EXECUTIVE SUMMARY 2017

WEATHER MODIFICATION
INTERNATIONAL

# THE ALBERTA HAIL SUPPRESSION PROJECT

Alberta Severe Weather Managment Society

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# ALBERTA HAIL SUPPRESSION PROJECT
## EXECUTIVE SUMMARY 2017

A Program Designed for Seeding Convective Clouds
With Glaciogenic Nuclei to Mitigate Urban Hail Damage
in the Province of Alberta, Canada

by

Weather Modification LLC
3802 20th Street North
Fargo, North Dakota
U.S.A. 58102

for the

Alberta Severe Weather Management Society
Calgary, Alberta
Canada

**SEPTEMBER 2017**

## EXECUTIVE SUMMARY

This report summarizes the activities during the 2017 field operations of the Alberta Hail Suppression Project. This was the twenty-second season of operations by Weather Modification LLC, dba Weather Modification International (WMI) of Fargo, North Dakota, under contract with the Alberta Severe Weather Management Society (ASWMS) of Calgary, Alberta. This season was the second season of the latest 5-year contract cycle for this on-going program; WMI has been the contractor since operations began in 1996. The program was again directed for the ASWMS by Dr. Terry Krauss. The program continues to be funded entirely by private insurance companies in Alberta with the sole intent to mitigate the damage to urban property caused by hail.

The cloud-seeding contract with WMI was renewed in 2001, 2006, 2011, and again in 2016. Calgary, Red Deer and many of the surrounding communities have seen significant growth in population and area since 1996. Calgary's population exceeded 1 million in 2006, and property values have more than doubled since the program's inception. In 2008 it was estimated that a hail storm similar to that which caused $400 million damage in Calgary in 1991 would now cause more than $1 billion damage. New record Alberta hailstorms have recently occurred in 2009 and 2010, and in 2012, a severe storm that struck Calgary on August 12 caused more than $500 million dollars damage, indicating that a billion dollar storm within Calgary is certainly now possible.

Springbank Airport (CYBW) continued to be the southern operational base in 2017. The project design has remained the same throughout the period, but a fourth seeding aircraft (Hailstop 4) was added to the project in the summer of 2008 to increase seeding coverage on active storm days. In 2013, a fifth aircraft (Hailstop 5) was added, which is another twin-engine turboprop King Air, the same model aircraft as Hailstop 1 and 3 have been in recent seasons. This fifth aircraft was based in Springbank with Hailstop 1 and Hailstop 2. Hailstop 3 and Hailstop 4 were once again based at the Red Deer Regional Airport (CYQF).

The program was operational from June 2nd to September 15th, 2017. Operations were scheduled and intended to start on June 1st, but delays in government paperwork within the FAA and NAV Canada resulted in the approval to fly the specially-equipped seeding aircraft being delayed by one day.

Only storms that posed a hail threat to an urban area, as identified by the project's weather radar situated at the Olds-Didsbury Airport (CEA3), were seeded. The project target area covers the region from High River in the south to Ponoka in the north, with priority given to the two largest cities of Calgary and Red Deer. The project area is shown in Figure 1.

Seven industry-accredited tours of the operations centre located at the Olds-Didsbury Airport were conducted for insurance brokers and insurance company staff, as well as one tour conducted for the mayors of the towns and cities within the target area. At each, a lecture on the history and science of the hail suppression program was given, the radar facility was explained and demonstrated, and one of the five Hailstop aircraft flew in to provide first-hand observation of the seeding equipment and allow some interaction with a flight crew. A total of 145 attended in the course of the 2017 tours.

