NATIONAL WEATHER SERVICE HYDROLOGIC SERVICES: PROVIDING INFORMATION FOR FLOOD PREPAREDNESS, DROUGHT MITIGATION AND WATER RESOURCES MANAGEMENT ON THE WESTERN SLOPE OF COLORADO

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1. Introduction

The Colorado River and its tributaries in the Upper Colorado River Basin quench the water needs of a significant portion of the arid southwestern United States including highly populated areas such as Las Vegas, Phoenix and Los Angeles. Through transmountain diversions, the waters from the Colorado River Basin also supplement the growing metropolitan areas along the Front Range of the Rocky Mountains. In the Southwest, population growth is placing a strain on water supplies, and because this region is prone to long-term periods of drought and reduced runoff, management of existing water supplies is critical.

Nearly 70% of the water which flows in the Colorado River originates from the snowpack in the mid and high elevations of the Rocky Mountains. Consequently, the amount of snow which accumulates in the Rockies can have a dramatic effect on water availability for several years to come. Abundant snowfall not only bolsters the economies of ski communities but also helps augment spring and summer snowmelt runoff, replenishing reservoirs which supply water for municipal, agricultural and industrial uses. The high flows also benefit water recreation such as whitewater rafting.

There can be a fine line between the hydrologic benefits of an above normal mountain snowpack and the increased flooding potential. As runoff-swollen rivers and streams leave the confines of their banks, the resulting flooding can threaten life and damage property. The economic and loss of human life can be devastating.

This paper will examine the record snowfall and snowpack of the 2007-08 winter season which heightened concerns for flooding during the 2008 snowmelt runoff. It will describe how outreach efforts and hydrologic products produced by the National Weather Service (NWS) Weather Forecast Office (WFO) in Grand Junction, Colorado, alerted the community of the spring flood threat. It will then discuss the actions taken by local governments and emergency managers to mitigate flood damage and maximize water supply reserves. Lastly, work being done to address the impacts of drought will be presented.

2. 2007-08 Winter Season

2.1 Seasonal summary

The 2007-08 winter seasons produced much above normal snowpack for much of the Upper Colorado River Basin in Western Colorado (Figure 1). The season was anomalously dry through November. Many ski areas had to delay the start of the season due to lack of snow. However, a strongly progressive meteorological pattern began on 30 November, and continued with frequent storms through February.

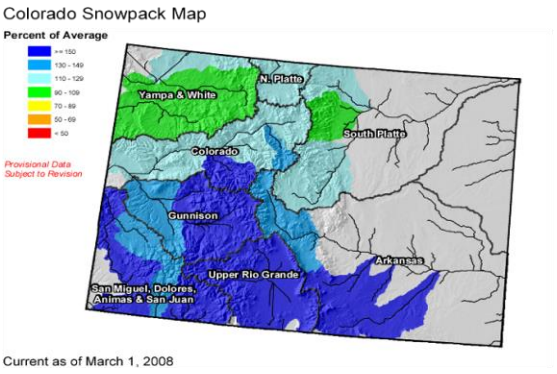


Figure 1 State of Colorado River Basin Snowpack as of March 1, 2008.

With a few breaks, this progressive pattern continued into early June. By late April, several headwater river basins topped 150 percent of normal snow water equivalent with some mainstem river basins averaging over 120% of normal snow water equivalent (Tables 1 and 2).

Basin	SWE Percent of Average
Yampa/White	110
Upper Colorado	113
Roaring Fork	146
Gunnison	124
Animas	106
Dolores/San Miguel	102
San Juan Headwaters	120

Table 1 Snow Water Equivalent (SWE) Values Percent of Normal ending April 30, 2008. Source: NRCS

Basin	Percent of Average Precipitation for WY2008
Yampa/White	108
Upper Colorado	112
Roaring Fork	128
Gunnison	121
Animas	111
Dolores/San Miguel	112
San Juan Headwaters	119

Table 2 Precipitation Percent of Average for Water Year 2008 as of April 30, 2008. Source:NRCS

Of further concern, heavy snowfall extended down to elevations as low as 2285 m MSL, which adversely impacted wildlife with record-breaking winter kill, and would potentially create flood concerns for the runoff season.

