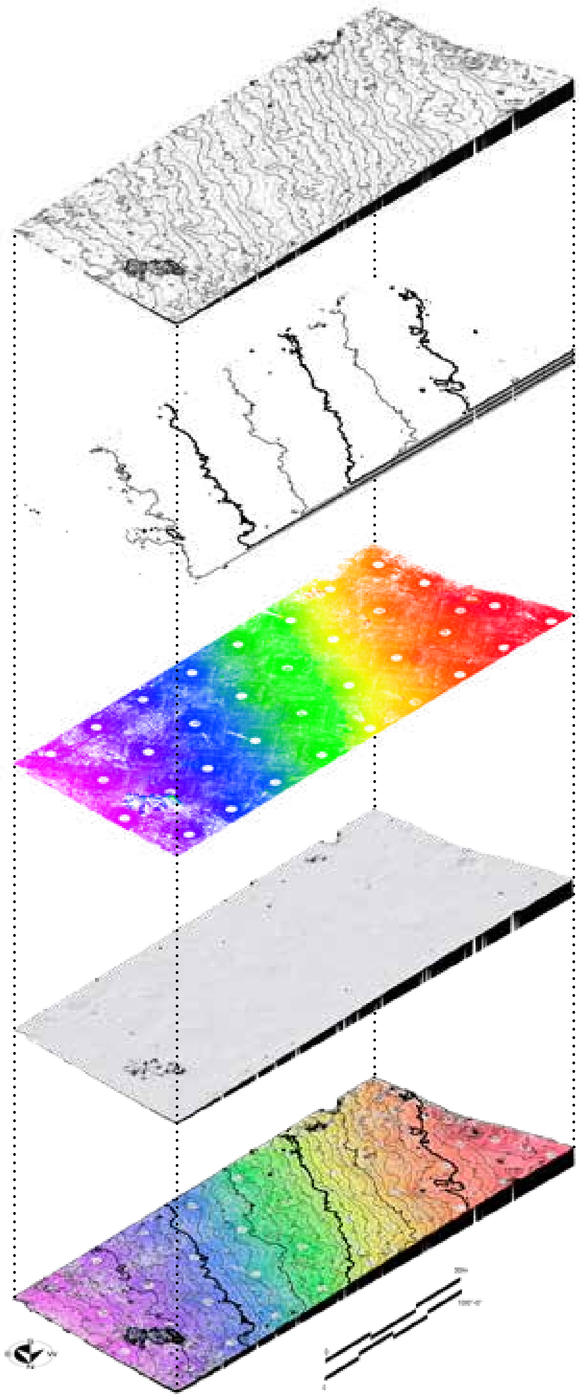
CENTER FOR HERITAGE CONSERVATION

TEXAS A&M UNIVERSITY College of Architecture

Terrestrial Laser Scanning Survey of Hockley Cemetery, San Antonio, Texas: Project Report II (CHC-2020-06-01)



Kevin Glowacki, Ben Baaske, & Andrew Billingsley

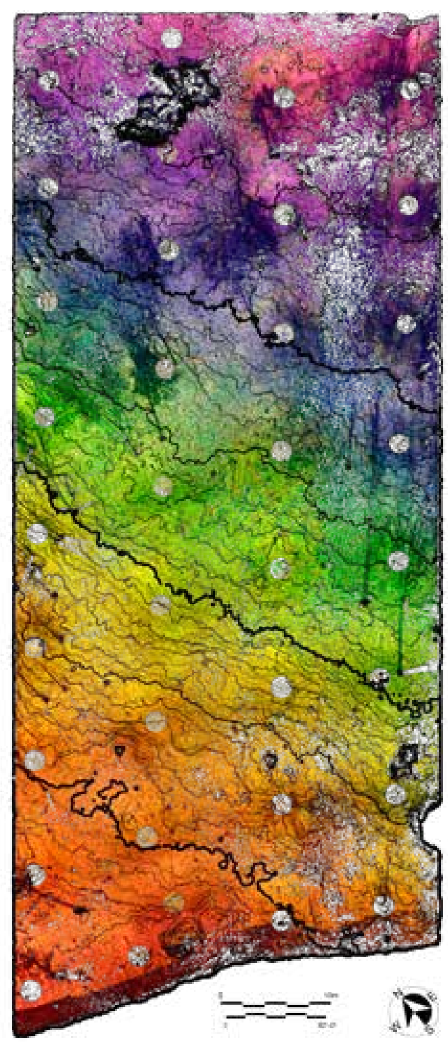


Figure 1. Aerial view showing location of Hockley Cemetery in northeast San Antonio, Bexar County, Texas. Google Earth (imagery date January 11, 2019).

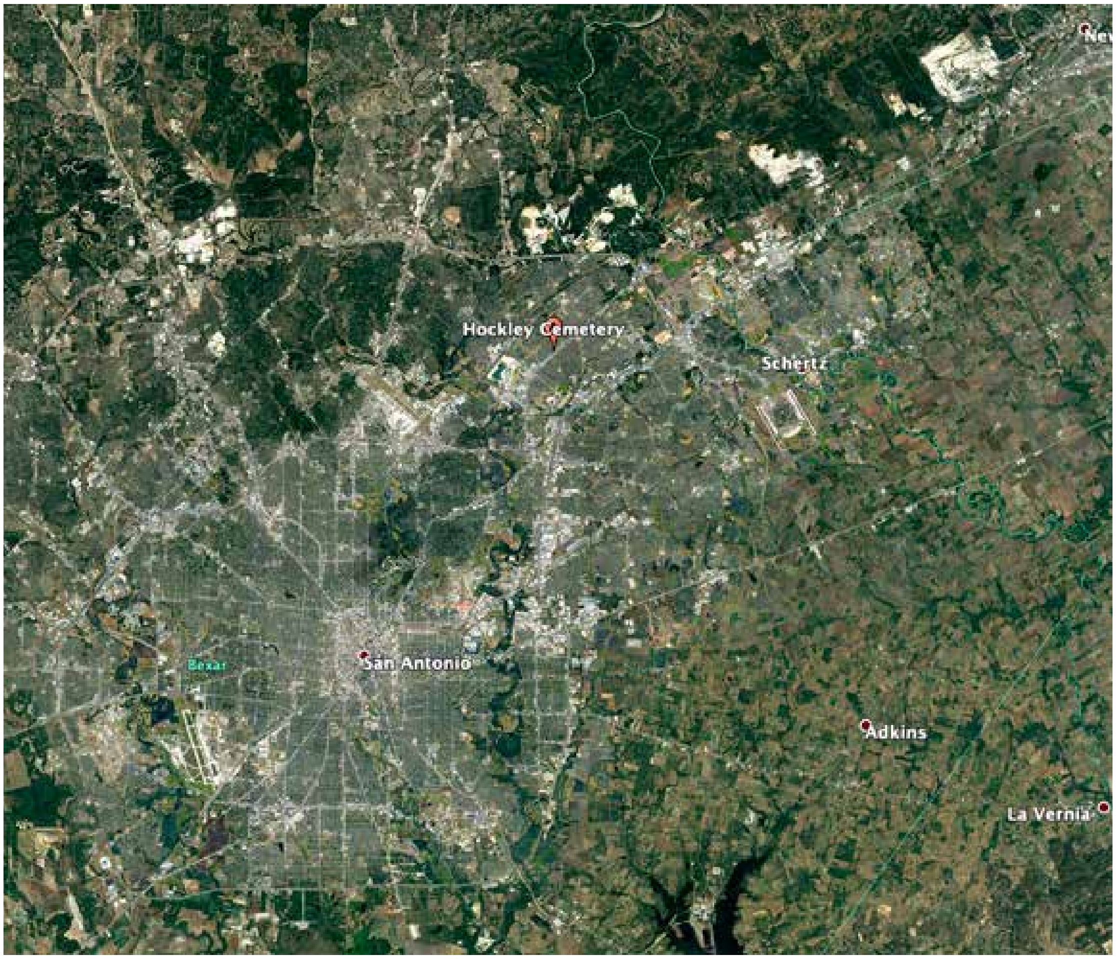
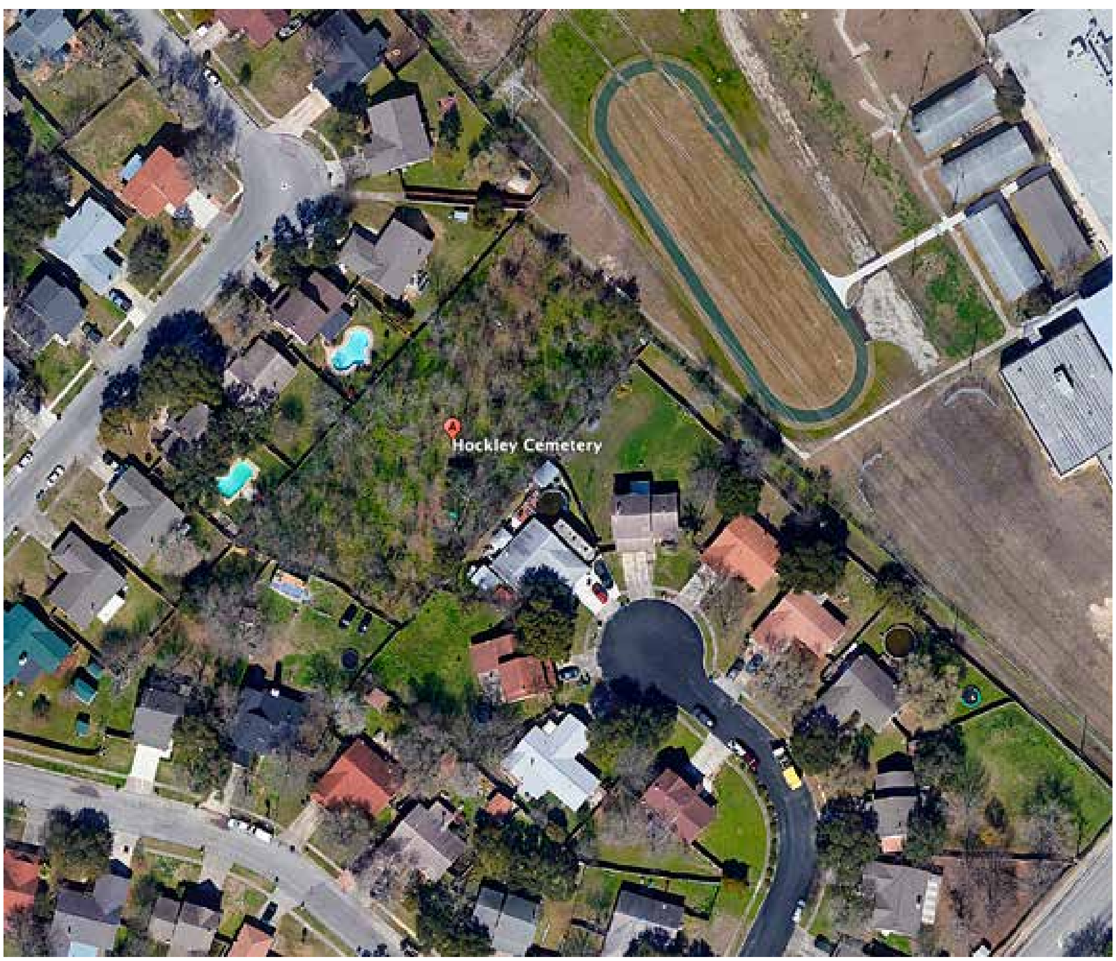


Figure 2. Aerial view of Hockley Cemetery. Google Earth (imagery date January 11, 2019).



