

Pilot Project
(VIDP; 15.94 sq.km)

Dated: November 16, 2018

**Validation Report of Digital Terrain and Obstacle
Data* with field survey and AIP**

***Created using the technologies of GIS, Remote Sensing and
photogrammetry)**

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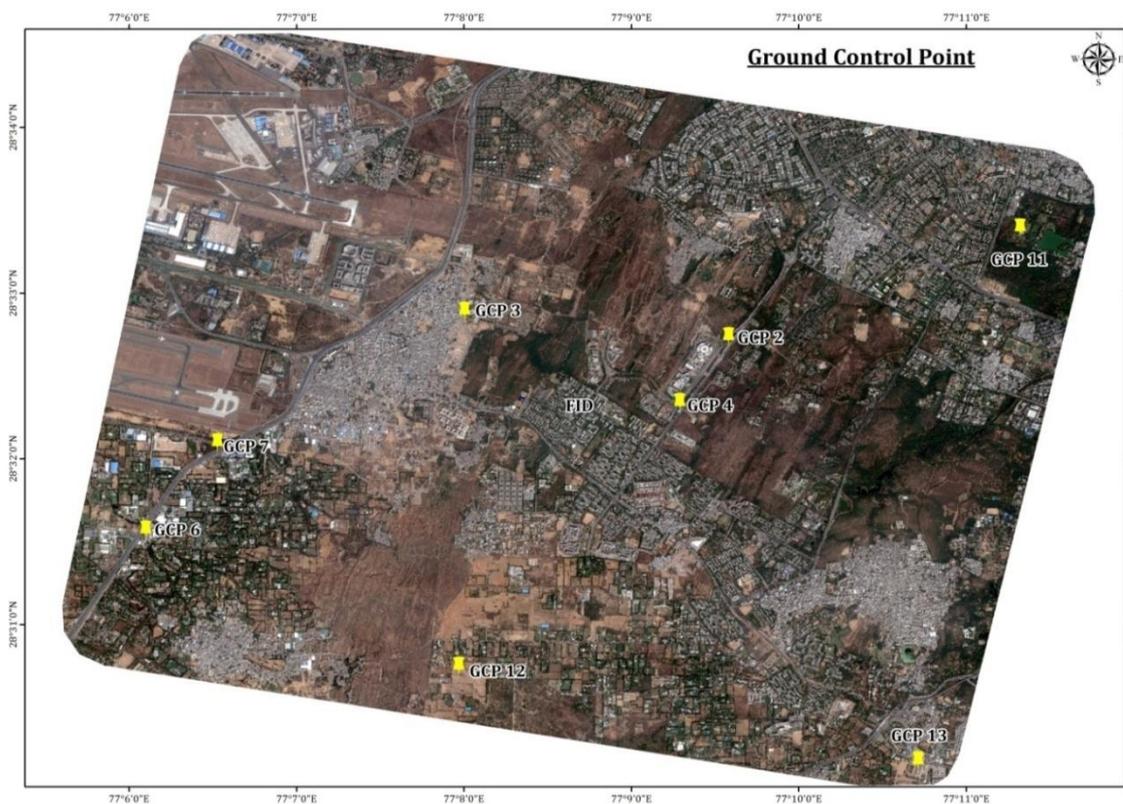
Project Summary

S.No.		Description
1	Project Name	Digital Terrain and Obstacle data for pilot Area of VIDP
2	Product of Data	Obstacle with additional Superstructure and Quality check
3	Difference of intersected and measured control points (X,Y,Z)	Z-Vertical Error: 0.72 m RMSE (Root-mean-square-error) X- Horizontal Error: 0.17m RMSE Y-Horizontal Error: 0.26m RMSE <i>Calculated based on 6 Ground Control points (GCPs)</i>
4	Pilot Area	15.94 sq km.
5	Digital Elevation Model Type	Above mean sea level (AMSL)
6	Production Mode	Photogrammetric optical satellite stereo based on conventional In-track 20-30 degree stereo acquisitions from two separate date passes
7	Production Method	Triangulation of 2 overlapping satellite images with off-nadir viewing angles and Manual digitization of building footprints and brake lines
8	Source Image Data Type	0.5m Panchromatic + MS Pleiades Satellite stereo imagery
9	Vertical Datum	MSL (EGM2008 Geoid)
10	Source Data	Airbus 50cm Stereo bundle satellite imagery
11	Source Image ID + Dates	One Stereo pair collected 12th April 2018 DIM_PHR1B_P_201804120537473_SEN_2976695101-001.XML (Airbus) DIM_PHR1B_P_201804120538159_SEN_2976695101-002.XML (Airbus)
12	Elevation Model Grid Spacing	1m
13	Projection	UTM WGS84 Zone 43 EPSG : 32643
14	Ground Control Data	Differential GNSS 30 min observation PPK processing (3-5 cm accuracy) Well distributed Satellite Photo-identifiable, survey-grade, Ground Control Points were used during the image pre-processing stages in order to achieve the highest accuracy XYZ absolute & relative accuracy (1m)

