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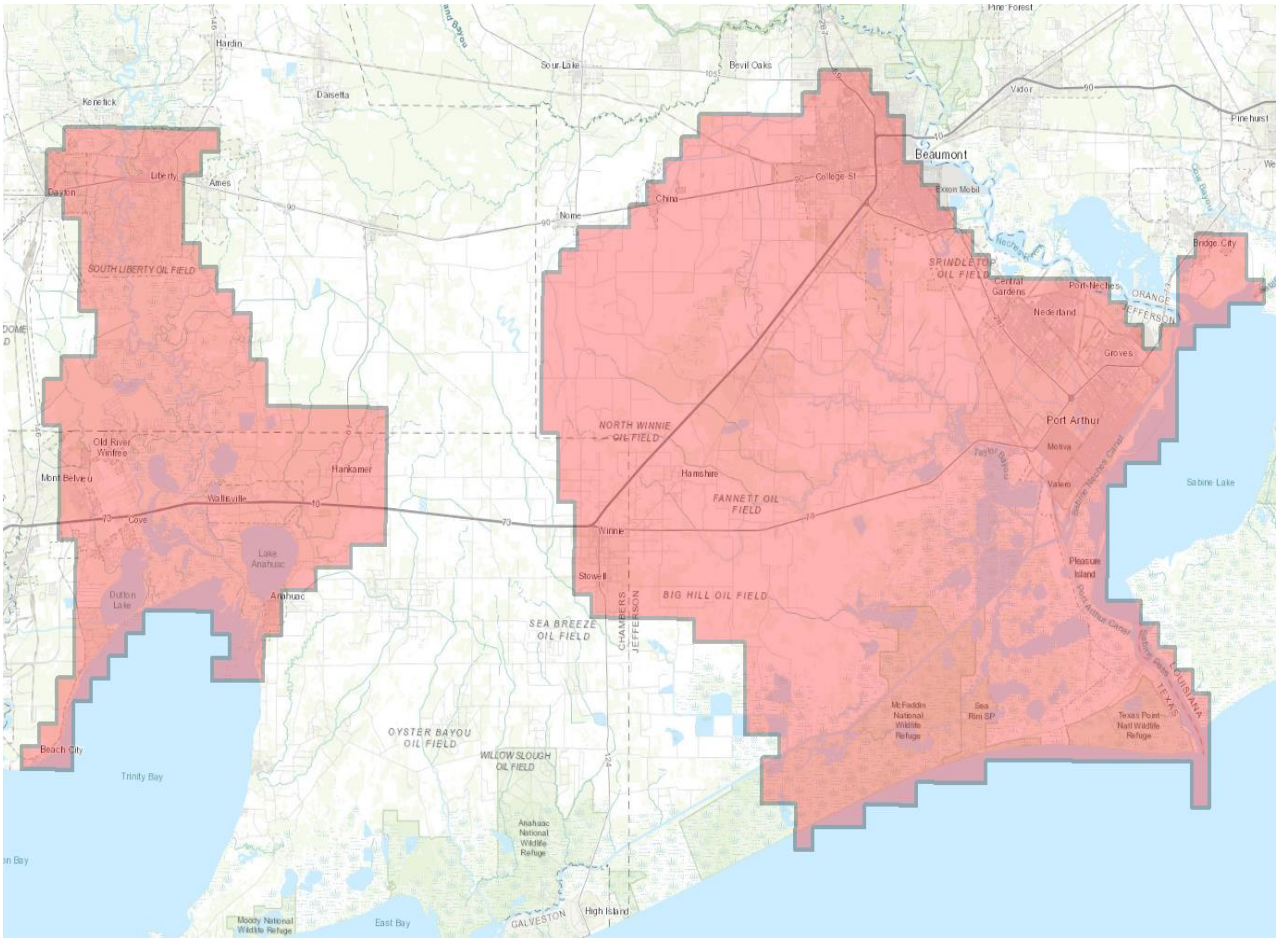
Statement of Work 580-17-SOW0039

LiDAR for Coastal Texas

GROUND CONTROL SURVEY REPORT

April 20,2017



EXECUTIVE SUMMARY

Sanborn Map Company is contracted by Texas Water Development Board (TWDB) in cooperation with the Trinity River Authority (TRA) to perform 2017 LiDAR aerial surveys of Texas coastal area of about 1130 square miles. Collections was completed utilizing multi-return systems, Light Detection and Ranging (LiDAR) data in the form of 3-dimensional positions of a dense set of mass points between February 22nd and March 23rd, 2017.

