Vertical Accuracy Report

VA Report for The Atlantic Group- Kansas 2015 Project Area

Produced for USGS and Kansas Department of Agriculture and the Kansas Data Access and Support Center

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LiDAR Positional Accuracy

The final positional accuracy of the full project-wide area, including all four AOIs, for the BAA Kansas 2015 LiDAR project is reported in this document.

RELATIVE ACCURACY

Dewberry verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthos. According to the SOW and USGS LiDAR Base Specifications v1.2, QL2 data must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using single or only returns from all classes. Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm -12 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 12 cm are colored red. Areas of vegetation and steep slopes (slopes with 12 cm or more of valid elevation change across 1 linear meter) are expected to appear yellow or red in the DZ orthos. When reviewing classified data, Dewberry may also create DZ Orthos from the ground classification only, while keeping all other parameters consistent. This allows Dewberry to review the ground classification relative accuracy beneath vegetation and to ensure flight line ridges or other issues do not exist in the final classified data.

Dewberry verifies the intra-swath or within swath relative accuracy by using Quick Terrain Modeler (QTM) scripting and visual reviews. QTM scripting is used to calculate the RMSE of all points within each 1-meter pixel/cell size of each swath. Dewberry analysts then identify planar surfaces acceptable for repeatability testing and analysts review the QTM results in those areas. According to the SOW and USGS LiDAR Base Specifications v1.2, QL2 data must meet an intra-swath relative accuracy threshold of 6 cm or less.

Lastly, to ensure horizontal alignment between adjacent or overlapping flight lines, Dewberry uses QTM scripting and visual reviews. QTM scripting is used to create files similar to DZ orthos for each swath but this process highlights planar surfaces, such as roof tops. In particular, horizontal shifts or misalignments on roof tops and other elevated planar surfaces are highlighted. Visual reviews of these features are used to confirm the results of this process.

The images below show the single/only return DZ Orthos created for all AOIs, an example from AOI3 used to verify intra-swath relative accuracy, and an image from AOI3 showing verification of horizontal alignment. All Kansas AOIs meet all relative accuracy specifications.

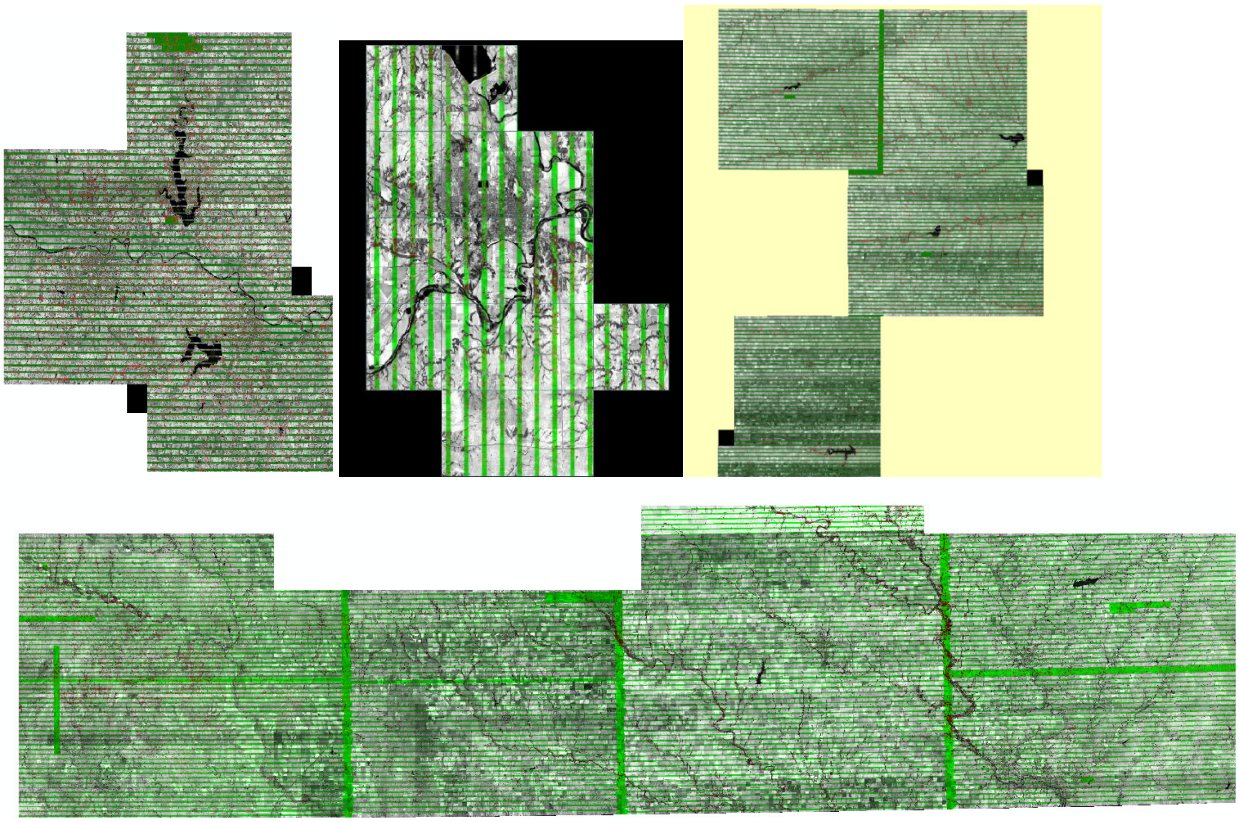

Figure 1- AOI1, 2, and 3 (left to right) and AOI4 (bottom) - Single return DZ Orthos. Inter-swath relative accuracy passes specifications.