15	Calculated Vertical Accuracy Report based on Z values of Ground control Points	Based on 6 elevation ICP control points lying in the pilot area Root Mean Square Error (RMSE): Z-Vertical Absolute RMSE: +/- 0.7216 m RMSE Maximum Z-Vertical Error: 1.22 m
16	Calculated Vertical Accuracy Report based on surveyed Top elevation	Based on 15 DGPS AMSL top elevation measurements (Building and superstructures) Root Mean Square Error (RMSE): Z-Vertical Absolute RMSE: +/- 0.569 m RMSE The maximum difference of absolute Z-Value: 1.35 m
17	Product Description	DTM and other products generated from stereo photogrammetric satellite image processing. 1. Ortho-rectified 50cm Pan Sharpened imagery in tiff format 2. Digital Terrain Model at 1m Post spacing in tiff format 3. Contours at a 1m interval in ESRI Shape file format 4. Obstacles feature in ESRI Shape file format 5. Height verification statistics and Accuracy

1	Digital elevation in Obstacles	Above mean Sea Level (AMSL) Above Ground level (AGL)
Obstacle feature information		
2	Obstacle type : Point features	1. <i>Antenna</i> 2. <i>App Lights</i> 3. <i>Small Building</i> 4. <i>Crane</i> 5. <i>LLZ Antenna</i> 6. <i>Pole</i> 7. <i>Traffic Signal</i> 8. <i>Tank</i> 9. <i>Tree</i>
4	Obstacle type : Polyline features	1. <i>Bridge</i> 2. <i>Fence</i> 3. <i>Transmission Line</i> 4. <i>Wall</i>
5	Obstacle type : Polygon features	1. <i>Vegetation</i> 2. <i>Building with Superstructures</i>

1. GCP's with RMS error



Six GCP's lies within the Pilot area of VIDP and their vertical RMSE = +/-0.7126

Projected Coordinates of GCP Points (Zone 43N)				
S.No.	Latitude	Longitude	Elevation (EGM96)	Height (Ellipsoid)
GCP2	28°32'43.93"N	77°09'34.85"E	248.809	196.219
GCP3	28°32'53.18"N	77°08'00.23"E	249.08	196.57
GCP4	28°32'20.08"N	77°09'17.34"E	257.911	205.324
GCP6	28°31'33.98"N	77°06'05.97"E	237.846	185.394
GCP7	28°32'05.52"N	77°06'31.64"E	238.121	185.661
GCP12	28°30'44.67"N	77°07'58.17"E	273.945	221.38

Positional and Vertical Accuracy:

Z-vertical Error: 0.72 m RMSE (Root-mean Square error)

X-Horizontal Error: 0.1725 m RMSE

Y- Horizontal Error: 0.265 m RMSE

Calculated Vertical Accuracy Report:

Based on 6 elevation ICP Control Points

Root mean Square Error (RMSE)

Z- Vertical Absolute RMSE: +/- 0.7126 m RMSE

Maximum Absolute Z-vertical Error: 1.22 m

2. Validation of obstacle heights* extracted through photogrammetry with field Survey

*All heights are in meters.

