THE SILVER LINING SOLUTION: ALLEVIATING WATER INSECURITY IN THE COLORADO RIVER BASIN THROUGH CLOUD SEEDING

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I. INTRODUCTION

Since ancient times, civilizations have relied on favorable weather conditions for their survival and development. Human history is spattered with a wide array of elaborate ceremonies dedicated to summoning the rain that sustains human civilizations.[1] These ceremonies demonstrate a common goal to reach the very heavens themselves to harness its water for the benefit of their society.[2] As our technology advanced, we employed the use of rockets and cannons in service of weather modification, to blow the water out of the sky.[3] Today, we have the means and the motivation to influence the weather of the United States Southwest.

The Colorado River ("River") is one of the most important natural resources in the United States. The River itself flows across several U.S. states (Colorado, Utah, Nevada, Arizona, and California) and two Mexican states (Sonora and Baja California).[4] The Colorado River Basin ("Basin") comprises portions of seven U.S. states (Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming), two Mexican states (Sonora and Baja California), and twenty-eight Native American reservations.[5] The Basin contains over forty million people who depend on the water from the Colorado River.[6] It almost goes without saying that the people in the Basin, the states outside the Basin, and the entire U.S. depend on

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[1] Jianlin Chen, *Optimal Property Rights for Emerging Natural Resources: A Case Study on Owning Atmospheric Moisture*, 50 U. MICH. J. L. REFORM 47, 63 (2016).

[2] WILLIAM R. COTTON & ROVER A. PIELKE SR., HUMAN IMPACTS ON WEATHER AND CLIMATE 3 (Cambridge Univ. Press, 2d ed. 2007); *see also* Ray Jay Davis, *Atmospheric Water Resources Development and International Law*, 31 NAT. RES. J. 11, 11–12 (1991).

[3] *See* COTTON & PIELKE SR., *supra* note 2.

[4] *See generally* Charles J. Meyers, *The Colorado River*, 19 STAN. L. REV. 1, 1–2, 10 (1966).

[5] Rhett B. Larson, *Colorado River Lessons for International Water Law*, 59 JURIMETRICS J. 83, 83 (2018).

[6] Michael L. Connor, *Foreword* to U.S. DEP'T OF INTERIOR, BUR. OF RECLAMATION, COLORADO RIVER BASIN WATER SUPPLY AND DEMAND STUDY (2012); *see also* Brooke Larsen, *What the Fed's New Proposal for Management of Colorado River Reservoirs Means*, HIGH COUNTRY NEWS (Oct. 31, 2023), https://www.hcn.org/articles/colorado-river-what-the-feds-new-proposal-for-management-of-colorado-river-reservoirs-means/ [https://perma.cc/8MHM-FHZ9].

this natural resource to thrive and provide the water that sustains our health, businesses, and crops.[7]

Concerns, however, have been growing for years that the Colorado River is being over-exploited to the point that it might no longer be able to provide adequate water to the Southwest, leading to a national water crisis.[8] While some characterizations among media outlets are exaggerated, they all highlight an important concern: the Southwest is facing water security issues that require solutions.[9] The U.S. states, Tribes, and Mexican states have difficult choices to make if they want to see a more prosperous future along the banks of the Colorado River. If they can cooperate and implement solutions to improve water supplies in reservoirs along the Colorado River, they can help remedy many issues stemming from water insecurity.[10] By addressing concerns over the increase in water consumption and decrease in water supplies throughout the Basin, all parties can find solutions to a brighter future.

Scientists, politicians, and concerned citizens have voiced a wide range of ideas on how to best improve water security in the Basin.[11] For example, desalination can turn saltwater into potable water but through a "costly and energy-intensive process[.]"[12] Cities can invest in technology that reclaims and recycles effluent for irrigation, industry, and consumption.[13] States can pass stricter regulations on water-intensive industries like fracking and agriculture to incentivize efficiency, despite a likely spike in energy and food prices.[14] All these options for water resource

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[7] Meyers, *supra* note 4, at 1.

[8] *See*, *e.g.*, Elena Shao, *The Colorado River is Shrinking. See What's Using All the Water*, N.Y. TIMES (May 22, 2023), https://www.nytimes.com/interactive/2023/05/22/climate/colorado-river-water.html [https://perma.cc/66TQ-H8FN]; Ian James & Molly Hennessey-Fiske, *The Colorado River is Overused and Shrinking. Inside the Crisis Transforming the Southwest*, L.A. TIMES (Jan. 26, 2023, 5 AM), https://www.latimes.com/environment/story/2023-01-26/colorado-river-in-crisis-the-west-faces-a-water-reckoning [https://perma.cc/6TRP-ZCEF].

[9] *See* Shao, *supra* note 8; James & Hennessey-Fiske, *supra* note 8.

[10] *See* RHETT LARSON, JUST ADD WATER: SOLVING THE WORLD'S PROBLEMS USING ITS MOST PRECIOUS RESOURCE 1–2 (Oxford Univ. Press 2020).

[11] *See, e.g.,* Richard Parker, *Opinion: American Dams are Being Demolished. And Nature is Pushing that Along*, L.A. TIMES, (Oct. 19, 2023, 3:10 AM), https://www.governing.com/infrastructure/american-dams-are-being-demolished-and-nature-is-pushing-that-along [https://perma.cc/4YUW-LCX3]; Kyle J. Paine, *What is Desalination, how can it End War over Colorado River?*, 8NEWSNOW.COM (May 3, 2023, 10:45 PM) https://www.8newsnow.com/investigators/what-is-desalination-how-can-it-end-war-over-colorado-river/ [https://perma.cc/38SA-BJ9U]; Larsen, *supra* note 6.

[12] Rhett B. Larson, *Innovation and International Commons: The Case of Desalination Under International Law*, 2012 UTAH L. REV. 759, 760, 764 (2012).

[13] Geraldine Burrola, *Reclaiming LA's "Mulholland Moment": Wastewater Recycling, the Public Trust Doctrine, and Saving the LA River*, 111 CAL. L. REV. 1551, 1575 (2023).

[14] *See* Hiroko Tabuchi & Blacki Migliozzi, *'Monster Fracks' Are Getting Far Bigger. And Far Thirstier*, N.Y. TIMES (Sept. 25, 2023) https://www.nytimes.com/interactive/2023/09/25/climate/fracking-oil-gas-wells-water.html [https://perma.cc/G754-YDNG]; Liza Gross, *Colorado Frackers Doubled Freshwater Use During Megadrought, Even as Drilling and Oil Production Fell*, INSIDE CLIMATE NEWS (May 22, 2023) https://insideclimatenews.org/news/22052023/colorado-fracking-wastewater-

management are viable but come with inherently difficult cost-benefit analyses. No matter what path the parties in the Basin take, they will have to make tough choices of what costs to bear and what benefits to forsake to achieve a diverse water portfolio and avoid future water insecurity.

But what if there was a new "emerging natural resource," capable of helping these parties manage their water resources and even increase their water supply? As technology has advanced, we have gained access to emerging natural resources that pose great opportunities and greater questions about how we should respond. Emerging natural resources are defined as resources that "are harnessed by recently developed and still-evolving technologies."[15] But as technology and our understanding evolves, our regulatory regimes and control mechanisms for such resources must evolve as well.[16]

Currently, atmospheric moisture can be accessed and extracted through a process called "cloud seeding."[17] This process is intended to affect the precipitation in clouds, which helps manage water supplies in a region.[18] With all members of the Basin facing water insecurity issues, cloud seeding is a possible solution to help mitigate those issues.

This Article argues that, as an emerging natural resource, cloud seeding across the Basin will need a uniform and comprehensive set of regulations. Current legal regimes across the Basin states should be revised to address cloud seeding. Uniform and comprehensive standards help improve the efficiency of the industry and ensure both operators and investors work effectively.[19] These regulations should come from a state commission created under an interstate compact.[20] The creation of such a state commission would require a difficult balancing of interests. It would

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drought/#:~:text=Colorado%20operators%20doubled%20their%20use,that%20time%2C%20the%20analysis%20found. [https://perma.cc/8CKD-T6BW]; Gianna Melillo, *In Drought-Stricken States, Fossil Fuel Production Jeopardizes Limited Water Supplies*, HILL (Feb. 8, 2023) https://thehill.com/changing-america/sustainability/energy/3847883-in-drought-stricken-states-fossil-fuel-production-jeopardizes-limited-water-supplies/#:~:text=Fossil%20fuels%20are%20primarily%20notorious,supplies%20in%20drought%2Dstricken%20states. [https://perma.cc/N2TT-BKZ8].

[15] Chen, *supra* note 1, at 50.

[16] *See id.* at 50–51 (recognizing that technological advancements drive uncertainty in resource utilization, requiring regulatory frameworks to remain adaptable to changing conditions).

[17] *Id.* at 65–66.

[18] *Id.* at 65.

[19] *Cf.* Melissa Currier, *Rain, Rain, Don't Go Away: Cloud Seeding Governance in the United States and A Proposal for Federal Regulation*, 48 U. PAC. L. REV 949, 960 (2017) (explaining that a sweeping federal regulatory scheme on cloud seeding would help reduce conflicts over cloud seeding between states and improve the industry).

[20] *See* Alexandra Campbell-Ferrari, *Managing Interstate Water Resources: Tarrant Regional and Beyond*, 44 TEX. ENVTL. L. J. 235, 237 (2014). An interstate compact is a legally binding agreement between two or more states that Congress consents to and enables states to collaboratively address regional issues, such as the allocation and management of shared water resources. *See id.* at 236–67. By entering into a compact, states relinquish some of their sovereign control over specific matters to create a cooperative framework for resolving disputes and managing shared resources effectively. *Id.*

need to have enough regulatory teeth to be effective but not be so powerful as to dissuade states from joining at risk of losing state sovereignty.[21] Nevertheless, a state commission is the ideal method to create a legal regime regulating cloud seeding technology and tailor such regulations to the Basin and its members' needs.[22]

This Article is broken down into three parts. Part II contains a comprehensive discussion on the importance of cloud seeding and why the Basin states should be proactive in working together to regulate this emerging natural resource. Part III overviews how cloud seeding is currently conducted in the Basin. Finally, Part IV proposes a method of improving regulations on the cloud seeding industry by amending the Colorado River Compact of 1922.[23]

II. THE IMPORTANCE OF CLOUD SEEDING

Weather modification through cloud seeding is complicated and can have a range of impacts. This part sets out factual context on weather modification by discussing the historical evolution of cloud seeding, the inner workings of current cloud seeding technology, the consequences of cloud seeding on the environment, and the legal rights regimes that have been proposed for accessing atmospheric moisture.

