Enhancing the Weather: Governance of Weather Modification Activities in Australia

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Abstract: Weather modification by cloud seeding refers to technologies intended to manipulate the weather at a local scale. Over the last 70 years, Australia has played a leading role in cloud seeding research and development. Australian states have developed frameworks to promote opportunities and manage risks from cloud seeding. Weather modification governance was studied in the United States context, but there has been little consideration to date for Australian frameworks. This article provides a contemporary analysis of the weather modification governance in Australia and assesses the extent to which legal and policy frameworks meet future governance challenges. We analyse the cloud seeding experience in Victoria, New South Wales and Tasmania, and identify common features in their governance

arrangements. We then point out gaps in current regulatory frameworks and call for a reconsideration of cloud seeding governance in Australia.

1 Introduction

On 5 June 2016, an extreme rainfall event in Tasmania's Central Highlands resulted in a major flooding that killed three people and caused significant damage to livestock, property and infrastructure.[1] Earlier the same day, Tasmania's commercial producer of hydroelectricity, Hydro Tasmania, had conducted a cloud seeding operation in the area.[2] Cloud seeding is a form of weather modification, in which silver iodide, or some other seeding agent, is delivered into the atmosphere to stimulate or enhance precipitation.[3] The purpose of this cloud seeding operation was to enhance precipitation over the Upper Derwent catchment, which was at record low storage capacity following months of drought.[4] Within days, local communities and media questioned whether the seeding operation had increased the severity of the flooding.[5] An independent review found that the cloud seeding operation did not contribute to the flood,[6] but Hydro Tasmania nonetheless suspended its cloud seeding program.[7]

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[1] "Hydro Tasmania Asked to Explain Cloud Seeding in Catchment Day before Flooding" *ABC News* (online, 6 June 2016), https://www.abc.net.au/news/2016-06-10/cloud-seeding-carried-out-over-tasmanian-catchment-before-floods/7499226.
[2] "Hydro Tasmania Asked to Explain Cloud Seeding in Catchment Day before Flooding", n 1, 1.
[3] See generally Andrea I Flossmann et al, "Peer Review Report on Global Precipitation Enhancement Activities" (2018).
[4] Mike Blake, *Report of the Independent Review into the Tasmanian Floods of June and July 2016* (Report, 1 June 2017).
[5] See, eg, "Hydro Tasmania Asked to Explain Cloud Seeding in Catchment Day before Flooding", n 1, 1; Adam Morton, "Did a Cloud-Seeding Flight on Sunday Deepen Tasmania's Flood Crisis? ", *The Sydney Morning Herald* (online, 10 June 2016), https://www.smh.com.au/national/did-a-cloudseeding-flight-on-sunday-deepen-tasmanias-flood-crisis-20160610-gpgk0q.html.
[6] "Hydro Report Finds Cloud Seeding Did Not Cause Derwent Valley Floods" *ABC News* (online, 29 July 2016), https://www.abc.net.au/news/2016-07-29/hydro-report-finds-cloudseeding-had-no-effect-on-flooding/7673726.
[7] Hydro Tasmania, "Cloud Seeding", https://www.hydro.com.au/water/rainfall/cloud-seeding.

Australia's interest in cloud seeding stems from the prevalence and severity of droughts across the country.[8] Cloud seeding was first developed in 1946 by American scientists working for General Electric ('GE').[9] Australia started experimenting with cloud seeding soon after, and became a pioneer in weather modification research and development.[10] Over the years, all Australian states have engaged in cloud seeding research, development and deployment for water management and hydroelectricity production. In order to support both experimental and operational programs, some of them have developed regulatory regimes for cloud seeding, including legislation.[11] Despite Australia's long history of cloud seeding, the 2016 Tasmanian incident suggests that there are still concerns regarding the management of risks for these technologies. These justify some reconsideration of current governance approaches. An extensive literature has emerged on weather modification governance issues in the United States,[12] but the governance of cloud seeding in Australia has received virtually no academic scrutiny since the 1970s.[13] This article therefore evaluates current governance frameworks for weather modification by cloud seeding in Australia, in order to determine their fitness-for-purpose for governing an expanded program of weather modification.

In 2016, researchers, scientists and engineers from the Sydney Institute of Marine Science and the School of Geosciences at the University of Sydney created a collaboration to

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[8] Brian F Ryan and Warren D King, "A Critical Review of the Australian Experience in Cloud Seeding" (1997) 78(2) *Bulletin of the American Meteorological Society* 243-44.
[9] Hydro Tasmania, *Cloud Seeding*, n 7.
[10] Ray Jay Davis, "Atmospheric Water Resources Development and International Law" (1991) *Natural Resources Journal* 20.
[11] See, eg, *Rain-Making Control Act 1967* (Vic); *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW).
[12] See, eg, Vaughn C Ball, "Shaping the Law of Weather Control" (1949) 58(2) *The Yale Law Journal* 213; Ray Jay Davis, "Weather Modification Law Developments" (1974) 27 Okla L Rev 409; Stanley A Changnon, "The Rise and Fall of Federal Weather Modification Policy" 19(1) *The Journal of Weather Modification* 12; Gregory N Jones, "Weather Modification: The Continuing Search for Rights and Liabilities" BYU L Rev 38; Melissa Currier, "Rain, Rain, Don't Go Away: Cloud Seeding Governance in the United States and a Proposal for Federal Regulation" 48 McGeorge L Rev 26.
[13] GN Heilbronn, "Some Legal Consequences of Weather Modification: An Uncertain Forecast" (1979) 6 Monash UL Rev 122; Ray Jay Davis, "The Law of Precipitation Enhancement in Victoria" 7 Land & Water L Rev 31.

develop 'marine cloud brightening for the Great Barrier Reef.'[14] Marine cloud brightening ('MCB') belongs to a broader category of climate engineering techniques, referred to as solar radiation management, that have been proposed to counteract the effects of anthropogenic climate change.[15] MCB is analogous to traditional cloud seeding. However, instead of enhancing rainfall, MCB involves seeding certain marine clouds with salt particles that reflect solar radiation, to increase the brightness and longevity of the cloud cover and reduce global temperatures.[16] Australian government authorities and scientists are developing MCB technologies as part of the Reef Restoration and Adaptation Program ('RRAP') to shade the reef and protect it from climate change stressors.[17] MCB research has progressed from modelling to outdoor experimentation, with the Great Barrier Reef Marine Park Authority authorising a small-scale field test on the reef in March 2020.[18]

MCB and weather modification by cloud seeding bear many similarities. At the most fundamental level, both technologies aim to manipulate the formation and physical properties of clouds. There is also considerable uncertainty as to the effectiveness of MCB and the potential risks and environmental side effects that could result.[19] Currently, MCB is not specifically regulated under existing Australian law.[20] It is instead regulated incidentally by

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[14] "Marine Cloud Brightening for the Great Barrier Reef", *Marine Cloud Brightening for the Great Barrier Reef*, https://www.savingthegreatbarrierreef.org.
[15] John G Shepherd, *Geoengineering the Climate: Science, Governance and Uncertainty* (Royal Society, 2009).
[16] For a general overview of MCB, see Philip Boyd et al, "High Level Review of a Wide Range of Proposed Marine Geoengineering Techniques", http://www.gesamp.org/publications/high-level-review-of-a-wide-range-of-proposed-marine-geoengineering-techniques. For a technical summary of proposals for the GBR, see LK Bay et al, *Reef Restoration and Adaptation Program: Intervention Technical Summary. A Report Provided to the Australian Government by the Reef Restoration and Adaptation Program* (2019), https://www.gbrrestoration.org/documents/20182/20686/T3+Intervention+Technical+Summary+FINAL3.pdf/d9c067d8-38bd-46e7-95d6-efce8682af04.
[17] 'Reef Restoration and Adaptation Program - Home", https://www.gbrrestoration.org/. See also Jan McDonald et al, "Governing Geoengineering Research for the Great Barrier Reef" (2019) 19(7) *Climate Policy* 801.
[18] Graham Readfearn, "Scientists Trial Cloud Brightening Equipment to Shade and Cool Great Barrier Reef", *The Guardian* (online, 16 April 2020), https://www.theguardian.com/environment/2020/apr/17/scientists-trial-cloud-brightening-equipment-to-shade-and-cool-great-barrier-reef.
[19] Boyd et al, n 16, 73-74.
[20] See Pedro Fidelman et al, "Regulatory Implications of Coral Reef Restoration and Adaptation under a Changing Climate" (2019) 100 Environmental Science & Policy 221.

the patchwork of environmental legislation and regulations that govern activities affecting the Great Barrier Reef. The RRAP aims to develop new governance mechanisms for climate change interventions on the reef, including for MCB.[21] However, discussions on geoengineering governance have largely avoided considering the lessons that might be drawn from earlier governance of weather modification techniques. With Australia embarking on a new chapter of cloud seeding research and development, it is pertinent to reflect on the governance of weather modification in Australia.[22] It is beyond the scope of this article to assess the extent to which the governance of weather modification by cloud seeding offers a valuable precedent for the governance of MCB. However, it is this contextual background that largely motivates the present evaluation of Australia's cloud seeding regulatory frameworks.

This article proceeds in 5 parts. Part 2 explains cloud seeding technologies and associated risks. Part 3 outlines the history of cloud seeding research and deployment in Australia, providing the necessary context for the development of law and governance. Part 4 presents the different approaches to cloud seeding governance in the three jurisdictions that have been most active users of the technology: Victoria, Tasmania and New South Wales ('NSW'). Drawing on this analysis, Part 5 identifies common features to weather modification governance and issues that require renewed attention. We conclude in Part 6 that, in the event when Australia moves forward with MCB by cloud seeding, future regulatory frameworks will have to avoid the pitfalls that have fraught weather modification governance.