Point_ID	Longitude	Latitude	Description	DGPS	Photogrammetry	Difference
5	77°08'58.85"E	28°31'45.00"N	Top of building with Superstructure	273.01	273.32	-0.305
7	77°08'56.42"E	28°31'46.02"N	Top of building	279.11	278.75	0.360
12	77°08'56.96"E	28°31'51.49"N	Top of building	277.47	276.95	0.519
13	77°08'56.97"E	28°31'51.94"N	Top of building	271.05	270.57	0.479
14	77°08'57.12"E	28°31'51.79"N	Top of building with Superstructure	274.58	273.22	1.357*
15	77°08'57.73"E	28°31'52.32"N	Top of building	278.65	278.75	-0.104
18	77°08'58.09"E	28°31'52.52"N	Top of building	278.59	277.85	0.735
20	77°09'06.08"E	28°32'07.09"N	Top of building	278.84	278.75	0.087
22	77°09'06.92"E	28°32'06.65"N	Top of building with Superstructure	281.86	280.85	1.014
24	77°08'30.32"E	28°31'37.33"N	Top of building	284.41	284.37	0.039
27	77°08'27.31"E	28°31'34.87"N	Top of building	283.52	283.38	0.139
28	77°08'27.31"E	28°31'34.87"N	Top of building with Superstructure	285.38	285.88	-0.502
30	77°08'09.98"E	28°31'38.34"N	Top of building	279.28	279.38	-0.100
31	77°08'09.96"E	28°31'38.55"N	Top of building with Superstructure	282.39	281.76	0.630
34	77°08'11.12"E	28°31'38.65"N	Top of building	282.72	282.51	0.212

Calculated vertical accuracy report based on Top elevation:

Root Mean Square Error (RMSE):

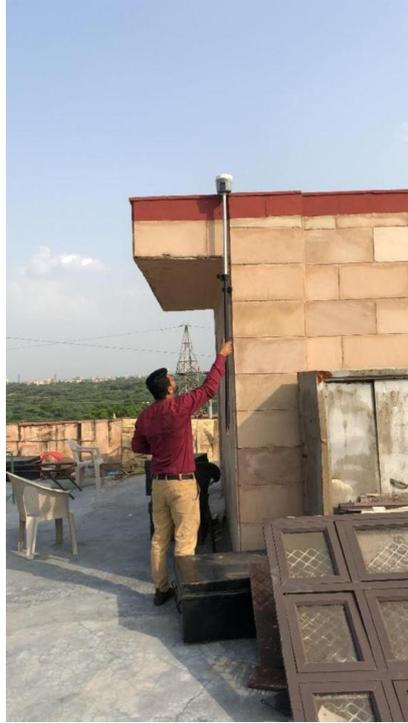
$$\begin{aligned}
 \text{Z- Value absolute RMSE} &= \sqrt{((-0.305)^2 + (0.360)^2 + (0.305)^2 + (-0.519)^2 + (0.479)^2 + (1.357)^2 \\
 &\quad + (-0.104)^2 + (0.735)^2 + (0.087)^2 + (1.014)^2 + (0.039)^2 + (0.139)^2 \\
 &\quad + (-0.502)^2 + (-0.100)^2 + (0.630)^2 + (0.212)^2)/15} \\
 &= \sqrt{0.32376} / 15 \\
 &= \pm 0.569 \text{ m}
 \end{aligned}$$

*Maximum difference of absolute Z- Value: 1.35 m but this is an aberration and needs to be checked again.