A. Background

Through the introduction of computers, satellites, radar, and aviation, we have made significant progress in collecting and interpreting meteorological data.[24] This data gives us greater access to the clouds in the skies and thus, atmospheric moisture.[25] Of course, this knowledge provides great opportunities for growing communities as well as destroying them. Military operations during the Cold War demonstrated the potential offensive capabilities of weather modification by attempting to flood military and civilian precincts.[26] Because of the import of

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[21] Rhett B. Larson, *Interstitial Federalism*, 62 UCLA L. REV. 908, 953–54 (2015).
[22] *Id.*
[23] *See generally* Colorado River Compact, COLO. REV. STAT. § 37-61-101, art. II(e).
[24] *See* Harold D. Orville, *Weather Modification*, *in* HANDBOOK OF WEATHER, CLIMATE, AND WATER: DYNAMICS, CLIMATE, PHYSICAL METEOROLOGY, WEATHER SYSTEMS, AND MEASUREMENTS 433, 444–47 (Thomas D. Potter & Bradley R. Colman eds., 2003); Chunglin Kwa, *The Rise and Fall of Weather Modification*, *in* CHANGING THE ATMOSPHERE: EXPERT KNOWLEDGE AND ENVIRONMENTAL GOVERNANCE 135, 143 (Clark A. Miller & Paul N. Edwards eds., 2001).
[25] Orville, *supra* note 24, at 445.
[26] *See* Noah Byron Bonnheim, *History of Climate Engineering*, 1 WIRES CLIM. CHANGE 891, 893 (2010); *see also* Foreign Relations of the United States, 1964–1968, vol. 28, Laos, Doc. 274 (Oct. 7, 1968), https://history.state.gov/historicaldocuments/frus1964-68v28/d274 [https://perma.cc/JV5U-2C6Q] ("The impact on civilian population will be much the same, in kind, and greater in degree…").

weather modification, the U.S. government and private enterprises have sponsored many research programs to develop weather modification technology.[27]

As weather modification technology has become easier to produce and access, dozens of countries have conducted their own weather modification experiments.[28] Countries such as China, South Africa, Morocco, India, and Australia are currently producing important findings on the efficacy of cloud seeding.[29] Weather modification is a worldwide research project because of the massive import and potential societal benefits of this new industry.[30] Instead of having to build new and expensive water infrastructure, countries can simply take advantage of the hydrologic cycle by making clouds deliver water more efficiently and, at least in theory, provide more water to their respective basins.[31]

B. How Cloud Seeding Works

Cloud seeding requires introducing chemicals (referred to as "seeding agents") into a saturated portion of our atmosphere (a cloud) to change the physical structure of the cloud so it will be more likely to precipitate in the form of rain or snow.[32] Put simply, the seeding agent acts as an impurity in a cloud that is almost entirely pure H2O, and as the impurity moves through the cloud, water molecules attach and form a droplet. The most common seeding agents used are dry ice pellets and silver iodide.[33] But a cloud's temperature and geographic location can affect what seeding agents and dispersal methods are ideal. For example, cold-based

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[27] *See* Charles F. Hutchinson & Stephanie M. Herrmann, *The Future of Arid Lands—Revisited*, 32 ADVANCES IN GLOB. CHANGE RSCH. 1, 47–48 (2008); *see generally* James R. Fleming, *The Pathological History of Weather and Climate Modification: Three Cycles of Promise and Hype*, 37 HIST. STUD. PHYSICAL & BIOLOGICAL SCI. 3, 3 (2006).

[28] William R. Cotton, *Weather Modification by Cloud Seeding—A Status Report 1989-1997*, *in* ANTHROPOGENIC CLIMATE CHANGE 139, 153 (Hans von Storch & Götz Flöser eds. 1999).

[29] *See* Hutchinson & Herrmann, *supra* note 27, at 55; *Weather Modification Inc. Projects Worldwide*, CLIMATE VIEWER MAPS, https://climateviewer.org/history-and-science/geoengineering-and-weather-modification/maps/weather-modificaiton-incorporated-projects-worldwide/ [https://perma.cc/C9C4-CZ6W] (listing projects in over twenty countries including Antigua, Argentina, Australia, Burkina Faso, Brunei, Canada, Greece, India, Indonesia, Jordon, Mali, Mexico, Morocco, Saudi Arabia, Senegal, Spain, Thailand, Turkey, the United Arab Emirates., and the U.S).

[30] Conrad G. Keyes Jr., *Societal, Environmental, and Economic Aspects*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION 11, 31 (Conrad G. Keyes Jr. et al. eds., 3d ed. 2016). (explaining that cloud seeding has been widely adopted around the world because the potential benefits outweigh the costs and uncertainties).

[31] *See* Larry R. Dozier, *Colorado River Augmentation*, 37 ABA TRENDS 1, 14 (2006) (explaining that increased rain may also increase the amount of hydropower generated, thereby reducing electricity costs); Conrad G. Keyes, Jr. & Thomas D. DeFelice, *Introduction and Brief Summary*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION, 1, 1 (Conrad G. Keyes, Jr. et al. eds., 3d ed. 2016) (discussing how adding more rainwater can benefit agriculture, hydropower, municipal water supplies, and irrigation interests).

[32] *See* Chen, *supra* note 1, at 65–66.

[33] Rhett Larson & Brian Payne, *Unclouding Arizona's Water Future*, 49 ARIZ. ST. L.J. 465, 505 (2017).

continental clouds are seeded with chemicals that are best suited for creating ice crystals.[34] These seeding agents trigger the formation of ice crystals from suspended supercooled liquid water.[35] Conversely, warm and maritime clouds are seeded with hygroscopic seeding agents.[36] These agents attract the water vapor until it forms a droplet large enough to fall from the cloud as a raindrop[37].

The method of dispersal also presents unique variations depending on the circumstances. Depending on the altitude of the cloud, aerial dispersion might be required via aircraft, surface-to-air missiles, or anti-aircraft guns.[38] These methods of dispersal can be expensive, especially for smaller commercial weather modification operators.[39] But as drone technology advances, we could see greater utilization of drones carrying payloads of seeding agents across a wider area than before.[40] Notably, certain clouds, such as orographic clouds, which are formed by the forced lifting of air by topographic features like mountains, can be seeded by ground generators that release the seeding agents as the cloud travels up the mountain.[41] This method is much less expensive than operating aerial methods of dispersal.[42]

The variability of the ideal way to introduce cloud seeding technology suggests a broader point. The best way to conduct cloud seeding operations depends on the climate, geography, and location of the targeted cloud. This technology is only in its infancy and will become more common as it becomes more effective and economically efficient. Compact states must develop a legal regime that can

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[34] Chen, *supra* note 1, at 65–66.
[35] *Id.* at 66.
[36] *Id.*
[37] *Id.*
[38] Robert Glennon, *Water Exchanges: Arizona's Most Recent Innovation in Water Law and Policy*, 8 ARIZ. J. ENVTL. L. & POL'Y 1, 3 (2018); *Chinese Cities Try Cloud Seeding to Beat the Heat*, NBC NEWS (July 22, 2004, 2:38 PM), https://www.nbcnews.com/id/wbna5488201 [https://perma.cc/PV97-PYYT]; Desislava Ivanova, *Masters of Hailstorms*, RADIO BULGARIA (July 7, 2015, 12:33 PM), https://bnr.bg/en/post/100577459/masters-of-hailstorms [https://perma.cc/GC25-CMHC].
[39] *See* Don A. Griffith, *Cloud Seeding Modes, Instrumentation, and Status of Precipitation Enhancement Technology*, *in* GUIDELINES FOR CLOUD SEEDING TO AUGMENT PRECIPITATION 119–20 (Conrad G. Keyes Jr. et al. eds., 2006) (clarifying that while ground based rockets and artillery offer the advantages of both ground and airborne dispersal methods, they are costly and prohibited in areas with high aircraft traffic); *see also* U.S. GOV'T ACCOUNTABILITY OFF., GAO-25-107328, CLOUD SEEDING: COSTS AND CHALLENGES OF WEATHER MODIFICATION PROGRAMS, 18 (2025), https://www.gao.gov/assets/gao-25-107328.pdf [https://perma.cc/GP5E-QKMG] (specifying that while aircraft dispersal can be more effective, it is more costly than ground-based generators); *see also* Chen, supra note 1, at 75–76 (charging cloud seeding operators a flat fee for attaining permits to cloud seed favors large-scale operators while placing a disproportionately heavy burden on small and medium operators).
[40] *See* Woonseon Jung, Joo Wan Cha, A.-Reum Ko, Sanghee Chae, Yonghun Ro, Hyun Jun Hwang, Bu-Yo Kim, Jung Mo Ku, Ki-Ho Chang, & Chulkyu Lee, *Progressive and Prospective Technology for Cloud Seeding Experiment by Unmanned Aerial Vehicle and Atmospheric Research Aircraft in Korea*, 2022 ADVANCES IN METEOROLOGY 1, 1 (2022); *see* Currier, *supra* note 19, at 968–69.
[41] *See* Griffith, *supra* note 39, at 110–15.
[42] *Id.* at 115.

transition alongside this emerging natural resource and our scientific understanding. Failure to develop an efficient legal regime could harm not only our environment, but also the people who depend on the Colorado River.

C. Cloud Seeding's Impact on the Environment

Cloud seeding can be used to help protect the environment by reducing air pollution, suppressing hailstorms, and mitigating flash floods.[43] Such natural disasters can cause significant damage to the environment by devastating landscapes, forests, and cities.[44] But given the effect that cloud seeding can have in creating substantial changes in precipitation, observers have raised several environmental concerns with the practice itself.[45]

The practice of having planes deploying chemical flares over forests and cannons firing volleys of silver iodide from mountaintops can present logical environmental concerns.[46] An observer could naturally wonder if the silver iodide is toxic, poses potential harm to wildlife, or has the potential to cause a natural disaster. Furthermore, the use of frozen carbon dioxide and silver iodide presents unconfirmed concerns over the potential for hazardous bioaccumulation in our environment.[47] Carbon dioxide and silver iodide, however, are not necessarily dangerous.[48] If adequately limited, the risk of toxic bioaccumulation should be

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[43] *See* Robert "Bo" Abrams & Alexis Clark, *Weather Modification Past and Prologue*, 37 NAT. RES. & ENV'T 21, 21 (2022).