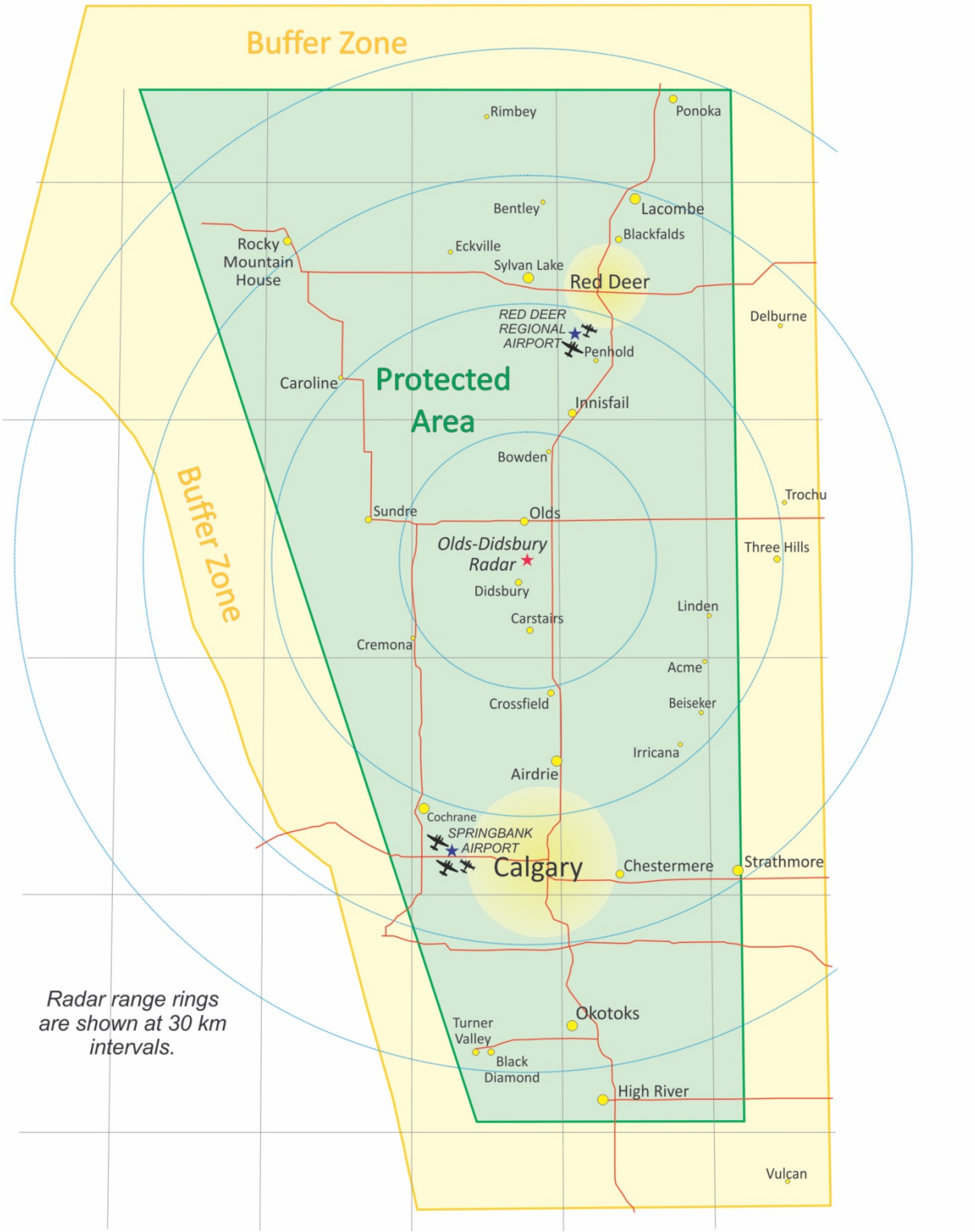


Fig. 1. Map of southern Alberta showing the project target area.

Hail was reported within the project area (protected area and buffer area) on 44 days. Larger than golf ball size hail was reported north of Olds on July 9th and on July 23rd northwest of Bashaw.

Golf ball size hail was reported or observed by radar signature on July 28th in Olds and on August 24th south of Rimbey.

Walnut size hail was reported or observed by radar signature on June 8th in Caroline; northwest of Calgary on June 27th; on July 3rd northeast of Rocky Mountain House and east of Lacombe; July 10th southeast of Lacombe; northwest of Sundre on July 12th; on the 16th of July in northwest Calgary; north of Ponoka on July 27th; July 31st southwest of Cochrane; the 10th of August in Calgary; and at Gull Lake August 13th.

The weather during the summer of 2017 produced fewer, but more intense storms (on average). Cloud bases were higher than usual, a reflection of the warmer and drier summer. There were 25 seeding days, whereas the mean is 31. A total of 107 seeding and patrol missions were flown, about average.

Of the 25 seeding days, all five Hailstop aircraft flew on eight days, and all five aircraft seeded on six of those eight days. When the weather was active, it was very active.

In June, 17 seeding missions were flown on 7 days, and an additional 13 flights flown for patrol on six days. A "patrol" flight is a flight flown to check cloud intensity or in anticipation of clouds becoming intense enough to warrant seeding, but during which no seeding was actually conducted.

July was the most active month, as is often the case. Fifty-six seeding missions were flown on 14 days, and 9 more patrol flights on 6 days. The most heavily-seeded day of the season occurred on July 23rd when two waves of strong storms moved through the northern portion of the protected area. The Red Deer area was affected by these storms, as well as Ponoka, Innisfail, and later, Rocky Mountain House. All five aircraft flew and seeded these storms. A detailed analysis of the July 23rd storm will be provided as a case study in the full version of the final report.

Activity diminished sharply after the first half of August. A total of 8 seeding missions were flown during the month, but only two of these occurred after August 14th. Two aircraft flew seeding missions on August 24th, the last seeding missions of the season.

There were thunderstorms reported within the project area on 59 days during the summer of 2017, compared with 84 days in 2016. Hail fell on 44 days, with hail of walnut size or larger on 14 days. During this season, there were 224.5 hours in flight accrued on 31 days with seeding and/or patrol operations. A total of 64 storms were seeded during 80 seeding flights on the 25 seeding days. There were 26 patrol flights, and 13 short "public relations" flights on which one aircraft was flown to the Olds-Didsbury Airport to be available for viewing by insurance company employees attending tours of the operations centre and radar. The distribution of flight time by purpose is given in Figure 2.

The amount of silver-iodide nucleating agent dispensed during the 2017 field season totaled 255.4 kg. This was dispensed in the form of 5,939 ejectable (cloud-top) flares (118.7 kg seeding agent), 842 burn-in-place (cloud-base) flares (126.3 kg seeding agent), and 170.2 gallons of silver iodide seeding solution (10.4 kg seeding agent).

Five specially equipped cloud seeding aircraft were dedicated to the project. Two Beech C90A King Airs and one Cessna 340A were based in Springbank, and a C90A and another C340A were based in Red Deer. The procedures used in 2017 remained the same as the previous years. The Springbank office and aircraft were at Springbank Aero Services, at that airport. The WMI Red Deer office was again set up in the Air Spray hangar at the Red Deer Regional Airport, as has been done in recent seasons.

