Colorado Snow Dust Alert #1, March 24, 2008

Spring and Easter Greetings to you all from Silverton and the Dust-In-Snow team. Here is our first dust-in-snow report of the season.

Some of us, and perhaps many of you, were hoping for a 'clean' spring season, without any dust deposition events in the Colorado snowpack at all, as a kind of 'control' year. Those hopes were erased, at least down here in the western San Juan Mountains, on Sunday, March 16th, by our first, 'dry' (without snowfall), characteristically pink, but rather low intensity dust event of the 2007/2008 snow season. We have no reports, so far, of the 3/16/08 (D1 – 2007/2008) event extending to the northeast, beyond the San Juans – the spatial extent of the D1 event is still to be determined. We have also observed that D1 was considerably less intense (virtually indiscernible in a snowpit) even just a few miles to the north of Silverton, at Red Mountain Pass, than it was just south of Silverton, at the same elevation on Molas Pass, and we have no reports of dust-in-snow observed from the Telluride area, just a few miles farther west. (Our active dust collector, a continuously running air sampler at Molas Pass, did capture this event on its filter.) Thus, D1 appears, as of this writing, to have been a comparatively small-scale event. Nonetheless, D1, carried by very strong SSW'ly winds over 24 hours, may signal that Colorado Plateau soils have begun to dry, making additional material available for mobilization, and that additional and more extensive dust events are possible.

As most of you are well aware, our snowpack in the San Juan Mountains watersheds remains well above average (per Snotel data) at 124% of the 30-year annual SWE peak in the San Juan/Animas basin, 132% in the Upper Rio Grande, and 124% in the Gunnison Basin (which includes many Snotel sites in the northern San Juans). In addition to ample alpine snowpacks, the San Juan Mountains (and Gunnison Basin) have developed considerable snow coverage at lower elevations. It is likely, then, that lower elevation snowpacks on the south side of the western San Juans, in particular, will see accelerated snowmelt in the near term driven by the combined affects of warming temperatures and the reduced snowpack albedo caused by this D1 dust event. Thus far, however, our stream gauge at 11,000', at the pour-point of Senator Beck Basin, is recording only very low winter 'base flow' discharge (0.07 cfs), and showing no diurnal fluctuation or upward trend. At the higher elevations of Senator Beck Basin, small snowfalls subsequent to D1 thinly covered the very lightly contaminated layer of snow that D1 fell upon, and albedo values has not been significantly reduced in the alpine snowpack since the deposition.

Senator Beck Basin SWE continues to accumulate, as of this writing, and snowmelt ablation has not yet begun except on the most southerly, lowest elevation slopes. Typically, significant SWE decline begins in early-mid April at our lower elevation study plot, but April precipitation can extend the SWE peak into late April or early May. Snowpack 'cold content' has begun to decrease, as is typical in March, with longer days of solar heating, but our alpine and subalpine sites are still some distance from becoming isothermal (or 'ripe', at 0.0° C). If dry and sunny weather persists for the remainder of March, any D1 dust present in the alpine snowpack is likely to emerge on the solar aspects and may result in some melt at the snowpack surface, infiltration of free water into the snowpack, and accelerated reduction in snowpack cold content. We have begun our weekly snowpack profile monitoring at the alpine and subalpine sites (our most recent subalpine snowpit was 2.3 meters, or 90" deep) and we will report the peak of SWE at those sites, the subsequent decline in SWE, and the discharge at our stream gauge throughout the spring. Future alerts will present graphic depictions of those and other data.

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Colorado Snow Dust Alert #2, April 3, 2008

March 2008 was something of a disappointment, snow-wise, and added insult to injury since our prior Alert with two more dust events, D2 and D3, since the first deposition, D1, on March 16th, described in Alert #1. Strong winds on March 26th and 27th delivered another relatively minor 'dry' deposition, D2, without significant associated precipitation. That D2 dust landed on top of the recently exposed D1 layer here in the San Juans, merging those two events into a single D2/D1 layer. However, we were able to capture D1 and D2 as distinct events in an air sampler operated by the CSAS at Molas Pass for graduate student Corey Lawrence at the University of Colorado. That sampler runs continuously and draws ~30 cubic feet of air per minute through a high-tech paper filter, resulting in 'visual' evidence of contaminants in the air. Both D1 and D2 had the characteristic 'pink' color of events originating in the Colorado Plateau.

As many of you and I (driving to/from Fort Collins to Hydrology Days) observed (myself in the Gunnison Basin and South Park vicinity), D1/D2 emerged over extensive areas during the last week of March under sunny skies and warm weather. Snowmelt was quite evident along the Hwy 285 corridor of the Gunnison Basin last week, and standing water/slush ponds appeared in the river bottoms, as well as a few small 'wet-loose', point-release avalanches scouring the 'ripe' (isothermal) snowpack to the ground on nearby slopes. Stream flow also made the first step upward from over-winter base flow levels in our Senator Beck Basin, but remained at or below 0.5 cfs, still quite low. We have reports that this D1/D2 layer was observed at the snowpack surface at least as far north as the Elk Mountains during the last week of March.

The most significant dust deposition of March, D3, arrived 'wet' during the evening and night of March 30 and into the morning of March 31 with the only 'storm' (defined as ½" of SWE or more) in our area during March 2008. That storm totaled 1" of SWE, as some 10-12" of new snow, and the dust was concentrated in the bottom of that new snow layer. That D3 dust layer was only slightly separated from the merged D1/D2 events by a thin layer of clean snow that fell during the early morning of March 29. D3 was a more substantial dust event than D1 or D2, also with the Colorado Plateau red/pink tint. In the absence of additional new snow, we would expect the D3 dust layer to absorb incoming solar energy even underneath the 12" of new snow it arrived with, and cause rapid settlement and melting of that overlying snow. In areas where the new snow above D3 was thinner, that process may be very rapid; here in Silverton, where the dust was covered by 5-6" of clean snow, it took only one full day of sun to reveal D3 over large areas. D3 will quickly settle down to and merge with the D1/D2 layers.

Snowpacks at sub-alpine and alpine elevations still contain 'cold content' but are trending, as is typical, toward becoming isothermal (ripe) at 0° C throughout. (Lowest elevation snowpacks are already isothermal, or very nearly so). As the D3/D2/D1 (merged) layer emerges at higher elevations, snowmelt will occur in the near-surface of the snowpack and free water will percolate into the snowpack as "wetting fronts". Those wetting fronts carry significant energy into the deeper layers of the snowpack and, at this time of the season, generally lose that energy into the 'cold' snow and refreeze, often as very distinct and continuous layers of clear, or sometimes 'dirty', ice. In this way, dust-induced snowmelt at the snowpack surface at this early stage in the snowmelt season, with the percolation of free water into the snowpack, can 'force' ripening of the snowpack at a quicker rate than would occur in the absence of dust (and reduced snow albedo). Periods of high pressure alternating with weak disturbances over the coming weekend and early week-next may result in sufficient sunshine to reveal the D3/D2/D1 layer extensively over low and high elevation terrain.

