WATER

Water plays a critical role in each of the sectors discussed in this report: it determines ecological success, influences health and safety, drives production of energy, and impacts the economy in a myriad of ways. In Aspen and throughout the West, changes in water supply and demand are already active areas of discussion, research, and planning. Locally, studies such as the *State of the Roaring Fork Watershed Report* and resulting *Roaring Fork Watershed Plan* have already explored many of the significant issues and trends affecting local water availability and quality.[52] At a state level, Western Water Assessment (WWA) produced a 2014 report for the Colorado Water Conservation Board (CWCB) examining the impacts of climate change in Colorado with a focus on water.[53] The CWCB also facilitates roundtable discussions and is involved in the creation of a basin-wide implementation plan that will assess consumptive and non-consumptive water needs in relation to water supply across Colorado's nine basins.[54]

Water management, a perennial challenge in the West, is further complicated by the prospect of climate change.

The purpose of this section on water is not to reproduce earlier studies or to examine all the numerous and complicated water issues in depth. Rather, the purpose is to highlight potential impacts from climate change on water-dependent resources. This general survey of potential climate-related impacts to the water sector should be considered in the context of numerous ongoing water availability studies and water management planning activities—locally, statewide, and regionally. For example, the City of Aspen water department has commissioned a water

[52] Clarke, S., K. Crandall, J. Emerick, M. Fuller, et al.. 2008. State of the Roaring Fork Watershed Report. Ruedi Water and Power Authority and Roaring Fork Conservancy, November 2008.

[53] Lukas et al. 2014

[54] A draft and proposed framework for Colorado's Water Plan can be found at: http://coloradowaterplan.com.

availability study and drafted a water efficiency plan that are intended to explore the issues discussed in this chapter in further detail and specificity.

Due to the difficulty of scaling models to address topographic variability in the Colorado Rockies, projections for future precipitation in the Roaring Fork Valley continue to include multiple possibilities, ranging from little or no change to either significant decreases or even increases. Projections for the southwestern U.S. *as a region,* however, show greater agreement among models and indicate a general decrease in annual precipitation.[55] These projections suggest that the southwest area of the United States may become more arid as temperatures increase, snowpack decreases, and runoff dates become earlier. Because of the geographically connected nature of watersheds and existing water law and agreements, such as the Colorado River Compact, precipitation and water availability changes that take place regionally will have a considerable impact locally for water management in the Roaring Fork Valley.[56]

While future trends for quantity of precipitation in the state of Colorado remain uncertain, trends more confidently indicate that the *form* in which the precipitation will fall is likely to alter over time. A shift to an increased percentage of precipitation falling as rain rather than as snow is projected both locally and at a regional level, particularly at elevations below 8,200 feet. This is an alteration that, combined with higher temperatures and earlier snowmelt, has the potential to impact groundwater and surface water supplies.[57]

Pitkin County's population is expected to increase by more than 50% to 25,229 people by 2025.

Additionally, higher average temperatures affect water resources. Streamflow is often used as a proxy measurement for water availability, and research indicates that higher temperatures may directly correlate with lower streamflow. Hydrologic modeling for the gage station at Lee's Ferry in Arizona showed that for every 1.8°F (1.0ºC) increase in average temperature, streamflow in the Colorado River declines between 3-10%.[58]

Furthermore, any climate-related shifts in water availability that take place occur within the context of changing human demographics as well. Population growth locally and on the Front Range is anticipated to continue, increasing demand for water and the likelihood of potential water shortages by stretching an already limited resource. According to 2010 data from the state demographer's office for the state of Colorado, Pitkin County's population is expected to swell

---

[55] Lukas et al. 2014.

[56] Vano et al. 2014.

[57] Ray, A., J. Barsugli, and K. Averyt. 2008. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board. Western Water Assessment.

[58] Vano et al. 2014.

from the 2010 population of 17,148 to increase by more than 50% to 25,229 people in 2025.[59] The population of Colorado as a whole is expected to grow significantly as well, reaching around 7.1 million residents in the next 16 years.[60]

Although Aspen sits at the top of the watershed, its water resources are unusual in that demand pulls water in two directions: downstream toward the southwestern states and eastward via diversions to the Front Range. Two of the five largest transmountain diversions in Colorado redirect water from from the Roaring Fork Valley.[61] Under conditions typical to the last few decades, spring streamflow of the Roaring Fork and Frying Pan Rivers were reduced by more than half due to diversions alone.[62] Diversions are essential for municipal uses and for agricultural production, so drying in the Front Range of Colorado and across the Southwest would doubly place pressure on local water availability from the standpoint of demand.