Introduction

The following is a report on the terrestrial laser scanning survey of the Hockley Cemetery in San Antonio, Texas, conducted by the Center for Heritage Conservation at Texas A&M University on December 6, 2019, for Everett Fly Associates. The CHC had previously documented the cemetery on March 15, 2019, but tall grass and brush obscured the several areas of surface at that time.

The primary objectives of the December 2019 documentation were
1) to document the terrain of the historic cemetery in more detail, now that the majority of the vegetation had been removed;
2) to create a more detailed plan and digital model of the surface terrain that might be useful in identifying mounds or depressions representing below ground features, such as burials;
3) to prepare a detailed plan and digital model that could be combined with data from geophysical survey work (ground penetrating radar) conducted by Dr. Mark Everett in April 2019.

The Terrestrial Laser Scanning Survey

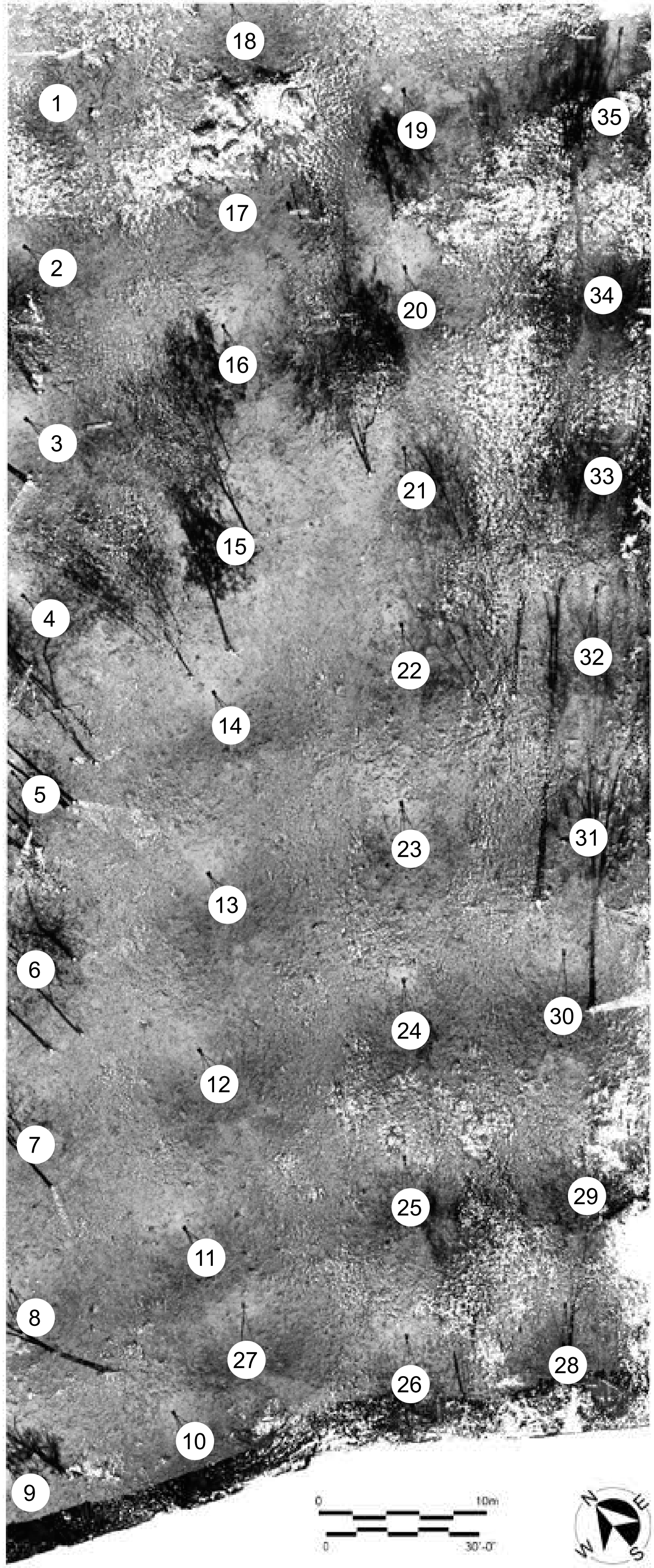
The Center for Heritage Conservation (CHC) at Texas A&M University (TAMU) documented the current condition of the Hockley Cemetery in San Antonio, Texas, using terrestrial laser scanning (TLS) technology on December 6, 2019. Temperatures during the site visit (ca. 12:00pm to 4:30pm) ranged from 66-75 degrees Fahrenheit with winds from the NNW at ~9 mph. This second documentation using TLS aimed to better document the cemetery's terrain, since the majority of the vegetation had now been removed.

The team utilized a FARO Focus3D X 330 HDR, a phase-based laser scanning system (a FARO Focus s350 phase-based laser scanning system was used in March). The scan data were initially processed with FARO Scene 2019.0 software. The team also recorded two previously established benchmarks (see survey by Gibbons Surveying & Mapping, Inc., January 30, 2019) and checkerboard registration targets with a Leica TPS1200 Series High Performance Total Station.

The scan project resulted in 35 usable scan positions, with each scan duration being approximately 5 minutes and 20 seconds. A scan resolution of 1/5 was set; this results in an average point spacing of 7.670mm 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.

In order to optimize scan registration, checkerboard targets were placed on the inside of the Hockley Cemetery fence. These targets allow for common registration points between scan positions, both within themselves and when combined with survey points. A minimum of 3 targets are typically desired to be visible from each scan position. Once placed, these targets can then be shot in with a total station and recorded as points with local x-y-z coordinates.

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



Processing & Registration

As with the earlier documentation on March 15, 2019, top-view and cloud-to-cloud registration proved to be the most effective means of aligning adjacent scans correctly (despite the use of targets). However, once clusters were created with top-view and cloud-to-cloud registration, manual selection of targets and surface planes common between adjacent scans in each cluster was necessary for complete registration. Initial registration output yielded a mean point error of 8.4mm (8.9mm in March) with a maximum point error of 24.4mm (16.5mm in March) and a minimum overlap of 43.8% (25.1% in March). Using the fine registration capabilities of Scene, scan point statistics were improved. The mean point error was reduced to 6.1mm (6.8mm in March) with a maximum point error of 9.8mm (10.1mm in March) and a minimum overlap of 47.3% (26.2% in March).

Once sufficiently registered, the project point cloud was created; this allowed for export of orthophotos, the project point cloud itself (in various file formats), the generation of surface meshes and the rendered animations of the model. Overall, the Hockley Cemetery project point cloud consists of 292,548,859 data points.

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

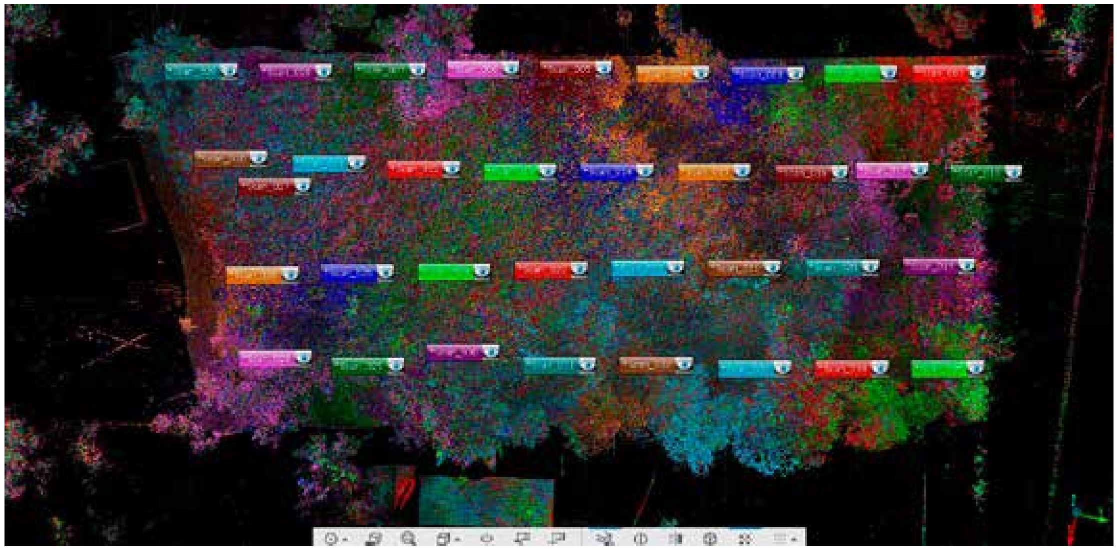
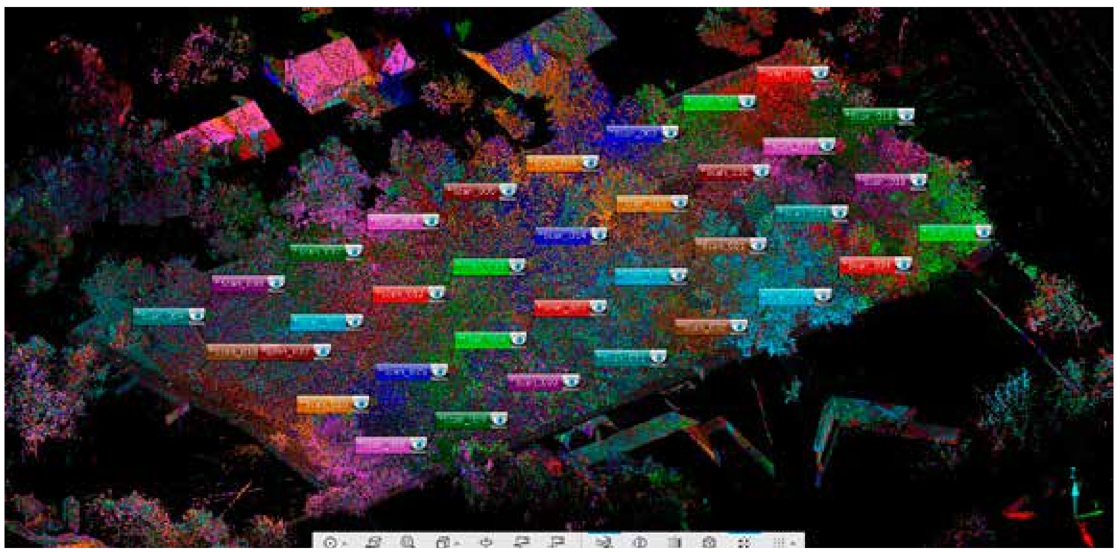


Figure 5. Isometric view (from South looking North). Screenshot of point cloud in visual registration from FARO Scene.



