Feasibility of Roof Water Harvesting in a Cold Climate

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ABSTRACT
Faced with mounting security of supply issues, the water supply authority in an Australian snowplay resort is trialling roof water harvesting to reduce mains water demand. A trial was established to harvest roof water from a building in Perisher Valley, New South Wales with both a roof and ground collection system. While the trial is ongoing, results from June 2004 to January 2005 show that the ground and roof collection systems collected approximately 100kL and 81kL respectively. Analysis of water quality also indicated that with no treatment, the collected water complied with Australian Drinking Water Guideline requirements, though it did have some bacterial contamination. The results provide encouragement that roof water harvesting is a viable and sustainable alternative to reducing mains water demand in alpine/cold climates.

KEYWORDS
Gutter, Harvesting, Roof Water, Water Quality

INTRODUCTION
Australia is renowned more for its harsh arid climate than for its snowfields. Nevertheless, covering a very small area in the south-eastern corner of the continent is Australia's alpine region which supports a vibrant snowplay industry across several resorts.

The resorts are generally located in National Parks with highly sensitive environments, with unique and diverse flora and fauna, much of it listed as threatened or endangered. One such resort is located in the Perisher Range in Kosciuszko National Park, New South Wales, and incorporates the villages of Perisher Valley, Smiggin Holes and Guthega. The snow season officially occurs between June and October each year.

The NSW Department of Environment and Conservation (DEC) operate the water and sewerage services and manage the stormwater system in the Perisher Range Resorts. Despite being in an area of high annual average precipitation with relatively little annual variability (compared to Europe and North America) the water supply for each of the villages is insufficient to meet the growing demand. Growth in demand is driven principally by proposed new resort development which will increase the amount of accommodation in the resorts by approximately 20%.

Despite efforts at demand reduction and augmentation of the water supply system, the future provision of environmental flows (providing minimum levels of flow for downstream ecosystems based on "cease to divert" protocols) at each of the three diversion weirs is likely to exacerbate the security of water supply issues.

Faced with these issues and constraints, the DEC has commissioned studies into the feasibility of roof water harvesting to:

1) reduce demand on water supplies; and
2) assist in reducing stormwater discharges and potential sediment transport to streams and wetlands.

Harvesting Roof Water

The resorts have atypical patterns of water use. They remain nearly empty of people for much of the year and their populations swell into the thousands in the snow season. Nearly all mains water consumption is for internal domestic and commercial (food preparation) uses. There is virtually no garden watering or car washing, and there are no water hungry uses such as commercial laundries, etc. Security of supply issues have been modelled to occur in both summer and winter (Gippel and Doeg, 2002).

For roof water harvesting to be effective in reducing mains water consumption, it must displace existing uses to which mains water is directed. This may include non-potable uses such as toilet flushing which would require separate plumbing to be retrofitted into buildings, or potable uses. Potable use of harvested roof water is feasible if the water is plumbed into hot water systems where it receives disinfection (Coombes *et al*, 2001; Snowy Monaro Councils, unpub. 2002), and otherwise where disinfection can readily be supplied (e.g. ultraviolet disinfection). Testing of the harvested water for the presence of pathogens is required to determine its fitness for use.

Roof water harvesting has the potential to be applied to every building in the ski resorts. The presence of snow and ice presents challenges to optimising the capture of roof runoff. Most buildings in the resorts have no gutters with snow/ice falling to soakage trenches below the eave. Two methods of capture therefore became obvious:

1) roof collection in a retrofitted gutter system, and
2) ground collection in a trench.

There is concern that ground collection systems have potential for increased contamination. Therefore, the water quality performance of each collection system would need to be assessed.

TRIAL METHODOLOGY

A trial was established in autumn (May) 2004 to assess the quantity of runoff from a roof on the DEC's Operations Building in Perisher Valley during the winter snow season and beyond.

The trial was conducted to measure the amounts of harvested roof runoff from both a roof gutter, and from a ground collection system. These two components of the trial were located adjacent to one another on the roof of the Department of Environment and Conservation's Perisher Valley Operations and Visitor Centre (Figure 1). Both had contributing roof areas of 92.88 m^2 each (plan area). The pitch of the roof was low and therefore conducive to holding snow which is most suitable for the operation of the gutter.

