Utah Cloud Seeding Program

Increased Runoff and Cost Analyses

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Introduction

Cloud seeding initially began in Utah in the early 1950's, and in 1973, the legislature passed the Utah Cloud Seeding Act that determined the ownership of water to be considered as part of Utah's basic water supply. The Cloud Seeding Act of 1973 also gave the authority to the Utah Division of Water Resources to be the only entity to license contractors and permit cloud seeding projects in the state of Utah.

The Utah Division of Water Resources has provided financial assistance to the sponsors since 1976. From 1976 to 1981, the total cost of cloud seeding was shared between the State and local sponsors, where the State funded 70% of the projects and the local sponsors covered the remaining 30%. Due to the extremely wet seasons, and the economic downturn in the early 1980's, the funding was limited until 1989. However, in 1991, the State Legislature authorized the Utah Division of Water Resources to fund up to half the cost of cloud seeding projects, or $150,000 each year from the Revolving Construction Fund from the Division. Even more funding was allocated to the cloud seeding projects in 2007 when the State Legislature appropriated an additional $150,000 from the sales tax funds. This allocation totals the cloud seeding funds to $300,000 from the State, which is limited by 50% of the total project cost.

Currently there are five sponsored projects: the Central and Southern Utah project areas, the Northern Utah project areas, the West Uintas project area, the High Uintas project area and the Emery propane project area (Figure 1). The Northern Utah project, comprised of the West Box Elder and the East Box Elder/Cache County areas, is sponsored by the Bear River Water Conservancy District and Cache County. The Central and Southern Utah Project, comprised of Central/Southern Utah and Tooele County areas, is sponsored by the Utah Water Resources Development Corporation. The West Uinta Project is sponsored by the Weber Basin Water Conservancy District, Provo River Water Conservancy District, and Central Utah Water Conservancy District. The High Uinta project is sponsored by the Central Utah Water Conservancy District, the Duchesne County Water Conservancy District, and the Uintah Water Conservancy District. The extended seeding periods in November and April for the High Uintas and Central/Southern Utah programs are funded by the Lower Colorado River Basin States in an effort

to augment water supply to the Colorado River. The contractor for all of the silver iodide projects is North American Weather Consultants located in Sandy, Utah.

Most of the cloud seeding programs in Utah operate during the December-March period with the exception of the High Uinta and Central and Southern Utah project which run longer. Starting in 2007, the Lower Colorado River Basin States (California, Arizona and Nevada) have funded an extensions of the cloud seeding period in the High Uinta project (November 1-30) and the Central and Southern Utah project (November 1-15 and March 16-April 15). For the 2014-2015 season, the cost for the Northern Utah Project was $81,929; the cost for the Central and Southern Utah Project was $169,359; the cost for the Western Uinta Project was $69,753; and the cost for the High Uinta Project was $86,758. That is a total of $407,798. The Division of Water Resources cost shared with the local sponsors at 50% ($203,899). The Lower Basin contributions to projects amounts to a total of $118,068, which adjusts the grand total cost to be $525,866.

The purpose of this report is to estimate an increased runoff due to cloud seeding and cost per acre-foot of water. The projects considered for this analysis include only the silver iodide projects. This analysis is based on the commonly used "target and control comparison" method, and comprises the following general steps:

1. Estimate the total average annual runoff from the seeded areas
2. Determine the relationship (linear regression) between annual runoff and April 1st snow water content for major gaged rivers and streams in the target areas
3. Estimate the increase in April 1st snow water content due to cloud seeding based on target and control analysis
4. Estimate the increase in average annual runoff due to cloud seeding based on 1, 2, and 3 above
5. Compute the estimated cost per acre-foot by dividing the project cost by the increase in average annual runoff determined in 4 above

