Section 6.0
Hydrology and Flow Regime

Summary

Watershed hydrology determines the amount, timing, and duration of runoff in the South Arkansas River watershed as well as the depth and amount of groundwater that sustains the river during most of the year. In an undisturbed watershed, a river's natural flow regime—spring floods, summer thunderstorm, and late-season low flows—is fundamental to the proper functioning of the stream ecosystem. Dams, water diversions, and drought have significantly altered the amount, timing, and location of flows in the South Arkansas River. Most of the time there is not enough water for the original channel, with resulting impacts to in-stream and streamside habitat, stream stability, and water quality. Since major changes in current water use in the watershed are not likely, decreasing the river channel's footprint would better utilize existing flows and improve in-stream and streamside conditions.

This section discusses the source of water in the South Arkansas River watershed, how and when that water arrives at the river, how the timing and amount of water influences the character of the river and river corridor, and how human activities affect watershed hydrology and flows in the river.

Background

Until the 1500s, oceans were considered the source of rivers and springs through underground seepage (Allan 1995). In fact, the actual source of water on land is the hydrologic cycle—the continuous circulation of water from the oceans to the atmosphere and back to the earth (Figure 6-1). Components of the cycle include precipitation, runoff, evaporation, transpiration by plants, and temporary storage as snowpack, soil moisture, groundwater, and water in rivers, lakes, and oceans (Dunne and Leopold 1978). Each component of the cycle influences the watershed in which it occurs.

Fully 84% of the water that reaches the earth returns to the atmosphere by evaporation and transpiration (CGS 2003, Allan 1995). That which remains moves across the surface as runoff ("overland flow"), as shallow subsurface flows ("infiltration"), or it moves deeper down to groundwater ("percolation") (Figure 6-2). Which path the water takes determines how much reaches local surface waters, when it arrives, and what it contains (e.g., dissolved minerals). Since subsurface flows represent the smallest contribution to stream flows (less than 20%) (Dunne and Leopold 1978), this discussion will concentrate on surface runoff and groundwater.

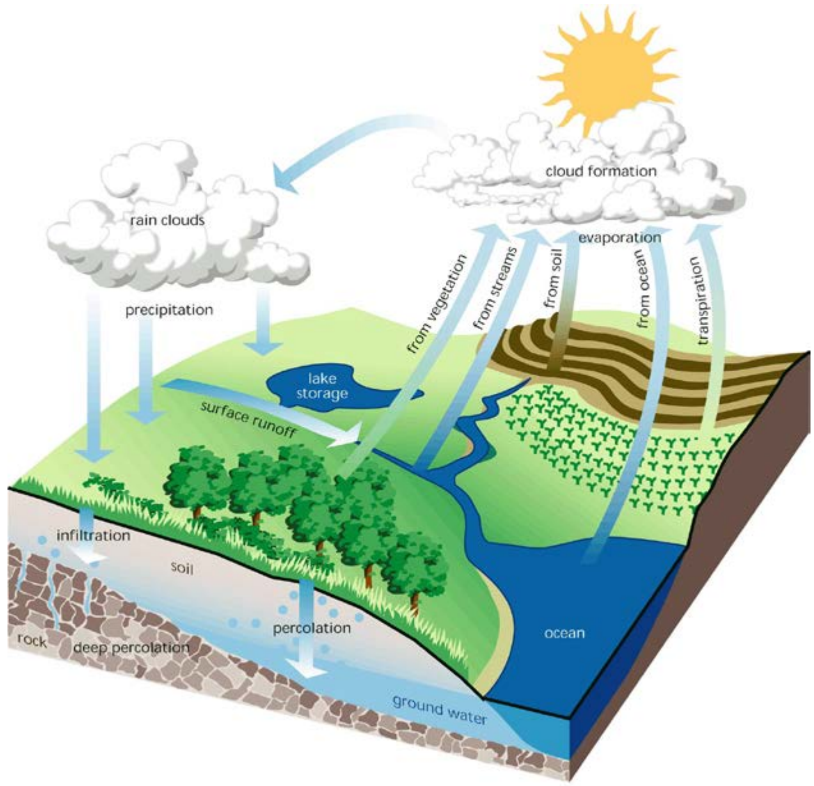

Figure 6-1. Components of the hydrologic cycle
(FISRWG 2001)