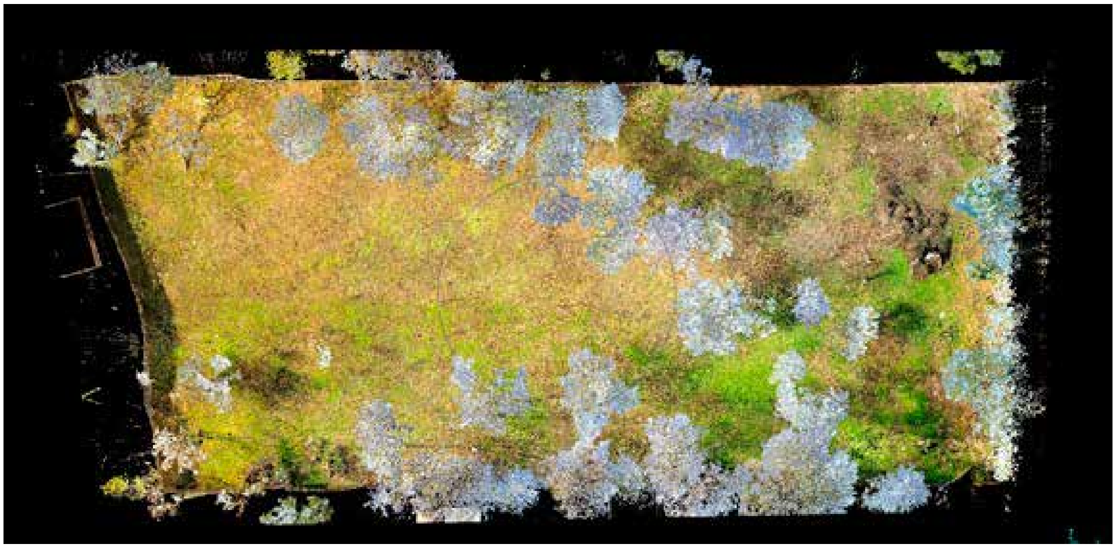


Figure 6. Site Plan. Screenshot of color point cloud from FARO Scene: actual state on December 6, 2019.

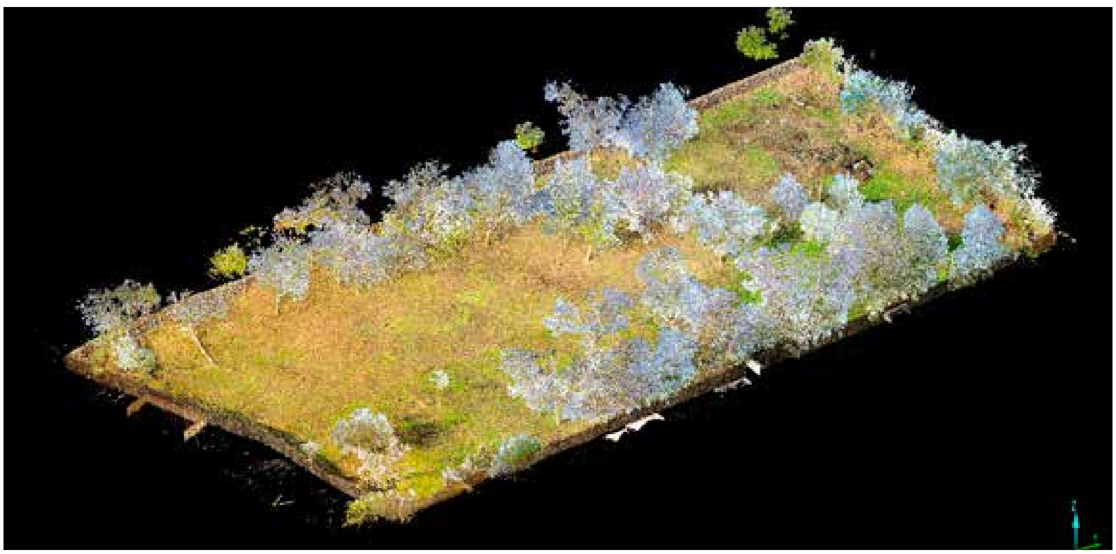


Figure .7 Isometric view (from South looking North). Screenshot of color point cloud from FARO Scene: actual state on December 6, 2019.

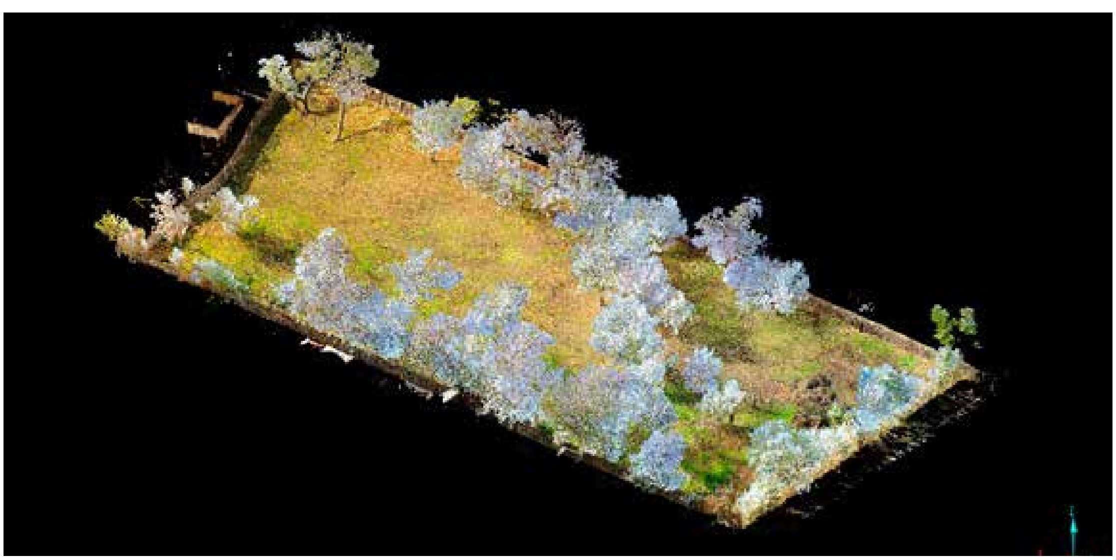


Figure 8. Isometric view (from East looking West). Screenshot of color point cloud from FARO Scene: actual state on December 6, 2019.

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

Registration Report

Project	Hockley_v2
Cluster	Scans
Report Date	12/6/2019, 7:06:39 PM

Color Coding

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

Overview

Scan Point Statistics

Maximum Point Error	9.8 mm
Mean Point Error	6.1 mm
Minimum Overlap	47.3 %

Scan Errors

Scan Point Statistics

Cluster/Scan	Connections	Max. Point Error [mm]	Mean Point Error [mm]	Min. Overlap
Hockley_v2_Scan_001	4	8.5	6.2	56.4 %
Hockley_v2_Scan_002	6	7.3	5.8	52.2 %
Hockley_v2_Scan_003	4	5.7	5.3	64.0 %
Hockley_v2_Scan_004	4	6.8	5.8	54.8 %
Hockley_v2_Scan_005	4	7.3	6.9	47.7 %
Hockley_v2_Scan_006	4	7.3	6.1	47.7 %
Hockley_v2_Scan_007	6	6.5	4.9	63.0 %
Hockley_v2_Scan_008	6	6.3	5.2	67.2 %
Hockley_v2_Scan_009	4	6.2	5.4	61.4 %
Hockley_v2_Scan_010	8	8.9	5.6	54.9 %
Hockley_v2_Scan_011	9	7.2	5.4	61.4 %
Hockley_v2_Scan_012	11	8.9	5.7	54.9 %
Hockley_v2_Scan_013	7	7.9	6.2	63.0 %
Hockley_v2_Scan_014	6	6.3	5.7	64.1 %
Hockley_v2_Scan_015	9	6.3	5.8	53.0 %
Hockley_v2_Scan_016	8	8.7	5.7	56.4 %
Hockley_v2_Scan_017	9	7.8	5.8	51.7 %
Hockley_v2_Scan_018	4	9.8	8.7	50.2 %
Hockley_v2_Scan_019	5	9.8	7.0	63.7 %
Hockley_v2_Scan_020	10	9.2	7.1	50.2 %
Hockley_v2_Scan_021	8	9.3	7.3	53.6 %
Hockley_v2_Scan_022	8	7.9	6.8	60.2 %
Hockley_v2_Scan_023	8	7.4	6.5	64.8 %
Hockley_v2_Scan_024	9	7.7	6.0	47.3 %
Hockley_v2_Scan_025	9	6.6	5.1	65.4 %
Hockley_v2_Scan_026	7	7.9	5.2	62.3 %
Hockley_v2_Scan_027	8	6.2	5.0	67.2 %
Hockley_v2_Scan_028	4	5.3	4.9	47.3 %
Hockley_v2_Scan_029	5	6.2	5.5	67.4 %
Hockley_v2_Scan_030	5	7.0	6.3	66.4 %
Hockley_v2_Scan_031	5	7.8	6.9	65.7 %
Hockley_v2_Scan_032	5	8.0	7.2	59.5 %
Hockley_v2_Scan_033	5	8.0	7.5	59.5 %
Hockley_v2_Scan_034	4	9.3	8.0	53.6 %
Hockley_v2_Scan_035	4	6.5	5.3	51.7 %

Table 2. Scan errors (registration statistics for each scan position, relative to its adjacent scan positions) from FARO Scene registration report.

Table 3. Detailed errors (registration statistics for specific scan position pairs) from FARO Scene registration report.