[44] *See* Emily Chung, *How Cloud Seeding Can Make it Rain or Prevent Extreme Weather*, CBC NEWS (Apr. 17, 2024, 1:11 PM), https://www.cbc.ca/news/science/cloud-seeding-faq-1.7176435 [https://perma.cc/CYZ4-3E3Q]; *see generally* Vishwambhar Prasad Sati & Saurav Kumar, *Environmental and Economic Impact of Cloudburst-Triggered Debris Flows and Flash Floods in Uttarakhand Himalaya: A Case Study*, 9 Geoenvironmental Disasters 5 (2022), https://doi.org/10.1186/s40677-022-00208-3 (noting that one moderate flash flood destroyed over 50 acres of forest land costing thousands of dollars in economic damage); *see also* Zainab Oyinkansola Akinsemoyin, *Investigating Flash Flood Occurrence Using Negative Binomial Models in Maryland, United States of America* 10 (M.S. thesis, Georgia Southern Univ. 2024), https://digitalcommons.georgiasouthern.edu/etd/2884 [https://perma.cc/9JSV-EYU8] ("The recent flash flood events in North Carolina on September 27, 2024, are a stark reminder of these events' sudden and devastating nature.").

[45] Rhett Larson, *Augmented Water Law*, 48 TEX. TECH L. REV. 757, 763–64 (2016); Erica C. Smit, *Geoengineering: Issues of Accountability in International Law*, 15 NEV. L. J. 1060, 1064–67 (2015); Bonnheim, *supra* note 26, at 893.

[46] Larson, *supra* note 45.

[47] See Larson & Payne, *supra* note 33, at 506*;* Manon Simon, *Enhancing the Weather: Governance of Weather Modification Activities of the United States*, 46 WILLIAM & MARY ENV'T. L. & POL'Y REV. 149, 154–56 (2021).

[48] *Cf.* Karen Bradshaw & Monika U. Ehrman, *Cloud Seeding, Wildfire Smoke Emissions, and Solar Geoengineering: Why is Climate Modification Unregulated?*, 35 GEO. ENVTL. L. REV. 459, 472 (2023) (explaining that hazardous substances are not automatically regulated because they are inherently hazardous, but rather they are only regulated once they reach a certain concentration that creates detrimental effects on human health).

manageable.[49] These environmental concerns pose an obvious political barrier to increasing the deployment of cloud seeding.

Cloud seeding today is used across many countries for a variety of reasons. The U.S. and Australia have used cloud seeding for scientific research purposes.[50] China and Russia have used cloud seeding operations for decades to disrupt unfavorable weather patterns during public events and holidays.[51] For example, during the 2008 Beijing Olympics, China claimed to successfully conduct a large-scale cloud seeding operation to dissipate potential rain clouds before they could reach the area where the games would be held.[52] Such an operation to stop rain from ruining a sporting event can appear innocuous. But the success of this operation, and many others like it, demonstrates the potential for destruction through targeted drought or flood.[53]

The chief environmental concern for cloud seeding should be the question of what if the technology works too well at producing water to the point it causes flood damage. For example, during the Vietnam War, the U.S. attempted to use cloud seeding as a tactical weapon, codenamed, "Operation Popeye."[54] Operation Popeye's goal in using cloud seeding was to soften road surfaces, cause landslides along roadways, wash out river crossings, and maintain saturated soil conditions beyond the normal time span.[55] Operation Popeye and other military efforts eventually led to the International Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques of 1977 (ENMOD).[56] ENMOD now provides a general international agreement to prohibit the use of hostile weather modification against enemy combatants and indicates how cloud seeding can be used to induce flood damage.[57]

This Article does not suggest that the utilization of cloud seeding will lead to intentionally targeted floods or droughts throughout the Basin. Rather, this Article is written assuming that cloud seeding operations in the Basin will solely target water

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[49] *See* Nathan LaCross, *Concerns Regarding Silver Iodide Cloud Seeding*, UTAH DEP'T OF HEALTH (2014) https://appletree.utah.gov/wp-content/uploads/2021/10/Silver_Iodide_Cloud_Seeding.pdf [https://perma.cc/269K-P533]; Joel P. Bartlett, *Environmental and Legal Considerations in Weather Modification Activities in the Northern Sierra Nevada*, 12 WATER, AIR, & SOIL POLLUTION 29, 33–34 (1979); *see also* Virginia Simms, *Making the Rain: Cloud Seeding, the Imminent Freshwater Crisis, and International Law*, 44 INT'L L. 915, 921 (2010) (discussing the operations of private weather modification companies).

[50] *See* Chen, *supra* note 1, at 63–64.

[51] *See* Erin Brodwin, *China Spent Millions on a Shady Project to Control the Weather Ahead of the Beijing Olympics — and Dozens of Other Countries Are Doing it too*, BUSINESS INSIDER (Jul. 29, 2016), https://www.businessinsider.com/china-sets-aside-millions-to-control-the-rain-2016-7 [https://perma.cc/RL7C-XG92].

[52] *Id.*

[53] Ed Darack, *Weaponizing Weather: The Top Secret History of Weather Modification*, WEATHERWISE 24, 26 (2019).

[54] Bonnheim, *supra* note 26.

[55] Darack, *supra* note 53, at 26.

[56] James R. Fleming, *The Climate Engineers*, 31 WILSON Q. 46, 56 (2007).

[57] *See* Joanna Jarose, Note, *A Sleeping Giant? The ENMOD Convention as A Limit on Intentional Environmental Harm in Armed Conflict and Beyond*, 118 AM. J. INT'L L. 468, 481 (2024).

reservoirs in the Basin. But, as the cloud seeding industry grows and operations increase in both the number and quantity of water produced, various parties in the Basin will inevitably be affected by this industry for better or worse. As cloud seeding becomes more effective at extracting atmospheric moisture, certain areas could be subject to less rainfall because other areas that are upwind are cloud seeded.[58] Without an effective and efficient legal regime for atmospheric moisture and effective control mechanisms, this emerging natural resource could end up becoming a tragedy of the commons.[59]

D. Cloud Seeding's Impact on People

Cloud seeding poses immense benefits for people throughout the Basin. Cloud seeding projects that aim to refill reservoirs can help mitigate the economic damage from drought that costs the U.S. an average annual economic loss of between six and eight billion dollars.[60] As a proven method of rain and hail suppression, fog diffusion, and mountain snowpack expansion, cloud seeding can be used in a wide range of industries for a multitude of economic benefits.[61] Such uses

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[58] *See* COTTON & PIELKE SR., *supra* note 2, at 75–76 (discussing a 1968 study that strongly suggests that higher concentrations of seeding agents can lead to reductions in rain fall in at least certain clouds and in some regions.); *contra* Davis, *supra* note 2, at 35 n. 127 (citing a 1973 study that strongly suggests that, "if anything, [cloud] seeding has a positive downwind effect" while also suggesting that such "downwind studies rest on inadequate data"). Current weather modification studies focus on cloud seeding's effect beyond a targeted area. One of the biggest concerns facing the cloud seeding industry is downwind ("extra-area") effects that reduce precipitation outside the target area. Simon, *supra* note 47, at 155. The World Meteorological Organization has repeatedly stated that extra area effects cannot be ruled out when conducting cloud seeding. *Id.* at 154. Recent studies show that cloud seeding can increase precipitation outside the target area. T.P. DeFelice, J. Golden, D. Griffith, W. Woodley, D. Rosenfeld, D. Breed, M. Solak, & B. Boe, *Extra Area Effects of Cloud Seeding — An Updated Assessment*, 135–136 ATMOSPHERIC RES. 193, 194 (2014). However, cloud seeding operations still run the risk of unintended consequences including reducing precipitation or causing hail. *See* WORLD METEOROLOGICAL ORG., *WMO Statement on Weather Modification*, 2 (Apr. 27, 2015), https://www.skywaterventures.com/uploads/7/0/6/1/70616003/wmr_documents.final_27_april_1.final.pdf [https://perma.cc/5286-F9KG]. The uncertainty surrounding the precise effects of cloud seeding underscores that cloud seeding poses serious risks and more research is needed.

[59] The "tragedy of the commons" refers to a situation where a shared resource is overexploited by individuals acting in their own self-interest, leading to the depletion or degradation of the resource to the detriment of all. *See generally* Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968). In the context of cloud seeding, this could occur if multiple parties extract or manipulate atmospheric water without regulation, potentially disrupting natural weather patterns and exhausting the resource's availability for equitable use. *See generally* Currier, *supra* note 19, at 960 (explaining that if a cloud seeding project affects a neighboring state, it may cause conflict between parties in different states).

[60] *See* Weather Mitigation Research and Development Policy Authorization Act, S. 601, 111th Cong. § 3 (2009).

[61] *See* Bradshaw & Ehrman, *supra* note 48, at 465 (listing the current uses of cloud seeding, including drought mitigation, agricultural, and recreational such as increasing snowpack for ski hills); *see* Currier, *supra* note 19, at 954.

could help prevent the destruction of property and even save lives.[62] But this technology is not just a promise of the proverbial sunshine and rainbows. Besides its wide range of potential benefits, it also has several side effects.[63]

One potential side effect is what has been termed the "extra area effect."[64] Several observers and research studies have pointed out concerns that cloud seeding in one area to induce precipitation may lead to a decrease in precipitation in a neighboring area.[65] Several studies have concluded that cloud seeding causes an increase in precipitation up to 150 kilometers downwind without any "extra area effect" causing other neighboring regions to receive less precipitation.[66] However, other researchers have reached the opposite conclusion.[67] For example, the U.S. conducted cloud seeding over the open seas to suppress hurricanes but ultimately stopped the operation after Mexico cited scientific research suggesting the practice was causing drought conditions there.[68]

Regardless of the scientific consensus as to whether general cloud seeding causes negative extra area effects, researchers have also concluded that cloud seeding can be used to decrease precipitation by releasing an excessively large amount of particulate into the cloud.[69] This process is known as "over seeding."[70] Over seeding operations, such as the ones in China, have been successful in dissipating rain clouds.[71] Cloud seeding affects the hydrologic cycle, but to what extent, scientists still are not certain and further research is required.[72]

We can rest assured that as the industry grows across the Basin and the weather is modified, some will experience, "on one hand, unwanted deprivation of

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[62] *See* U.S. GOV'T ACCOUNTABILITY OFF., CLOUD SEEDING: EVALUATING ITS POTENTIAL BENEFITS AND LIMITATIONS, GAO-25-107328, 11 (2024), https://www.gao.gov/assets/gao-25-107328.pdf [https://perma.cc/US4M-TGZW]; *but see* MacKenzie L. Hertz, *It's Raining, It's Pouring, Weather Modification Regulation Is Snoring: A Proposal to Fill the Gap in Weather Modification Governance*, 96 N.D. L. REV. 31, 35 (2021) (cautioning that while cloud seeding may be used to divert hurricanes and suppress tornadoes, hail, and lightning, cloud seeding may harm others effected by such actions).