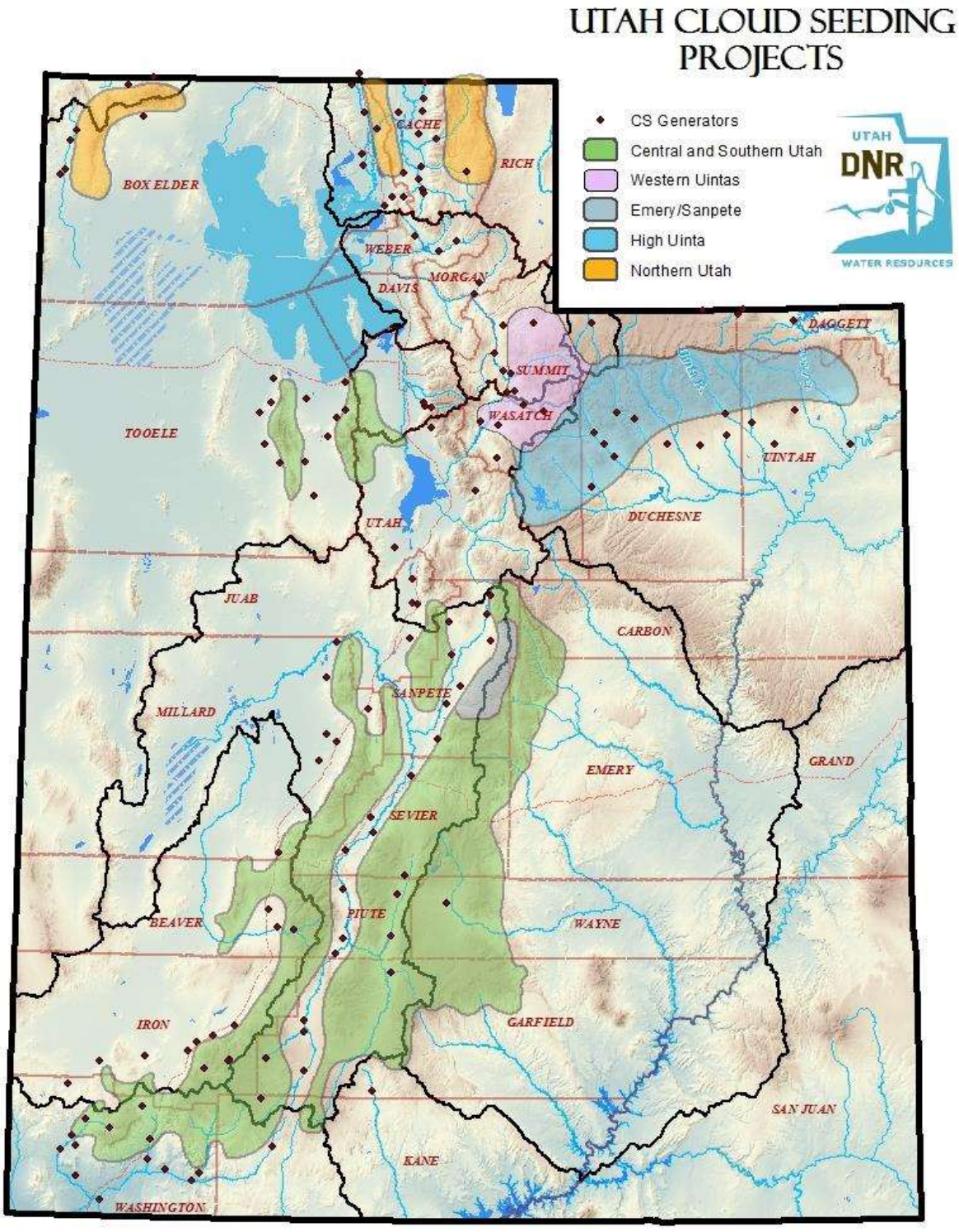

Figure 1. Current Cloud Seeding Project Areas and Generators

Average Annual Runoff in the Cloud Seeding Project Areas

To determine the amount of increased runoff due to cloud seeding, it was necessary to estimate the average annual runoff in the different project areas. The Utah Division of Water Resources has published annual stream flow charts for the 1941-1990 period for most streams in the State (Appendix A). Based on data from these charts and hydrologic inventories, the average annual runoff for the 50-year period has been estimated for the cloud seeding project areas. A summary of the estimated annual average runoff is listed in Table 1.