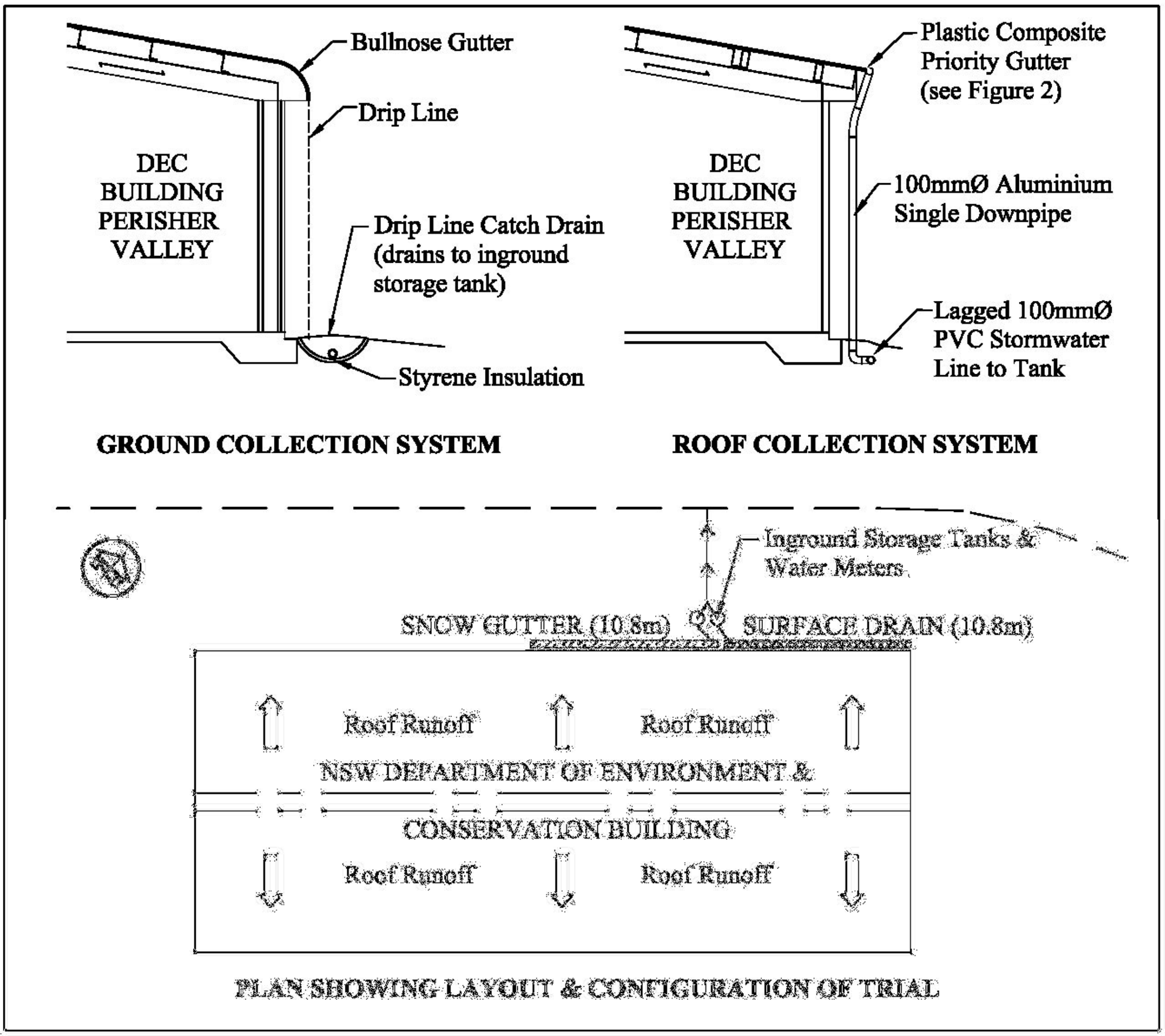

Figure 1. Location and configuration of the roof water harvesting trial at Perisher Valley (1,720m ASL).

It is important to note that a north-northwest facing roof section was chosen. In the southern hemisphere, northerly aspects receive the greatest solar exposure and thus the greatest snowmelt. This becomes important when extrapolating the results to entire buildings which will only have partial exposure to the north.