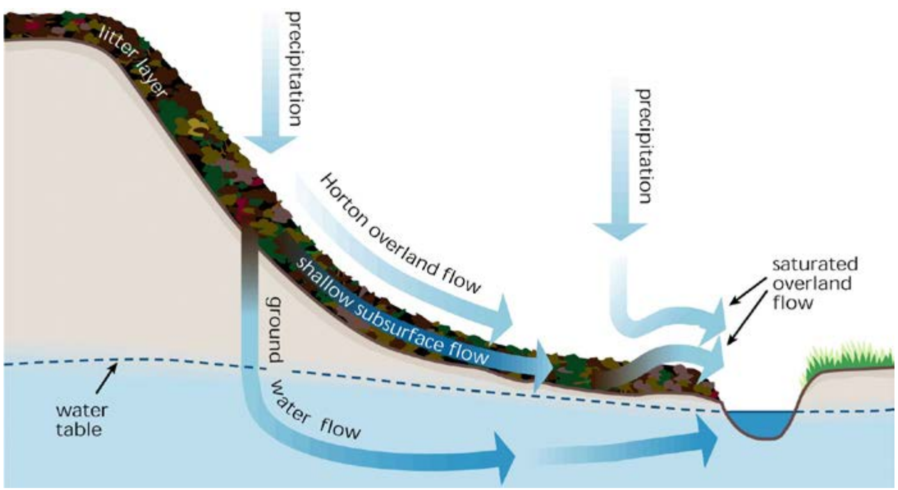

Figure 6-2. Water finds its way to the river by several paths
(FISRWG 2001)

Analysis of watershed hydrology provides information regarding the timing and seasonal variation, magnitude, duration, and frequency of stream flows ("discharge") (Poff et al. 1997). This information is fundamental for understanding stream channel processes and for planning channel work and restoration projects (Rosgen 1996).

Surface Runoff and the Natural Flow Regime

Surface runoff arrives at the stream much quicker than groundwater. Just how fast, how much, and when is determined by:

- **precipitation**—how much and how quickly rain falls, and how much snow and ice accumulates and how quickly it melts;
- **topography**—how steep or flat the terrain is;
- **soils and substrate**—how easily and quickly the water moves into the soil ("permeability"); and
- **existing vegetation**—the type of vegetation and the extent of groundcover (Dunne and Leopold 1978, Allan 1995).

According to Poff et al. (1997), "streamflow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems." In particular, the authors noted that "high- and low-flow events…often serve as ecological 'bottlenecks' that present critical stresses and opportunities for a wide array of riverine species." The authors use the phrase "natural flow regime" to describe a river's characteristic pattern of flow quantity, timing, and variability. Components of the natural flow regime include:

- **magnitude**—the volume of water in the stream that is moving past a point per unit time, usually measured as cubic feet per second (cfs);
- **frequency**—how often a certain flow recurs over a specified period;
- **duration**—the period of time associated with specific flow conditions;
- **timing, predictability**—the regularity with which a certain flow occurs; and
- **rate of change**—how quickly flow changes from one magnitude to another, also referred to as "flashiness".

By considering these components, the ecological consequences of a particular change in the flow regime can be anticipated. For instance, dams and water diversions reduce the magnitude and frequency of high flows by storing water or removing it from the channel. On the other hand, urbanization increases the amount of hard ("impervious") surface which increases the amount of runoff and the speed with which that runoff arrives at the stream (Poff et al. 1997). Urbanization also increases the frequency with which habitat-disturbing flows occur (Booth and Jackson 1997).

