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Comparing the Canopy Penetration of Airtanker Drops Between Forest Fuel-Treated Stands and Untreated Stands

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Technical report – 20

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1. INTRODUCTION

Wildfire is a natural phenomenon in Canada that threatens to destroy property and endanger lives. Wildfire agencies are tasked with reducing the threat of wildfire in the wildland-urban interface, which becomes a greater issue as more communities locate near or within forests or become more populated.

Forest fuel treatments that reduce or modify forest stands are the most common and effective methods to reduce wildfire danger around communities. However, convincing the public to support forest fuel treatments around their communities can be a challenge for wildfire managers. Understandably, communities want some assurance that what they are committing to will make a difference. One of the many benefits of forest fuel treatments is thought to be an increase in the effectiveness of wildfire operations.

Forest fuel treatments alone cannot stop wildfires. They need to be used in combination with wildfire operations tactics such as airtanker drops to be effective. Airtankers carry wildfire suppressants such as water, retardant and foam in large quantities to drop on or ahead of wildfire to reduce or stop it from spreading. Wildfire managers believe that airtanker drops produce the best results when surface fuels are coated with wildfire suppressants, and an open forest canopy should allow more of an airtanker's load to reach the surface fuels.

Managers from Alberta Agriculture and Forestry in Slave Lake asked FPInnovations to demonstrate that an open canopy in a forest fuel–treated stand will allow more of an airtanker's load to reach the forest floor. Comparing the difference in canopy penetration of airtanker drops between untreated forest stands and treated stands can demonstrate to the public the effectiveness of wildland fire suppression efforts from the use of fuel treatments.

2. OBJECTIVE

The objective of this study was to demonstrate that an open canopy in forest fuel–treated stands will allow more of an airtanker's load to reach the forest floor than in untreated stands.

3. SITE DESCRIPTION

The drop testing site was located near Slave Lake, Alberta. Two plots were established — one plot was untreated, and the other plot (i.e., the fuel treatment plot) had been strip-mulched during the winter of 2014 (Figure 1). In this plot, each mulch strip was 3 m wide with a 3-m strip of trees left standing. In both plots, the stands were dominated by black spruce (*Picea mariana*), and both shared the same stand characteristics prior to the mulching that was performed in the treated plot (Table 1). Hvenegaard & Hsieh (2014) describe the treatment in more detail.

4. METHODS

Airtanker drops

A Canadair CL-215 airtanker from Alberta Agriculture and Forestry performed four salvo[1] drops into each of the untreated and treated plots. Each drop released 1,440 U.S. gallons of 0.3% Class A foam. The drop height was determined by the air attack officer[2] in the Bird Dog[3] and then communicated to the airtanker pilot. The target airtanker flying speed was 120 knots when dropping the load.

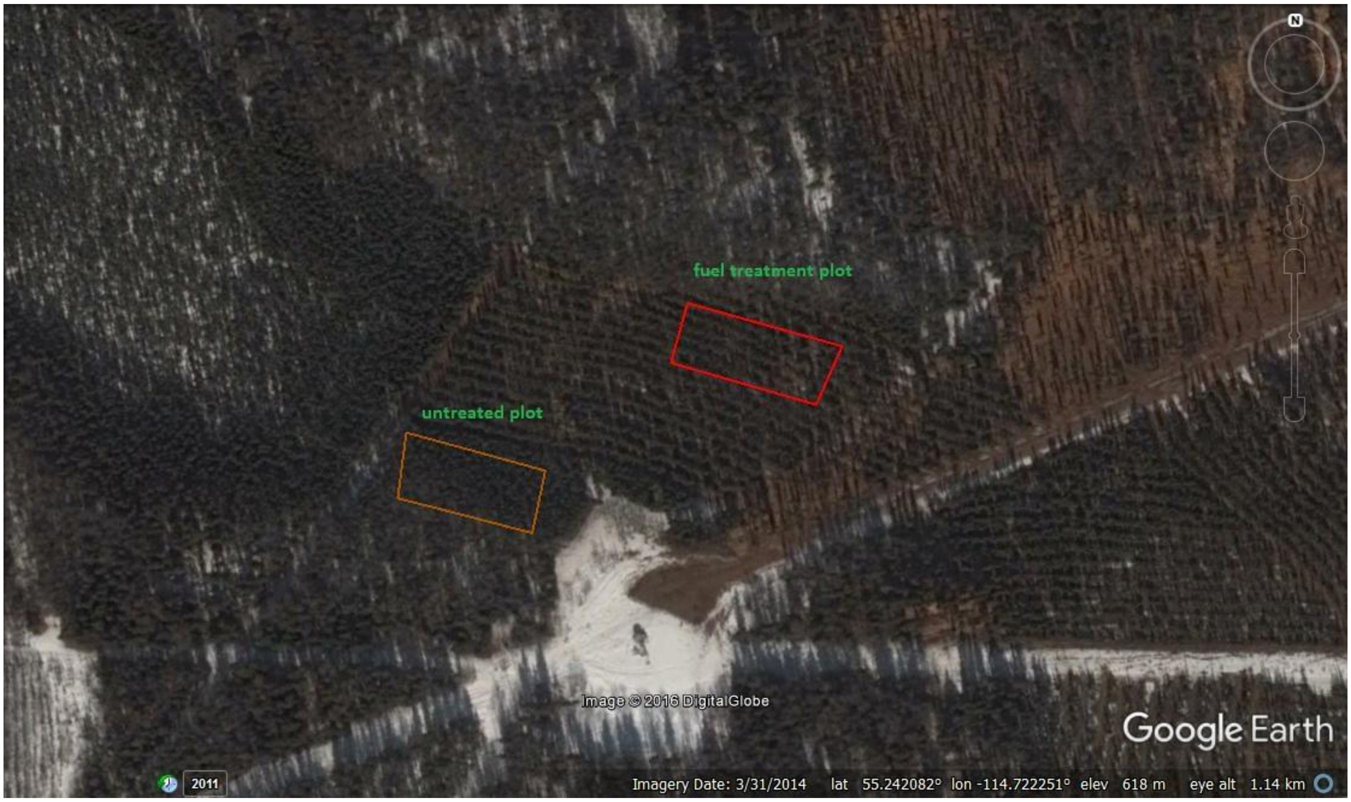

Figure 1. Untreated and treated plots at the drop testing site

[1] Entire load dropped at the same time
[2] Ensures that aerial suppression operations are carried out in a safe and efficient manner (Murray, 1988)
[3] An aircraft that leads or directs the airtankers to their target

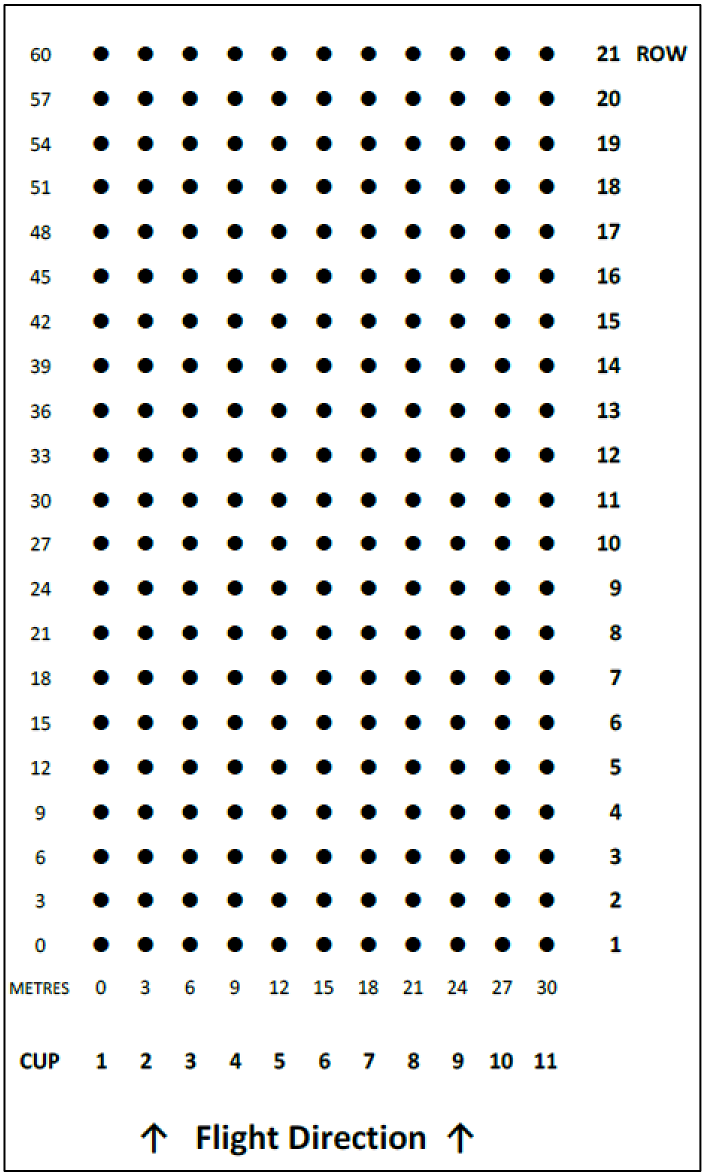

Figure 2. Drop grid

Table 1. Stand characteristics of the drop testing site

Stand density (stems/ha)			Average tree height (m)
> 9 cm dbh[4]	< 9 cm dbh	Total	
1,400	3,887	5,287	8

[4] Diameter at breast height

Data collection

The cup-and-grid method has been used to quantify airtanker drop ground patterns since 1950. The method involves an airtanker flying overhead and dropping wildfire suppressants into open cups arranged in a regularly spaced grid (Suter, 2000).

In this study cups were placed 3 m apart in both the untreated and fuel treatment plots, in a 60 m x 30 m grid consisting of 21 rows and 11 columns (Figure 2).

Alberta Agriculture and Forestry wildland firefighters and FPInnovations researchers collected the drop data by picking up each cup within the plot after each drop and recording the amount of fluid in the cup. The amount of fluid in each cup was measured using the visual assessment method described by Thomasson (2012). The fluid delivery was identified by coverage level, with coverage level 1 indicating 1 U.S. gallon per 100 square feet, coverage level 2 indicating 2 U.S. gallons per 100 square feet and so on.

The data were entered into a database to generate average distribution maps. A visual estimate was made of the percentage coverage on these maps. Drops with over 50% coverage area on cup grids were considered to be valid. Valid drops with similar percentage coverages were paired up to compare the recovery volume[5], recovery rate[6] and average coverage level. The following formulas were used to calculate these values:

Drop adjustment = estimated drop coverage area on the grid

Recovery volume = total coverage level in grid/drop adjustment

Recovery rate = recovery volume/1,440 U.S. gallons[7]

Average coverage level = total coverage level in grid/number of cups covered

Peak coverage level analysis was carried out on these drops. Peak coverage level maps showed the concentration in the core or heaviest part of an airtanker drop (George, 1985). A greater distribution of high coverage levels means that a greater volume of wildfire suppressants reached the ground and thus the drop is more effective in suppressing wildfire. Coverage level 4 (4 U.S. gallons per 100 square feet) was used for peak coverage level analysis because this is the level that is required to be effective on wildfires in short-needle conifer stands (Solarz and Jordan, 2000).