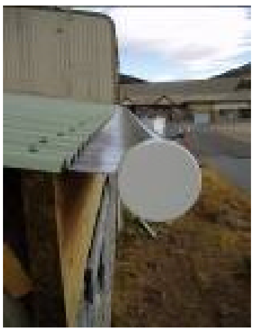

Figure 2. Roof gutter collection system

Figure 3. Priority Alpine roof gutter fitted to existing roof

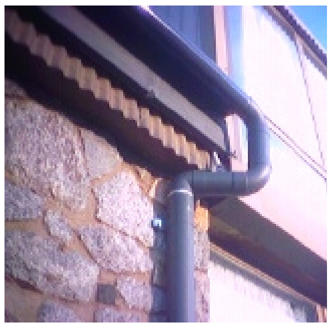

Figure 4. Downpipe conveying flow into collection sump

The roof gutter component of the trial incorporated a proprietary gutter developed for cold climates with the trade name of Priority Alpine (Figures 2 and 3). The gutter is able to collect water and convey it in a downpipe to a collection sump (Figure 4). One design feature of this gutter is that when larger masses of snow/ice slide down the roof, the gutter flips over to allow this material to fall to the ground, thus protecting the structural integrity of the roof and gutter. Only the precipitation that enters the downpipe is collected and measured in this component of the trial.

The ground collection system was located under a 'bullnose' roof where precipitation deposited directly into a stone-filled collection trench and was then transferred into the collection sump (Figures 5, 6 and 7).

Figure 5. Ground collection component of trial showing dual collection sump on LHS

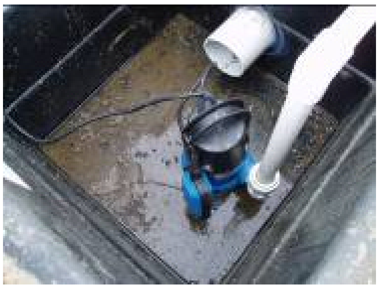

Figure 6. View inside one of the collection sumps showing pumping arrangement

Figure 7. The trial in operation during winter

In order to simulate demand for water from the tank and measure the potential yield from the systems the pumps were controlled by float switches and pumped water from the collection sumps when water levels triggered the float switch. The volume of water pumped was measured by water meters and recorded. We acknowledge that this is not fully representative of the normal way in which water would be supplied from a storage tank, however, it does provide an indication of the gross potential yield from the collection systems as opposed to the potential yield from a storage tank.

The pump meters within the collection sumps were intended to be measured daily with observation on climatic conditions logged concurrently. In addition to monitoring the amounts of water harvested from each collection system, routine water sampling and analysis was meant to be undertaken to assess the quality of the water for potable purposes and to determine contamination. The pump meters were measured sporadically during the 213 days of the trial reported in this paper. Water quality was sampled from the collection sumps on five occasions during the trial and sent to an accredited laboratory for analysis of pathogens and a range of contaminants including lead, zinc and polycyclic aromatic hydrocarbons.

RESULTS AND DISCUSSION

The 2004 winter snow season in Australia was one of the best in recent years in terms of snow depth, quality and length of season. This has provided ideal conditions to undertake this trial and demonstrate significant results. The snow season began early in June 2004 with significant snow dumps, ending in early October 2004. Tables 1 and 2 present the snow depth statistics for 1954-1993 and 2004 respectively. Based on Tables 1 and 2, the 2004 snow season had approximately 13% more snow than the average for the 1954-1993 snow seasons, and 21% more snow in August which led to the extended ski season for the year.

Table 1. Snow Depth (in cm's) Statistics for 1954-1993 at Spencer's Creek (1830m ASL)

	June	**July**	**August**	**September**	**Season**
Mean	45.3	107.3	164.3	178.0	120.6
Std. Dev.	42.3	60.0	64.1	68.6	54.3
Median	35.9	100.2	153.4	171.0	110.6
Range	188.0	212.6	281.7	252.7	202.8

Source: Slater (1995)

Table 2. Snow Depth (in cm's) Statistics for 2004 at Spencer's Creek (1830m ASL)

	June	**July**	**August**	**September**	**Season**
Mean	33.3	110.9	199.4	186.9	135.8
Std. Dev.	27.3	46.1	24.9	11.6	71.7
Median	54.8	127.4	204.5	192	149.6
Range	54.8	149	78.6	40.3	228.2

During the trial period of 213 days, both systems captured significant quantities of water. The ground system collected 100.52kL of water, while the roof system collected 81.27kL (approximately 80% of the ground system's total). The results of the trial are summarised in Table 3. For each period listed in Table 3, the ground collection system captured the same or more water than the roof collection system. The data indicates that during winter, volumes of water collected from both systems are comparable.