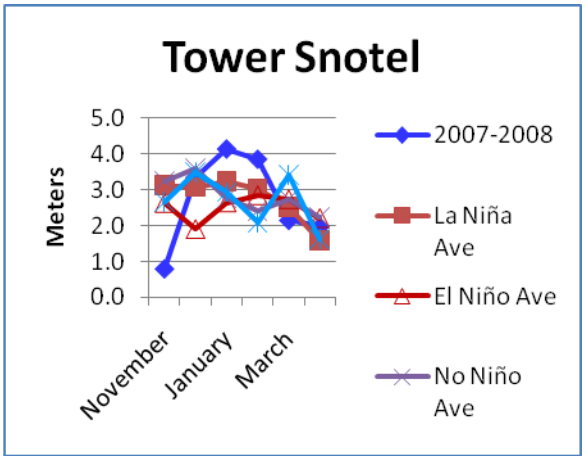
An example of this snowfall distribution is seen in Figure 3 a,b,c from the Park Range which shows more normal snowfall at the higher elevation site (Tower Snotel) and record-breaking amounts at the lower two sites.

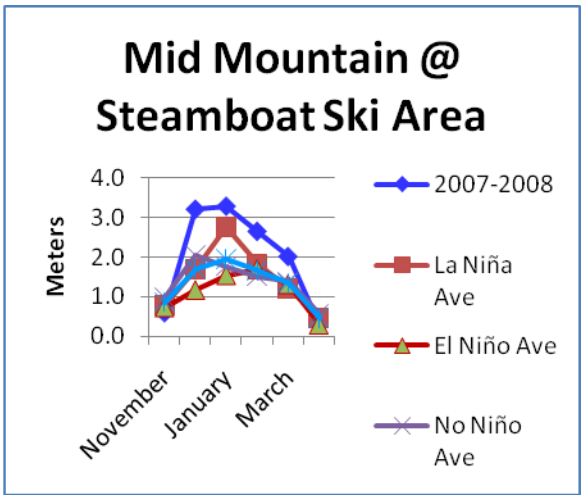
2.3 Late Spring Weather Pattern

The spring weather pattern slowed excessive snowmelt runoff as the progressive weather pattern continued. This progressive pattern resulted in periods of cooler than normal temperatures with passing storms. Between the storms, the warming temperatures would arrive in 2- to 3-day increments (Figure 5); just enough to start the melting process and bring the rivers to and above bank full. As dangerous flood stages were approached, another storm would enter the region and decrease the snowmelt.

This scenario was repeated through the peak snowmelt months of May and June. The lower elevation snowpack melted first in early and mid May. The mid-level snowpack then melted and ran off during mid and late May, with the high-elevation snow melting in early to mid June. Figures 5 and 6 show hydrographs for gage locations on the Gunnison and East River. Each hydrograph shows several intermediate crests which closely correspond to the intervals of warmer than normal temperatures.

If seasonably warm and dry conditions occurred early in the snowmelt process, flow levels could have reached major flood levels at many locations across western Colorado.





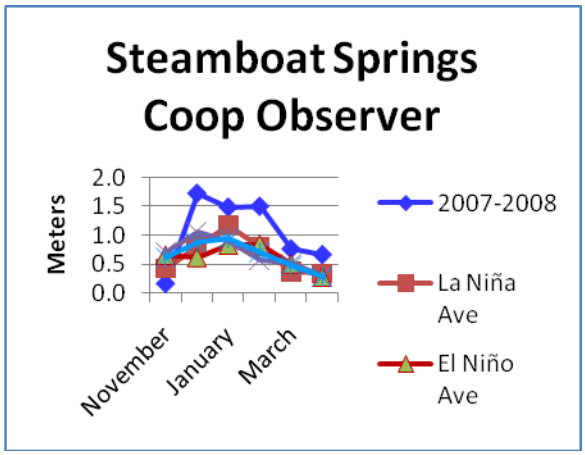


Figure 3 a, b, c. Seasonal snowfall in meters under different climate regimes for the Tower SNOTEL, mid-mountain, and the Steamboat Springs Cooperative Weather Observer reporting sites.