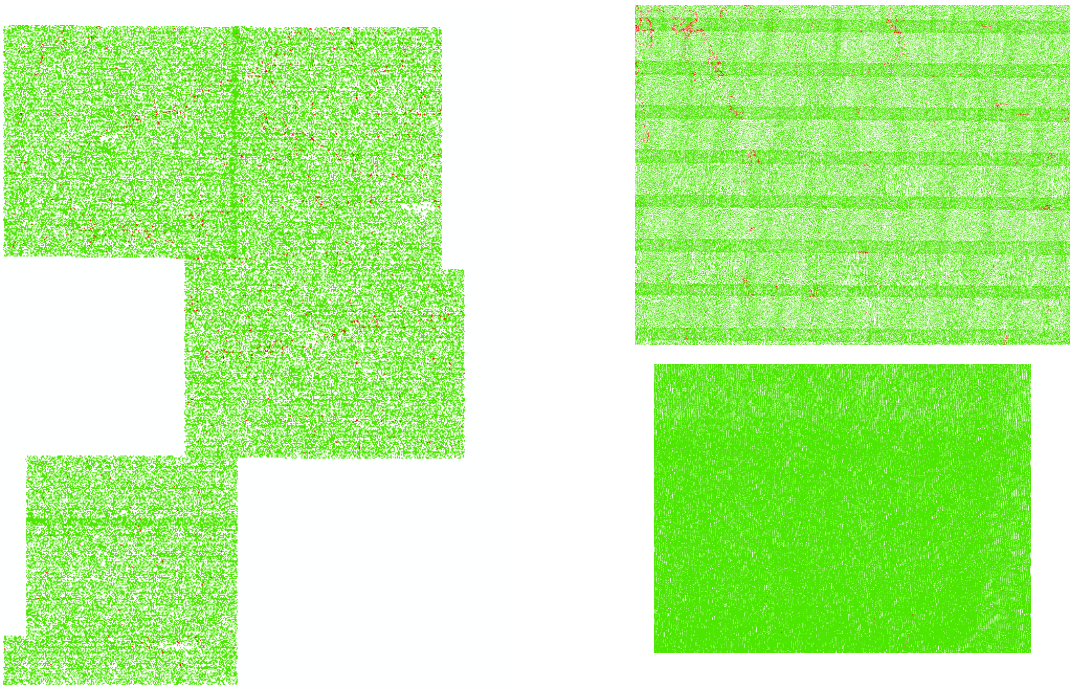

Figure 2– Example from AOI3- Intra-swath relative accuracy. The left screenshot is that of the whole project area. The top right is a portion of the dataset, and the bottom right image is a flat area showing little to no elevation change with several trees. Deviations above 6cm (red) are found in vegetation and on high slopes. Intra-swath relative accuracy passes specifications for all AOIs in the BAA Kansas 2015 project areas.

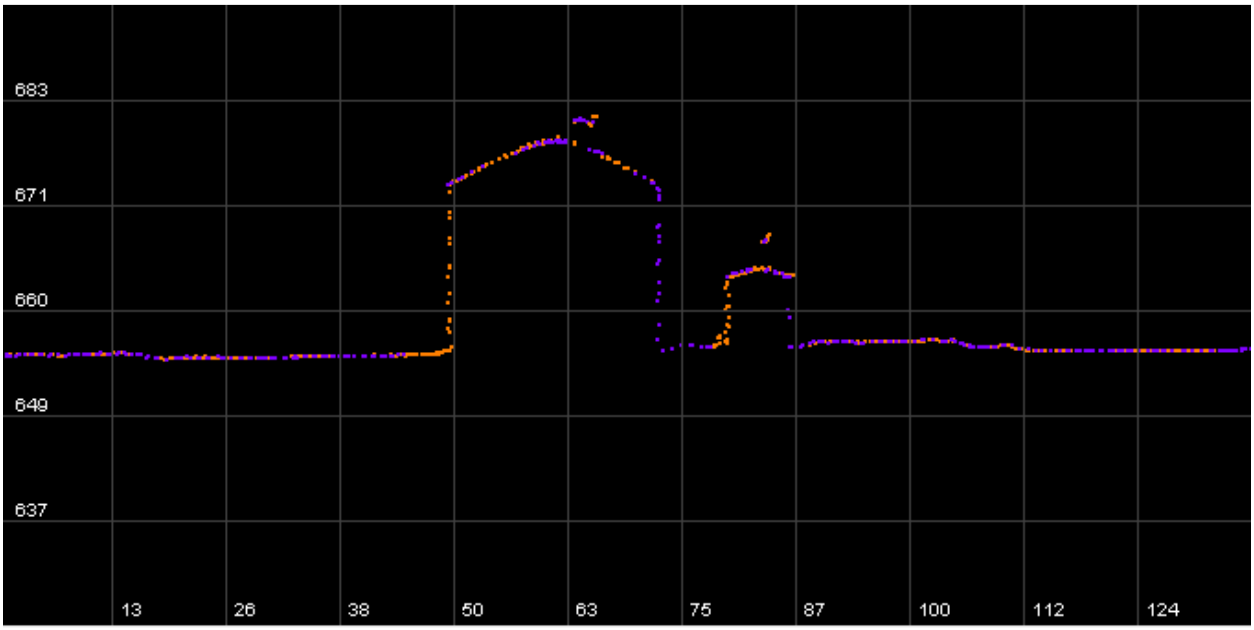

Figure 3– An example from AOI3- Horizontal Alignment. Two separate flight lines differentiated by color (Orange/Purple) are shown in this profile. There is no visible offset between these two flight lines. Horizontal alignment passes specifications for all AOIs in BAA Kansas 2015 project areas.

SURVEY VERTICAL ACCURACY CHECKPOINTS

The following table lists all checkpoints surveyed for use in vertical accuracy testing. Dewberry was provided 545 checkpoints by The Atlantic Group for all AOIs in the BAA Kansas 2015 project area. Interim vertical accuracy was tested for each individual AOI and the final vertical accuracy reported here was tested for the entire project area using all AOIs. Each table below lists the checkpoints separated by AOI.

AOI1 Point ID	NAD83(HARN) UTM 15		NAVD88
	Easting X (m)	Northing Y (m)	Elevation (m)
OT01	311886.486	4294001.043	333.709
OT02	314064.580	4293151.841	326.774
OT03	296061.698	4315607.480	331.775
OT04	301662.378	4312809.742	263.173
OT05	302938.306	4316060.706	300.965

OT06	318513.575	4310229.694	271.285
OT07	312021.767	4307794.663	277.499
OT08	307064.542	4303057.432	274.393
OT09	313526.353	4302884.988	274.397
OT10	271161.083	4327558.503	270.060
OT11	277889.565	4324832.449	287.948
OT12	272940.190	4324151.281	301.091
OT13	273566.116	4319704.169	312.167
OT14	284782.156	4310830.985	305.619
OT15	284209.687	4306882.643	284.239
OT16	279990.110	4307282.648	285.865
OT17	286727.393	4324239.879	321.763
OT18	283302.042	4323967.035	332.474
OT19	289441.648	4307221.737	303.581
OT20	291706.280	4301028.278	317.729
OT21	295040.054	4305761.263	309.828
OT22	269781.308	4337725.594	308.344
OT23	272439.454	4333934.760	309.272
OT24	286091.817	4338306.084	311.876
OT25	279556.400	4341289.808	288.716
OT26	307887.568	4349394.103	334.064
OT27	308118.243	4356666.052	349.838
OT28	310422.195	4352715.211	328.786
OT29	309794.611	4326393.002	329.532
OT30	302766.241	4326543.153	298.204
OT31	309073.719	4322003.731	267.016
OT32	298768.319	4336868.983	358.488
OT33	303521.090	4331764.780	315.189
OT34	302748.572	4335214.292	321.223
OT35	248939.367	4338406.175	325.215
OT36	253916.218	4343058.654	320.015
OT37	261989.054	4333640.363	300.293
OT38	257996.754	4330168.638	276.085
OT39	282920.458	4349435.491	294.110
OT40	287894.586	4355852.318	293.519
OT41	292426.777	4357309.391	304.420
OT42	287894.571	4355852.277	293.552
OT43	256058.224	4319830.587	345.769
OT44	260625.841	4313995.843	337.744