[63] Hertz, *supra* note 62, at 35–36.

[64] Weijan Wang, Zhanyu Yao, Jianping Guo, Chao Tan, Shuo Jia, Wenhui, Zhao, Pei Zhang, & Liangshu Gao, Abstract, *The Extra-Area Effect in 71 Cloud Seeding Operations During Winters of 2008–14 over Jiangxi Province, East China*, 33 J. METEOROLOGICAL RSCH. 528, 528 (2019) (120 kilometers); *see also* DeFelice et al., *supra* note 58, at 200 (100 to 150 kilometers).

[65] Wang et al., *supra* note 64; *see also* DeFelice et al., *supra* note 58.

[66] Mark E. Solak, David P. Yorty, & Don A. Griffith, *Estimations of Downwind Cloud Seeding Effect in Utah*, 35 J. WEATHER MODIFICATION 52, 53 (2003); Weijan Wang et al., *supra* note 64; *see also* DeFelice et al., *supra* note 58.

[67] MARSHA L. BAUM, WHEN NATURE STRIKES: WEATHER DISASTERS AND THE LAW 32 (2007).

[68] *Id.*

[69] Michael Brown, *Present and Future Regulation of Cloud Seeding Activities in California*, 43 J. WEATHER MODIFICATION 97, 98 (2011).

[70] *Id.*

[71] Helen Davidson, *China 'Modified' the Weather to Create Clear Skies for Political Celebration – Study*, GUARDIAN (Dec. 5, 2021, 11:28 PM), https://www.theguardian.com/world/2021/dec/06/china-modified-the-weather-to-create-clear-skies-for-political-celebration-study [https://perma.cc/9TUR-TN4A].

[72] DeFelice et al., *supra* note 58, at 201.

precipitation or, on the other, an undesired increase in precipitation."[73] For example, cloud seeding projects could produce unwanted excesses of rain or snow resulting in floods. Weather modification could be used to direct storms away from population centers but toward others.[74] Also, suppressing hail and thunderstorms may protect crops or airports, but that suppression will inevitably suppress precipitation that others downwind or downstream may depend on.[75]

Cloud seeding across the Basin reveals pressing legal questions. How do we regulate operations that can redirect rainwater, harming neighboring lands? How do we resolve conflicting ideas between public and private entities about what are the ideal weather conditions to induce?[76] Currently, these are issues that each state's cloud seeding regulatory entity answers.[77] But each state answers them independently of any other state.[78] Such state agencies only assess the costs and benefits of their regulations and operations as they concern their state.[79] They do not assess the costs and benefits of a cloud seeding operation on another state.[80] If each state in the Basin is left to craft its own legal regimes, control mechanisms, and regulatory goals, then the likelihood of states being drawn into conflict as clouds travel across state borders only increases.[81]

State courts have overseen litigation regarding cloud seeding disputes for over fifty years.[82] In 1959, the Texas Supreme Court reviewed a case brought by ranchers seeking a preliminary injunction on cloud seeding activities by a weather modification operator.[83] Both sides argued over whether cloud seeding would cause more or less damage to their crops from hail.[84] This early case did not help foreclose litigation over rights to atmospheric moisture that would continue to come before courts. Cross-boundary disputes over cloud seeding have persisted for decades. For

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[73] Hertz, *supra* note 62, at 35.
[74] Jamie Harris, *Law and Technological Change: The Case of Weather Modification*, 3 YALE REV. L. & SOC. ACTION 26, 30 (1973).
[75] *See* Abrams & Clark, *supra* note 43; *see* Hertz, *supra* note 62, at 36.
[76] *See* Chen, *supra* note 1, at 67.
[77] *See generally id.* at 69–92.
[78] *Compare* N.M. STAT. ANN. § 75-3-7 (1965) (avoiding the use of the term professional and only requiring applicants to "demonstrate[] . . . skill and experience necessary to accomplishment of weather control without actionable injury to property or person"), *with* ARIZ. REV. STAT. § 45-1603.A.3 (2010) (requiring would-be operators to provide information related to their professional qualifications during the application process but not expressly requiring that applicants possess any particular level of expertise to receive a permit or license).
[79] *See* Chen, *supra* note 1, at 81–82.
[80] *See id.* at 83 (discussing how three states reached three different conclusions regarding ownership of atmospheric pressure, none of which assessed costs and benefits to another state).
[81] *See* Larson, *supra* note 21, at 920 ("Neighboring states can thus have dramatically different legal regimes, not to mention policy aims, governing water use and management. These differences inevitably led to water disputes between states over transboundary waters.").
[82] *See*, *e.g.*, Slutksy v. City of New York, 97 N.Y.S. 2d 238, 239 (N.Y. Sup. Ct. 1950); Sw. Weather Rsch., Inc. v. Duncan, 319 S.W.2d 940, 941 (Tex. Civ. App. 1958); Pennsylvania. Nat. Weather Ass'n v. Blue Ridge Weather Modification Ass'n, 44 Pa. D. & C.2d 749, 749 (Pa. Com. Pl. 1968).
[83] Sw. Weather Rsch., Inc. v. Jones, 327 S.W.2d 417, 419 (Tex. 1959).
[84] *Id.*

example, in 1992, North Dakota sued the Board of Natural Resources and Conservation over its rejection of North Dakota's application for two permits to conduct cloud seeding activities just twenty miles inside Montana's border, known as the "buffer zone."[85]

Intrastate and cross-boundary disputes over cloud seeding in the Basin could present a substantial increase in transaction costs and make using atmospheric moisture highly inefficient.[86] Because of the potential for cloud seeding to improve our water management or wreak havoc and cause disputes, the Basin will need a coordinated and comprehensive legal regime to best utilize this emerging natural resource. This Article next addresses several proposed legal regimes for atmospheric moisture.

E. Current Competing Legal Regimes for Atmospheric Moisture

Cloud seeding can be an effective means of augmenting water supplies.[87] But conducting weather modification operations over such a wide area with so many diverse peoples and parties will inevitably lead to disputes.[88] One of the guiding principles of American jurisprudence is the deep reverence for property rights and personal autonomy.[89] Weather modification activities to extract atmospheric moisture over other people's land presents a complicated legal quagmire without an obvious solution. Since the advent of weather modification technology following World War II, the issue of ownership has always been a salient question in legal discussions of weather modification.[90] American jurisprudence on the legal arrangement for atmospheric moisture could develop into either private ownership or state ownership.[91]

Developing a legal regime that would allow for atmospheric moisture to be privately owned, however, is highly unlikely. Generally, all water in the U.S. is a public trust resource.[92] This means that it is owned by the government and held in trust for the benefit of all citizens.[93] Unlike property such as land which can be

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[85] North Dakota Atmospheric Res. Bd. v. Bd. of Nat. Rsch. & Conservation, No. ADV-92-918, 1992 Mont. Dist. LEXIS 60, at *2 (1st Jud. Dist., Lewis & Clark Co., Mont. Jul 24, 1992).
[86] Chen, *supra* note 1, at 56–57.
[87] *See generally* Larson, *supra* note 45 (arguing that cloud seeding could be a viable means of enhancing precipitation, thus increasing access to water resources).
[88] *See* Chen, *supra* note 1, at 68–69.
[89] *See* Gerald Korngold, *Resolving the Intergenerational Conflicts of Real Property Law: Preserving Free Markets and Personal Autonomy for Future Generations*, 56 AM. U. L. REV. 1525, 1548 (2007) (highlighting that personal autonomy is a central principle that has helped shaped how American law has developed over time).
[90] *See Who Owns the Clouds?*, 1 STAN. L. REV. 43 (1948) (discussing legal ownership of atmospheric moisture following the technological progress of advances in flight and weather modification of WWII).
[91] *See* Tarek Majzoub, Fabienne Quilleré-Majzoub, Mohamed Abdel Raoud, & Mire El-Majzoub, *"Cloud Busters": Reflections on the Right to Water in Clouds and A Search for International Law Rules*, 20 COLO. J. INT'L ENVTL. L. & POL'Y 321, 330–32 (2009).
[92] *See* The Daniel Ball, 77 U.S. 557, 564 (1870); *see generally* Illinois Cent. R. Co. v. Illinois, 146 U.S. 387 (1892).
[93] *See The Daniel Ball*, 77 U.S. at 564; *Illinois Cent. R. Co.*, 146 U.S. at 458 (quotation omitted).

owned individually, the government gives usufructuary rights to water.[94] And with the federal government also owning the airspace above all lands,[95] it is very difficult to imagine a court finding that the clouds above a public or private entity's land to be anything other than a public trust resource. Providing landowners with exclusive control over atmospheric water would go against current jurisprudence of treating bodies of water as a public trust resource.[96] For over a century, courts have treated bodies of water as public resources to be reviewed under the public trust doctrine.[97]

State ownership of water in clouds is the better legal arrangement and has largely been adopted in the U.S.[98] Under a state ownership system, for an individual to access water in clouds, they must get consent from the government agency responsible for granting licenses to conduct cloud seeding operations in U.S. airspace.[99] Conversely, under a private ownership system, an individual could be required to gather consent from each landowner the cloud passes over.[100] Under private ownership, ownership of atmospheric moisture can be asserted through ownership of the underlying land.[101] Allowing each property owner to claim rights to the clouds passing over their land would create prohibitively high transaction costs due to the expensive and impractical consent-gathering process required.[102]

Under state ownership, ownership of atmospheric moisture would be held by the state in trust for the general benefit of the public.[103] This proposal would classify atmospheric moisture as either *res communes*, meaning it is common property available for public use and enjoyment, or *res nullius*, meaning it belongs to no one.[104] Under these doctrines, the government, either through state or federal authorities, would have the authority to regulate and implement control mechanisms