3. Photographs of field Survey measurement



Point ID: 15



Point ID: 22



Point ID: 30



Point ID: 34

4. Validation of 3D data extracted from photogrammetry with data published in the AIP

*All heights are in meters

S.No	Longitude	Latitude	Description	Photogrammetry	AIP	Difference
1.	77°7'54.41"E	28°33'16.30"N	Pole	252.12	251.10	1.02
2.	77°7'55.70"E	28°33'20.08"N	Pole	253.01	253.93	-0.92
3.	77°7'58.58"E	28°33'28.97"N	Pole	254.36	253.50	0.86
4.	77°7'56.60"E	28°33'19.15"N	Tree	251.63	252.90	-1.27
5.	77°7'58.42"E	28°33'24.00"N	Tree	251.49	253.20	-1.71
6.	77°7'58.90"E	28°33'16.63"N	Building	250.85	250.50	0.35
7.	77°8'1.490"E	28°33'22.22"N	Tree	254.24	255.36	-1.12
8.	77°8'3.581"E	28°33'23.31"N	Tree	256.80	257.49	-0.69
9.	77°8'4.537"E	28°33'22.28"N	Building	257.68	258.77	-1.09
10.	77°8'9.900"E	28°31'39.76"N	Building	284.74	285.73	-0.99
11.	77°7'32.50"E	28°33'25.99"N	Building	240.89	241.20	-0.31
12.	77°7'0.771"E	28°32'17.31"N	Building	256.59	256.64	-0.05
13.	77°6'59.50"E	28°32'16.92"N	Building	256.96	255.94	1.02
14.	77°6'58.98"E	28°32'16.68"N	Building	252.51	251.79	0.72
15.	77°6'56.29"E	28°32'13.69"N	Building	253.69	253.91	-0.22
16.	77°6'56.51"E	28°32'13.26"N	Building	252.92	254.52	-1.60
17.	77°6'50.89"E	28°32'11.13"N	Building	246.45	246.95	-0.50
18.	77°6'51.69"E	28°32'11.39"N	Building	247.63	247.85	-0.22
19.	77°6'51.68"E	28°32'6.381"N	Building	252.46	252.10	0.36
20.	77°6'47.89"E	28°32'9.640"N	Building	249.78	249.67	0.11
21.	77°6'58.07"E	28°32'15.14"N	Building	249.78	250.28	-0.50
22.	77°6'57.24"E	28°32'14.56"N	Building	249.78	249.67	0.11
23.	77°7'8.601"E	28°32'13.02"N	Building	256.18	256.64	-0.46
24.	77°7'16.27"E	28°32'14.17"N	Building	259.75	260.88	-1.13
25.	77°7'13.85"E	28°32'9.550"N	Building	256.29	257.55	-1.26
26.	77°7'13.03"E	28°32'9.439"N	Building	256.22	256.64	-0.42
27.	77°7'11.92"E	28°32'10.18"N	Building (U/C)	256.90	257.55	-0.65

S.No	Longitude	Latitude	Description	Photogrammetry	AIP	Difference
28.	77°7'10.67"E	28°32'11.10"N	Building	257.81	257.55	0.26
29.	77°7'8.700"E	28°32'12.47"N	Building	256.18	256.34	-0.16
30.	77°8'13.56"E	28°31'36.85"N	Building	287.61	286.94	0.67
31.	77°8'14.64"E	28°31'36.79"N	Building	285.95	286.55	-0.60
32.	77°8'15.74"E	28°31'36.70"N	Building	286.36	286.85	-0.49
33.	77°7'0.750"E	28°32'14.98"N	Building	256.96	256.73	0.23
34.	77°7'5.969"E	28°32'13.30"N	Building	257.20	257.55	-0.35
35.	77°7'18.06"E	28°32'16.40"N	Building	259.08	260.01	-0.93
36.	77°8'56.56"E	28°31'45.97"N	Building	278.75	279.09	-0.34
37.	77°8'40.24"E	28°31'33.77"N	Building	297.61	298.15	-0.54
38.	77°8'22.06"E	28°31'36.35"N	Building	287.86	288.15	-0.29
39.	77°8'17.88"E	28°31'35.53"N	Building	287.61	286.85	-1.24
40.	77°8'17.24"E	28°31'36.05"N	Building (U/C)	287.99	287.55	0.44
41.	77°8'30.19"E	28°31'35.73"N	Building	282.74	283.31	-0.57
42.	77°8'29.79"E	28°31'39.37"N	Building	281.62	282.40	-0.78
43.	77°8'12.08"E	28°31'36.94"N	Building	286.18	286.94	-0.76
44.	77°8'49.48"E	28°31'28.89"N	Building	294.95	295.20	-0.25
45.	77°8'14.53"E	28°31'34.81"N	Building	287.49	287.85	-0.36
46.	77°8'56.32"E	28°31'50.22"N	Building	280.54	282.70	-2.16*
47.	77°8'57.48"E	28°31'52.28"N	Building	282.97	283.31	-0.34
48.	77°7'17.71"E	28°32'13.99"N	Building	259.15	258.76	0.39
49.	77°8'58.14"E	28°31'53.24"N	Building	282.97	282.49	0.48
50.	77°9'3.789"E	28°31'51.42"N	Building	285.05	286.34	-1.29
51.	77°6'43.75"E	28°32'19.54"N	Tree	245.14	246.26	-1.12
52.	77°6'43.59"E	28°32'17.02"N	Tree	242.74	242.77	-0.03
53.	77°6'56.87"E	28°32'14.27"N	Tree	250.18	250.28	-0.10
54.	77°6'49.13"E	28°32'11.56"N	Tree	246.91	247.64	-0.73
55.	77°6'48.40"E	28°32'11.27"N	Tree	246.69	246.00	0.69
56.	77°6'46.63"E	28°32'10.32"N	Tree	246.14	245.70	0.44