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Colorado Snow Dust Alert #3, April 20, 2008

A major, state-wide dust-on-snow event on April 15, extending into the 16th, leads the news.

During the week of April 14-18 the dust-in-snow team conducted a wide-ranging tour of the State, beginning at Senator Beck Basin on the 14th and then traveling over the next several days to seven additional sites at or near Snotel installations to the east and north. We began our tour on the 15th, at the **Park Cone** Snotel near Taylor Reservoir in the Gunnison Basin, and then drove east to Fairplay, just ahead of the dramatic, approaching dust storm (event D4 in the San Juans). That dust event continued into and through the night of the 15th, generally without precipitation, and conditions remained quite hazy and windy into the morning of Wednesday, the 16th, in South Park. That morning we continued our tour of Snotel sites going first to the **Hoosier Pass** site, then the Loveland Pass (**Grizzly Peak** Snotel) site, and we found the fresh dust present at the snowpack surface at both sites (and observed that dust being stirred up on the Arapahoe Basin ski runs leaving dirty piles next to white tracks). Fresh snow began falling that afternoon as we sampled the Loveland Pass snowpack and eventually totaled several inches by the following morning in some areas. Our Snotel tour continued at **Berthod Pass** the morning of Thursday, the 17th, then proceeded to the **Willow Creek Pass** Snotel, and finished the day at the **Rabbit Ears** (west summit) Snotel. We found the fresh April 15th dust present at all those sites as well, under a few inches of fresh snow at Berthod, but at/near the surface farther to the north, where less fresh snow fell. Finally, on Friday, the 18th, the **McClure Pass** Snotel site was checked, and the fresh April 15 dust was also exposed at the snow surface there. In addition to the April 15 dust layer (except at Park Cone, where we preceded that event), we also found additional dust layers deeper in the snowpack at every Snotel site we visited, and the depths of those buried dust layers correspond well to the events D1 (March 16) and D3 (March 30) in our Senator Beck Study Area in the San Juans. Returning to Silverton, the fresh dust was widely exposed at the lowest snow covered elevations, and sampling at our Swamp Angel Study Plot (11,050') on Saturday, the 19th, revealed D4 dust exposed at the surface.

Thus, our trip confirmed that the dust event of April 15 affected the majority of the State's mountain ranges, and that other dust events appear to have been equally extensive. We did not visit the Sangre de Cristo Range, but we do assume that the entire San Juan Mountains range was affected based on the magnitude of the D4 layer seen at Senator Beck Basin and in our active air sampler, very near the **Molas Pass** Snotel.

As of today, Sunday, April 20th, aside from a slight chance of snow showers later in the week in the Northern Mountains, the National Weather Service Grand Junction office expects generally dry, windy, and sunny weather in Western Colorado through Sunday, the 27th. At higher alpine elevations, enhanced surface snowmelt resulting from the exposed April 15 (D4) dust layer will infiltrate the snowpack and further reduce the 'cold content' of the snowcover, accelerating the trend toward snowpack ripening (to isothermal at 0° C). (We are currently seeing a second, albeit still quite small, streamflow pulse at Senator Beck Basin driven by runoff from the sub-alpine, tree-covered elevations.) The lowest elevation snowpacks, such as persist in the upper Yampa, Blue, Colorado, and Gunnison River valley floors, have already become isothermal and begun melting. Wherever the snowpack was already isothermal, *all* of the additional energy being absorbed by the April 15 dust layer (and preceding dust layers that may have already emerged at the surface and merged with D4) is available to accelerate snowmelt rates. Finally, given recent reports of very dry soils in the Colorado Plateau, this coming week's sustained winds may also result in additional dust deposition events.

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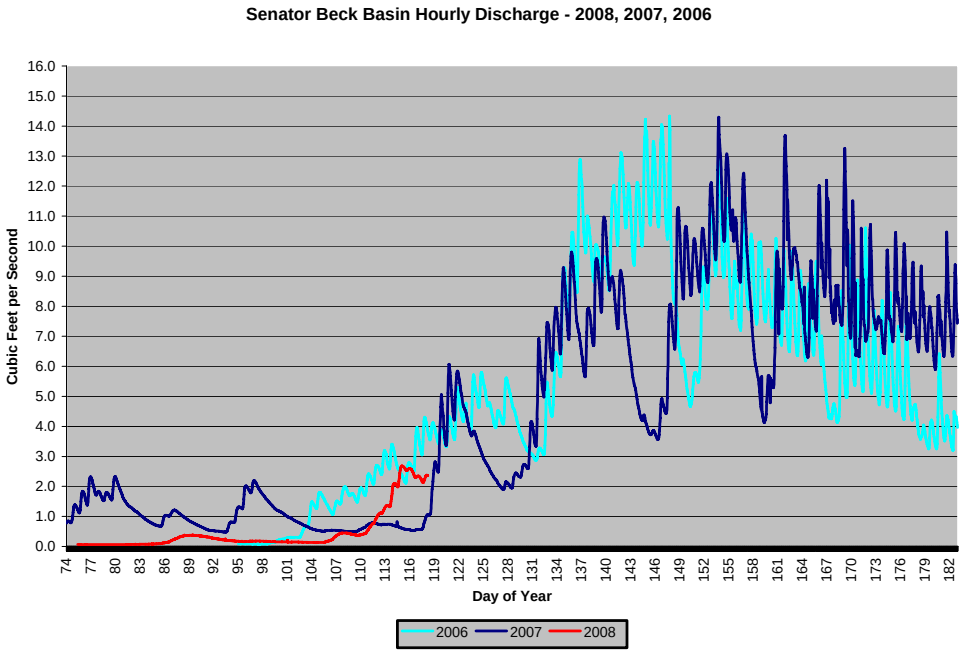
Colorado Dust-in-Snow Alert #4, April 27, 2008

Following a very windy, hazy and dusty, sunny, yet trending-cooler week since our last Alert, the coming final days of April and early days of May are likely to offer more sun, more wind, and trending-warmer weather until mid-week, followed by some cooler days and potential snow for the Central and Northern mountains. Pre-frontal SW'ly winds on Wednesday may also be sufficiently strong and 'focused' to deliver additional dust either with (esp. Northern) or without (esp. Southern mountains) new snow, according to current models.

Strong SW'ly winds early last week resulted in a long duration, widespread, but comparatively low intensity 'haze' and dust event in Western Colorado, which we've labeled D5 in our chronology for the San Juans. This D5 event was most intense on Monday, April 21st here in Silverton, but may have peaked at different times at different locations. Any aerosols that did reach the ground early last week generally landed on the D4 (April 15) dust layer exposed at the snowpack surface throughout the mountains. Subsequent NW'ly winds at the end of the week and over the weekend delivered cool air, light precipitation to some of the Northern and Central mountains, but probably not much new dust. What little new snow did accumulate in some areas was or will be quickly melted, revealing the merged D4/D5 surface again.