3. Hydrological Impacts

3.1 Snowmelt Flood Planning and Activities

Given the potential of an extreme runoff season, the staff at WFO GJT began educational outreach during the winter of 2008.

This advanced education of local media and emergency management teams across the Western Slope allowed WFO GJT staff to reach both those who would benefit and be threatened by flooding.

By starting efforts 4 months in advance, emergency management teams were able to set aside resources and make long-term plans as the runoff season approached.

Outreach activities can be divided into internal and external efforts. Internally, WFO GJT increased training on hydrologic software systems and reviewed how best to serve our customers and/or partners. The staff changed their work schedule to optimally meet the needs to protect life and property in the community. Externally, WFO GJT regularly coordinated with the Colorado Basin River Forecast Center (CBRFC), the Colorado Division of Water Resources, emergency management officials, and the media. This included regular meetings and conference calls.

WFO GJT regularly issued statements such as the Spring Flood and Water Resources Outlook (ESF), Daily River and Reservoir Summary (RVD), River Statements (RVS), and Public Notification Statements (PNS) to keep the community informed of flood potential, peak flow dates, current river levels, and the potential dangers of fast-moving water and erosion of banks. The NOAA/NWS Advanced Hydrologic Prediction Service (AHPS) web portal provided quick access to deterministic and probabilistic forecast river levels as well as hydrologic advisory and warning information. When conditions warranted it, WFO GJT also issued Flood Advisories and Statements (FLS), Flood Watches (FFA) and Flood Warnings (FLW). For the 2007-2008 winter season, WFO GJT issued 7 Flood Warnings, 6 Flood Watches, 33 Flood Advisories, and 6 Areal Flood Advisories. River products were active from 7 to 10 May and 19 May to 26 June. That is a total of 41 days and 38 consecutive days with active hydrologic products.

This coordinated effort paid off. Thirteen main rivers and creeks went above bankfull stage, including 22 gauge sites. Three of the rivers (four gauge sites) reached or exceeded flood stage. Early planning and preparation helped mitigate flood risks. Levees were enhanced and strengthened in Grand Junction, Gunnison and other communities around western Colorado. Sand bags were placed around homes and buildings in Routt County and other locations. Informational signs were posted at recreational areas along rivers.

Three fatalities occurred during the runoff season. There was one fatality on the Gunnison River in Gunnison County when a person who was not wearing a personal floatation device (PFD) fell off a raft. A woman riding a horse was lost in Beaver Creek when her horse fell into the fast-moving water. The third death was when a man fell out of his blowup kayak into the Colorado River near Glenwood Springs. It is unclear if the man was wearing a PFD.

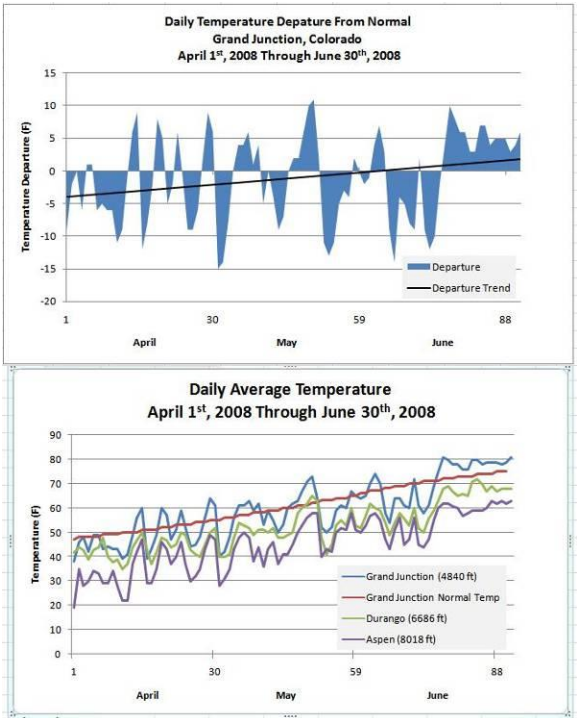


Figure 4. Two temperature graphs representing the steady rise and fall of temperatures across western Colorado. The top graph is of WFO GJT. The bottom graph includes, Grand Junction, Durango and Aspen. All temperatures are in degrees Fahrenheit.