S.No	Longitude	Latitude	Description	Photogrammetry	AIP	Difference
57.	77°6'56.96"E	28°32'18.14"N	Light Pole	246.05	246.96	-0.91
58.	77°6'56.08"E	28°32'17.11"N	Light Pole	246.04	246.66	-0.62
59.	77°6'55.58"E	28°32'16.63"N	Light Pole	246.05	246.66	-0.61
60.	77°6'55.05"E	28°32'16.15"N	Light Pole	246.05	246.66	-0.61
61.	77°6'54.50"E	28°32'15.74"N	Light Pole	246.05	246.36	-0.31
62.	77°6'53.93"E	28°32'15.35"N	Light Pole	246.04	246.66	-0.62
63.	77°6'53.33"E	28°32'14.97"N	Light Pole	246.05	246.66	-0.61
64.	77°6'52.70"E	28°32'14.61"N	Light Pole	246.05	246.96	-0.91
65.	77°6'52.11"E	28°32'14.28"N	Light Pole	246.05	246.96	-0.91
66.	77°6'51.44"E	28°32'13.95"N	Light Pole	246.05	246.96	-0.91
67.	77°6'50.82"E	28°32'13.60"N	Light Pole	246.09	246.96	-0.87
68.	77°6'50.18"E	28°32'13.27"N	Light Pole	246.09	246.96	-0.87
69.	77°6'49.56"E	28°32'12.96"N	Light Pole	246.09	246.96	-0.87
70.	77°6'48.92"E	28°32'12.62"N	Light Pole	246.06	246.66	-0.60
71.	77°6'51.97"E	28°32'13.72"N	Light Pole	246.04	245.63	0.41
72.	77°6'50.88"E	28°32'13.16"N	Light Pole	246.09	245.63	0.46
73.	77°6'49.81"E	28°32'12.60"N	Light Pole	246.06	245.63	0.43
74.	77°6'48.22"E	28°32'11.78"N	Light Pole	246.06	245.32	0.74
75.	77°6'46.62"E	28°32'10.97"N	Light Pole	246.06	245.32	0.74
76.	77°6'47.04"E	28°32'11.66"N	Light Pole	246.05	246.66	-0.61
77.	77°6'47.66"E	28°32'11.96"N	Light Pole	246.09	246.36	-0.27
78.	77°6'48.30"E	28°32'12.30"N	Light Pole	246.09	246.66	-0.57
79.	77°6'42.06"E	28°32'8.798"N	Light Pole	246.09	245.75	0.34
80.	77°6'42.78"E	28°32'9.109"N	Light Pole	246.09	246.06	0.03
81.	77°6'43.34"E	28°32'9.451"N	Light Pole	246.09	246.06	0.03
82.	77°6'43.96"E	28°32'9.779"N	Light Pole	246.09	246.36	-0.27
83.	77°6'44.61"E	28°32'10.10"N	Light Pole	246.09	246.06	0.03
84.	77°6'45.27"E	28°32'10.44"N	Light Pole	246.09	246.06	0.03
85.	77°6'45.91"E	28°32'10.76"N	Light Pole	246.09	246.06	0.03