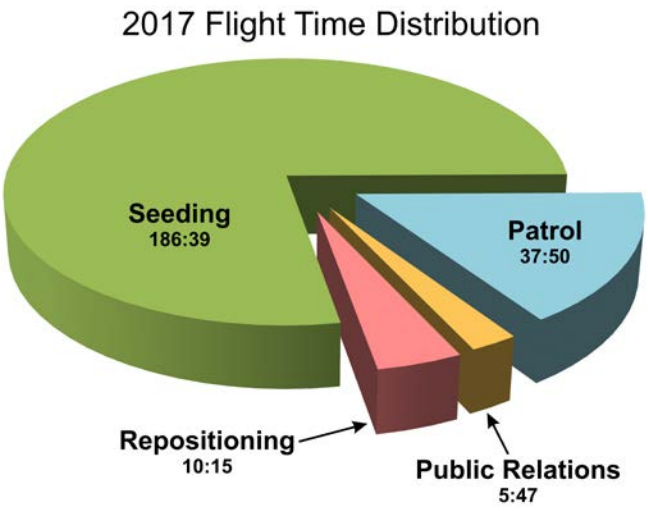


Fig. 2. The distribution of flight time during the 2017 season is shown, by purpose. "Public relations" flights were those from the aircraft's base to the Olds-Didsbury Airport on days that insurance industry continuing education training sessions were given. Times given are from takeoff to landing.

The aircraft and crews provided a 24-hour service, seven days a week throughout the period. Twelve full-time pilots and three meteorologists were assigned to the project this season. In addition, WMI's Director of Flight Operations, Mr. Jody Fischer, served as overall project manager. The 2017 crew was very experienced. The Red Deer aircraft team was led by Mr. Mike Torris, Ms. Jenelle Newman, and Mr. Joel Zimmer, who has been with the Alberta program for 15 seasons. The Springbank team was anchored by Mr. Brian Kindrat, Mr. Brook Mueller, and Mr. Andrew Brice. The radar crew was led by WMI's Chief Meteorologist, Mr. Daniel Gilbert, now with eight seasons' experience in Alberta, in addition to seven seasons' work in a similar capacity on a hail suppression program in North Dakota.

Overall, the personnel, aircraft, and radar performed well and there were no interruptions or missed opportunities. A radar calibration at the beginning of the project season ensured that during the 2017 season the radar was calibrated correctly.

High speed Internet service was once again obtained at the Springbank and Red Deer offices for the pilots so that they could closely monitor the storm evolution and storm motion using the radar images on the web prior to take-off. All of the project's radar data, meteorological data, and reports have been recorded onto a portable hard drive as a permanent archive for the Alberta Severe Weather Management Society. These data include the daily reports, radar maps, aircraft flight tracks, as well as meteorological charts for each day. The data can be made available for outside research purposes through a special request to the Alberta Severe Weather Management Society. In addition, the season's radar (TITAN) data are available to ASWMS Program Director Dr. Terry Krauss. Thus, Dr. Krauss has access to all data in the off-season, should the need arise.

### *Comparison of 2017 with Previous Years*

Table 1 gives a list of the operational statistics for all twenty-two seasons of the Alberta Hail Suppression Project. These statistics can be useful in understanding how the current season compared with those before, and for planning purposes. The 2017 summer ranked tenth all-time in terms of activity. Seeding occurred on 25 days [mean is 31 days, record (2011) was 48 days]; 107 project missions were flown for patrol and seeding.

**Seeding Activity by Season 1996-2017**

| Season | Storm Days With Seeding | Aircraft Missions (Seeding & Patrol) | Total Flight Time (hours) | Number of Storms Seeded | Total Seeding Agent (kg) | Seeding Agent Per Day (kg) | Seeding Agent Per Hour (kg) | Seeding Agent Per Storm (kg) | Ejectable Flares | Burn-in-place Flares | Seeding Solutions (gallons) | Season Activity Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2017** | 25 | 107 | 224.5 | 64 | 255.4 | 10.2 | 1.14 | 3.99 | 5939 | 842 | 170.2 | 10 |
| **Mean** | **31** | **105** | **216.2** | **91** | **220.1** | **7.1** | **1.03** | **2.52** | **5274** | **689** | **166.8** | |
| 2016 | 35 | 139 | 277.1 | 96 | 294.9 | 8.4 | 1.06 | 3.07 | 6496 | 1000 | 246.9 | 6 |
| 2015 | 26 | 115 | 233.3 | 79 | 349.2 | 14.6 | 1.37 | 4.42 | 8127 | 1138 | 262.9 | 8 |
| 2014 | 32 | 128 | 259.5 | 101 | 382.5 | 12.0 | 1.47 | 3.79 | 10782 | 1020 | 228.6 | 3 |
| 2013 | 26 | 103 | 229.6 | 70 | 233.3 | 9.0 | 1.02 | 3.33 | 6311 | 636 | 131.7 | 13 |
| 2012 | 37 | 143 | 300.1 | 116 | 314.6 | 8.5 | 1.16 | 2.70 | 7717 | 914 | 260.3 | 2 |
| 2011 | 48 | 158 | 383.0 | 134 | 400.1 | 8.3 | 1.13 | 3.00 | 10779 | 1020 | 350.2 | 1 |
| 2010 | 42 | 115 | 271.8 | 118 | 263.8 | 6.3 | 1.10 | 2.20 | 5837 | 851 | 227.5 | 7 |
| 2009 | 20 | 38 | 109.3 | 30 | 48.4 | 2.4 | 0.84 | 1.60 | 451 | 237 | 56.5 | 22 |
| 2008 | 26 | 112 | 194.7 | 56 | 122.9 | 4.7 | 1.00 | 2.20 | 1648 | 548 | 113.5 | 17 |
| 2007 | 19 | 76 | 115.3 | 41 | 99.7 | 5.2 | 0.90 | 2.40 | 1622 | 413 | 77 | 21 |
| 2006 | 28 | 92 | 190.2 | 65 | 214 | 7.6 | 1.10 | 3.30 | 4929 | 703 | 145.4 | 14 |
| 2005 | 27 | 80 | 157.9 | 70 | 159.1 | 5.9 | 1.00 | 2.30 | 3770 | 515 | 94.2 | 19 |
| 2004 | 29 | 105 | 227.5 | 90 | 270.9 | 9.3 | 1.20 | 3.00 | 6513 | 877 | 132.7 | 9 |
| 2003 | 26 | 92 | 163.6 | 79 | 173.4 | 6.7 | 1.10 | 2.20 | 4465 | 518 | 92.6 | 16 |
| 2002 | 27 | 92 | 157.4 | 54 | 124.2 | 4.6 | 0.80 | 2.30 | 3108 | 377 | 80.3 | 20 |
| 2001 | 36 | 109 | 208.3 | 98 | 195 | 5.4 | 0.90 | 2.00 | 5225 | 533 | 140.8 | 11 |
| 2000 | 33 | 130 | 265.2 | 136 | 343.8 | 10.4 | 1.30 | 2.50 | 9653 | 940 | 141.3 | 4 |
| 1999 | 39 | 118 | 251.3 | 162 | 212.7 | 5.5 | 0.80 | 1.30 | 4439 | 690 | 297.5 | 5 |
| 1998 | 31 | 96 | 189.9 | 153 | 111.1 | 3.6 | 0.60 | 0.70 | 2023 | 496 | 193.8 | 12 |
| 1997* | 38 | 92 | 188.1 | 108 | 110.8 | 2.9 | 0.60 | 1.00 | 2376 | 356 | 144.3 | 15 |
| 1996* | 29 | 71 | 159.1 | 75 | 163.3 | 5.6 | 1.00 | 2.20 | 3817 | 542 | 80.5 | 18 |