All but one of the Snotel sites visited in mid-April, and described in our previous Alert #3, saw a net decline in SWE last week, whether the site received precipitation or not (only Willow Creek Pass showed a net gain of 0.4" SWE, from new snow). Grizzly Peak Snotel, at Loveland Pass, lost the most, at -1.4" SWE. Here in our Senator Beck Basin Study Area we also observed an ~1" decline in SWE at our Swamp Angel Study Plot, at 11,050', and the snowpack there became isothermal at 0° C mid-week. The 2.24 m (88") snowpack there contained 950 mm (37.4") of SWE on Tuesday, April 22, with the D4/D5 layer at the surface. Our Senator Beck Basin stream gauge also measured our first significant pulse of runoff last week, rising from 24-hour average flows of 0.1 cfs to 2.6 cfs, then declining to 2.2 cfs over the past weekend under much cooler air temperatures. Our snowpack at the upper Senator Beck Study Plot, 12,200', remains cold at aprox. -2° C and 'dry', except at/near the surface, where the D4/D5 layer thawed during daylight hours.



Considerable snowpack remains across the elevation range of our Senator Beck Basin Study Area (11,000' – 13,510') here in the San Juans, and ablation rates at those elevations here last week were not particularly high. However, Silvertonians were pleasantly surprised at the rapid ablation of the snowpack last week around our once snowbound town, at 9,300'. As a consequence, the threat of simultaneous surges of snowmelt from both high and low elevation snowpacks *may* be decreasing in the western San Juan Mountains, and perhaps in other ranges elsewhere in the state, *but flood forecasters will need to assess the residual low elevation snowmelt potential in their areas.*

Given the extent of the ubiquitous D4 layer and its position at/near the snowpack surface throughout the Colorado Mountains, and the several days or more of sunny skies ahead, and with somewhat warmer temperatures early in the week, snowmelt is certain to continue and likely to accelerate, especially in the lower elevation snowpacks where either no new snow or only light accumulations of new snow occur later in the week. Any additional dust deposited this week as a 'dry' event, without associated precipitation, will merge with and further reduce the albedo of the snow surface, further enhancing the absorption of solar energy. New dust that arrives with small amounts (<6") of new snow, as a 'wet' deposition event, will enhance the melt of that new snow on sunny aspects and quickly merge with the underlying D4/D5 layer.

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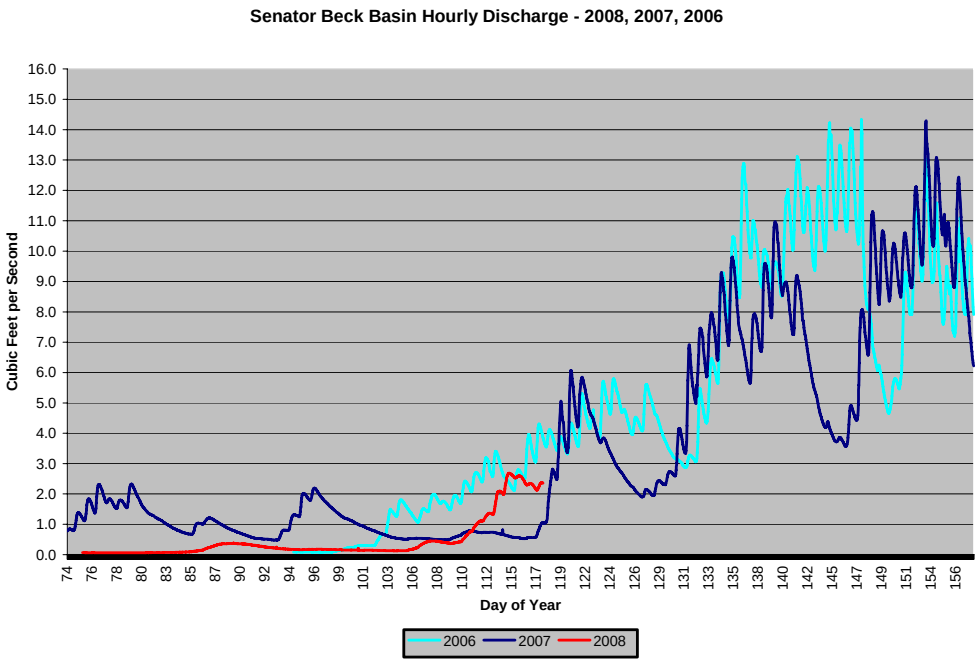
Colorado Dust-in-Snow Alert #5, May 7, 2008

As anticipated by NWS – Grand Jct., strong pre-frontal SW'ly winds on the afternoon of April 30 (DOY 121) were sufficient to generate a strong dust event here in Southwest Colorado (D6), deposited directly onto the merged D5/D4 dust already at the snowpack surface. That dust event (which happened to be mixed with very heavy smoke from a nearby controlled burn here in Silverton) was followed by fresh snow totaling 8" at our Swamp Angel Study Plot by Tuesday morning (our Storm #24). Storm winds left exposed ridges and other terrain stripped of new snow, revealing the very dirty merged D6/D5/D4 surface. Elsewhere in the state, we do know that the same storm did deliver similar or larger amounts of fresh snow to most of the Snotel sites where we sampled for dust in mid-April but we have not received confirmation that the snow was preceded by, or included, the D6 dust that we observed here in the San Juans. Nonetheless, all of those sites showed a net loss of SWE between April 27 and today, and some sites here in the San Juans (not visited during April) showed substantial losses, with the Beartown Snotel in the upper Rio Grande drainage losing 5.1" of SWE during that period, undoubtedly exacerbated by D6 (and perhaps the smoke and ash observed in Silverton). Sites in the Northern and Central Mountains showed less SWE loss than the Southern Mountains.

Here in our Senator Beck Basin Study Area, our most recent snowpits and observations (as of yesterday) show that our subalpine snowpack remains isothermal and is melting, that our alpine study plot (12,200') snowpack remains nominally 'cool' at -1 to -2 C (on level terrain) except on S'ly aspects where it has recently become isothermal, and the merged D6/5/4 layer is either fully exposed below treeline, on all aspects) or, in the alpine terrain, is partially exposed but rapidly emerging where thinly covered by traces of the Storm #24 clean snow. Our profile at the subalpine Swamp Angel Study Plot (SASP, 11,050') yesterday (May 6) found 894 mm of SWE, down ~8% from the season high of 977 mm on April 14. Streamflow from Senator Beck Basin showed a short decline during and following Storm #24, which momentarily restored a high albedo throughout the Basin, but has begun to rebound as the D6/5/4 layer becomes more widely exposed.



With only light snow and/or rain expected through the end of this week here in the Southwestern Mountains, we anticipate that snowmelt rates will sustain current levels and then accelerate over the weekend into early next week. Similarly light precipitation, as either snow or rain, is expected in the Central and Northern Mountains during the remainder of this week, with periods of sun over the weekend and into early next week. Therefore, no major new snowfall is currently expected until at least Tuesday, May 13th, and areas where D6/5/4 is at or near the snowpack surface will continue to see a generally reduced albedo and consequent increased absorption of the solar energy available.