Groundwater and the Natural Flow Regime

Groundwater is water under the surface of the earth found in the cracks and spaces in soil, sand, gravel, and permeable rock. Of the estimated 16% of precipitation that remains after evaporation and transpiration, a small fraction reaches the groundwater (CGS 2003). The level of the water table (the surface of groundwater) in the vicinity of a stream varies depending on soils, the distance from the stream channel, time since stream surface flows have increased or decreased, and the composition and permeability of the stream bottom (e.g., bedrock) (Dunne and Leopold 1978, Allan 1995). Groundwater discharges to the stream slowly and over a long period of time. It also represents the low level of flows ("base flow") observed in the South Arkansas River during late summer and fall. The exchange between the stream and the local groundwater is critical to the health of the stream ecosystem, including the survival of stream organisms as well as the terrestrial plants, wildlife, and people that depend on the stream for water (Allan 1995). This is especially true for smaller rivers and headwater streams like the South Arkansas River.

The Stream in Four Dimensions

Most of the time it seems that rivers only move in one direction, that is, downstream. However, rivers move in a second dimension—laterally, especially evident when spring runoff overflows onto the floodplain. Hidden from view is a third dimension—vertical, that is, the continual movement of groundwater into and out of the channel. The fourth dimension—time—reflects the seasonal changes in the water's movement (Figure 6-3). Each of these dimensions affects the processes and functions of the stream and stream corridor and each is critical to the health of the stream ecosystem (see Section 2.0). Consideration of all these dimensions also improves understanding of the stream system, the nature and cause of stream problems and, therefore, the success of subsequent attempts at restoration (Ward 1989).

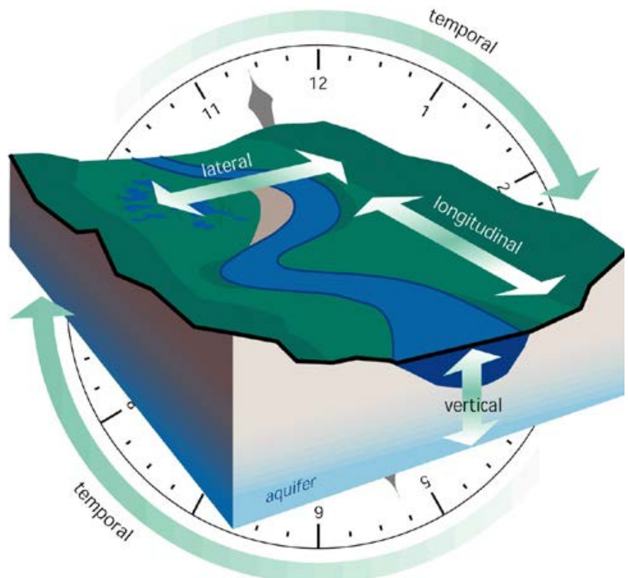

Figure 6-3. The four dimensions of stream hydrology (FISRWG 2001)

Hydrology of the South Arkansas River Watershed

The majority of precipitation in the South Arkansas River watershed falls as snow during the winter months.[1] As such, the majority of runoff reaches the river as snowmelt in May

[1] Exceptions involve intense, convective summer thunderstorms that may create flooding locally.

and June each year, with the volume and duration dependent on the extent of the snowpack and seasonal temperatures. Variation from average stream flows from year to year in the South Arkansas watershed can be significant (CNHP 2006). Snowmelt in the watershed is faster on south-facing compared to north-facing slopes, but there is little difference between east- and west-facing slopes (Rink and Kiladis 1986).

In general, as elevation increases in the South Arkansas watershed, soil development decreases, ending in talus slopes and coarsely-weathered parent material of granite, gneiss, and schist above tree line (CNHP 2009a). In such areas—the alpine and subalpine zones—the downward movement of rain and melt water is rapid. With a few exceptions, soils on lower valley slopes and the valley bottom are highly permeable and runoff is slow (SCS 1975). On the other hand, developed areas make land less permeable and increase the speed of runoff (Allan 1995).

Figure 6-4 on the next page depicts the South Arkansas River watershed and its location in the larger Arkansas River basin in Colorado. Table 6-1 provides information on the South Arkansas River tributary drainage areas (CWCB 2010).