**The 1996 and 1997 seasons began on June 15, not June 1, which has been the norm ever since.*

Table 1. Operational statistics for seeding and patrol flights, 1996 through 2017.

The *Season Activity Rank* shown at the far right of Table 1 was calculated as follows: Each parameter for each year was divided by the project mean for that parameter to produce a normalized value. Then, the normalized values of *Storm Days with Seeding*, *Aircraft Missions*, *Total Flight Time*, *Number of Storms Seeded*, *Ejectable Flares*, *BIP Flares*, and *Seeding Solution* were summed for each season. The seasons were then ranked. *Total Seeding Agent*, *Seeding Agent per Day*, *Seeding Agent per Hour*, and *Seeding Agent per Storm* were not included in the ranking as those are all quantities derived from the others.

A summary of the flare usage, by aircraft, during the 22 seasons is given in Table 2. The Cessna 340s (Hailstop 2 and Hailstop 4) are used mainly as cloud base seeding aircraft because they have lesser performance than the three turbine aircraft and are equipped with the liquid AgI solution burners. Hailstop 1 (Calgary and Springbank) had been a Piper Cheyenne II for all 15 seasons through 2010, but was replaced with a Beech C90 King Air beginning with the 2011 season. The King Airs are newer, have the same engines as the Cheyenne (the Pratt and Whitney of Canada PT-6A), and parts are more readily available. Hailstop 2, based in Springbank, has been a Cessna 340A for the project duration. Hailstop 3 in Red Deer was a C340 for 4 years (1996-99), a Cheyenne II in 2000, 2003 and 2005, and a King Air C90 in 2004, and now from 2006 to present. The advantages of the C90 are that it has slightly longer endurance for increased seeding time, and good performance for reaching the far western regions of the target area in a reasonable amount of time (*i.e.* less than 30 min). The second C340, Hailstop 4, was added in 2008 and based in Red Deer. This was the fourth season for Hailstop 5, a third King Air C90, which was added to the project in 2013, based at Springbank.

There were no aircraft maintenance issues that impacted operations. Scheduled maintenance (fifty-hour inspections) was conducted on a non-interference basis with flight operations.

The best seeding coverage consists of seeding a storm simultaneously using two aircraft; one at cloud base and another at cloud top (-5 to -10°C) along the upwind "new growth" side of the storm. The King Air aircraft have proven themselves as excellent cloud-top seeders. The seeding strategy has been to stagger the launch of the seeding aircraft, and use one aircraft to seed at cloud base and one aircraft at cloud top when the storm is immediately upwind or over the highest priority areas. However, if multiple storms threaten three or more areas at the same time, generally only one aircraft is used on each storm, or more aircraft are concentrated on the highest population area around Calgary.

Seeding was conducted on the following 25 days: June 2$^{nd}$, 9$^{th}$, 16$^{th}$, 20$^{th}$, 21$^{st}$, 27$^{th}$, and , 28$^{th}$; July 1$^{st}$, 3$^{rd}$, 7$^{th}$, 8$^{th}$, 9$^{th}$, 10$^{th}$, 12$^{th}$, 16$^{th}$, 20$^{th}$, 23$^{rd}$, 27$^{th}$, 28$^{th}$, 30$^{th}$, and 31$^{st}$; August 7$^{th}$, 13$^{th}$, 14$^{th}$, and 24$^{th}$. No seeding was conducted in September.

All five aircraft were used for operations (seeding and/or patrol) on the following 8 days (local time) this season: June 9$^{th}$, and 27$^{th}$; July 1$^{st}$, 3$^{rd}$, 9$^{th}$, 12$^{th}$, 23$^{rd}$ and 28$^{th}$. Patrol flights were flown on June 12$^{th}$, 14$^{th}$, 16$^{th}$, 20$^{th}$, 26$^{th}$ and 27$^{th}$; July 8$^{th}$, 9$^{th}$, 10$^{th}$, 12$^{th}$, 13$^{th}$, 23$^{rd}$, and 27$^{th}$; and August 7$^{th}$, 10$^{th}$, 13$^{th}$, and 23$^{rd}$. No patrol missions were flown in September. Flight operations are summarized in Figure 3.