ALS70 LiDAR was flown to produce four (4) points and eight (8) points per square meter return density or 0.5 meters and 0.35 meters respectively Nominal Point Spacing (NPS). Break lines will be produced to supplement the bare-earth classified LiDAR with the objective of producing a high-accuracy topographic map.

A network of ground control points has been design and implemented into the project process to establish common basis for geo-referencing of the LiDAR data products. These control points are used in conjunction with airborne GPS data collected during acquisition of LiDAR data. Additionally, twenty three (23) LiDAR calibration points were collected and tied to the national HARN control network. Many of the calibration points are photo identifiable for additional horizontal control.

The local network was designed, processed and adjusted using Trimble Business Center (TBC) version 3.10. Final horizontal coordinates are projected on UTM Zone 15, on the North American Datum of 1983 (2011). Furthermore, orthometric elevations were estimated for all points in the network using sophisticated geoidal modeling techniques (GEOID12) and are provided on the North American Vertical Datum of 1988 (NAVD88).

A set consisting of four (4) NGS monuments, part of HARN network, two AGPS base station points and twenty three (23) LiDAR calibration points were established within project area by Sanborn. The calibration points set was implemented in LiDAR data processing and adjustments.

TABLE OF CONTENTS

1. INTRODUCTION

This report contains the technical write-up of the differential GPS surveys performed for the ground control LiDAR calibration points in support of high-resolution digital elevation model developed from LiDAR data for the 2017 TX Coastal LiDAR project.

Sanborn was responsible for the preparation of this report, all fieldwork including reconnaissance of existing control points, establishment of additional control points, GPS surveys, all GPS data processing and reductions.

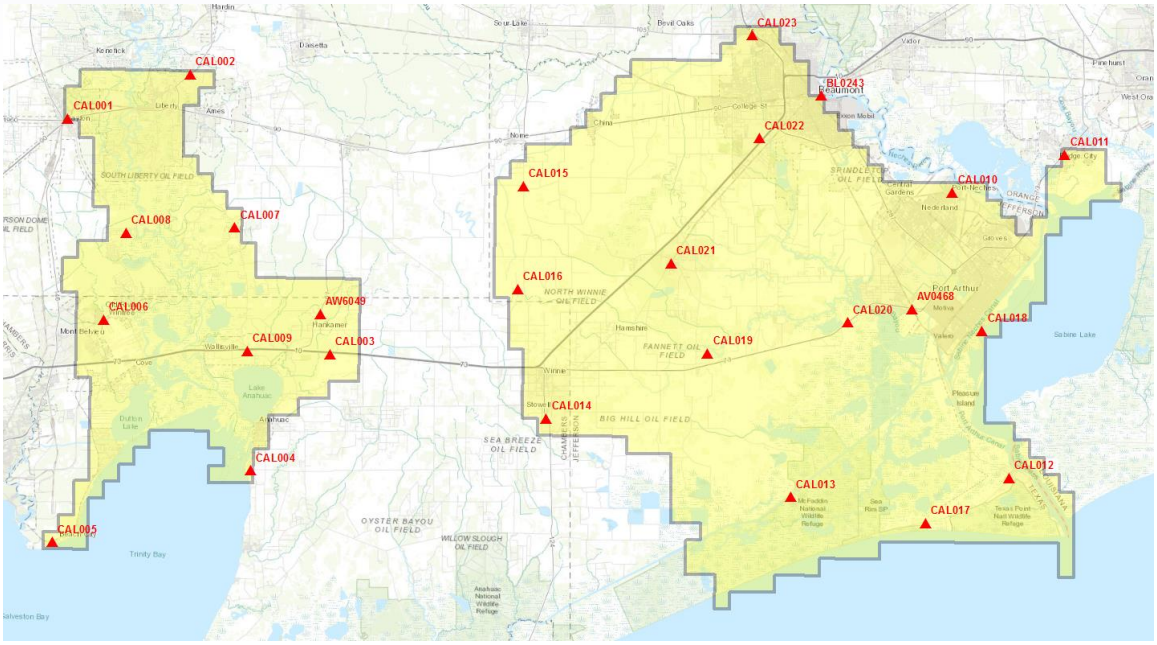


Figure 1: Project Layout with LiDAR control Points.

