Executive Summary

The Snowy Mountains Cloud Seeding Trial Act 2004 (NSW) (the "Act") authorises Snowy Hydro Limited ("Snowy Hydro") to undertake the Snowy Precipitation Enhancement Research Project ("SPERP") over the Snowy Mountains region of NSW.

The objectives of the SPERP are to determine the environmental, technical and economic feasibility of the use of cloud seeding to enhance snowfall over the catchments of the Snowy Mountains Scheme.

The Act was amended in May 2008, extending the duration of the trial until April 2015 and increasing the size of the target area from around 1,000 square kilometres to approximately 2,150 square kilometres. Cloud seeding operations over the expanded target area commenced during the current reporting period.

Under Section 6 of the Act, the relevant Ministers imposed an obligation on Snowy Hydro to develop and implement an Environmental Management Plan ("EMP") for the SPERP. In addition, Section 8 of the Act requires the New South Wales Natural Resources Commission ("NRC") to supervise authorised cloud seeding operations and report on the environmental impact of those operations to the relevant Ministers.

The current EMP was developed in collaboration with experts from the NSW Department of Environment, Climate Change and Water[1] ("DECCW"), and in consultation with the NRC. The EMP describes in detail the entire scope of the environmental monitoring and reporting to be undertaken by Snowy Hydro. Importantly, the EMP has been endorsed by DECCW, and formally approved by the responsible Ministers and the NSW government.

Section 6 of the EMP describes the annual and extraordinary reporting requirements for the SPERP. In addition to the standard items reported, this Annual Report includes:

- A statistical evaluation of cloud seeding efficacy (including assessment of potential downwind effects) and an assessment of ultra trace snow chemistry data collected over the period 2005 through 2009; and
- An analysis of the environmental monitoring undertaken during the period 2004 through 2009.

The key findings included in this report are summarised below.

Evaluation of Cloud Seeding Efficacy

Cloud seeding efficacy was determined using two separate sets of analyses. The *primary evaluation* examined the targeting effectiveness and impacts on precipitation. The criterion for success for this evaluation was prescribed in advance, and required a statistical significance of at least 10% (that is, a 10% or less probability that the outcome observed could have been due to chance alone).

The outcomes of the primary evaluation (Manton 2010) have shown:

[1] Formerly the NSW Department of Environment and Conservation, and the NSW Department of Environment and Climate Change

- The targeting of seeding material to be "*unequivocally positive"*, with "*…a probability of 2,000,000 to 1 that the observed differences occur by chance*"; and
- *"…that seeding yielded an increase of 7% in precipitation across the primary target area at a statistical significance of 24%. That is to say, there was a 24% probability that this outcome could have been due to chance".*

The *secondary evaluation* comprised a number of lines and levels of analysis undertaken to support the primary evaluation. Most importantly, when the primary analysis is repeated using only those experiments where the overall target was effectively covered[†] we find:

- *"…when the analysis is applied to the overall target area the precipitation increase is 14% at the 3% significance level"*

Furthermore, Manton & Warren (2010) noted that:

- *"…seeding impacted on virtually all the physical variables examined in a manner consistent with the seeding hypothesis*", and the SPERP evaluation outcomes were *"…consistent with the results of the earlier cloud seeding project of Smith et al. (1963)*".

The secondary analyses (Manton 2010) also investigated potential seeding impacts outside of the target area. This investigation has shown no impact of seeding downwind of the target area *viz.*

- "*Careful analysis of the distribution of silver and indium in seeded and unseeded EUs finds that the seeding material is consistently confined to the target area. Moreover, analysis of the spatial patterns of precipitation in seeded and unseeded EUs shows no sign of any impact of seeding downwind of the target area."*

Environmental Outcomes

In reporting on these matters, environmental outcomes were considered based on potential impacts associated with:

- Installation, operation and maintenance of infrastructure;
- Ecotoxic effects relating to the use of silver iodide and indium (III) oxide; and
- Effects caused by changes to precipitation.

The key outcomes were found to be:

Infrastructure

Cloud seeding infrastructure is managed in accordance with the requirements of the EMP. All generators and some instrumentation are deployed and recovered at the end of each season.

Audits of infrastructure by Snowy Hydro, DECCW and the NRC over the duration of the trial have not identified any significant adverse environmental impacts associated with cloud seeding infrastructure.