S.No	Longitude	Latitude	Description	Photogrammetry	AIP	Difference
86.	77°6'46.55"E	28°32'11.09"N	Light Pole	246.09	246.36	-0.27
87.	77°6'41.76"E	28°32'8.478"N	Light Pole	246.01	245.87	0.14
88.	77°6'43.27"E	28°32'9.270"N	Light Pole	246.01	245.87	0.14
89.	77°6'44.29"E	28°32'9.800"N	Light Pole	246.01	245.87	0.14
90.	77°6'45.32"E	28°32'10.31"N	Light Pole	246.01	245.87	0.14
91.	77°6'46.32"E	28°32'10.83"N	Light Pole	246.01	245.87	0.14
92.	77°6'48.20"E	28°32'11.78"N	Light Pole	246.01	245.87	0.14
93.	77°6'49.69"E	28°32'11.89"N	Light Pole	246.06	246.64	-0.58
94.	77°6'51.00"E	28°32'11.85"N	Light Pole	246.06	246.34	-0.28
95.	77°6'49.93"E	28°32'11.31"N	Light Pole	246.06	246.03	0.03
96.	77°6'48.85"E	28°32'10.75"N	Light Pole	246.06	246.03	0.03
97.	77°6'49.22"E	28°32'10.53"N	Light Pole	246.06	246.34	-0.28
98.	77°6'48.77"E	28°32'10.30"N	Light Pole	246.06	246.03	0.03
99.	77°6'47.59"E	28°32'10.83"N	Light Pole	246.06	246.34	-0.28
100.	77°6'47.54"E	28°32'9.691"N	Light Pole	246.06	246.03	0.03
101.	77°6'46.15"E	28°32'10.08"N	Light Pole	246.06	246.34	-0.28
102.	77°6'45.88"E	28°32'9.239"N	Light Pole	246.06	245.73	0.33
103.	77°6'46.25"E	28°32'15.62"N	Light Pole	240.54	240.00	0.54
104.	77°8'46.53"E	28°31'34.74"N	Pylon	302.46	302.13	0.33
105.	77°8'34.04"E	28°31'30.61"N	Light Pole	297.93	297.40	0.53
106.	77°6'47.13"E	28°32'11.24"N	Light Pole	246.06	246.34	-0.28

Calculated vertical accuracy report based on Top elevation:

Root Mean Square Error (RMSE):

$$\begin{aligned}
 \text{Z- Value absolute RMSE} &= \sqrt{(\text{Difference})^2 / \text{total number of obstacle}} \\
 &= \sqrt{(47.4877)/106} \\
 &= \sqrt{(0.44799)} \\
 &= \pm 0.669 \text{ m}
 \end{aligned}$$

*Maximum difference of absolute Z value = 2.16 m but this is an aberration and needs to be checked again

5. Validation of survey with AIP Data

*All heights are in meters

Point_ID	Longitude	Latitude	Description	DGPS	AIP	Difference
26	77°08'30.219"E	28°31'37.416"N	Mobile Tower on Building	294.262	294.742	-0.48
29	77°08'26.704"E	28°31'34.852"N	Mobile Tower on Building	301.078	302.057	-0.979
33	77°08'10.032"E	28°31'38.535"N	Mobile Tower on Building	288.097	288.646	-0.549

Calculated vertical accuracy report based on Top elevation:

Root Mean Square Error (RMSE):

$$\begin{aligned} \text{Z- Value absolute RMSE} &= \sqrt{((-0.48)^2 + (0.979)^2 + (-0.549)^2 + (-0.519)^2)/3} \\ &= \sqrt{1.4902}/3 \\ &= \pm 0.704 \text{ m} \end{aligned}$$

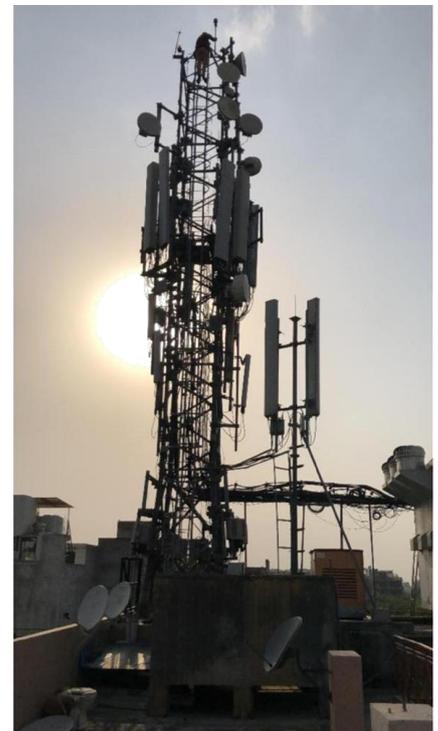
Photograph of field Measurement of Mobile Tower