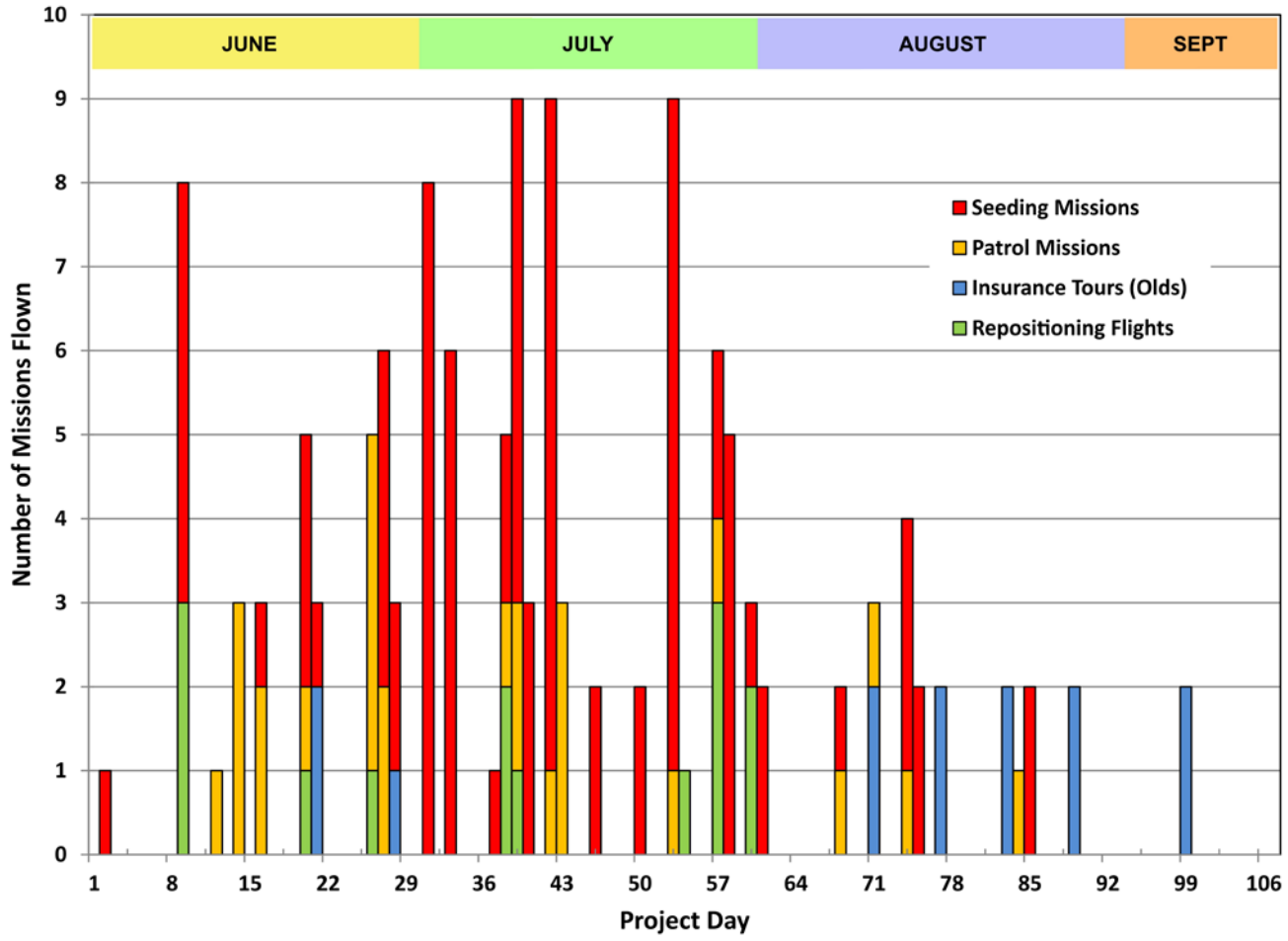


Fig. 3. The number of flights, by type, is shown for each project day of the 2017 season. Months are shown at the top of the graphic. The "Insurance Tours" flights were those made to the Operations Centre at the Olds-Didsbury Airport for the seven continuing education training sessions certified by the Alberta Insurance Industry. On one of the seven days only one flight is shown in this category because weather developed that caused the departing flight to be a seeding flight.

| ***AIRCRAFT LEGEND:*** | C340 | CESSNA 340A | C90 | BEECH KING AIR C90 | CHEY | PIPER CHEYENNE II |
|---|---|---|---|---|---|---|

**hours = flight hours, EJ = ejectable pyrotechnic, BIP = burn-in-place pyrotechnic, gen hr = hours wingtip solution-burning seeding time**

