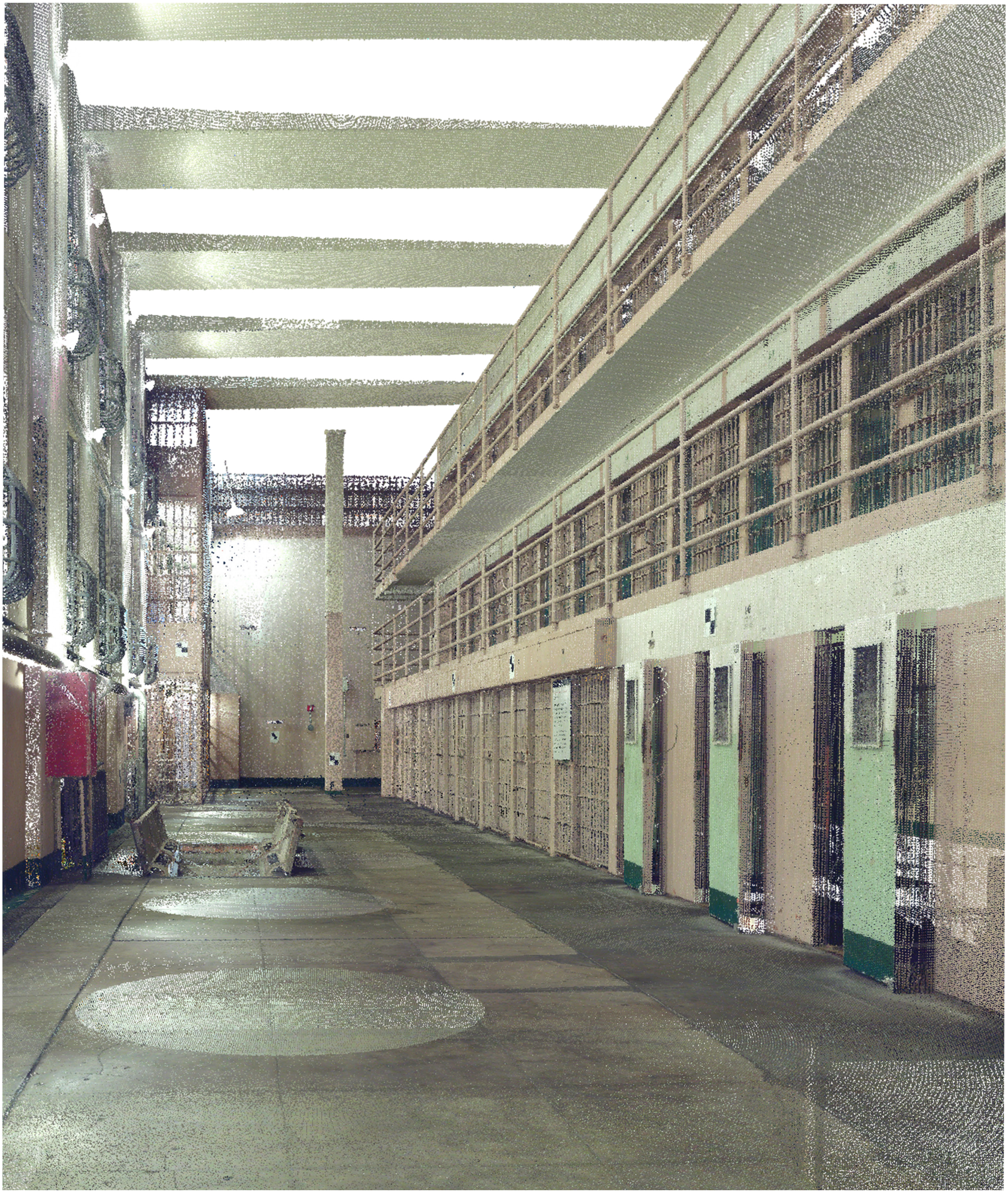


Figure 22: Solitary Block [From South end looking North]