2 Weather Modification by Cloud Seeding

[21] Pedro Fidelman et al, *Reef Restoration and Adaptation Program: Regulatory Assessment Findings. A Report Provided to the Australian Government by the Reef Restoration and Adaptation Program* (2019), https://www.gbrrestoration.org/documents/20182/20686/T2+Regulatory+Assessment+Findings3.pdf/d9c57969-3d36-479e-867c-e10e8ebc68af.

[22] See, eg, "Putting the Great Barrier Reef Marine Cloud Brightening Experiment into Context" (C2G, 13 May 2020), https://www.c2g2.net/putting-the-great-barrier-reef-marine-cloud-brightening-experiment-into-context/.

Precipitation enhancement by cloud seeding refers to a deliberate human intervention in the atmosphere to enhance the volume of rainfall. In 1946, the process of "cloud seeding" was developed by American scientists working for GE, under the supervision of the Nobel Prize Laureate, Irving Langmuir.[23] They discovered that adding substances such as dry ice and silver iodide to certain types of clouds could encourage the formation of ice crystals and thereby initiate or enhance precipitation.[24] Later on, scientists also developed cloud seeding techniques using salt particles, that enhance the formation of water droplets in warm clouds, more suited to cloud seeding in tropical and semi-tropical regions.[25] Following GE's discovery, national governments were quick to realise the promise of cloud seeding. Between the 1950s and 1970s, several countries, including the United States, Soviet Union, Canada, and Australia, for instance, invested heavily in cloud seeding research and development.[26] Their aim was to use cloud seeding to mitigate extreme weather events and enhance precipitation for agricultural and hydro-electricity production.[27]

Cloud seeding continues to be widely practised around the world, and its use is likely to increase. Over fifty countries currently use cloud seeding, with major projects conducted in China, the United States, Thailand and India notably.[28] In recent years, there has been renewed interest in cloud seeding to address climate change impacts. As noted by Flossman et al,

> 'In a period of accelerating climate change, the continuous struggle for reliable water resources has taken renewed urgency. There are indications that an increasingly number of WMO [World Meteorological Organisation] Members are planning or actually

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[23] Irving Langmuir, "The Production of Rain by a Chain Reaction in Cumulus Clouds at Temperatures above Freezing" (1948) 5(5) J*ournal of Meteorology* 175.
[24] See generally Vincent J Schaefer, "The Early History of Weather Modification" (1968) 49(4) *Bulletin of the American Meteorological Society* 337.
[25] Flossmann et al, n 3, 1; William R Cotton and Roger A Pielke Sr, *Human Impacts on Weather and Climate* (Cambridge University Press, 2007) 32-33.
[26] Howard J Taubenfeld, "Weather Modification and Control: Some International Legal Implications" (1967) 55(2) *California Law Review* 494.
[27] Steven T Sonka, *Economics of Weather Modification: A Review* (Illinois State Water Survey, 1979) 1.
[28] WMO, *WMO Statement on Weather Modification* (Report from Expert Team on Weather Modification Research for 2015, 17 March 2015) ('*Statement on Weather Modification*').

carrying out precipitation enhancement activities in response to water shortages or other societal needs.'[29]

Despite its widespread use over the past seventy years, the effectiveness of cloud seeding is still uncertain. Atmospheric processes are complex and subject to large natural variability. Therefore, measuring the effectiveness of cloud seeding is extremely complex.[30] Because all clouds are unique, scientists cannot attribute precisely a certain volume of rainfall to a specific operation by comparing cloud formations at a different place or time.[31] At best, operations are randomised, which means that potentially suitable clouds are seeded on a random basis so as to compare seeded and unseeded events.[32] This statistical analysis is then combined to physical analyses (ie rain gauges, radars) to estimate the potential for seeding in one area.[33] In recent years, the development of modelling and remote sensing tools has enabled better estimations of cloud seeding effects on precipitation.[34] Scientists have demonstrated that precipitation enhancement by cloud seeding can lead, under specific conditions, to an increase in precipitation.[35]

As well as questions of effectiveness, cloud seeding raises environmental, social and economic concerns. Silver iodide, one of the most commonly used chemical, may have long-term environmental effects. According to Fajardo et al, silver iodide may have accumulative properties and, in high concentrations, create risks of ecotoxicity for soil biota both in terrestrial

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[29] Flossmann et al, n 3, 77.
[30] 'The complexity and natural variability of clouds result in significant challenges and difficulties in understanding and detecting the effects of attempts to modify them artificially.' WMO, n 28, 5.
[31] '[E]xcept in rare and nearly unique instances, every storm is different from all others. To compare one with another is a frustrating exercise and one that is bound to fail.' Vincent Schaefer, "The Future of Weather Modification" (1976) 8(2) *The Journal of Weather Modification* 127.
[32] WMO, n 28, 5-6.
[33] WMO, n 28, 6.
[34] WMO, n 28, 5.
[35] Flossmann et al, n 3, 2.

and aquatic environments.[36] In contrast, the Weather Modification Association suggests that the amounts of silver iodide used in cloud seeding is too small to affect human health or the environment.[37] The World Meteorological Organization ('WMO'), nevertheless, warns of potential persistent effects and recommends monitoring closely the impacts of cloud seeding agents on the environment.[38]

A further concern is that continued cloud seeding operations may change precipitation averages over time.[39] This could have detrimental effects on weather systems, land structures, plants and animal communities.[40] According to Bigg, silver iodide may remain in the atmosphere for weeks or even months, and continue to affect regional rainfall over a wider area and longer timeframe than originally anticipated.[41] Scientists may therefore underestimate the duration and scale of the impacts of cloud seeding activities.

A related issue is the extent to which cloud seeding may have impacts on areas adjacent to the intended target area. For example, there has traditionally been concerns that by increasing rainfall in one area, cloud seeding may deprive downwind areas of their natural precipitation.[42] This could lead to transboundary issues between states in federalised legal systems (ie United States or Australia) or between nation states if cloud seeding is conducted near national

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[36] See especially C Fajardo et al, "Potential Risk of Acute Toxicity Induced by AgI Cloud Seeding on Soil and Freshwater Biota" (2016) 133 *Ecotoxicology and Environmental Safety* 433. See also Bruce D Williams and John A Denholm, "An Assessment of the Environmental Toxicity of Silver Iodide - with Reference to a Cloud Seeding Trial in the Snowy Mountains of Australia" (2009) 41 *Scientific Papers* 22.
[37] Weather Modification Association, "*Position Statement on the Environmental Impact of Using Silver Iodide as a Cloud Seeding Agent*" (July 2009).
[38] '[A]ny plans to use either a massive quantity of such a product or a different seeding agent should be accompanied with a preliminary evaluation of its potential effects on environment and on human health.' WMO, n 28, 2.
[39] Wills, A. K & Queensland, "Effects of Weather Modification on the Australian Environment" (1973) *Division of Land Utilisation & Queensland. Department of Primary Industries* 8.
[40] See generally Charles F Cooper, *Ecological Effects of Weather Modification: A Problem Analysis* (University of Michigan, Department of Resource Planning and Conservation, 1969).
[41] E Keith Bigg, "Unexpected Effects of Cloud Seeding with Silver Iodide" (2012) 17(1) *The Journal of Weather Modification* 7.
[42] Davis, "Atmospheric Water Resources Development and International Law", n 10, 35.

borders.[43] The impacts of cloud seeding beyond the target area, are still unclear, notably whether these 'extra-area effects' decrease or increase precipitation.[44] Flossman et al suggest that a poorly designed project could reduce precipitation or prevent the precipitation process altogether,[45] thereby depriving neighbouring areas of rainfall. Conversely, DeFelice et al suggest that cloud seeding activities could *increase* the amount of precipitation up to two hundred kilometres from the target area.[46] Such an increase could harm a neighbouring area, especially if it increases the risk of floods.[47] In the US, several cases have been brought against cloud seeding operators for allegedly causing floods, but in each case, the plaintiffs failed to establish a causal link between a particular operation and the flood.[48]

Studies have demonstrated that, in absence atmospheric moisture, cloud seeding operations are likely to be unsuccessful.[49] Therefore, cloud seeding is not an adequate emergency response in times of drought and more typically used as a 'long-term water resources management tool.'[50] In recent years, cloud seeding projects have been upscaled to catchment basin-size projects to increase freshwater reservoirs in key locations.[51] However, the uncertainties concerning the impacts and effectiveness of cloud seeding suggest the need

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[43] See generally Taubenfeld, n 26; Ray Jay Davis, "The United States and Mexico: Weather Technology, Water Resources and International Law" 12(4) *Natural Resources Journal* 16; JW Samuels, "International Control of Weather Modification Activities: Peril or Policy" (1973) *Natural Resources Journal* 17; Lada L Roslycky, "Weather Modification Operations with Transboundary Effects: The Technology, the Activities and the Rules" (2003) 16 *Hague Yearbook of International Law* 3.

[44] Flossmann et al, n 3, 30.

[45] Flossmann et al, n 3, 31.

[46] TP DeFelice et al, "Extra Area Effects of Cloud Seeding — An Updated Assessment" (2014) 135 *Atmospheric Research* 193.

[47] 'The major risks are the possibility of creating severe weather or floods, and to increasing rainfall in one local region at the expense of rainfall in a neighboring local region.' Cotton and Pielke Sr, n 25, 250.

[48] See, eg, *Samples v Irving P Krick Inc* (WD Okla, 1954); *Auvil Orchard Company Inc v Weather Modification Inc,* (Wash, 1956); *Adams v California* (Calif, 1964); *Lunsford v US,* 418 F.Supp 1045 (DS Dak, 1976).

[49] 'Instant drought relief is difficult to achieve. In particular, if there are no clouds, precipitation cannot be artificially stimulated. It is likely that the opportunities for precipitation enhancement will be greater during periods of normal or above normal rainfall than during dry periods.' WMO, n 28, 4.