Table 6-1
South Arkansas River Tributary Drainage Areas

Sub-Watershed	**HUC Designation**[2]	**Size (acres)**	**Percent of Total**
Poncha Creek	110200010714	15,653.6	11.5
Starvation Creek	110200010710	11,752.5	8.6
Silver Creek	110200010712	11,596.5	8.5
	Subtotal – Poncha Creek	39,002.7	28.7
Little Cochetopa Creek	110200010708	14,942.6	11.0
North Fork – South Arkansas	110200010704	14,170.7	10.4
Middle Fork – South Arkansas	110200010701	14,166.0	10.4
Missouri Park	110200010705	13,827.4	10.2
Green Creek	110200010706	11,646.0	8.6
Poncha Springs	110200010716	9,784.4	7.2
Fooses Creek	110200010702	9,637.4	7.1
Maysville	110200010703	8,749.6	6.4
	Total – South Arkansas	135,926.8	100.0

[2] The U.S. Geological Survey designates each watershed with a "hydrologic unit code" (HUC). Under this system, the largest drainage area has the smallest number and each successive sub-drainage has a larger number. For instance, the HUC for the entire Arkansas River drainage—from the headwaters above Leadville to the confluence with the Mississippi River at Napoleon, AR—is 11. The HUC for the Arkansas River above the Colorado-Kansas border is 110200, and that for the South Arkansas River is 1102000107 (USGS 1987, 2012).