3.4 Cellhouse - Citadel Relationship

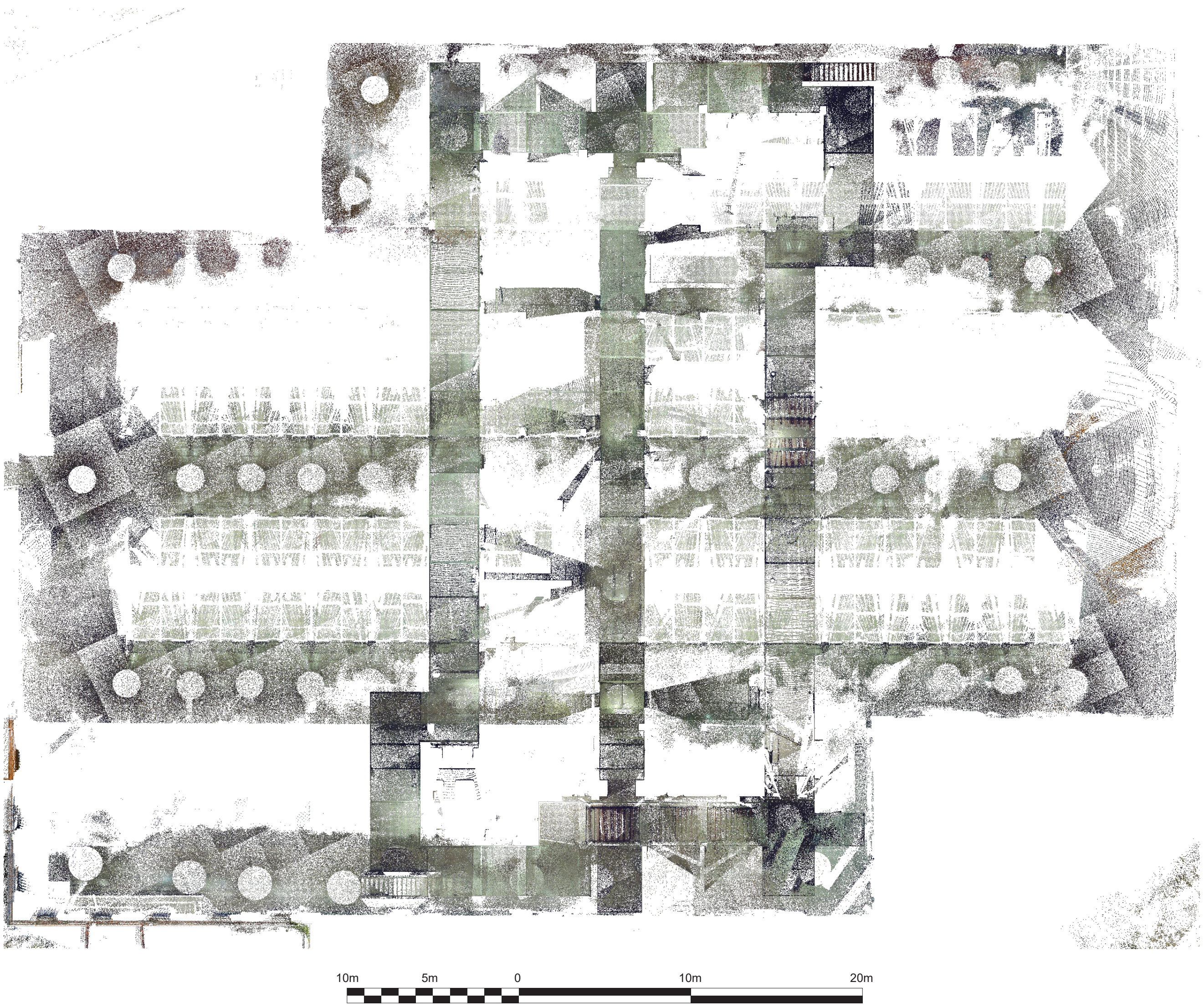


Figure 23: Floor Plan | Cellhouse & Citadel | 1:400

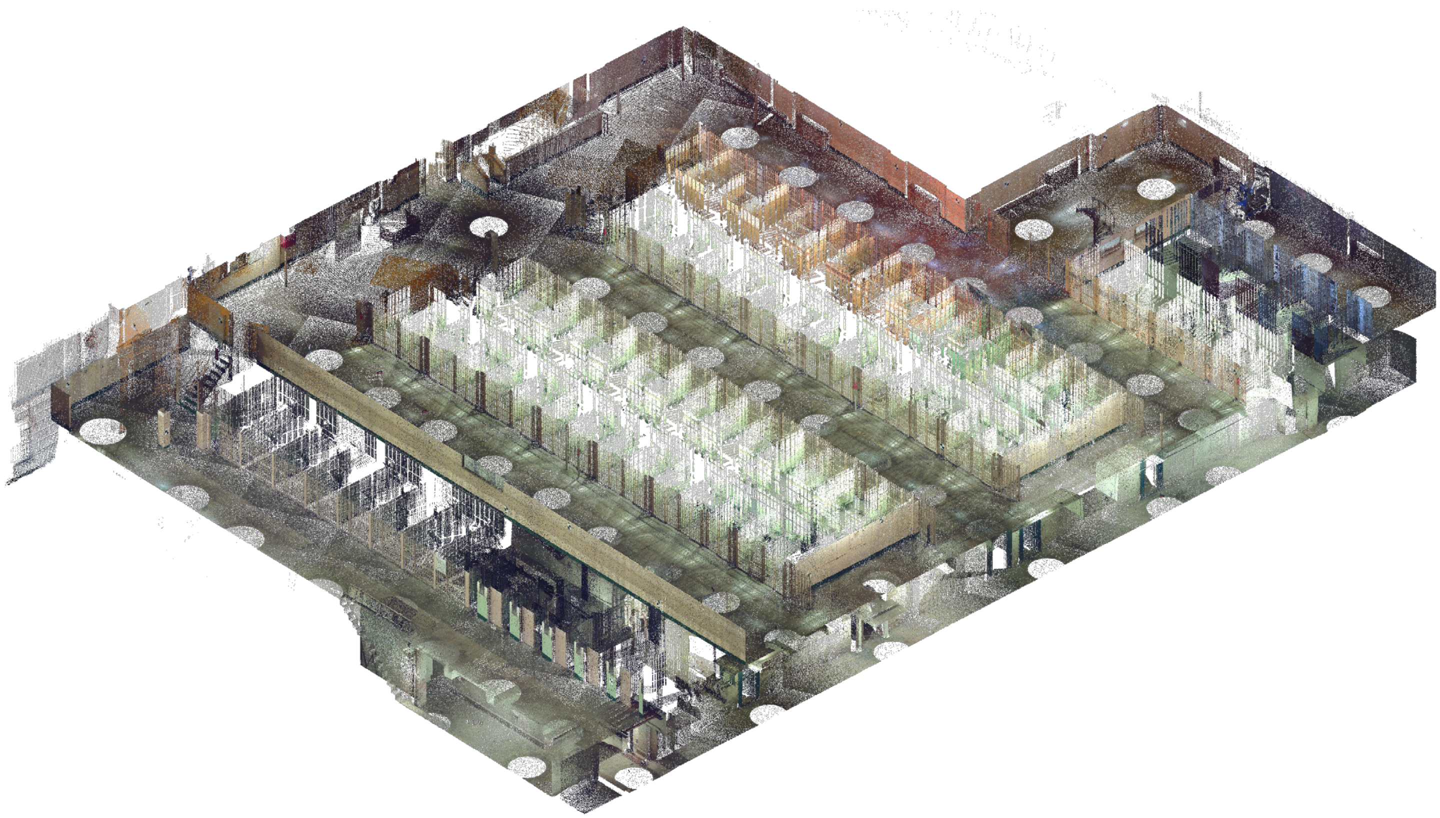


Figure 24: Plan-Dual Section Isometric View, through Solitary Block & Central Corridor of the Citadel [From Southwest looking Northeast]