[50] '[I]n order to be beneficial in the context of an overall water shortage, the seeding needs to be extended to larger areas and time periods.' Flossmann et al, n 3, 78. See also Roelof Bruintjes, *Report of the Expert Team on Weather Modification Meeting* (Report, 17-19 March 2015) 3.

[51] Flossmann et al, n 3, 61-76.

for long-term monitoring and evaluation,[52] including through appropriate governance arrangements to manage risks and uncertainties. The next section outlines the use of cloud seeding technologies in Australia, in order to evaluate the adequacy of governance arrangements.

3 Weather Modification Operations in Australia

3.1 Introduction

Australia is one of the driest countries on earth, with the lowest average annual rainfall of any inhabited continent.[53] It is therefore unsurprising that Australia has used cloud seeding to enhance precipitation. Two days after GE's first outdoor experiments were conducted in the US, in 1947, the Australian House of Representatives requested the Commonwealth Scientific and Industrial Research Organisation ('CSIRO')[54] to conduct its own research on cloud seeding.[55] The first CSIRO experiment, conducted in NSW, was also the first experiment in the world to trigger rain successfully.[56] Between 1947 and 1952, over 100 cloud seeding experiments were conducted in NSW, using dry ice or silver iodide as a seeding agent.[57] With CSIRO's assistance, state agriculture, public works and water resources departments also conducted cloud seeding experiments to investigate practical applications of cloud seeding.[58] In 1965, NSW became the first Australian state to conduct an operational program.[59]

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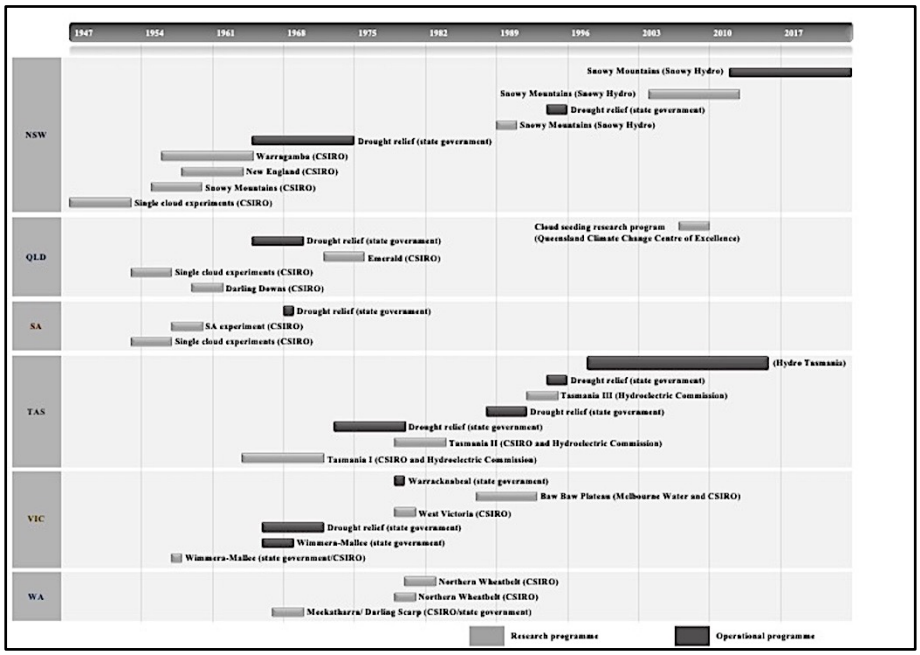
[52] 'The implications of any projected long-term weather modification operation on ecosystems need to be assessed.' WMO, n 28, 12.
[53] Paul N Holper, *Climate Change, Science Information Paper: Australian Rainfall: Past, Present and Future* (CSIRO, 2011) 46.
[54] Australia's national science agency established by the *Science and Industry Research Act 1949* (Cth).
[55] EB Kraus and P Squires, "Experiments on the Stimulation of Clouds to Produce Rain" (1947) 159 (4041) *Nature* 489. See Geoffrey Reid McBoyle, *Weather Modification: Australia's Role in the World Scene* (Department of Geography, University of Queensland, 1980), 48.
[56] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 3.
[57] McBoyle, n 55, 48.
[58] For an overview of the cloud seeding experiments between 1947 and 1994, see Ryan and King, n 8.
[59] McBoyle, n 55, 68-81.

Table 1 summarises the major research and deployment cloud seeding programs conducted in Australia from 1947 to 2020. Research operations are represented in white, whereas operational programs are shaded in grey, and the entity conducting each project is indicated between parentheses.

Table 1 Overview of Australian major cloud seeding experiments



The table shows that the number of cloud seeding programs in Australia has decreased over time. The research programs conducted throughout Australia between the 1950s and 1980s had limited success in increasing rainfall demonstrably.[60] Scientists formed the opinion that most cloud formations in Australia were not cold enough to be suitable for seeding.[61] The results of cloud seeding were consistently inconclusive and the costs of research and

[60] Only the experiment conducted between 1955-1959 over the Snowy Mountains had shown an increase in rainfall, but the CSIRO casted doubts over the results of the experiment as interpreted by the Snowy Mountains Hydro-Electricity Authority ('SMHEA'). See McBoyle, n 55, 63.
[61] McBoyle, n 55, 63.

development outweighed the benefits.[62] Therefore, in 1981, CSIRO terminated its cloud seeding research program,[63] and water managers in Australia largely considered cloud seeding a 'marginal water-management tool.'[64]

Tasmania, however, has been an exception to the downward trend in cloud seeding. According to Hydro Tasmania, 'of all of the areas in the world, evidence for [cloud seeding] effectiveness is strongest in Western Tasmania.'[65] Before the 2016 flood incident, Hydro Tasmania had carried out the longest operational program in the country, spanning four decades. More recently, with climate change straining water resources around the country, other Australian states have shown a renewed interest in cloud seeding. NSW is now conducting a long-term program in the Snowy Mountains, and Australia continues to receive international scientific attention for its research and development activities.[66]

Efforts by government departments, CSIRO and state-owned enterprises to develop cloud seeding have led states to develop various governance approaches to cloud seeding. Yet, in 1979, Heilbronn remarked that '[w]hile scientific undertakings in this area have for many years been carried out in Australia, there has been virtually no discussion here of the legal questions involved.'[67] In the ensuing forty years, legal scholars have not remedied this deficiency and the role of law in Australia's cloud seeding governance has remained

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[62] Parliament of Australia House of Representatives, *Getting Water Right(s) The Future of Rural Australia, Chapter 7 Research & Development - Cloud Seeding; Climate Change; and Water Resources* (Australia House Standing Committee on Agriculture, Fisheries and Forestry, 2004) 154.
[63] Andrew Bell, "Why CSIRO Has Stopped Cloud-Seeding" (1982) 32 *ECOS Magazine* 23.
[64] Ryan and King, n 8, 247.
[65] Hydro Tasmania and West Coast Council, *Effects of Cloud-Seeding on Rainfall in the West Coast: Background Report 1* (2008) 1.
[66] Between 2007 and 2009, for instance, the Queensland Climate Change Centre of Excellence (a state-owned research institute) gathered researchers from Australia, the US and South Africa to conduct the Queensland Cloud Seeding Research Program ('QCSRP') and investigated the potential for cloud seeding of Queensland summertime clouds. The QCSRP used some of the best technology available (e.g. advanced remote sensing tools). See generally Sarah A Tessendorf et al, "Overview of Queensland Cloud Seeding Research Program" (2010) 42(1) *The Journal of Weather Modification* 33. See also Bruintjes, n 50, 6.
[67] Heilbronn, n 13, 123.

unaddressed. In spite of a decline in cloud seeding activities in Australia, continued research in widening cloud seeding applications shows that the issue is still relevant.

The most active cloud seeding states in Australia have historically been Victoria, Tasmania and NSW. The following sections examine the different approaches that these states have taken to regulating cloud seeding activities from the advent of cloud seeding research in 1947 until June 2020.

3.1.1 Victoria

Victoria was the first state in Australia to develop primary and subordinate legislation to govern cloud seeding. Victoria's first cloud seeding program was commenced to address drought conditions in the grain-growing region of Wimmera-Mallee, in 1957, but was suspended soon after as heavy rainfalls naturally put an end to the drought.[68] When the program resumed in 1966, the Victorian state government considered developing legislation to regulate cloud seeding.[69] The 'Interdepartmental Committee on Cloud Seeding in Victoria to Promote Rainfall'[70] recommended that the Victorian government develop legislation for cloud seeding 'to control operations in the best interests of the community as a whole' before any litigation should arise.[71] Victoria enacted the *Rain-Making Control Act 1967* and the *Rain-Making Control Regulations 1968* to regulate cloud seeding activities and to make provisions for any subsequent claims for damages against operators.[72]

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[68] McBoyle, n 55, 71.
[69] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 6.
[70] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 6.
[71] Interdepartmental Committee on Cloud Seeding in Victoria to Promote Rainfall, *Report 9* (1967), quoted in in Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 8.
[72] 'An Act to regulate certain Rain-making and other Cloud-modification Processes, to make Provision with respect to Claims for Damages against Persons lawfully engaged therein and for other purposes.' *Rain-Making Control Act 1967* (Vic).