Table 3. Summary of Monitoring Results*

Description	**Dates**	**No. of days**	**Ground System**		**Roof system**	
			Pumped volume (kL)	L/d/m^2	Pumped volume (kL)	L/d/m^2
Overall trial (7mths)	15/6/04 – 13/1/05	213	100.53	5.1	81.27	4.1
Initial trial evaluation (2.5mths)	15/6/04 – 31/8/04	77	29.69	4.2	29.65	4.2
Snow/winter season	15/6/04 – 10/10/04	117	51.71	4.8	51.42	4.7
6 months of data	15/6/04 – 15/12/04	183	95.88	5.7	77.15	4.5
Summer season	9/12/04 – 13/1/05	35	12.08	3.7	8.74	2.7

* Calculations based on roof area of 92.88m^2 (plan area)

Throughout the snow season, water collected in both collection systems includes rainwater precipitation supplemented by snow melt. Figure 8 presents rainfall and snow precipitation data on a daily basis, along with cumulative pump-out volumes from the ground and roof systems. A slight lag may be observed between ground and roof systems during mid to late August. It is expected that it would take longer for snow to melt and pass through the system than from direct rainfall. It is also possible that additional snow adjacent to the gravel trench (non-direct precipitation source) may also be directed towards the ground collection system and to provide an additional source of water.

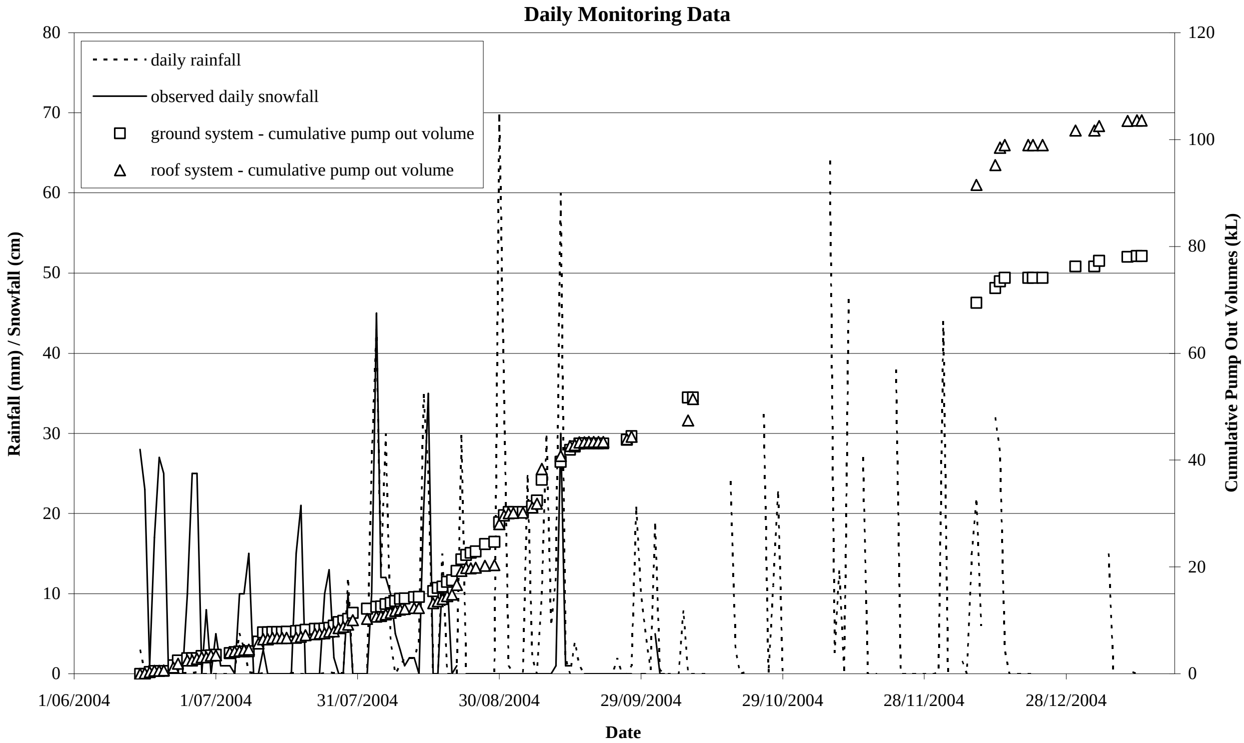

Figure 8. Daily Trial Observations showing precipitation and cumulative pump out volumes.

Metered readings taken between mid-June and mid-October increased at a relatively similar rate. A significant jump in ground system meter readings was observed between mid-October and mid-December, which appears to be a feature of increased spring rainfalls. Snow melt would not have contributed at this stage.