[†] There were 107 experiments in total undertaken for SPERP 1. The analysis referred to here used 84 of those experiments

Ecotoxicity

The SPERP uses silver iodide as a seeding agent and indium (III) oxide as an inert tracer agent. Analysis of data collected before commencement of the trial confirmed silver and indium to be present in measureable concentrations at all locations. The statistical analysis of the ecotoxicological data for the period 2004 to 2009 indicates that the concentrations of silver and indium at all locations and for all environmental matrices remain very low compared to the relevant environmental guidelines.

Evaluation of the ecotoxicity data indicates low likelihood of a statistical Type II error (the error of failing to observe a difference when in truth there is one). Analysis of statistical power for silver and indium in soil from the Generator locations indicate that there is a high likelihood that a statistically significant increase (above the pre-trial levels) would be detected well before the relevant environmental guideline value was reached.

Stream sediment samples were also analysed for the years 2007 through 2009. This analysis concluded that there was no evidence of any accumulation of silver and indium in the aquatic sediments as a result of cloud seeding operations.

Overall, there is no evidence to suggest that cloud seeding has contributed to ambient levels of silver and indium in any of the areas monitored.

Effects caused by changes to precipitation

These assessments considered potential effects on aquatic and terrestrial ecology.

Monitoring of Aquatic Macroinvertebrate Fauna

Statistical comparisons between target and control area stream sediments were undertaken to determine if there was any change to silver and indium concentrations above background levels. Comparisons were also made between the condition of aquatic macroinvertebrate fauna in target and control areas over time. Analyses of data collected following the 2009 winter cloud seeding confirmed:

- Concentrations of silver and indium in the aquatic sediment were too low to have had any ecotoxic effects on aquatic macroinvertebrates;
- No evidence of an accumulation of silver or indium in streams was found to have occurred as a result of cloud seeding operations; and
- No evidence of impairment of the aquatic macroinvertebrate fauna that was consistent with cloud seeding operations.

Snow Density

In April 2009, the NRC provided a report to the State Government on the progress of the Snowy Mountains Cloud Seeding Trial. In this report, the NRC considered that changes in snow density resulting from cloud seeding operations could potentially have adverse impacts on the subnivean space and snow dwelling fauna.

Analysis of snow density data collected during 2009 found:

- The difference in mean densities of seeded and unseeded snow samples in the target area was not statistically significant;

- The differences in mean densities of seeded and unseeded snow samples were not dependent on the key locations considered;
- When data were pooled across key locations, the difference in mean densities of seeded and unseeded snow samples was statistically significant, with seeded samples having a lower density than unseeded samples;
- When data from seeded and unseeded snow samples were pooled, statistically significant differences in mean densities of snow samples were found among key locations within the target area.

Snow density data collected and analysed from previous years were also considered in this assessment. Seeded and unseeded snow samples densities were found to be very similar, and well within the range of natural variability.

A review of the scientific literature was also undertaken to support the analysis described above. The review found that any differences in the density of snow resulting from cloud seeding to be well within the range of natural variability, and that additional snowfalls resulting from cloud seeding would be unlikely to have impacts of any ecological significance on the subnivean space.

Late Season Snowfall Events

In previous reports to NSW, the NRC has noted that *"…cloud seeding could be beneficial if it delays early season snow melt. Alternatively, it could be detrimental to the hibernation patterns of small mammals if it contributes to late season snow events following significant snow melt*".

In addressing this issue, a detailed analysis of snow course data records has shown a large temporal and spatial variation in snow depths across the Snowy Mountains. The effect of elevation is clearly evident in the amount of snow and duration of snow cover across all sites.

Importantly cloud seeding operations have never taken place following complete snow melt at Spencers Creek. Moreover, in 2009 it should be noted that significant snowfalls occurred in October, well after cessation of cloud seeding operations for the year. Complete snowmelt had already occurred at Deep Creek and Three Mile Dam prior to these natural falls.

Causing Rain rather than Snow

The Act requires that cloud seeding operations only take place when precipitation is likely to fall as snow and not rain. The freezing level criterion prescribed by the EMP requires that operations can only commence when the freezing level is at or below 1600 metres Above Sea Level. This restriction has been implemented and enforced to minimise the risk of precipitation falling as rain rather than snow over the primary target area.

An independent audit of the operational logs has confirmed 100% compliance with the freezing level criterion.

An analysis of multiple lines and levels of environmental monitoring, assessment and evidence provides a compelling argument that the SPERP has not had, and is unlikely to have, a significant adverse impact on the environment.