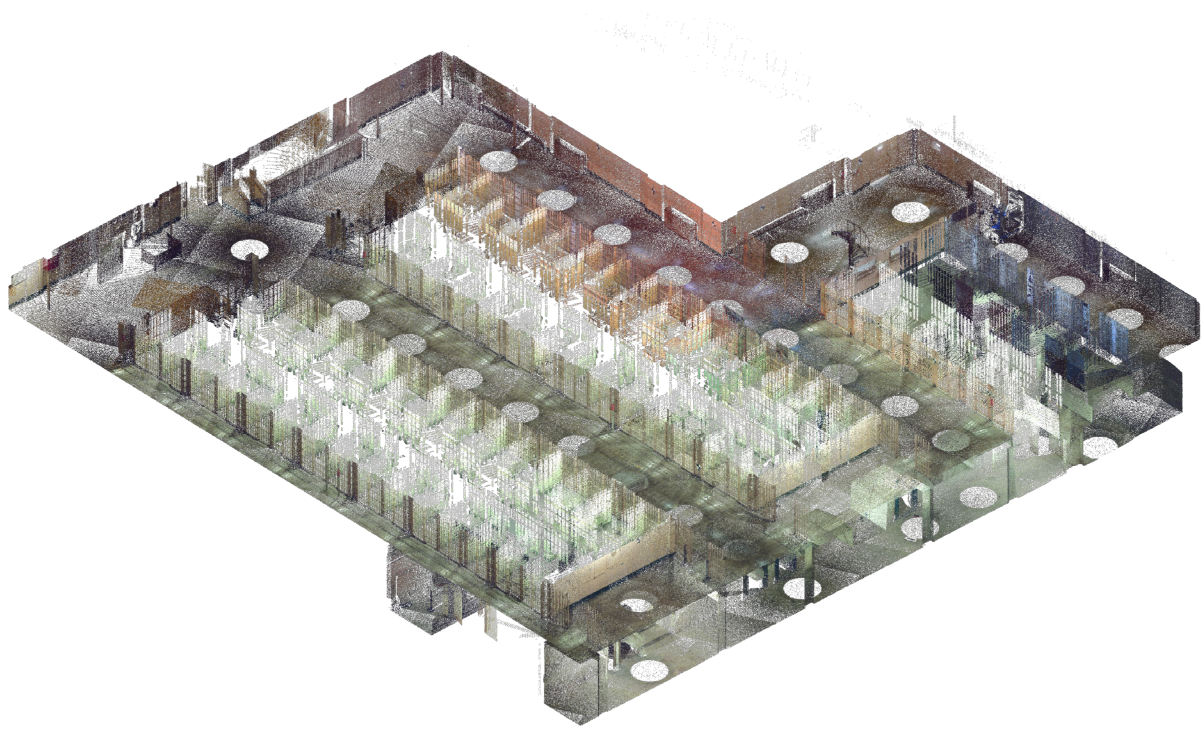


Figure 25: Plan-Dual Section Isometric View, through D Block & Central Corridor of the Citadel [From Southwest looking Northeast]