It appears that the performance of the systems varies between snow and rain precipitation conditions. At the end of August, there was significant rainfall for two days. During this time the ground and roof systems collected 5.004 kL and 9.332 kL respectively. The general trends indicate that the roof system is likely to collect more water during periods of heavy rainfall. The yields obtained during this rainfall need to be tempered by the fact that a rain tank with fixed volume and limited demand placed on it would overflow and thus limit the maximum yield form the tank in that period to the volume of the tank.

During July 2004, a period of significant snowfalls occurred with no rainfall (8/7/04 – 27/7/04) and so the water pumped through the systems consisted of melted snowfall only. During this time, the ground system collected 4.78kL and roof system collected 3.43kL. Over

19 days, this equates to 27.1 L/d and 19.5 L/d per $10m^2$ of roof which may be used as an alternative water supply for the ski lodge.

There is no standard roof area for buildings in Perisher Valley, but populated buildings such as ski lodges may have north facing roof areas of 100 m^2 (often more) and so the potential capture can be extrapolated to about 271 and 195 litres per lodge per day. This is equivalent to the water demand of approximately 2-3 people per day. One of the apparent limits to this study is the fact that pumped volumes were measured far more infrequently than would have been desirable. Figure 8 shows a fairly constant gradient for the cumulative volumes of captured and pumped water, therefore indicating a relatively constant rate of capture over the trial period. This means that this data is unlikely to suffer from large errors in estimating the potential yield from a tank.

Results from mid December to mid January show the ground and roof systems collecting 12.08kL and 8.74kL respectively over 35 days. For buildings with $100m^2$ of north facing roof, this equates to collection of 371L/day and 269L/day. Despite the fact that buildings are not populated significantly during summer, it is a time of modelled water supply failure. These amounts of harvested water would almost certainly drought-proof buildings during summer. Water collected is still considered significant despite rainfalls in 2004 tending to be less than the long term averages.

Water quality was also assessed as part of this trial. PAHs were not detected above laboratory detection limits throughout the trial period. Lead and zinc were detected at levels well below the Australian Drinking Water Quality guidelines of 0.01mg/L (health based criteria) and 3mg/L (note that the criteria for zinc is aesthetic/taste considerations) respectively. It may also be noted that zinc levels from the roof continually exceeded those from the ground system, probably due to zinc from the roof's galvanized sheeting. The ground collection system had higher bacterial levels as measured by Total Plate Counts, and this may be in part attributed to the fact that the trench is at ground level and therefore more accessible by humans and wildlife.

There are no guideline values for coliforms (excluding *Escherichia coli*) in the Australian Drinking Water Guidelines (ADWG) "due to the lack of direct health significance". The ADWG suggest that *E. coli* should not be detected in a minimum 100mL sample of drinking water. *E.Coli* was not detected in any of the samples and on this basis the water is compliant with the ADWG though a larger statistical sample would be required to exactly satisfy the requirements of the ADWG. Other bacteria were detected through various tests including plate counts.

Based on the data obtained to date, the water collected from both systems within the trial appear to be of suitable quality for potable purposes. However we do recommend that where the water is to be used for potable purposes that it is either treated in a hot water unit complying with the relevant guidelines and standards or passed through a disinfection process such as an ultraviolet (UV) process. The current centralised water supply serving Perisher Valley is disinfected by UV disinfection.

The water supply managers in Perisher Valley have shown concern about ground collection systems becoming contaminated. The results of this trial have shown ground collection to be more effective in collecting water with no increased risk (as determined by the current water quality results). The roof collection system has higher costs than ground collection systems and it is likely that many roofs would either need considerable structural alteration in order to retrofit a gutter, or are not suitable for retrofit. Ground collection may be hampered by the presence of rock outcrops in this resort area.

CONCLUSIONS

The results provide encouragement that roof water harvesting may be feasible in a cold climate. In the Perisher Range Resorts, it appears that roof and ground water collection systems would reduce mains water demand where they are plumbed into buildings. Obviously the amount of mains water demand reduction depends on the extent of uses to which harvested water is put. Results show that the water is of suitable quality for all non-potable uses. With *in-situ* hot water system treatment, or with simple ultraviolet treatment of potable cold water, the water would be suitable for all potable uses.

The implications of the trial results provide an alternative way to increase security of water supply in the resorts to enable proposed development to proceed, whilst also meeting environmental flow requirements below water supply weirs in the Perisher Range Resorts. This would constitute an excellent example of sustainable development.

For this to be realised, the trial needs to be continued through all seasons and over several years to see how the systems perform in a range of conditions. The next step in the trial is to plumb the harvested water into a building so that yield can be measured as opposed to collection.

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