1.1 Purpose of the Survey

The GPS Network surveys were designed to provide ground control for high-accuracy LiDAR data collection of the TX Coastal LiDAR mapping project. The network consists of twenty nine (29) control stations. The network includes four (4) NGS monuments: AW5658, AW6049, AV0468 and BL0243, two semi-permanent AGPS base station points: 501 and 502 and one twenty three (23) calibration points, see APPENDIX A for adjusted coordinates and APPENDIX C for points recovery sheets. The horizontal and vertical datum of the local GPS network is based on HARN network and published values of NGS monuments used. Error was discovered with the published value of the 3 NGS monuments. Published value of the NGS monuments: AW6049 and BL0243 vertical component are off from the actual value by ~21 cm, while NGS monument: AV0468 is off by ~55 cm. It could have been caused by sinking of the monuments or incorrect calculation by the NGS services.

The LiDAR calibration points were established throughout project area to serve in LiDAR data processing and adjustments. Calibration points were positioned with the intent of accomplishing even and random point distribution over the area of interest. See APPENDIX C for point recovery sheets.

1.2 Duration/Time Period

The acquisition of ground control points were completed between February 28, 2017 (Julian day 059) and April 05, 2017 (Julian day 095).

1.3 Personnel

Sanborn field data acquisition technicians are cross-trained as Survey Technicians as well as Airborne Sensor Operators to maximize their utility.

Field Survey Personnel	
Name	**Function**
William Dunkan	Sensor Operator/ Survey Technician
Karol Szczubelek	Geomatics Engineer

1.4 Equipment

The ground control survey was performed using survey grade L1/L2 GPS antennas attached to adjustable height tripods with tribrach. The antennas include:

Trimble 5700 receivers with Zephyr Geodetic 2 antennas

1.5 Field Procedures

A careful reconnaissance was undertaken prior to the monumentation and subsequent GPS survey. Most of the points in the network have good satellite visibility. The satellite window provided 24–hour coverage, and GPS observation sessions were scheduled between 7:00 am and 7:00 PM, local time, each day. No difficulties were experienced with solar storm activity. All baseline processing, analysis, and preliminary reductions were performed on a daily basis, thus allowing for continuous quality control.

The GPS control survey was set up as a fast static at 1s logging rate. Field crew members followed a session schedule established by office personnel to facilitate observation location and duration, which were at least 40 minutes per session for LiDAR calibration point surveys. Each point was surveyed at least twice. If 2 surveys did not match within 2 cm, point was resurveyed until required precision was achieved. Network points were surveyed for at least 2 hours per observation. Personnel navigated to points using hand-held GPS receivers, USGS Quadrangle maps and state road maps. The hand-held GPS receivers had approximate geodetic coordinates loaded for the required observation points. Upon arriving at the desired location, the field personnel initiated a search for an adequate control point location that was in a GPS "friendly" spot. The receiver was set on the tripod and leveled over the point. The following information was recorded: control point name and code, stamping if available, date, Julian date, observer name, receiver model & serial number, antenna type, where the antenna height was measured to, antenna height, start time, end time, site sketch with ties. The data file name is also included on this sheet. The file name convention is SSSSJJJf.dat, where "SSSS" is the last four digits of the receiver serial number, "JJJ" is the Julian date, and "f" is the data file number for that day's work. "f" = 0 for the first file, 1 for the second and so on. See APPENDIX E with field logs for details.

Digital photographs or sketches were taken at each point showing the control point surveyed and its relationship to its surroundings.

1.6 Contact

Questions regarding technical aspects of this report should be addressed to:

Sanborn
1935 Jamboree Drive, Suite 100
Colorado Springs, Colorado, 80920

Attention:	Bridget Marcotte	Project Manager
	Karol Szczubelek	Geodetic Engineer
Telephone:	(719) 593-0093	
FAX:	(719) 528-5093	

1.7 Accuracy requirements

The final horizontal datum NAD 83 (2011) yielded 2 sigma (95%) station confidence levels of less than 0.03 meters horizontally (X, Y) and vertical datum NAVD88 of less than 0.017 meters vertically (Z).