The *Rain-Making Control Act 1967* makes cloud seeding a governmental function and provides immunity from liability.[73] It provides that only Victoria's Minister of Agriculture may authorise rain-making operations and 'shall issue his authority to some officer or body under his control to make arrangements for carrying out those operations.'[74] The Minister may also authorise operations in Victoria to promote rainfall in an adjoining state at the request of a Minister administering a corresponding Act.[75] Yet, no other state has passed such legislation and the provision has never been used in practice.[76] Operational cloud seeding in Victoria has been principally funded by the Agricultural Aviation Section of the Department of Agriculture, even though sometimes carried out on behalf of other departments (eg for fire prevention and water catchments replenishment).[77] Victoria conducted some 15 operational projects regulated under the Act between 1967 and 1980,[78] thereby placing itself 'at the forefront of the practical application of rain-making.'[79]

Operations authorised by the Minister provides statutory immunity 'in respect of any loss or damage caused by or arising out of the precipitation of rain hail sleet snow ice fog or mist in consequence of the rain-making operations so carried out.'[80] Cloud seeding operations that are not authorised under the Act incur a penalty at $1,000 or imprisonment for up to twelve months.[81] In addition, the Minister retains the power to require an operator to discontinue or refrain from commencing cloud seeding activities, with a fine of up to $1000 for everyday the operator continues the activities in contravention of the order.[82] The Act, however, provides

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[73] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 10.
[74] *Rain-Making Control Act 1967* (Vic), s 4. This is consistent with the recommendation of the Committee. See Victoria, *Parliamentary Debates* (Legislative Assembly, 1 November 1967) 1607.
[75] *Rain-Making Control Act 1967* (Vic), s 8.
[76] *Rain-Making Control Act 1967* (Vic), s 8.
[77] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 10.
[78] McBoyle, n 55, 138.
[79] McBoyle, n 55, 71.
[80] *Rain-Making Control Act 1967* (Vic), s 12.
[81] *Rain-Making Control Act 1967* (Vic), s 9.
[82] *Rain-Making Control Act 1967* (Vic), s 11.

no rules for potential interstate liability or remedies in case of conflicts over the allocation of interstate river waters (eg the Murray River).

The Act does not require environmental impact assessment ('EIA') prior to approving cloud seeding activities, and no EIA has been conducted under the *Environmental Effects Act 1979* (Vic). In 1979, Warracknabeal, Victoria, was shortlisted as the site for the Precipitation Enhancement Project ('PEP'), an international research project conducted by the WMO.[83] After Spain was selected for the project, CSIRO and Victoria's Department of Agriculture pursued a major research project at the same location. McBoyle suggests that because the project was considered unlikely to involve significant environmental risks, no EIA was required.[84] The Act also makes no provision for public participation. McBoyle notes that 'public meetings were scheduled for the project area in early 1979, but a favourable public response to press releases put out by the Victoria Department of Agriculture prior to this led the CSIRO to dispense with any meetings.'[85] The Act requires the operator to submit a report to the Minister of Agriculture 'in order to ensure that adequate statistics are available to enable assessment of the operations to be made.'[86] However, '[n]othing in the law requires officials of Victoria to report to CSIRO or any other central depository of information about weather modification activities in Australia.'[87]

The *Rain Making Control Act 1967* remains in force and has been regularly amended to keep up to date with legal reforms (eg *Water Act 1989* (Vic), *Conservation, Forests and*

[83] McBoyle, n 55, 90-91.
[84] McBoyle, n 55, 150.
[85] McBoyle, n 55, 92.
[86] Victoria, *Parliamentary Debates* (Legislative Assembly, 1 November 1967) 1609.
[87] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 22.

Lands Act 1987 (Vic) and *Local Government Act 1989* (Vic)), despite there being no cloud seeding operation in Victoria since 1986,[88] and no research project since 1992.[89]

3.1.2 Tasmania

Tasmania's first major research project was conducted between 1964 and 1971, by CSIRO and the Hydro-Electricity Commission ('HEC') (now Hydro Tasmania), to experiment with silver iodide seeding over catchments in Tasmania's Central Plateau (Tasmania I).[90] These experiments yielded encouraging results and another 4-year experiment between 1979 and 1983 (Tasmania II) suggested an increase in rainfall of up to 30%.[91] The HEC conducted a third experiment between 1992 and 1994, this time using dry ice, that yielded mixed results (Tasmania III).[92] Nevertheless, the suitability of Tasmania's weather conditions and the hydropower high cost/benefit ratio justified pursuing cloud seeding research.[93] The HEC launched a fourth research project in 1998 (Tasmania IV), which soon became fully operational. Between 1998 and 2016, Hydro Tasmania seeded wintertime clouds on average 20 days per year, using silver iodide.[94] The map below shows Tasmania cloud seeding target areas as of 2008.[95]

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[88] In 2016, a Freedom of Information (FOI) request was addressed to the Victoria Department of Economic Development, Jobs, Transport and Resources for copies, notably, of all cloud seeding reports lodged under the Act on or after the 1st January 1986. FOI – Notice of Decision (Ref. 16/43939), https://www.righttoknow.org.au/request/2671/response/7545/attach/3/16%2043939%20Signed%20decision%20letter%20No%20docs.pdf.

[89] Between 1988–92, Melbourne Water – the government authority in charge of water supply – conducted a development project in the Baw Baw plateau. However, CSIRO considered that the statistical evidence of increased rainfalls did not justify pursuing cloud seeding operations and Water Melbourne gave up its cloud seeding plans in the area. The experiment was not regulated under the Act, most likely because the project was a *research* project as opposed to an operation per se. Nevertheless, the project remained under governmental control. Ryan and King, n 8, 246.

[90] Ryan and King, n 8, 243.

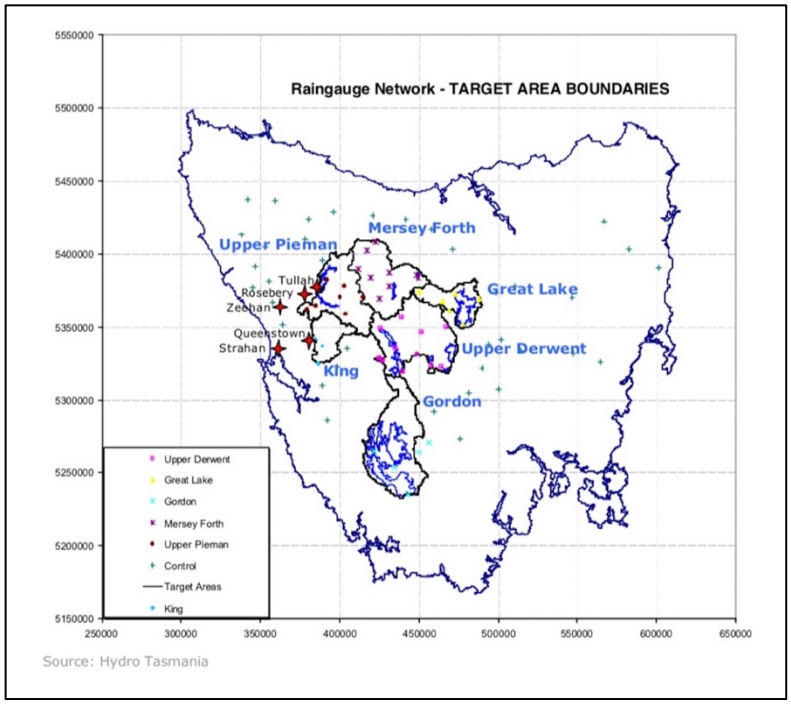
[91] AJ Miller et al, "Analyzing the Results of a Cloud-Seeding Experiment in Tasmania" (1979) 8(10) *Communications in Statistics-Theory and Methods* 1017.

[92] Ryan and King, n 8, 244.

[93] Ryan and King, n 8, 252.

[94] Steven T Siems and Michael J Manton, "Recent Progress in Glaciogenic Cloud Seeding over Southeast Australia and Tasmania".

[95] Hydro Tasmania and West Coast Council, *Economic Impacts of Cloud Seeding* (2008) 3.



Map 1. Tasmania's targeted cloud seeding catchment areas

In Tasmania, the state government has used its executive power to allow Hydro Tasmania (a trading name of the HEC) to conduct cloud seeding operations, but no legislation has ever been enacted to regulate cloud seeding operations. Davis reports that the HEC had considered that such a legislation could hinder its cloud seeding efforts.[96] Operations did not operate in a legal vacuum, however; Hydro Tasmania is subject to its own statutory requirements under the *Hydro-Electric Corporation Act 1995*.[97] In some circumstances, it is also subject to the environmental assessment and development approval processes of the *Land Use Planning and Approvals Act 1993* (Tas) and the *Environmental Management and Pollution Control Act 1994* (Tas), though neither have been applied to cloud seeding activities.

[96] 'The Commission had, however, earlier obtained legislation exempting it from being enjoined from carrying out its activities.' Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 9.
[97] Minister for Energy and Resources and Treasurer, *Hydro Tasmania Ministerial Charter* (2012).

Hydro Tasmania follows a number of "self-governance" frameworks, including an 'Environment Policy' and a 'Sustainability Code.'[98] In addition, it operates under an Environmental Management System ('EMS') certified under the international standard ISO 14001.[99] Under the EMS, for instance, the HEC conducted an EIA for the Tasmania IV experiment.[100] The EIA procedure was not regulated by law and consisted of a literature review and three expert reports on the impacts of silver iodide, the existence of persistence effects, and the downwind effects of cloud seeding.[101] It concluded that the use of silver iodide would have no adverse impacts on the environment, but recognised that the high natural rainfall variability created uncertainties concerning persistent and downwind effects.[102] Following this assessment, the Tasmanian government authorised the HEC to launch an operational cloud seeding program to supply the water catchments of Central Tasmania's hydro-electric dam network. The target area was increased by up to 5000 square kilometres.