Two cameras with in-fire camera boxes, which are metal boxes that protect the cameras from extreme heat (Hsieh, 2003), were placed in the stands at each plot to record footage of drop penetration. The video footage provided detailed drop pattern analysis when a drop went through the stands and hit the ground.

[5] The recovery volume is the estimated amount of fluid recovered from the cup-and grid method
[6] The recovery rate is the comparison of recovery volume with the total amount of fluid dropped, expressed as a percentage of the total drop (Suter, 2000)
[7] Full drop volume for the CL215 airtanker

A differential GPS[8] receiver was installed on the CL-215 airtanker. A GPS reference station[9] was installed at the site by a professional GPS contractor, Norman Giorgi, who calculated the flight path, flight speed and above-ground drop height over the plots.

5. RESULTS

The drop testing was conducted on June 1, 2016. A total of eight drops were completed. The Slave Lake Tanker Base weather station, which was 6 km away from the drop testing plots, was used to monitor the weather conditions. The drop testing schedule and weather conditions are summarized in Table 2.

Table 2. Drop schedule and weather conditions

Drop no.	Time of drop	Plot	Wind speed (knots)	Wind direction (degrees)	Temperature (°C)	Relative humidity (%)
1	10:25	untreated	8	100	17	56
2	11:25	treated	6	100	17	55
3	12:25	untreated	9	120	20	46
4	13:18	treated	9	120	20	46
5	13:48	untreated	6	160	19	46
6	14:18	treated	6	360	16	63
7	14:48	untreated	6	50	17	77
8	15:15	treated	5	330	19	71

The GPS contractor provided a detailed report that included flight path, flight height and flight pattern over the plots for each flight (Appendix A).

Data collected from cup-and-grid method

All drop testing data were entered into a database which was used to produce an estimated coverage level pattern map for each drop (Appendix B).

The data analysis and visual validation of the individual drop coverage level pattern map indicated that five drops had over 50% plot coverage and, thus, were considered valid. Of the valid drops, Drops 4 and 7 and Drops 2 and 5 were considered the most similar and were paired for comparison purposes (Table 3). Drop 3 was the other valid drop and is also included in Table 3.

[8] A global positioning system that provides high location accuracy to 10 cm
[9] A GPS receiver at a known location which provides GPS precision reference for another roving GPS receiver

Table 3. Recovery rates and average coverage levels for valid drops

Drop no.	Total coverage level in grid	Number of cups covered	Drop adjustment (%)	Recovery volume (U.S. gal)	Recovery rate (%)	Average coverage level (U.S. gal/100 ft^2)
4 (treated)	711	226	100	688.782	47.83	3.146
7 (untreated)	424	218	100	410.750	28.52	1.944
2 (treated)	442	177	50	856.377	59.47	2.497
5 (untreated)	412	229	50	798.251	55.43	1.799
3 (untreated)	370	213	70	512.055	35.56	1.737

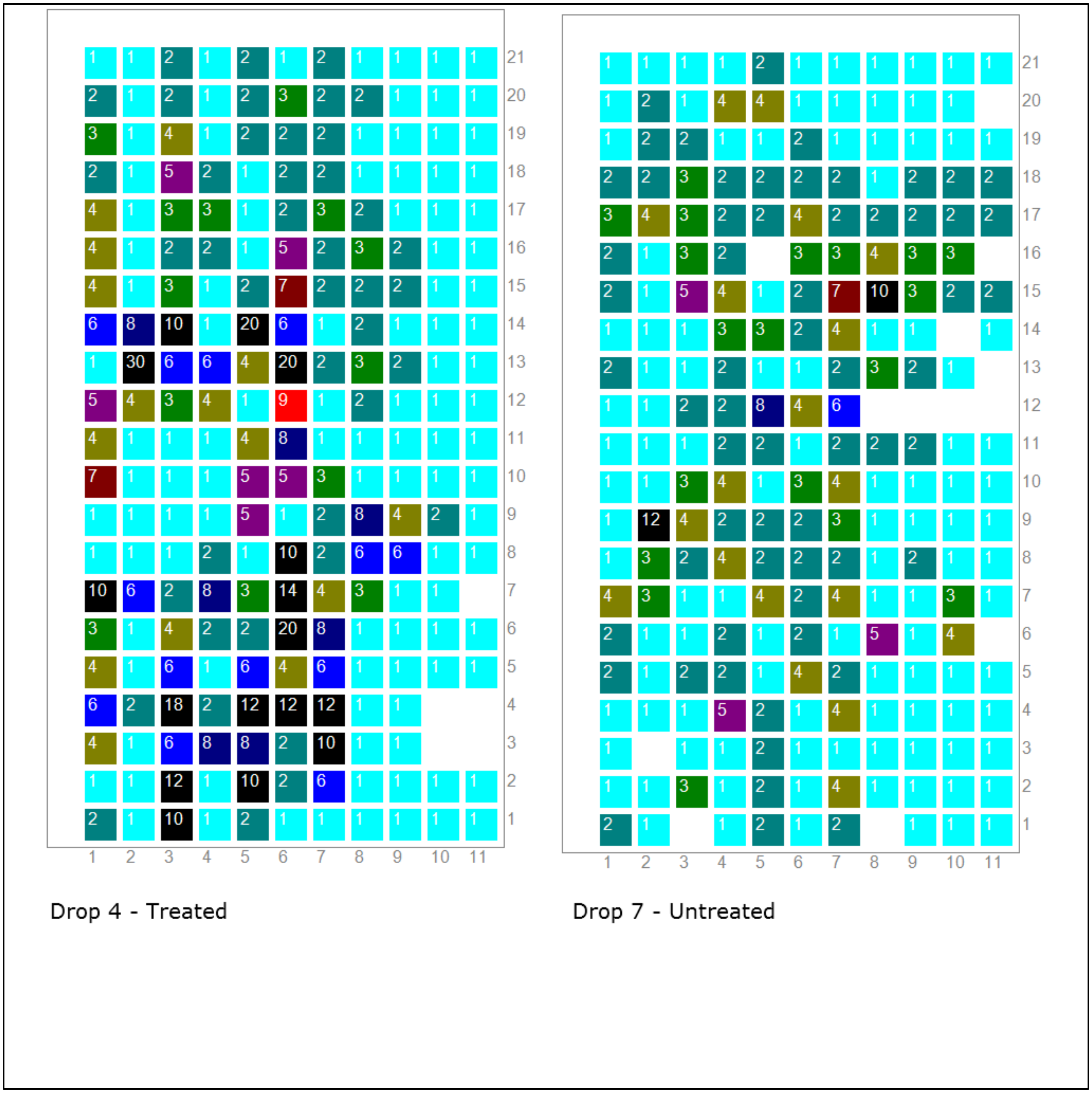

Figure 3. Coverage level pattern map of Drops 4 and 7

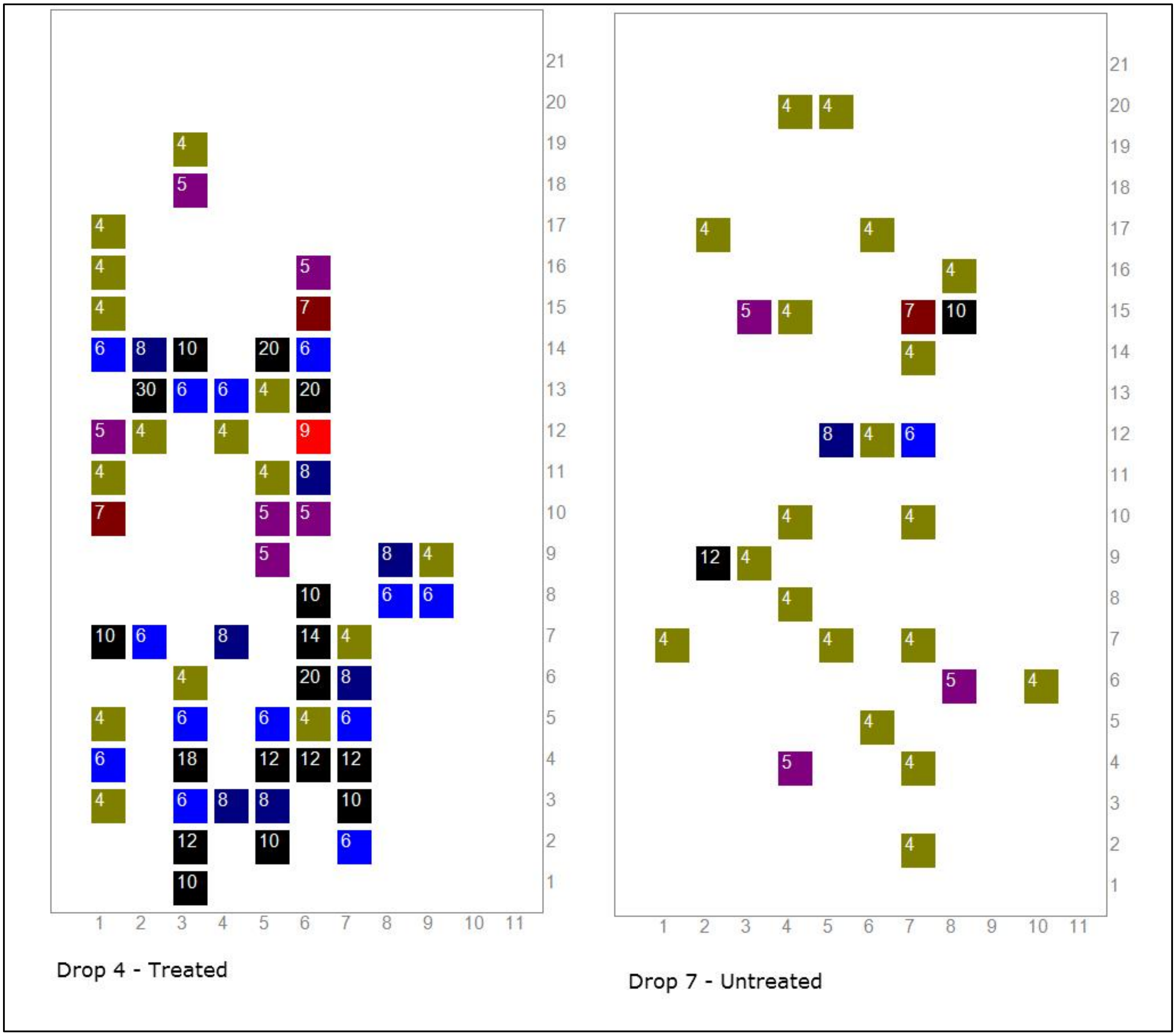

Figure 4. Peak coverage level map of Drops 4 and 7

Drops 4 and 7 had similar coverages with the drops on the grid centres (Figure 3). The estimated drop coverage area on both grids was 100% by visual inspection on the coverage level pattern maps. The recovery rate and average coverage level for Drop 4 was 19.31% and 61.75% higher, respectively, than Drop 7.