3.4 Cellhouse - Citadel Relationship

Figures 26-30: Longitudinal Sections | North-South Axis, looking East | 1:400

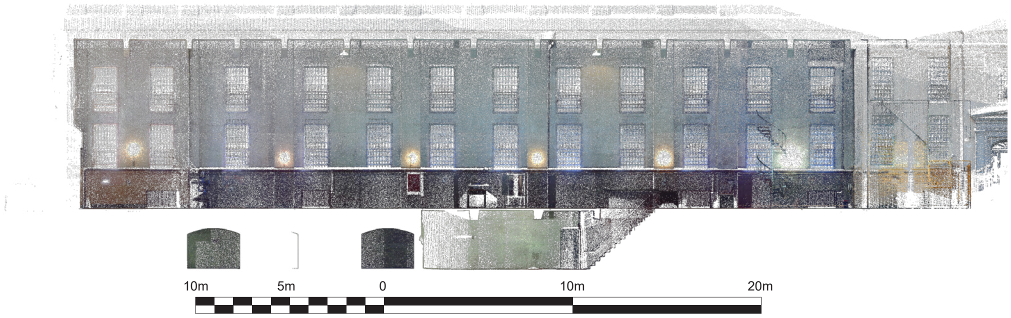


Figure 26: A Block

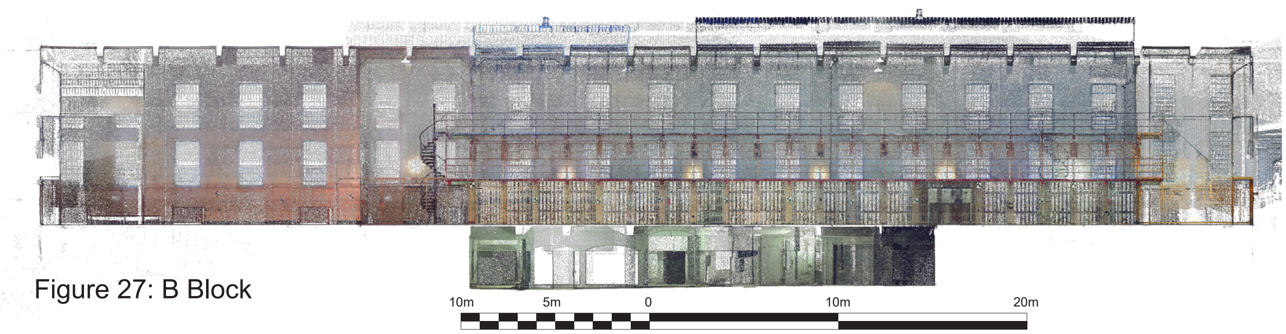


Figure 27: B Block

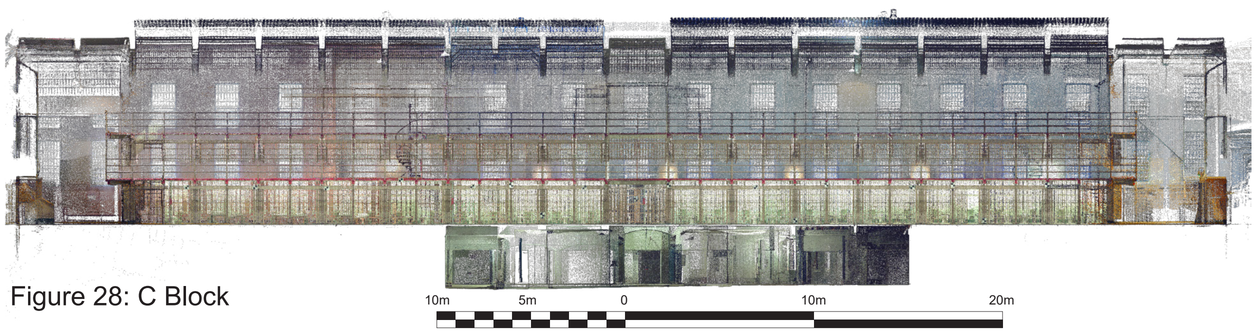


Figure 28: C Block

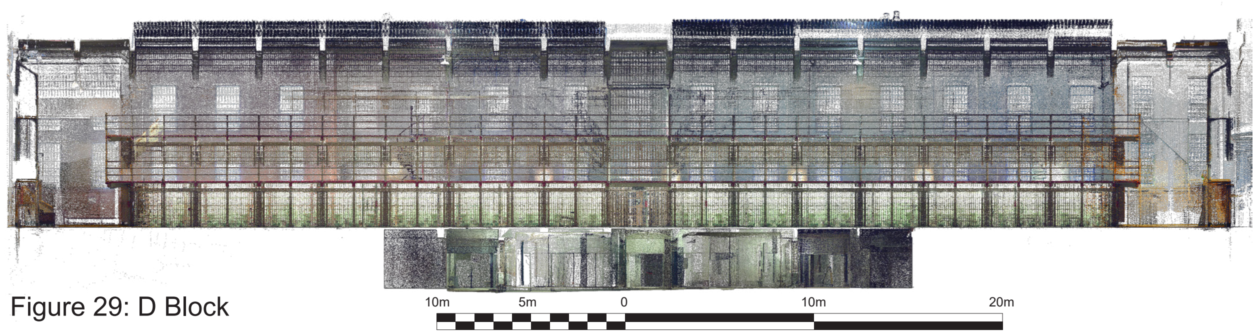


Figure 29: D Block

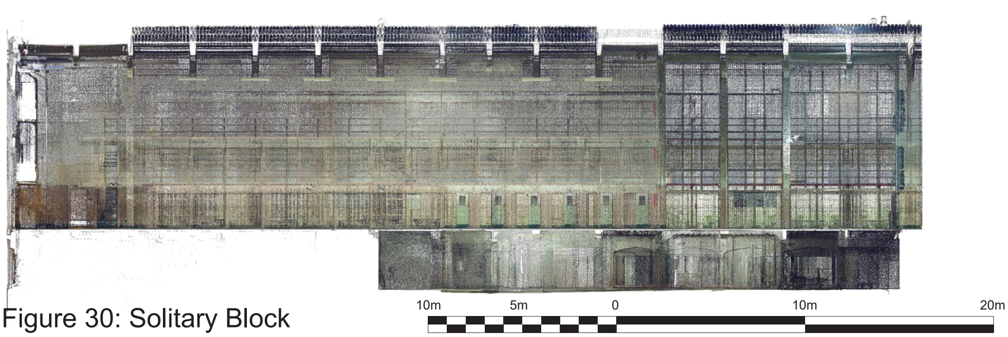


Figure 30: Solitary Block

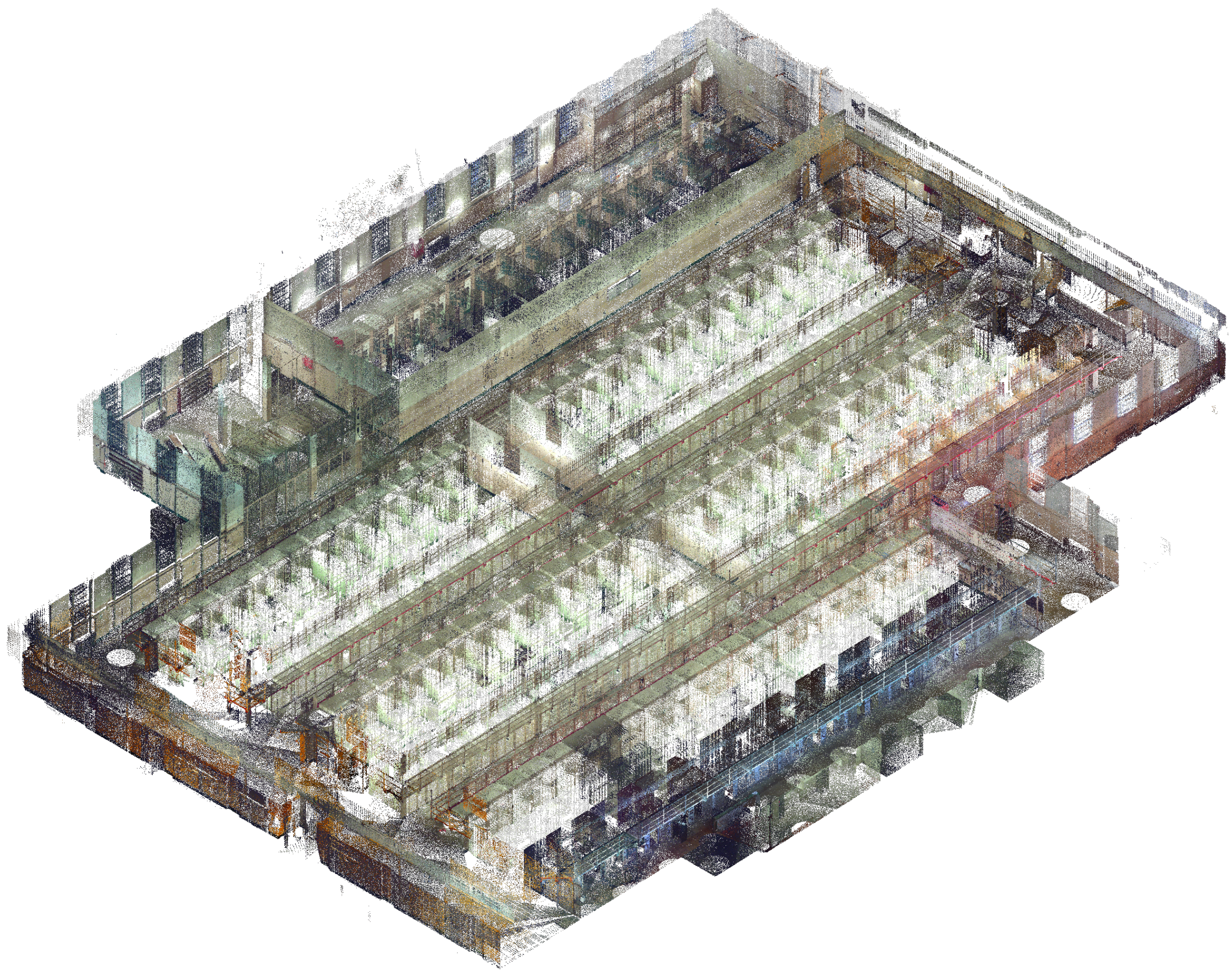


Figure 31: Plan-Section Isometric View, through A Block [From Southeast looking Northwest]