OT45	255843.635	4314100.019	342.823
OT46	310122.226	4296036.934	322.824
OT47	302572.445	4314655.770	299.034
OT48	274369.951	4330232.526	284.092
OT49	276699.060	4315167.305	336.818
OT50	290610.218	4302659.774	331.610
OT51	277720.407	4335786.379	301.174
OT52	304849.954	4354490.894	357.724
OT53	305554.553	4328118.140	279.720
OT54	298791.509	4329102.151	269.423
OT55	254821.751	4332190.846	276.707
OT56	287955.134	4349701.803	293.652
OT57	292910.880	4361276.785	321.286
OT58	259160.419	4319709.353	325.428
BR01	313101.272	4298045.493	291.561
BR02	300477.915	4319432.167	269.241
BR03	315310.758	4309251.824	266.067
BR04	313573.609	4304475.260	284.243
BR05	306243.085	4304572.056	276.081
BR06	273879.805	4313638.902	322.667
BR07	280879.411	4314628.724	326.049
BR08	280618.632	4321506.409	309.541
BR09	286279.051	4321847.723	332.637
BR10	275438.106	4337727.928	300.761
BR11	279587.872	4339867.185	293.674
BR12	304791.787	4352736.941	344.765
BR13	309920.917	4324436.342	327.351
BR14	298007.540	4331407.023	303.792
BR15	250582.740	4338343.702	304.175
BR16	259534.364	4330977.920	274.645
BR17	285926.656	4349341.942	309.149
BR18	284452.463	4359153.537	281.208
BR19	257910.506	4317202.603	353.751
HG01	317341.682	4294687.744	325.946
HG02	310235.467	4300798.195	272.185
HG03	302611.675	4318955.611	263.063
HG04	297418.101	4313445.701	300.720
HG05	316932.220	4311494.150	268.724
HG06	307558.146	4307903.041	268.312
HG07	270604.533	4324977.226	276.629

HG08	276147.985	4322319.543	291.549
HG09	272351.420	4321842.826	279.978
HG10	278557.802	4316716.339	334.753
HG11	271987.530	4316932.433	309.770
HG12	279111.324	4309937.701	296.036
HG13	284752.519	4309747.950	283.626
HG14	281852.538	4322770.208	315.515
HG15	293148.487	4306634.931	310.112
HG16	293671.469	4304332.850	307.638
HG17	275667.856	4332962.125	279.313
HG18	284916.869	4340533.563	313.098
HG19	281074.377	4337446.240	295.510
HG20	309488.261	4351164.111	297.615
HG21	303864.953	4349643.336	344.367
HG22	307443.344	4322373.718	253.536
HG23	307294.941	4325465.252	315.806
HG24	297075.629	4333722.997	334.970
HG25	305218.310	4333532.777	324.399
HG26	247451.128	4341680.297	303.223
HG27	256856.943	4335471.977	279.128
HG28	260218.806	4338074.547	303.624
HG29	288304.993	4353405.385	302.792
HG30	287748.324	4362304.580	312.379
HG31	289715.069	4363100.376	312.558
HG32	262670.649	4315510.385	349.095
HG33	257434.749	4312811.957	351.295

Table 1: Kansas AOI1 surveyed accuracy checkpoints

AOI2 Point ID	**NAD83(HARN) UTM 14**		**NAVD88**
	Easting X (m)	**Northing Y (m)**	**Elevation (m)**
BARE01	708801.996	4344370.019	323.459
BARE02	714739.591	4335457.884	421.233
BARE03	704428.047	4340041.839	321.360
OT01	706633.786	4346999.905	335.921
OT02	702502.221	4347366.609	411.366
OT03	709492.439	4339570.128	312.281
OT04	714762.644	4338244.150	305.924
OT05	714892.888	4341531.417	309.758

OT06	719538.866	4332902.758	330.783
OT07	703765.807	4337738.093	330.274
OT08	705411.659	4344760.998	414.148
OT09	706453.909	4332146.388	320.104
OT12	708877.890	4349253.445	367.702
OT13	707727.765	4346412.453	331.009
OT14	712546.425	4342327.996	308.646
OT15	719199.057	4334716.922	334.750
OT16	703209.368	4338991.726	380.760
OT17	701774.165	4341847.739	336.249
OT18	705499.211	4343472.494	365.043
OT19	703290.918	4340257.009	325.118
OT20	704013.076	4334868.605	315.561
OT21	706780.901	4334861.787	312.176
OT22	704930.735	4334007.433	316.104
OT23	712962.130	4328272.496	419.982
UB01	708789.580	4348573.064	353.201
UB02	710990.292	4339573.727	308.269
BR02	705081.758	4346817.424	356.872
BR04	703414.757	4330752.004	327.890
BR05	712879.292	4329226.661	404.674
HG01	705964.110	4342056.796	337.253
HG02	706191.699	4332851.567	316.397
HG03	717485.123	4332891.969	334.345

Table 2: Kansas AOI2 surveyed accuracy checkpoints

AOI3 Point ID	NAD83(HARN) UTM 14		NAVD88
	Easting X (m)	Northing Y (m)	Elevation (m)
OT01	404207.646	4418885.123	769.806
OT02	430447.263	4419799.081	721.197
OT03	438560.3	4425652.254	712.329
OT04	406080.406	4409200.181	766.711
OT05	430264.879	4410253.761	677.003
OT06	439942.102	4415940.701	655.227
OT07	406032.423	4397954.589	769.378
OT08	428557.611	4399356.341	729.252
OT09	440155.827	4405681.68	721.39

OT10	405873.078	4385056.966	741.115
OT11	430066.099	4389668.088	672.504
OT12	439746.025	4396986.944	681.89
OT13	454365.611	4420087.191	642.709
OT14	463978.662	4424483.461	635.156
OT15	473541.828	4423202.596	657.006
OT16	473622.769	4402298.896	593.922
OT17	483072.707	4408738.439	585.932
OT18	473060.387	4392867.45	554.009
OT19	484676.407	4398294.826	552.387
OT20	454170.976	4390811.954	590.365
OT21	474309.56	4383038.616	600.541
OT22	440256.088	4301025.76	674.491
OT23	430866.323	4313951.843	722.967
OT24	432099.428	4297225.829	683.136
OT25	422390.316	4292738.547	659.196
OT26	414286.416	4290006.04	723.918
OT27	402923.247	4286160.932	752.876
OT28	414711.979	4307669.039	727.456
OT29	414867.165	4318083.343	742.21
OT30	429781.645	4330069.222	680.61
OT31	438660.933	4326874.811	704.092
OT32	422383.503	4312461.751	749.189
OT33	436518.078	4315966.463	723.099
OT34	441554.779	4317120.023	700.74
OT35	442719.679	4373551.415	695.285
OT36	465898.445	4374861.995	634.844
OT37	474824.804	4373309.614	587.568
OT38	486567.195	4371748.218	576.73
OT39	417607.417	4415382.835	750.381
OT40	420728.634	4405815.42	715.528
OT41	413274.659	4394628.074	766.288
OT42	429683.52	4382922.044	700.972
OT43	454307.873	4410054.929	673.471
OT44	463702.044	4415212.492	682.831
OT45	464009.644	4394276.547	594.833
OT46	463813.916	4386662.758	594.527
OT47	464144.597	4367011.047	592.92
OT48	463992.032	4356844.539	577.587
OT49	483608.595	4388262.64	544.005
OT50	453972.358	4368688.956	664.882
OT51	487760.166	4342835.198	629.124
OT52	478530.57	4365239.414	532.389
OT53	478530.515	4365239.381	532.264
OT54	487740.837	4350916.789	580.354
OT55	442933.475	4344626.772	699.999
OT56	420613.697	4396143.777	739.752