Table 1. Cloud Seeding Project Areas and Estimated Average Annual Runoff (1941-1990)

Project Runoff Areas	Project	Annual Runoff (acre-feet)
Cache County	NUP	424,000
West Box Elder	NUP	57,800
Tooele County	CSUP	43,300
Sevier River	CSUP	653,000
Cedar-Beaver	CSUP	135,000
West Colorado	CSUP	411,500
Virgin River	CSUP	192,400
Western Uinta	WUP	492,000
High Uinta	HUP	773,300
Total		3,181,500
Northern Utah Project		481,800
Central and Southern Utah Project		1,435,200
Western Uinta Project		492,000
High Uinta Project		773,300

Precipitation Increase

As indicated, the increase in precipitation due to cloud seeding is determined by using a technique called target and control comparison analysis. The technique is based on variables that are affected by cloud seeding such as precipitation and snowpack. The control sites are unseeded areas located upwind from the target sites. The target and control analyses have been made and published by North American Weather Consultants. The data and analyses have been reviewed by the Division of Water Resources. A summary of the results from the analyses is summarized in Table 2.

Table 2. Summary of Cloud Seeding Project Areas and estimated effect of Cloud Seeding

Project Area	Number of Cloud Seeding Generators 2014-2015 Season	Seeded Seasons	Precipitation Increase during Seeding Period	April 1 Snow Water Content Increase
Central/Southern Utah	66	35	14%	5%
Tooele County	11	28	12%	10%
East Box Elder/Cache County	22	27	14%	8%
West Box Elder	9	23	NA	14%
Western Uintas	13	20	0%	4%
High Uintas	24	13	3-5%	3%

The primary target area of the Central/Southern Utah project has operated continuously since 1974, with exception of the period from 1984-1987. There were 66 cloud seeding generators in the project area for the 2014-2015 winter season. The target and control regression analyses covering 35 seasons show an average increase in precipitation of 14% and an average increase in April 1st snow water content of 5% (Yorty et al, 2015).

Cloud seeding began in Tooele County in 1976 and continued through 1982. Seeding resumed in 1989 through 1992 and again in 1996. The project area has 11 cloud seeding generators that operated during the 2014-2015 season. The target and control regression analyses covering 28 seasons show an average increase in precipitation of 12% and an average increase in April 1st snow water content of 10% (Yorty et al, 2015).

Cloud seeding in the Eastern Box Elder/Cache County area has been ongoing since 1989. There were 22 cloud seeding generators in the project area for the 2014-2015 winter season. The target and control regression analyses covering 27 seasons of seeding show an average increase in precipitation of 14% and an average increase in April 1st snow water content of 8% (Ward et al, 2015).

In the West Box Elder project area cloud seeding began in 1989 but was suspended during 1998, 1999, 2002 and 2003. The project area has 9 cloud seeding generators. The target area has no precipitation gages but it does have two snow courses. A target and control regression analysis covering 23 seasons shows an average increase in April 1st snow water content of 14% (Ward et al, 2015).

Through 2015, twenty winter seasons of cloud seeding have now been conducted in the Western Uinta Mountains. There are 13 cloud seeding generators in the project area. The target and control regression analyses shows an average increase in April 1st snow water content of 4% (Yorty et al, 2015).

The High Uinta Mountain region has been seeded for 13 years now. There were 24 operational cloud seeding generators in the project area during the 2014-2015 season. The target and control regression analyses indicates an average 3-5% increase in precipitation and an average 3% increase in April 1st snow water content (Yorty et al, 2015).

Annual Runoff Estimated from April 1st Snow Water Content

April 1st snow water content is often considered as a predictor of the spring runoff. Because spring runoff is 40% to 70% of annual runoff, snow water content can also be a predictor of annual runoff. Regression equations were derived by relating annual runoff to April 1st snow water content. The snow water content was then increased by ten percent and the equations were used to determine what the increase in annual runoff would be. The ten percent increase was chosen, because it is considered an expected nominal increase of the April 1st snow water content due to cloud seeding.

The actual increases in April 1st snow water content are used in the following analysis to estimate the increase in runoff for each project area. Table 3 listes the gaged streamflow stations used for each project area, the correlated SNOTEL/snow course stations, the regression equation correlation coefficients, and the percent annual runoff increase for a ten percent increase in April 1st snow water content.