Before the 2016 flood, Hydro Tasmania's cloud seeding activities had already given rise to controversy. In 2006-2007, the West Coast Council reported negative impacts on the communities and a lack of trust in the self-governance model. The public had not been involved in the decision-making process and local populations started to question the transparency and legitimacy of the operations, and the merits and impacts of cloud seeding.[103] These concerns

[98] "Management Approach', https://www.hydro.com.au/about-us/our-governance/management-approach.
[99] "Management Approach', n 99.
[100] Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 38.
[101] Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 61.
[102] Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 38.
[103] Hydro Tasmania and West Coast Council, *Socio-Economic Impacts of Cloud Seeding on the West Coast Community* (2008) 3.

resulted in the suspension of the seeding over the King River catchment and the preparation of a series of reports on effects and socio-economic impacts of cloud seeding in the region.[104]

After the flood, another investigation was conducted to estimate the possible contribution of cloud seeding in the disaster. The report concluded that the cloud seeding flight of 5 June 2016 'did not cause or contribute to the floods.'[105] However, some considered that Hydro Tasmania should have been aware that heavy rainfalls were forecasted and flood warnings issued in surrounding areas.[106] Ultimately, all cloud seeding operations were put on hold. Hydro Tasmania asserted that 'the cloud seeding program (…) will not resume until a full internal review of the program has been completed, including implementation of any appropriate improvements, and extensive engagement with stakeholders.'[107] With the Tasmanian Liberal Party promising to phase out cloud seeding in the 2018 campaign,[108] Hydro Tasmania has not recommenced its operations since they were suspended in 2016.

3.1.3 NSW

The Snowy Mountains precipitation enhancement program currently is Australia's only operational cloud seeding program. Experiments were first conducted in the Snowy Mountains in 1955–59, yielding successful results.[109] A Committee on Cloud Seeding was appointed in 1966 but did not result in the adoption of any legislation.[110] In the 1980s, the Snowy Mountains

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[104] See, eg, Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65; Hydro Tasmania and West Coast Council, *Socio-Economic Impacts of Cloud Seeding on the West Coast Community*, n 103.
[105] "Term of Reference 3: Cloud seeding", http://www.dpac.tas.gov.au/__data/assets/pdf_file/0015/313143/Hydro_3_Cloud_Seeding.pdf.
[106] See, eg, "Hydro Tasmania Asked to Explain Cloud Seeding in Catchment Day before Flooding", n 1.
[107] Hydro Tasmania, "Annual Report", n 106, 12. See also "Cloud Seeding Statement", https://www.hydro.com.au/news/media-releases/2017/09/14/cloud-seeding-statement.
[108] See, eg, "No More Cloud Seeding under a Re-Elected Majority Liberal Government", *Tasmanian Liberals* (22 February 2018), https://www.tas.liberal.org.au/news/no-more-cloud-seeding-under-re-elected-majority-liberal-government.
[109] McBoyle, n 55, 63.
[110] New South Wales Department of Agriculture Committee on Cloud Seeding, Report to Director General (1966), discussed in Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 9.

Hydro-Electric Authority ('SMHEA'),[111] the agency in charge of managing and maintaining Australia's largest network of hydro-electric dams and power stations, showed a renewed interest in cloud seeding. The SMHEA requested Siromath (a company set up by CSIRO in 1981) to assess the feasibility of the potential for cloud seeding in the Snowy Mountains.[112] The study demonstrated potential to increase the Scheme's inflows,[113] and in 1988–89, the NSW departments of Agriculture and Energy funded the Snowy Mountains Atmospheric Research Program ('SMARP') to conduct field investigations.[114]

Opposition from environmental groups, ski resort operators and downwind farmers caused the project to be abandoned, but it was resurrected in 2003 following prolonged drought in South-East Australia. Snowy Hydro Limited (former-SMHEA)[115] proposed to invest in cloud seeding to increase precipitation in the Snowy Mountains alpine catchments of up to 150 gigalitres a year.[116] The House of Representatives Standing Committee on Agriculture, Fisheries and Forestry considered the project to be 'potentially a very significant win/win situation' as the operations would represent a significant boost to the Murray River system, without imposing costs on taxpayers.[117] When the state of NSW reassessed the project, Snowy Hydro assured that the new program would address public concerns: operations would be conducted outside of the wilderness areas and when precipitation is likely to fall as snow.[118]

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[111] The SMHEA was established by the *Snowy Mountains Hydro-electric Power Act 1949* (Cth).
[112] Douglas E Shaw and WD King, *Report of a Feasibility Study to Assess the Potential for a Cloud Seeding Experiment over the Catchment of the Snowy Mountains Scheme* (Siromath Pty. Limited, 1986) discussed in LoredanaWarren, "Snowy Precipitation Enhancement Research Project" *Australian Cloud Seeding Research Symposium* (Bureau of Meteorology, 2009).
[113] Michael Bergmann, "The Snowy Mountains Hydro-Electric Scheme: How Did It Manage without an EIA?" 5.
[114] *Australian Cloud Seeding Research Symposium*, n 112, 31.
[115] Incorporated by the *Snowy Hydro Corporatisation Act 1997* (Cth). Snowy Hydro Limited is owned by NSW (58%), Victoria (29%) and the Australian Federal Government (13%).
[116] Parliament of Australia House of Representatives, n 62, 162.
[117] Parliament of Australia House of Representatives, n 62, 162.
[118] Parliament of Australia House of Representatives, n 62, 162. See 'Land based operations may be carried out within or outside the target area, but the seeding agent is not to be discharged from within the Jagungal

In 2004, the NSW Parliament authorised Snowy Hydro Limited to pursue a cloud seeding experiment under the NSW *Snowy Mountains Cloud Seeding Trial Act 2004*.[119] The Act authorised Snowy Hydro Limited to conduct a 6-year trial over the Kosciuszko National Park in a target area of about 1000 square kilometres.[120] The Snowy Precipitation Enhancement Research Project ('SPERP') was designed to evaluate whether cloud seeding using land-based silver iodide generators could markedly increase snowfall in the region, both for agriculture and hydro-electricity production. The Act was amended in 2008 to extend the trial until 2014 and increase the target area to 2150 square kilometres. In 2010, the results of the trial phase showed an increase in precipitation of up to 14% and no significant adverse impact on the environment.[121] Thus, in 2012, the project became operational under the *Snowy Mountains Cloud Seeding Trial Amendment Act 2012* (NSW). The map below reproduces the target area as authorised under the Act.[122]

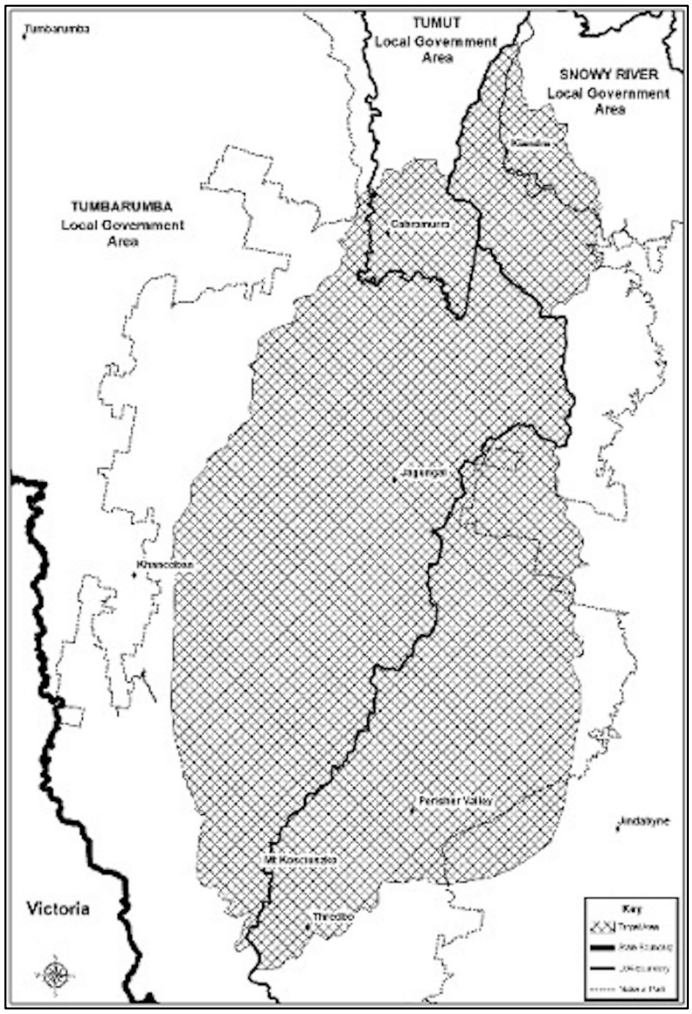
Wilderness Area;' 'The discharge of the seeding agent is carried out at a time when increased precipitation in the target area is likely to fall as snow.' *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), s 4(1)(b)-(c).

[119] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 4 s 4.

[120] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 2 s 4(1)(a), sch 1.

[121] Siems and Manton, n 94, 1.

[122] *Snowy Mountains Cloud Seeding Trial Amendment Act (No 73) 2012* (NSW).



Map 2. Snowy Mountains cloud seeding target area

The Act overrides requirements for approvals or licenses under other laws, specifically requirements for formal EIA.[123] It provides that '[a]uthorised cloud seeding operations may be carried out despite any other Act or law.'[124] The SMHEA had prepared a draft environmental impact statement ('EIS') in 1993,[125] revised the draft EIS in 1997, and presented it to the NSW government in 2002.[126] No new or supplementary EIA was conducted when the project became operational in 2012. Nevertheless, Snowy Hydro Limited is expected to prepare and update an

[123] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 7(2)(b).
[124] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 7(1).
[125] See generally B Harasymiw and J McGee, "Snowy Precipitation Enhancement Project—Draft EIS" (SMHEA, 1993).
[126] *Australian Cloud Seeding Research Symposium*, n 112, 31.

environment management plan ('EMP')[127] and to report on environmental performance to the NSW Natural Resources Commission ('NRC').[128] In addition, the Ministers administering the *Environmental Planning and Assessment Act 1979* (NSW) and the *National Parks and Wildlife Act 1974* (NSW) may suspend or terminate authorisation if the operations create a risk of significant adverse environmental impact, or if Snowy Hydro fails to comply with the Ministers' requirements, such as implementation of the EMP.[129] Like Victoria, the Act provides statutory immunity for authorised operations:

> '[c]ompensation is not payable by or on behalf of the Crown arising directly or indirectly from any of the following: (a) the enactment of this Act, (b) the carrying out of authorised cloud seeding operations, (c) the exercise by any person of a function under this Act or a failure to exercise any such function.'[130]

The analysis of the governance arrangements in Victoria, Tasmania and NSW raises questions about decision-making framework, EIA and scientific uncertainty, public participation, monitoring of operations and liability for damage. Key aspects of each issue are summarised in Table 2 below. The following section compares how each state has dealt with these issues.