Detailed Errors

Scan Point Statistics

Cluster/Scan 1	Cluster/Scan 2	Point Error [mm]	Overlap
Hockley_v2_Scan_001	Hockley_v2_Scan_002	7.2	79.6 %
Hockley_v2_Scan_003	Hockley_v2_Scan_002	4.6	64.0 %
Hockley_v2_Scan_003	Hockley_v2_Scan_004	5.3	72.1 %
Hockley_v2_Scan_003	Hockley_v2_Scan_016	5.6	72.2 %
Hockley_v2_Scan_005	Hockley_v2_Scan_004	6.8	54.8 %
Hockley_v2_Scan_006	Hockley_v2_Scan_005	7.3	47.7 %
Hockley_v2_Scan_006	Hockley_v2_Scan_012	6.1	71.0 %
Hockley_v2_Scan_007	Hockley_v2_Scan_006	5.2	68.7 %
Hockley_v2_Scan_007	Hockley_v2_Scan_012	6.5	80.8 %
Hockley_v2_Scan_007	Hockley_v2_Scan_008	4.0	70.6 %
Hockley_v2_Scan_007	Hockley_v2_Scan_011	5.5	79.7 %
Hockley_v2_Scan_007	Hockley_v2_Scan_027	4.9	67.9 %
Hockley_v2_Scan_007	Hockley_v2_Scan_010	3.4	63.0 %
Hockley_v2_Scan_008	Hockley_v2_Scan_012	5.1	67.2 %
Hockley_v2_Scan_008	Hockley_v2_Scan_011	6.3	84.0 %
Hockley_v2_Scan_009	Hockley_v2_Scan_008	4.9	76.1 %
Hockley_v2_Scan_009	Hockley_v2_Scan_011	6.0	61.4 %
Hockley_v2_Scan_010	Hockley_v2_Scan_008	4.9	77.9 %
Hockley_v2_Scan_010	Hockley_v2_Scan_009	4.6	74.6 %
Hockley_v2_Scan_010	Hockley_v2_Scan_027	4.7	85.7 %
Hockley_v2_Scan_010	Hockley_v2_Scan_011	7.2	80.6 %
Hockley_v2_Scan_010	Hockley_v2_Scan_012	8.9	54.9 %
Hockley_v2_Scan_010	Hockley_v2_Scan_026	7.9	66.7 %
Hockley_v2_Scan_010	Hockley_v2_Scan_025	3.2	71.5 %
Hockley_v2_Scan_011	Hockley_v2_Scan_025	4.9	84.5 %
Hockley_v2_Scan_012	Hockley_v2_Scan_011	5.0	83.2 %
Hockley_v2_Scan_012	Hockley_v2_Scan_025	5.4	81.4 %
Hockley_v2_Scan_012	Hockley_v2_Scan_023	6.0	74.8 %
Hockley_v2_Scan_013	Hockley_v2_Scan_005	7.3	63.0 %
Hockley_v2_Scan_013	Hockley_v2_Scan_006	5.7	63.5 %
Hockley_v2_Scan_013	Hockley_v2_Scan_012	5.4	83.5 %
Hockley_v2_Scan_013	Hockley_v2_Scan_023	5.4	86.5 %
Hockley_v2_Scan_013	Hockley_v2_Scan_024	6.2	82.4 %
Hockley_v2_Scan_013	Hockley_v2_Scan_014	5.5	80.9 %
Hockley_v2_Scan_013	Hockley_v2_Scan_022	7.9	77.9 %
Hockley_v2_Scan_014	Hockley_v2_Scan_004	5.4	68.5 %
Hockley_v2_Scan_014	Hockley_v2_Scan_005	6.3	64.1 %
Hockley_v2_Scan_014	Hockley_v2_Scan_023	5.8	79.4 %
Hockley_v2_Scan_015	Hockley_v2_Scan_002	6.0	53.0 %
Hockley_v2_Scan_015	Hockley_v2_Scan_003	5.7	70.6 %
Hockley_v2_Scan_015	Hockley_v2_Scan_004	5.8	70.9 %
Hockley_v2_Scan_015	Hockley_v2_Scan_014	5.9	70.6 %
Hockley_v2_Scan_015	Hockley_v2_Scan_022	6.0	72.3 %
Hockley_v2_Scan_015	Hockley_v2_Scan_016	5.3	69.9 %
Hockley_v2_Scan_015	Hockley_v2_Scan_021	5.4	72.2 %

Table 3 (continued). Detailed errors (registration statistics for specific scan position pairs) from FARO Scene registration report.

Detailed Errors

Scan Point Statistics

Cluster/Scan 1	Cluster/Scan 2	Point Error [mm]	Overlap
Hockley_v2_Scan_015	Hockley_v2_Scan_020	6.3	53.3 %
Hockley_v2_Scan_015	Hockley_v2_Scan_017	6.1	66.9 %
Hockley_v2_Scan_016	Hockley_v2_Scan_001	2.3	56.4 %
Hockley_v2_Scan_016	Hockley_v2_Scan_002	4.8	78.8 %
Hockley_v2_Scan_016	Hockley_v2_Scan_017	4.5	83.6 %
Hockley_v2_Scan_016	Hockley_v2_Scan_020	7.1	74.6 %
Hockley_v2_Scan_016	Hockley_v2_Scan_021	6.9	66.4 %
Hockley_v2_Scan_016	Hockley_v2_Scan_019	8.7	63.7 %
Hockley_v2_Scan_017	Hockley_v2_Scan_001	6.6	64.6 %
Hockley_v2_Scan_017	Hockley_v2_Scan_002	4.7	77.5 %
Hockley_v2_Scan_017	Hockley_v2_Scan_021	7.1	59.9 %
Hockley_v2_Scan_017	Hockley_v2_Scan_018	7.8	64.3 %
Hockley_v2_Scan_018	Hockley_v2_Scan_001	8.5	63.0 %
Hockley_v2_Scan_019	Hockley_v2_Scan_017	5.0	74.0 %
Hockley_v2_Scan_019	Hockley_v2_Scan_018	9.8	65.2 %
Hockley_v2_Scan_019	Hockley_v2_Scan_020	6.9	74.9 %
Hockley_v2_Scan_020	Hockley_v2_Scan_002	7.3	52.2 %
Hockley_v2_Scan_020	Hockley_v2_Scan_017	4.9	77.4 %
Hockley_v2_Scan_020	Hockley_v2_Scan_018	8.5	50.2 %
Hockley_v2_Scan_020	Hockley_v2_Scan_021	8.1	65.6 %
Hockley_v2_Scan_020	Hockley_v2_Scan_034	9.2	64.2 %
Hockley_v2_Scan_022	Hockley_v2_Scan_014	5.4	80.0 %
Hockley_v2_Scan_022	Hockley_v2_Scan_021	6.2	78.4 %
Hockley_v2_Scan_022	Hockley_v2_Scan_023	7.0	81.9 %
Hockley_v2_Scan_024	Hockley_v2_Scan_011	5.4	75.0 %
Hockley_v2_Scan_024	Hockley_v2_Scan_012	5.3	85.2 %
Hockley_v2_Scan_024	Hockley_v2_Scan_023	6.5	83.3 %
Hockley_v2_Scan_024	Hockley_v2_Scan_025	6.6	81.1 %
Hockley_v2_Scan_024	Hockley_v2_Scan_028	4.5	47.3 %
Hockley_v2_Scan_026	Hockley_v2_Scan_011	4.4	73.7 %
Hockley_v2_Scan_026	Hockley_v2_Scan_012	3.8	62.3 %
Hockley_v2_Scan_026	Hockley_v2_Scan_025	4.7	80.9 %
Hockley_v2_Scan_026	Hockley_v2_Scan_028	5.3	65.9 %
Hockley_v2_Scan_027	Hockley_v2_Scan_008	6.0	79.1 %
Hockley_v2_Scan_027	Hockley_v2_Scan_009	6.2	67.2 %
Hockley_v2_Scan_027	Hockley_v2_Scan_011	3.8	88.9 %
Hockley_v2_Scan_027	Hockley_v2_Scan_012	5.4	71.3 %
Hockley_v2_Scan_027	Hockley_v2_Scan_025	4.3	80.5 %
Hockley_v2_Scan_027	Hockley_v2_Scan_026	5.0	80.9 %
Hockley_v2_Scan_028	Hockley_v2_Scan_025	4.8	65.4 %
Hockley_v2_Scan_029	Hockley_v2_Scan_024	5.6	72.3 %
Hockley_v2_Scan_029	Hockley_v2_Scan_025	5.9	80.6 %
Hockley_v2_Scan_029	Hockley_v2_Scan_026	5.3	67.4 %
Hockley_v2_Scan_029	Hockley_v2_Scan_028	4.9	71.3 %
Hockley_v2_Scan_030	Hockley_v2_Scan_023	7.0	73.5 %

Table 3 (continued). Detailed errors (registration statistics for specific scan position pairs) from FARO Scene registration report.

Detailed Errors

Scan Point Statistics

Cluster/Scan 1	Cluster/Scan 2	Point Error [mm]	Overlap
Hockley_v2_Scan_030	Hockley_v2_Scan_024	6.1	80.8 %
Hockley_v2_Scan_030	Hockley_v2_Scan_025	6.0	66.4 %
Hockley_v2_Scan_030	Hockley_v2_Scan_029	6.2	70.2 %
Hockley_v2_Scan_030	Hockley_v2_Scan_031	6.2	69.5 %
Hockley_v2_Scan_031	Hockley_v2_Scan_022	7.8	66.9 %
Hockley_v2_Scan_031	Hockley_v2_Scan_023	6.5	77.7 %
Hockley_v2_Scan_031	Hockley_v2_Scan_024	7.7	65.7 %
Hockley_v2_Scan_031	Hockley_v2_Scan_032	6.4	70.9 %
Hockley_v2_Scan_032	Hockley_v2_Scan_021	7.3	66.3 %
Hockley_v2_Scan_032	Hockley_v2_Scan_022	6.8	73.5 %
Hockley_v2_Scan_032	Hockley_v2_Scan_023	7.4	64.8 %
Hockley_v2_Scan_032	Hockley_v2_Scan_033	8.0	59.5 %
Hockley_v2_Scan_033	Hockley_v2_Scan_020	7.5	63.1 %
Hockley_v2_Scan_033	Hockley_v2_Scan_021	7.8	75.1 %
Hockley_v2_Scan_033	Hockley_v2_Scan_022	7.2	60.2 %
Hockley_v2_Scan_033	Hockley_v2_Scan_034	7.1	66.7 %
Hockley_v2_Scan_034	Hockley_v2_Scan_021	9.3	53.6 %
Hockley_v2_Scan_035	Hockley_v2_Scan_017	5.5	51.7 %
Hockley_v2_Scan_035	Hockley_v2_Scan_019	4.7	74.5 %
Hockley_v2_Scan_035	Hockley_v2_Scan_020	4.7	64.6 %
Hockley_v2_Scan_035	Hockley_v2_Scan_034	6.5	76.0 %

Inclinometer Mismatches

Table 4. Inclinometer mismatches from FARO Scene registration report.

Cluster/Scan	Scan	Mismatch [deg]
Hockley_v2_Scan_015	Hockley_v2_Scan_015	0.0158
Hockley_v2_Scan_007	Hockley_v2_Scan_007	0.0168
Hockley_v2_Scan_030	Hockley_v2_Scan_030	0.0088
Hockley_v2_Scan_029	Hockley_v2_Scan_029	0.0253
Hockley_v2_Scan_003	Hockley_v2_Scan_003	0.0266
Hockley_v2_Scan_013	Hockley_v2_Scan_013	0.0123
Hockley_v2_Scan_010	Hockley_v2_Scan_010	0.0050
Hockley_v2_Scan_027	Hockley_v2_Scan_027	0.0316
Hockley_v2_Scan_031	Hockley_v2_Scan_031	0.0281
Hockley_v2_Scan_006	Hockley_v2_Scan_006	0.0350
Hockley_v2_Scan_009	Hockley_v2_Scan_009	0.0499
Hockley_v2_Scan_035	Hockley_v2_Scan_035	0.0459
Hockley_v2_Scan_032	Hockley_v2_Scan_032	0.0251
Hockley_v2_Scan_016	Hockley_v2_Scan_016	0.0147
Hockley_v2_Scan_008	Hockley_v2_Scan_008	0.0102
Hockley_v2_Scan_019	Hockley_v2_Scan_019	0.0200
Hockley_v2_Scan_033	Hockley_v2_Scan_033	0.0448
Hockley_v2_Scan_024	Hockley_v2_Scan_024	0.0147
Hockley_v2_Scan_026	Hockley_v2_Scan_026	0.0202
Hockley_v2_Scan_020	Hockley_v2_Scan_020	0.0276
Hockley_v2_Scan_022	Hockley_v2_Scan_022	0.0146
Hockley_v2_Scan_034	Hockley_v2_Scan_034	0.0380
Hockley_v2_Scan_017	Hockley_v2_Scan_017	0.0114
Hockley_v2_Scan_012	Hockley_v2_Scan_012	0.0249
Hockley_v2_Scan_021	Hockley_v2_Scan_021	0.0297
Hockley_v2_Scan_014	Hockley_v2_Scan_014	0.0063
Hockley_v2_Scan_005	Hockley_v2_Scan_005	0.0176
Hockley_v2_Scan_018	Hockley_v2_Scan_018	0.0448
Hockley_v2_Scan_011	Hockley_v2_Scan_011	0.0314
Hockley_v2_Scan_001	Hockley_v2_Scan_001	0.0287
Hockley_v2_Scan_004	Hockley_v2_Scan_004	0.0095
Hockley_v2_Scan_023	Hockley_v2_Scan_023	0.0108
Hockley_v2_Scan_028	Hockley_v2_Scan_028	0.0176
Hockley_v2_Scan_002	Hockley_v2_Scan_002	0.0395
Hockley_v2_Scan_025	Hockley_v2_Scan_025	0.0160

Figure 9. Perspective view (from Northeast looking Southwest). Color point cloud image export from Autodesk ReCap.The white areas visible within the fence line represent scan locations (circles) and tall grasses/brush present on site on December 6, 2019.