Our team will revisit the Snotel sites at Park Cone, Hoosier Pass, Loveland Pass (Grizzly Peak), Berthoud Pass, Willow Creek Pass, Rabbit Ears Pass, and McClure Pass next week to ascertain the extent and position within the snowpack of the D6/5/4 layer(s), as well as the depth of the underlying layers previously observed in mid-April.

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Colorado Dust-in-Snow Alert #6, May 16, 2008

This past Tues/Weds/Thurs the dust team revisited the Park Cone, Hoosier Pass, Grizzly Peak (Loveland Pass), Berthoud Pass, Willow Creek Pass, Rabbit Ears Pass, and McClure Pass Snotel sites first observed in mid-April. Four salient observations were made: 1) considerable lower elevation areas that were snow-covered in mid-April are now snow free (as you'd expect), 2) recent clean new snow has restored a high albedo to virtually all of the mountain elevations where snowpack was still present, 3) a significant amount of dust is concentrated in the old 'corn snow' surface underlying that new snow at all the sites we visited, and 4) the snowpack was isothermal ('ripe', at 0° C and moist or wet throughout) at every Snotel site we visited, except for the new snow at Hoosier Pass. The amount of clean new snow observed ranged in depth from 9" at Hoosier Pass on Wednesday morning to only a trace left by Thursday afternoon at McClure Pass; water content of that new snow ranged at all sites except McClure Pass from 0.4-0.5" to 1.2". The new snow also covered the San Juan Mountains and our Senator Beck Basin Study Area but was preceded by a new dust deposition (D7) on pre-frontal SW'ly winds during the evening of Monday, May 12. That dust has merged with the existing merged D6/5/4 layer just below the (now clean) snowpack surface. D7 may have extended further to the north and east but we were unable to discern a distinct D7 layer at the various Snotel sites we visited this week, with the possible exception of the Rabbit Ears Pass site. All Snotel sites presented a single 'merged' layer of dust underneath the new snow.

Given the current NWS outlook for generally dry, sunny, and warming weather through the weekend and into early next week, it is quite likely that rapid settlement and melt will reduce the overlying layer of clean new snow and expose the very dirty underlying snow. (Incoming short-wave radiation will penetrate through clean snow and be absorbed by dust layers as much as 12" below the snowpack surface, dramatically accelerating the settling and melting of new snow layers above a dust layer.)

Streamflow in our Senator Beck Basin Study Area leveled during the stormy weather since our last Alert on May 7, as seen in the chart below. This was not the case throughout the state, however, as some areas received rain-on-snow with warm temperatures and saw rising streamflows, even local flooding, as in the Yampa basin. We observed bank-full and quite turbid flows in Willow Creek, south of Willow Pass, during cloudy and stormy weather on Wednesday, as well. Areas which had elevated flows during the past week may now be particularly prone to problematic streamflows as the buried dust layer that we observed at all sites this week re-emerges at the snowpack surface, significantly enhancing and accelerating snowmelt rates already being driven by warming temperatures during coming days.

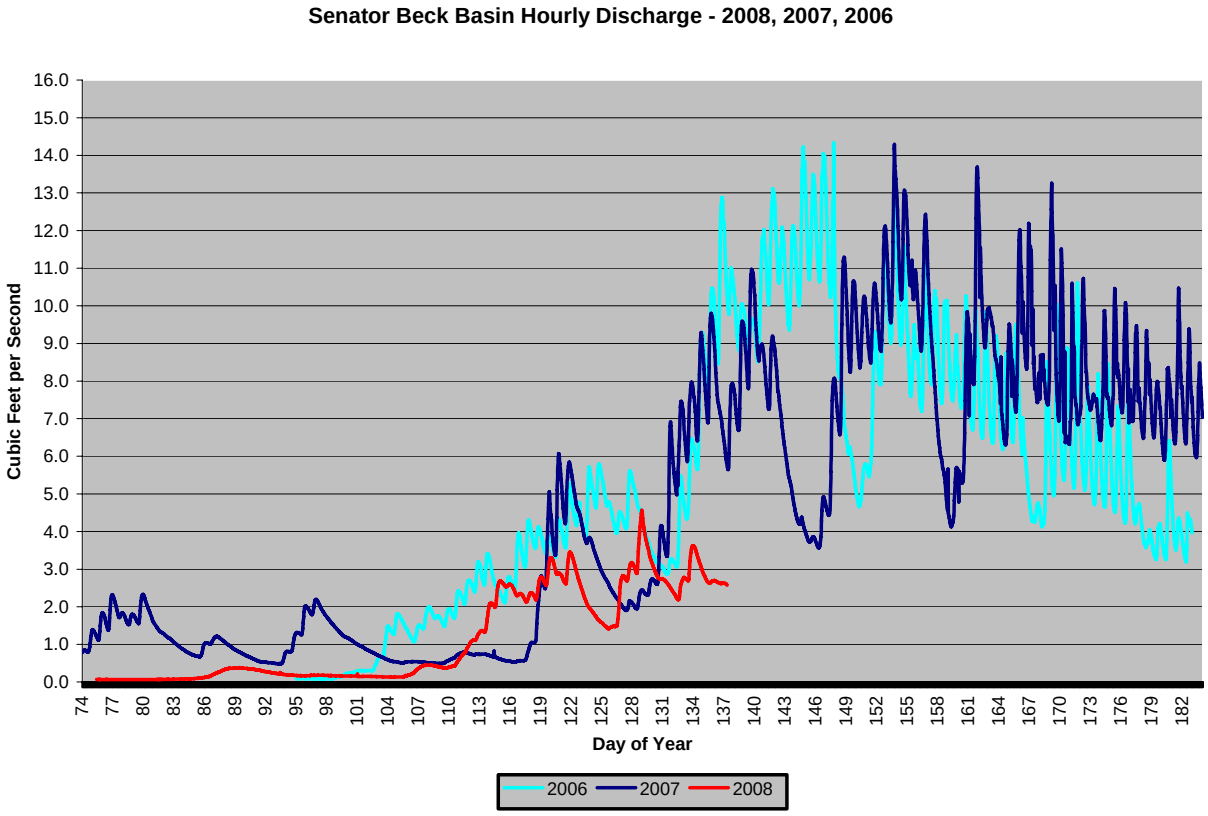
In many areas, however, snowmelt has been delayed by a combination of cooler weather, restoration of high snowpack albedo by new snow, and even the addition of as much as 2-3" of SWE by storms since May 5 (a total of 2.64" at 11,050' in Senator Beck Basin), counterbalancing some preceding melt. These areas are also susceptible to rapidly accelerating snowmelt during coming days as the substantial, merged dust layer becomes re-exposed. Currently the Gunnison, Upper Colorado, South Platte, and Laramie and North Platte basins all still contain 92-103% of their average seasonal peak SWE and 128-156% of today's average SWE, and the Yampa/White and Arkansas basins retain 84-85% of their peak SWE and 124-144% of today's average SWE. A period of prolonged clear and warm weather will enable enhanced direct absorption of radiation by the dust-contaminated snow that will match and exceed the amount of energy contributing to snowmelt by warm air temperatures alone. The duration of the expected high pressure system building this weekend will be of particular concern in those areas. By way of a rough proxy for this scenario, compare the change in rates in 2006 streamflow at Senator Beck Basin from days-of-year 103 to 124 to the period after day-of-year 132, when a prolonged period of sunny and dry weather with significant dust exposed at the snow

surface, produced the very intense snowmelt rates observed after day-of-year 132 in Senator Beck Basin and

statewide.