Table 2. Key issues in Australia weather modification governance

Issue	Victoria	Tasmania	New South Wales
Decision-making framework	- Specific legislation - Minister of Agriculture authorises cloud seeding (in practice, authorisation	- Executive power of state government	- Specific legislation - Snowy Hydro Limited conducts cloud seeding (government-owned enterprise)

[127] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 2 s 6(2)(b).
[128] Established the *Natural Resources Commission Act 2003* (NSW), pt 2.
[129] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 2 s 6.
[130] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 9(1).

	granted to government departments only)	- Hydro Tasmania conducts cloud seeding (government-owned enterprise)	
EIA and management of uncertainty	- CSIRO as a training agency and assist in design and evaluation of projects - No provision for EIA - No EIA conducted in practice - No precautionary measures	- Hydro Tasmania follows the ARMCANZ guidelines for the utilisation of cloud seeding as a tool for water management in Australia - No legal requirements - EIA conducted for the experimental phase (Tasmania IV) in 1998. - No precautionary measures	- CSIRO and the Bureau of Meteorology engaged in experiment design - Exemption from EIA under the *Environmental Planning and Assessment Act 1979* - EIA conducted in 1991, but no EIA conducted for the 2004 program. - Snowy Hydro to develop and implement an EMP (reviewed every five years.)
Public participation	- None formally required. - In practice, no public notice, meeting or consultation occurs	- None formally required. - From 2008, informal notice on local radio and daily update on Hydro Tasmania's website, but no meetings or consultation.	- None formally required. - No public notice, meeting or consultation. - NRC reports made available to the public e.g. Snowy Hydro's website
Monitoring	- Requirement for reporting operations to the Minister of Agriculture - Cloud seeding officer must keep a logbook of all cloud seeding flights	- No formal reporting obligations - Reviews of operations motivated by public concerns over impacts (in 2008 and 2016)	- NSW NRC acts as a supervisory and reporting agency - Monitoring obligation under the EMP and NSW EPA reviews EMP compliance
Liability	Statutory immunity for authorised cloud seeding operations	No legal protection Common law negligence provisions and the *Civil Liability Act 2002* (Tas) apply to government exercising executive authority	Statutory immunity for authorised cloud seeding operations

4 Discussion

4.1 Responsibility for Cloud Seeding Decisions and Activities

Cloud seeding in Australia has traditionally been funded and carried out by state governments.[131] Apart from a provision of Australia's *Civil Aviation Safety Regulations 1998* that requires aircraft certificate for the special purpose of 'weather control and atmospheric

[131] McBoyle, n 55, 69.

research (for example, cloud seeding),'[132] there is no national cloud seeding law in Australia. The Commonwealth has consistently declined to take a formal role in implementing or overseeing rain making programs.[133] Instead, it encouraged states initiative with the assistance of the CSIRO.[134] While this has not been problematic to date, cloud seeding activities may have potential interstate impacts that could benefit from national coordination and standards. For example, in the Snowy Mountains, operations take place close to the Victorian border and may affect public lands, reserves and agriculture land in Victoria.

To date, cloud seeding has been considered a public service. Operational cloud seeding programs have traditionally remained under state governments' control.[135] Never was a private operator granted the authority to carry out operations.[136] However, in recent years, the private sector has been increasingly involved in cloud seeding. For instance, in a 2004 report on cloud seeding, climate change and water resources, the Parliament House of Representatives considered the involvement of the private sector in cloud seeding research and development.[137] In Victoria, the authority to conduct rain-making operations can now be granted to all business structures (sole trader, partnership, company, co-operative, trust, incorporated association, etc.).[138] The incorporation of Hydro Tasmania and Snowy Hydro also show that the commercial development of weather modification science and technology has gained in popularity.

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[132] *Civil Aviation Safety Regulations 1998* (Cth), s 21.25(2)(f).
[133] McBoyle, n 55, 84-85.
[134] Davis, 'The Law of Precipitation Enhancement in Victoria', n 13, 7.
[135] In the two states that have specific legislative frameworks governing cloud seeding activities, the primary statutory objective is to restrict the use of cloud seeding without authorisation. In Victoria, authorisations have traditionally been granted to state departments. In Tasmania and NSW, cloud seeding operations have been exclusively carried out by government-owned enterprises: Snowy Hydro Limited and Hydro Tasmania.
[136] Farmers' organisations have played a lobbying role in pushing for operational programs (eg in Western Australia) but were never directly involved in rain-making projects. McBoyle, n 55, 92-94. See also Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 10.
[137] Parliament of Australia House of Representatives, n 62, 164-65.
[138] Department of Industry, Innovation and Science, "ABLIS" (13 September 2017), https://ablis.business.gov.au/service/vic/authority-to-carry-out-rain-making-operations/24339.

Although Australia continues to engage in cloud seeding research and development as a public service, it increasingly recognises the competence and experience of cloud seeding companies in project design. In the US, the private sector has been heavily involved in the development of weather modification and private cloud seeding operators offer their services worldwide, including to Australia. For instance, a recent experiment in Queensland was a public/private initiative, involving the American-based company, Weather Modification Inc.[139] However, the involvement of the private sector requires mechanisms that allow government agencies to verify the soundness of their operations. This is best accomplished through clear legislative oversight (like in NSW and Victoria) as activities conducted under the discretion of the executive power (like in Tasmania), lack legitimacy, accountability and transparency.

If the trend towards greater private involvement in cloud seeding continues, it may become necessary to clarify the relative priority of public and private interests in precipitation. In a 1950 American case, *Slutsky v. The City of New York,* 197 Misc 730 (NY, 1950), the Court rejected the claim of a resort owner who sued the city for conducting cloud seeding operations that would have detrimental impacts on his business. [140] The decision reads: '[t]he Court will not prevent a possible private injury at the expense of a particular public advantage;'[141] and '[the plaintiffs] clearly have no vested property rights in the clouds or the moisture therein.'[142] Yet, in a later case, another state's Court recognised that 'under our system of government the landowner is entitled to such precipitation as Nature deigns to bestow.'[143] While we are unaware of any legal action brought against cloud seeding operators in Australia, these

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[139] 'Queensland Environmental Protection Agency | Weather Modification, Inc', http://www.weathermodification.com/projects.php?id=4.
[140] In Victoria, the Committee referred to this case and recommended that the public interest outweigh any private interests in precipitation. Victoria, *Parliamentary Debates* (Legislative Assembly, 1 November 1967) 1609.
[141] *Slutsky v City of New York*, 197 Misc 730 (NY, 1950).
[142] *Slutsky v City of New York*, 197 Misc 730 (NY, 1950).
[143] *Southwest Weather Resources Inc v Rounsaville*, 320 SW 2d 211 (Tex Civ App, 1958).

conflicting decisions suggest that there exist different approaches to private versus public rights over precipitation. Were landowners in Australia to advocate for greater use of cloud seeding to support particular land uses such as agriculture, it may be necessary to clarify the rights of private actors to conduct cloud seeding operations and use atmospheric resources in Australia.

4.2 Environmental Impact Assessment and Management of Uncertainty

CSIRO has always refused to take part in operational programs, only to play an advisory role in states' cloud seeding operations. Up until the 1970s, CSIRO acted as a professional licensing agency by testing and certifying the cloud seeding competencies of governmental officers.[144] In Victoria, for instance, the Regulations provide that cloud seeding operations must be carried out using CSIRO-approved techniques, equipment and personnel.[145] According to Davis '[s]uch pooling of experience and resources is one of the reasons why Australia (…) has been one of the leaders in weather modification work in the world.'[146] In recent years, CSIRO has retained a certain expertise in evaluating cloud seeding projects undertaken by the Water Industry.[147] For instance, both the SMARP and the SPERP, in the Snowy Mountains, were designed by Snowy Hydro, with assistance from CSIRO and the Bureau of Meteorology to ensure that experiments were scientifically sound.[148] Therefore, even though the national government has played a limited role in regulating cloud seeding, it has conserved some scientific oversight functions.

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[144] Between 1965 and 1970, the CSIRO provided training on weather modification to operators and administrators (i.e. Courses of Instruction in Cloud Seeding Techniques). McBoyle, n 55, 76; Davis, "Atmospheric Water Resources Development and International Law ", n 10, 21.
[145] *Rain-Making Control Regulations (No 98) 1968* (Vic) pt 2 s 5(a).
[146] Davis, "The Law of Precipitation Enhancement in Victoria", n 13, 17.
[147] Brian F Ryan and Brian S Sadler, *Guidelines for the Utilization of Cloud Seeding as a Tool for Water Management in Australia* (Agricultural and Resource Management Council of Australia and New Zealand, 1995) 8.
[148] Ryan and Sadler, n 147, 7. CSIRO and the Australian Government Bureau of Meteorology have also been involved in research symposiums on Australian cloud seeding to explore the potential and mechanisms for cloud seeding research in Australia. See *Australian Cloud Seeding Research Symposium*, n 112.