OT57	455764.473	4383902.497	650.733
OT58	484679.182	4379835.744	570.287
OT59	463894.578	4405109.052	612.736
OT60	422716.196	4305973.968	736.536
OT61	423652.668	4411138.358	719.636
OT62	436426.027	4310727.96	700.687
OT63	427460.574	4303548.877	709.325
OT64	436918.556	4423393.436	701.133
OT65	401442.299	4409210	770.547
OT66	402644.743	4387545.916	776.097
OT67	452017.461	4420093.006	636.65
OT68	475168.116	4424796.127	636.449
OT69	436972.619	4388002.816	620.267
OT70	484725.395	4395098.302	534.385
OT71	435386.587	4299434.373	682.097
OT72	441457.798	4293007.848	644.959
OT73	407868.704	4290645.24	727.042
OT74	424528.906	4318472.026	743.66
OT75	435861.53	4323655.459	711.916
OT76	445054.416	4370344.856	679.125
OT77	464266.197	4373438.419	638.315
OT78	483372.057	4371759.74	585.143
OT79	418025.545	4425160.228	745.293
OT80	419112.206	4409037.649	723.773
OT81	422016.704	4386584.532	679.23
OT82	466930.841	4365397.712	575.867
OT83	479839.911	4385831.669	589.693
OT84	453438.431	4365451.761	625.959
OT85	478493.71	4362447.524	550.668
OT86	439858.317	4352795.926	672.161
OT87	487846.342	4347682.042	596.443
OT88	444494.822	4341056.48	698.863
OT89	454192.272	4343182.514	691.115
OT90	462971.656	4338047.386	668.861
OT91	410239.78	4410764.203	753.042
OT92	449606.551	4418483.702	640.864
OT93	432185.746	4294218.377	657.968
OT94	435836.188	4316154.375	724.101
OT95	483113.837	4349218.76	606.438
UB01	454162.612	4339476.988	685.417
UB02	406222.44	4409230.589	767.406
UB03	406205.416	4409230.749	767.325
UB04	403818.789	4383481.696	738.653
UB05	402639.951	4383506.629	740.656
UB06	454392.985	4422041.96	631.155
UB07	454393.093	4422026.23	631.077
UB08	441300.646	4389585.407	622.026

UB09	439694.669	4389586.976	623.43
UB10	435710.518	4315252.924	717.716
UB11	435708.215	4315190.064	719.383
UB12	424080.149	4425087.62	716.328
UB13	424087.122	4425060.355	716.93
UB14	420423.806	4386554.007	675.15
UB15	418842.728	4386111.318	680.334
UB16	464394.507	4363815.342	574.714
UB17	464329.217	4363807.954	576.314
UB18	440903.866	4356811.5	625.269
UB19	440904.157	4356819.527	625.166
UB20	451683.174	4345380.345	684.365
UB21	451569.405	4345557.193	687.571
BR01	406661.271	4306185.734	735.493
BR02	406804.655	4313235.049	769.112
BR03	416747.437	4327862.791	719.653
BR04	453172.59	4376760.122	676.137
BR05	486438.823	4360521.68	569.556
BR06	455153.01	4347752.533	647.641
BR07	431274.707	4317094.726	738.923
BR08	441717.12	4423589.581	673.777
BR09	407867.363	4409493.558	734.573
BR10	404125.769	4383089.644	725.052
BR11	454488.121	4423281.855	629.705
BR12	472854.374	4424829.543	636.355
BR13	471695.607	4416752.62	648.843
BR14	437012.373	4383200.215	683.839
BR15	440875.166	4304269.093	698.941
BR16	423613.747	4300057.251	699.046
BR17	486575.782	4369049.671	546.981
BR18	420931.188	4426707.261	730.486
BR19	418820.807	4389275.732	707.427
BR20	454158.547	4338296.098	677.981
BR21	442494.504	4351074.85	658.658
BR22	487585.497	4352936.279	573.99
BR23	467348.918	4338053.956	653.534
HG01	439663.757	4386396.561	667.974
HG02	454254.862	4400814.302	653.74
HG03	405851.989	4333581.029	756.514
HG04	430713.769	4305485.282	728.02
HG05	422600.011	4302789.109	717.239
HG06	437608.295	4291790.906	685.686
HG07	428742.336	4288244.435	701.739
HG08	408022.76	4294893.607	683.32
HG09	407067.941	4323153.906	773.902
HG10	434238.145	4323634.918	710.703
HG11	411343.345	4423627.053	733.389

HG12	421238.374	4425106.636	730.447
HG13	418850.545	4386087.442	678.607
HG14	464069.167	4405575.916	615.403
HG15	441546.022	4364029.747	643.138
HG16	443121.212	4354287.228	644.612
HG17	474426.823	4354085.857	599.953
HG18	465394.497	4338887.695	655.624
HG19	422664.392	4307578.569	738.445
HG20	473451.765	4393927.313	569.257
HG21	423879.5	4407243.551	699.386
HG22	430679.255	4302716.416	714.365
HG23	440942.275	4426576.718	702.397
HG24	459129.066	4420140.75	664.045
HG25	439702.892	4389405.686	620.903
HG26	473496.215	4405501.385	603.898
HG27	483061.749	4400311.725	560.569
HG28	437613.753	4289161.73	692.472
HG29	422032.233	4289972.645	696.468
HG30	404742.18	4293350.955	706.58
HG31	415467.914	4304444.064	719.201
HG32	423100.377	4325327.483	707.043
HG33	439214.609	4329738.633	645.803
HG34	422773.406	4311173.888	740.354
HG35	437380.674	4317060.451	710.643
HG36	441846.812	4373599.598	683.637
HG37	445041.007	4372004.628	690.729
HG38	465976.836	4378261.595	595.699
HG39	420899.359	4421935.61	736.168
HG40	481442.029	4389485.715	542.431
HG41	452996.083	4371915.827	677.439
HG42	441306.942	4357022.089	619.463
HG43	442917.664	4341387.446	702.516
HG44	454174.565	4345007.353	686.25
HG45	464800.407	4341262.638	667.695

Table 3: Kansas AOI3 surveyed accuracy checkpoints

AOI4 Point ID	NAD83(HARN) UTM 14		NAVD88
	Easting X (m)	Northing Y (m)	Elevation (m)
BARE01	527174.176	4099742.604	442.765
BARE02	507852.666	4118921.501	607.294
BARE03	545069.885	4105392.451	417.943
BARE04	505029.475	4104346.732	508.662
BARE05	565769.586	4129061.127	476.794
BARE06	651123.711	4128451.929	393.873
BARE07	622496.625	4114627.221	353.113
BARE08	619525.647	4105077.854	366.568