The peak coverage level map (Figure 4) shows Drop 4 had 60 cups above coverage level 4, and Drop 7 had 27 cups above coverage level 4. Drop 4 had 122% higher peak coverage levels than Drop 7.[10]

[10] Peak coverage level difference: (60 [Drop 4] – 27 [Drop 7]) / 27 [Drop 7]

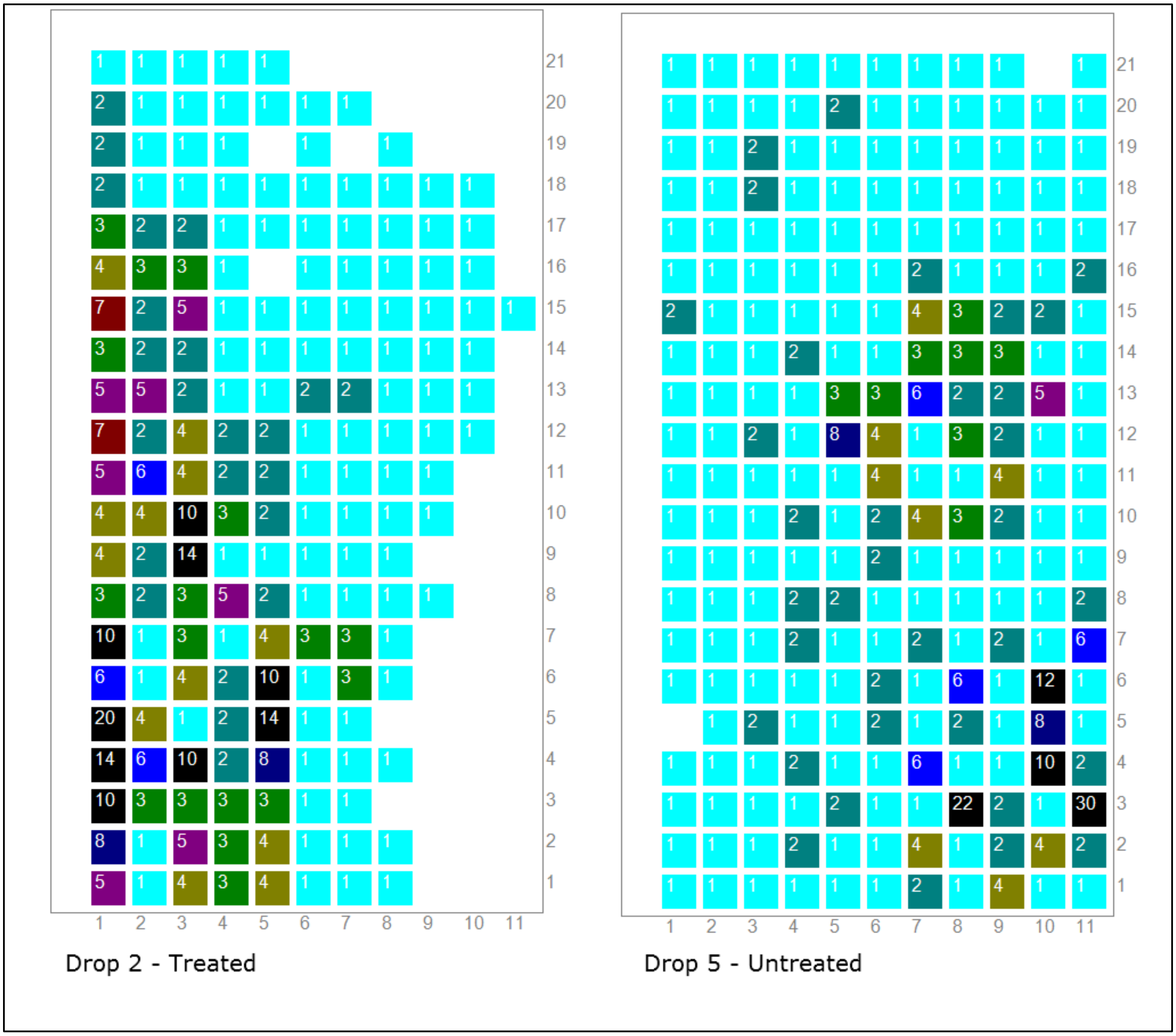

Figure 5. Coverage level pattern map for Drops 2 and 5

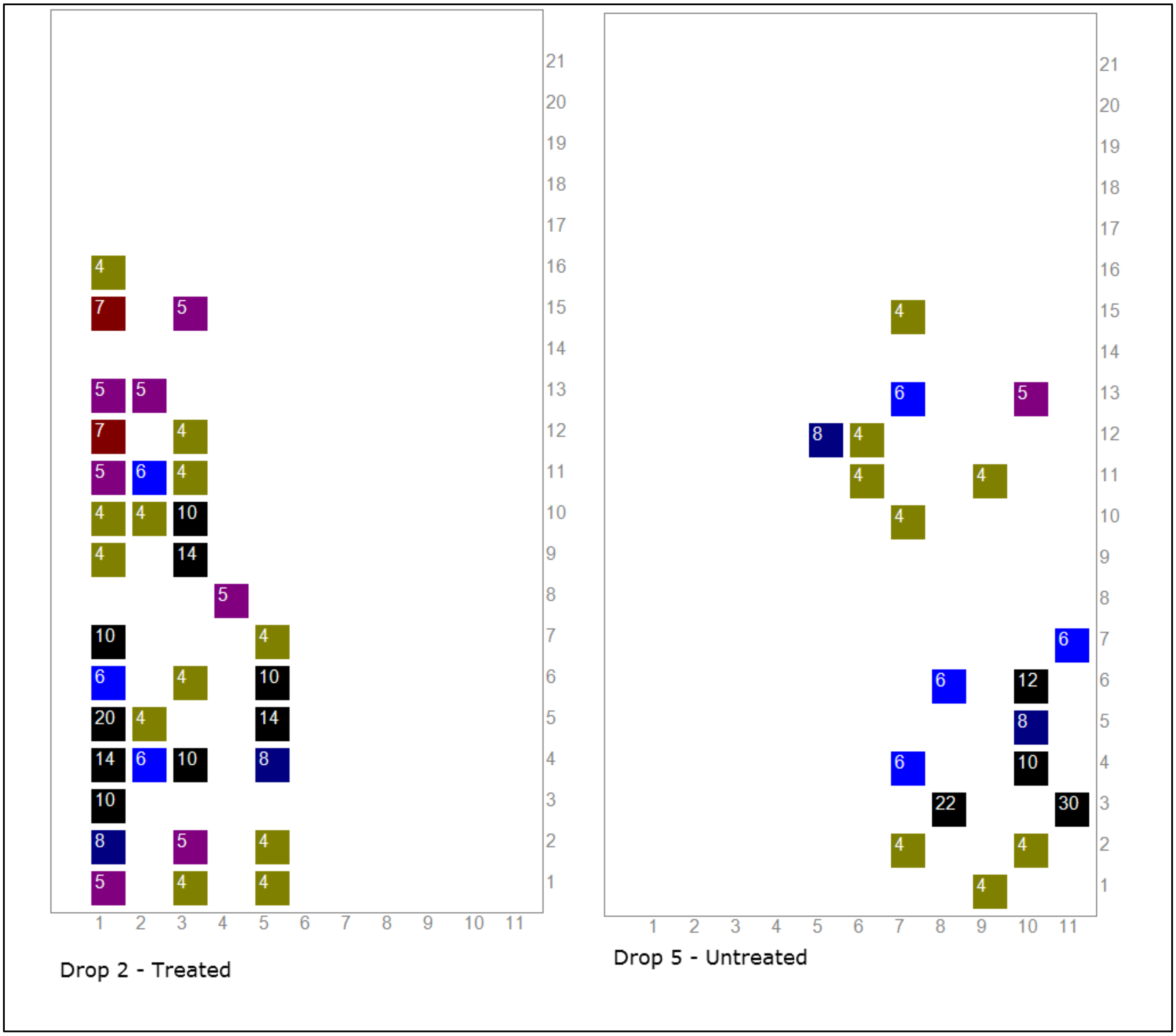

Figure 6. Peak coverage level map of Drops 2 and 5.

Drops 2 and 5 had similar drop coverages and drop loads off the grid centres. The drop coverage area on the grids for both plots was estimated at 50% by visual inspection on the coverage level pattern maps (Figure 5). Drop 5 had more gaps that allowed more fire to escape. Drop 2 had a long linear coverage pattern which covered more fire front than Drop 5. The average coverage level was 38.8% higher for Drop 2 than for Drop 5. The difference between the recovery rates was only 4.04%; this small difference may have been due to the delayed dripping from the previous drop. There were a few cups that indicated high coverage levels due to the dripping from the tree crowns.

The peak coverage level map (Figure 6) shows Drop 2 had 35 cups over coverage level 4, and Drop 5 had 19 cups over coverage level 4. Drop 2 had 84% higher peak coverage levels than Drop 5.[11]

Video comparison

Video footage of drops in the treated plot shows that the drops covered the entire mulched area, whereas video footage of drops in the untreated plots show that the drops were intercepted by the crowns, thus leaving some areas uncovered. An edited video clip of the drops is available for viewing (Alberta Agriculture and Forestry & FPInnovations, 2016).

6. CONCLUSION

The fuel treatment plot had consistently higher recovery rates and higher average coverage levels than the untreated plot. The drops in untreated stands had more gaps that allowed more fire to escape. The drops in treated stand had long linear coverage pattern which covered more fire front that untreated stands. The drops on the treated stands had higher peak coverage levels than the untreated stands. A drop with higher peak coverage levels on the forest floor reduces ground fire intensity and likelihood of crown fire generation.

Footage of video taken within the stands showed that the crowns intercepted drops and reduced the recovery rates, which indicates that an open canopy in a treated stand allows more of an airtanker's load to reach the forest floor to enhance wildland fire suppression operations.

7. REFERENCES

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[11] Peak coverage level difference = (35 [Drop 2] – 19 [Drop 5]) / 19 [Drop 2]

Suter, A. (2000). *Drop testing airtankers: a discussion of the cup-and-grid method.* Missoula, Montana: United States Department of Agriculture Forest Service, Technology & Development Program.