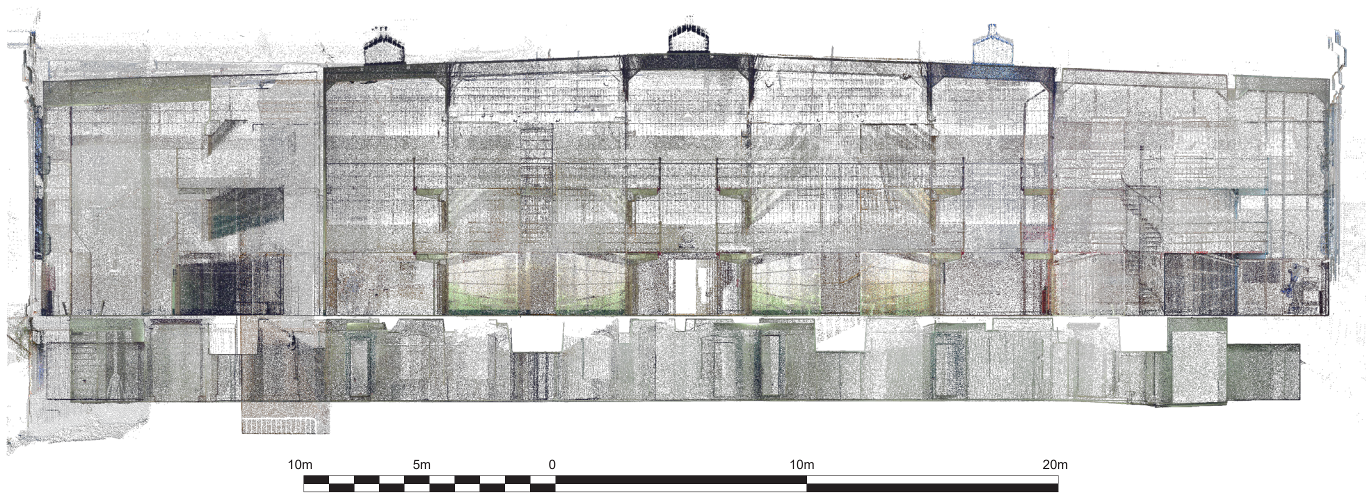
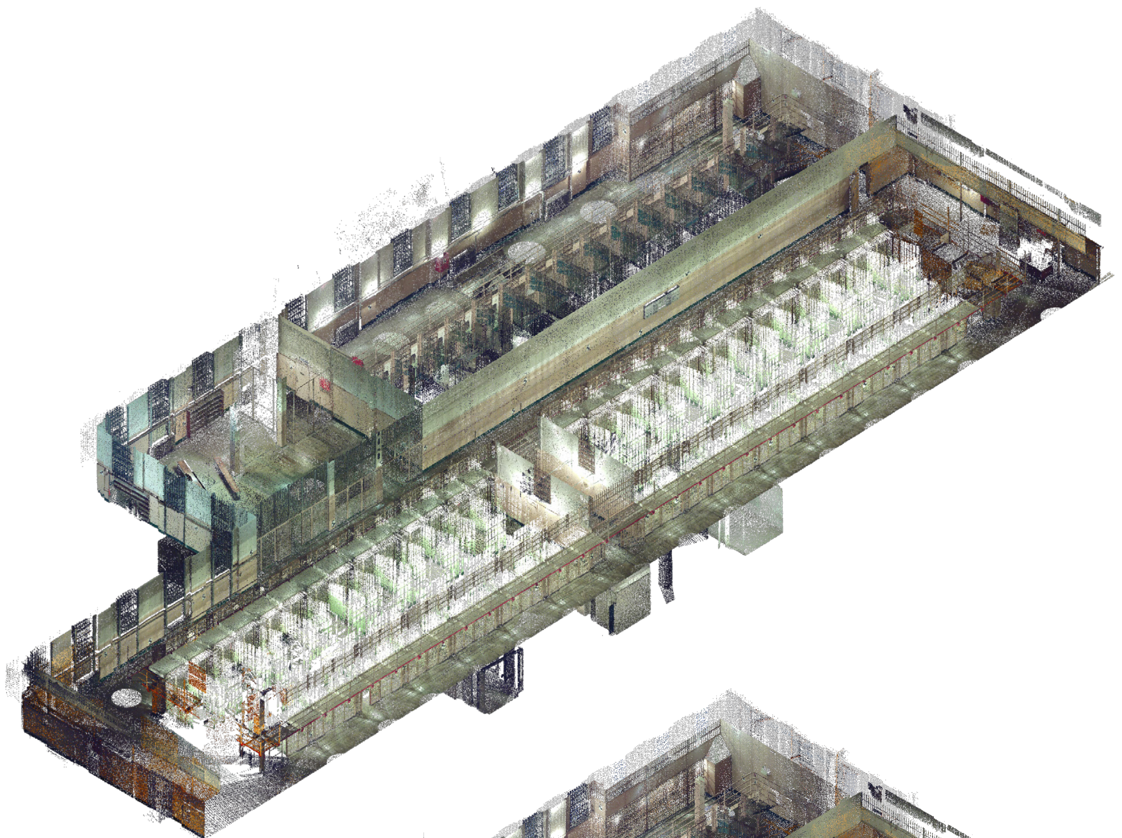


Figure 32: Transverse Section | West-East Axis, looking North, through Central Corridor of the Citadel | 1:300

3.4 Cellhouse - Citadel Relationship



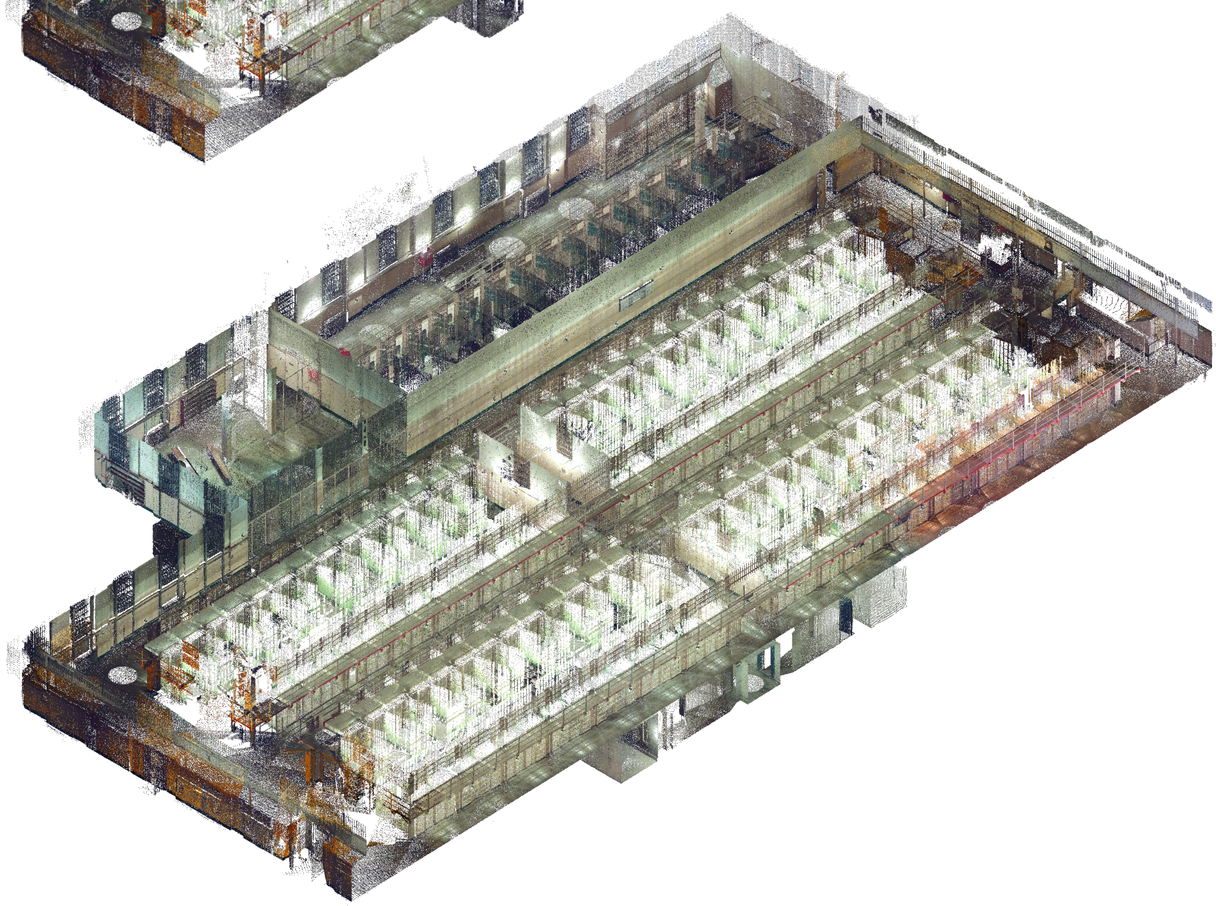


Figure 33: Plan-Section Isometric View, through C Block [From Southeast looking Northwest] (above)
Figure 34: Plan-Section Isometric View, through B Block [From Southeast looking Northwest] (below)