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[94] Alan W. Witt, Comment, *Seeding Clouds of Uncertainty*, 57 JURIMETRICS J. 105, 121 (2016).
[95] Sovereignty and Use of Airspace, 49 U.S.C. § 40103(a)(1) (1994).
[96] *See The Daniel Ball,* 77 U.S. at 564 (holding that bodies of navigable water at the time of statehood are to be held in trust by the government for the benefit of all people).
[97] *See* James L. Huffman, *Speaking of Inconvenient Truths–a History of the Public Trust Doctrine*, 18 DUKE ENV'T L. & POL'Y F. 1, 57, 62 (2007) (explaining how *Illinois Central Railroad* has been the "lodestar" of the modern application of the public trust doctrine which affirms that states can only subject water bodies to private ownership so long as it does not prevent the state from meeting its trust responsibilities).
[98] *See* Chen, *supra* note 1, at 69–92.
[99] *Id.* at 71–74.
[100] *See id.* at 83–84 (highlighting that Texas and Pennsylvania courts concluded private landowners can bring injunctions against cloud seeding companies by asserting a property interest in the clouds that pass over their land in certain circumstances).
[101] *See* Simms, *supra* note 49, at 929; *but see Who Owns the Clouds?*, *supra* note 91, at 48–49 (concluding that the *ad coelum* doctrine does not support and has never supported the assertion that private land ownership extends to atmospheric moisture).
[102] *See* Chen, *supra* note 1, at 55.
[103] *Cf.* Illinois Cent. R. Co. v. Illinois, 146 U.S. 387 (1892). This case states that water, as a public trust resource, is held in trust by the government for the benefit of all citizens. *See id.* at 452. Thus, if water in clouds were to be concluded as a public trust resource it would likely be treated similarly.
[104] *See* Chen, *supra* note 1, at 68–69.

to manage atmospheric moisture.[105] Treating atmospheric moisture as *res communes* would be consistent with current Western and American jurisprudence as it would run parallel with the public trust doctrine.[106]

It is because American jurisprudence is best suited for treating atmospheric moisture as *res communes* under state ownership that the Basin states should work together to create a state commission on weather modification.[107] Creating such a commission would allow states to cooperate and create a well-informed regulatory apparatus that can meet the water management needs of the Basin.[108] Developing such a commission would require a thorough understanding of how the cloud seeding industry is currently operating throughout the Basin.

III. CLOUD SEEDING IN THE COLORADO RIVER BASIN

This Part lays out how cloud seeding is currently conducted in the Basin and the challenges it poses.

A. Current Cloud Seeding Projects in the Basin

Cloud seeding has been conducted in the Basin since the 1960s for operational and research purposes.[109] With well over six decades of research and water scarcity in the Basin implying water will be an even more valuable resource, monetary incentives for water augmentation are climbing.[110] Public agencies and private parties invest millions of dollars in cloud seeding projects across the Basin.[111]

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[105] *Cf.* Samuel T. Ayres, *State Water Ownership and the Future of Groundwater Management*, 131 YALE L.J. 2213, 2224, 2284–85 (2022) (explaining that when the state controls a natural resource, it allows the state to manage and regulate the resource).

[106] *See* Hope M. Babcock, *Grotius, Ocean Fish Ranching, and the Public Trust Doctrine: Ride 'Em Charlie Tuna*, 26 STAN. ENV'T L.J. 3, 33–34, 46–48 (2007) (explaining that oceans have been considered *res communes* "since the time of Grotius" and that American jurisprudence over the decades has developed to become consistent with the public trust doctrine to protect *res communes* resources); Huffman, *supra* note 97, at 21–22.

[107] *See infra* Part IV.

[108] *Id.*

[109] Steven M. Hunter, *Potential Water Augmentation from Cloud Seeding in the Colorado River Basin,* 38 J. WEATHER MODIFICATION 51, 51 (2006).

[110] *See*, *e.g.*, Sophie Quinton, *Why Cloud Seeding Is Increasingly Attractive to the Thirsty West*, STATELINE (Feb. 20, 2018, 12:00 AM), https://stateline.org/2018/02/20/why-cloud-seeding-is-increasingly-attractive-to-the-thirsty-west/ [https://perma.cc/J4CH-ZV9C].

[111] *See*, *e.g.*, Brittany Peterson, *Feds Spend $2.4 Million on Cloud Seeding for Colorado River*, ASSOCIATED PRESS (Mar. 17, 2023, 12:00 PM), https://apnews.com/article/climate-change-cloud-seeding-colorado-river-f02c216532f698230d575d97a4a8ac7b [https://perma.cc/JW57-ENW8]; Katie Brigham, *How States Across the West are Using Cloud Seeding to Make it Rain*, CNBC (Dec. 17, 2022, 9:00 AM) https://www.cnbc.com/2022/12/17/how-cloud-seeding-can-help-replenish-reservoirs-in-the-west.html [https://perma.cc/3V9A-5TJ2]; Sarah A. Tessendorf, Jeffrey R. French, Katja Friedrich, Bart Geerts, Robert M. Rauber, Roy M. Rasmussen, Lulin Xue, Kyoko Ikeda, Derek R. Blestrud, Melvin L. Kunkel, Shaun Parkinson, Jefferson R. Snider, Joshua Aikins, Spencer Faber, Adam Majewski, Coltin Grasmick, Philip T. Bergmaier, Andrew

Many of these projects are conducted in the Upper Basin states like Utah because the state's topography, climate, and water infrastructure are cost-effective for such projects.[112]

There is also a great deal of interest in Lower Basin states to ensure that cloud seeding projects in Upper Basin states are effective.[113] While all Basin states depend on precipitation, states vary in the sources they depend on for their water supply.[114] For example, states in the Lower Basin not only depend on precipitation from local clouds, but they also depend on Colorado River water that has made it all the way from the melting snowpack in the Rocky Mountains down to the Lower Basin.[115] Ninety percent of the stream flow of the Colorado River originates in the Upper Basin.[116] Thus, if it rains and snows more in the Upper Basin, more water will enter the Lower Basin.[117]

The cloud seeding projects that successfully produce more rain or snow result in more water that flows down the Upper Basin.[118] That water then travels into various reservoirs of the Upper Basin and naturally flows through the Colorado River system until it reaches the crossing point between the Upper and Lower Basin.[119] While water is in the Upper Basin, it is subject to the use of Upper Basin water users until it passes into the Lower Basin.[120]

B. The Overall Goal of Cloud Seeding Projects in the Basin

Despite having a long history of experiments researching whether cloud seeding is possible, many states are only recently realizing that not only is cloud

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Janiszeski, Adam Springer, Courtney Weeks, David J. Serke, & Roelof Bruintjes, *A Transformational Approach to Winter Orographic Weather Modification Research: The SNOWIE Project*, 100 BULL. AMER. METEOR. SOC. 71, 73 (2019).

[112] UTAH DEP'T NAT. RES., *Cloud Seeding: Enhancing Our Water Supply*, UTAH, https://water.utah.gov/cloudseeding/#:~:text=The%20Cloud%20Seeding%20Act%20of,it%20helps%20form%20ice%20crystals [https://perma.cc/S422-HCHZ].

[113] *See* Peterson, *supra* note 111.

[114] *See* Tessendorf et al., *supra* note 111; Quinton, *supra* note 110.

[115] *Id.*

[116] Daniel Hogan & Jessica D. Lundquist, *Recent Upper Colorado River Streamflow Declines Driven by Loss of Spring Precipitation*, 51 GEOPHYSICAL RSCH. LETTERS, 16, 1 (2024).

[117] *See id.*

[118] *See* TODD FLANAGAN, N. AM. CONSULTANTS, INC., ANNUAL CLOUD SEEDING REPORT 8, 10, 50–51 (2024) (concluding that several Utah rivers in the basin received an estimated 5-13% increase in streamflow due to a 5-6% increase in precipitation and snowpack from cloud seeding).

[119] *Id.* at 2, 9–10 (explaining that lower basin states worked together to fund an extension period for the central and southern Utah cloud seeding program, which was expected to increase precipitation to tributaries of the Colorado River).

[120] Colorado River Compact, COLO. REV. STAT. § 37-61-101, art. III(e).

seeding possible, but it is economically feasible.[121] Private cloud seeding projects have been increasing as technology becomes cheaper and more effective.[122]

Cloud seeding is one of the most cost-effective means of acquiring more water through augmentation.[123] In 2023, Utah lawmakers invested an unprecedented $12 million into the cloud seeding program of the Utah Division of Water Resources.[124] The Director of Natural Resources for Utah commented that this program can produce water between $2 and $15 per acre-foot.[125] This small cost per acre-foot is quite appealing when considering that the Bureau of Reclamation has offered Colorado River water users compensation between $330 and $400 per acre-foot of unused water.[126] This ability to produce water at such a cost-effective rate is driving parties to invest.[127]

Public institutions are investing quite heavily in out-of-state projects with the hope of creating more water in a cost-effective way.[128] The Central Arizona Project (CAP), Southern Nevada Water Authority (SNWA), and California's six agency committee ("California Agencies") currently fund weather modification projects in Upper Basin states such as Wyoming, Colorado, and Utah.[129] The Central Arizona Water Conservation District (CAWCD) commits $650,000 annually to weather modification projects in Colorado.[130] Like SNWA and the CAP, California Agencies intend their investment to generate greater runoff volumes in the Colorado

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[121] *See* Leia Larsen, *Utah Put Millions Into Cloud Seeding This Year. Here's What It Expects in Return*, THE SALT LAKE TRIBUNE, (Sep. 29, 2023, 3:48 PM), https://www.sltrib.com/news/environment/2023/09/29/utah-put-millions-into-cloud/ [https://perma.cc/HE8V-B2AC] ("[w]hen you compare [cloud seeding] to anything else we do . . . it is hands-down a fraction of the cost of any other water [conservation] program").

[122] Witt, *supra* note 94, at 128.

[123] *See* Larsen, *supra* note 122.

[124] *Id.*

[125] *Id.* (quoting Joel Ferry, director of Utah's Department of Natural Resources).