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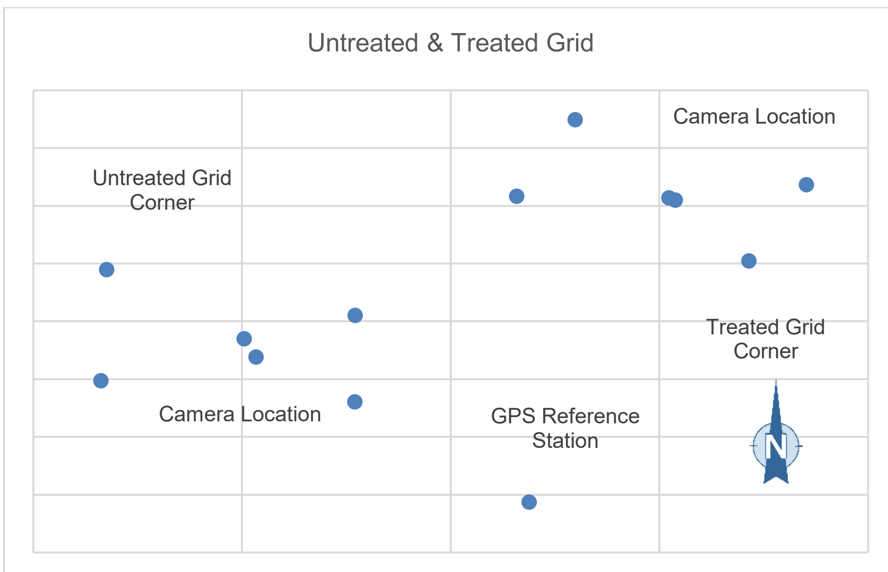
8. APPENDIX A. GPS REPORT PREPARED BY CONTRACTOR NORMAN GIORGI

The location of the GPS positions for the grid and aircraft were processed in Leica Geo-Office. Where as the GPS Reference Station corrected position was processed using a method of collecting raw satellite data over the period of the drop test. These data sets were then exported in RINEX format from Leica Geo-Office to the NRCan PPP system for processing.

This new position supplied by the NRCan PPP processing was then applied to the collected data sets that had been collected onboard the plane and in field. The following table shows a visual representation of the corrected GPS locations of the untreated and treated plots.



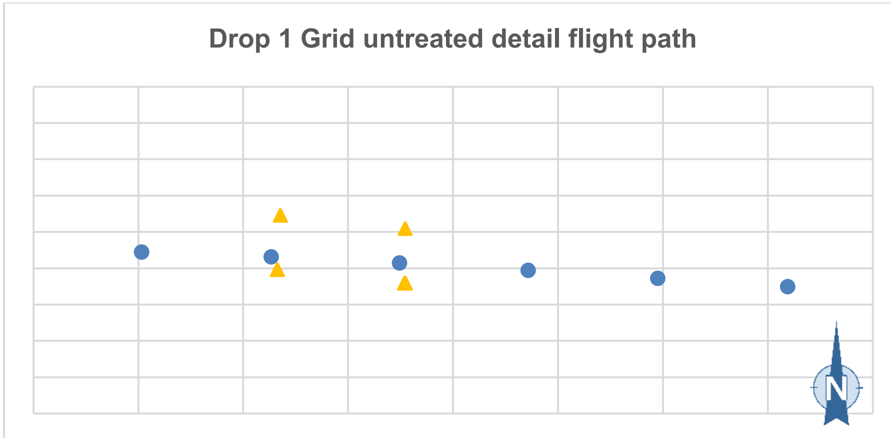
The following table shows the grid altitude calculation used for the vertical profile which was calculated based on the corrected Orthometric Elevation using NRCan's distribution model HT2.0.

Point ID	Easting	Northing	Altitude	Average Altitude	Grid Altitude
GPS Reference Station	644818.8112	6123997.312	619.3671		
Camera 1	644753.3894	6124047.622	622.4602		
Camera 2	644853.798	6124101.882	618.1703		
Untreated Plot					
R1 1 (SE)	644777.0447	6124032.045	619.6305		
R1 11 (NE)	644777.1655	6124062	619.2618	619.446	
R21 1 (SW)	644716.261	6124039.387	623.3286		620.176
R21 11 (NW)	644717.5972	6124077.885	618.4839	620.906	
Treated Plot					
TR1 1 (SE)	644871.4332	6124080.853	618.0893		
TR1 11 (NE)	644885.2729	6124107.218	618.4112	618.250	
TR21 1 (SW)	644815.8432	6124103.253	618.4701		618.325
TR21 11 (NW)	644829.873	6124129.751	618.3306	618.400	

Once the average grid height was determined, that value could be subtracted from the GPS altitude of the aircraft. This would give the above ground level (AGL) height of the flight path. The following tables represent the vertical profile (meters) of the eight drops conducted in Slave Lake.

Along with the AGL profile, the GPS data sets give us the ability to display the flight path of the aircraft.