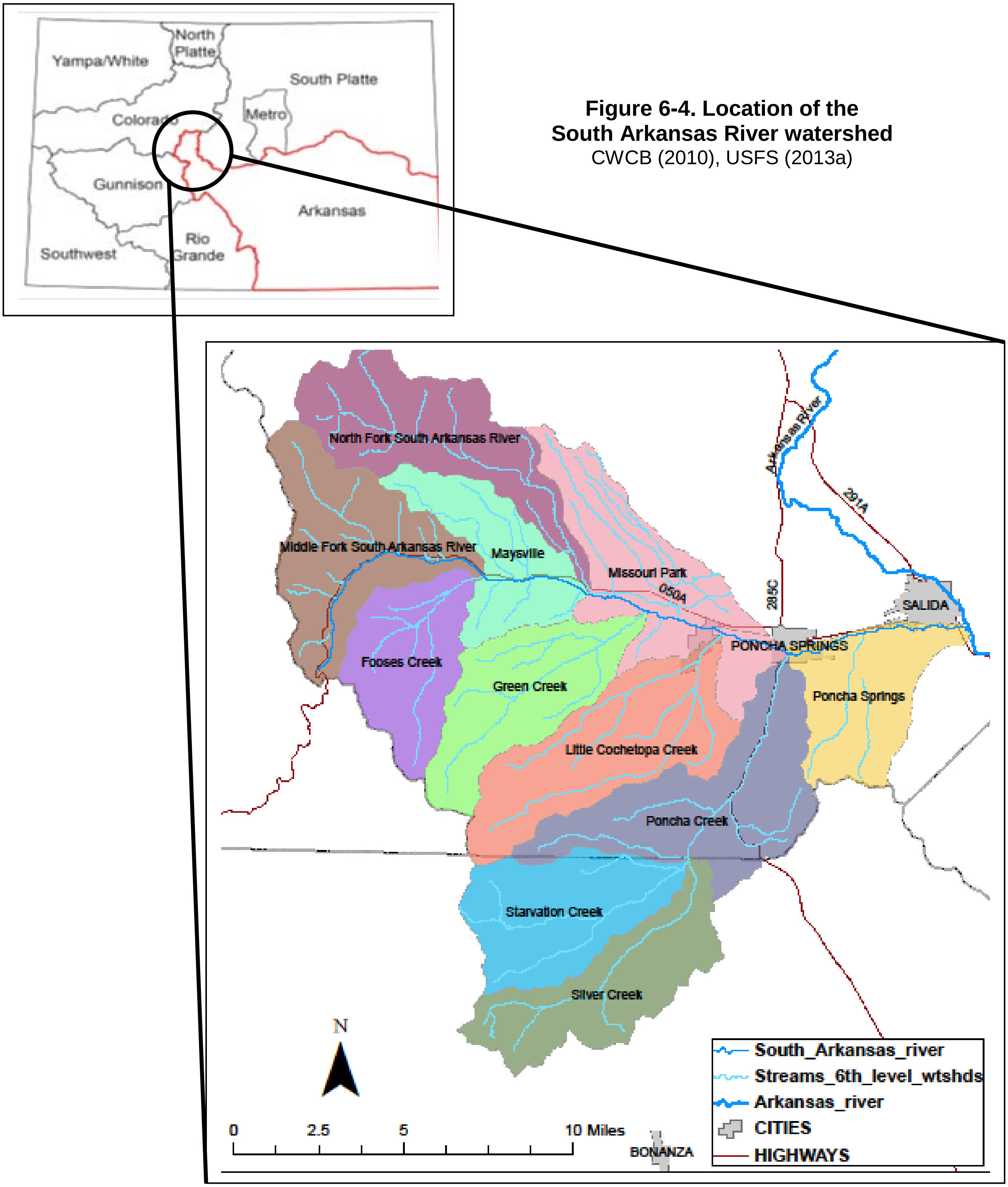

Figure 6-4. Location of the South Arkansas River watershed
CWCB (2010), USFS (2013a)

Figure 6-5 presents a graph of seasonal flows in the South Arkansas River (USGS 2013) and provides insights into the size and variety of flows that shaped the South Arkansas River channel and floodplain in the past. Average annual flows during this period ranged from 13 cubic feet per second (cfs) in 1940 to 73 cfs in 1923. Average flows during the high-flow months of May and June ranged from 70 to 86 cfs, although the highest ("peak") flows ranged from 100 to 500 cfs. The highest recorded flow occurred on June 17, 1923 – 1,220 cfs (CGS 2006). Decreed water rights with priority dates before 1903 represent 328 cfs of maximum flow rates in the South Arkansas River watershed (CDWR 2013a, Kastner 2013).

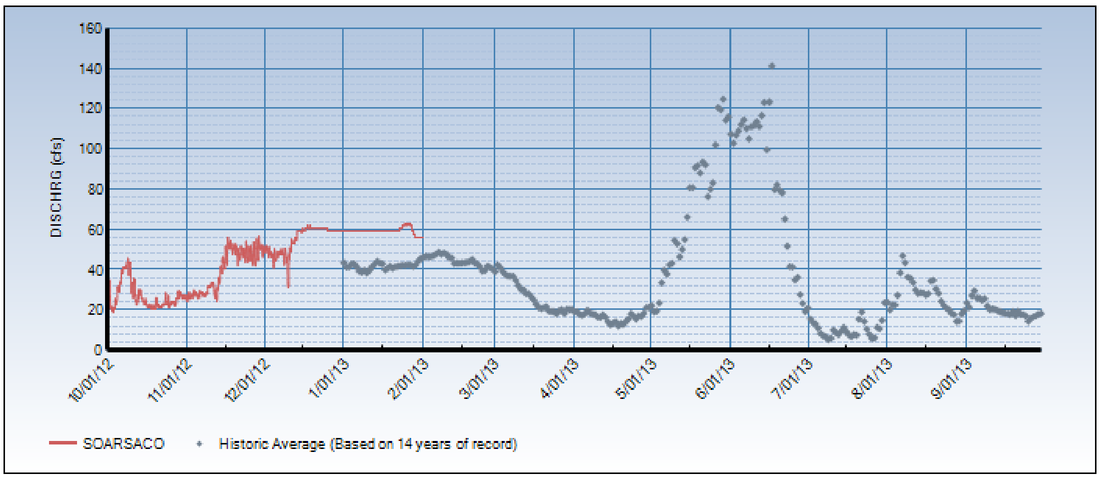

Figure 6-5. Hydrograph of the South Arkansas River (USGS 2013)

Water Rights and Water Use in the South Arkansas River Watershed

A total of 181 surface water rights exist in the South Arkansas River watershed, including water diversions ("maximum decreed flows"), lake and reservoir water levels, augmentation plans, and minimum in-stream flow decrees. There are 37 surface water diversions in the South Arkansas River project corridor with priority dates before 1903. Of those 37 diversions, 15 represent 81% of maximum decreed flows in the South Arkansas River (CDWR 2013a, Kastner 2013).

