Transmittal

April 12, 2011

To: Inyo County Building Department

From: Tim Rudolph PE

Project: Aspendell Mutual Water Company -Reservoir Roof Replacement
In December 2010 the roof over the reservoir that supplies water to part of the community of Aspendell collapsed. Since this is in the SAHO – the general plan requires a study and an Engineer to develop the required design loads for any structure in the SAHO.

Please review the attached report and conclusions. We would like to make sure the Special Avalanche Load meets your requirements prior to proceeding with plans and engineering for permit.

Thanks

PINYON ENGINEERING
115 EAGLE VISTA BISHOP, CA. 93514
949 98-8454
TimRudolph@cox.net

Aspendell Mutual Water Company
Rt 1 117 Columbine Drive
Bishop, CA 93514

April 12, 2011

Design Values for Avalanche Loading:
The Aspendell water tank is located in the Snow Avalanche Hazard Avalanche Overlay (SAHO) area. Per the Inyo County General Plan Section 9.4 Avalanches page 9-19 paragraph # 2. We propose the to use the following loads to design a replacement roof for the Aspendell Mutual Water Company Reservoir replacement roof.

The report by Snow Survey Associates points out the following

1. The depth of snow anticipated at the tank site due to a 100 year Avalanche event is 10-15 feet. This is in addition to the any existing snow on the ground.
2. Densities of avalanche debris snow for a wet snow avalanche had an average density of 35 pounds per cubic foot (pcf) with a range of 30 pcf to 40 pcf.

The Inyo County Building Department requires,

1. Design snow load for the Aspendell Area is given as a 100 psf roof snow load which corresponds to a 140 psf ground snow load.

The Report by Art Mears titled Inyo County Snow Avalanche Hazard Analysis pointed out the following.

1. The expected lateral force from an avalanche on a vertical surface normal to the flow direction from Figure 2-9 at the tank location exceeds 500 psf of kinetic snow energy. See #2 below

It is proposed that the snow load to meet the Avalanche Resistant Requirement of Inyo County be designed to the following:

1. For the depth of snow use the full 15 foot depth and use the average density of 35 pcf. Plus use the 140 pcf ground snow load. This results in a Avalanche Snow Load of 15ft x35pcf +140psf= **665 psf Avalanche ground snow load pressure** to the replacement roof.
2. The tank roof will be 1-2 feet above ground level and will have a separate protection structure to eliminate any horizontal kinetic energy loads from the design avalanche imposing loading to the new roof structure.

This Avalanche load will be in addition to the other code required loads and load combinations. Please review the attached report and above conclusions. We would like to make sure the Special Avalanche Load meets your requirements prior to proceeding with plans and engineering for permit.

Submitted by:

Tim Rudolph

Tim Rudolph, P.E. C63207 — Date: 4-12-2011

Inyo County Building Department Approval of the proposed design loads			
Signature	date	printed name	title

Estimation of avalanche snow depths and densities for the Aspendell water tank project

Sue Burak

04-Apr-11

Table of Contents

List of Figures

INTRODUCTION

Most avalanches that occur in the Jawbone Canyon area in the winter are small to medium sized and pose no threat to homes and facilities. However, during rare and unusually strong storms, widespread snow instability exists and exceptionally large destructive avalanches have released. These avalanches have entrained huge volumes of snow that flowed unexpectedly long distances across the alluvial fan above Aspendell (Mears 1989). In 1986, a home was destroyed by avalanche impact and crushing.

Figure 1. Knapp home after the February 1986 avalanche.

The design avalanche is defined by the area covered by the avalanche and destructive effects within that area. Planning and construction of fixed facilities and homes within avalanche runout zones are planned for the design period or avalanche return period, traditionally 100 years or longer (Mears 1987, 1989).

Large and destructive avalanches reached the Aspendell community in 1952, 1969 and 1986. Dry snow avalanche debris reached the vicinity of Alpine Drive and Highway 168 in February 1998 and January 2006. The January 2006 avalanche pushed over a dog fence at the east end of Alpine Drive but otherwise did not cause any damage to structures.

Mears identified the characteristics of the design avalanche that could reach Aspendell (Mears 1989). Dry flow avalanches may reach velocities of 95 mph. Powder snow air blasts that usually accompany large dry snow avalanches can blow out windows and doors and lift roofs off buildings. Design wet snow avalanches flow at slower velocities but can flow for long distances across low angle terrain because of reduced frictional resistance at the avalanche boundaries caused by the liquid water content of the snow (McClung and Schaerer, 2006). Large static loads often result because thick ridges of snow can produce crushing overburden pressures to structures. These slides can be destructive as thick ridges of snow subject structures to "crushing overburden pressure" (Mears 1989). An example of a large destructive wet snow avalanche is shown in figure 2.

Figure 2. Wet snow avalanche, Pine Creek Canyon, March 28, 2011.