1.8 GPS Network and Calibration Points Diagram

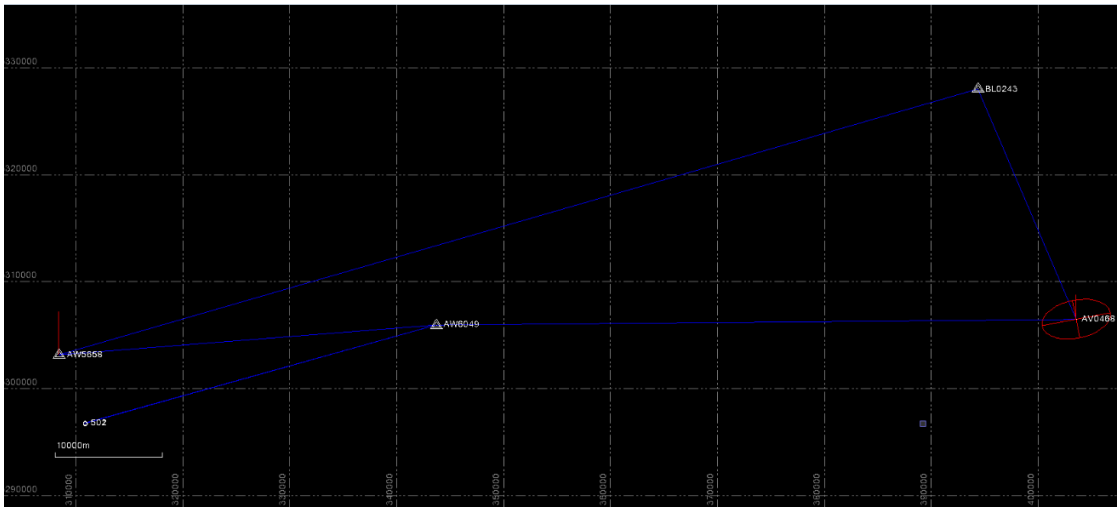


Figure 1: NGS Network Diagram

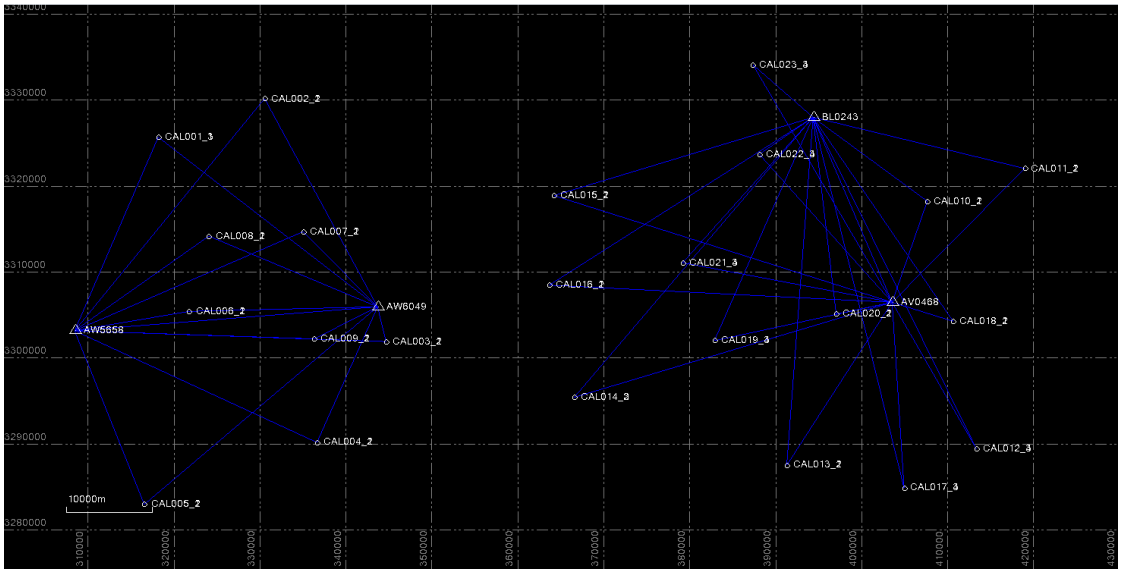


Figure 2: Control Points Diagram

2. PROJECT AREA SCOPE AND DETAILS

Sanborn Map Company is contracted by Texas Water Development Board (TWDB) in cooperation with the Trinity River Authority (TRA) to perform 2017 LiDAR aerial surveys of Texas coastal area of about 1130 square miles. Collections was completed utilizing multi-return systems, Light Detection and Ranging (LiDAR) data in the form of 3-dimensional positions of a dense set of mass points between February 22nd and March 23rd, 2017.