The CSIRO has been involved in the development of international standards and guidelines. CSIRO scientists have greatly contributed to the WMO PEP and the development of guidelines that remain 'a test of the scientific credibility of any proposed cloud seeding project.'[149] Similarly, the Agricultural and Resource Management Council of Australia and New Zealand ('ARMCANZ') published a set of non-binding *Guidelines for the utilisation of cloud seeding as a tool for water management in Australia 1995*.[150] These scientific guidelines are designed 'for water managers (…) to assist them in developing planning procedures and decision-making processes that will maximise the possibility for a successful experiment.'[151] They provide general recommendations on the role of water managers, cloud seeding operators, design scientists and independent review scientists in the development of scientifically acceptable projects.[152] Two decades later, these guidelines remain a reference.

State agencies also play a significant role in ensuring that cloud seeding programs are based on the best science available. In Victoria and NSW, relevant Ministers are designated to authorise operations.[153] In NSW, the Act also gives competency to the NSW NRC to conduct independent reviews of Snowy Hydro's annual reports,[154] and to the NSW Environmental Protection Agency ('EPA') to review compliance with the EMP. In the mid-term review of the trial phase, 'the NRC confirms that the trial is being conducted in compliance with the Act, is of a high scientific standard and the evaluation plan is statistically sound.'[155] The NRC also 'sought input from relevant NSW agencies and engaged expert scientists to peer review the

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[149] Michael J Manton, "Evaluation of the Impacts of Cloud Seeding", *Australian Cloud Seeding Research Symposium*, n 112, 24.
[150] See generally Ryan and Sadler, n 147.
[151] Ryan and Sadler, n 147, 2.
[152] Ryan and Sadler, n 147, 12.
[153] *Rain-Making Control Act 1967* (Vic), s 3; *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 1 s 3.
[154] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 8.
[155] New South Wales and Natural Resources Commission, *Mid-Term Review of the Snowy Mountains Cloud Seeding Trial* (Natural Resources Commission, 2010) 3.

information and analysis presented in Snowy Hydro's 2009 SPERP report.'[156] Indeed, the scientific community is actively involved in the evaluation of cloud seeding experiments in Australia, with regular publications from the peer-reviewed literature.[157] Informed by the research community, state agencies provide a scientific advice; they have a special weight in the decision-making process and allow for regular revision of the program.

In spite of WMO's recommendations, there is no legal requirement to conduct EIA for cloud seeding in Australia. In Victoria, no EIA is required by the law and none has been conducted in practice.[158] In NSW and in Tasmania, an EIA was conducted for the experimental phase of the programs, in absence of any legal requirement. However, no EIA has been conducted for the operational phase of these programs. In operational projects, seeding operations are non-randomised – clouds are seeded in all suitable occasions – and it becomes impossible to conduct accurate statistical evaluation of the effects of a seeding.[159] It is therefore impossible to assess the impacts of an operational program, especially longer term environmental impacts.[160] Hydro Tasmania recognises that randomisation represented a significant economic loss, as seeding only part of the suitable clouds reduced chances of enhancing precipitation in key locations.[161] The 2008 background report explains 'this strategy means that Hydro Tasmania and the community have no reliable information on the impacts

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[156] New South Wales and Natural Resources Commission, n 155, 2.
[157] For Tasmania, see, eg, Anthony E Morrison et al, "On the Analysis of a Cloud Seeding Dataset over Tasmania" (2009) 48(6) *Journal of Applied Meteorology and Climatology* 1267; Bigg, n 40; Siems and Manton, n 94. For NSW, see, eg, Williams and Denholm, n 36; Arlen Wesley Huggins et al, "The Snowy Precipitation Enhancement Research Project: A Description and Preliminary Results" (2008) 40(1) *The Journal of Weather Modification* 28; Michael J Manton et al, "A Confirmatory Snowfall Enhancement Project in the Snowy Mountains of Australia. Part I: Project Design and Response Variables" (2011) 50(7) *Journal of Applied Meteorology and Climatology* 1432.
[158] In the Warracknabeal project, for instance, social, ecological and legal aspects were not considered by decision-makers. McBoyle, n 55, 90.
[159] WMO, n 28, 5-6.
[160] See, eg, Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 49.
[161] '[G]iven the past evidence showing effectiveness and the current practice of seeding every suitable day, the introduction of randomised non-seeded days will represent a loss of rainfall and its value in terms of power production.' Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 49.

of cloud seeding on rainfall in the region since the 1980s.'[162] It concluded that further research was needed to assess the potential long-term effects of the program.[163] Yet, cloud seeding activities continued in Tasmania, without any precautionary measure to integrate these uncertainties. A review of the governance arrangements should, therefore, ensure that scientific uncertainties can be monitored and decreased overtime.

In NSW, thorough studies were conducted to determine the potential impacts of silver iodide on the environment, including extensive literature review and investigation of background levels before trial. During the experimental phase, 107 experiments were conducted using silver iodide as a seeding agent and indium oxide as a tracer to monitor the silver levels.[164] In 2010, the NRC mid-term review confirmed that there was no evidence of silver iodide accumulation in the environment, nor impacts on snow habitats and downwind areas.[165] However, the NRC noted that the potential long-range transport and accumulative properties of silver iodide created a risks of persisting in the food chain and affecting biodiversity. Therefore, it recommended monitoring the effects of the seeding agents overtime.[166] In 2012, an independent Expert Panel was appointed to assess the environmental issues associated with the project. However, no formal EIA was conducted.

The NSW Act explicitly rejects the application of the *Environmental Planning and Assessment Act 1979*, notably Part 5 on infrastructure and environmental impact assessment.[167] The conducting of operations is also taken to be consistent with the *National Parks and Wildlife*

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[162] Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 49.
[163] Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 49.
[164] Snowy Hydro, *Snowy Precipitation Enhancement Research Project Executive Summary*, n 157. See also Williams and Denholm, n 36.
[165] New South Wales and Natural Resources Commission, n 155, 3.
[166] 'A key uncertainty identified by the NRC and our specialist peer reviewers is the transport and potential long-term accumulation and impacts of silver iodide and indium (III) trioxide.' New South Wales and Natural Resources Commission, n 155, 3.
[167] *Environmental Planning and Assessment Act (No 203) 1979* (NSW).

Act 1974.[168] Instead, the NSW Act sets an innovative procedure of assessment and monitoring. Under the Act, Snowy Hydro is to prepare and review an EMP in consultation with the Office of Environment and Heritage, the NSW EPA and National Parks and Wildlife Service.[169] Snowy Hydro reports annually to the EPA on its compliance with the EMP for the EPA to review.[170] The EMP is reviewed at least once every five years and has been reviewed in 2013 and 2018. Given high scientific uncertainty, traditional EIA have proven limited in their capacity to assess the impacts of cloud seeding. In NSW, the law has created a derogatory legal regime for cloud seeding. However, cloud seeding has been taking place largely outside of the general principles of environmental law and EIA requirements, including consideration of alternatives and consultation of stakeholders.

4.3 Public Participation

Procedural obligations, including public access to information, public participation and access to remedies, is particularly problematic in the governance of cloud seeding in Australia. Studies have demonstrated that public acceptance of weather modification is better achieved when the public is involved in decision-making,[171] but there is currently very limited opportunity for public participation in any of the states examined. McBoyle conducted the first survey of public opinion on weather modification in Australia, in the Warracknabeal area, Victoria, in 1980.[172] The study was conducted in the form of questionnaires of residents within and downwind of the target area and showed an overall positive attitude, despite downwind

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[168] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 7(3).
[169] "Environmental Management & Monitoring | Snowy Hydro", https://www.snowyhydro.com.au/our-energy/cloud-seeding/environmental-management-monitoring/.
[170] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 2 s 6(1). See, eg, NSW EPA, *Report on the Findings of the NSW Environment Protection Authority's Review of Snowy Hydro Limited Cloud Seeding Program:2017 Annual Compliance Report* (2017), https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/legislation/18p0868_shl_cloud-seeding-annual-compliance-report-2017.pdf.
[171] 'It would seem that, as in the North America situation, there is less likelihood of opposition to a project where the public is kept fully informed throughout the whole process.' McBoyle, n 55, 135.
[172] McBoyle, n 55, 107.

residents' concerns about information, notification, participation and EIA.[173] Interestingly, most respondents had obtained their information through media sources, not government agencies.[174] Media still plays a critical role in informing the public about cloud seeding in Australia, and it is worth questioning whether media constitutes a trustworthy source of information. Governments, on the other hand, relay limited information on the matter, contributing to a certain confusion of the concerned populations.

Deficiencies in government-led information and engagement on cloud seeding are also evidenced in Tasmania. The 2008 report on socio-economic impacts of cloud seeding involved the consultation of Tasmanian West Coast residents through interviews, surveys and focus groups.[175] The report pointed out an 'information vacuum' and a feeling of distrust in cloud seeding activities, conducted without public notice, participation nor benefit-sharing.[176] Access to information and notification were particularly contentious. Local populations recommended the provision of real-time information about seeding activities and better public education.[177] The report resulted in regular reporting on local radio station, daily updates of the Hydro Tasmania website, and the establishment of a community consultative group.[178]

Cloud seeding operations do not directly affect local communities in NSW because of the remoteness of the infrastructures. Yet, there are still significant pockets of opposition. The Colong Foundation for Wilderness, for instance, considers that the NSW Act 'sets a very dangerous precedent for undertaking proposals without environmental impact assessment in

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[173] McBoyle, n 55, 107.
[174] McBoyle, n 55, 107.
[175] Hydro Tasmania and West Coast Council, *Economic Impacts of Cloud Seeding*, n 95, 5-7.
[176] Hydro Tasmania and West Coast Council, *Socio-Economic Impacts of Cloud Seeding on the West Coast Community*, n 103, 21.
[177] Hydro Tasmania, "Report into Cloud Seeding on the West Coast" (online, 4 June 2008), https://www.hydro.com.au/docs/default-source/water/cloud-seeding/cloud-seeding-media-release_4june2008.pdf?sfvrsn=17441228_0, 1.
[178] Hydro Tasmania, "Report into Cloud Seeding on the West Coast", n 177.

one of Australia's most environmentally sensitive areas of national park.'[179] The Foundation argues that the Act allows Snowy Hydro to bypass existing environmental laws, with operations near sites protected under the UNESCO and Ramsar Conventions.[180] They argue that the costs far outweigh the benefits of the program, that could impact local wildlife (eg Mountain Pigmy Possum, Southern Corroboree Frog) and populations living in the rain-shadow areas. These experiences point to a need for more pro-active, and less reactive, public engagement. More systematic consultation, including through public meetings or hearings, could allow a more meaningful participation of community groups, affected individuals and industries in the decision-making process.

