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Cloud seeding operations in 2022 began over the EAA target area in April. This annual report serves as a summary of the results. A total of **57 clouds** were seeded and identified by TITAN in **27 operational days**. Table 1 on page 1 summarizes the general figures:

Table 1: Generalities

First operational day: **April 12th, 2022**
Last operational day: **September 7th, 2022**

Number of operational days: 27
(Four in April, two in May, three in June, nine in July, eight in August, and one in September)

According to the daily reports, operational days were qualified as:

Fifteen with excellent performance
Four with very good performance
Three with good performance

Five with technical problems (no TITAN data)

Number of seeded and identified clouds: 57
(37 small-seeded clouds, 13 large-seeded clouds, 7 type B-seeded clouds)

Missed Opportunities: one (with a lifetime longer than 1 hour)

July 22nd: **# 729 over Medina County** (18:00 – 20:30 UTC)

Small Clouds

Evaluations were done using TITAN and NEXRAD data.

Table 2 shows the results from the classic TITAN evaluation for the 37 small-seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (37 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	50 min	35 min	1.43	43 (28)
Area	56.6 km ²	29.1 km ²	1.95	95 (31)
Volume	201.6 km ³	83.5 km ³	2.41	141 (35)
Top Height	9.0 km	8.0 km	1.13	13 (5)
Max dBz	51.9	49.9	1.04	4 (2)
Top Height of max dBz	3.6 km	3.6 km	1.00	0 (- 3)
Volume Above 6 km	58.2 km ³	13.0 km ³	4.48	348 (60)
Prec.Flux	491.9 m ³ /s	187.2 m ³ /s	2.63	163 (74)
Prec.Mass	1736.1 kton	420.8 kton	4.13	313 (149)
CloudMass	191.9 kton	67.3 kton	2.85	185 (40)
η	9.0	6.3	1.43	43 (76)

Bold values in parentheses are modeled values, whereas **η** is defined as the quotient of Precipitation Mass divided by Cloud Mass and is interpreted as efficiency. A total of 244 AgI-BIP and 38 hygroscopic flares were used in this sub-sample with good timing (**71 %**) for an average effective silver iodide dose of about **85 ice-nuclei per liter**. The seeding operations lasted on average about 10 minutes. An excellent increase of **149 %** in precipitation mass, together with a **40 %** increase in cloud mass illustrates that the seeded clouds grew at expense of the environmental moisture (they are open systems) and used only a fraction of this moisture for their own maintenance. The increases in lifetime (28 %), area (31 %), volume (35 %), volume above 6 km (60 %), and precipitation flux (74 %) are

noticeable. There were small increases in maximum reflectivity (2 %) and in top height (5 %). The seeded sub-sample seemed 76 % more efficient than the control sub-sample. Results are evaluated as **very good for this sample**.

An increase of **149 %** in precipitation mass for a control value of 420.8 kton in 37 cases means:

$$\Delta^1 = 37 \times 1.49 \times 420.8 \text{ kton} \approx 23\,199 \text{ kton} \approx 18\,814 \text{ ac-f (layer: 11.1 mm} \approx 0.44 \text{ in)}$$

Large Clouds

The sub-sample of 13 large-seeded clouds received a synergetic analysis. On average, the seeding operations on these large clouds affected 70 % of their whole volume with perfect timing (100 % of the material went to the clouds in their first half-lifetime). A total of 171 AgI-BIP and 20 hygroscopic flares were used in this sub-sample for an effective glaciogenic dose of about **20 ice nuclei per liter**.

Also, on average, large clouds were 30 minutes old when the operations took place; the operation lasted about 20 minutes, and the large-seeded clouds lived 210 minutes.

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (13 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	210 min	175 min	1.20	20
Area	254 km ²	210 km ²	1.21	21
Prec.Mass	32 764 kton	20 350 kton	1.61	61

An increase of 61 % in precipitation mass for a control value of 20 350 kton in 13 cases may mean:

$$\Delta^2 = 13 \times 0.61 \times 20\,350 \text{ kton} \approx 161\,376 \text{ kton} \approx 130\,876 \text{ ac-f}$$

(Layer: 48.9 mm $\approx$ 1.9 in)

Type B Clouds

Seven type B clouds were initially seeded over EAA target area during the season. On average, the seeding operations on these type B clouds affected 12 % of their whole volume with very good timing (81 % of the material went to the clouds in their first half-lifetime). A total of 69 AgI-BIP flares and 14 hygroscopic flares were used in this sub-sample for an effective dose of about **45 ice nuclei per liter**.

Also, on average, these type B clouds were 85 minutes old when the operations took place; the operation lasted about 5 minutes, and the B-seeded clouds lived 240 minutes.

Table 4: Type B Seeded Sample versus Virtual Control Sample (7 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	240 min	220 min	1.09	9
Area	670 km ²	640 km ²	1.04	4
Prec.Mass	259 303 kton	235 730 kton	1.10	10

$$\Delta^3 = 7 \times 0.10 \times 235\,730 \text{ kton} \approx 165\,011 \text{ kton} \approx 133\,824 \text{ ac-f}$$

(Layer: 22.9 mm $\approx$ 0.9 in)

$$\text{The total increase: } \Delta = \Delta^1 + \Delta^2 + \Delta^3 = 283\,514 \text{ ac-f}$$

(508 ac-f/small, 10 067 ac-f/large, 19 118 ac-f/B)

Micro-regionalization

Increases in precipitation mass were analyzed county by county in an attempt to better describe the performance and corresponding results. **Table 5** below offers the details:

County Seeding	Initial Seeding	Extended (increase)	Acre-feet (increase)	Inches (increase)	Rain gage (season value*)	% (increase)
Uvalde	11	16	74 600	0.89	11.63 in	7.7
Bandera	19	23	37 200	1.01	8.99 in	11.2
Medina	14	18	34 200	0.46	5.98 in	7.8
Bexar	11	15	47 200	0.70	5.48 in	12.8
Subtotal			193 200			
Outside (downwind effects)			~ 90 300			
Total			283 500			
Average				0.77 in	8.02 in	9.9 %

(**Initial seeding** means the number of clouds seeded when the operations began; whereas **extended seeding** means the counties favored by seeding after the initial operations took place.

*** Seasonal precipitation values: April-August 2022 (no TITAN data in September)**

Final Comments

- Results are evaluated as **excellent**.
average timing: **80 %**, average dose: **65 icn/L**; missed opp.: **1**
- The micro-regionalization analysis showed increases per county; different zones received downwind benefits; the average increase in precipitation, referred to as rain gauge seasonal value, is about **10 %**
- Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, seeding operations improved the dynamics of the seeded storms.
- In 2022, the total increase in the region, estimated in 0.19 million acre-feet, should be considered a great help to the freshwater natural resources.