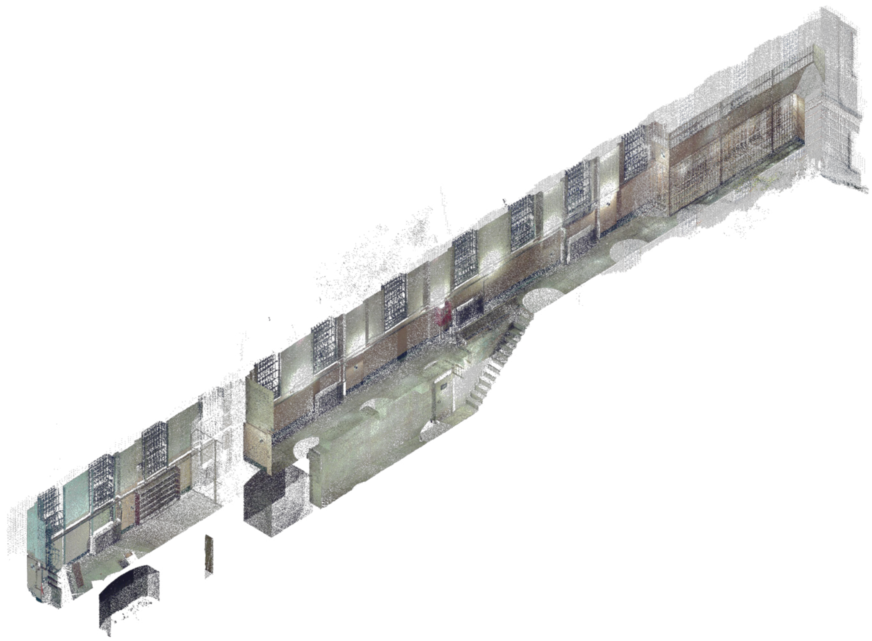


Figure 35: Plan-Section Isometric View, through Solitary Block [From Southeast looking Northwest]

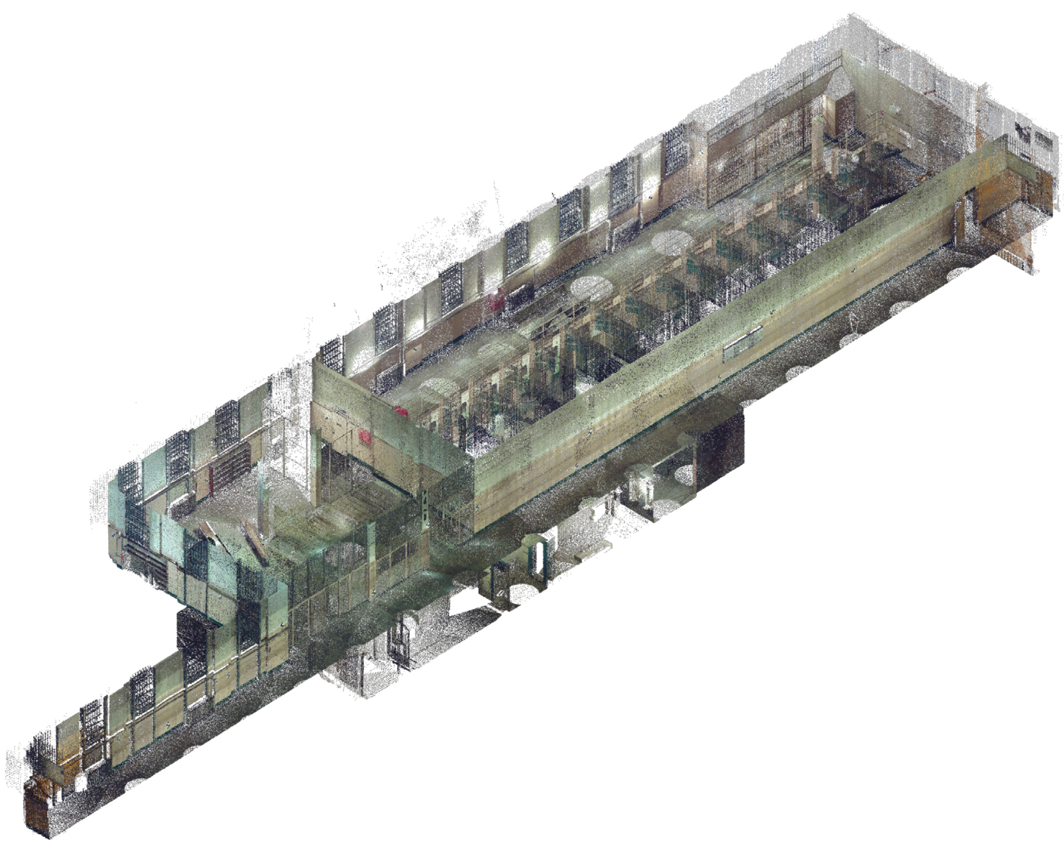


Figure 36: Plan-Section Isometric View, through D Block [From Southeast looking Northwest]

4. POINT CLOUD TO REVIT MODEL

Texas A&M students referenced the Cultural Landscape Report (CLR) to build a base building information model (BIM) in Autodesk Revit. For the present project, the composite ReCap point cloud (overall island, Cellhouse, and citadel) was linked to the Revit model. The ReCap point cloud was placed and oriented using the Cellhouse and its entry plaza as the primary reference points, since these features held the most accurate corresponding data across data sets: CLR, Revit model, and ReCap point cloud. The Revit model based on the CRL was then updated to correspond to the point cloud as far as possible. Areas for which point cloud data were missing or were incomplete were modeled based on data available in the CLR. Additional exterior scan data would be desirable to fill in the point cloud and optimize its accuracy, which would in turn improve the accuracy of the Revit model.

In general, the CLR topography enclosed the point cloud topography. Laser scan data collected by the CHC indicates a reduction of mass along the cliffs and upon the terrain surfaceThe Revit topography was reduced in mass to match the point cloud. The south cliff by the Parade Ground, and the cliffs in general, are much steeper than the CLR indicates. The CLR indicates steep slopes, but the scan data indicates the cliffs are nearly vertical. What is not clear is whether the discrepancy is due to erosion or the limitations of the survey.