| SEASON | Hailstop 1 | | Hailstop 2 | | Hailstop 3 | | Hailstop 4 | | Hailstop 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Springbank (Calgary prior to 2012) | | Springbank (Calgary prior to 2012) | | Red Deer | | Red Deer | | Springbank | |
| | FLIGHT HOURS, EJ FLARES, BIP FLARES | | FLIGHT HOURS, EJ FLARES, BIP FLARES, GEN HOURS | | FLIGHT HOURS, EJ FLARES, BIP FLARES | | FLIGHT HOURS, EJ FLARES, BIP FLARES, GEN HOURS | | FLIGHT HOURS, EJ FLARES, BIP FLARES | |
| 2017 | C90 | 52 hours, 2071 EJ, 201 BIP | C340 | 57 hours, 0 EJ, 152 BIP, 47 gen hr | C90 | 39 hours, 2354 EJ, 203 BIP | C340 | 56 hours, 0 EJ, 117 BIP, 38 gen hr | C90 | 45 hours, 1514 EJ, 169 BIP |
| 2016 | C90 | 62 hours, 2460 EJ, 183 BIP | C340 | 78 hours, 0 EJ, 296 BIP, 82 gen hr | C90 | 49 hours, 1989 EJ, 164 BIP | C340 | 54 hours, 0 EJ, 132 BIP, 42 gen hr | C90 | 59 hours, 2047 EJ, 225 BIP |
| 2015 | C90 | 55 hours, 2798 EJ, 230 BIP | C340 | 76 hours, 0 EJ, 272 BIP, 76 gen hr | C90 | 47 hours, 2845 EJ, 208 BIP | C340 | 61 hours, 0 EJ, 199 BIP, 55 gen hr | C90 | 46 hours, 2484 EJ, 229 BIP |
| 2014 | C90 | 71 hours, 3554 EJ, 268 BIP | C340 | 60 hours, 0 EJ, 198 BIP, 57 gen hr | C90 | 41 hours, 3558 EJ, 207 BIP | C340 | 64 hours, 90 EJ, 190 BIP, 58 gen hr | C90 | 72 hours, 3580 EJ, 157 BIP |
| 2013 | C90 | 41 hours, 1149 EJ, 115 BIP | C340 | 58 hours, 0 EJ, 148 BIP, 37 gen hr | C90 | 42 hours, 3381 EJ, 166 BIP | C340 | 48 hours, 0 EJ, 78 BIP, 31 gen hr | C90 | 40 hours, 1781 EJ, 129 BIP |
| 2012 | C90 | 76 hours, 3250 EJ, 232 BIP | C340 | 87 hours, 0 EJ, 224 BIP, 72 gen hr | C90 | 83 hours, 4464 EJ, 198 BIP | C340 | 85 hours, 3 EJ, 260 BIP, 63 gen hr | | |
| 2011 | C90 | 97 hours, 4783 EJ, 239 BIP | C340 | 105 hours, 244 EJ, 269 BIP, 91 gen hr | C90 | 99 hours, 5646 EJ, 273 BIP | C340 | 108 hours, 106 EJ, 239 BIP, 92 gen hr | | |
| 2010 | CHEY | 62 hours, 1612 EJ, 132 BIP | C340 | 82 hours, 74 EJ, 236 BIP, 53 gen hr | C90 | 96 hours, 4154 EJ, 200 BIP | C340 | 68 hours, 2 EJ, 286 BIP, 64 gen hr | | |
| 2009 | CHEY | 22 hours, 250 EJ, 27 BIP | C340 | 31 hours, 0 EJ, 65 BIP, 6 gen hr | C90 | 24 hours, 201 EJ, 48 BIP | C340 | 33 hours, 0 EJ, 97 BIP, 17 gen hr | | |
| 2008 | CHEY | 65 hours, 953 EJ, 88 BIP | C340 | 44 hours, 0 EJ, 171 BIP, 27 gen hr | C90 | 51 hours, 695 EJ, 169 BIP | C340 | 35 hours, 0 EJ, 120 BIP, 19 gen hr | | |
| 2007 | CHEY | 40 hours, 979 EJ, 81 BIP | C340 | 41 hours, 0 EJ, 155 BIP, 31 gen hr | C90 | 34 hours, 643 EJ, 177 BIP | | | | |
| 2006 | CHEY | 54 hours, 3217 EJ, 179 BIP | C340 | 70 hours, 72 EJ, 248 BIP, 58 gen hr | C90 | 66 hours, 1640 EJ, 276 BIP | | | | |
| 2005 | CHEY | 49 hours, 2750 EJ, 169 BIP | C340 | 45 hours, 0 EJ, 121 BIP, 38 gen hr | CHEY | 64 hours, 1020 EJ, 225 BIP | | | | |
| 2004 | CHEY | 83 hours, 5574 EJ, 359 BIP | C340 | 62 hours, 0 EJ, 196 BIP, 53 gen hr | C90 | 82 hours, 939 EJ, 322 BIP | | | | |
| 2003 | CHEY | 64 hours, 3598 EJ, 250 BIP | C340 | 54 hours, 0 EJ, 130 BIP, 37 gen hr | CHEY | 46 hours, 867 EJ, 138 BIP | | | | |
| 2002 | CHEY | 57 hours, 1994 EJ, 163 BIP | C340 | 49 hours, 2 EJ, 73 BIP, 32 gen hr | CHEY | 51 hours, 1112 EJ, 141 BIP | | | | |
| 2001 | CHEY | 62 hours, 3174 EJ, 216 BIP | C340 | 75 hours, 4 EJ, 215 BIP, 56 gen hr | CHEY | 68 hours, 2093 EJ, 102 BIP | | | | |
| 2000 | CHEY | 90 hours, 4755 EJ, 379 BIP | C340 | 77 hours, 164 EJ, 193 BIP, 56 gen hr | CHEY | 97 hours, 4734 EJ, 368 BIP | | | | |
| 1999 | CHEY | 91 hours, 3795 EJ, 313 BIP | C340 | 81 hours, 244 EJ, 197 BIP, 60 gen hr | C340 | 79 hours, 400 EJ, 180 BIP, 59 gen hr | | | | |
| 1998 | CHEY | 62 hours, 1880 EJ, 107 BIP | C340 | 68 hours, 134 EJ, 199 BIP, 29 gen hr | C340 | 59 hours, 9 EJ, 190 BIP, 48 gen hr | | | | |
| 1997 | CHEY | 70 hours, 1828 EJ, 62 BIP | C340 | 58 hours, 264 EJ, 128 BIP, 26 gen hr | C340 | 60 hours, 284 EJ, 166 BIP, 32 gen hr | | | | |
| 1996 | CHEY | 62 hours, 2128 EJ, 143 BIP | C340 | 46 hours, 895 EJ, 192 BIP, 9 gen hr | C340 | 52 hours, 794 EJ, 207 BIP, 23 gen hr | | | | |

Table 2. Cloud seeding pyrotechnic and seeding solution usage by aircraft, through the 2017 season.