Table 3. Increase in Annual Runoff for a Ten Percent Increase in April 1st Snow Water Content

Stream Gages	Correlated SNOTEL / Snow Course Stations	Correlation Coefficient	Annual Increase
10109001 LOGAN RIVER COMBINED FLOW	TONY GROVE LAKE, BUG LAKE, DRY BREAD POND, BEN LOMOND PEAK, MONTE CRISTO	0.85	9.8%
10113500 BLACKSMITH FORK	BUG LAKE, MONTE CRISTO, BEN LOMOND PEAK	0.79	12.9%
10104700 LITTLE BEAR NEAR AVON	BEN LOMOND PEAK, LITTLE BEAR, FARMINGTON	-	-
10172952 DUNN CREEK NEAR PARK VALLEY	GEORGE CREEK SNOW SURVEY	0.83	16.5%
13077700 GEORGE CREK NEAR YOST UTAH	GEORGE CREEK SNOW SURVEY	-	-
10172800 SOUTH WILLOW CREEK NEAR GRANTSVILLE	DESERET PEAK, MINING FORK, ROCKY BASIN-SETTLEME, VERNON CREEK	0.77	10.0%
10172700 VERNON CREEK NEAR VERNON	VERNON CREEK, ROCKY BASIN-SETTLEME	0.67	9.0%
09405500 NORTH FORK VIRGIN RIVER	MIDWAY VALLEY, WEBSTER FLAT, KOLOB	0.93	12.0%
09406000 VIRGIN RIVER AT VIRGIN	MIDWAY VALLEY, KOLOB, WEBSTER FLAT, CASTLE VALLEY	0.94	11.0%
09409880 SANTA CLARA RIVER AT GUNLOCK	LONG FLAT, KOLOB, MIDWAY VALLEY	0.88	16.5%
10174500 SEVIER RIVER AT HATCH	MIDWAY VALLEY, BIG FLAT, MERCHANT VALLEY, CASTLE VALLEY	0.93	11.0%
10194200 CLEAR CREEK NEAR SEVIER	KIMBERLY MINE, BOX CREEK, PINE CREEK	0.78	9.0%
10205030 SALINA CREEK NEAR EMERY	PICKLE KEG, FARNSWORTH LAKE, PINE CREEK, DILL'S CAMP	0.83	15.0%
10215900 MANTI CREEK	RED PINE RIDGE, SEELEY CREEK, CLEAR CREEK #1, PAYSON R.S., PINE CREEK	0.83	3.0%
10183500 SEVIER RIVER NEAR KINGSTON	MIDWAY VALLEY, BIG FLAT, MERCHANT VALLEY, CASTLE VALLEY	0.86	11.0%
10183900 EAST FORK SEVIER RIVER NEAR RUBYS INN	MIDWAY VALLEY, KOLOB, CASTLE VALLEY	0.96	13.4%
10234500 BEAVER RIVER NEAR BEAVER	KIMBERLY MINE, MERCHANT VALLEY, BIG FLAT, BOX CREEK	0.87	11.3%
10242000 COAL CREEK NEAR CEDAR CITY	MIDWAY VALLEY, WEBSTER FLAT, CASTLE VALLEY	0.91	12.5%
09310000 GOOSEBERRY CREEK NEAR SCOFIELD	CLEAR CREEK #1, RED PINE RIDGE	0.82	7.6%
09310500 FISH CREEK ABOVE RESERVOIR, NEAR SCOFIELD	CLEAR CREEK #1, RED PINE RIDGE, MAMMOTH-COTTONWOOD, PAYSON R.S.	0.87	12.5%
09312600 WHITE RIVER BL TABBYUNE C NEAR SOLDIER SUMMIT	WHITE RIVER #1, MAMMOTH-COTTONWOOD, CLEAR CREEK #1, PAYSON R.S.	0.87	15.9%
09317997 HUNTINGTON CREEK NEAR HUNTINGTON	MAMMOTH-COTTONWOOD, CLEAR CREEK #1, PAYSON R.S.	-	-
09326500 FERRON CREEK (UPPER STATION) NEAR FERRON	BUCK FLAT, FARNSWORTH LAKE, DILL'S CAMP, PICKLE KEG	0.87	14.0%
09329050 SEVEN MILE CREEK NEAR FISH LAKE	BOX CREEK, FARNSWORTH LAKE	0.76	10.1%
09330500 MUDDY CREEK NEAR EMERY	DILL'S CAMP, PICKLE KEG, BUCK FLAT, FARNSWORTH LAKE	0.82	13.2%
09337500 ESCALANTE RIVER NEAR ESCALANTE	MIDWAY VALLEY, WIDSTOE #3, DONKEY RESERVOIR, CASTLE VALLEY	0.7	13.3%
10128500 WEBER RIVER NEAR OAKLEY	TRIAL LAKE, CHALK CREEK #1, CHALK CREEK #2, MONTE CRISTO, DRY BREAD POND, BEN LOMOND PEAK	0.83	9.9%
10130500 WEBER RIVER NEAR COALVILLE	TRIAL LAKE, CHALK CREEK #1, CHALK CREEK #2, MONTE CRISTO, DRY BREAD POND, BEN LOMOND PEAK	0.78	13.1%
10131000 CHALK CREEK	SMITH&MOREHOUSE, CHALK CREEK #1, CHALK CREEK #2, MONTE CRISTO, DRY BREAD POND, BEN LOMOND PEAK	0.75	16.9%
10154200 PROVO RIVER	TRIAL LAKE, CLEAR CREEK #1, TIMPANOGOS DIVIDE, LOOKOUT PEAK, DANIELS-STRAWBERRY	0.84	8.5%
09266500 ASHLEY CREEK	KINGS CABIN, MOSBY MTN.,TROUT CREEK,CHEPETA,FIVE POINTS LAKE, LAKE FORK BASIN	0.77	7.5%
09277500 DUSCHESNE RIVER NEAR TABIONA	ROCK CREEK, BROWN DUCK, LAKE FORK BASIN	0.72	15.4%
09299500 WHITEROCKS RIVER	CHEPETA, MOSBY MTN., BROWN DUCK, ROCK CREEK, TROUT CREEK, CURRANT CREEK	0.81	11.1%
09279000 ROCK CREEK	LAKE FORK #1, FIVE POINTS LAKE, ROCK CREEK, BROWN DUCK, LAKE FORK BASIN	0.66	16.0%