Drop	Time (Seconds)	Distance (Meters)	Speed (meter/second)	Speed (knots)	AGL (Meters)
1	3	185.633	61.878	120.2812	50.862
2	Not available				
3	1	62.463	62.463	121.418	62.955
4	1	61.311	61.311	119.179	53.304
5	1	61.242	61.242	119.399	57.234
6	1	66.399	66.399	129.069	63.863
7	1	61.585	61.585	119.712	56.579
8	1	66.613	66.613	129.485	61.091
Average	1.429	72.178	63.070	122.65	57.984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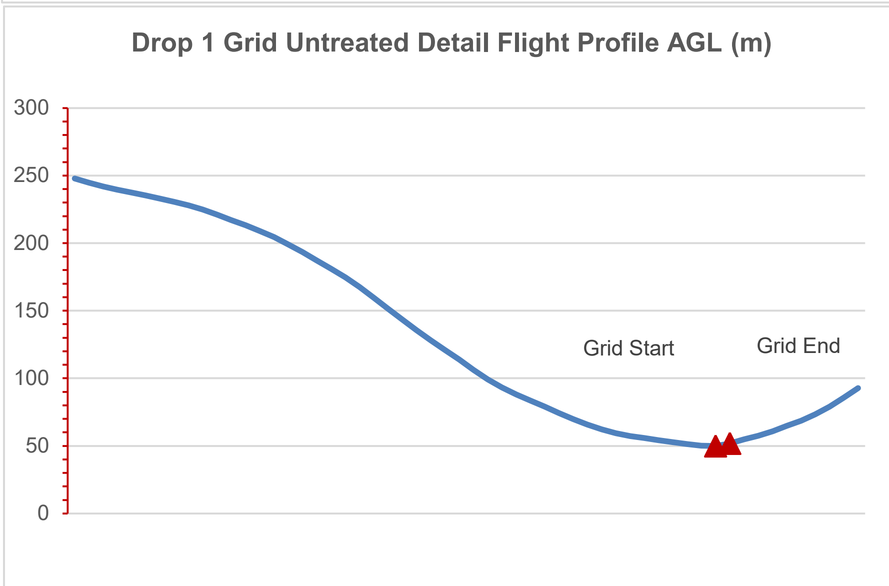
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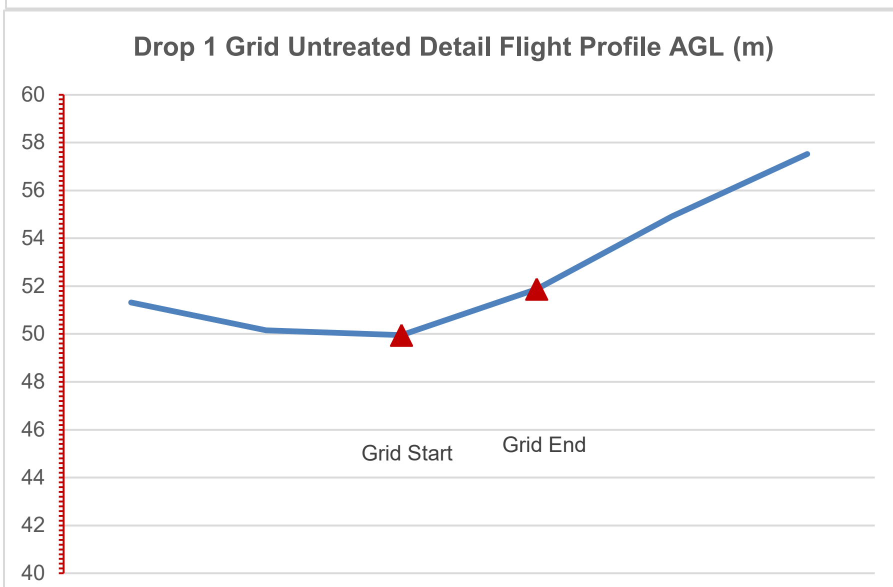
250
200
150
100
50
0
Grid Start
Grid End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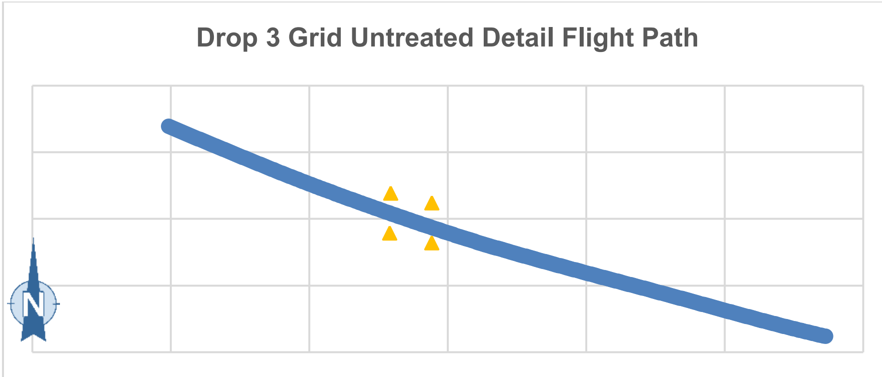
58
56
54
52
50
48
46
44
42
40
Grid Start
Grid End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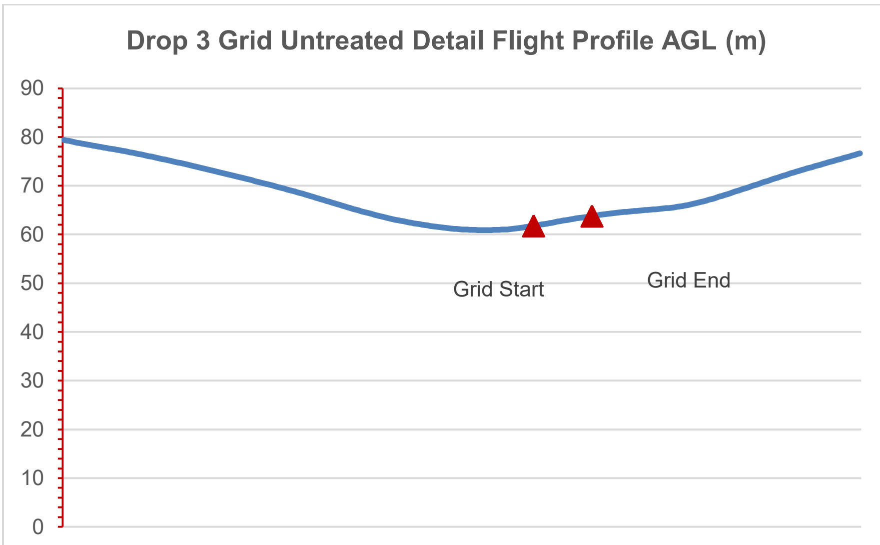
N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80
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60
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40
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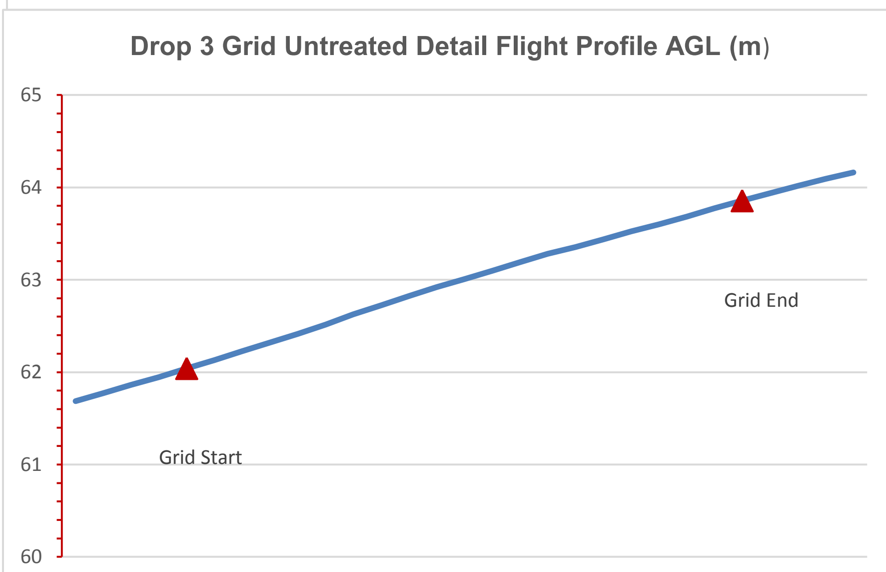
Grid Start
Grid End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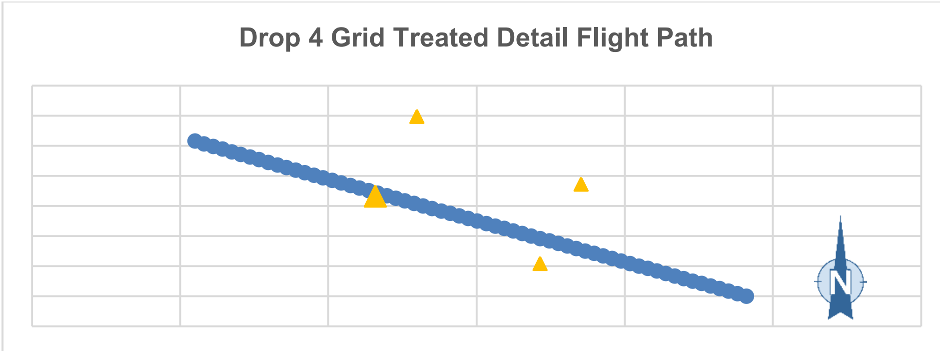
65
64
63
62
61
60
Grid End
Grid Start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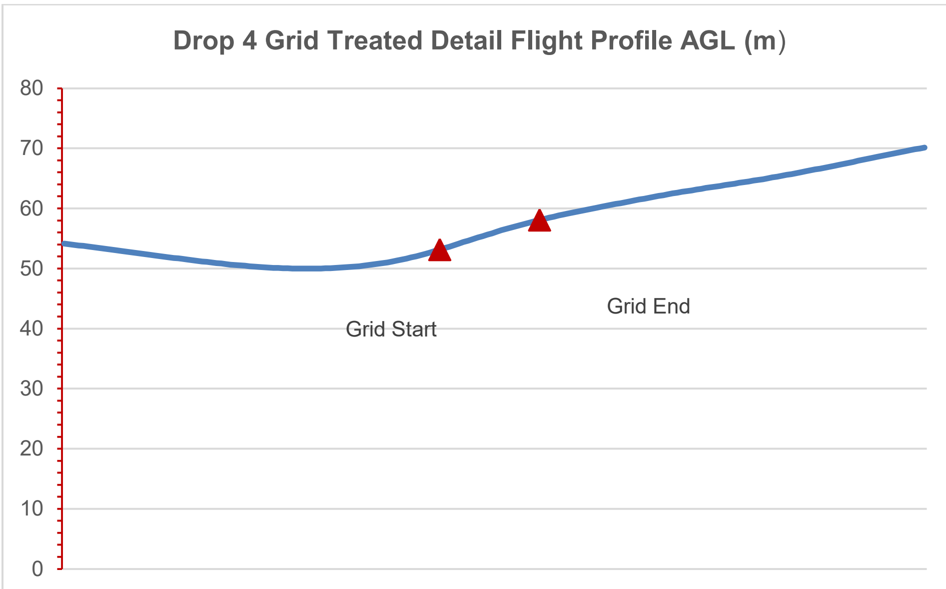