In terms of stream impacts, water diversions from the South Arkansas River can be viewed as those diversions that return to the river and those that do not. Diverted flows return to the river at some point downstream as direct flows from ditches and as subsurface flows, minus that consumed by use. As such, these diversions represent a temporary loss of water to a section of the river between the diversion point and the point of return. Diverted flows that do not return to the river represent a permanent loss of flows, such as North Fork, Cameron, Missouri, and Harrington ditches. However, some flows from the North Fork, Cameron, and Missouri ditches may return via groundwater (Figure 6-6).

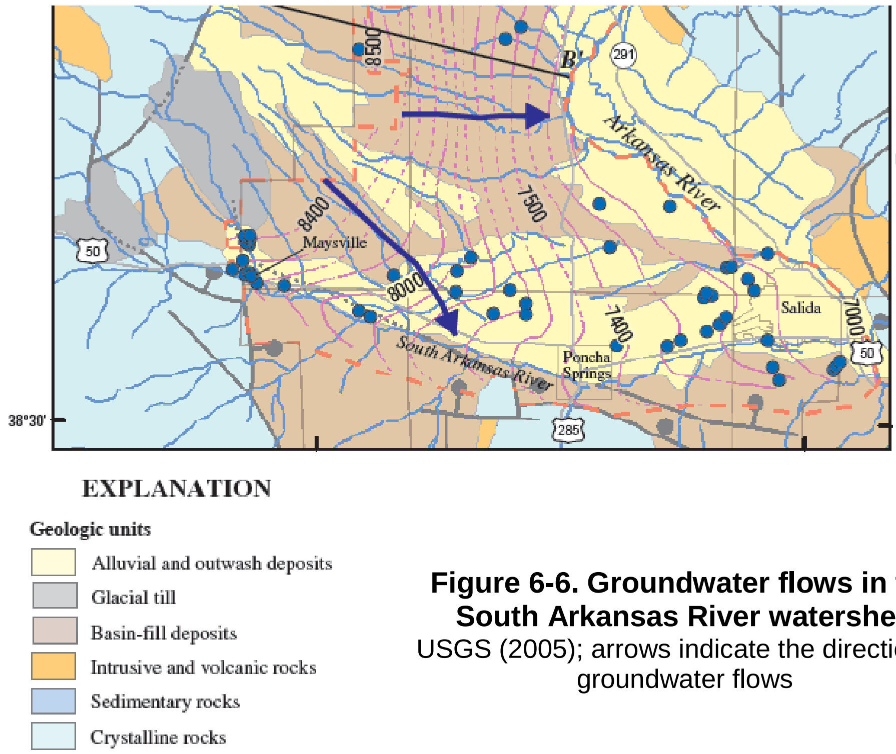

Figure 6-6. Groundwater flows in the South Arkansas River watershed
USGS (2005); arrows indicate the direction of groundwater flows

The City of Salida receives its drinking water from the Harrington Ditch (52%), the Salida water gallery (33%), and the Champ Ditch (15%) (Salida 2008b). This water serves the residents of and visitors to Salida and, after it is used, is treated at the city's wastewater plant and returned to the main stem of the Arkansas River below the confluence of the South Arkansas River. (The Salida plant also treats water used by Poncha Springs. That water is drawn from groundwater. See the discussion of groundwater below.) These flows represent 0.7% of maximum decreed flows in the South Arkansas watershed and 1.5% of maximum decreed flows in the South Arkansas River. Water use by the city during the summer is 3.75 times higher than during the winter. Water use during 2010 was 1,701 acre-feet, and is projected to increase 60% to 2,726 acre-feet by 2025 (Salida 2008b). Local government planning documents indicate that, in conjunction with the activities of the Upper Arkansas Water Conservancy District, there is sufficient water to support modest increases in population (Chaffee County 2000, Poncha Springs 2011, Salida 2013).

In-Stream Flow Decrees

In-stream flow decrees are water rights held by the Colorado Water Conservation Board that reflect a water appropriation for a lake or specific section of stream. Such decrees are intended to preserve the natural environment by maintaining a certain amount of water in the lake or stream. Like other water rights in Colorado, in-stream flow decrees are assigned a priority date and administered within Colorado's water rights system (CWCB 2013b).