[126] Letter from Jacklynn Gould, U.S. Department of the Interior, Bureau of Reclamation, on Funding Opportunity for Voluntary Participation in the Lower Colorado Conservation Efficiency Program, to Interested Parties (2022) (available at https://www.usbr.gov/inflation-reduction-act/docs/LC-Conservation-Program-Letter-with-Enclosures.pdf.).

[127] *See* Larsen, *supra* note 122.

[128] *See Weather Modification Projects*, CENT. ARIZ. PROJECT, https://www.cap-az.com/water/water-supply/building-resiliency/weather-modification-projects/ [https://perma.cc/2YBG-Y4JQ]; Angus M. Thuermer Jr., *Officials Scrutinize Cloud Seeding Program,* WYOFILE (Nov. 30, 2021), https://wyofile.com/officials-scrutinize-cloud-seeding-program/ [https://perma.cc/GU73-TNMM].

[129] *Weather Modification Projects*, *supra* note 128.

[130] CENTRAL ARIZONA PROJECT, BIENNIAL 2024-2025 BUDGET 2-19 (2024).

River.[131] This funding allows cloud seeding operations in the Upper Basin states, such as Utah, to expand substantially.[132]

These ideal economic circumstances are also driving private entities, such as utilities, to invest heavily in cloud seeding projects.[133] Private utility companies, such as the Idaho Power Company, substantially fund cloud seeding projects.[134] Many private utility companies receive a significant portion of their power from hydroelectric projects like dams.[135] More freshwater in rivers translates to better conditions for generating hydroelectric power.[136] Private company interests can drive investment for projects across multiple states.[137]

As this industry grows, so too will the expectations that investors have when funding out-of-state projects. In practice, investors would fund projects that create water with the reasonable expectation that they will be able to use that cloud -seeded water.[138] Investing in a project with the expectation that in return for your capital, you will receive water effectively creates a water market.[139] But when a party from the Lower Basin invests in a project that will take place in the Upper Basin, that water in the Upper Basin needs to be generated, accounted for, transported through the Colorado River system, and then delivered from Lake Mead to the

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131 *See, e.g.*, *Utah Holds Its First Cloud Seeding Symposium*, UTAH DEP'T NAT. RES. (Sept. 28, 2023), https://water.utah.gov/utah-holds-its-first-cloud-seeding-symposium/ [https://perma.cc/CL7V-38M2] (quoting Tom Ryan, Resource Specialist of the Metropolitan Water District of Southern California as stating "[c]ollaboration between states is not only about improving individual programs but also has the intention of providing more water supply for the entire region").

132 TODD FLANAGAN & GARRETT CAMMANS, N. AM. WEATHER CONSULTANTS, INC., ANNUAL CLOUD SEEDING REPORT: SOUTHERN & CENTRAL UTAH PROGRAM 2022-2023 WINTER SEASON, 1, 4 (2023) (reporting that funding from Lower Basin states extending the cloud seeding period has resulted in early-season (November 1–15) and late season (March 16–April 15) extensions to the cloud seeding program since 2010).

133 Tessendorf et al., *supra* note 111.

134 *Id*.

135 U.S. ENERGY INFO. ADMIN., *Hydropower Explained*, (last updated April 20, 2023) https://www.eia.gov/energyexplained/hydropower/ [https://perma.cc/X6HS-G5H9] (noting that across the entire U.S., total annual electricity generated between 2001 through 2022 was almost a seven percent average).

136 *See* Tessendorf et al., *supra* note 111, at 72; Samantha Young, *Governments Turn to Cloud Seeding to Fight Drought*, PHYS.ORG (Dec. 10, 2009), https://phys.org/news/2009-12-cloud-seeding-drought.html [https://perma.cc/JU6G-6J4B].

137 *See*, *e.g.*, Peter Maloney, *SMUD, Among Other Utilities, Uses Cloud Seeding to Increase Hydropower*, AM. PUB. POWER ASS'N (Jan. 22, 2018), https://www.publicpower.org/periodical/article/smud-among-other-utilities-uses-cloud-seeding-increase-hydropower [https://perma.cc/PQ9C-B2ML]; Tessendorf et al., *supra* note 111 (showing multiple utilities both privately and publicly owned across several states have made substantial investments in cloud seeding to generate greater runoff for hydropower).

138 *See* James A. Lochhead, *An Upper Basin Perspective on California's Claims to Water From the Colorado River*, 4 U. DENV. WATER L. REV. 290, 322 (2001).

139 *See id.* at 322–24 (arguing that implementing marketing mechanisms that allow for the purchase and/or transfer of water between the Upper and Lower Basins constitutes a water market).

ultimate state of use and, finally, to the ultimate water user in the Lower Basin.[140] Such a system where a Lower Basin user could purchase the legally enforceable right to water in the Upper Basin likely qualifies as an inter-basin transfer.[141] But inter-basin transfers are a type of transaction that comes with many complications.

C. Interstate Cloud Seeding Projects Qualify as an Inter-basin Sale or Transfer

The diversion of water from one water source basin to another constitutes an inter-basin transfer.[142] However, cloud seeding presents a new problem not yet addressed through an inter-basin transfer lense. A Lower Basin water user funding a cloud seeding project in the Upper Basin does not necessarily constitute an inter-basin transfer. Hypothetically, if a user in Arizona were to fund a cloud seeding project in Colorado with only the hope that this other state would not increase its consumptive use, then the additional water that flowed from one basin to another would not likely constitute an inter-basin sale or transfer. This is because there would be no contractual obligation or formal arrangement ensuring the water's availability to the Lower Basin. In other words, this investor would simply be gambling on the fact that the Upper Basin will continue to underutilize its consumptive use allocation, and the excess water will make its way down to the Lower Basin for their benefit.

Conversely, if that same user were to fund the same project with the belief that they would have a legally enforceable right to the cloud-seeded water, that would likely constitute an inter-basin water transfer. To have such a right to this water, they would likely have needed to contract for the right to ownership of that water with an Upper Basin State in the process of securing their state permit to conduct cloud seeding operations.[143]

All water users in the Lower Basin, both public and private, would be able to contract with Upper Basin water users for water from cloud seeding while it is still in the Upper Basin, thus creating a water market of inter-basin sales.[144]

D. Inter-basin Transfers are Currently Illegal Under the Colorado Compact

The Colorado Compact ("the Compact"), also referred to as the Law of the River, is the result of a complex negotiation between Upper and Lower Basin states over how to allocate the consumption of water.[145] The Lower Basin states wanted major regulatory structures to alleviate the threat of flooding and create opportunities for water development.[146] The Upper Basin states wanted to avoid the interstate

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[140] Lochhead, *supra* note 138, at 328.
[141] *Id.* at 327.
[142] Barbara Cosens, *The Eternal Quest for Water: Historical Overview and Current Examination of Interbasin Transfers of Water*, 55 ROCKY MT. MIN. L. INST. 17-1, § 17.01 (2009).
[143] *See* David J. Guy, *When the Law Dulls the Edge of Chance: Transferring Upper Basin Water to the Lower Colorado River Basin*, 1991 UTAH L. REV. 25, 28 (1991).
[144] *See* Lochhead, *supra* note 138, at 323.
[145] *Id.* at 292 n. 5.
[146] *Id.* at 323.

imposition of the prior appropriation doctrine and to protect future development rights in the Upper Basin.[147] The Law of the River struck a bargain between the conflicting interests and helped alleviate some of the controversies between Upper and Lower Basin states.[148] The Upper Basin received a specified perpetual allocation of the right of consumptive use of water.[149] In exchange, the Upper Basin agreed to let any water for which it lacked a reasonably anticipated consumptive need to pass to the Lower Basin without charge.[150] Allowing inter-basin transfers over cloud-seeded waters would do more harm than good by going against the very basis of that bargain.[151]

The Compact does not apportion water itself, but rather the use of water.[152] Pursuant to Article III(a), both the Upper and Lower Basins are apportioned from the Colorado River System in "perpetuity . . . the exclusive beneficial consumptive use of 7,500,000 acre feet of water per annum[.]"[153] Furthermore, Article III(e) states that the Upper Basin shall not withhold excess water for its own use if there is a demand for it in the lower basin.[154]

To determine each basin's consumptive use, the Compact states that the place of use is determinative.[155] Two requirements must be met for the Lower Basin to be charged with use.[156] First, the water must have passed Lee Ferry, Arizona.[157] Second, the water must be used in the Lower Basin.[158] Thus, according to the Compact, that water does not belong to either basin until it is determined at what place the water is used.[159]

Moreover, there is very little legal precedent, if any, to create a system that could effectively account for inter-basin transfers over cloud-seeded water between the basins.[160] Apportioning cloud-seeded water in the Upper Basin for Lower Basin

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[147] Lochhead, *supra* note 138, at 323.
[148] *See id.* at 324
[149] *Id*. (citing Colorado River Compact, COLO. REV. STAT. § 37-61-101, art. III(a)).
[150] Sandra Zellmer, *The Anti-Speculation Doctrine and Its Implications for Collaborative Water Management*, 8 NEV. L.J. 994, 1000–01 (2008).
[151] Providing water to the Basin via cloud seeding is a benefit, but if it comes at the potential cost of opening a "Pandora's box" of allowing all other kinds of inter-basin transfers, Compact states will rightfully reject proposals to expand cloud seeding operations between Upper and Lower Basin members. *See* John Ruple, *The Navajo-Gallup Project: Legality of Intrastate/Interbasin Diversions Under the Colorado River Compact*, 24 J. LAND RES. & ENV'T. L. 475, 478 (2004).
[152] Lochhead, *supra* note 138, at 324 (citing § 37-61-101, art. III).
[153] § 37-61-101, art. III(a).
[154] *Id.* § 37-61-101 Art. III(e) ("The States of the Upper Division shall not withhold water, and the States in the Lower Division shall not require the delivery of water, which cannot reasonably be applied to domestic agricultural uses.").
[155] Lochhead, *supra* note 138, at 325; § 37-61-101 Art. I ("To these ends the Colorado River Basin is divided into two Basins, and an *apportionment of the use* of part of the water of the Colorado River System *is made to each of them* with the provision that further equitable apportionments may be made") (emphasis added).
[156] Lochhead, *supra* note 138, at 325.
[157] Colorado River Compact, § 37-61-101, Art. III(d).
[158] *See id.* at Art. III(a).
[159] *See id.* at Art. I; III(a); Lochhead, *supra* note 138, at 325.
[160] Lochhead, *supra* note 138, at 326.