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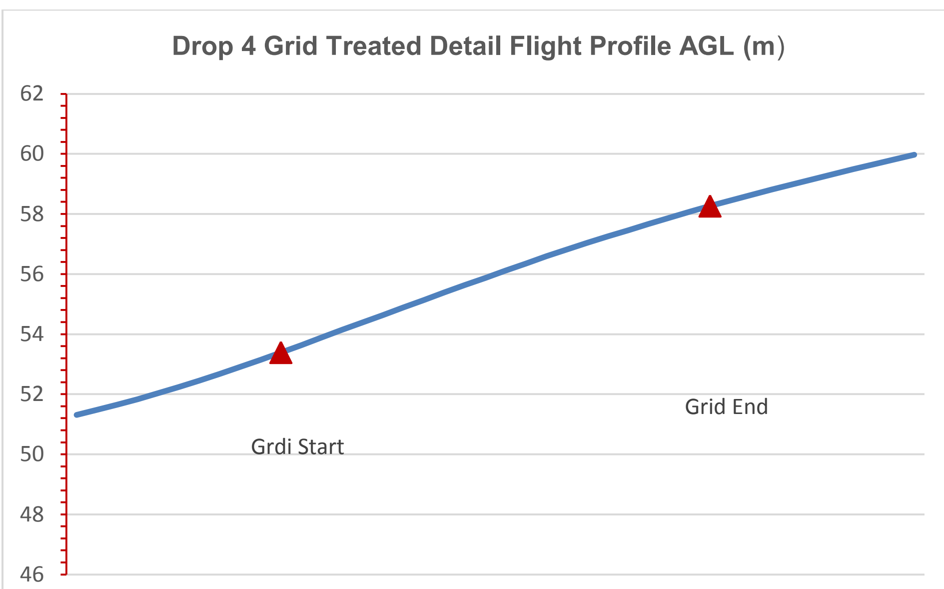
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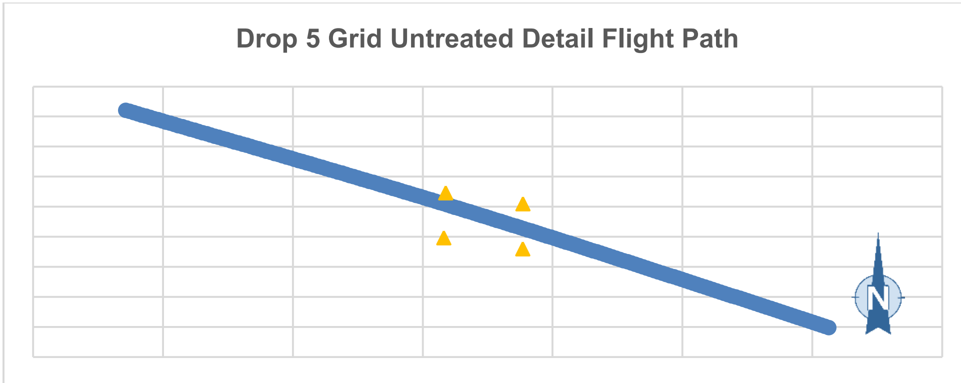
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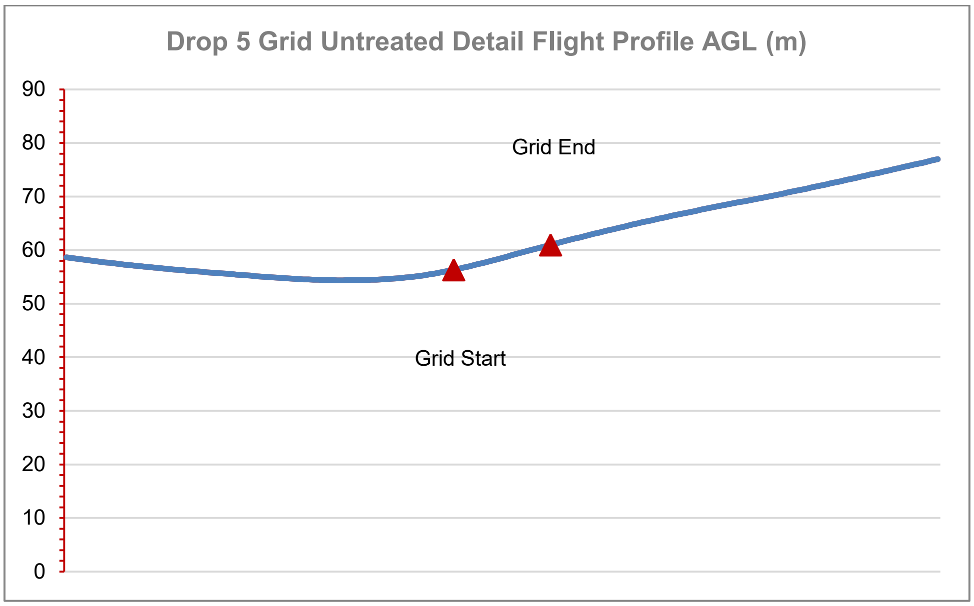
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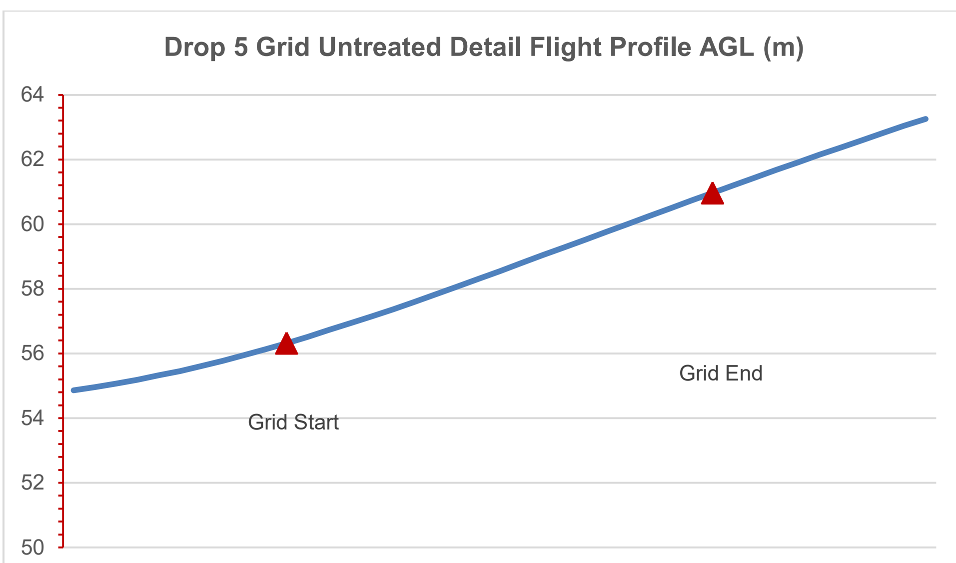
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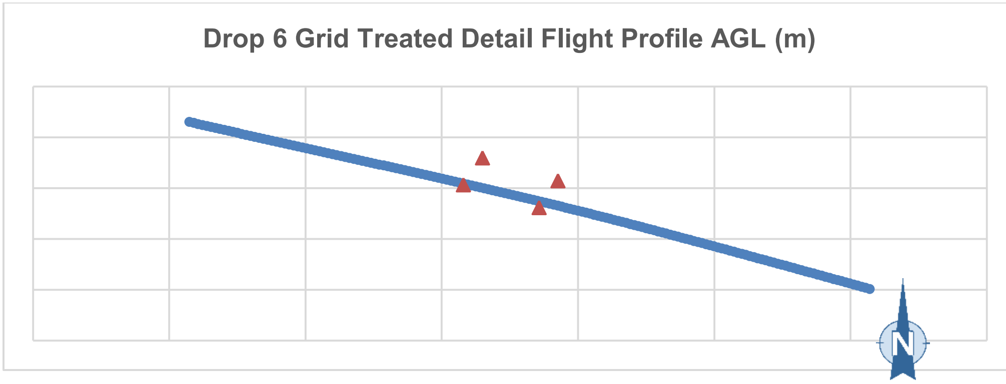
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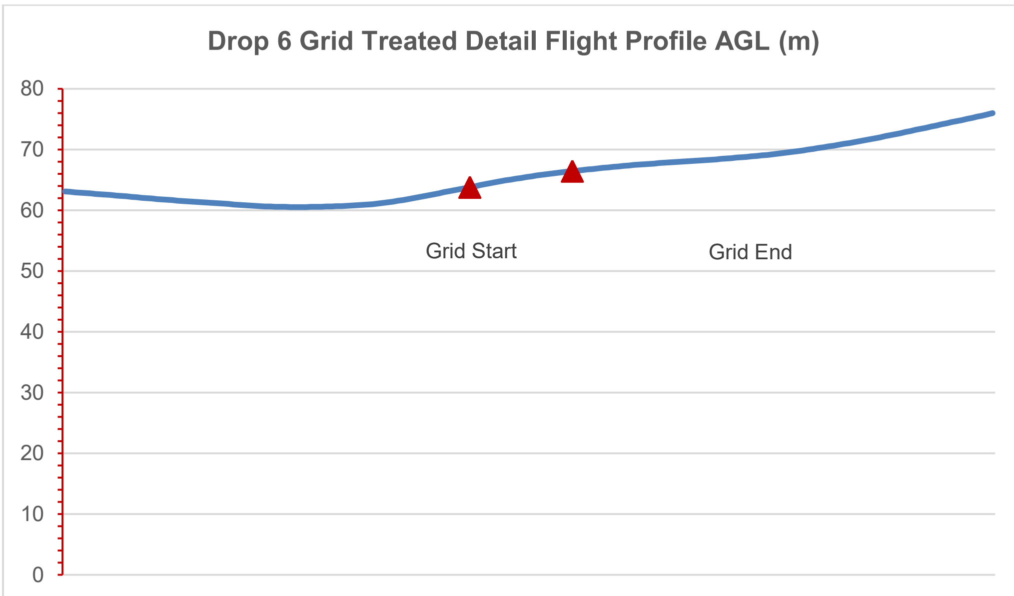
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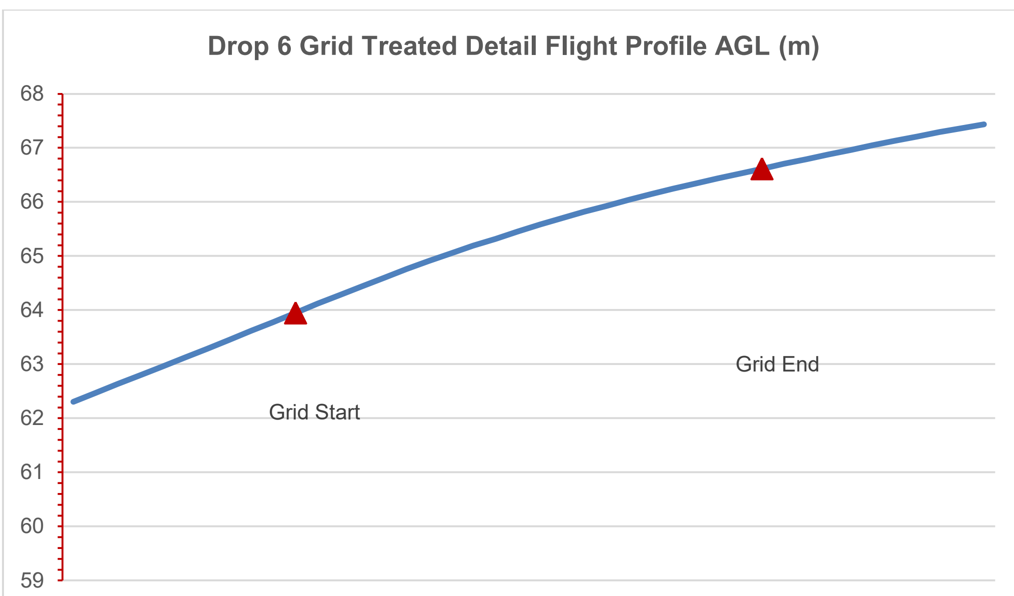
10
0
Grid Start
Grid End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65
64
63
62
61
60
59
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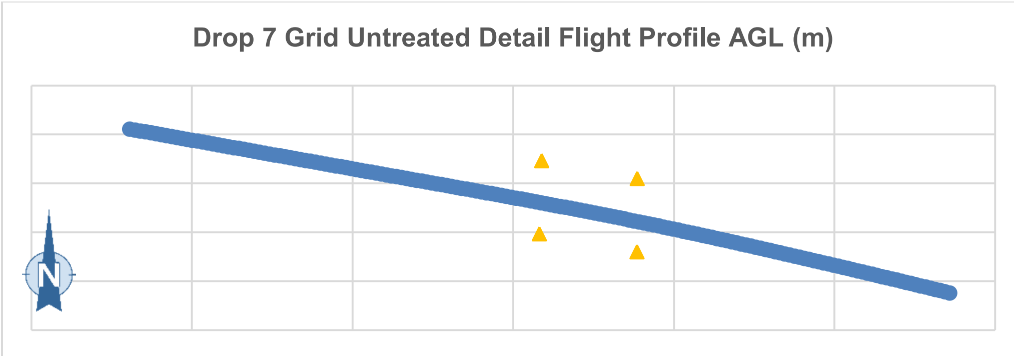
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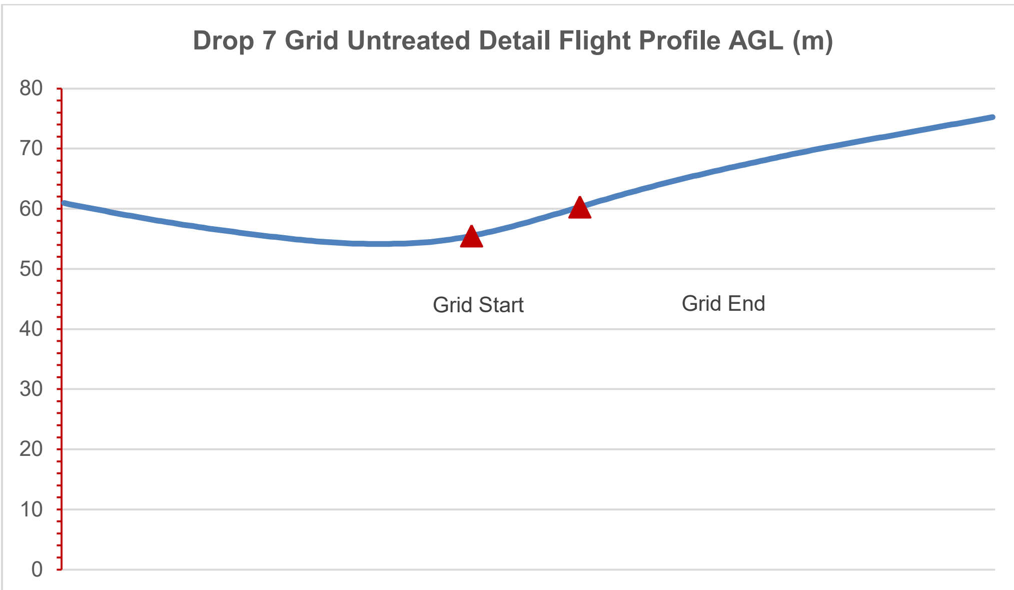
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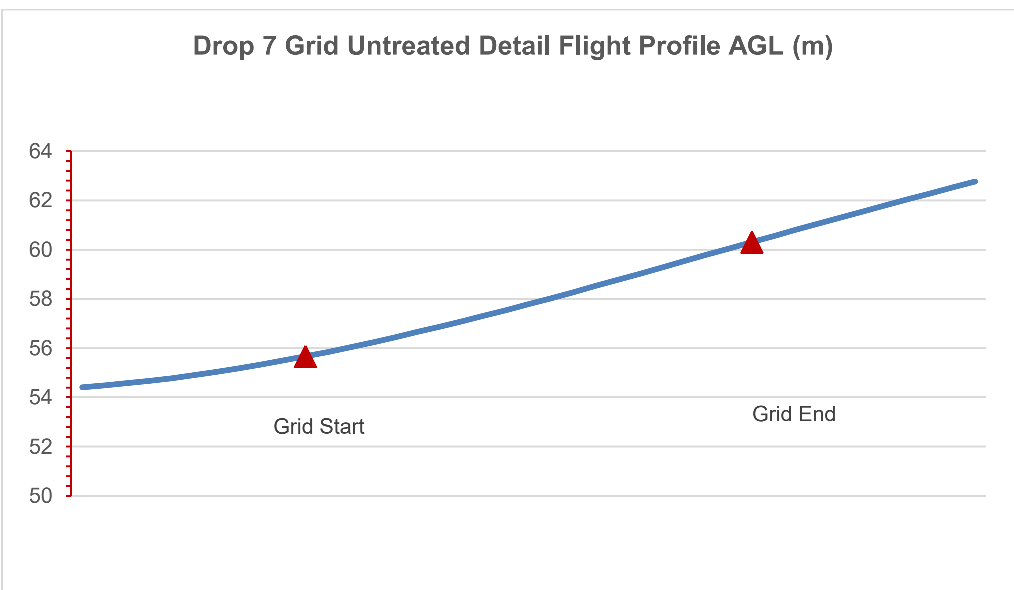
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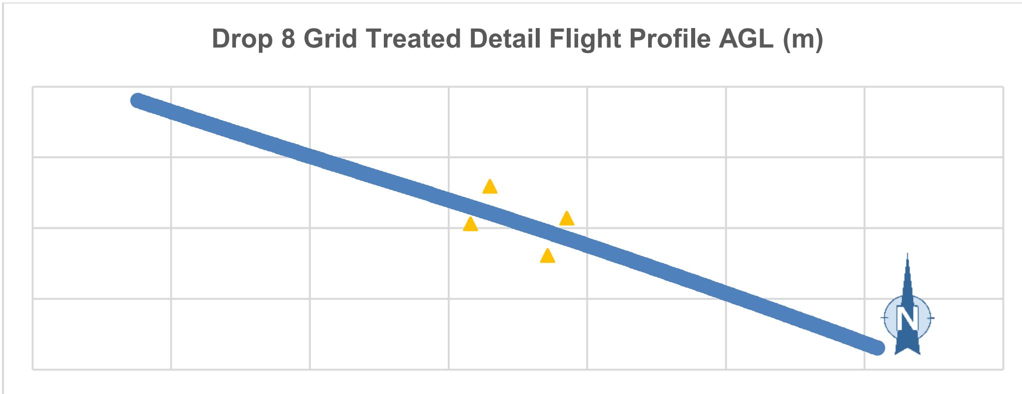
Grid Start
Grid End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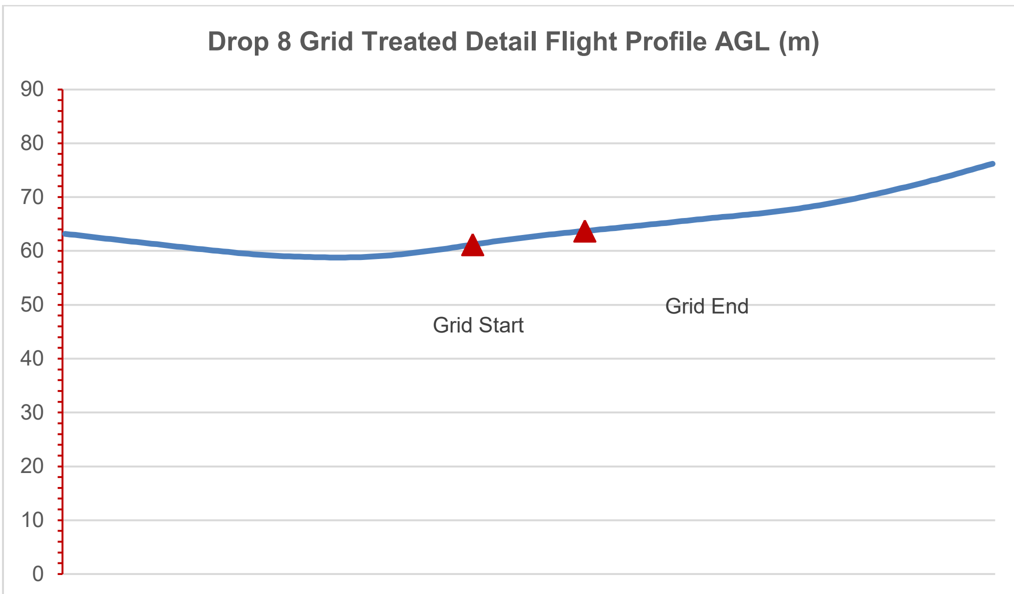
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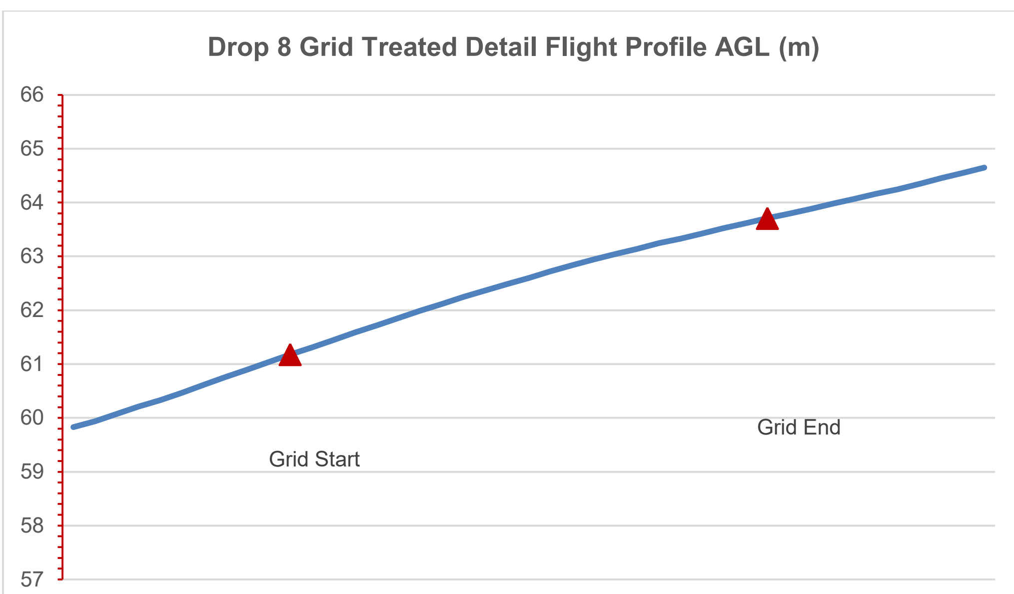
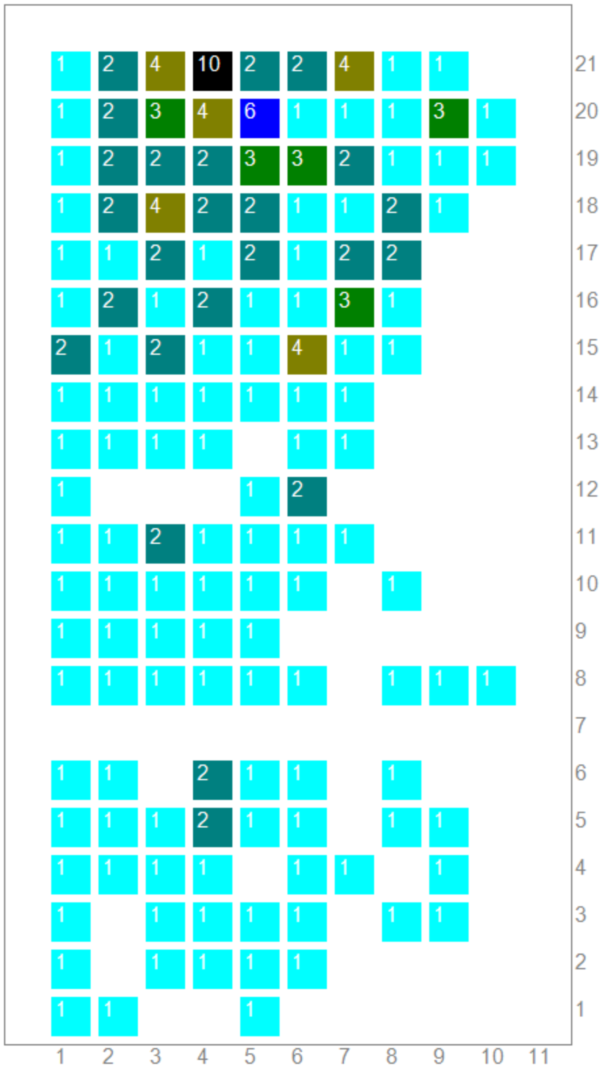
90
80
70
60
50
40
30
20
10
0
Grid Start
Grid End