Farther south, in the San Juan Mountains basins, Snotel reports that snowcover has declined to 64-67% of average peak SWE, at 106-108% of today's average SWE, although some stations are not generating valid data. As the buried D7/6/5/4 merged dust surface re-emerges, we could see rapid acceleration in discharge occur early next week in these areas as well, particularly from portions of those basins which remain at 100%+ of average seasonal peak SWE. The 'latency' of Senator Beck Basin snowmelt, with ~900 mm (~35") of SWE still on the ground today at 11,050' (Swamp Angel Study Plot), stands in sharp contrast to the 550 mm SWE at that site on May 16, 2007, and the 411 mm at Swamp Angel Study Plot on May 17, 2006.

NWS – Grand Jct. does see a cooling trend in their models for the latter half of next week, as a new trough of unsettled weather develops over the West. If that period delivers *both* cooler air *and* snow precipitation (restoring a high albedo), an early week surge in snowmelt could be curtailed and then decline (as is seen clearly in the on/off pattern of 2007 discharge). However, if cooler weather later next week remains dry and clear, without significant cloud cover or new snow, enhanced absorption of energy by the still-exposed merged dust layer at the snowpack surface could sustain the discharge rates observed early next week.



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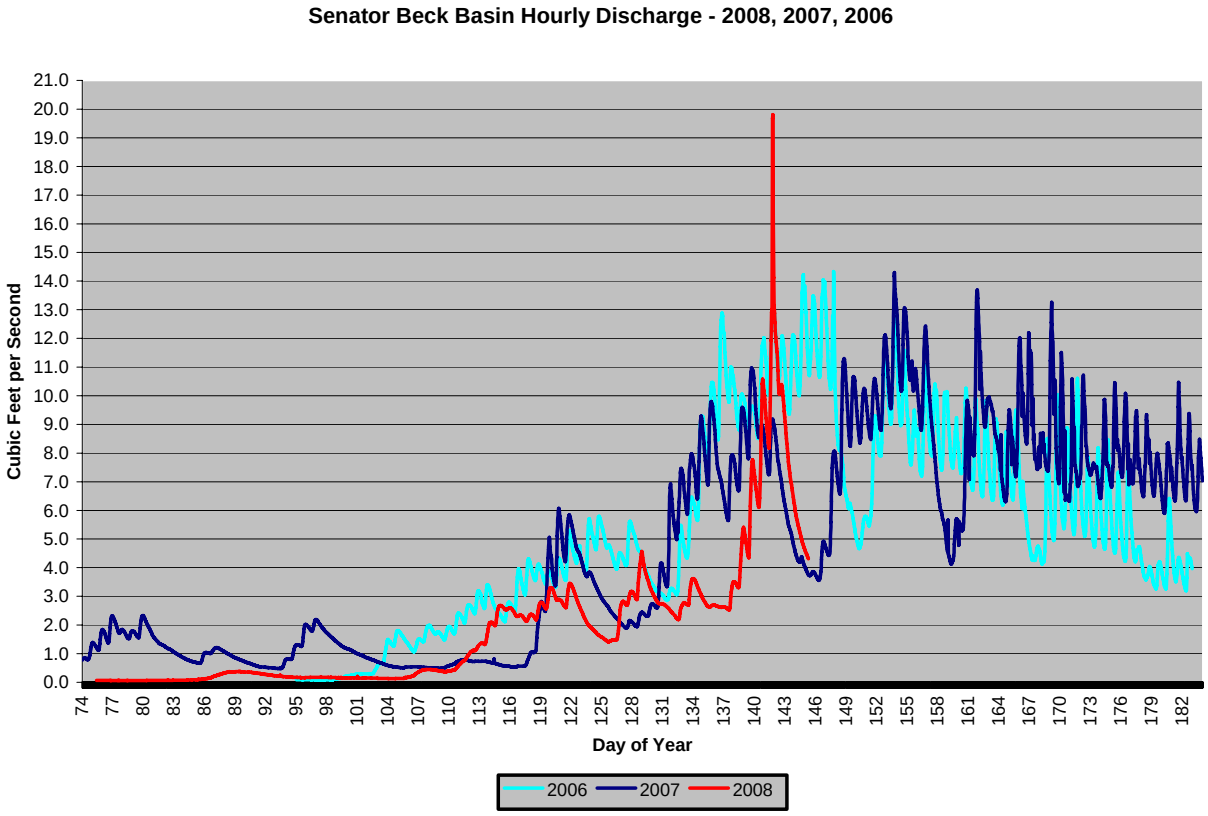
Colorado Dust-in-Snow Alert #7, May 24, 2008

Snowmelt accelerated dramatically in the days following our May 16, 2008 Alert due to the combined effects of a very warm air mass, sunny skies, and rapidly exposed dust layers substantially reducing snowcover albedo at large spatial scales around the state, as a recent layer of clean snow was ablated. All Snotel sites that we visited in mid-May, and that we otherwise monitor, showed *very* high rates of dust-enhanced snowmelt until May 23rd, when unsettled weather re-entered the state, cooling air temperatures and adding fresh snow SWE at most locations (just as NWS – Grand Jct. had anticipated, based on their model analyses on May 16). Rain-on-snow may have also contributed to snowmelt in some lower-elevation locales on May 23rd and 24th. Streamflows rose at correspondingly high rates statewide and we recorded the highest flows observed during our dust-on-snow research at the Senator Beck Basin stream gauge on the evening of May 20 (DOY 141), averaging 19.8 cfs from 2000-2100 hrs, and over 19 cfs in the preceding hour. As anticipated in Alert #6, the recent rate of acceleration in Senator Beck Basin flows, seen below, matched and perhaps exceeded the spike in flows observed from DOY 132-138 in 2006, which was driven by the exposure of the February 15, 2006 and subsequent dust events, all merged together, to sunny skies. We assume that other basins saw rates of increase in discharge comparable to those observed in early May 2006.



As of this date, most Snotel sites show a small rebound in SWE related to fresh snow received on May 23rd and 24th. Where received, that new snow will temporarily restore a high albedo to the snowpack surface, except where wind-stripped down to the old, dirty surface. That new snow (and high albedo) is likely to be short-lived, however, as the heat contained in the thoroughly wetted, isothermal snowpack underneath the new snow, and the radiation penetrating the new snow and being absorbed by the underlying dirty snow, will

rapidly settle and melt this clean layer as stormy weather slowly clears out of the state today and Sunday, from south to north. Warming is expected to resume under generally sunny skies but NWS Grand Jct. sees hints, today, of another round of unsettled weather by Thursday, although uncertainty is still present in their models.