use would require some kind of debit-credit system.[161] Because the Compact does not reference any kind of debit-credit system, some authorities argue the sale of inter-basin water "would allow the Lower Basin to consumptively use the amount of the water sale in excess of 75 m.a.f. every ten years and require the use of the Upper Basin to deliver the same."[162] Creating an open market for this kind of water between the basins would blur the clear line of the Compact that apportioned the right of use between the two basins in perpetuity and would complicate the right of development between the two basins.[163]

States are also powerless to unilaterally allow for the selling of rights to cloud-seeded water while it is in the Upper Basin.[164] The Compact, as federal law ratified by each state legislature and Congress, imposes terms on each state that limit the ability to confer rights on water.[165] States are so limited that Upper Basin states cannot confer upon any water user or government agency the right to sell, lease, or transfer the right to use water in a Lower Basin state.[166] Such a right does not exist under the Compact.[167] If any state attempts to grant such a right, it may be sued by another Compact member.[168] Alternatively, the Compact member could sue the federal government if it seeks to grant such a right involving accounting or delivery through a federal reservoir.[169]

E. Assuming Inter-basin Transfers do not Pose a Concern, Cloud-Seeded Water Would Likely Violate Prior Appropriation Regimes

Stepping away from the issues posed by cloud seeding between Upper and Lower Basin water users, cloud-seeded water poses other challenging issues to prior appropriation regimes that need to be addressed. Water from cloud seeding does not neatly fit into either of the typical categories contemplated in water law: groundwater

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[161] Lochhead, *supra* note 138, at 325–26. A debit/credit system in this context would function as an accounting mechanism to track and balance the allocation and use of water between basins. *See id.* Under such a system, "credits" would represent water contributed or made available by one basin (e.g., through cloud seeding), while "debits" would account for water consumed or withdrawn by the other basin. *See id.* This approach would ensure transparency and equity in water transfers, but it would require complex agreements and consistent monitoring to implement effectively. *See id.*

[162] Lochhead, *supra* note 138, at 325–26.

[163] *See* Zellmer, *supra* note 150, at 1000 (explaining that Chevron Oil's proposal to lease water from the Upper Basin of Colorado to the Lower Basin of Nevada was resisted by Compact states "for fear of encouraging commoditization of water and opening up unfettered water markets between Upper and Lower basins," which the Compact sought to avoid); Lochhead, *supra* note 138, at 324.

[164] *See* Lochhead, *supra* note 138, at 326.

[165] *Id.*

[166] *Id.*

[167] *See* Colorado River Compact, COLO. REV. STAT. § 37-61-101–104 (2000).

[168] The U.S. government may be sued under federal law by states should any officer or agency fail to adhere to the compacts, international treaties, or Supreme Court Decrees or the Colorado River Storage Project Act. *See* 43 U.S.C § 620m (1994).

[169] Lochhead, *supra* note 138, at 326.

or surface water.[170] Water law principles, while helpful in many cases, fall short in helping to resolve disputes over innovative means of water augmentation.[171]

"Water rights in the arid Western United States are generally based on the doctrine of prior appropriation."[172] Prior appropriation allocates the relative priority of water rights based on the date a user first put a specified amount of water to beneficial use.[173] This regime requires an observer to know the quantity, use, and relative priority date of each water right.[174] Additionally, this regime relies on an important distinction between "developed" and "salvaged" water.[175]

The distinction between whether water is developed or salvaged is critical because it determines whether the water in question is subject to the prior appropriation regime.[176] Developed water is water brought into a system from outside the Basin where it did not originally exist.[177] Salvaged water refers to water within the river basin that was previously inaccessible or unusable but has been made usable through human intervention.[178] The party that develops water retains ownership of it, regardless of the prior appropriation system.[179] Thus, the "party that imports water into a prior appropriation basin owns that water without it being subject to senior priority claims."[180] Salvaged water, on the other hand, remains part of the priority system, and the party that salvaged the water has no superior claim to the water.[181]

Cloud-seeded water throws a rather large wrench into the mechanics of this distinction. On one hand, it is developed water because the water is from clouds that typically fly high *above* the Basin.[182] Assuming those clouds are not considered part of the Basin, the water brought down through cloud seeding would likely be classified as developed water, allowing it to be used outside the prior appropriation system. However, cloud seeding can occur at a wide range of altitudes.[183] Orographic cloud seeding operates by having ground generators emit cloud seeding particulate from elevations as little as ten feet.[184] These low-altitude orographic clouds that form in response to the Earth's topography could be considered part of the Basin. The

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[170] Larson, *supra* note 45, at 767.
[171] *Id.* at 765, 767.
[172] *Id.* at 765; John D. Leshy, *A Conversation About Takings and Water Rights*, 83 TEX. L. REV. 1985, 1988–89 (2005).
[173] Alexandra B. Klass, *Property Rights on the New Frontier: Climate Change, Natural Resource Development, and Renewable Energy*, 38 ECOLOGY L.Q. 63, 86 (2011).
[174] *See id.*
[175] *See* S.E. Colo. Water Conservancy Dist. v. Shelton Farms, Inc., 529 P.2d 1321, 1325 (1974).
[176] *Id.*
[177] Larson, *supra* note 45, at 766.
[178] *Id.*
[179] *Id.*
[180] *Id.*
[181] *Id.*
[182] *See id.* at 765–67 (highlighting how the law has not provided any answers to whether the water in a cloud is temporarily part of the basin while it floats above or is only part of the basin once the water hits the basin ground, of if cloud seeded water is truly developed or salvaged water).
[183] Chen, *supra* note 1, at 66.
[184] Griffith, *supra* note 39, at 100–01.

ranging altitudes of clouds and cloud seeding operations present a difficult question of at what point is a cloud no longer part of the basin it travels across.

On the other hand, cloud-seeded water could be categorized as salvaged water.[185] The water in clouds has always traveled across basins and contributed to the Basin's hydrologic cycle but was previously inaccessible until it happened to rain.[186] Through human intervention, water that was once suspended in the atmosphere now has a significantly higher likelihood of descending from the skies and being put to beneficial use.[187] This interpretation, however, assumes that the cloud was already part of the Basin prior to any human intervention.[188]

Water generated from cloud seeding does not neatly fit into the typical distinctions used by courts to decide the legal status of a person's right to use certain kinds of water.[189] Asking the judicial branch to resolve a complex issue like classifying water from cloud seeding as developed or salvaged water and how that affects the Compact is a heavy lift.[190] Furthermore, recent Supreme Court precedent has put the responsibility of statutory interpretation more squarely on the shoulder of the courts and away from administrative agencies such as the Environmental Protection Agency and its goal to regulate the "waters of the United States."[191] Courts also face resource and institutional constraints in resolving such complex issues.[192]

Constraints such as the judicial system's relative lack of expertise in water law are a substantial factor.[193] Signatories to the Compact would be wise to avoid asking courts to impose a rule on how cloud-seeded water is to be categorized under the compact. Instead, they should negotiate among themselves to compromise on how to legally define water from cloud seeding operations, how it is handled in the context of the Compact, and how it should be regulated.

IV. Proposed Compact Amendment to Regulate Cloud Seeding

This Part lays out what provisions the amendment should include, why amending the Colorado River Compact is the best option for addressing the challenges posed by cloud seeding, and the limitations of this proposal.

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[185] Larson, *supra* note 45, at 775.
[186] *See* Larson & Payne, *supra* note 33, at 504 (discussing how salvaged water is water that is part of the basin but was previously unusable whereas developed water is water that is not part of the basin and must be imported).
[187] *See* Chen, *supra* note 1.
[188] *See* Larson, *supra* note 45, at 766.
[189] *Id.* at 767.
[190] *See* Larson & Payne, *supra* note 33, at 507.
[191] *See generally* Loper Bright Enters. v. Raimondo, 603 U.S. 369 (2024); Sackett v. Env't Prot. Agency, 598 U.S. 651, 661 (2023).
[192] Larson & Payne, *supra* note 33, at 507.
[193] *Id.*

A. The Necessary Elements of the Compact Amendment

The Basin states should negotiate an amendment to the Colorado Compact of 1922 to add three provisions. First, the states should specify how cloud-seeded water in the Basin will be regulated under the Compact.[194] Second, the states should specify how cloud-seeded water will be classified as either developed or salvaged water concerning each member state's water rights regime.[195] And third, the states should create the Interstate Commission on Weather Modification for the Colorado Basin (ICWMB), a hypothetical entity proposed for illustrative purposes.

The Compact member states should create an interstate water commission known as ICWMB. This commission would generally parallel The Weather Mitigation Research and Development Policy Authorization Act (WMA).[196] ICWMB should have the power to regulate cloud seeding activities in the Basin, issue permits, provide operational guidelines, and conduct research on improving methods of cloud seeding. ICWMB should be made up of voting members from each of the seven member states. The member states should create the Commission so that the twenty-eight indigenous tribes are represented to facilitate stakeholder participation in an inclusive and transparent manner.[197] It is unlikely that the seven states would agree to give each tribe a vote,[198] but some sort of representation on the Commission through advisory boards or grouping upper and lower basin tribes as groups with a single vote may be more realistic. ICWMB should also have an advisory board made up of experts who are familiar with emerging cloud seeding technology to create an effective Commission.[199]

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[194] *See supra* Part III.

[195] *See supra* Part III.

[196] *See* Currier, *supra* note 19, at 961 n. 139; Weather Mitigation Research and Development Policy Authorization Act, S. 601, 111th Cong. (2009). The WMA establishes a Research Program within the National Science Foundation's Geosciences Directorate, headed by a Program Director appointed by the Director of the Geosciences Directorate. S. 601 § 5(a). The WMA also creates an eleven-member Working Group, composed of representatives from states that support weather mitigation programs and experts in cloud dynamics, precipitation physics, hydrology, and related fields. *Id.* § 5(c). Similarly, ICWMB would form a commission where each participating state appoints a voting member, while the federal representative is designated by the Director of the Geosciences Directorate. However, ICWMB would extend beyond the advisory role of the WMA's Working Group, as it would have the authority to establish regulatory standards and decide whether to grant or deny cloud-seeding applications. Conversely, the WMA's Working Group primarily advises on research priorities and coordinates federal-state research efforts.

[197] *See* Larson, *supra* note 5; *see also* Larson, *supra* note 21, at 955.