2.1 Monuments and Station Naming

The LiDAR control points were established throughout project area to serve as LiDAR calibration points and were used in LiDAR data processing and adjustments. The calibration points have been identified with the following naming sequence: CAL001 thru CAL023. AGPS base stations have been named: 501 and 502. Four NGS monuments were used in surveys: AW5658, AW6049, AV0468 and BL0243

3. CONDITIONS AFFECTING PROGRESS

A careful reconnaissance was undertaken prior to check point control selection and subsequent GPS surveys. All calibration points are boldly visible and un-obscured. All of the points in the network have good satellite visibility. The satellite window provided 24–hour coverage, and GPS observation sessions were scheduled between 7:00 am and 7:00 PM, local time, each day. No difficulties were experienced with solar storm activity.

4. POST PROCESSING

4.1 Baseline Processing

All static baselines and vectors for the TX Coastal LiDAR project were processed using Trimble Business Center (Ver. 3.10) (TBC) software. Fixed solutions were adopted for all baselines using the broadcast ephemeris. GEOID12A was incorporated into the reductions, thereby allowing rigorous interpolation of the geoidal undulation values (N) at each point in the network. This provides a useful method of estimating the elevations at all points in the network. For baseline processing reports and adjustments, see APPENDIX B.

TABLE 1. ADJUSTMENT CONSTRAINTS

Station Name	PID	Horizontal/Vertical
S 1015	AV0468	(NA)/1
HGCSD	AW5658	0/k
MCBRIDGE	AW6049	0/1
V 1199	BL0243	0/1

4.2 OPUS test

OPUS tests have been run for every GPS observation and compared to processed value. Below is the table showing OPUS results. See Appendix F for OPUS solutions.

				Difference		
ID	Easting (Meter)	Northing (Meter)	Elevation (Meter)	D-E(m)	D-N(m)	D-Elevation(m)
AV0468	403555.579	3306440.380	1.442			
AV0468-OPUS1	403555.592	3306440.357	1.464	0.013	-0.023	0.022
AV0468-OPUS2	403555.565	3306440.369	1.438	-0.014	-0.011	-0.004
AV0468-OPUS3	403555.567	3306440.368	1.447	-0.012	-0.012	0.005
AV0468-OPUS101	403555.563	3306440.367	1.455	-0.016	-0.013	0.013
AV0468-OPUS102	403555.564	3306440.367	1.452	-0.015	-0.013	0.01
AV0468-OPUS103	403555.554	3306440.369	1.453	-0.025	-0.011	0.011