3.2 Impact of River Flooding

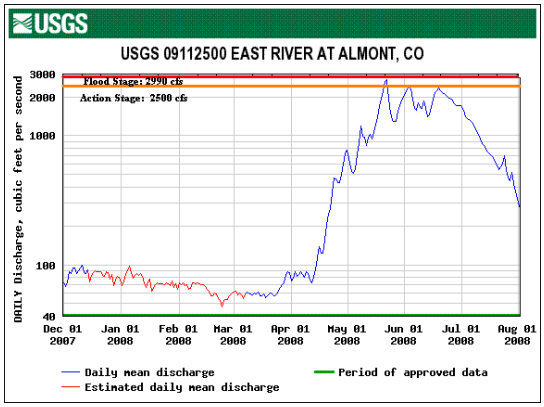


Figure 5 Hydrograph from the USGS River Gage on the East River at Almont, Colorado for the Period December 1, 2007 to August 1, 2008

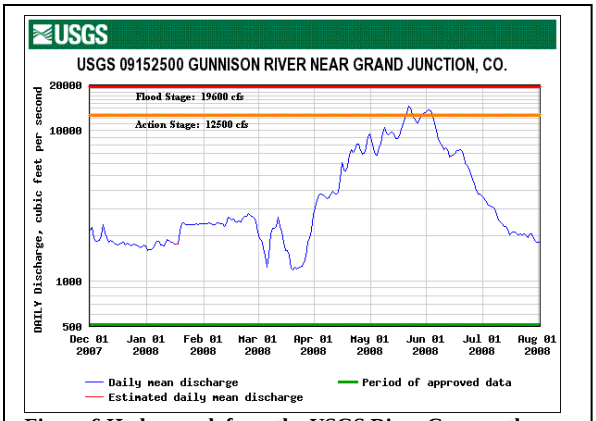


Figure 6 Hydrograph from the USGS River Gage on the Gunnison River near Grand Junction, Colorado for the Period December 1, 2007 to August 1, 2008

4. Reservoir Operation Impacts

Reservoir operations are tailored so that water appropriations and water rights can be met throughout the year. To complicate this, specific flows are required at various times during the year to satisfy the needs of recreation and environmental interests.

The Aspinall Unit is a collection of three reservoirs on the Gunnison River near Gunnison, Colorado. From upstream to downstream, it consists of the Blue Mesa Reservoir, the Morrow Point Reservoir and the Crystal Reservoir. In addition to hydroelectric power, the Aspinall Unit also supplies water for municipal, agricultural and industrial needs. It provides a method to regulate the flows of the Gunnison River, helping to prevent major flooding of downstream communities such as Delta and Grand Junction.

The operation of the Aspinall Unit is usually determined by late April through a series of joint meetings hosted by the United States Bureau of Reclamation (USBR). An important goal is to fill the reservoirs without having to spill any of them. This maximizes the available water supply for the drier summer and fall months. In preparation for the forecast 2008 excessive spring runoff, releases from the Aspinall Unit were increased to make room for the anticipated runoff. The hydrograph in Figure 7 is for a gage located just below the Aspinall Unit. Releases were ramped up from 300 to 2000 cfs in late March and up to 8000 cfs by 1 June. Releases were then decreased during June even though as shown in Figure 8 the inflow into the Aspinall Unit remained high through much of the month

of June and into Early July. The net effect of these operations on the pool height of the Blue Mesa Reservoir are shown in Figure 9.

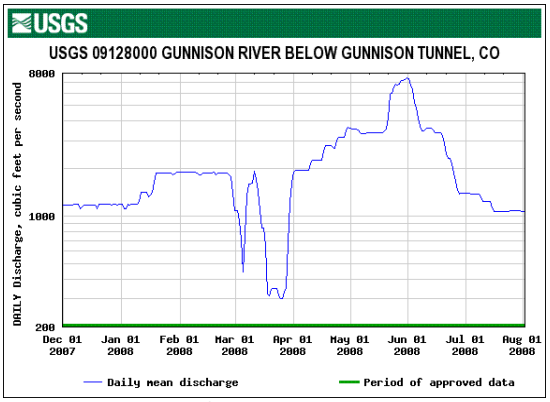


Figure 7 Hydrograph from the USGS River Gage on the Gunnison River below Gunnison Tunnel, Colorado for the Period December 1, 2007 to August 1, 2008.