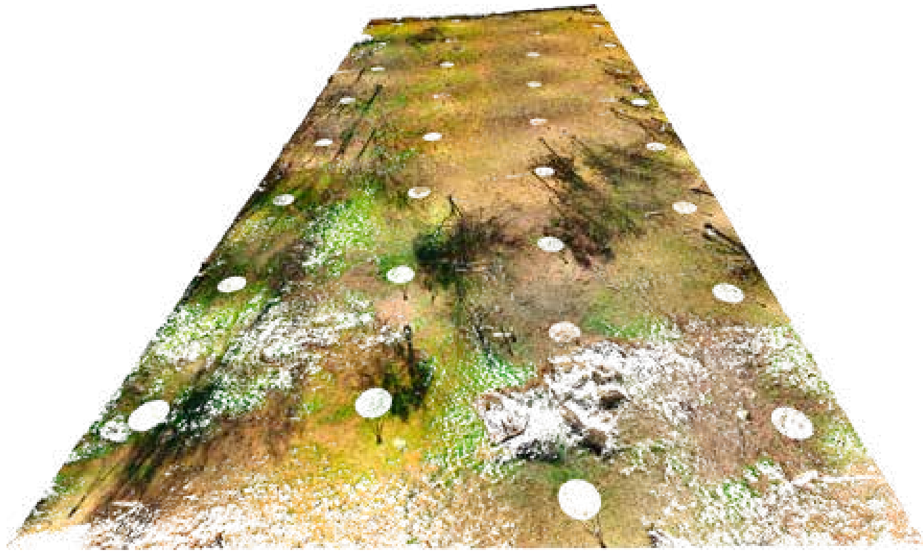


Figure 10. Perspective View (from Northeast looking Southwest). Color point cloud image export from Autodesk ReCap ("heat map" filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

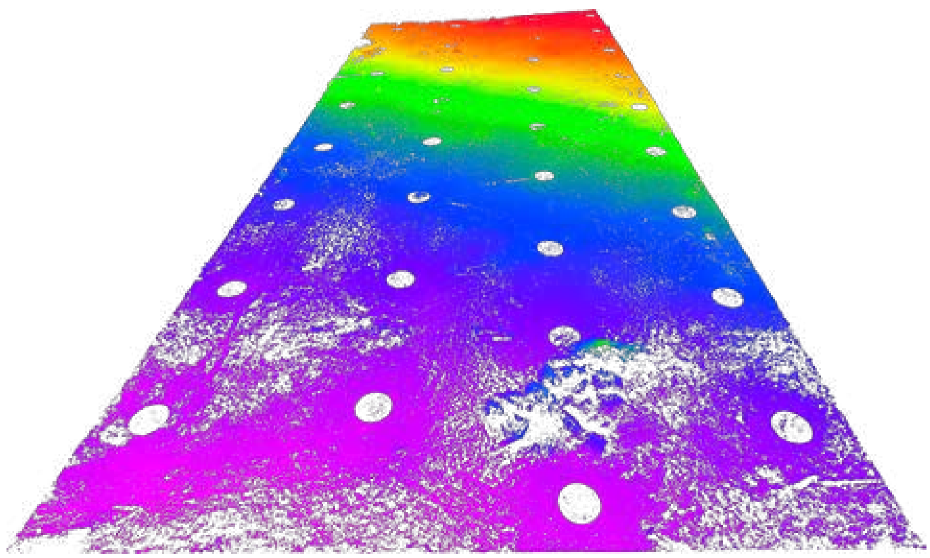
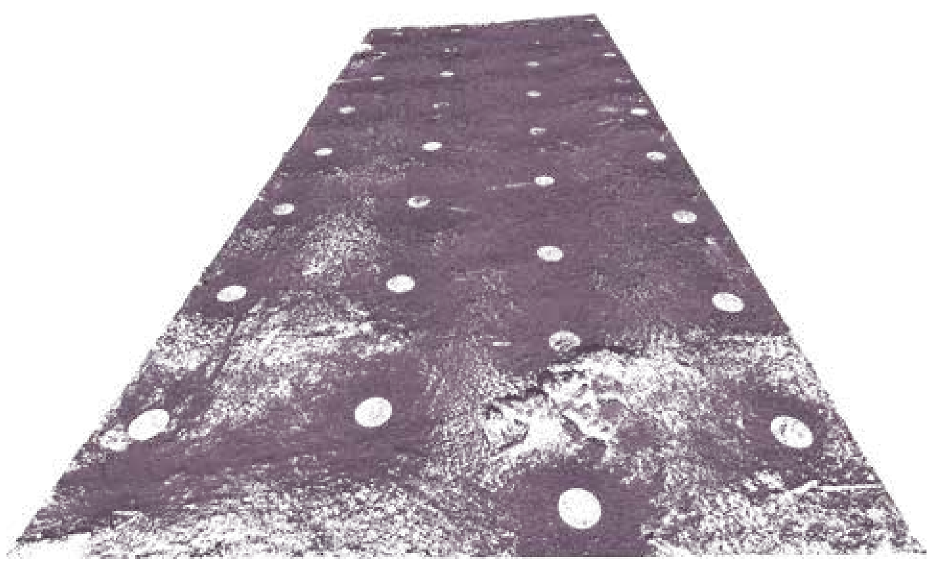


Figure 11. Perspective view (from Northeast looking Southwest). Point cloud image export from Autodesk ReCap ("scan location" filter, rendering all features similarly to observe surface resolution).



Post Processing & Modeling

Once sufficiently 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.). In the context of this project, the E57 file was imported into Autodesk ReCap Pro 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.

FARO Scene also allows for surface meshing of the project point cloud. While relatively poor in the recent past, the meshing capabilities have improved considerably over the past few years. A mesh was created and exported to OBJ format and imported into Rhinoceros. Within Rhinoceros, the mesh was rendered monochromatic to examine surface features. Additionally, contour lines were created using the mesh at intervals of 1cm, 5cm, 10cm, 50cm, and 1m. These renderings and contours were combined into composite drawings of the cemetery using Adobe Illustrator and Photoshop.

Figure 12. Isometric view (from North looking South). Color point cloud image export from Autodesk ReCap. ("heat map" filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations overlaid on color point cloud).

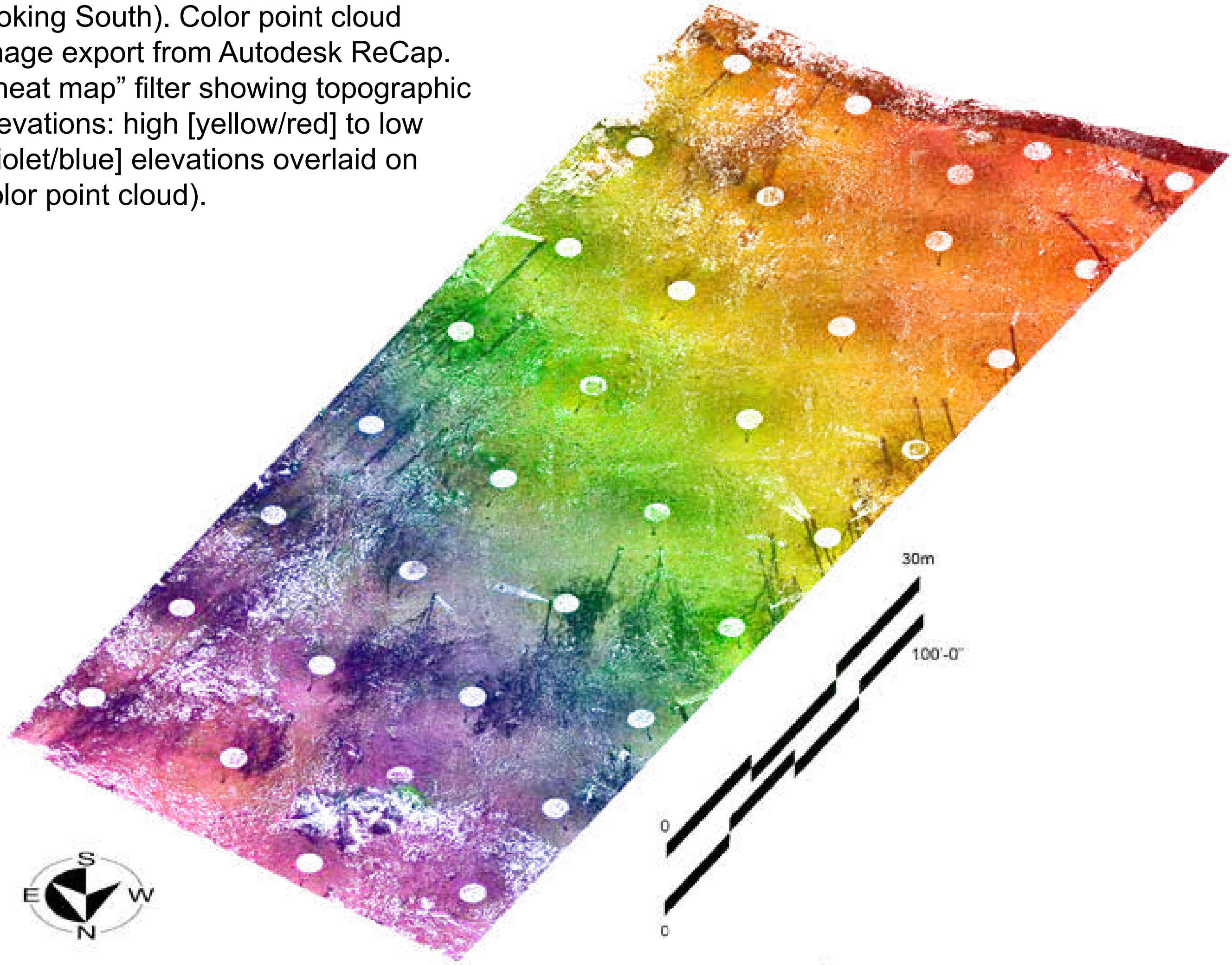


Figure 13. Isometric view (from North looking South). Color point cloud image export from Autodesk ReCap.