Drop 8 Grid Treated Detail Flight Profile AGL (m)
66
65
64
63
62
61
60
59
58
57
Grid Start
Grid End

9. APPENDIX B. COVERAGE LEVEL PATTERN MAPS

Drop 1



Drop1 - Untreat

Time: 01/06/2016 10:25:00 AM

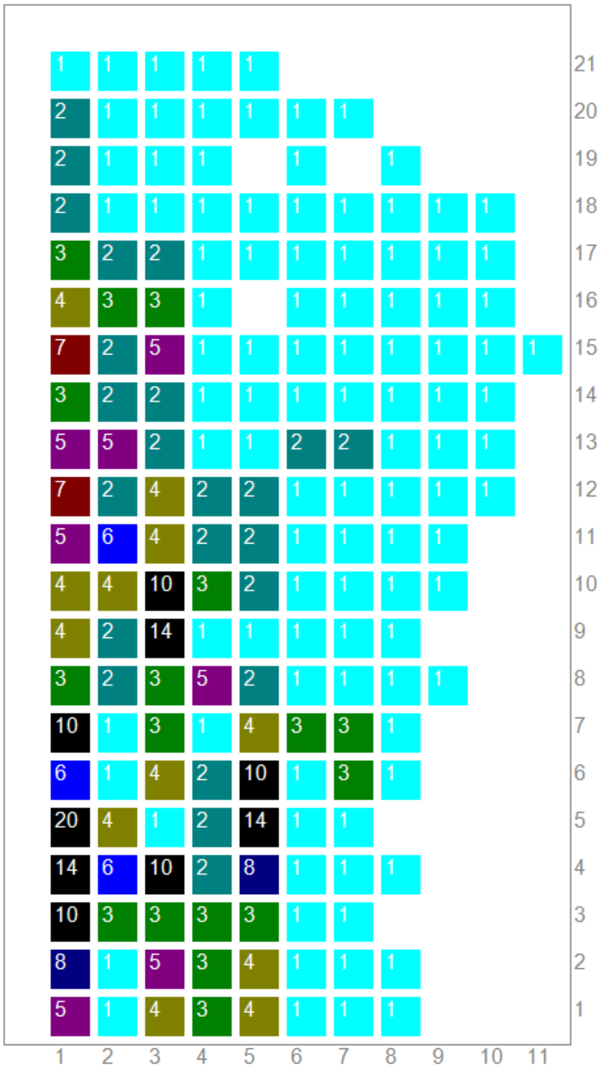
Wind Speed: 8 knots

Wind Direction: 100 degrees

Temperature: 17 degrees C

RH: 56%

Drop 2



Drop2 - Treated

Time: 01/06/2016 11:25:00 AM

Wind Speed: 6 knots

Wind Direction: 100 degrees

Temperature: 17 degrees C

RH: 55%

Drop 3

	1	2	3	4	5	6	7	8	9	10	11
21	1	1	1	1	1	1	2	1	1		1
20	1	1	1	1	3	1	2	1	1	1	1
19	1	1	1	1	1	1	1	1	1	2	1
18	1	2	2	1	1	1	2	1	3	1	1
17	2	1	1	1	1	1	2	1	1	1	1
16	2	1	2	3	2	1	1	1	2	1	1
15	2	1	2	2	2	2	2	4	3	2	1
14	1	1	1	2	1	1	1	1	4	2	1
13		1	1	1	1	1	1	3	1	1	1
12		1	1	1	1	1	2	3	1	1	1
11	1	1	1	1	2	1	1	2	4	1	1
10	1	1	1	1	1	4	3	2	3	1	1
9		1	1	1	9	1	2	1	1	2	1
8		1	1	6	6	4	3	3	6	2	4
7		1	1	1	3	1	2	2	2	2	1
6			1	3	3	10	1	10	1	12	7
5			1	1	3	2	1	1	1	12	1
4			1	1	1	3	4	1	1	1	2
3		1	1	1	1	1	1	3	1	1	1
2		1	1	1	1	1	1	1	2	1	1
1					1	1	1	1	1	1	1