All of the Snotel sites we monitor developed above- to well-above-average SWE totals this winter. Some of the Snotel sites that we monitor now show that the majority of their season-maximum SWE has been lost: Park Cone has lost 82% of its SWE, McClure Pass has lost 97%, and Bear Town has lost 60%, for instance. Many more, however, still have more than half of their season-maximum (and above-average) SWE on the ground: Hoosier Pass has 72% of the season-maximum SWE remaining, Grizzly Peak has 54% remaining, Berthoud Pass has 77% remaining, Wolf Creek Pass has 81% remaining, Rabbit Ears Pass has 68% remaining, Schofield Pass has 80% remaining, and the Red Mountain Pass Snotel indicates that 68% of its SWE remains. (Our Swamp Angel Study Plot, less than 1 km NW of the Red Mountain Pass Snotel, may actually have a higher proportion of SWE remaining). This, despite the losses of SWE observed last week, ranging from -3.3" SWE at Hoosier Pass to -8.1" at Schofield Pass (but prior to the small rebound in SWE from new snow). All but the San Juan Mountain watersheds are currently showing basin-scale SWE values well above 100% for this date, up to 154% (Upper Colorado River Basin). The San Juan Mountain basins retain 97-100% of their average SWE, for this date.

Given the anticipated drying, warming, and sunnier weather into mid-week, it is likely that snowmelt rates will reverse their recent decline at moderate rates as long as snow albedo remains high, but resume the very high rates observed last week as soon as the underlying dirty snow surface re-emerges. Thus, the amount of new snow recently received will dictate the rate of acceleration in streamflows in coming days. Some systems will have seen only minor drops in stage over this weekend and may resume the very high rates of dust-enhanced snowmelt seen last week with elevated streamflows already in place. Due to the extent of dust-in-snow we documented in mid-May (in Alert #6), a sustained period of sunny weather is likely to match and may exceed last week's surge in streamflows, even with only seasonably warm temperatures.

In the context of the very high proportions of season-maximum SWE remaining in many basins, the NWS Grand Jct. weather forecast Discussions (available in the Additional Forecasts & Information box in the lower right corner of your local area forecast window) for the latter half of next week should be monitored very closely. A return of unsettled, cloudy, cooler, and wet weather mid-week, perhaps with additional new snow, could result in dampening the next dust-enhanced surge in streamflow early in the week. However, cooler but still sunny weather could result in only minor reductions in snowmelt rates, as the direct absorption of solar energy by the dust is sustained. With substantial dust layers present in the snowpack throughout the state, and as we approach June with a very high proportion of above-average SWE still perched at high elevations, we are witnessing yet another pattern in dust-enhanced snowmelt in Colorado, unlike those observed in either 2006 or 2007.

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Colorado Dust-on-Snow Alert #8, June 1, 2008

Following the expected brief pause in snowmelt discussed in Alert #7 of May 24th, all Snotel sites that we've been monitoring this spring have shown a second steep decline in SWE during the past week. All sites showed losses in SWE of equal or greater magnitude than the drop seen earlier, in mid-May, and some sites have reached "Snow All Gone (SAG). The substantial dust layer (composed of multiple, 'merged' layers) that was temporarily covered by clean new snow over the weekend of May 24th and 25th has extensively re-emerged at the snowpack surface, first at lower elevations on all aspects, and more recently at the highest elevations on even northerly aspects. Lingering patches of the May 23/24 storm snow stand in stark, bright white contrast to the surrounding dirty snow, as seen in the May 31st photo below, looking westward at the Senator Beck Basin Study Area (far right) and nearby terrain at Red Mountain Pass, here in the San Juan Mountains.

The direct absorption of solar energy by this dust layer, in tandem with two periods of sunny weather and warm air temperatures, has produced two periods of much-greater-than-average rates of snowmelt, as compared to the 30-year average rate of decline in SWE. This is clearly evident in Snotel 2007/2008 Water Year graphs around the State. Thus, even though all the Snotel sites we monitor reported substantially greater-than-average SWE values this season, most sites are also currently on a snowmelt trajectory that will result in earlier-than-average dates of SAG (Snow All Gone), some perhaps several weeks earlier than average. Some lower elevation sites that have recently reached SAG on/about their average date have done so beginning with a much above-average season maximum SWE, under very high snowmelt rates.

Of equal significance, as the table below shows, many sites also retain more than 50% of their average annual peak SWE, with Wolf Creek Pass and Schofield Pass retaining fully ~100% of average annual peak SWE, as of June 1. Willow Creek Pass has lost 45% of the SWE accumulated this year, but still retains 84% of the average annual peak SWE. Similarly, Hoosier Pass has lost 52% of this seaon's SWE, but retains 61% of average annual peak SWE.

June 1, 2008 Snotel Data

Snotel Site	SWE Loss Since 5/24/08	% of WY 0708 Max SWE Gone	Remaining % of Average Peak SWE
Park Cone	3.3" to SAG	100%	0%
Hoosier Pass	4.0"	52%	61%
Grizzly Peak	7.6"	79%	26%
Berthoud Summit	5.5"	43%	65%
Willow Creek Pass	5.8"	45%	84%
Rabbit Ears Pass	8.0"	53%	59%
McClure Pass	0.9" to SAG	100%	0%
Beartown	4.6"	69%	36%
Wolf Creek Pass	3.5"	23%	98%
Schofield Pass	6.9"	31%	101%
Red Mountain Pass	5.0"	45%	68%

Given that many basins contain some high elevation Snotel sites with unusually high SWE amounts still on the ground, for June 1, discharges may have not yet peaked in many/most basins – local water managers are best able to make that judgment. In basins which do retain high levels of SWE, the current dust-enhanced rate of snowmelt can be expected to continue unabated into mid-week, perhaps even accelerate as additional bare ground creates localized heat island effects, absorbing and transferring additional melt energy laterally into the adjoining snowpack. As seen in the photograph above, our own Senator Beck Basin is certainly an example of that lingering kind of lingering snowcover. As of last Monday, May 26th, we had lost only ~25% of our season maximum 38.5" SWE at our subalpine Swamp Angel Study Plot (11,050'). Senator Beck Basin streamflows climbed steadily all last week and have resumed 24-hour average flows equivalent to the prior major surge in flows from May 16-20. We expect discharge to continue to climb into mid-week.

However, NWS – Grand Jct. currently anticipates another opportunity for snow in the Colorado mountains by late Wednesday or Thursday of the coming week, favoring the Northern and Central mountains with snow levels as low as 7,000', but perhaps neglecting the southern side of the San Juan Mountains altogether. As has occurred already this spring, this return to unsettled weather could 'refresh' the snowpack albedo with clean new snow (in the absence of an associated dust event) and, also aided by temporarily cooler temperatures, moderate the snowmelt rates achieved by mid-week, further delaying peak discharge. Any new snow layer less than 10-12" thick will have a short life, however, and will quickly settle and melt as sunny and warm weather is expected to resume over the following weekend, re-exposing the underlying dirty snow surface. Should snowmelt then resume rates similar to recent rates, as seems likely, some higher elevation catchments and basins could discharge a very high proportion of their average peak annual SWE in a very short period, still resulting in earlier-than-average SAG at those sites which haven't already lost all their snow.