### *Storm Tracks*

A map of all hailstorm tracks (representative of grape-size ail and larger, determined by radar) during 2017 is shown in Figure 4. July was the stormiest month, which is the climatological normal. There were just four storms that tracked across or within the city limits of Calgary during the 2017 season. The 2017 season was somewhat unusual, in that while the total number of storms was lower than in most recent seasons, storm intensity was not abated. Also, the northern half of the protected area experienced significantly more storms than the south. The northern storms tended to be long-track events, while the opposite was true at the lower latitudes. The most damaging storm of the season occurred on July 23rd. This storm day is reviewed in detail in the full final report.

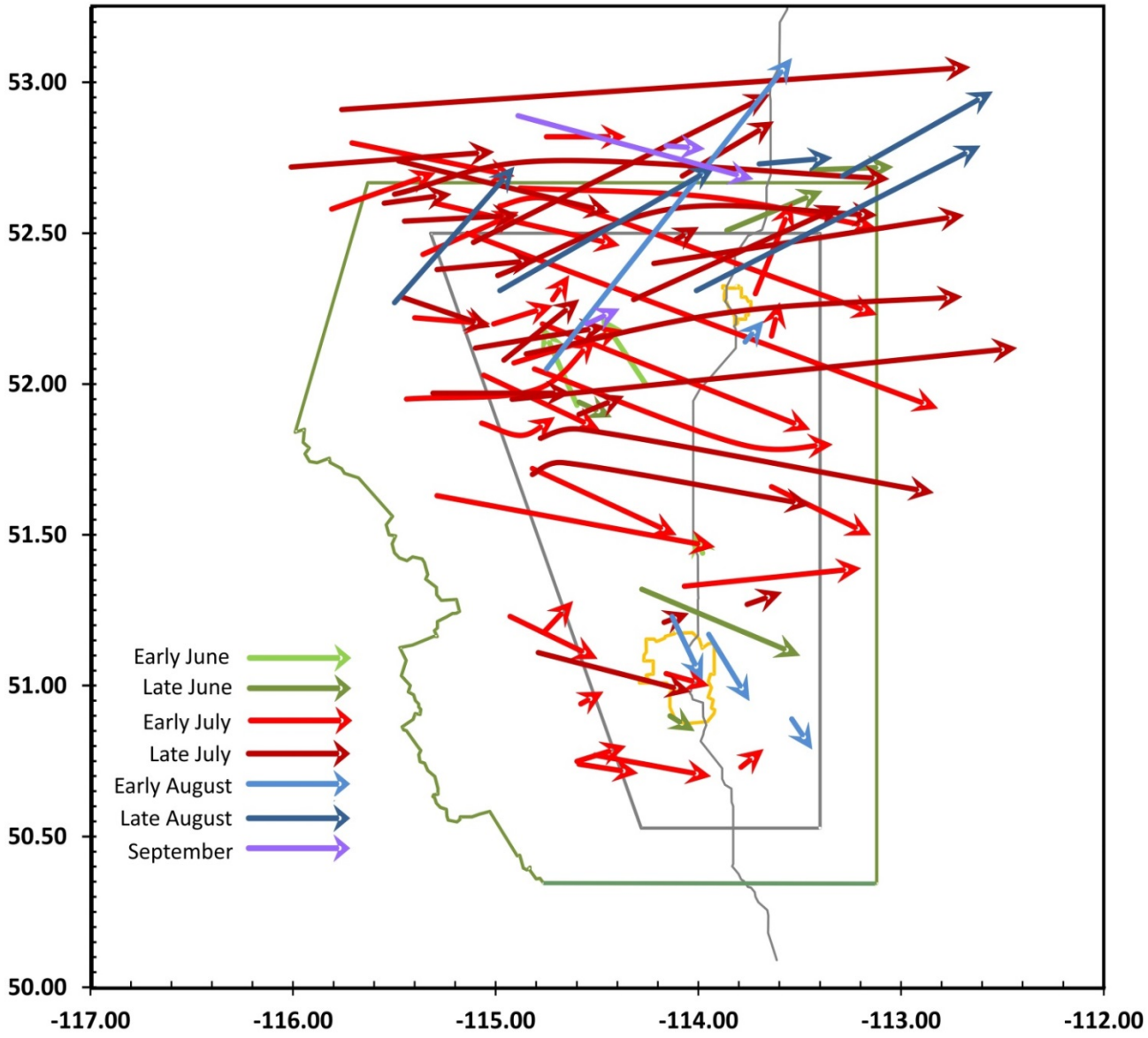


Fig. 4. Map of all potential hailstorm tracks within radar coverage during 2017, as indicated by a minimum vertically-integrated liquid (VIL, from the radar) of at least 30 kg/m$^2$. This map shows all of the 64 storms seeded, plus others of hail potential that did not move near cities or towns. All storms must be carefully monitored because as the tracks show, direction of movement often changes. June storms are green, July red, August blue, and September, violet. For each month, the lighter color denotes storms that occurred during the first half of that month.

The number and distribution of storm tracks during 2017 were similar to previous seasons, with July getting honors for being the most active month. Activity waned sharply after mid-August. No seeding or patrol missions were flown in September. The storm tracks plotted in Figure 4 include more than just start and end points. Whenever storms turned appreciably during their lifetimes this is shown. Nevertheless, an unusually large fraction of the storms had more-or-less linear tracks. Month-by-month storm track plots are included in the full final report.