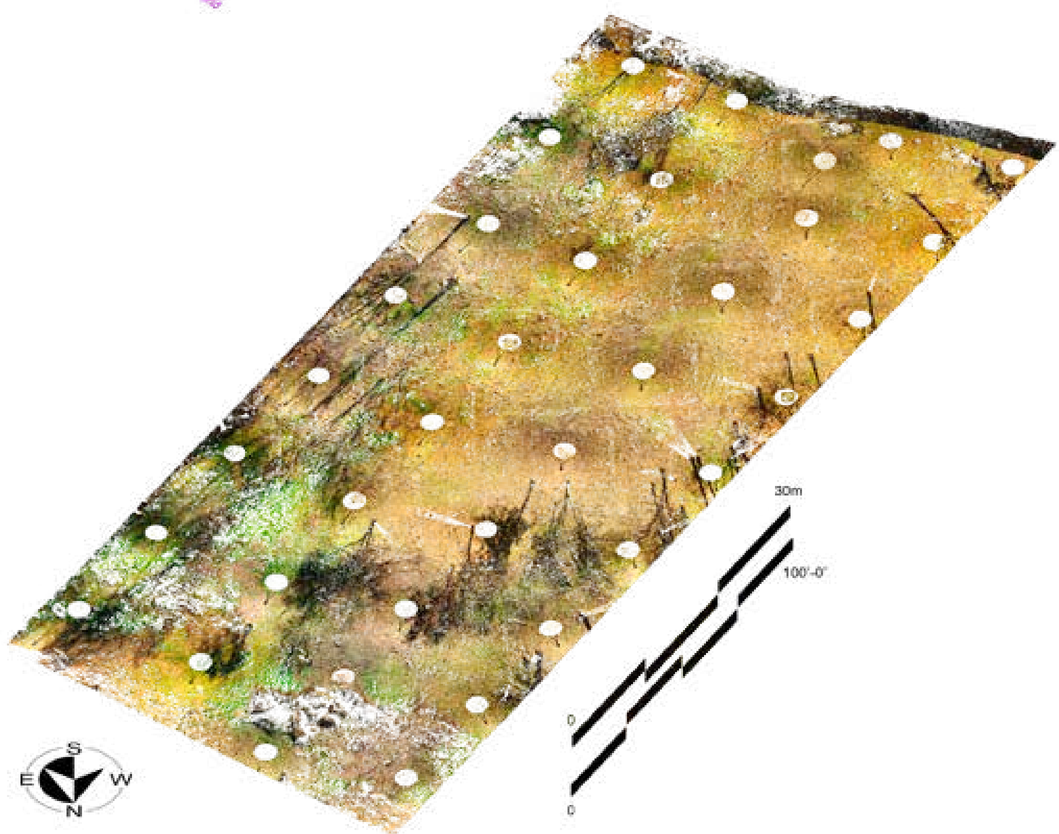
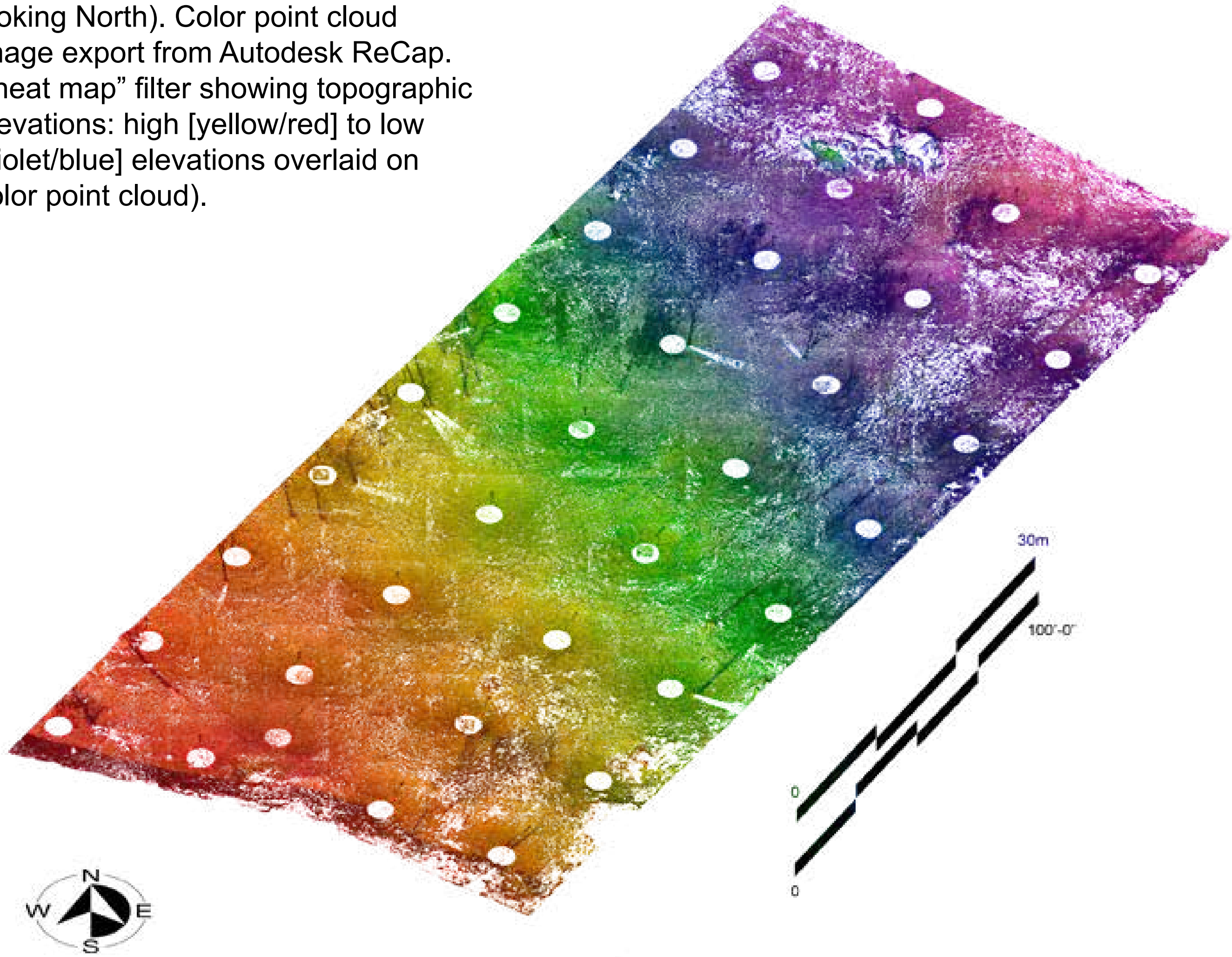


Figure 14. Isometric view (from South looking North). Color point cloud image export from Autodesk ReCap. (“heat map” filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations overlaid on color point cloud).



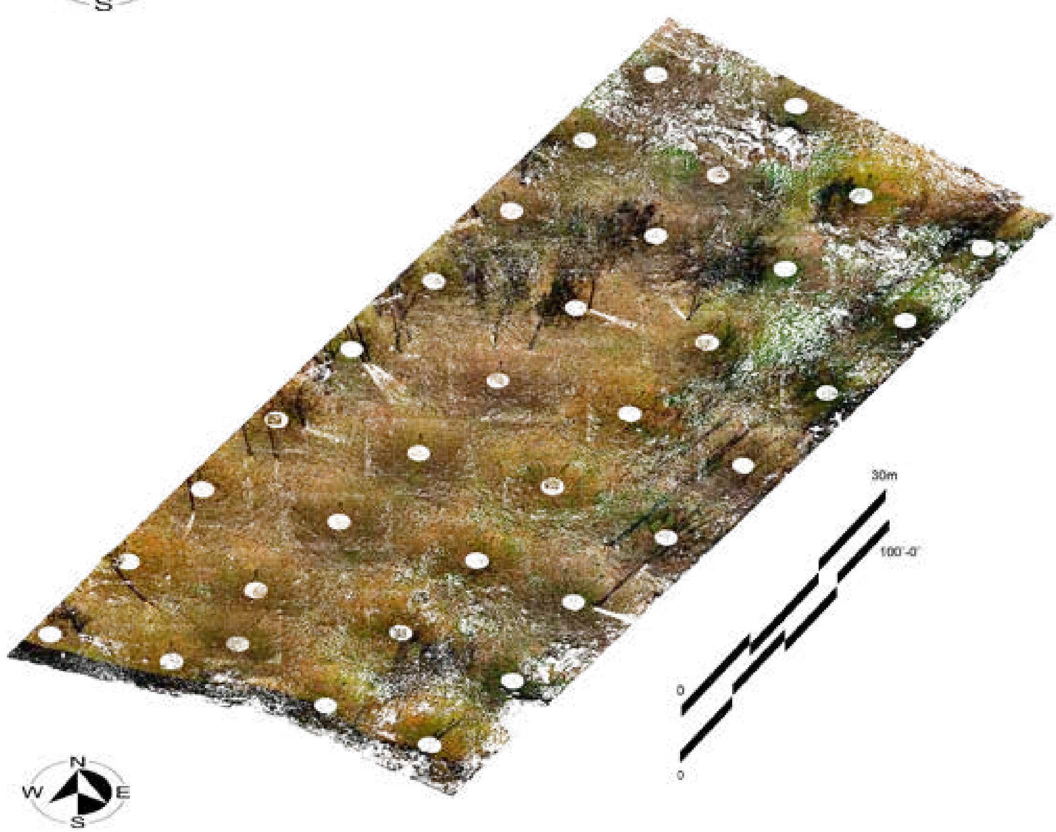


Figure 15. Isometric view (from South looking North). Color point cloud image export from Autodesk ReCap.

Figure 16. Isometric view (from North looking South).

a. 1cm contour lines from Rhino, based on mesh created in FARO Scene.

b. 5cm and 10cm contour lines from Rhino, based on mesh created in FARO Scene.

c. 50cm and 1m contour lines from Rhino, based on mesh created in FARO Scene.

d. Color point cloud image export from Autodesk ReCap (“heat map” filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

e. Rendering from Rhino, based on mesh created in FARO Scene.

