THE FRANKLIN BASIN PROBLEM

[1]Randall P. Julander, G. Ray Wilson, Robert Nault

ABSTRACT

The Franklin Basin SNOTEL site displayed very curious and conflicting data during the winter of 96-97. Pillow data were far too high and various means and tests were undertaken to determine the cause and extent. The more data gathered, the more confusing reality seemed to become. The eventual conclusion was that a combination of snow creep and additional water from rain on snow events which formed an ice layer on the pillow resulted in the pillow overweigh.

INTRODUCTION

During the winter of 1996-1997, a data problem became evident at the Franklin Basin SNOTEL site. The pillow readings were higher than the precipitation catch (20 cm) and higher than a nearby site Tony Grove Lake which characteristically has much more snow than does Franklin Basin. Complicating matters, very warm storms and temperatures made snowpacks uncharacteristically dense for the time period and later, very cold temperatures induced plugging in the precipitation gage rendering it less effective for comparative purposes. Manual sampling revealed that the pillow was measuring far in excess of the snowpack around it but the manual manometer readings confirmed the weight on the pillow. Several tests were undertaken that showed the electronics were operating correctly and that the pillow was free to respond to weight increase and decrease. Soils around the pillow were not frozen, eliminating frost heave as the cause. Snow creep is not generally a problem at this site as the slope is not very steep (8 to 10%) and evidence of creep had not been historically observed on the pillow. There were obvious signs of creep this year manifested by bent trees, broken sensor markers and fence damage. There were several thick ice layers in the snowpack and evidence of water percolating through the snow and running horizontally across these layers was visible. When the manual samples reached the no snow mark, there was still considerable snowpack (13 cm of SWE) on the pillow as well as a thick layer of ice. At meltout, the pillow came back to the zero mark. So, what to do with the data for this season and how to prevent future situtations ?

SNOWPACK AND PRECIPITATION

Water Year 97 started off with essentially dry weather followed by a series of small rain events. In mid November, there were several storms that had both rain and snow. The rain component was 1.5 times the snow increment. At the beginning of December, snowpack began to increase faster than precipitation, typically on the order of 0.25 to 0.5 cm per storm event. There were 17 events in December where snowpack outpaced precipitation and only 6 events where precipitation was greater. In all, 8.1 cm more snowpack accumulated in December than registered as precipitation. No individual event appeared to be unusual. What does appear to be unusual is

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[1] Hydrologist, Hydrologist, Hydrologic Technician respectively, Snow Surveys, Natural Resources Conservation Service, USDA, Salt Lake City, Utah

that creep could be such a significant problem at this early stage of the season.

January on the other hand, had very unusual circumstances, 6.1 cm of precipitation (most likely rain) fell in the first several days with a net loss of 4.3 cm of snowpack. Average daily temperatures were 0 degrees to 2.2 degrees C. Over the next several days, average temperatures became extremely cold ranging from -15 to -7 degrees C. Snowpack consistently outpaced precipitation during this period. There is a significant potential that rainwater moving through the snowpack from the slope above accumulated on the level pillow area during this time frame and froze in place for the duration of the winter. Toward the end of the month, average temperatures plunged even further ranging from -26 to -12 degrees above zero. During this time, the precipitation gage became plugged with snow and the daily data are of little comparative value. Temperatures warmed to 0 degrees on the last few days of January and at least some portion of the accumulated snowpack fell in and mixed with the antifreeze solution. This occurred on February 1 with a resounding 9.6 cm of precipitation and no snowpack accumulation. The total difference between snowpack and precipitation accumulation during January was 23.6 cm. It is impossible to tell how much precipitation was suspended, frozen in the gage but at least 9.6 cm should be subtracted from the 23.6 giving a net 14.0 cm more snow than precipitation.

February continued the snowpack over precipitation accumulation with a difference of 9.9 cm. Out of 22 accumulation events, 21 had more snow than precipitation, typically only a very small amount, 0.25 to 0.8 cm, but enough to make almost 10.2 cm of total difference during the month. the accumulated total of snowpack greater than precipitation now becomes 32 cm.

March turned off dry and warm with average temperatures ranging from -11 to 6 degrees. Precipitation outpaced snowpack by a total of 3.6 cm, 10.9 to 7.4 cm respectively. During this period of warm temperatures, the pillow data reflected the loss of 6.9 cm of weight and a gain of 14.2 cm for the net of 7.4 cm of increase. This probably is indicative of snowpack settling, with a possible redistribution of weight and force exerted on the pillow from snow creep or ice layers. The great majority of this snowpack "loss" came on extremely warm days, and on days with no precipitation. The pack was not isothermal and sustained melt did not occur until late April.

In the month of April, snowpack outpaced precipitation by 4.8 cm. Average temperatures during the first half of April were cool, ranging from -12 to -4 degrees, and during the second half they were warm, from -4 to 7 degrees. The snowpack went isothermal toward the end of April and began steady melt near the first of May. In total from December through April, the snowpack had increased 33.3 cm more than precipitation.