AV0468-OPUS104	403555.564	3306440.373	1.447	-0.015	-0.007	0.005
AW5658	308388.530	3303131.042	11.710			
AW5658-OPUS1	308388.526	3303131.059	11.734	-0.004	0.017	0.024
AW5658-OPUS2	308388.524	3303131.064	11.724	-0.006	0.022	0.014
AW6049	343653.232	3305919.126	9.723			
AW6049-OPUS1	343653.235	3305919.125	9.722	0.003	-0.001	-0.001
AW6049-OPUS2	343653.231	3305919.127	9.710	-0.001	0.001	-0.013
AW6049-OPUS3	343653.180	3305919.122	9.744	-0.052	-0.004	0.021
AW6049-OPUS4	343653.239	3305919.134	9.698	0.007	0.008	-0.025
AW6049-OPUS101	343653.246	3305919.145	9.722	0.014	0.019	-0.001
BL0243	394350.246	3327978.217	6.018			
BL0243-OPUS1	394350.233	3327978.209	6.014	-0.013	-0.008	-0.004
BL0243-OPUS2	394350.236	3327978.214	6.010	-0.01	-0.003	-0.008
BL0243-OPUS3	394350.235	3327978.207	6.004	-0.011	-0.01	-0.014
BL0243-OPUS4	394350.236	3327978.214	6.010	-0.01	-0.003	-0.008
BL0243-OPUS101	394350.234	3327978.209	6.003	-0.012	-0.008	-0.015
BL0243-OPUS102	394350.233	3327978.213	5.991	-0.013	-0.004	-0.027
BL0243-OPUS103	394350.234	3327978.206	6.000	-0.012	-0.011	-0.018
BL0243-OPUS104	394350.237	3327978.210	5.990	-0.009	-0.007	-0.028
CAL001_1	318115.645	3325668.960	24.709			
CAL001_3	318115.643	3325668.954	24.712	-0.002	-0.006	0.003
CAL002_1	330499.742	3330160.044	13.939			
CAL002_2	330499.749	3330160.015	13.925	0.007	-0.029	-0.014
CAL003_1	344633.848	3301868.391	9.346			
CAL003_1-OPUS	344633.852	3301868.421	9.305	0.004	0.03	-0.041
CAL003_2	344633.852	3301868.410	9.330	0.004	0.019	-0.016
CAL003_2-OPUS	344633.854	3301868.427	9.317	0.002	0.017	-0.013
CAL004_1	336596.078	3290131.886	5.055			
CAL004_1-OPUS	336596.084	3290131.876	5.085	0.006	-0.01	0.03
CAL004_2	336596.077	3290131.888	5.036	-0.001	0.002	-0.019
CAL004_2-OPUS	336596.089	3290131.883	5.052	0.012	-0.005	0.016
CAL005_1	316498.247	3282917.951	7.573			
CAL005_1-OPUS	316498.255	3282917.951	7.627	0.008	0	0.054
CAL005_2	316498.247	3282917.953	7.591	0	0.002	0.018
CAL005_2-OPUS	316498.256	3282917.957	7.633	0.009	0.004	0.042
CAL006_1	321710.303	3305387.276	11.327			
CAL006_1-OPUS	321710.308	3305387.269	11.331	0.005	-0.007	0.004
CAL006_2	321710.303	3305387.277	11.346	0	0.001	0.019
CAL006_2_OPUS	321710.305	3305387.276	11.354	0.002	-0.001	0.008

CAL007_1	334996.477	3314673.055	10.049			
CAL007_2	334996.481	3314673.048	10.038	0.004	-0.007	-0.011
CAL008_1	324010.727	3314150.756	12.909			
CAL008_2	324010.730	3314150.747	12.925	0.003	-0.009	0.016
CAL009_1	336271.255	3302183.957	6.674			
CAL009_1-OPUS	336271.257	3302183.947	6.651	0.002	-0.01	-0.023
CAL009_2	336271.253	3302183.957	6.675	-0.002	0	0.001
CAL009_2-OPUS	336271.260	3302183.951	6.669	0.007	-0.006	-0.006
CAL010_1	407647.975	3318209.267	5.255			
CAL010_1-OPUS	407647.975	3318209.266	5.247	0	-0.001	-0.008
CAL010_2	407647.978	3318209.261	5.271	0.003	-0.006	0.016
CAL011_1	418992.448	3322019.717	2.809			
CAL011_1-OPUS	418992.439	3322019.720	2.789	-0.009	0.003	-0.02
CAL011_2	418992.445	3322019.720	2.803	-0.003	0.003	-0.006
CAL011_2-OPUS	418992.440	3322019.722	2.811	-0.005	0.002	0.008
CAL012_3	413386.463	3289352.929	1.282			
CAL012_4	413386.467	3289352.927	1.293	0.004	-0.002	0.011
CAL013_1	391286.729	3287467.698	1.434			
CAL013_3-OPUS	391286.719	3287467.698	1.438	-0.01	0	0.004
CAL013_2	391286.733	3287467.710	1.435	0.004	0.012	0.001
CAL013_2-OPUS	391286.723	3287467.701	1.330	-0.01	-0.009	-0.105
CAL014_2	366545.568	3295378.202	6.026			
CAL014_2-OPUS	366545.556	3295378.194	6.077	-0.012	-0.008	0.051
CAL014_3	366545.573	3295378.204	6.044	0.005	0.002	0.018
CAL014_3-OPUS	366545.557	3295378.195	6.046	-0.016	-0.009	0.002
CAL015_1	364195.764	3318864.890	10.064			
CAL015_1-OPUS	364195.756	3318864.884	10.050	-0.008	-0.006	-0.014
CAL015_2	364195.767	3318864.889	10.040	0.011	0.005	-0.01
CAL016_1	363635.956	3308439.319	10.917			
CAL016_1-OPUS	363635.955	3308439.317	10.938	-0.001	-0.002	0.021
CAL016_2	363635.951	3308439.315	10.933	-0.005	-0.004	0.016
CAL016_2-OPUS	363635.956	3308439.318	10.900	0.005	0.003	-0.033
CAL017_3	404949.617	3284825.360	1.194			
CAL017_3-OPUS	404949.609	3284825.357	1.222	-0.008	-0.003	0.028
CAL017_4	404949.619	3284825.360	1.207	0.002	0	0.013
CAL018_1	410650.716	3304233.945	2.087			
CAL018_2	410650.714	3304233.951	2.108	-0.002	0.006	0.021
CAL018_2-OPUS	410650.704	3304233.949	2.136	-0.01	-0.002	0.028
CAL019_3	382862.460	3301972.008	1.875			