Impacts to snowpack and the water cycle

A 2014 report produced for the Colorado Water Conservation Board (CWCB) found that since the 1980s onset of snowmelt has shifted earlier in the year by 1-4 weeks and is projected to continue shifting to earlier in the year in the future as a response to warming temperatures.[63] The CWCB's previous 2008 report[64] found that between 2000 and 2004, the Colorado River experienced its lowest 5-year flow since records began in the early 1900s, and hydrologic studies project that low flows may continue as a result of declining runoff—as much as a 6-20% decrease from 20th century averages in the Colorado River Basin. The cited drivers for this decline are increased drought severity in the Western US and high temperatures exacerbated by decreases in soil moisture.[65]

On a local level, records from the USGS Glenwood Springs gage station show that from 1981 to 2012, peak flow showed a decline of 722 cubic feet per second (see Figure 2.9). Peak flow, the quantity of water in the river on the date of its highest flow of the year, is often considered to be indicative of of depth of snowpack for the preceding winter in snowpack dominated watersheds. Because the Roaring Fork is a heavily diverted river, the observed decline is more indicative of

---

[59] DeGroen, Cindy. 2012. Population Forecasts (Presentation). State Demography Office Annual Meeting, Colorado Department of Local Affairs, Nov.
[60] Clarke et al. 2008.
[61] More information available through the Roaring Fork Watershed at: www.roaringfork.org/sitepages/pid170.php
[62] Clarke et al. 2008.
[63] Lukas et al. 2014.
[64] Ray, A., J. Barsugli, and K. Averyt. 2008. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board. Western Water Assessment.
[65] Lukas et al. 2014.

ongoing diversions to the Front Range than it is of local snowpack conditions. Local snow water equivalent (a proxy of snowpack) has not decreased sharply since 1981 (see Figure 4.1).

As discussed in Chapter 2, precipitation and snowfall within the Aspen area have been variable over the period of their observation from 1940-2013. Since 1981, both the data records for precipitation and snowfall have suggested slight decline, although both were increasing in the period before 1980 and the extraordinary winter of 1983/1984 skews the trend analysis (Figures 2.7 and 2.8). As temperatures continue to rise, though, duration of snowpack and percent of precipitation falling as snow rather than rain may decline. Depth of snowpack and duration of snow cover are linked closely to watershed functions, winter ecology, and water availability.

Particularly in snowpack-driven watersheds, early snowmelt or low snowpack during winter months can decrease soil moisture levels throughout the following summer, affecting plant growth and stress.[66]

In addition to the ecologic changes associated with changing water regimes, water availability forms a critical component of the structure of all other systems in the Valley. Human activities as diverse as production of energy or summer water sports are dependent upon sufficient flows.