Estimated Increased Runoff

The percent increase in annual runoff for a ten percent increase in April 1st snow water content was estimated for each streamflow station. All of the streamflow stations in each project area were volume weighted to determine the average percent increase in annual runoff for a ten percent increase in snow water content for the entire project area (See Appendix B for calculations). This weighted value was then multiplied by the actual percent increase in April 1st snow water content determined from target and control analysis and divided by ten to obtain a runoff factor. The runoff factor was multiplied by the average annual runoff for the project area to determine the increase in annual runoff due to cloud seeding (see Table 4 for the results).

The sum of estimated average annual increase in runoff for all of the projects is 186,663 acre-feet. This is nearly a 12 percent increase overall. The increase in runoff for the Northern Utah Project is 50,698 acre-feet. The Central/Southern Utah Project increase is 83,654 acre-feet. The Western Uinta Mountain project increase is 22,364 and the High Uinta Mountain project increase is 29,947.

Table 4. Cloud Seeding Project Areas and Estimated Increased Runoff

Area within Project	Average Annual Runoff (ac-ft)	Increase in April 1 SWC* (percent)	Increase in Runoff** (percent)	Runoff Factor*** (percent)	Increased Runoff (ac-ft)
Cache County	424,000	8	11.0	8.8	37,341
West Box Elder	57,800	14	16.5	23.1	13,357
Western Uintas	492,000	4	11.4	4.5	22,364
High Uintas	773,300	4	12.9	3.9	29,947
Tooele County	43,300	10	9.6	9.6	4,160
Sevier River	653,000	5	10.4	5.2	33,938
Cedar-Beaver	135,000	5	11.8	5.9	7,963
West Colorado	411,500	5	12.9	6.4	26,540
Virgin River	192,400	5	11.5	5.7	11,053
Total	3,182,300				186,663
Project Areas					
Northern Utah Project	481,800				50,698
Central and Southern Utah Project	1,435,200				83,654
Western Uinta Project	492,000				22,364
High Uinta Project	773,300				29,947

*April 1 snow water content found through target and control analysis
**Increase in annual runoff based off of a 10% increase in April 1 SWC
***Runoff Factor (percent) equals increase in April 1 SWC times increase in runoff in April 1 SWC divided by 10.