CAL019_4	382862.466	3301972.007	1.897	0.006	-0.001	0.022
CAL020_1	397045.666	3305063.800	1.924			
CAL020_1-OPUS	397045.647	3305063.796	1.914	-0.019	-0.004	-0.01
CAL020_2	397045.658	3305063.796	1.919	-0.008	-0.004	-0.005
CAL020_2-OPUS	397045.645	3305063.800	1.921	-0.013	0.004	0.002
CAL021_3	379170.025	3311051.820	4.631			
CAL021_3-OPUS	379170.012	3311051.814	4.636	-0.013	-0.006	0.005
CAL021_4	379170.021	3311051.819	4.626	-0.004	-0.001	-0.005
CAL022_3	388096.264	3323675.962	4.517			
CAL022_3-OPUS	388096.248	3323675.959	4.480	-0.016	-0.003	-0.037
CAL022_4	388096.262	3323675.964	4.517	-0.002	0.002	0
CAL023_3	387357.484	3334088.112	10.595			
CAL023_3-OPUS	387357.476	3334088.123	10.600	-0.008	0.011	0.005
CAL023_4	387357.479	3334088.115	10.603	-0.005	0.003	0.008

5. FINAL COORDINATES AND ELEVATIONS

The final NAD83 (2011) UTM Zone 15, are presented in meters in APPENDIX A. Final orthometric elevations, referenced to the North American Vertical Datum of 1988 (NAVD88) in meters, are also presented in the above given APPENDIX. All final coordinates are derived from the constrained adjustments shown in APPENDIX B.

APPENDIX A

Calibration Points Adjusted Coordinates

Sanborn Map Company

Photo ID Point Control for TX Coastal

Final Coordinate List

Horizontal Datum: NAD83 (2011)

Vertical Datum: NAVD88

Projection: UTM Zone 15

POINT NO.	EAST (Y) meters	NORTH (X) meters	NAVD88 ELEV (Z) meters
AV0468	403555.579	3306440.380	1.442
AW5658	308388.530	3303131.042	11.710
AW6049	343653.232	3305919.126	9.723
BL0243	394350.246	3327978.217	6.018
CAL001	318115.644	3325668.957	24.711
CAL002	330499.746	3330160.030	13.932
CAL003	344633.850	3301868.401	9.338
CAL004	336596.078	3290131.887	5.046
CAL005	316498.247	3282917.952	7.582
CAL006	321710.303	3305387.277	11.337
CAL007	334996.479	3314673.052	10.044
CAL008	324010.729	3314150.752	12.917
CAL009	336271.254	3302183.957	6.675
CAL010	407647.977	3318209.264	5.263
CAL011	418992.447	3322019.719	2.806
CAL012	413386.465	3289352.928	1.288
CAL013	391286.731	3287467.704	1.435
CAL014	366545.571	3295378.203	6.035
CAL015	364195.766	3318864.890	10.052
CAL016	363635.954	3308439.317	10.925
CAL017	404949.618	3284825.360	1.201
CAL018	410650.715	3304233.948	2.098
CAL019	382862.463	3301972.008	1.886
CAL020	397045.662	3305063.798	1.922
CAL021	379170.023	3311051.820	4.629
CAL022	388096.263	3323675.963	4.517
CAL023	387357.482	3334088.114	10.599

APPENDIX B

Adjustment Reports

(Electronically Attached)

APPENDIX C

Calibration Points Recovery Sheets

(Electronically Attached)

APPENDIX D

NGS Sheets

(Electronically Attached)

APPENDIX E

Field Logs

(Electronically Attached)

APPENDIX F

OPUS solutions

(Electronically Attached)