BARE09	653552.862	4097759.286	344.458
BARE10	668455.146	4143077.509	383.779
BARE11	668932.996	4122146.063	355.266
BARE12	689875.421	4102617.824	372.502
BARE13	685520.785	4135462.773	390.535
BARE14	704616.313	4131646.356	381.092
BARE15	704130.697	4126530.487	369.625
BARE16	704130.719	4126530.477	369.653
BARE17	596546.202	4117223.386	405.412
BARE18	606079.678	4128727.728	389.440
BARE19	625695.073	4117929.807	366.576
BARE20	709404.781	4108577.202	410.347
BARE21	599942.192	4109304.745	387.775
BARE22	598770.782	4107641.595	381.743
BARE23	604891.040	4101368.672	375.593
BARE24	603293.874	4102934.239	363.820
BARE25	604865.690	4104550.237	371.360
BARE26	516671.080	4134238.877	501.793
BARE27	510722.868	4126137.168	563.685
BARE28	517746.835	4126167.100	503.136
BARE29	532990.729	4143956.944	555.073
BARE30	547773.453	4118318.085	472.589
BARE31	531066.576	4107709.993	468.872
BARE32	573301.510	4124948.176	435.057
BARE33	593942.856	4128481.535	420.374
BARE34	603248.887	4106146.397	376.736
BARE35	636103.612	4136211.677	391.809
BARE36	617285.013	4137065.669	432.547
BARE37	652780.214	4129246.434	380.660
BARE38	629293.100	4099623.741	345.359
BARE39	658731.436	4114011.311	351.607
BARE40	693141.110	4116149.744	396.191
BARE41	622599.174	4109781.534	354.447
BARE42	702419.696	4141883.471	434.691
BARE43	708907.878	4098897.167	359.705
BARE44	707017.520	4136233.960	389.045
BARE45	697726.745	4124276.150	414.089
BARE46	710799.760	4115034.282	432.448
BARE47	711146.433	4102204.104	376.954
BARE48	686431.730	4099117.187	320.889
BARE50	598194.862	4122101.755	404.246
BARE51	635819.326	4115029.138	367.468
BARE52	606030.867	4109414.751	382.486
BARE53	520147.140	4132371.517	483.179
OT01	527148.635	4102128.981	453.905
OT02	569084.641	4122392.622	443.931
OT03	642966.233	4138932.134	391.962
OT04	649400.590	4126845.812	368.556
OT05	622510.080	4113727.966	359.012
OT06	621167.920	4101720.749	360.131
OT07	651876.176	4100954.382	345.912
OT08	666869.797	4143023.395	381.074
OT09	668902.001	4123085.415	357.130
OT10	667236.818	4124086.720	355.009
OT11	687786.665	4102328.486	326.794
OT12	688090.248	4116026.590	383.349
OT13	705922.875	4132537.753	395.773
OT14	648404.734	4111242.251	374.914

OT15	631766.432	4134191.168	385.766
OT16	600712.001	4107701.172	381.668
OT17	606025.335	4102972.475	362.123
OT18	604036.935	4107766.342	382.269
OT19	510522.860	4135537.627	503.049
OT20	505902.690	4126085.804	613.310
OT21	534499.888	4138398.983	497.638
OT22	529597.616	4100485.673	454.714
OT23	552644.103	4119934.297	444.333
OT24	510703.188	4121730.938	612.749
OT25	523298.471	4111788.785	491.708
OT26	571327.886	4116874.079	436.034
OT27	601650.053	4109295.502	386.839
OT28	630090.432	4138569.254	397.152
OT29	648325.257	4133201.112	396.739
OT30	662490.326	4123314.245	348.566
OT31	697522.580	4143058.962	430.694
OT32	674517.325	4109354.656	353.275
OT33	704137.865	4129229.386	382.096
OT34	695828.245	4108683.825	369.952
OT35	710817.118	4113130.643	412.902
OT36	711110.522	4104288.987	383.470
OT37	700935.089	4100228.557	402.949
OT38	604625.804	4112645.453	388.937
OT39	653227.548	4112771.047	368.477
OT40	648404.743	4111242.255	374.909
OT41	517961.300	4096022.617	482.344
OT42	528461.990	4142408.492	529.914
OT43	513300.617	4126066.108	568.191
OT44	520758.281	4096688.806	487.393
UB01	643013.845	4137438.764	395.865
UB02	644290.832	4126574.421	379.164
UB03	623353.052	4099986.476	349.020
UB04	653429.145	4102636.331	349.341
UB05	666418.347	4139310.891	391.879
UB06	686337.061	4102298.032	347.490
UB07	686304.608	4132258.617	386.505
UB08	697418.294	4138331.331	422.778
UB09	706827.798	4132632.316	386.298
UB10	700988.461	4124382.502	394.265
UB11	643104.548	4125004.561	366.263
UB12	642687.395	4128192.016	381.614
UB13	507460.096	4136939.796	511.862
UB14	568427.977	4122459.721	444.076
UB15	589746.522	4129998.600	432.429
UB16	643005.871	4137433.303	396.475
UB17	644262.003	4126587.649	379.686
UB18	623364.545	4099968.235	348.784
UB19	675381.185	4123116.436	353.879
UB20	675642.797	4105332.338	330.776
UB21	674357.021	4102246.807	327.116
UB22	700211.687	4109553.069	378.709
UB23	642016.674	4108817.265	356.644
HG01	532016.198	4140159.152	520.012
HG02	531997.069	4141504.401	537.301
HG03	509119.353	4104676.583	521.633
HG04	506530.211	4104608.217	510.686
HG05	585097.192	4126410.999	435.084

HG06	639698.762	4139348.393	387.351
HG07	639702.767	4139350.991	387.356
HG08	651165.737	4127361.573	374.607
HG09	622593.191	4113056.622	358.044
HG10	651864.448	4102277.786	349.996
HG11	668505.432	4142188.777	378.811
HG12	667370.372	4122140.566	356.755
HG13	668294.041	4122141.18	355.469
HG14	689576.144	4102389.86	371.509
HG15	686278.327	4133273.877	391.245
HG16	704699.559	4132230.63	378.679
HG17	701000.279	4124389.936	393.511
HG18	701353.306	4099432.307	401.914
HG19	594954.548	4116666.004	401.339
HG20	641252.83	4113647.117	372.02
HG21	531186.049	4098668.547	451.055
HG22	529014.746	4096451.416	446.237
HG23	528818.487	4098866.269	435.446
HG24	636694.608	4132922.902	384.084
HG25	634233.313	4132655.477	386.151
HG26	601560.782	4110929.195	391.205
HG27	601488.8	4115790.532	404.232
HG28	603124.514	4117454.287	402.762
HG29	604674.915	4115073.545	393.829
HG30	577174.703	4121734.814	427.597
HG31	578759.449	4123350.381	435.112
HG32	577168.411	4124952.94	440.18
HG33	572251.248	4128151.804	449.901
HG34	651279.048	4123593.64	353.994
HG35	648131.364	4121889.988	364.426
HG36	644866.171	4124228.147	373.851
HG37	620046.793	4117799.271	365
HG38	515078.559	4138193.226	537.314
HG39	515806.004	4129565.882	508.521
HG40	536061.297	4140013.37	527.405
HG41	547965.334	4121422.37	449.524
HG42	529416.09	4110252.4	455.743
HG43	506906.263	4118222.47	612.805
HG44	575568.933	4121139.595	426.002
HG45	611172.678	4106317.532	368.33
HG46	651007.371	4138134.437	364.439
HG47	641539.927	4132988.031	386.489
HG48	638147.109	4139048.931	390.858
HG49	653109.226	4125256.653	362.692
HG50	626001.714	4103550.24	357.402
HG51	654329.264	4107484.676	375.76
HG52	686739.15	4105457.496	375.751
HG53	667437.919	4118917.414	344.971
HG54	672337.417	4117396.078	354.682
HG55	688078.207	4117641.403	386.602
HG56	678057.164	4111034.475	358.494
HG57	703063.204	4108389.013	396.196
HG58	713964.785	4109784.766	337.931
HG59	688137.086	4125687.325	405.871
HG60	672337.414	4117396.082	354.696
HG61	677847.905	4105342.306	346.746
HG62	703263.195	4101946.437	383.6
HG63	643776.287	4112116.815	373.906