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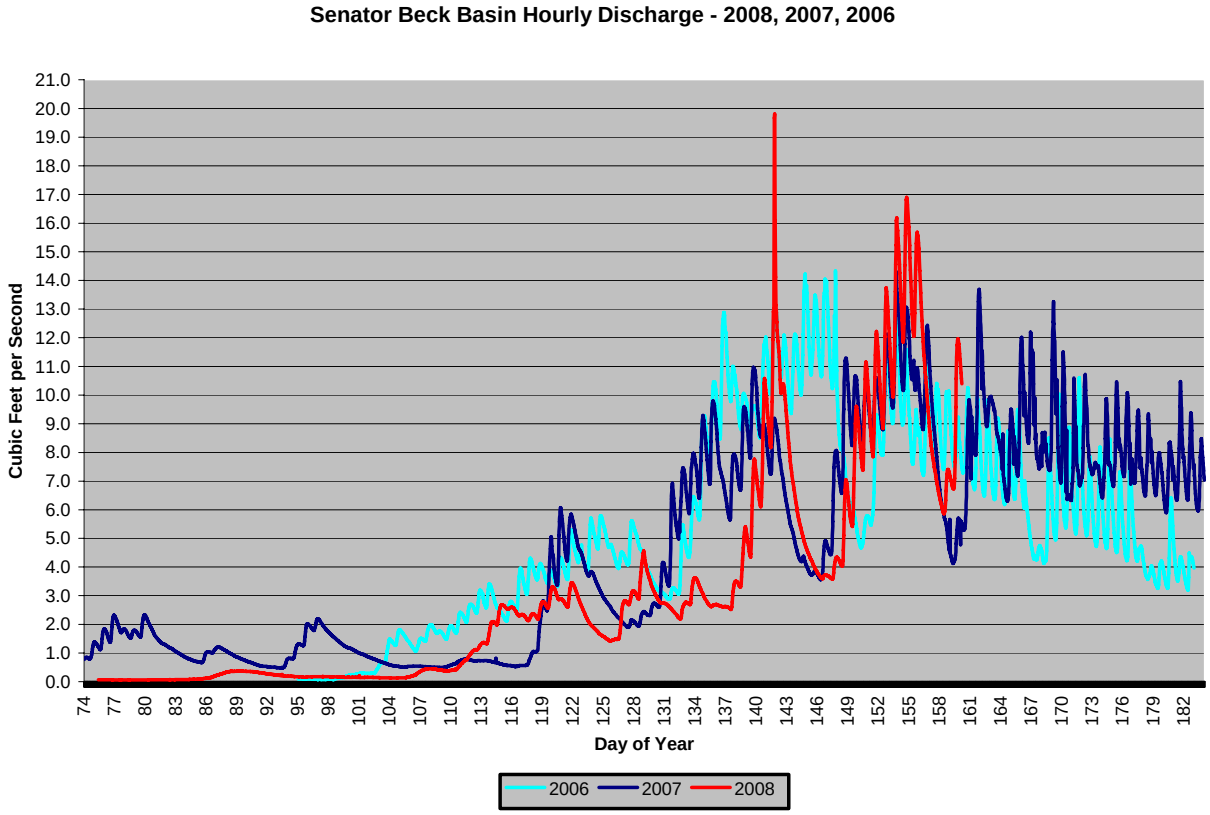
Colorado Dust-on-Snow Alert #9, June 8, 2008

As anticipated by NWS – Grand Junction, fresh snow and cool air 'reset' the snowmelt clock on Wednesday and Thursday of last week; we received 16 mm of SWE in the Senator Beck Basin Study Area, as 4-8" of new snow, varying by elevation. We did not detect any fresh dust with this storm here in our study area, and have received no reports of fresh dust elsewhere. That fresh snow layer resulted in a temporary return to a high albedo that, combined with cooler temperatures, dropped our Basin discharge from near 17 cfs on June 3 to 6 cfs by June 6, as seen below, ending our second major surge of snowmelt and stretching the date of snow-all-gone (SAG) a few days further into the future. Following that low point in streamflow on June 6, however, the new clean new snow quickly succumbed to sunny skies and the absorption of direct solar radiation by the underlying dust, revealing the underlying dirty snow surface once again. Our third surge in flows this season has now begun, as of this writing, despite somewhat cooler air temperatures here in the San Juans over the past weekend.



Based on our first-hand observation of extensive dust layers in mid-May, it is our assumption that a similar return to high albedo (caused by new snow) occurred throughout most of the remaining Colorado mountain snowpack last Wednesday and Thursday, followed by a similar, subsequent ablation of the clean new snow and re-emergence of the underlying dirty snow surface. Some Central and Northern mountain areas may have received additional snow showers on Saturday or Sunday, but not in amounts that will cause a prolonged return to high snowcover albedo values. Therefore, given that the current NWS – Grand Jct. 7-day forecast calls for generally sunny skies through Sunday, June 15th, except for a brief disturbance on Wednesday the 11th, and temperatures at 10,000' in the 60's (except Wednesday and Thursday), another surge of dust-enhanced snowmelt is expected.

Basins and sites highlighted in our previous Alert (#8) that then retained high proportions of this year's SWE, and/or of their average peak SWE values, may quickly return to and sustain high flows during the coming week, perhaps for an extended period. Wolf Creek Pass and Schofield Pass Snotel sites, in particular, still have ~30" of SWE on the ground as of this writing. Here in Senator Beck Basin, we measured 14.9" of SWE today at our 11,050' Swamp Angel Study Plot, still 39% of our maximum WY 2008 SWE of 38.5" in mid-April. However, most of the sites we've been monitoring show only 5-10" of SWE remaining. Despite achieving substantially above-average WY 2008 maximum SWE values, most of the sites discussed in Alert #8 still appear to be on a trajectory for a 1-2 week earlier-than-average date of SAG, and Grizzly Peak has essentially reached SAG, almost 3 weeks earlier than average. While many factors contribute to and interact to cause snowmelt, the extensive dust depositions observed throughout the Colorado mountains this past season have certainly played a role in the rapid rates of snowpack decline seen in WY 2008 Snotel SWE graphs, even with (at least) two significant interruptions caused by spring storms.