4.4 Monitoring of Effectiveness and Impacts

The WMO recognises that '[u]ncertainties inherent in the current technologies can only be addressed by programmes of focused research that lead to deeper understanding of the effects of cloud seeding on cloud and precipitation development.'[181] If Australian states are to pursue cloud seeding activities, they should also ensure that appropriate research programs help to decrease scientific uncertainties over time. Yet, cloud seeding is currently used on an operational basis without integrated research addressing the risks of large-scale and long-term effects.

Resuming cloud seeding activities in Victoria or Tasmania would also require improvements in monitoring and reporting systems. The Victorian Act require reporting to the Department of Agriculture, but nothing requires monitoring the impacts of cloud seeding

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[179] National Parks Association of NSW Colong Foundation for Wilderness, "Briefing on Cloud Seeding on Kosciuszko National Park", https://www.colongwilderness.org.au/campaigns/save-kosciuszko-national-park/briefing-on-the-proposed-cloud-seeding-kosciuszko-national-park.

[180] 'The enabling legislation overturns the National Parks and Wildlife Act 1974; Wilderness Act 1987; Fisheries Management Act 1994; Threatened Species Act 1995; Local Government Act 1993; Protection of the Environment Operations Act 1997; and Environmental Planning and Assessment Act 1979.' Colong Foundation for Wilderness, n 179, 3.

[181] WMO, n 28, 4.

operations. This is inconsistent with the WMO and the ARMCANZ guidelines that recommend monitoring long-term impacts of silver iodide, extra-area effects and persistent effects.[182] In Tasmania, even though the EIA had identified several uncertainties to monitor, Hydro Tasmania has not been subject to any specific monitoring or reporting obligations related to cloud seeding activities.[183] In 2008, the local communities expressed the need for better monitoring, but no monitoring system was implemented.[184] This was explained on the ground that the natural variability of rainfall renders the assessment of extra-area and downwind effects impossible.[185]

Conversely, there are binding monitoring obligations in NSW.[186] The EMP 'includes an adaptive environmental monitoring program where the future program is informed by the results of the previous environmental monitoring.'[187] Each year, Snowy Hydro Limited reports its research and monitoring results to the EPA (eg concentrations of silver iodide and indium trioxide, as well as impacts on montane riverine ecosystems and snow habitats). In the 2017 annual compliance report of Snowy Hydro's EMP, the EPA notes that: '[e]nvironmental monitoring has, to date, not detected any significant adverse environmental impacts.'[188] This adaptive monitoring approach creates flexible arrangements that allows to integrate scientific uncertainty and could be replicated in other states. Nevertheless, it could gain from independent programs designed to advance fundamental research in atmospheric sciences.

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[182] Similarly, the WMO warns '[u]nintended consequences of cloud seeding, such as downwind effects, persistent effects of silver iodide in soil, and environmental and ecological impacts, have not been demonstrated but cannot be ruled out.' WMO, n 28, 7.
[183] Historically, Hydro Tasmania addressed cloud seeding activities briefly in its annual reports : Hydro Tasmania, *Annual Report* (2012), https://www.hydro.com.au/docs/default-source/about-us/our-governance/annual-reports/hydro-tasmania-annual-report-2012.pdf?sfvrsn=e26e1328_2.
[184] Hydro Tasmania and West Coast Council, *Socio-Economic Impacts of Cloud Seeding on the West Coast Community*, n 103.
[185] Hydro Tasmania and West Coast Council, *Effects of Cloud Seeding on Rainfall in the West Coast: Background Report 1*, n 65, 1.
[186] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 2 s 4(1).
[187] NSW EPA, n 170, 3.
[188] NSW EPA, n 170, 2.

4.5 Liability

Cloud seeding laws in Australia currently limit access to judicial remedies to persons that might be affected by cloud seeding.[189] In his 1980 survey of Warracknabeal residents, McBoyle found that an overwhelming majority of respondents thought that cloud seeding operators should be held liable for damage resulting from operational cloud seeding projects.[190] No subsequent study has considered this question, but it is noteworthy that the regimes currently in place in NSW and Victoria explicitly afford forms of statutory immunity from liability. This immunity was considered necessary throughout the 1970s-80s, for fear that regulations and punitive measures would constrain the benefits of this emerging technology.[191] In Victoria, the statutory immunity was considered reasonable because 'in the authorization of rain-making operations, particular attention will be paid to any adverse effect rainfall might have on certain crops.'[192] It was agreed that any disaster would be dealt similarly as natural bushfires and floods, and that the Crown should not be held liable for damage resulting from weather modification activities.[193]

Similarly, the NSW Act prevents administrative actions to be taken against the authorised operations. It lists the orders or notices that *may not* be made to prevent or interfere with the operations, including interim protection orders and environment protection notices. Interestingly, the immunity from civil liability does not extend to Snowy Hydro.[194] The Act

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[189] 'Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided.' *Rio Declaration on Environment and Development*, United Nations Conference on Environment and Development (13 June 1992) 31 ILM 874, Principle 10.
[190] McBoyle, n 55, 123.
[191] 'Weather modification activities, no adverse effects of which have been proved on the basis of the present state of scientific knowledge, were distinguished from other activities involving pollution and other harmful effects ; the view was expressed that the development of new beneficial technology should not be constrained unduly by "punitive" legal sanctions.' WMO and UNEP, *Report of the WMO/UNEP Informal Meeting on Legal Aspects of Weather Modification* (1975) 731.
[192] Victoria, *Parliamentary Debates* (Legislative Assembly, 1 November 1967) 1608.
[193] Victoria, *Parliamentary Debates* (Legislative Assembly, 1 November 1967) 1609.
[194] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 7(6).

defines the Crown 'within the meaning of the *Crown Proceedings Act 1988*, and includes an officer, employee or agent of the Crown, but does not include Snowy Hydro Limited.'[195] Therefore, Snowy Hydro Limited *does not* benefit from the sovereign immunity and could, theoretically, be sued for compensation of damage resulting from cloud seeding activities. Liability will be extremely hard to establish, however. The difficulty of attributing a particular weather-related damage to a seeding operation still represents a significant obstacle to proving causation or "direct interference" for actions in trespass.[196]

In Tasmania, in the absence of statutory immunity, both the Tasmanian government and Hydro Tasmania could potentially be sued in tort for negligence and nuisance for damage caused by cloud seeding activities. In 2016, the independent review of the flood found that Hydro Tasmania's cloud seeding activities that morning had no measurable effect on rainfall because the targeted clouds already contained sufficient ice to precipitate.[197] Therefore, no evidence of causation justified imposing liability for the flood. The report also concluded that Hydro Tasmania's program design and evaluation had complied with the ARMCANZ Guidelines.[198] This report is obviously helpful, but not necessarily determinative of negligence or liability in a legal sense. Although there was no legal action engaged against Hydro Tasmania, these inconsistent approaches to liability in state-based regimes suggest that this is an issue ripe for reform.

5 Conclusion

Australia has played a major role in weather modification research and implementation. Although Australian experiments have been carried out in accordance with applicable

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[195] *Snowy Mountains Cloud Seeding Act (No 19) 2004* (NSW), pt 3 s 9.
[196] Heilbronn considered trespass the only cause of action available under Australian law: plaintiffs do not need to prove actual loss or damage but need to demonstrate negligence or intent, as well as interference with a property right. Heilbronn, n 13, 131-143.
[197] Blake, n 4, 5.
[198] Blake, n 4, 54.

international standards, experience with the practice and governance of weather modification highlights deficiencies in the regulation of cloud seeding activities. First and foremost, non-randomised operations have prevented accurate assessment of impacts in practice (especially persistent and extra-area effects). There is limited evidence of precautionary experimental program or comprehensive assessment and monitoring of environmental, social and economic impacts of cloud seeding activities, both within and beyond target areas. In addition, cloud seeding laws do not provide for the procedural rights of the local communities, including access to information, public participation and access to justice. Where they exist, statutory immunity provisions raise questions of accountability, especially for individuals and industries who may be adversely affected. Some of these drawbacks patently conflict with principles of good governance so that a revision of cloud seeding frameworks is mandated.

The prospect of climate-induced drought may prompt renewed interest in cloud seeding in Australia. This presents an opportunity to reconsider the adequacy of the current regulations. With the newest regime more than two decades old, it is time to modernise these laws and locate them within a broader framework of environmental law principles. This process of reform can also provide a useful starting point for wider conversations about how best to govern solar radiation management technologies such as MCB. Given Australia's increasing interest in the potential to expand MCB to protect the Great Barrier Reef, as well as wider interest in planetary-scale solar radiation management, weather modification activities like cloud seeding could offer a localised example of governance approach for these new technologies. This paper has identified a number of shortcomings, all of which can be used as lessons in future efforts to govern technologies intended at modifying atmospheric processes.