HG64	593199.82	4125829.064	413.065
LT01	532002.678	4140326.052	523.973
LT02	507225.939	4104831.919	487.743
LT03	584252.307	4125056.824	432.776
LT04	562617.885	4105574.378	392.819
LT05	646424.845	4126782.39	378.618
LT06	653481.978	4099363.957	337.061
LT07	668622.415	4140039.313	369.827
LT08	706669.599	4132883.276	399.745
LT09	583912.891	4105730.208	405.812
LT10	531333.89	4096524.504	434.489
LT11	522854.314	4095713.887	483.035
LT12	632941.105	4135824.531	396.153
LT13	607269.95	4114284.078	384.14
LT14	575554.021	4123437.871	438.132
LT15	575511.227	4126549.808	449.822
LT16	575480.251	4128149.29	457.982
LT17	570687.453	4126525.498	443.069
LT18	573017.838	4126571.063	448.581
LT19	650498.76	4122015.10	354.11
LT20	644902.38	4122630.09	365.67
LT21	513662.00	4134788.53	495.06
LT22	535851.27	4136847.55	497.77
LT23	552230.40	4124767.96	453.00
LT24	527057.92	4109501.74	466.35
LT25	590513.46	4126809.38	422.16
LT26	609628.31	4111735.11	371.82
LT27	648077.96	4124615.92	375.07
LT28	667960.72	4126997.12	359.63
LT29	667960.72	4126997.12	359.63
LT30	677929.60	4114128.39	344.97
LT31	701862.93	4113155.05	366.97
LT32	704892.52	4098938.08	375.92
LT33	589037.74	4121896.15	434.96
LT34	568343.58	4119262.15	425.07
LT35	606853.90	4104621.85	367.75
LT36	531662.06	4109519.17	449.46

Table 4: Kansas AOI4 surveyed accuracy checkpoints

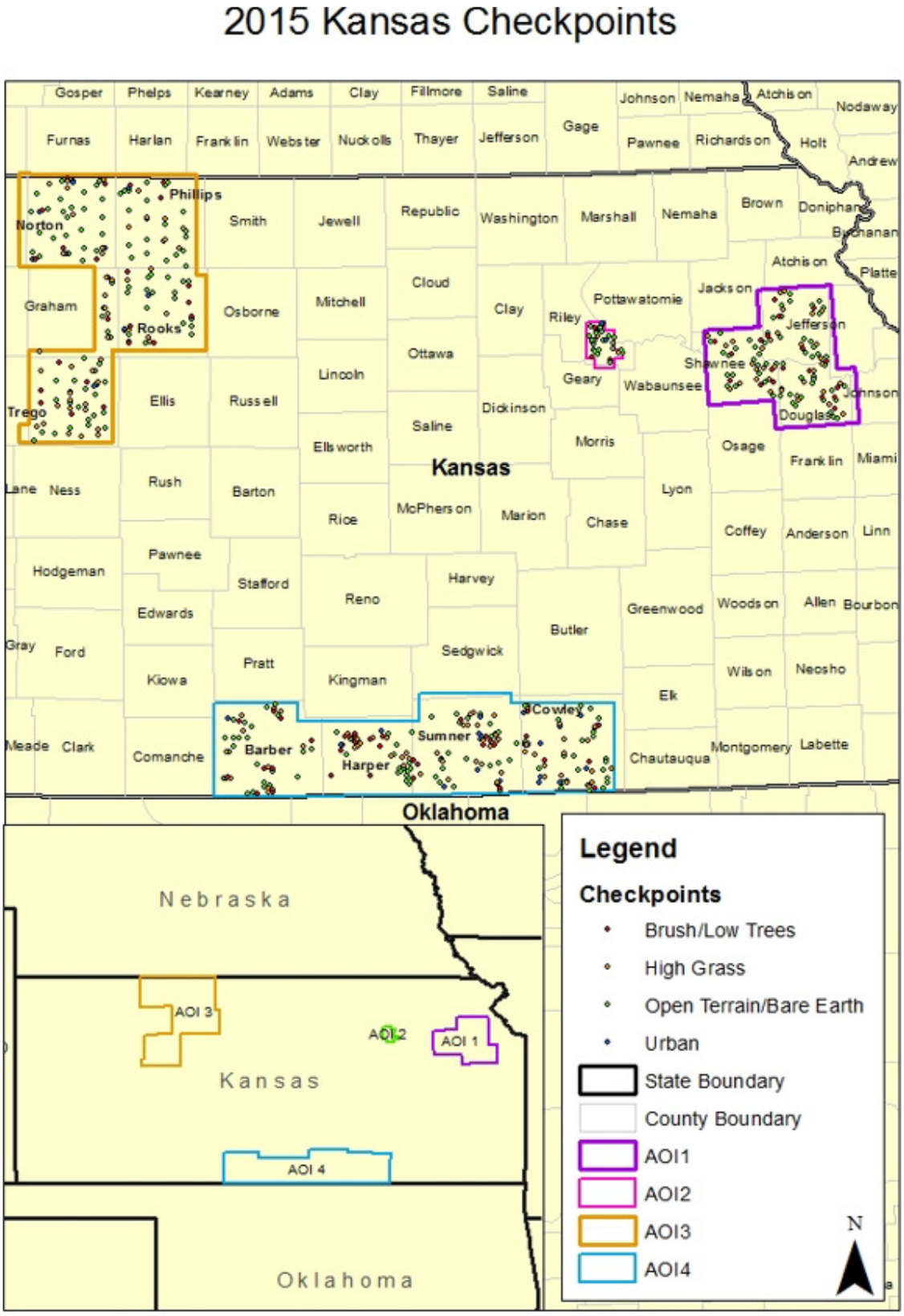

Figure 4 – Checkpoint distribution the 2015 BAA Kansas LiDAR Project.

The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The X/Y locations of the survey checkpoints are overlaid on the TIN and the interpolated Z values of the LiDAR are recorded. These interpolated Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements. Once all the Z values are recorded, the NVA and VVA are computed. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies.