### *Seeding Amounts*

The amount of AgI dispensed on each day of operations in 2017 is shown in Figure 5. There were 10 days on which more than 10 kg (10,000 grams) of seeding material was dispensed, just one fewer than 2016. All of these were days on which a least four of the five Hailstop aircraft flew; on six of those days all five aircraft seeded. The amount of seeding agent dispensed per storm (3.99 kg) was well above the project mean (2.52 kg), a testament to 2017 storm intensity and duration. This was still well below the 2015 value pf 4.42 kg per storm, the highest of any season to date. The benefits of having five aircraft continue to be realized. This is especially demonstrated on those days when convection is widespread; more storms can be effectively treated.

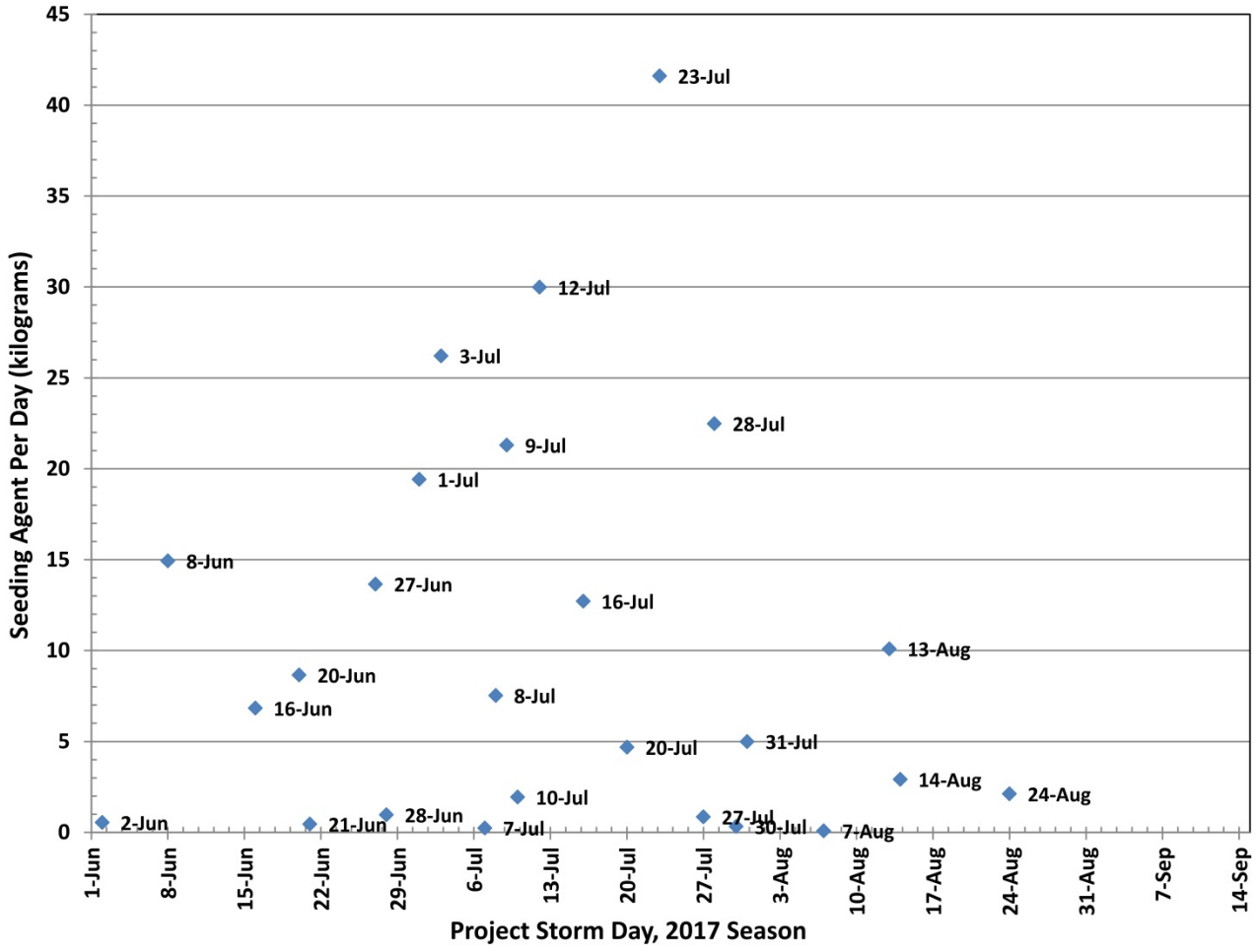


Fig. 5. Amount of seeding agent (silver iodide, AgI) dispensed per operational day, 2017.

## CONCLUSIONS

The 2017 field program ran smoothly, except the administrative delays within the Canadian government that resulted in operations beginning on June 2nd, rather than the scheduled June 1st date. All storms worthy of treatment according to the current operational guidelines were seeded in a timely way. The most significant storm day of the season was July 23rd when all five aircraft seeded, and some flew multiple missions. Numerous strong, storms, many having supercell characteristics, blossomed over the project area during the afternoon and evening, threatening northern cities. A detailed storm summary of this day is included in the full final report.

Aircraft maintenance was mostly routine; no aircraft was in maintenance for more than a day through the entire season.

The storm frequency was near normal; the season ranked tenth in terms of seeding activity. Having the fifth aircraft available allowed the project Lead Meteorologist to increase aircraft coverage when long-lived storms moved through or near a succession of municipalities, and to seed earlier at sustained, effective rates when severe storms threatened high priority cities and towns. Overall, it was a good year.

Bruce Boe, Vice President - Meteorology
Daniel Gilbert, Chief Meteorologist, Alberta Lead Meteorologist
Bradley Waller, Field Meteorologist
Adam Brainard, Field Meteorologist
Jody Fischer, Director of Flight Operations

September 2017