BACKGROUND

The water tank is located within the historic avalanche boundaries identified and mapped by Art Mears for Inyo County (Mears 1989). Figure 2 displays the Jawbone

Canyon alluvial fan and the eastern portion of the community of Aspendell. The red line represents the historic avalanche runout limits of all avalanche observations and study of 1955 aerial photographs (figure 2-4 in Mears 1989). Scale is 3.2” = 610 ft. Figure 4 is a high-resolution aerial photograph of the alluvial fan including the water tank.

Figure 3. Google Earth image with historic avalanche runout drawn in red. The area around the intersection of Alpine Drive and highway 168 is blank because the historic boundary is uncertain. Adapted from Mears, 1989, figure 2-4.

The Red Zone is defined as an area of either high frequency and /or high-energy avalanches with a return period between 3 and 30 years (Mears 1989). Avalanches within the Red Zone produce dynamic pressures on a rigid surface normal to the flow of around 600 lbs/ft^2, though the actual pressures can be greater or less due to the structure’s shape and orientation.

Figure 4. Aerial photograph water tank with avalanche flow directions as red arrows. The water tank is the rectangular building to the right of the star. Historic avalanche runout boundaries taken from Mears, 1989, figure 2-4.

The home destroyed in the February 1986 avalanche was located 465 ft to the northeast and 465 feet below the current water tank location on the alluvial fan. The tank site is subject to both dry snow and wet snow avalanches and is the highest elevation structure (8514 feet) on the alluvial fan. The location of the water tank relative to structures on Alpine Drive results in more exposure to avalanche flow.

In order to provide design wet snow avalanche densities, avalanche debris from a large destructive wet snow avalanche in the Pine Creek watershed was measured on March 28, 2011. It is reasonable to assume wet snow avalanche deposit densities represent a reasonable range of values for engineering purposes (A. Mears, pers. comm, April 1, 2011).

The purpose of this report is to provide estimates of

1. Depth of snow deposition at the site after a 100-year event
2. Density of deposited snow in the resulting avalanche deposition.
3. Estimates of possible depth of ground surface scour.

Figure 5. Pine Creek wet snow avalanche. Channels and levees are visible in the upper portion of the avalanche debris. Thick ridges of snow and separate flow fingers form thick impressive deposits and tongue shaped frontal lobes. One lobe of the avalanche flowed for approximately 1000 ft along an 8-10 degree slope shown in figure 5. The avalanche flowed from the steep canyon onto a mostly bare alluvial fan. Gouging into the dirt was not observed but may become visible as the avalanche deposits melt.

LIMITATIONS OF STUDY

There is a wide variation in avalanche snow densities reported in the scientific literature. Deposit density of avalanche snow is assumed to be 250 $kg*m^{-3}$ for dry snow and 400 $kg*m^{-3}$ for wet snow (McCLung and Schaerer, 2006). The densities of avalanche debris of the Pine Creek avalanche ranged from 32.03 lb/ft^3 (513 kg/m^3) to 39.21 lb/ft^3 (628 kg/m^3) and represent densities from a maritime snowpack.

- The measured avalanche densities and depths are assumed to represent reasonable values of the design or 100 year wet snow avalanche in the Aspendell area.

- Overburden pressure calculations require the height of snow to determine static load. The depth of snow in avalanche debris is highly variable, ranging from a few inches at the outer boundaries to over 13 ft as measured in the Pine Creek avalanche debris.

- Estimates of avalanche deposit depths around the heavily damaged Knapp house in February 1986 were made adjacent to the Knapp house (figure 1). The avalanche debris ranged from eight to 10 feet on the uphill side of the house.

- Depth and density measurements made in Pine Creek were conducted in terrain somewhat similar to the Aspendell alluvial fan. While it would be ideal to measure design avalanche depths and densities from the Aspendell alluvial fan, it is reasonable to assume design avalanche snow densities are similar between the Pine Creek and Aspendell locations because both sites are somewhat similar in topographic characteristics.

- The Jawbone Canyon avalanche path has a starting zone area of ~ 30 acres with 10-20 feeder gullies that can contribute to avalanche flow. Total vertical drop is 11,000 to 8500 ft and the alluvial fan ranges from 8-12 degrees in slope steepness.

- The Pine Creek avalanche starting zone begins at 12,000 ft with an estimated starting zone area of 10 acres. Numerous steep feeder gullies with vertical drops of 1000 feet of more contributed to the avalanche flow of March 26-27 2011. The runout zone has less area compared to the Aspendell alluvial fan. Slope angle in the avalanche runout zone ranges from 13-18 degrees. It is reasonable to assume snow densities and snow depths obtained from the Pine Creek avalanche represent the range of conditions that would occur in a design wet snow avalanche in Aspendell (Mears, pers.comm, April 1, 2011).

RESULTS AND DISCUSSION

Based on density measurements of the Pine Creek avalanche, 15 years of personal observations, scientific study and consultation with Art Mears, it is reasonable to expect a range of densities of wet snow avalanche deposits from 31 to 40 lb/ ft^3 with an average density of approximately 35 lb/ft^3.