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in the open terrain (grass, dirt, sand, and/or rocks) and Urban land cover categories, where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated LiDAR sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. For the BAA Kansas project, vertical accuracy must be 19.6 cm or less based on an $RMSE_z$ of 10cm x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in all vegetated land cover categories combined where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The BAA Kansas VVA standard is 29.4 cm at the 95% confidence level. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution.

The relevant testing criteria are summarized in Table 5.

Quantitative Criteria	Measure of Acceptability
Non-vegetated Vertical Accuracy (NVA) in open terrain and urban only using $RMSE_z$ *1.9600	0.196m (based on $RMSE_z$ (0.10cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	0.294 m (based on 95th percentile)

Table 5 - Acceptance Criteria

VERTICAL ACCURACY RESULTS

Table 6 outlines the calculated $RMSE_z$ and associated statistics, in meters, while Table 7 outlines vertical accuracy as computed by the different methods, in meters.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.100 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
Open Terrain	273	0.062	-0.007	-0.011	0.109	0.062	-0.141	-0.168	0.197
Urban	46	0.074	-0.012	-0.001	-0.091	0.074	-0.958	-0.139	0.124
NVA	**319**	**0.064**	**-0.008**	**-0.010**	**0.055**	**0.064**	**-0.294**	**-0.168**	**0.197**
Tall Weeds and Crops	145	N/A	0.015	0.012	-0.077	0.071	-0.251	-0.170	0.169
Brush Lands and Trees	81	N/A	0.028	0.019	0.154	0.078	-0.828	-0.124	0.192
VVA	**226**	**N/A**	**0.020**	**0.014**	**0.044**	**0.074**	**-0.452**	**-0.170**	**0.192**

Table 6 - The table shows the calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the 2015 Kansas LiDAR project area.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.294 m
NVA	319	0.126	
VVA	226		0.150

Table 7 - The table shows the calculated NVA and VVA, in meters, at the 95% confidence level.

Table 8 lists the 5% outliers that are larger than the 95th percentile, or 0.150 meters.

Point ID	NAD83 (HARN) UTM Zone 14N/15N		NAVD88 (Geoid 12A)		Delta Z	AbsDelta Z
	Easting X (m)	Northing Y (m)	Z-Survey (m)	Z-LiDAR (m)		
BR04	703414.757	4330752.004	327.890	328.082	0.192	0.192
BR07	280879.411	4314628.724	326.049	326.231	0.182	0.182
BR34	532002.678	4140326.052	523.973	524.135	0.162	0.162
BR36	584252.307	4125056.824	432.776	432.931	0.155	0.155
HG02	531997.069	4141504.401	537.301	537.463	0.162	0.162
HG03	509119.353	4104676.583	521.633	521.463	-0.170	0.170
HG07	639702.767	4139350.991	387.356	387.523	0.167	0.167
HG13	668294.041	4122141.180	355.469	355.625	0.156	0.156
HG18	701353.306	4099432.307	401.914	402.081	0.167	0.167
HG27	483061.749	4400311.725	560.569	560.412	-0.157	0.157
HG35	437380.674	4317060.451	710.643	710.812	0.169	0.169

Table 8 – 5% Outliers

Figure 5 illustrates the magnitude of the differences between the QA/QC checkpoints and LiDAR data. This shows that the majority of LiDAR elevations were within +/- 0.10 m of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +/- 0.20 m.

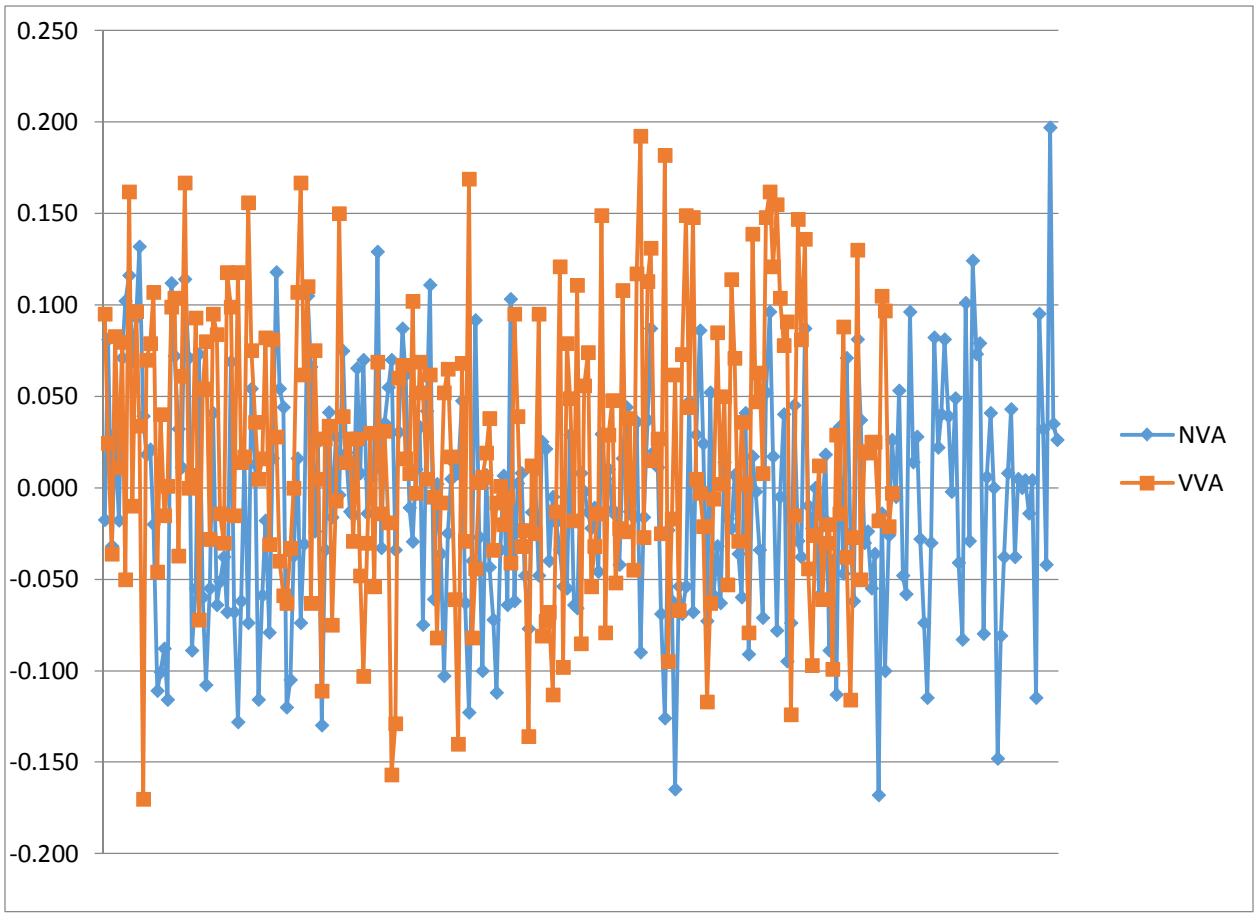

Figure 5 – Magnitude of Elevation Discrepancies

Figure 6 illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the LiDAR triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.170 m and a high of +0.20 m, the histogram shows that the majority of the discrepancies are positive or greater than zero. The majority of points are within the ranges of -0.075 m to +0.075 m.