MANUAL MEASUREMENTS

Through routine data quality control procedures, Snow Survey Staff ascertained the potential error early in the season. March 1 manual measurements around the pillow were 29.5 cm less than the pillow reading, fairly close to the 32 inch precipitation to pillow deficit. The manometer reading however, confirmed that there was actually that amount of weight physically on the pillow. The precipitation gage at this point was still very suspect due to the freezing temperatures and the record amount of snowpack that had fallen in the season. The next manual measurement was completed on the May 1 Snow Survey. This revealed that the difference between the pillow reading and the manual measurement had widened considerably to 51.6 cm. The manometer again confirmed the pillow reading, all the electronics were in order. The manual measurement revealed an increase of only 2.3 cm over the past two months, totally unrealistic given surrounding conditions. The pillow had registered 25.4 cm of increase, the precipitation gage had increased 26.7 cm. Another snow course, 122 m lower in elevation increased 8.1 cm and Tony Grove pillow and precipitation increased 16.3 and 17.8 cm respectively.

Three days later, a party met onsite to remeasure and try to ascertain the problem. Manual measurements were 102.9 cm whereas the pillow was close to 152.4 cm. There were 24.1 cm of new snow at the site and the new reading was 3.8 cm greater than the manual measurement of three days previous, a greater increase than the past 2 months. The depth at this time was about 254 cm which given 101.6 cm of Snow Water Equivalent would be 40% density, a little high for the time of year but well within reason given the unusual circumstances of rain and temperature experienced throughout the year.

Several tests were undertaken to see if the problem could be determined. In order to see if the sensor was free to move both up and down, two snowmobiles were driven onto the pillow area, a combined weight of near 681 kg. The pillow manometer immediately registered an increase of 5.0 cm. The snowmobiles were then driven off to see if the manometer would decrease back to its original location which it immediately did. The sensor was free to respond in both directions. This was repeated several times and the results consistent for each replication. Interestingly enough, a weight of 681 kg (combined weight of snowmobiles and riders), located directly on the pillow without any other influences, should have moved the pillow manometer up 12.2 cm, more than double the actual increase. Thus one can speculate that weight was not only being transfered to the pillow but from the pillow area outward as well. The soil was sampled to a depth of 15.2 cm and determined that it was not frozen. During the manual measurements, several substantial ice layers were found on the southeast corner of the pillow and the bottom 76 cm of the snowpack were extremely hard in this area.

SNOW CREEP

There were unmistakable signs of snow creep at this site, including trees bent in the downhill direction, marker poles bent and broken and fence damage. The slope of this site is about 9%, within the range specified by Cox et al for pillow installation. While the slope of this site is near the upper limit of 10% cited, it is very typical of many sites throughout the NRCS SNOTEL system. Many factors may have contributed to the observed creep phenomenon. The rare climatic conditions, specifically warm temperatures and the rain on snow events followed by severe cold. These in turn led to unusually dense snowpacks with various layers and ice lenses. Also at this site, the fairly long uphill reach is devoid of trees for approximately 21 m, leaving a smooth, bare slope with no anchors to retard snow movement. Given that snow creep is the problem, one would expect that as the pack ripens and layers become discontinuous, the horizontal force exerted by creep would eventually break down to only vertical gravitational force directly to the ground surface below it. This in reality, never occurred as the pillow continued to sense greater weight than the manual measurements around it clear to the meltout point.

THE FRANKLIN BASIN DATA SOLUTION

At this point, it is clear that there was a tremendous impact from snow creep on the pillows and that there was a compounding affect of the ice layer which was not reflected in the ground truth samples. The amount of the error due to creep and that due to the ice layer is impossible to accurately quantify, however the amount due to the ice layer could be as much as 12.7 to 17.8 cm, 25% or more of the total error. Given the fact that the affect of the ice layer and the snow creep could not be quantitatively accounted, more traditional data estimation techniques were employed. Historical ground truth data were correlated to the corresponding telemetered readings (Rsqr=0.97, Std Err=1.53) and this relationship used to calculate 7 adjusted pillow values based on the ground truth values taken during the season. These adjusted values were then correlated to the observed pillow values (Rsqr=0.94, Std Err=2.99) and that relationship used to adjust the record from mid December through the meltout date. This puts the estimated pillow data about 2.5 to 5.0 cm higher than the corresponding ground truth samples and at the peak, about 50 cm less than the observed pillow reading.

THE FRANKLIN BASIN SITE SOLUTION

Several site modifications were performed to prevent or mitigate future creep at this site. The most substantial modification was to alter the slope profile in 2 critical locations. First, the pillow area was enlarged on the upslope side, providing a greater area for compression away from the pillow. The excavated soil was placed in a berm outside of the fence area, again on the uphill side. This berm will place a solid compression wall on the uphill slope which should provide a natural break point for any contiguous snowpack movement. Any pressure downhill from this should be dissipated in the wider area of the pillow pad, prior to the pillow. Approximately 9 m upslope from a newly installed extra heavy duty steel fence a 0.6 m foot wide, 0.3 m deep trench was excavated. The excavated soil and rock was placed in a berm on the downhill side of the trench, making a substantial wall above the pillow. This trench will divert all meltwater around the site, act as a compression wall and serve as an anchor on the bare slope above the pillow.

REFERENCES

Cox, L.M., L.D. Bartee, A. G. Crook, P.E. Farnes, and L.L. Smith. "The Care and Feeding of Snow Pillows." Report of the study team to Soil Conservation Service, USDA, Western Snow Conference, April 1982.