[198] There are thirty federally recognized tribes within the Basin. *Tribes*, WATER & TRIBES INITIATIVE: COLO. RIVER BASIN, https://www.waterandtribes.org/tribes [https://perma.cc/T6KT-L78R]. To give each tribe a vote on the commission would create a large voting block that outweighs the seven states. The states are not likely to allow tribes to dilute their voting power. *See* Erica Porvaznik, *Renegotiating the Colorado River Compact: How a One Size Fits All Approach Has Led to a State Centric Future, and How the Commerce Clause Can Solve It*, 43 N. ILL. U. L. REV. 120, 150 (2023) ("As it currently stands, the states are willing to negotiate with the country of Mexico regarding any new negotiations but remain wary about allowing tribes access to the negotiations and the water.").

[199] Currier, *supra* note 19, at 969.

The operators who receive permits from this Commission would likely conduct operations that affect several states in the Basin and their citizens.[200] As such, it seems reasonable to allow a state commission to set the standards for an operator's license by implementing licensing requirements, operational guidelines, and a fee collection structure.[201] The ICWMB's goal should be to issue binding decisions and regulations that are comprehensive and specific. But it should also be flexible enough to leave room for innovative means of weather modification so that the industry can maximize efficiency and grow to help provide more fresh water to the Basin.[202]

B. Amending the Compact so it can Regulate Cloud Seeding is the Best Option

There are several competing options when deciding the best method of regulating weather modification.[203] Federal regulation, while able to standardize cloud seeding regulation and backed by adequate resources for enforcement, is bureaucratically stifling and notoriously expensive.[204] State administrative regulations, on the other hand, provide more flexibility, allowing each state to tailor its policies to address its unique circumstances.[205] But compartmentalizing cloud seeding regulation to each state fails to address the cross-boundary movement of clouds between states and does not address how to resolve disputes between states.[206]

This Article proposes that the parties of the Compact amend it as a middle ground between state and federal governance. Instead of relying on the federal government to regulate cloud seeding in the Basin or leaving it up to each state, the Compact signatories should convene to narrowly negotiate the issue of regulations related to cloud seeding and the inter-state movement of clouds.[207]

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[200] Currier, *supra* note 19, at 970.

[201] *See id.*, *contra* LOUIS J. BATTAN, RITA F. TAUBENFELD, PETER H. WYCKOFF, RALPH W. JOHNSON, RAY J. DAVIS, SHO SATO & ARTHUR MURPHY, CONTROLLING THE WEATHER: A STUDY OF LAW AND REGULATORY PROCEDURES 21 (Howard J. Taubenfeld, ed., 1970) ("since weather respects no state boundary and since operators are likely to conduct activities in many states and to affect the citizens of many states by their activities, it seems reasonable to suggest that federal standards for an operators' license be set and that a federal entity issue the license once an individual shows his competence").

[202] Currier, *supra* note 19, at 972

[203] *Compare id.* at 965, *with* Hertz, *supra* note 62, at 53.

[204] *See* Currier, *supra* note 19, at 961 (discussing failed attempts to pass federal weather modification legislation); Hertz, *supra* note 62, at 53.

[205] Hertz, *supra* note 62.

[206] *See* Currier, *supra* note 19, at 959–60 (discussing how current state and local cloud seeding regulation fails to adequately account for cross boundary projects and leads to a market inefficiency).

[207] *Id.* at 972; Lochhead, *supra* note 138, at 326 (recognizing that signatories cannot agree to amend the Compact without congressional approval). While achieving congressional approval for a multi-state compact would be difficult to achieve, such a proposal would likely be less controversial than a national policy change on weather modification. *Id.* at 971–72. Furthermore, prior weather modification legislation likely failed because research at the time was not sufficient

Amending the Compact to create an effective regulatory agency would provide several benefits. Such an approach best complies with the internalization prescription typical for water resource management.[208] Additionally, Basin states, which are the most competent at evaluating their respective interests, will have the most control in articulating and advocating the specific provisions of the compact.

Furthermore, ICWMB would be able to impose consistent and unified operational standards across the Basin. Currently, operational guidelines and standards vary across the Compact states with some arguably too lax.[209] Experts agree that for the cloud seeding industry to reach optimal efficiency, licensing standards need to be sufficiently strict.[210] ICWMB would implement binding and uniform standards across the Basin. Consistent and unified standards would increase industry efficiency, promote safe practices for all involved, and make cloud seeding research more accurate.[211]

C. Amending the Compact Will be Limited in What it Can Fix

Relying solely on the Compact as the vehicle to create solutions for cloud seeding is not without its pitfalls. First, ratifying the Compact in 1922 was already a historic feat that took a tremendous amount of negotiation and powerful political circumstances that pushed states to the negotiation table and incentivized ratification.[212] Convincing the Compact members to come back to the table and amend the Compact is easier said than done.

While this Article argues that states should agree on a method to account for the water precipitating into the Colorado River, member states have argued for years regarding the accounting of water evaporating from the Colorado River system without success. For example, Compact states have yet to reach a sensible agreement on how the Compact should account for evapotranspiration.[213] Currently, all states in the Basin agree that they want a collaborative solution to water insecurity along

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to convince Congress. *Id.* at 972. Data only recently forthcoming now supports its effectiveness. *See* Bradshaw, *supra* note 48, at 465; *see also* Currier, *supra* note 19 at 972 ("If new legislation were introduced with the means and purpose of continuously gathering up-to-date research, Congress's fears should be abated.").

[208] For example, amending the Compact would ensure that a cloud seeding commission has the appropriate authority to act, integrate diverse stakeholder interests—including tribe and non-state actor interests—through a transparent and inclusive process, and balance legitimacy with effective governance to manage cloud seeding projects. *See* Larson, *supra* note 21, at 955.

[209] *See generally* Chen, *supra* note 1, at 70–77; *see also* Currier, *supra* note 19, at 971.

[210] Currier, *supra* note 19, at 971.

[211] *See* BATTAN et al., *supra* note 201, at 136.

[212] *See generally* Lochhead, *supra* note 138, at 293–295.

[213] Evapotranspiration, in a general sense, encompasses all water loss from the Earth's surface to the atmosphere. *See* Water Science School, *The Water Cycle*, U.S. GEOLOGICAL SURVEY, https://www.usgs.gov/special-topics/water-science-school/science/water-cycle# [https://perma.cc/DMS2-LPPM]. However, within the context of ADWR's usage, evapotranspiration specifically refers to the water released from plant leaves and soil. ARIZ. DEP'T WATER RES., FOURTH MANAGEMENT PLAN: PHOENIX ACTIVE MANAGEMENT AREA, Hydrology 2–3 (2020).

the River but have yet to reach an agreement to account for the 1.5 million acre-feet of water lost along the River due to evapotranspiration.[214]

It is also difficult to develop a large regulatory body that has meaningful authority and sufficient resources.[215] If the regulatory body is too effective at passing and enforcing regulations, states may be dissuaded from participating out of fear that if the regulatory body is co-opted by a member state, then the regulatory body could be used against the interest of other members.[216] The creation of a hegemon within the regulatory body could harm state sovereignty and is a significant factor when trying to incentivize stakeholder participation.[217]

Additionally, ICWMB's resources and ability to enforce regulations will likely be far more limited than if it were backed by the federal government.[218] One possible solution to the relative lack of funding is for ICWMB to increase licensing fees above what state agencies currently charge.[219] This increase in fees for cloud seeding operations could hypothetically help offset at least some costs. Additionally, technological advances in cloud seeding equipment such as the use of drones could lower operation costs and help offset an increase in fees.[220]

V. CONCLUSION

Human civilization has evolved a great deal from ceremonial prayers for rain to the development of technologically advanced methods of weather modification. Through time, collaboration, and the scientific method, humanity is closer to manipulating the clouds that travel over our heads to provide us with greater access to freshwater. The new emerging resource that is atmospheric moisture, like any great innovation, comes with costs and benefits to our society.

Those costs and benefits of cloud seeding have important implications in the legal context for states in the Colorado River Basin. Cloud seeding is a growing industry in the Colorado River Basin but is currently affronted by several legal obstacles. Cloud seeding operations between parties of the Upper and Lower Basin would likely constitute an inter-basin sale or transfer which is prohibited under the

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[214] *See* Greg Haas, *Here's What 7 States Say About Solving the West's Water Crisis*, KLAS 8 NEWS NOW (Sept. 9, 2023, 9:55 AM), https://www.8newsnow.com/news/local-news/heres-what-7-states-say-about-solving-the-wests-water-crisis/ [https://perma.cc/E7LV-QJUX].

[215] *See* Rhett B. Larson, *Water Security*, 112 NW. U. L. REV. 139, 178 (2017).

[216] *See id.* at 221–22.

[217] *See id.*; Larson, *supra* note 21, at 942.

[218] *See generally* Currier, *supra* note 19, at 970.

[219] For example, Colorado's Department of Natural Resources charges commercial weather modification application two percent of their contract or budget to cover regulatory costs, absent a waiver for extraordinary circumstances. *See* 2 COLO. CODE REGS. § 401-1:5(E) (2024).

[220] Matt Weiser, *Cloud Seeding, No Longer Magical Thinking, is Poised for Use This Winter*, SACRAMENTO BEE (last updated Oct. 6, 2014, 8:47 PM), http://www.sacbee.com/news/local/article2582373.html [https://perma.cc/MU8U-CAHK]; Lauren Sommer, *It's Not Magic On The Mountain, It's A Rain-Making Machine*, NPR (Jan. 9, 2014), http://www.npr.org/2014/01/09/261070150/its-not-magic-on-the-mountain-its-a-rain-making-machine [https://perma.cc/N98G-VLPE] (quoting Jeff Tilley of the Desert Research Institute).

Law of the River. Additionally, water from cloud seeding operations does not neatly fit into the salvaged and developed water distinctions common to the prior appropriation regimes of the Upper and Lower Basin states. These legal obstacles could stop or seriously hinder the progress of a growing industry that could help mitigate water security issues facing the Basin.

These obstacles can best be solved by the Compact states reconvening to narrowly negotiate the issue of cloud seeding. In addition to adding provisions defining how water from cloud seeding should be treated under the law, the states should also ratify the creation of an interstate commission on weather modification. Such a commission would impose regulations on cloud seeding operators throughout the entire Basin. This commission, made up of U.S. states, Mexican states, Indigenous tribes, and weather modification experts should be able to create comprehensive and effective policy that will guide this growing industry away from stormy legal weather.