Estimated Cost per Acre-Foot

The unit cost of the augmented runoff is based on the total costs of the cloud seeding and estimated augmented runoff. The cost analysis results are shown in Table 5. The cost for the 2014-2015 cloud seeding project is $407,798. With the estimated increased runoff being 186,663 acre-feet, the cost per acre-foot equals $2.18. This cost will fluctuate year-to-year as a longer record of data is collected. When the Lower Basin funds are included, which is $118,068, in the total cost

for the cloud seeding effort, the total amount increases to $525,866. This inclusion adjusts the cost per acre-foot of cloud seeding to be $2.82.

Table 5. Increased Runoff and Cost for the Cloud Seeding Projects

Project	Increased Runoff (ac-ft)	Cost ($)	Cost ($/ac-ft)
Northern Utah	50,698	81,929	1.62
Central and Southern Utah	83,654	169,359	2.02
Western Uinta	22,364	69,753	3.12
High Uinta	29,947	86,758	2.90
Total	186,663	407,798	2.18

Summary and Recommendations

The purpose of this report was to estimate the augmented runoff from the cloud seeding projects (seeded by silver iodide) and unit cost of the runoff. The analysis was based on the target and control comparison method. The cost per acre-foot for cloud seeding has slightly decreased from the 2010 runoff/cost analysis. This decrease in cost results from a higher estimate of the runoff in 2015 as compared to the 2010 runoff estimate. In 2010, the estimated increase in runoff was 181,700 ac-ft and the estimate runoff in 2015 was 193,500 ac-ft. Also, the West Colorado area had the largest increase in expected cloud seeding runoff; 19,900 ac-ft in 2010 to 27,100 ac-ft in 2015. As more years of data are collected a better average can be determined. A summary of the 2010 versus 2015 runoff results is listed in Table 6. The total cost per acre-foot decreased from $2.27 in 2010 to $2.18 in 2015.

Table 6. Comparison on Increased Runoff and Unit Cost of Cloud Seeding in 2010 and 2015

Project Areas	Increase in April 1 SWC 2010 (percent)	Increase in April 1 SWC 2015 (percent)	Increased Runoff (ac-ft) 2010	Cost/ac-ft	Increased Runoff (ac-ft) 2015	Cost/ac-ft
Cache County	9	8	45,029		37,341	
West Box Elder	15	14	11,271		13,357	
Tooele County	10	10	4,503		4,160	
Sevier River	4	5	31,083		33,938	
Cedar-Beaver	4	5	6,966		7,963	
West Colorado	4	5	19,917		26,540	
Virgin River	4	5	9,620		11,053	
Western Uinta's	3	4	17,122		22,364	
High Uinta's	4	4	36,190		29,947	
Total			181,701	$2.27	186,663	$2.18
Northern Utah Project			56,300	$1.55	50,698	$1.62
Central & Southern Utah Project			72,089	$2.62	83,654	$2.02
Western Uinta Project			17,122	$2.67	22,364	$3.12
High Uinta Project			36,190	$2.50	29,947	$2.90

The cost per acre-foot for cloud seeding ($1.62 to $3.12) is based on the assumption of ten percent increase in 1st April snow water content and corresponding increase in annual runoff from the project areas. The stream flow analysis was derived by applying the historical target–control regression method that was developed and applied in the previous studies in the state of Utah. This calculated unit cost is relatively higher compared to the historical unit rate (e.g., $1.55 to $ 2.67 in 2010).

It is well reported that multiple hydrological and climatic factors will affect the effectiveness of cloud seeding and the volume of runoff. For example, elevation of the seeded areas, spatial distribution of snowpack, amount and timing of rainfall on the pack, temperature, evapotranspiration, soil infiltration, antecedent soil moisture, slope and aspect, vegetative cover and etc. Most of the listed hydrological and meteorological variables are associated to uncertainty, and often measured/observed data are not available. Therefore the seeding results, as presented, is based on the simple analysis and may not have estimated the seasonal snowpack and resulting runoff volume accurately.