In general, building location and orientation correlate well between the CLR/Revit model and the scan data, the one exception being the Warden's House. The location of the Warden's House on the initial CLR/Revit model was

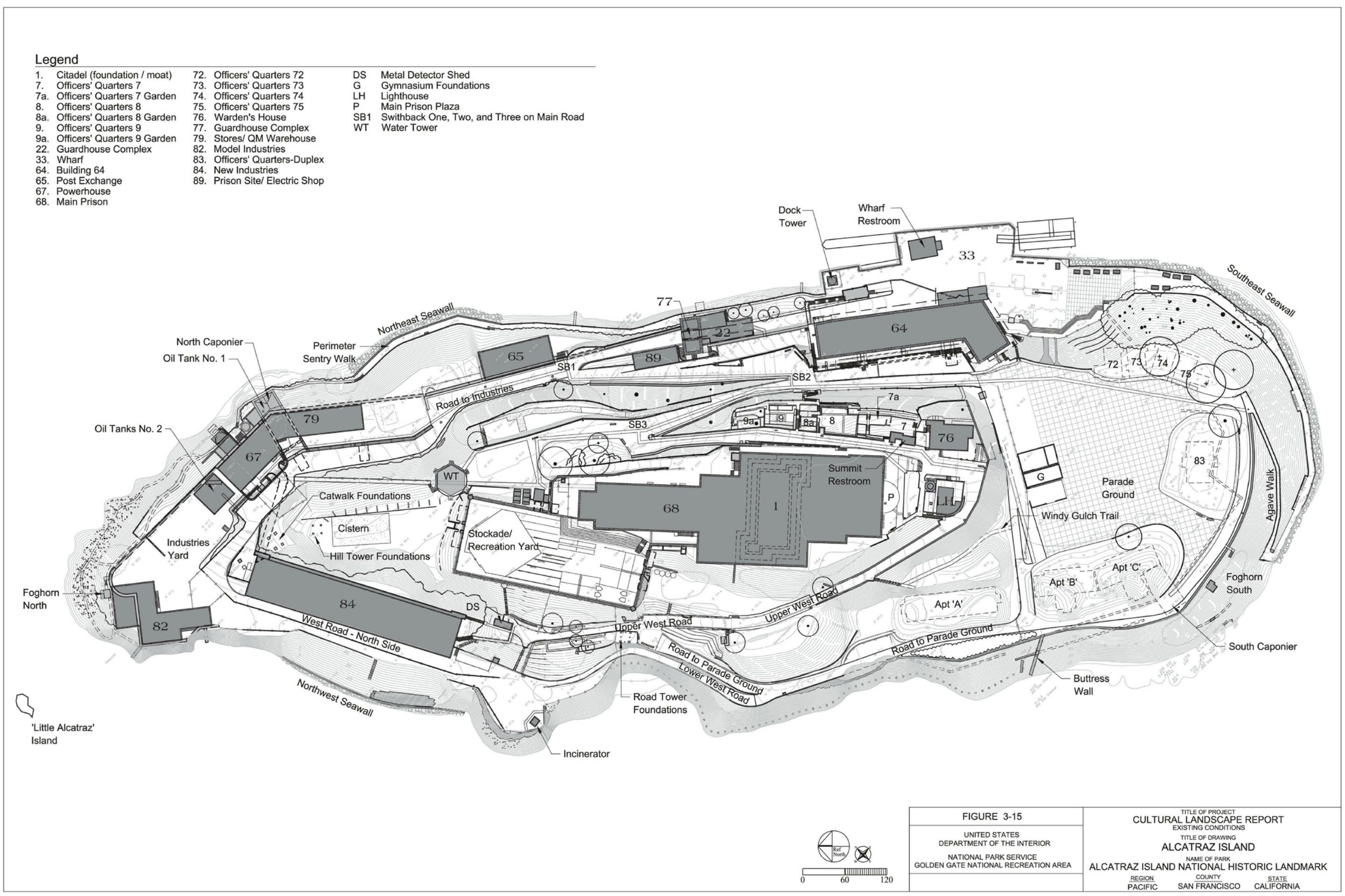


Figure 37: Cultural Landscape Report

4. Point Cloud to Revit Model

Figure 38. Site Plan, Revit Model with Recap Point Cloud | 1:2500

accurate, but its walls did not align with scan data. Therefore, the Warden's House was rotated, or reoriented, to align with the scan data. Building heights were adjusted to match the scan data.

Exterior scan data possess gaps, which need additional scanning to fill. Gaps in exterior scan data are due to deliberate focus by scan teams on specific exterior features, and not on the topography of the island itself. Where these gaps occur, the Revit model topography defers to the CLR data. Given the discrepancy in topography between the CLR and the scan data, it would be desirable to do more comprehensive scanning that focuses on the island exterior terrain.

Built features on the island were aligned with point cloud data present. Most buildings on the island have not been completely scanned on their exterior, and all but one have not been scanned on the interior. The Cellhouse and Citadel are the only areas that have been scanned on the interior. The Revit model does not yet reflect these interior elements. Further work will be proposed in the conclusions.

No elements in the Revit model contain reliable meta data. Building elements in the current model indicate massings with correct location and orientation. Those building elements (walls, roofs, floors, columns, etc.) are not yet based on any construction level detail. Placement and orientation of meta data elements rely on accurate and thorough scan data, while the accuracy of the meta data itself relies heavily on construction documents (in this case, historic as-built drawings and any construction material specifications). To create the most accurate Revit model of the Cellhouse and Citadel, scan data must consist of scan positions on all levels. This data will ensure a high level of resolution in the model and its meta data.

The final Revit model consists of an updated topography and building envelope position and orientation. The model is to serve as a dynamic document with which to update changes in the island's condition.