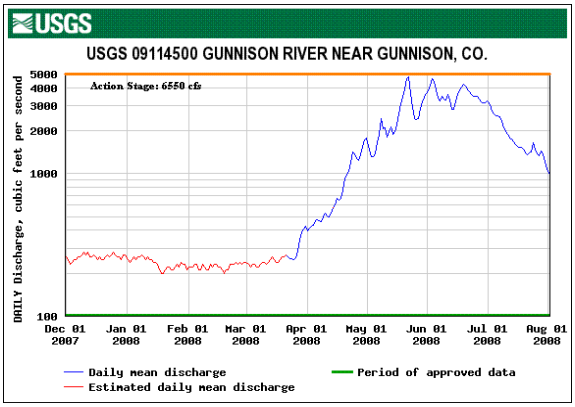


Figure 8 Hydrograph from the USGS River Gage on the Gunnison River near Gunnison, Colorado for the Period December 1, 2007 to August 1, 2008.

5. Drought and Low Water Impacts

Historically, droughts of varying time scales have affected the Upper Colorado River Basin. In an attempt to design a common portal of drought forecasts, conditions and impacts, the National Integrated Drought Information Service (NIDIS) is being developed as a joint effort by local, state and federal agencies. The Upper Colorado River Basin is a NIDIS pilot project. Low water impacts are not as well documented as high water impacts. An effort by the National Drought Mitigation Center is under way to define low water impacts.

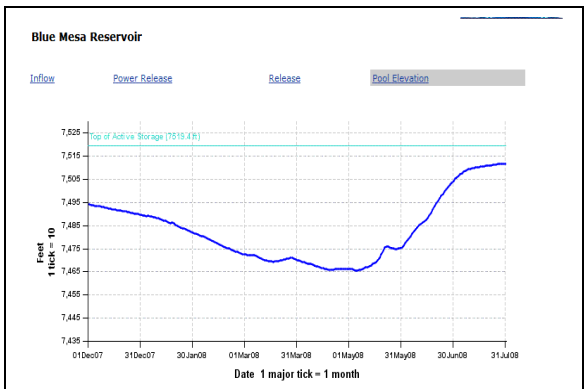


Figure 9 Blue Mesa Reservoir Pool Height from December 1, 2007 to August 1, 2008. Source: USBR

6. Conclusions

The snowpack in the Colorado Rocky Mountains is the primary contributor to the water supply of the southwestern United States. An above normal snowpack helps to replenish water supplies and can stimulate local agricultural and recreation based economies. However, the increased spring snowmelt runoff creates the danger of flooding which can threaten life and property.

Through outreach and hydrologic products, NOAA's National Weather Service informs the community of flood threats, information which can be used to save life and lessen flood damage. NWS water supply forecasts are used by water resource managers to help ensure optimal water availability throughout the year.

The socio-economic impacts of drought are becoming increasingly recognized, and efforts are being made at many different levels of government and academia to develop ways to mitigate these impacts.

The record breaking 2007-08 winter season is an example of a partnership between WFO GJT and local and government officials to develop a methodology to mitigate loss of life and damage due to flooding. Such partnerships can be used to mitigate, and in some cases avoid, major societal flood impacts

7. References

Colton, J.C. M. Meyers, A. Strautins, B. Lawrence, J. Ramey, 2009: Avoiding Disaster Across Western Colorado: The 2007-08 Winter Season Near-Record Snowfall and Impact of the Spring Runoff

Colton, J.C. M. Meyers, J. Ramey, D. Wesley, I. McCubbin, G. Haller, 2008: Unique Snowfall Distribution over the Park Range and Upper Yampa River Valley during the La Niña Winter of 2007-08.