The 100-year return period for the design avalanche usually corresponds to the 100-year storm because large destructive avalanches result from rare and unusually large storms. The February 1986 storm and the resulting avalanches removed entire forests and destroyed homes on the west and east sides of the Sierra from south of Mt. Whitney to the Lake Tahoe area.

The average depth of avalanche deposits is difficult to determine because of extreme variability in deposit depths between the outer boundaries of the flow and within the levee/channel structure. The 100- year avalanche event will likely deposit 10 to 15 ft of debris at the tank site. This would be in addition to any snow that was on the ground at the time of the avalanche.

It is appropriate to use ground snow load values of 140 lb/ft^2. This is a conservative value that includes the pre- existing snowpack load. Avalanche events with a shorter return period (eg., 25, 50 or 75 year events) could also deposit similar amounts of snow at the tank site due to the fact that the water tank is located 450 feet or more upslope from the nearest structures. The exposed tank location makes it more likely to be reached by avalanches with shorter runout distances than the 100-year design avalanche.

Scour and Gouging

There is evidence of debris flow and wet snow avalanche gouging on the Aspendell alluvial fan. The main channel feature is located near the base of the mountain on the east side of the alluvial fan. During the February 1986 avalanche, the channel was filled with prior snowpack and avalanche debris and the avalanche flowed laterally onto the alluvial fan and moved the home shown in Figure 1 at least 200 feet to the northwest (Mears, 1989).

Figure 6. Photograph of Aspendell, fall 2002. Jim Archer photograph. A channel is seen extending from the left side of the top of the alluvial fan, along the base of the mountain in an east trending direction. A broad gully extends towards the water tank. Numerous runnel features are visible on the alluvial fan.

Figure 6.

Closer examination of a Google Earth image (figure 7) of the alluvial fan reveals details of the channels seen in Figure 6.

Figure 7. Google Earth image of alluvial fan. Scale 3.12” = 405 ft.

Three levee features are visible at the mouth of Jawbone Canyon. A northeast trending channel is visible along the base of the mountain that forms the left side of Jawbone Canyon. This channel diverts avalanche flow away from the community. The central levee feature forms the right boundary of a broad gully that could direct avalanche or mud/debris flow towards the tank site.

These features could be the result of wet snow avalanches or rock/mud debris flows resulting from snowmelt or torrential summer rainfall. As of the date of this report, further review of the alluvial fan features after the snow melts and the alluvial fan is bare, would help determine what measures will be needed to protect the tank.

In figures 8 and 9, historic aerial photographs at the same scale were compared between 1988 and 2004 to see if wet snow avalanche debris had enlarged the channel since 1988.

Figure 8. Google Earth image of Aspendell, 1988.

Figure 9. Google Earth image of Aspendell, 2004.

The area of riparian vegetation in the channel increased from 1988 to 2004. The grainy quality of the black and white images taken in 1988 and 1995 hinders detailed investigation of channel scour but the increased in riparian vegetation is evident. 2004.

While scour might occur in the water tank location, the presence of a pre existing channels would continue to both divert flow away from the tank and the community and possible direct flow towards the tank location.   Further scour and earth gouging would likely occur in the established channel during a design avalanche.

SUMMARY

Design wet snow avalanche deposits were measured from a large 100-year avalanche on March 28, 2011. Avalanche debris depths ranged from 2.6 to 13.1 feet. Avalanche debris densities ranged from 30.72 to 39.21 lb/ft^3.

There is a possibility a horizontal load could occur if the tank surface is not flush to the ground surface. If there is fill material around the site, it could be eroded by wet snow avalanche deposits.

ADDITIONAL CONSIDERATIONS

A long design period would ensure residents are assured of a reliable domestic water supply in the middle of winter.

Statement of Qualifications

Sue Burak is a hydrologist who specializes in avalanche forecasting and snow hydrology in the winter months. She will receive her M.Sc. in December 2011 in hydrogeology. Her research includes using isotope tracers in snowmelt to identify source regions of the Big Springs complex in Mono County.

Sue has worked as Inyo County's avalanche hazard forecaster since 1998 and has directed the backcountry Eastern Sierra Avalanche Center since 2006. Her on- going research on avalanche climatology of the Eastern Sierra, including the Aspendell area, has been published and another paper is in press with the California Geographical Society. Sue consults with Mono County and Mono County Search and Rescue.

Sue began her snow related work on a NASA climate change project in northern Manitoba, collecting snow samples during the arctic winter for CO_2 analysis.

LITERATURE

A.I. Mears. Snow-Avalanche Hazard Analysis for Land-Use Planning and Engineering. Colorado Geological Survey. Department of Natural Resources, Denver, C) 1992.

A.I. Mears. Snow-Avalanche Hazard Analysis, County of Inyo, California. 1989

A.I. Mears. Snow-Avalanche Hazard Analysis, County of Mono, California. 1987.

A.I. Mears.pers.comm. Phone call, April 1, 2011.

McClung, D. and P. Schaerer. The Avalanche Handbook, 3rd ed. 2006