4. Point Cloud to Revit Model

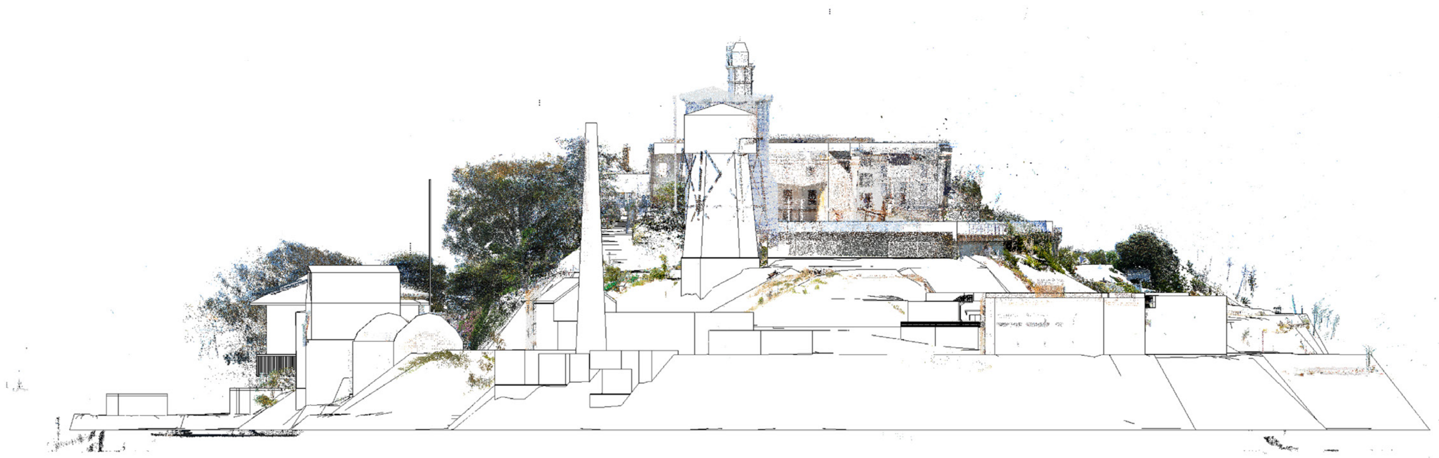


Figure 39: North Elevation | 1:1200

Figure 40: South Elevation | 1:1200

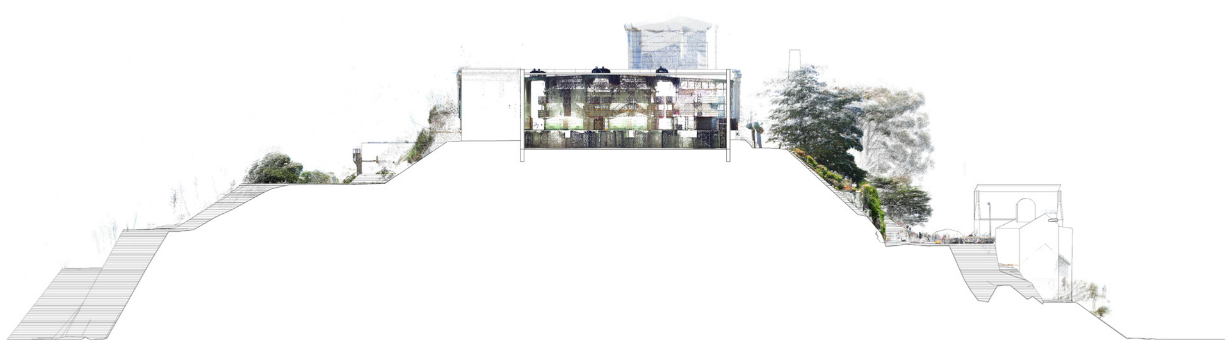


Figure 41: Transverse Section | West-East Axis, looking North | 1:1200

Figure 42. East Elevation | 1:2500

Figure 43. West Elevation | 1:2500

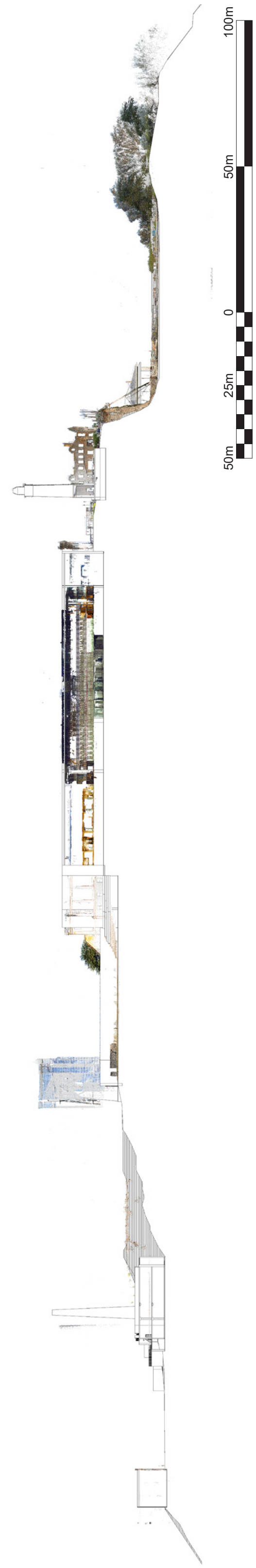


Figure 44. Longitudinal Section | North-South Axis, looking East | 1:2500

5. CONCLUSIONS

A highly accurate data set was generated of the Cellhouse and the Citadel in 2016. However, a more complete model would be possible with scans of each cell and each level of the Cellhouse. Additionally, scan data of service rooms in the south end of the Cellhouse would add to the completeness of the 3D models. The cell blocks have corresponding cavity spaces between the back walls of adjacent cell blocks. Scan data of these would add information pertaining ot the integrity of the cell blocks as well as the infrastructural systems nested in these cavities. These are necessary areas for the completeness of the scan data itself, but also is essential for complete and accurate meta data in the Revit model.

While collecting more scan data on the Cellhouse is necessary, another option for future 3D scanning pertains to the other buildings on the island and all the exterior spaces. The process employed on the Cellhouse in 2016 could be similarly applied to the island's other structures. This would add valuable interior scan data. Exterior scans of these buildings and their associated terrain would further fill in the blank areas of the 3D models. More than completing the model, further scanning on the exterior terrain may help to determine why there is much discrepancy between CLR topography and scan data topography. The different methodologies employed could produce vastly different results, or the island's cliffs are eroding rapidly.

The process of accumulating 3D scan data is best suited for detailed documentation of the building interiors. Collaboration with teams conducting LiDAR, or aerial photogrammetry, indicate potential for cross-disciplinary projects where the exterior data is linked with interior scan data. The suggestion of a process like LiDAR is to acknowledge the environmental factors (mainly wind) that may render it a better alternative to aerial photogrammetry. 3D documentation of the terrain of an island like Alcatraz quickly exposes the limitations of terrestial scanners employed by the CHC team. However, a composite model using aerial scanning techniques on the island's surface and building exteriors, with terrestial scanning techniques on the building interiors, seems like the next step.

This procedural report concludes with timetables pertaining to specific areas for further research and design development:

Proposed Timetable: Interior Laser Scanning

2018	North end, Main Cellhouse
	Building 64
2019	Lighthouse
	Warden's House
	New Industries Building
2020	Model Industries Building
	Powerhouse
	Stores / QM Warehouse
2021	Post Exchange Building
	Guardhouse Complex
	Prison Site / Electric Shop

Proposed Timetable: Exterior Laser Scanning

2018	North end, moving south along east side to Guardhouse
2019	West side, moving south from to New Industries Building to Parade Ground
	Southern most area from Wharf to Guardhouse

Proposed Timetable: Expanding on Revit Model

2017, Fall - 2018, Spring	Interior modeling of Main Cellhouse & Citadel
2018, Spring - 2018, Summer	Exterior building details with available scan data

5. Conclusions