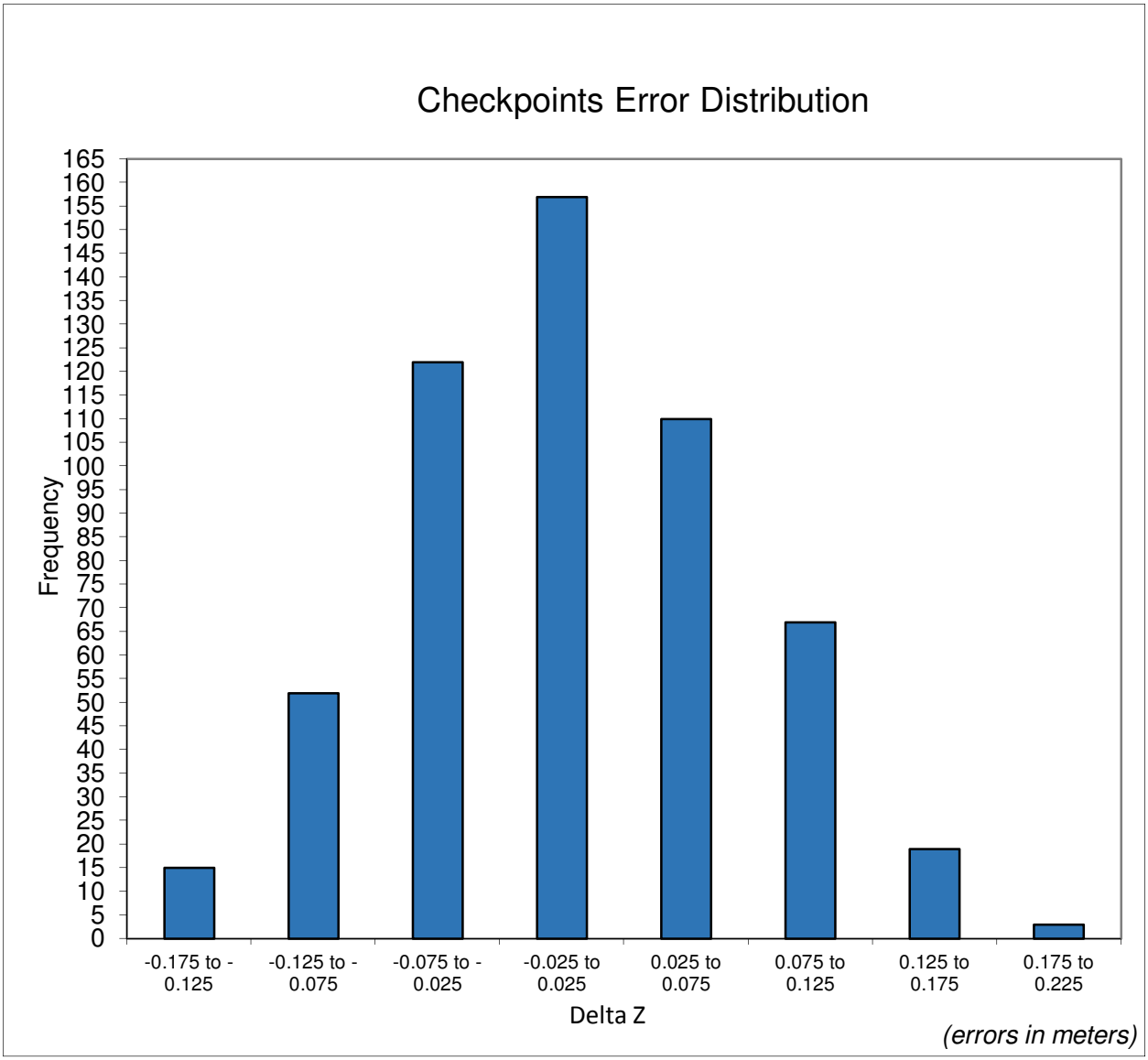

Figure 6 — Histogram of Elevation Discrepancies within errors in meters

Based on the relative accuracy testing and vertical accuracy testing conducted by Dewberry, the LiDAR dataset for BAA Kansas 2015 project satisfies the project's pre-defined accuracy criteria.

DEM QUANTITATIVE REVIEW

The same checkpoints used to test the vertical accuracy of the LiDAR data were also used to test the vertical accuracy of the DEMs. Table 9 outlines the calculated $RMSE_z$ and associated statistics, in meters, while Table 10 outlines vertical accuracy as computed by the different methods, in meters.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.100 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
Open Terrain	273	0.062	-0.009	-0.012	0.171	0.061	0.005	-0.179	0.205
Urban	46	0.075	-0.014	-0.009	-0.036	0.074	-0.861	-0.142	0.126
NVA	**319**	**0.064**	**-0.010**	**-0.011**	**0.113**	**0.063**	**-0.161**	**-0.179**	**0.205**
Tall Weeds and Crops	145	N/A	0.016	0.014	-0.010	0.073	-0.086	-0.171	0.195
Brush Lands and Trees	81	N/A	0.027	0.013	0.141	0.079	-0.759	-0.153	0.180
VVA	**226**	**N/A**	**0.020**	**0.013**	**0.071**	**0.075**	**-0.351**	**-0.171**	**0.195**

Table 9 - The table shows the calculated $RMSE_z$ values, in meters, as well as associated statistics of the errors for the DEMs in the Kansas 2015 project area.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.294 m
NVA	319	0.125	
VVA	226		0.160

Table 10 - The table shows the calculated NVA and VVA, in meters, at the 95% confidence level for the DEMs in the Kansas 2015 project area.

Table 11 lists the 5% outliers that are larger than the 95th percentile, or 0.160 meters.

Point ID	NAD83 (HARN) UTM Zone 14N/15N		NAVD88 (Geoid 12A)		Delta Z	AbsDelta Z
	Easting X (m)	Northing Y (m)	Z-Survey (m)	Z-LiDAR (m)		
BR04	703414.8	4330752	327.89	328.0702	0.18	0.18
BR07	280879.4	4314629	326.049	326.2195	0.171	0.171
BR23	467348.9	4338054	653.534	653.7111	0.177	0.177
HG02	531997.1	4141504	537.301	537.4939	0.193	0.193
HG03	509119.4	4104677	521.633	521.4623	-0.17	0.171
HG07	639702.8	4139351	387.356	387.5238	0.168	0.168
HG18	701353.3	4099432	401.914	402.109	0.195	0.195

HG35	437380.7	4317060	710.643	710.813	0.17	0.17
LT01	532002.7	4140326	523.973	524.1518	0.179	0.179
LT03	584252.3	4125057	432.776	432.9411	0.165	0.165
HG27	483061.749	4400311.725	560.569	560.408	-0.161	0.161
HG62	703263.195	4101946.437	383.600	383.762	0.162	0.162

Table 11– 5% Outliers

The Kansas 2015 project area DEMs pass vertical accuracy specifications.