Recent research on cloud studies has proven that a high resolution cloud seeding physically based computer models (e.g., High-resolution Weather Research and Forecasting (WRF) model using an NCAR (The National Center for Atmospheric Research) cloud-seeding module) and robust statistical techniques using machine learning algorithms (e.g., Artificial Neural Network, Principal Component Analysis, Support Vector Machine etc.) can be applied to evaluate the performances of the cloud seeding and runoff. It is recommended that the cloud seeding evaluation approach considered in this report needs a critical review to identify a feasible and robust approach applicable to the State of Utah. It may be done either by collaborating with a higher education institution to build a physically based cloud seeding model, or by teaming in-house technical resources to develop a robust statistical model.

References

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7. Yorty, David P.,Weston, T. Warren, Griffith, Don A., and Solak, Mark E., *Summary and Evaluation of 2014-2015 Winter Cloud Seeding Operations for the South Slope of the Uinta Mountains, Utah,* North American Weather Consultants, Inc., Sandy, Utah, 2015
8. Utah Division of Water Resources, State Water Plan, Basin Plans:

    Bear River Basin – February 2004

    Cedar/Beaver Basin – April 1995

    Kanab Creek/Virgin River Basin – 1993

    Sevier River Basin – June 1999

    Weber River Basin – September 2009

    West Colorado River Basin – August 2000

    West Desert Basin – April 2001

Appendix A

Average Annual Runoff 1941-1990

for the Cloud Seeding Project Areas

Western Uintas			West Box Elder			Tooele-Rush Valleys			West Colorado		
Weber		312,000	**Raft River**		39,900	**Tooele Valley**		22,987	**Price River**		96,300
Chalk Creek	58,000		Lynn	9,100		Box Elder Creek	3,630		Gooseberry	16,500	
Misc.	27,000		Yost	5,700		South Willow Creek	4,778		Ungaged Inflow	21,800	
Beaver Creek	69,000		Clear Creek	14,400		North Willow Creek	3,205		Mud Creek	11,600	
Weber River	115,000		Goose Creek	10,700		Devenport Creek	1,379		White River	20,600	
Smith & Morehouse	43,000		**Grouse Creek**		7,100	Pine Creek	1,430		Beaver Creek	3,300	
			Pine Creek	2,000		Middle Creek	4,865		Willow Creek	8,400	
Provo			Ungaged	1,400		Settlement Creek	3,700		Coal Creek	4,100	
Upper Provo River	36,000	180,000	Etna Area	3,700		**Rush Valley**		20,263	Misc	10,000	
Shingle Creek	5,000		**Park Valley**		10,800	Vernon Creek	2,070		**San Rafael**		200,700
North Fork	27,000		Indian Creek	2,900		Bennion Creek	405		Huntington Creek	76,100	
Weber/Provo Diversion	35,000		Dove Creek	900		Dutch Creek	125		Cottonwood Creek	75,900	
Francis	65,000		Fish Creek	2,200		Harker Creek	270		Ferron Creek	48,700	
Misc.	12,000		Dunn Creek	4,100		Clover Creek	3,168		**Dirty Devil**		67,100
			Ungaged	700		Big Hollow Creek	2,030		Muddy Creek	28,700	
Total		**492,000**				Hickman Creek	2,540		Ivie Creek	2,900	
			Total		**57,800**	Soldier Creek	2,422		Fremont River	32,300	
						Ophir Creek	6,205		Pine Creek	3,200	
						Mercur Creek	1,028		**Escalante**		39,600
									Paria		7,800
						Total		**43,250**	**Total**		**411,500**
High Uintas			**Sevier River**			**Cache County**					
Current Creek	41,400		Mammoth Creek	83,900		Logan River		184,000			
West Fork Duchesne	34,400		Panguitch	26,400		Blacksmith Fork		98,000			
Upper Duchesne	66,100		Otter Creek	19,200		East Fork Little Bear		26,000			
Upper Rock Creek	109,100		East Fork	42,200		South Fork Little Bear		41,000			
Brown Duck	6,900		Piute Reservoir	12,500		High Creek		21,000			
Lake Fork	82,500		Marysville	32,300		Summit Creek		14,000			
Red Creek	6,100		Richfield	55,100		Misc		40,000			
Yellowstone River	102,600		San Pitch	207,000							
Uinta River	134,500		Gunnison	45,000		**Total**		**424,000**			
Farm Creek	4,800		Scipio-Levan-Eureka	13,800							
White Rocks River	84,200		Oak-Fool Creeks	16,400							
Misc	100,700		Fillmore	74,200							
			Nephi-Salt Creek	25,000							
Total	**773,300**		**Total**	**653,000**							