Point ID: 26



Point ID: 29



Point ID: 33

6. List of Obstacles published in the AIP but not Captured by photogrammetry

S.No.	Longitude	Latitude	Name	H_AMSL
1	77°7'1.719"E	28°32'18.17"N	Building	253.61
2	77°7'11.98"E	28°32'10.58"N	Building	259.67
3	77°7'10.72"E	28°32'12.12"N	Building	261.79
4	77°6'56.87"E	28°32'14.27"N	Tree	250.28
5	77°6'47.65"E	28°32'9.091"N	Group Of Trees	256.04
6	77°8'26.75"E	28°31'34.89"N	Building	300.27
7	77°8'57.10"E	28°31'51.37"N	Building	283.31
8	77°8'57.72"E	28°31'52.76"N	Building	287.24
9	77°8'30.24"E	28°31'37.43"N	Building	293.00
10	77°8'10.23"E	28°31'38.62"N	Building	286.94
11	77°8'11.10"E	28°31'38.97"N	Building	286.03
12	77°8'38.84"E	28°31'35.14"N	Building	301.18
13	77°9'8.498"E	28°32'7.388"N	Building	286.64
14	77°8'58.82"E	28°31'44.95"N	Cell phone Mast	287.85
15	77°7'17.71"E	28°32'13.99"N	Building	258.76
16	77°9'6.330"E	28°32'4.210"N	Building	288.46
17	77°9'9.268"E	28°32'3.270"N	Building	293.30
18	77°7'0.499"E	28°32'14.94"N	Antenna Top	257.58
19	77°8'25.07"E	28°31'57.57"N	Cell phone Mast	291.21
20	77°8'28.64"E	28°32'0.869"N	Cell phone Mast	291.82
21	77°8'42.32"E	28°31'56.35"N	Cell phone Mast	291.52
22	77°8'58.82"E	28°31'44.95"N	Cell phone Mast	287.88
23	77°7'6.159"E	28°32'13.23"N	Communication- Antenna	263.64
24	77°7'32.36"E	28°33'25.94"N	Electrical	243.64
25	77°8'42.50"E	28°31'39.10"N	Flood Light	284.24
26	77°6'47.65"E	28°32'9.091"N	Group Of Trees	256.06
27	77°6'49.40"E	28°32'14.41"N	Group Of Trees	244.24
28	77°6'51.26"E	28°32'12.66"N	Group Of Trees	248.49

S.No.	Longitude	Latitude	Name	H_AMSL
29	77°6'54.08"E	28°32'14.24"N	Group Of Trees	249.09
30	77°8'30.33"E	28°31'40.95"N	Group Of Trees	285.15
31	77°8'34.27"E	28°31'38.82"N	Group Of Trees	284.24
32	77°6'47.34"E	28°32'11.78"N	Mobile Road	243.64
33	77°6'48.63"E	28°32'12.48"N	Mobile Road	243.94
34	77°6'42.86"E	28°32'17.22"N	Pole	241.82
35	77°8'52.01"E	28°31'44.88"N	Pole	283.64
36	77°8'56.35"E	28°31'42.66"N	Pole	285.46
37	77°8'36.69"E	28°31'36.60"N	Pylon	297.88
38	77°8'39.37"E	28°31'36.22"N	Pylon	297.58
39	77°8'54.42"E	28°31'47.05"N	Pylon	282.42
40	77°8'55.47"E	28°31'48.58"N	Pylon	281.82
41	77°8'58.64"E	28°31'57.80"N	Pylon	284.85
42	77°6'48.17"E	28°32'9.950"N	Sign-Dee mark	249.09
43	77°6'43.66"E	28°32'17.84"N	Tree	243.03
44	77°6'47.38"E	28°32'10.65"N	Tree	246.67
45	77°6'48.57"E	28°32'12.81"N	Tree	243.33
46	77°6'51.25"E	28°32'9.919"N	Tree	253.64
47	77°7'55.53"E	28°33'16.41"N	Tree	257.88
48	77°7'56.14"E	28°33'18.72"N	Tree	256.36
49	77°7'56.12"E	28°33'13.22"N	Tree	261.52
50	77°7'59.56"E	28°33'28.71"N	Tree	256.36
51	77°8'0.169"E	28°33'30.77"N	Tree	257.88
52	77°8'0.328"E	28°33'31.36"N	Tree	257.88
53	77°8'42.21"E	28°31'38.23"N	Tree	285.76
54	77°8'48.28"E	28°31'36.49"N	Tree	286.06

7. Reference Documents

1. ICAO Annex 15, Chapter 10, sixteenth edition in 2018
2. ICAO Annex 4
3. ICAO Annex 14
4. Doc 9881
5. Euro control Terrain and Obstacle Data Manual V 2.1
6. AIP data for Airport Information