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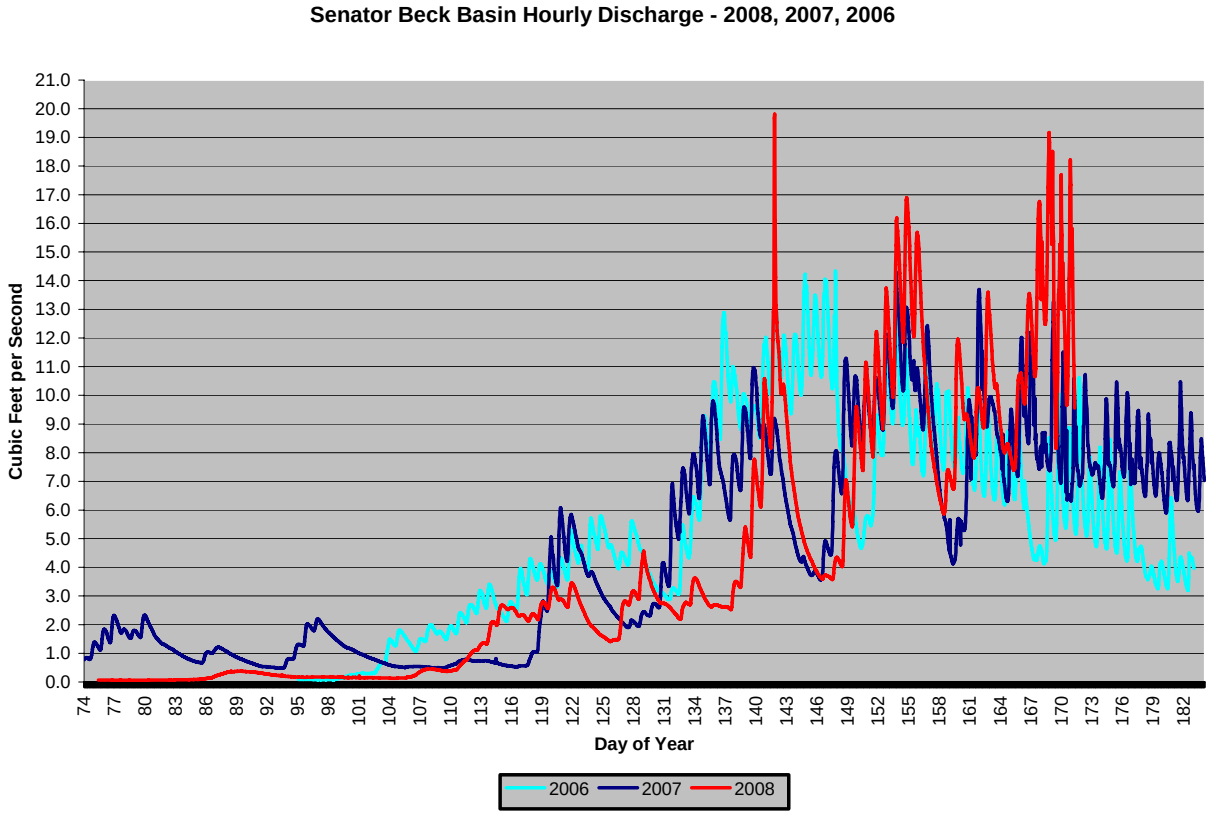
Colorado Dust-on-Snow Alert #10, June 19, 2008

Since our last Dust Alert (#9) on June 8, snowmelt and streamflow have peaked in the CSAS's Senator Beck Basin Study Area., reaching this season's maximum 24-hour average flow rate of 15.27 cfs on June 16 (DOY 168). Rapid warming beginning on June 12 (DOY 164), light winds, and a 'uniformly' dirty snowpack throughout our Basin, with the entire 2007/2008 dust load merged at the surface, resulted in the third significant surge of snowmelt we've observed this season. This recent 'perfect storm' of snowmelt forcing factors – high air temperatures, clear skies, light winds (minimizing evaporative cooling), and low snowpack albedo (reduced by dust) – is rapidly releasing the lingering SWE content of Senator Beck Basin. Based on a strictly subjective estimation, we may have reached and passed the SWE-based "center of mass" of runoff at the stream gauge in the past day or two, as seen below.

Both of our study plots reached Snow All Gone (SAG) nearly simultaneously earlier this week. This was the latest date of SAG yet observed in the brief history at our sub-alpine plot at 11,050', thanks in part to the nearly-3 meter snowpack in April. On the other hand, despite receiving the same heavy precipitation, our alpine site at 12,200' was routinely stripped by unusually persistent winds during the winter (according to a 30-year veteran avalanche forecaster at Telluride ski area), thereby squelching the accumulation of snowpack at the alpine plot site and redistributing snow into exceptionally deep depositions in gullies and snow 'pillows' in other areas of the Basin's alpine terrain. As a result, SAG came somewhat earlier at the alpine plot than in previous, less windy winters. That wind redistribution will result in long-lingering patches of snow in our Basin this summer, overlapping with the monsoon season more than usual.



All of the Snotel sites we physically visited in April and May 2008 (Park Cone, Hoosier Pass, Grizzly Peak, Berthoud Summit, Willow Creek Pass, Rabbit Ears Pass, and McClure Pass) presently report either SAG or

will reach SAG within a day or two. Previous Alert discussions of SAG at Snotel sites around the state referred to the "average date" of SAG, as represented on the site graphs of precipitation and SWE presented on the Snotel system website. Those graphs typically show a tapering 'tail' of diminishing SWE values at the end of the season. We have been informed by the Snotel program staff that those graphs, while accurately representing an 'average' (mean) date of SAG, are somewhat misleading in regards to the pattern of snowmelt as SAG approaches, and that plotting the *median* snowmelt behavior at most sites (not presented graphically on the Snotel website) shows both an earlier date of SAG (than the graphed 'average' on the website) and a more-or-less 'straight line' descent of SWE values to zero, with no 'tailing off'. In comparison to long-term *median* SAG values, many of the Snotel sites we monitored this winter experienced 1-2 week longer-duration snowpacks than median SAG, and some other sites like Schofield Pass and Wolf Creek Pass will persist for a month, or more, longer than the median date of SAG. It's worth noting, for context, that all those sites that we monitored (as well as others like Wolf Creek and Schofield Pass) also experienced substantially above-average maximum SWE values this season. As we accumulate additional seasons of dust and snowmelt data at these and other sites, an ensemble of patterns of snowmelt timing and intensity may emerge.

Numerous travelers to Silverton last week, attending the MTNCLIM conference on climate change in Western mountains, including some of you receiving this Alert, were able to confirm that the dust-in-snow our team observed throughout the Colorado mountains in May is still present and fully apparent wherever snowcover remains. This morning's NWS – Grand Jct. office discussion of the mid-term weather modeling describes persistent high pressure, southwesterly flow, and air temperatures (highs and lows) some 5-7 degrees F above normal through next Wednesday. In the absence of new snow precipitation, the reduced snowpack albedo caused by dust now at the surface will not be 'restored' to higher values during this period. Therefore, the complex interactions of warm air temperatures (day and night), increasingly large areas of bare ground interspersed throughout otherwise snow covered areas, wind effects, and direct absorption of solar energy by dust in the snowpack surface will continue, perhaps for the duration of the Spring 2008 snowmelt season.

Barring an unforeseen weather or dust event, this Alert will conclude our series of Colorado dust-on-snow updates for the spring 2008 season. We greatly appreciate the financial support many of you have provided this season, and the feedback we've received regarding these Alerts. I (Chris Landry) will be in touch with our funding Districts to arrange for an in-person report to your boards of directors. We will also be in touch with the Districts and others receiving these Alerts in coming months to discuss ways to improve on these products and explore how we might best expand the network of Alert users to reach and benefit all Colorado snowmelt water stakeholders.

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