Drop3 - Untreat

Time: 01/06/2016 12:25:00 PM

Wind Speed: 9 knots

Wind Direction: 120 degrees

Temperature: 20 degrees C

RH: 46%

Drop 4

1	1	2	1	2	1	2	1	1	1	1	21
2	1	2	1	2	3	2	2	1	1	1	20
3	1	4	1	2	2	2	1	1	1	1	19
2	1	5	2	1	2	2	1	1	1	1	18
4	1	3	3	1	2	3	2	1	1	1	17
4	1	2	2	1	5	2	3	2	1	1	16
4	1	3	1	2	7	2	2	2	1	1	15
6	8	10	1	20	6	1	2	1	1	1	14
1	30	6	6	4	20	2	3	2	1	1	13
5	4	3	4	1	9	1	2	1	1	1	12
4	1	1	1	4	8	1	1	1	1	1	11
7	1	1	1	5	5	3	1	1	1	1	10
1	1	1	1	5	1	2	8	4	2	1	9
1	1	1	2	1	10	2	6	6	1	1	8
10	6	2	8	3	14	4	3	1	1		7
3	1	4	2	2	20	8	1	1	1	1	6
4	1	6	1	6	4	6	1	1	1	1	5
6	2	18	2	12	12	12	1	1			4
4	1	6	8	8	2	10	1	1			3
1	1	12	1	10	2	6	1	1	1	1	2
2	1	10	1	2	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	10	11	

Drop4 - Treated

Time: 01/06/2016 1:18:00 PM

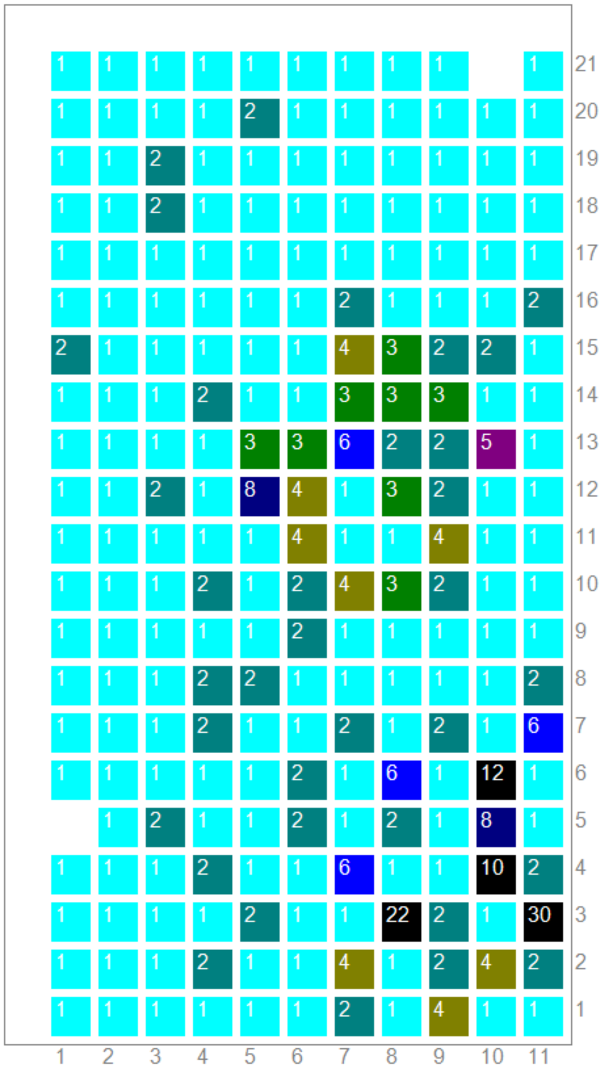
Wind Speed: 9 knots

Wind Direction: 120 degrees

Temperature: 20 degrees C

RH: 46%

Drop 5



Drop5 - Untreat

Time: 01/06/2016 1:48:00 PM

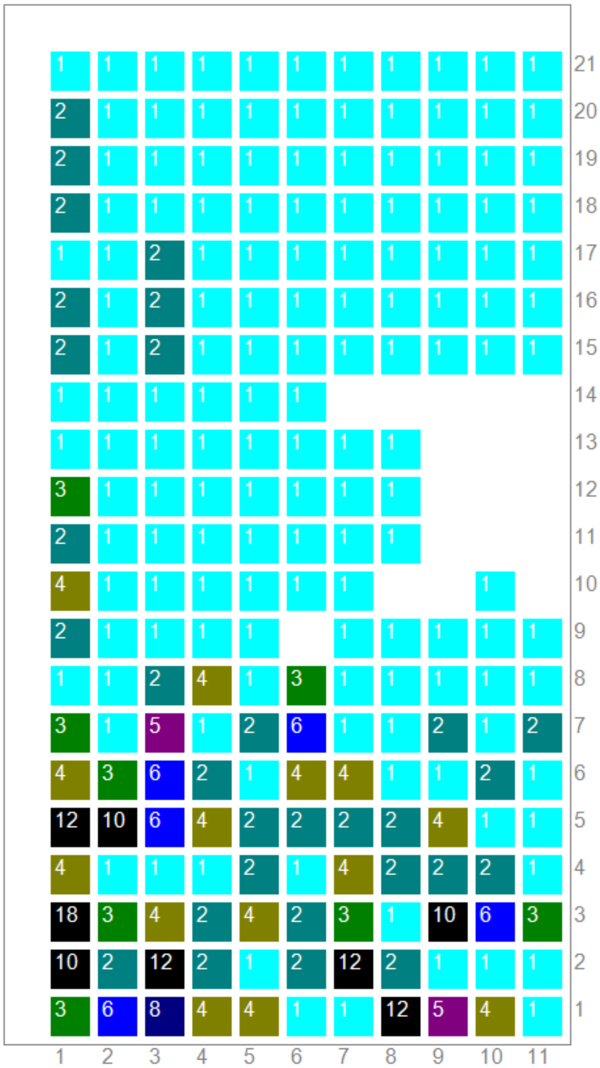
Wind Speed: 6 knots

Wind Direction: 160 degrees

Temperature: 19 degrees C

RH: 46%

Drop 6



Drop6 - Treated

Time: 01/06/2016 2:18:00 PM

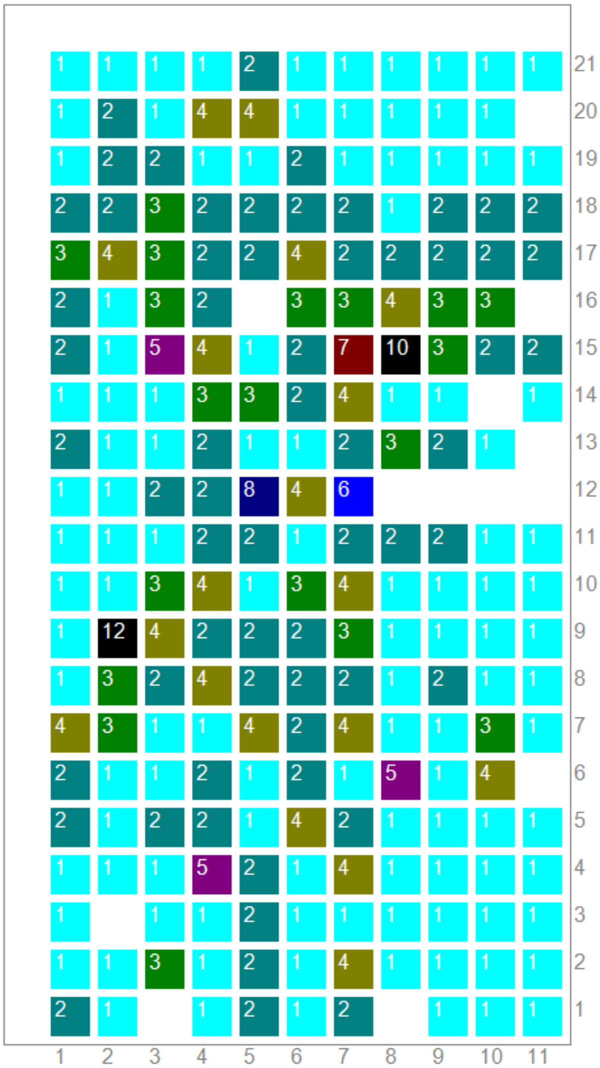
Wind Speed: 6 knots

Wind Direction: 360 degrees

Temperature: 16 degrees C

RH: 63%

Drop 7



Drop7 - Untreat

Time: 01/06/2016 2:48:00 PM

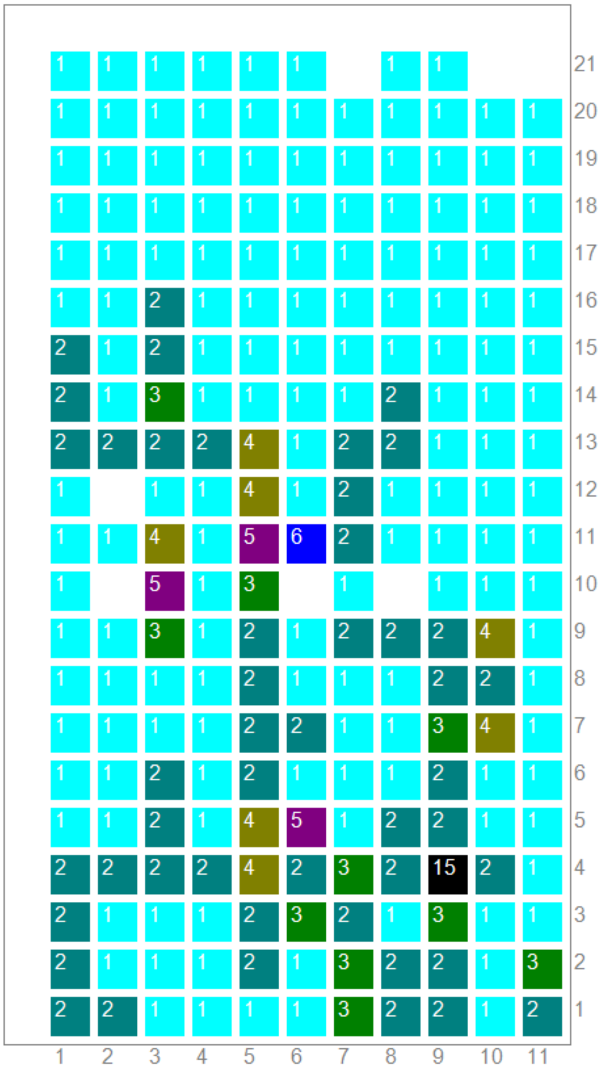
Wind Speed: 6 knots

Wind Direction: 50 degrees

Temperature: 17 degrees C

RH: 77%

Drop 8



Drop8 - Treated

Time: 01/06/2016 3:15:00 PM

Wind Speed: 5 knots

Wind Direction: 330 degrees

Temperature: 19 degrees C

RH: 71%

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