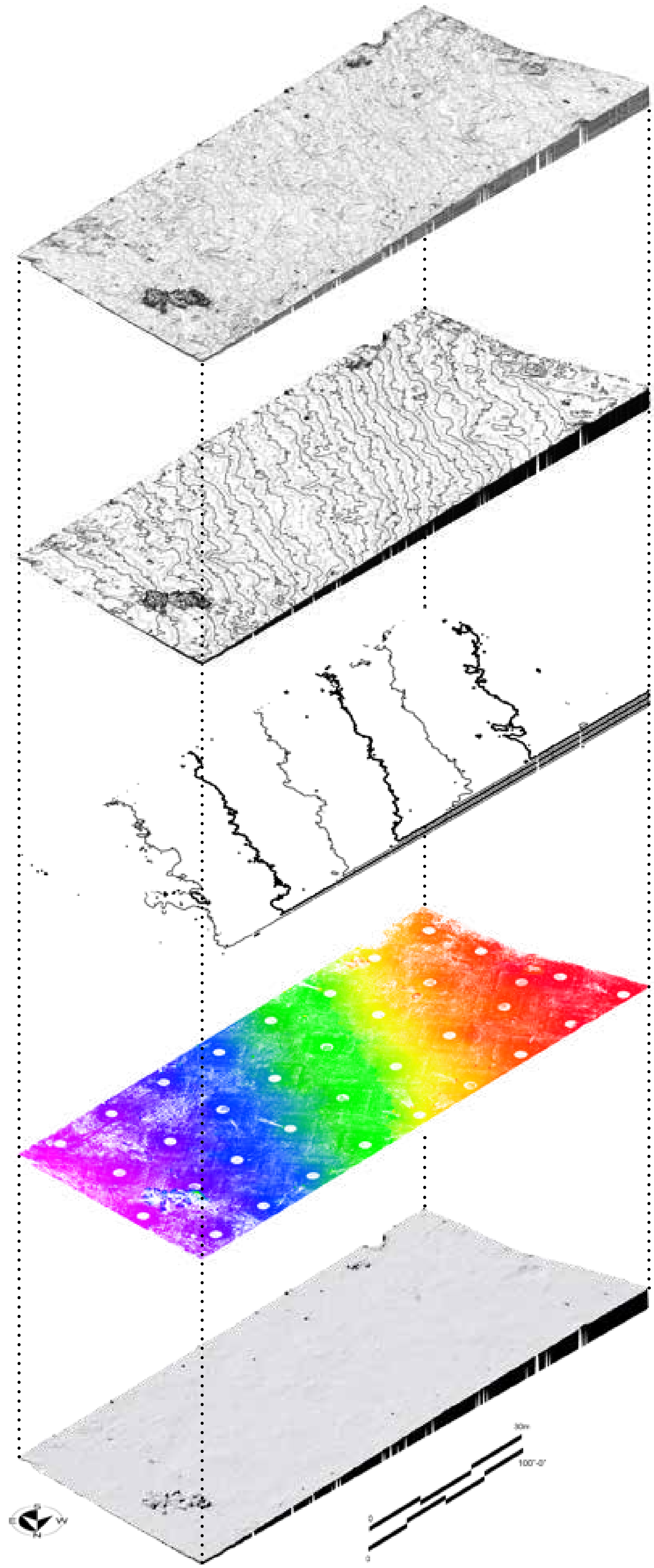


Figure 17. Isometric view (from North looking South). Contour lines & rendering from Rhino, based on mesh created in FARO Scene.

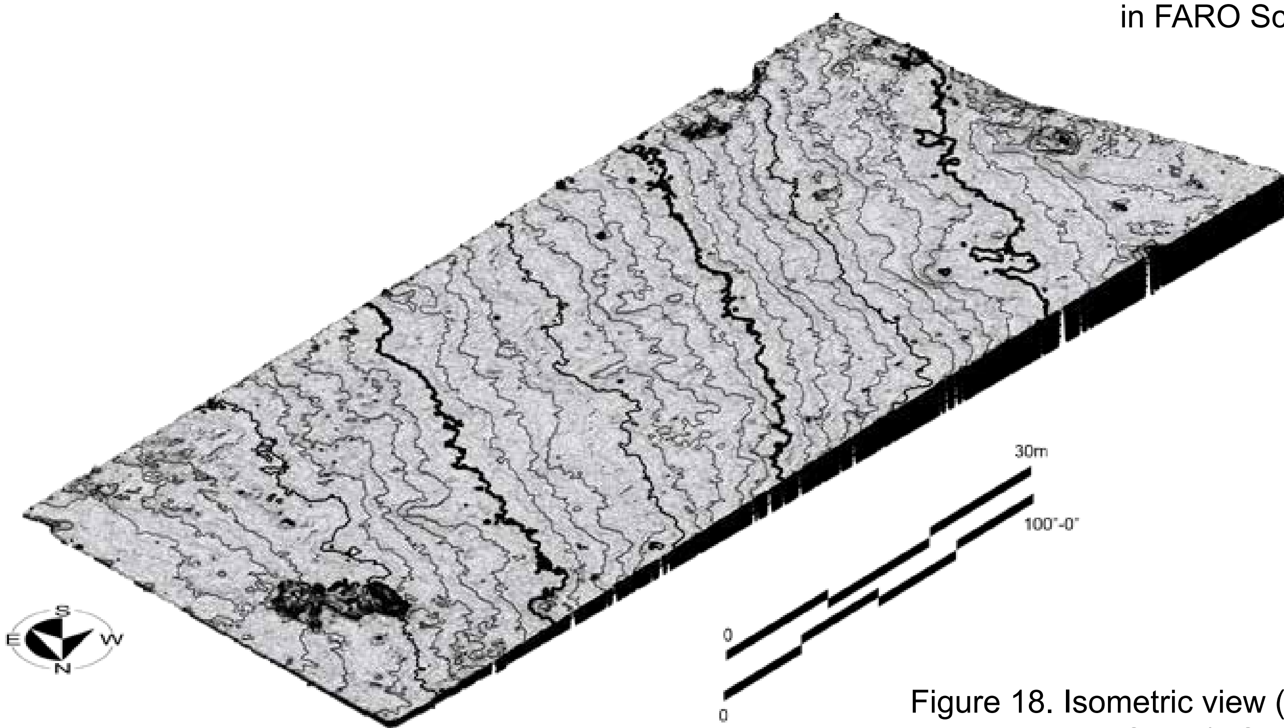


Figure 18. Isometric view (from North looking South). Contour lines & rendering from Rhino, based on mesh created in FARO Scene (with ReCap “heat map” filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).

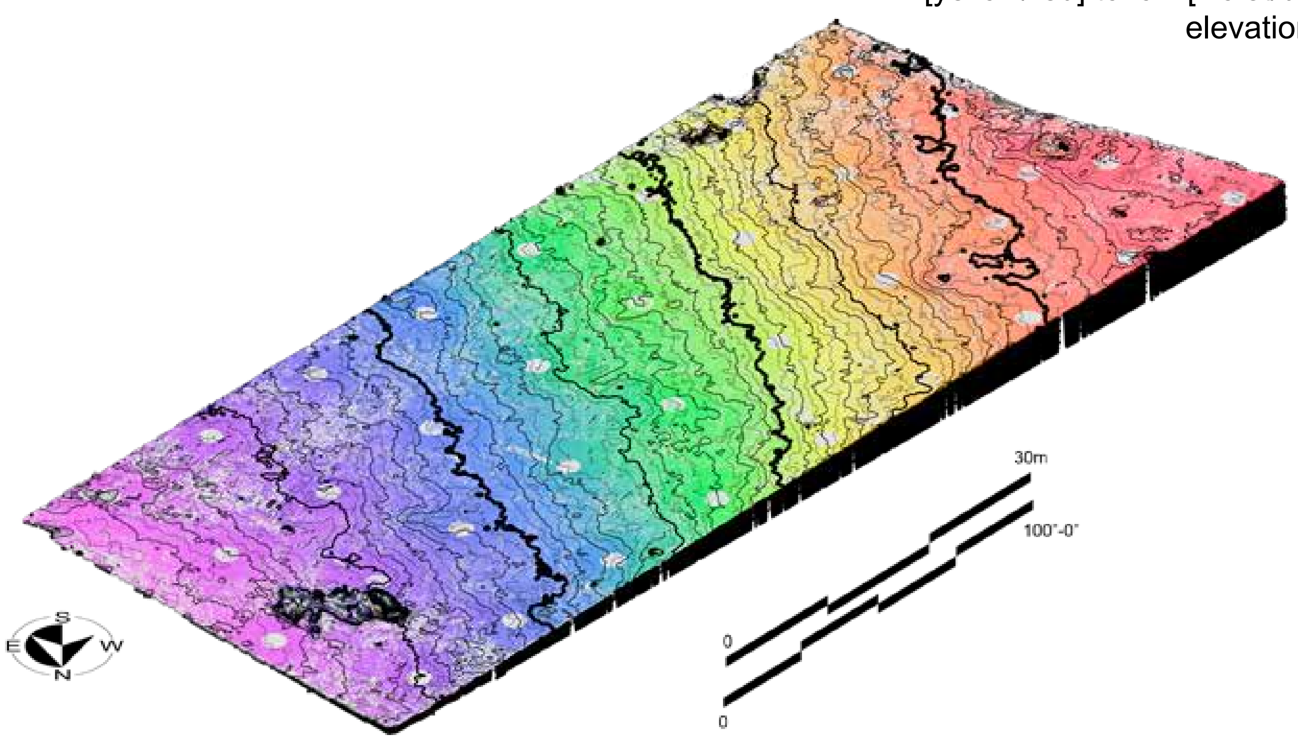
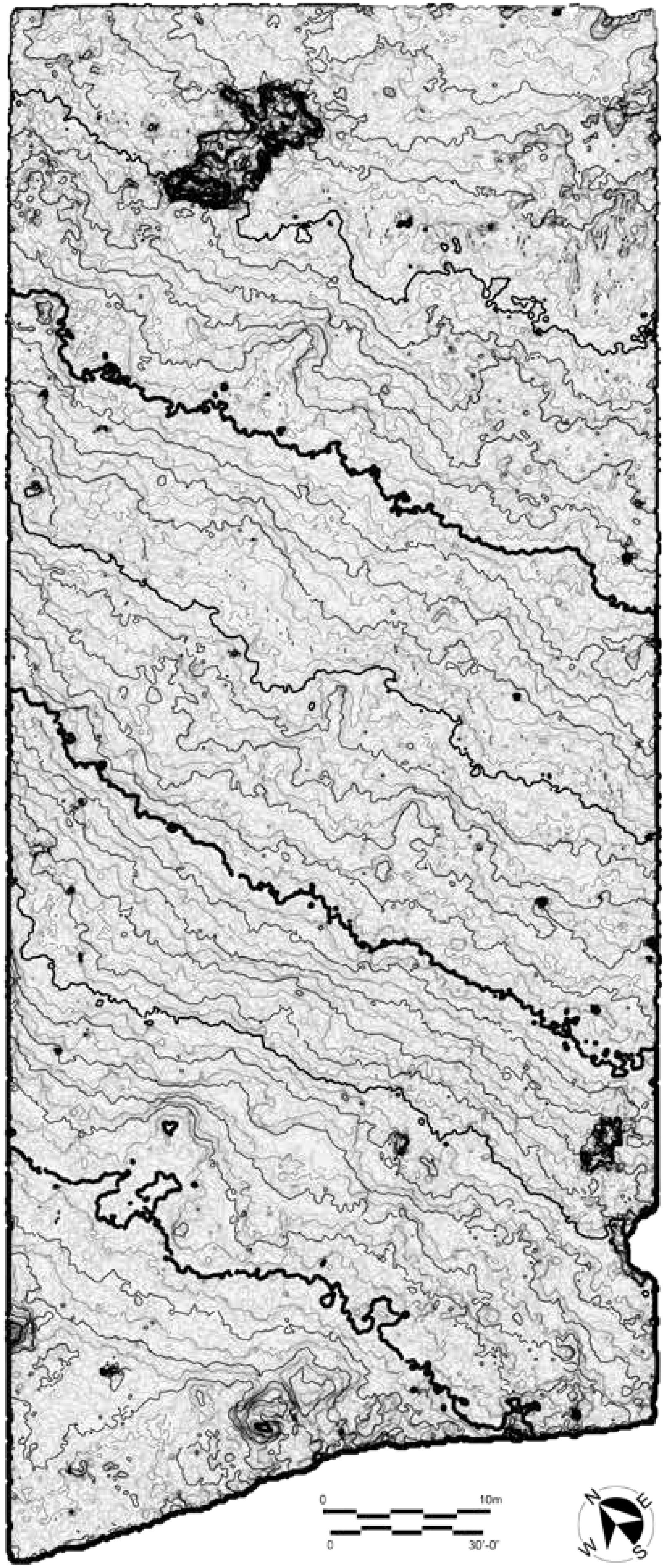


Figure 19. Site plan. Contour lines & rendering from Rhino, based on mesh created in FARO Scene.