No in-stream flow decrees exist on the main stem of the South Arkansas River, but such decrees exist on 17 tributaries of the river—Fooses, North Fooses, South Fooses, Gray's, Green, Lake Fork (Middle Fork), Little Brown, Little Cochetopa, McCoy, Middle Fork, North Fork, Ouray, Pass, Poncha, Silver, Starvation, and Tent (Figure 6-7). Decreed flows total 86.9 cubic feet per second. Priority dates range from 1976 to 2008, and so are junior to the majority of existing water rights in the watershed (CDWR 2013a, CWCB 2013c, Kastner 2013).

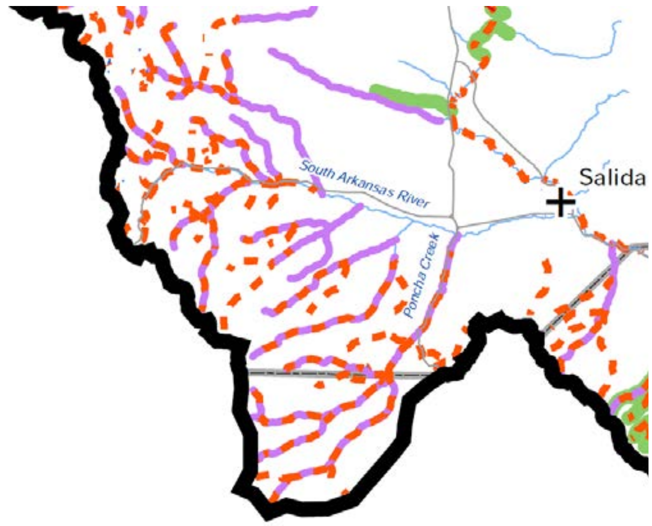

Figure 6-7. In-stream flow decrees in the South Arkansas River watershed CWCB (2010)

In-stream flow decrees

Other CWCB grant projects

In addition to their relatively low priority dates, the effectiveness and functional impact of in-stream flow decrees have been questioned because most have not incorporated improved understanding of the important connection between the full range of stream flow variability and river ecosystem integrity. It is this variability that is a primary force driving the structure and function of riverine systems (Richter et al. 1997, Poff et al. 2011).

Dams in the South Arkansas River Watershed

A total of 13 dams and other impoundments exist in the South Arkansas River watershed (CDWR 2013a, CWCB 2013c, Kastner 2013). Two hydropower dams are located on the South Arkansas River itself, one upstream of Chaffee County Road 225 just outside of the project corridor and one west of Maysville within the project corridor.

Groundwater Use in the South Arkansas River Watershed

Groundwater flows in the South Arkansas River watershed are depicted in Figure 6-6. Groundwater use in the watershed arises mostly from individual domestic water wells, and as drinking water for the residents of Poncha Springs. These wells draw from alluvial and outwash deposits and basin-fill deposits (CGS 2006). Figure 6-8 indicates the location of decreed groundwater wells in the South Arkansas River watershed. Domestic and household groundwater use in the area represents less than 1% of the available groundwater in the upper 300 feet of the subsurface (USGS 2005). As such, groundwater withdrawals in the watershed are not expected to appreciably affect the South Arkansas River. For instance, in the Maysville area, wells have water levels of about 15 feet that yield 12-15 gallons per minute (gpm). On higher terraces and on the south side of the river, wells can be as deep as 200-300 feet and yield as little as 0.1 gpm (CGS 2006). For Poncha Springs, per capita water use in 2010 was estimated to 187 gallons per day (BOR 2013).