Appendix B

Calculation of percent

increase in annual runoff

			Annual Runoff	Estimated Annual Increase for a 10% increase in SWE	Fraction of Total	Percent Increase in Runoff for the Entire Area
10109001 LOGAN RIVER COMBINED FLOW			178820.1	0.10	0.67	
10113500 BLACKSMITH FORK			89323.4	0.13	0.33	
10104700 LITTLE BEAR NEAR AVON						
	Cache County	Total	268143.5			0.11
10172952 DUNN CREEK NEAR PARK VALLEY			3601.8	0.17	1.00	
13077700 GEORGE CREEK NEAR YOST UTAH						
	West Box Elder	Total	3601.8			0.17
10128500 WEBER RIVER NEAR OAKLEY			149909.5	0.10	0.31	
10130500 WEBER RIVER NEAR COALVILLE			148595.2	0.14	0.31	
10131000 CHALK CREEK			50960.7	0.17	0.10	
10154200 PROVO RIVER			136602.9	0.09	0.28	
	Western Uintas	Total	486068.3			0.11
09266500 ASHLEY CREEK			65339.1	0.07	0.20	
09277500 DUSCHESNE RIVER NEAR TABIONA			105801.4	0.15	0.32	
09299500 WHITEROCKS RIVER			80226.1	0.11	0.24	
09279000 ROCK CREEK			78296.4	0.16	0.24	
	High Uintas		329662.9			0.13
10172800 SOUTH WILLOW CREEK NEAR GRANTSVILLE			4443.7	0.10	0.61	
10172700 VERNON CREEK NEAR VERNON			2883.3	0.09	0.39	
	Toelle County	Total	7327.0			0.10
09405500 NORTH FORK VIRGIN RIVER			76807.0	0.12	0.33	
09406000 VIRGIN RIVER AT VIRGIN			134578.3	0.11	0.58	
09409880 SANTA CLARA RIVER AT GUNLOCK			18980.4	0.17	0.08	
	Virgin River	Total	230365.6			0.12
10174500 SEVIER RIVER AT HATCH			83111.0	0.11	0.34	
10194200 CLEAR CREEK NEAR SEVIER			26603.1	0.09	0.11	
10205030 SALINA CREEK NEAR EMERY			12056.4	0.15	0.05	
10215900 MANTI CREEK			21675.1	0.03	0.09	
10183500 SEVIER RIVER NEAR KINGSTON			89230.0	0.11	0.36	
10183900 EAST FORK SEVIER RIVER NEAR RUBYS INN			12464.5	0.13	0.05	
	Sevier River	Total	245140.1			0.10

10234500 BEAVER RIVER NEAR BEAVER		36515.1	0.11	0.59	
10242000 COAL CREEK NEAR CEDAR CITY		25869.5	0.13	0.41	
Cedar-Beaver	Total	62384.6			0.12
09310000 GOOSEBERRY CREEK NEAR SCOFIELD		13051.1	0.08	0.08	
09310500 FISH CREEK ABOVE RESERVOIR, NEAR SCOFIELD		33868.1	0.13	0.22	
09312600 WHITE RIVER BL TABBYUNE C NEAR SOLDIER SUMMIT,		17564.6	0.16	0.11	
09317997 HUNTINGTON CREEK NEAR HUNTINGTON					
09326500 FERRON CREEK (UPPER STATION) NEAR FERRON		45043.6	0.14	0.29	
09329050 SEVEN MILE CREEK NEAR FISH LAKE		10988.2	0.10	0.07	
09330500 MUDDY CREEK NEAR EMERY		27398.5	0.13	0.18	
09337500 ESCALANTE RIVER NEAR ESCALANTE		7293.6	0.13	0.05	
West Colorado	Total	155207.7			0.13