Figure 4.1 Snow water equivalent on April 1 since 1981

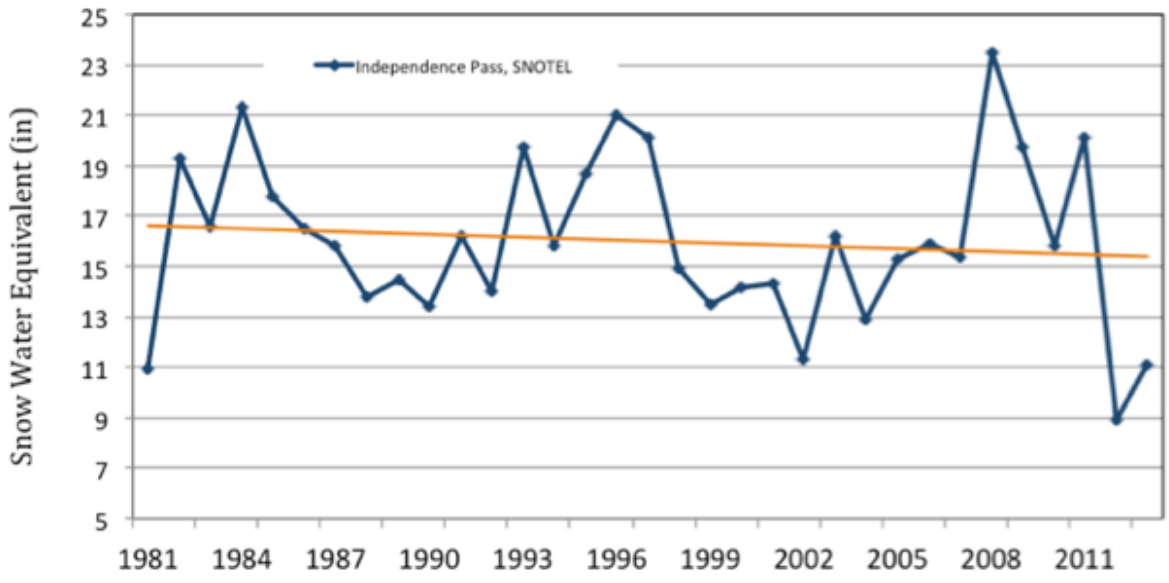


Figure 4.1 shows snow water equivalent (SWE) on April 1st in inches from 1981-2013. The blue line shows SWE for each year, and the orange line represents the overall trend of the data. The graph was created using NRCS data from the SNOTEL site on Independence Pass at 10,600ft.

[66] Clow, David W. 2010. Changes in the Timing of Snowmelt and Streamflow in Colorado: A Response to Recent Warming. *J. Climate* 23: 2293–2306. doi: http://dx.doi.org/10.1175/2009JCLI2951.1

Winter recreation is tied closely to snowfall and duration of snowpack. Public health relies upon the assurance of water quality and availability, as do many aspects of our built environment and agriculture and local food production. Public uses, from municipal water supply and wastewater treatment plants to city parks and golf courses, rely upon water being available at critical times of the year.

Response strategies

Building climate resiliency in the water sector requires the consideration of many environmental, societal, legal, and ecological factors such as total annual precipitation, percent rain vs. snow, increases in temperature, soil moisture, population, and societal uses of and allocations for water.

Box 4.2 Water summary

Climate-related changes:
- Increased dry periods in the western U.S.
- Decrease in percent of precipitation falling as snow
- Changes to the timing and availability of water

Future Potential Impacts
- Greater pressure on existing water resources
- Changes to ecological regimes; decreased soil moisture, lower river flows
- Increased risk of fire
- Changes to timing and volume of peak flows
- Reduced hydroelectric generating potential
- Local population growth leading to increased municipal and recreational demand for water

Potential Responses
- Anticipatory planning and adaptation for multiple climate scenarios
- Increased water use efficiency
- Development of adaptive plans for ecological impacts
- Education and public outreach
- Stakeholder involvement in discussion and adaptive planning

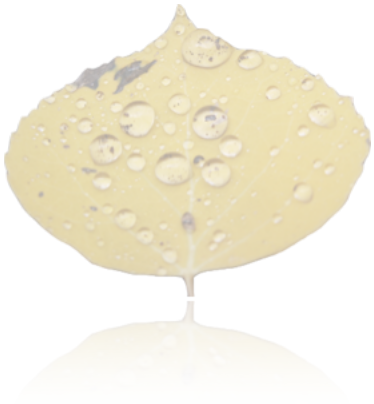
Opportunities
- Renewed consideration of current water allocations, rights, and laws

Lingering Uncertainties
- Future trends in precipitation
- Seasonality of temperature changes in mountain climates under climate change
- Future population growth and water demand

Potential types of adaptation in the water sector include:

- Enhanced education and public outreach
- Local and regional research, monitoring, planning, and investment
- Ecological restoration and conservation

Activities of this sort are underway—and have been for many years— both locally and statewide, but they are now needing to integrate new shifting hydrologic conditions resulting from climate change. The Roaring Fork Watershed Action Plan recognizes the need and has considered climate change into actions proposed.[67] For Colorado, Governor Hickenlooper requested a State Water Plan be adopted that recognizes key issues such as population, the Colorado Compact, and climate change. All of these efforts are conducted in the context of existing policies and legal structures that could potentially evolve in the future.



[67] Clarke, S., M. Fuller, and R.A. Sullivan. 2012. Roaring Fork Watershed Plan. Retrieved from http://www.roaringfork.org/sitepages/pid175.php