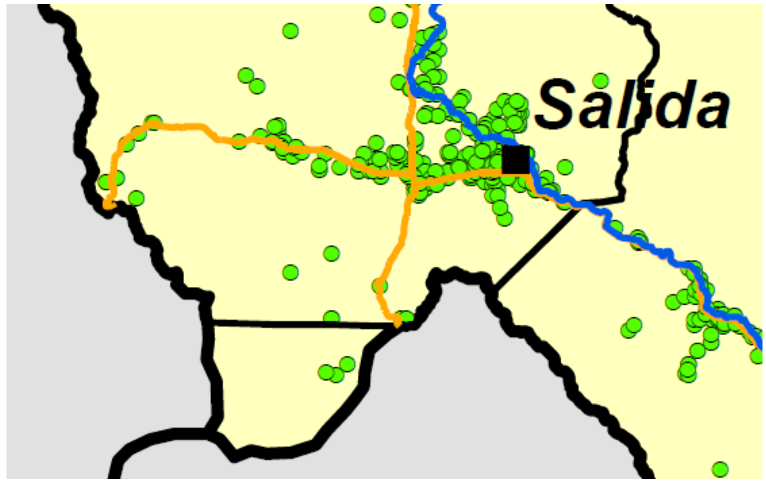

Figure 6-8. Location of decreed groundwater wells in the South Arkansas River watershed CWCB (2011b)

Impact of Climate Change on Hydrology in South Arkansas River Watershed

According to a recent report, "no consistent long-term [statewide] trends in annual precipitation have been detected in Colorado" (CWCB 2008). However, the same report indicated that Colorado's snowpack above 8,200 feet is projected to decline 10 to 20% by the mid-21st century, the timing of spring runoff is projected to shift 2 to 4 weeks earlier, and late-summer flows may be reduced, regardless of changes in precipitation (see Section 5.0, Climate and Precipitation).

Hydrology and Flow Regime—
Impacts and Issues in the South Arkansas River and Watershed

Dams, reservoirs and water diversions in the South Arkansas River watershed alter the river's natural flow regime by changing the amount of water in the channel, and when and where it is present. Impacts include:

- lower water levels in the channel;
- reduced base flows during summer and fall; and
- reductions in or loss of water available for streamside habitat.

These conditions diminish the river's ability to create and sustain the in-stream and streamside habitats necessary for the species and processes that characterize a healthy stream ecosystem. For instance, lack of high ("flushing") flows limits the river's ability to move and remove fine sediments from the stream bottom, especially downstream of U.S. 285 (Figure 6-9). This limits the suitability of several areas for trout spawning and for aquatic invertebrate habitat. Low in-stream flows also result in several segments of the river that are too shallow for fish to occupy during several months of the year. In addition, low water levels and lack of in-stream structural diversity combine to limit cover for fry and juvenile trout and limit the amount of deeper areas needed for overwintering habitat. Last, loss of subsurface flows and overbank flooding remove processes critical to the survival and regeneration of native riparian plant communities. At several locations, the loss of vigor in existing riparian plants, such as willows and sedges, and their replacement by upland species has reduced or eliminated the ability of the remaining plants to anchor the stream bank. This increases erosion and bank collapse, processes that further degrade the river.

Figure 6-9. Excess sediment deposition in the South Arkansas River at CCR 107 (2012)

The current shape of the South Arkansas River and its floodplain—how wide, how deep, how sinuous—reflects hydrology working over and through the watershed for thousands of years. Historical flows were larger and more variable than at present; dams, water diversions, and drought have significantly altered and diminished the amount, timing, and location of river flows. Stream ecosystem processes and native plants and animals are adapted to, and in many cases require, that natural flow regime to function and flourish. Simply put, there is not enough water for the original channel and floodplain to function properly.

However, given the water demands on the South Arkansas River and the constraints imposed by the water rights system, re-establishing natural flow variability does not seem likely. However, bypass flows have been established to improve fish habitat as part of the operation of hydro-electric dams on the South Arkansas River (CDOW 2004). In addition, the Voluntary Flow Management Program on the Arkansas River provides an example of cooperative changes in stream flows (CPW 2013a). Other, similar projects and experiments exist on other rivers (Poff et al. 2003, Bednarek and Hart 2005, Richter et al. 2006, Richter and Thomas 2007).

More details regarding the implications of these hydrological changes for in-stream and streamside habitats and organisms in the South Arkansas River are provided in the following sections.

- Section 7.0, Vegetation
- Section 8.0, Wildlife, Fish, and Aquatic Invertebrates
- Section 9.0, Water Quality
- Section 10.0, Channel and Floodplain Processes

Restoration goals and recommendations for the South Arkansas River and watershed are discussed in Section 11.0, Establishing Watershed and Riparian Restoration Goals.

Water is the driving force of all nature.

Leonardo da Vinci