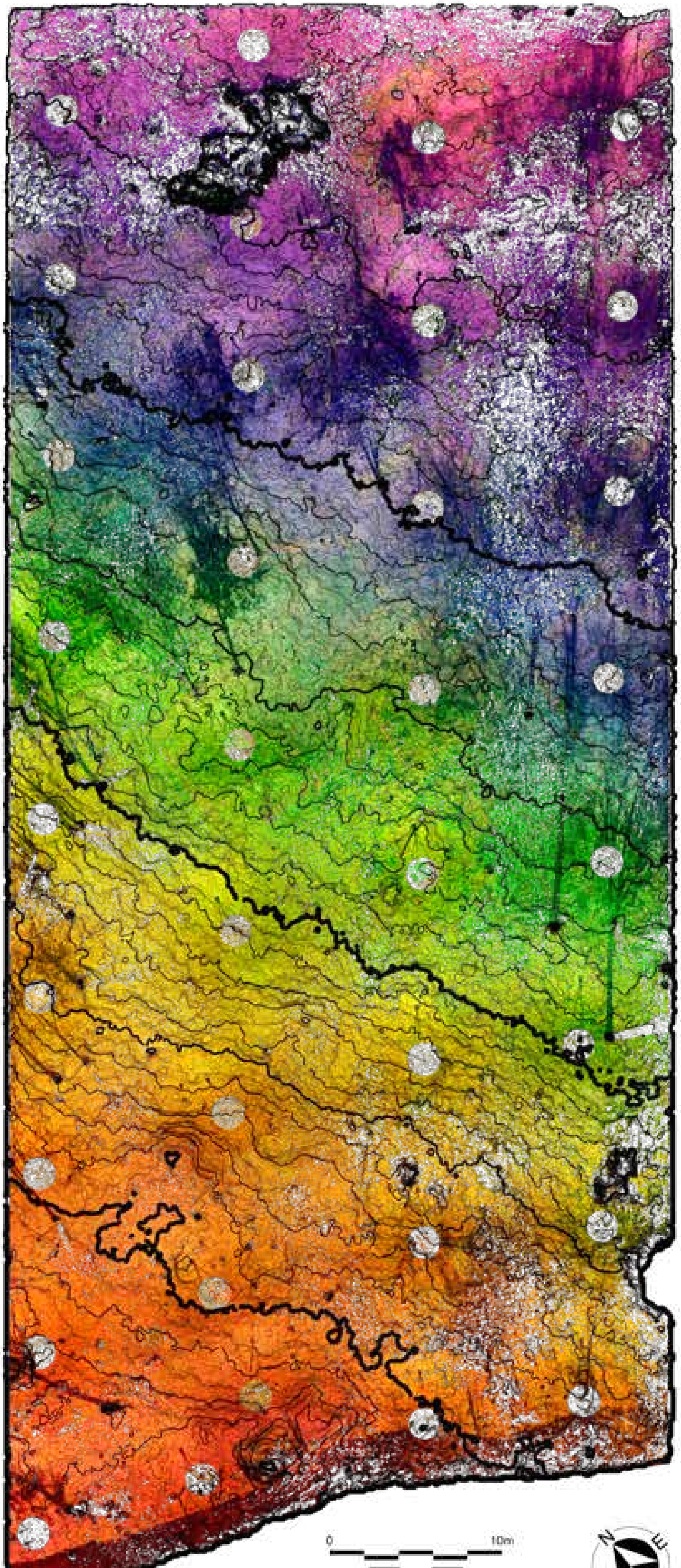
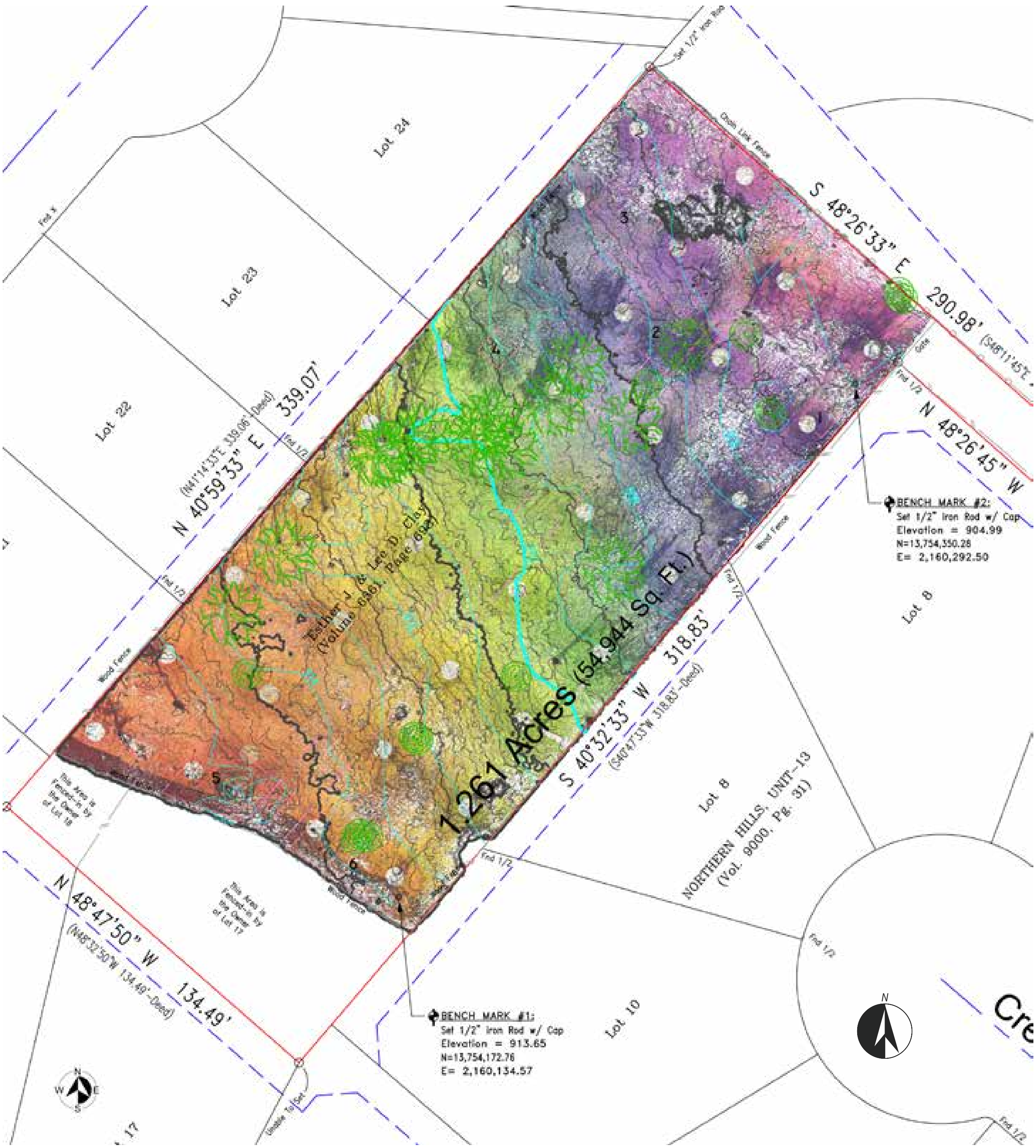


Figure 20. Site plan. Contour lines from Rhino, based on mesh created in FARO Scene (with ReCap "heat map" filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations overlaid on color point cloud).

Figure 21. Site plan combining detail of previously surveyed site plan (Gibbons Surveying & Mapping, Inc., January 30, 2019) with underlay: mesh created in FARO Scene, contour lines (1m, 50cm, 10cm, and 5cm intervals) from Rhino (with ReCap "heat map" filter showing topographic elevations: high [yellow/red] to low [violet/blue] elevations).



Site benchmarks established by Gibbons Surveying & Mapping, Inc., January 30, 2019.

Datum in ND ‘83
Texas State Plane, South Central Zone
State Plane Zone 4 Zone 5401 FIPS 4204 TX-S Central
State Plane Coordinate System (SPCS)

Bench Mark #1
N = 13,754,172.760 (US Survey feet)
E = 2,160,134.570 (US Survey feet)
Elevation = 913.65 (US Survey feet)
[= 278.481 meters]

Conversions to other systems
https://www.ngs.noaa.gov/NCAT/
Input Datum NAD83(2011); Output Datum (NAD82(2011)

UTM Zone 14
Northing 3,270,951.835; Easting 558,395.294

LAT-LON
29.5669388271, -98.3971452343
29°34’01.0”N 98°23’49.7”W

GOOGLE MAPS
https://www.google.com/maps/place/29%C2%B034’01.0%22N+98%C2%B023’49.7%22W/@29.5669498,-98.3977227,207m/

Bench Mark #2
N = 13,754,350.28 (US Survey feet)
E = 2,160,292.50 (US Survey feet)
Elevation 904.99 (US Survey feet)
[=275.842 meters]

Conversions to other systems
https://www.ngs.noaa.gov/NCAT/
Input Datum NAD83(2011); Output Datum (NAD82(2011)

UTM Zone 14
Northing 3,271,005.933; Easting 558,443.418

LATLONG
29.5674247857, -98.3966455371
29°34’02.7”N 98°23’47.9”W

GOOGLE MAPS
https://www.google.com/maps/place/29%C2%B034’02.7%22N+98%C2%B023’47.9%22W/@29.567426,-98.3971927,146m/

Summary and Recommendations

The terrestrial laser scanning survey of the Hockley Cemetery on December 6, 2019, produced a slightly more accurate point cloud, but a much more accurate digital surface model, which was primarily the result of the more thorough removal of surface vegetation on the site. While the model still reflects some residual vegetation as well as the ground topography, the renderings of the contours at 1cm, 5cm, and 10cm provide the maximum resolution possible using this technology for the purposes of surface modeling. The recommended next stage of the project is to combine the surface plans with images from the geophysical survey work (ground penetrating radar) conducted by Dr. Mark Everett in April 2019 in order to look for correspondences between the GPR anomalies and changes in the surface contours.